Operation and Fueling (O/F) Workgroup Meeting Notes from October 20, 2016 Teleconference

(Note: Voting Members are in bold-face)

Meeting led by **John Crouch** (HPBA, Co-Chair of O/F Workgroup) and **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), **Marc Cohen** (Massachusetts), **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 details of today's presentations are noted below in the meeting highlights as well as in Rick Curkeet's and Bob Ferguson's presentation slides posted to Basecamp. This is background material to educate the workgroup; no official conclusions have yet been drawn by the group.

To-Do List:

- The Workgroup should post their questions to Basecamp. State regulators are also encouraged to send their questions to Lisa Rector and Bob Lebens.

- The Workgroup should suggest ways to transition from these background educational meetings to working on the group's charge.

- Lisa Rector will work with Bob Ferguson to post testing data from the ASTM CTM development process to the Operation and Fueling Workgroup's Basecamp, as requested by Tom Morrissey.

Highlights from Meeting:

- John Crouch opened the meeting, noting the agenda was on the GoToMeeting screen including announcements and roll call, followed by a presentation by Rick Curkeet on wood density as a possible solution to the species question, and then the third-part of Bob Ferguson's presentation on ASTM's draft cordwood method. It was agreed that a brief overview regarding EPA's research efforts will be given by Adam Baumgart-Getz at the next meeting (November 3, 2016).

- Regarding upcoming presentations, John noted that the ASTM TG worked on the [cordwood/species] problem resulting from not being able to move cordwood freely around the country, unless it was fumigated or kiln-dried, both of which are counterproductive in terms of representing in-home use. Bob will then conclude the last third of the draft ASTM CTM presentation. John further noted that the next meeting will include an overview by Adam plus a few other presentations. John suggested that the states may want to caucus and develop questions that Bob Lebens or Lisa Rector collect for the group, noting it was hard to believe there are no questions. [Perhaps Lisa and Bob facilitating questions may bring forth more.]

- Lisa Rector noted that one of things she's struggling with is how to transition from these background educational topics to the workgroup's charge. Should they [the background presentations and beginning to do the work of the O/F group] happen concurrently or sequentially? John Crouch also asked for input from the group on how that transition should best happen.

Rick Curkeet's ASTM Presentation on Cordwood – Specification for Emissions Testing:

- Rick noted he would discuss 4 topics: common firewood species, species vs density, availability of firewood (related to "don't move firewood"), and his recommendations. Rick further noted that he is the chairman of the ASTM subcommittee and worked on this issue even before becoming the chairman.

- Rick explained that when one is discussing [cord]wood, one must speak of trees and tree species. The specific gravity/density of wood is an important parameter and the specific gravity is widely available in the literature for various species. Rick showed a slide entitled "Common Species & Specific Gravity" which contained a listing of the specific gravity for many different species. Rick noted that wood is divided into deciduous/hardwoods and conifers/softwoods, although the hardness varies a lot within each group.

- Softwoods have their highest value when used for construction lumber because they are light weight but have a high strength to weight ratio. Softwoods are also used for pulp/paper and utility poles, because they are straight and tall. When harvested commercially, the waste (called "slash") is of low value and is typically left behind to decompose, or is chipped up.

- Hardwoods are most valuable in the furniture industry, for veneers and decorative flooring, and are also used for railroad ties and landscape timbers. Typically only relatively clear straight grain portions of tree have a high value. The waste includes substantial portion (larger limbs and defects) that are good for firewood.

- Rick noted that there is a lot of information on the internet from various wood-burning groups on the most commonly available firewoods. Such information includes density (pounds/cubic foot), specific gravity, pounds per cord (green or dry), BTUs per cord, and even how good the "coaling" is (poor, fair, good, excellent) – that is, how good a coal bed forms when different species are burned.

- Rick showed a table of softwood and hardwood with specific densities, noted that the draft ASTM CTM's specified density range is 0.48-0.73 based on dry weight and volume, which is equivalent to 30 to 45.5 lb/ft^3.

- Rick noted that when looking at the specific gravity of common wood species, about 53% of species fit into the 0.48-0.73 range. Rick showed a bar chart showing specific gravity on x axis and the number of wood species at each specific gravity range on the y axis.

- Rick explained that one of the concerns about combustion emissions from one tree species versus another species is their chemical composition when heated and burned. For this, one can look at the chemical composition in a *proximate analysis*, which breaks down wood material into carbon, volatiles and ash by heating samples of wood in an oxygen free environment. Rick explained that it's a simple test to get carbon %, volatile %, and % ash content. Rick noted that most of this data comes from the wood/biofuels atlas compiled by the Renewable Energies lab in Colorado. Rick explained that an *ultimate analysis* can also be done, which looks at carbon, hydrogen, oxygen, nitrogen, and sulfur component. Rick noted that 99% of a tree's components falls into carbon, hydrogen and oxygen.

- Proximate analysis shows all common wood is about 84% volatiles and 16% fixed carbon. Particulate emissions are generated almost entirely from the volatile products of pyrolysis. Volatiles represent about 84% of the fuel dry mass and about 73% of the heating value. Rick averaged all values, breaking out hardwoods and softwoods, and did not find much of a difference between hardwoods and softwoods from proximate and ultimate analysis. There was lots of crossover with the averages within 1% of each other. Rick noted that this makes sense since chemically all common wood species are very similar.

- The biggest difference between hardwoods and softwoods tends to be their lignin content (which is higher in softwoods). This higher lignin content results is a somewhat higher heating value – about 4-5%. Hardwoods tend to be denser than softwoods, but there is considerable overlap. Density does directly relate to burn rate when burning conditions are equal (that is, coal bed heat, air supply, fuel size and configuration). Rick noted that the higher the density, the slower the burn rate. However, burn rate is equal to the heat release rate. So, <u>at equal burn rates</u> there is very little difference in terms of combustion zone temperatures, air to fuel ratio, heat output or efficiency.

- Regarding what consumers burn, Rick pointed to a 2008 paper by Houck which contained survey data, noting that the net result around the country is that 19% burn softwoods and 81% burn hardwoods. Rick noted that this came from census data, but the northwest was probably underrepresented. The conclusion is that hardwoods are the dominant tree type for heating.

- The wood density data available in the literature is based on averages of large sample sets, without an indication of variability. The density is actually quite variable within species from tree to tree and even from different parts of a single tree. The range is generally ± 10 to 20%. The Douglas fir density range seen in EPA testing has varied from 0.45 to 0.66 specific gravity (28 to

41 lb/ft^3). Specifying test fuel simply by species does not mean that the wood density will be uniform. Consumers who heat with wood prefer higher density wood if available, because this provides more BTUs per cord. Most information resources regarding wood heating recommend hardwoods as the preferred fuel.

- Rick noted that 34 States have restrictions on the movement of untreated firewood. Most states limit the movement to within 50 miles and some to within 10 miles. The purpose of these restrictions is to slow the spread of invasive, destructive pests and diseases such as the Gypsy Moth, Emerald Ash Borer, 1000 Cankers Disease, Asian Longhorn Beatle and many others. Rick further noted that 38 million Ash trees are expected to be killed by the Emerald Ash Borer within 10 years.

- Restrictions apply in states where most labs and many manufacturers are located. The purchase of treated firewood is not a viable option, as treatment requires heating wood to a core temperature of 140 to 160 F (varies by state). This treatment is done in kilns and to make the process efficient kilns are run at 180 to 200 F. This results in drying wood unevenly and below normal firewood levels (<18% moisture content with shell moisture contents as low as 6-10% after treatment. In addition, treatment is expensive as is shipping cordwood long distances. Fortunately common species with densities in the most common range are broadly available locally (i.e., well within the 50 mile restricted range).

- Regarding species identification, Rick noted that it is typically quite difficult to determine the species of a piece of wood without specialized training and knowledge. While possible, the process generally requires fresh clean cuts to examine grain and cell structure and this usually requires 10 to 15X magnification. In addition, this requires references to a detailed data base and knowledge of wood cellular biological characteristics. In some cases differences between species are very difficult to detect. Rick further noted that firewood suppliers often mix species within a load making sorting very tedious and time consuming.

- Regarding how much species matters, Rick noted that the chemical process of burning is relatively the same for two [different] species with equivalent densities – suggesting that density matters more than species. Comparing softwoods to hardwoods, an OMNI study used 2 stoves (one with “high emissions” at 5.9 g/hr and one with “low emissions” at 2.1 g/hr) and tested with cold starts at low burn and hot starts for the high burn rates. Two replicate tests were run under each (i.e., 2 softwood tests and 2 hardwood tests at each burn rate, for a total of 8 runs). The results showed that the higher emissions stove had lower emissions when burning hardwood compared to softwoods, but the lower emissions stove had lower emissions when burning softwood compared to hardwoods. Rick noted therefore that these tests reveal that one can’t conclude how hardwood versus softwood affects emissions. (In response to a question from Lisa, Rick clarified that the bar chart at the bottom of this slide #16 was from a different study than the table at the top of the slide.)

- Regarding the bar chart at the bottom of slide#16, Rick noted that g/kg as a measure of completeness of combustion reveals something. Ignoring the fireplace bar, Rick explained that

the testing on the non-catalytic woodstove resulted in white oak giving the highest emissions, while red maple gave the lowest emissions. Sugar Maple and Douglas fir results were similar for the non-cat stove, while loblolly was slightly higher emitting (but not as high as white oak). In other words, the data shows no discernable trend in terms of softwoods versus hardwoods.

- Lisa Rector requested, for both the OMNI data and the second bar chart (on slide #16), if Rick could provide the g/hr and the burn rates. Lisa noted that hardwoods and softwoods have different burn rates. Rick replied that unfortunately the studies didn't provide the burn rates. Rick further explained that the stoves were run at same control settings, so it may well be that the hardwood was burning slower than the softwood. Rick noted that he would look for the burn rate data. Lisa asked if the different burn rates for hardwoods versus softwoods could be a reason for the variability. Rick replied that no, he thinks it's the burning of wood itself which introduces the variability, not the fuel.

- Regarding the next slide#17, Rick noted that they took data and put it through a corner score test to determine if there was an association between density and emissions. The corner score was +2 and Rick explained that anything less than 11 means there is little association between variables. In addition, the regression R^2 value was close to 0 (it was 0.0048). Rick concluded that this analysis showed that the density range used in EPA testing didn't directly relate to emissions.

- According to Rick, the EPA proficiency test program data clearly demonstrated high emissions rate variability even though the fuel used in all tests was from a single species and the fuel crib configuration was very reproducible. This leads to the conclusion that the fuel characteristics are not the likely source of the variability in results. Rick noted that in his view, we need to rethink and redefine what we mean by clean technology in wood burning. It should be an appliance that produces acceptable emissions even though it will be supplied with variable fuel in its intended use. Rick opined that, to properly evaluate these products, they should be tested with similarly variable fuel.

- Regarding Rick's recommendations, he noted that due to firewood movement restrictions laboratories need to be able to source cordwood fuel supplies locally. Since fuel must be well seasoned to meet Moisture Content limits, labs must be able to use what their local suppliers have available. There is no way to assure than adequate supplies of fuel of specific species or narrow density range will be obtainable. (Rick noted that it's not practical for the labs to store firewood for two years.) Rick asserted that there is no compelling evidence that species or density have a significant effect on results given roughly equal test load weights and burn rates.

- Rick noted that it is not difficult to determine density. It is relatively easy to determine and verify wood density and that it is within the range specified in the ASTM method. This need not be a precise measurement since the load weight and moisture content are quite tightly specified and accurately measured. Purchasing seasoned cordwood from a reputable local dealer should not be a problem and would be typical of normal consumer practice. Appliance designs will need to be able to perform well even though the fuel used in qualification [certification] tests may be

as variable in the lab as it is in the real world. This is, in fact, the point of moving to a cordwood test method.

- Rick noted that the ASTM Draft Cordwood method has an adequate cordwood fuel specification, supported by a broad consensus. It has been vetted through a significant number of tests by experienced labs and manufacturers. It is similar to the fuel specifications in CSA B415.1 and ASTM E2618 for furnaces and hydronic heaters, which have demonstrated it is workable and does not result in unusual variability. The ASTM Method should be used as published so that the development of a database for tests with a well-defined cordwood fueling procedure can be begin in advance of any implementation of regulatory requirements. Rick noted this was the end of his presentation.

- Adam thanked Rick for his presentation, noting that it was obvious he'd done a lot of work on this topic. Adam noted that EPA and ASTM are coming up with slightly different angles on the same problems. EPA needs substantial evidence that species does not produce variability – the burden of proof is on showing that different species don't show variability, rather than showing that there is little variability. Adam noted that this is a subtly different angle. Rick replied that it sounds like Adam/EPA wants us to prove a negative, which we can't do. Adam clarified that, rather than look through a body of evidence [as Rick has done], it would require burning a bunch of wood to show that little variability results. Adam further noted that EPA is doing this and is not asking for Rick or industry to do this. Rick noted that he was skeptical of how that can be dealt with/accomplished, since we know there is a large variability in emissions even when the species and density is taken out of the equation, as it has for the last 30 years. Rick further noted that it's difficult when so many other variables exist, because multiple different parts of the process [burning wood in a wood heater] effect the end results. Adam agreed and noted that EPA is working on it. Adam clarified that we won't resolve the issue of the inherent variability of wood now. Adam concluded that his obligation is to show [or not] that no variability results from changing species.

- Adam asked, regarding the tests Rick referred to, if they were done with the same test method and similar stoves. Rick replied that the OMNI study [top of slide#16] was done with two different stoves with variations in burn rates. The chart [on bottom of slide#16] shows test results from same stoves [a cat and non-cat, plus a fireplace] tested with multiple fuels [in each stove]. Adam noted that there is data from the late 80's from testing done on an old Vermont Castings stove. Bob Ferguson is looking for that data. Adam asked if that data from the late 80's informed Rick's and ASTM's analysis as well. Rick replied that if there is more data, he/ASTM would love to see it. Adam noted that EPA once had this data (from the late 80's) but doesn't currently. Adam too would like to review that data.

- John asked if there were any other questions for Rick.

- Tom Morrissey noted that he had some questions for Rick and Bob Ferguson. Tom noted that reportedly the ASTM CTM has been vetted through a significant number of test labs and manufacturers. Tom would like to know who did the vetting and how many tests they

performed. Bob replied that Mark Champion did most of the testing, but he is not sure of the exact number of tests. Tom asked if any of that data been released. Bob confirmed it had. Tom asked if the data included appliance temperature, gas compositions and emissions – Tom wanted to know if there was enough information in the data released from Mark's testing to determine reproducibility. Bob replied that yes, data was published in different chunks in various reports, but it's all on ASTM's website and some has also been posted to Basecamp as well. [Note: this ASTM data is posted on the Steering Committee's Basecamp, not on the Operation & Fueling Workgroup's Basecamp.] Bob noted that there were other tests conducted by other labs, but he doesn't know the number of data points collected. Bob further noted that some manufacturers used the draft ASTM CTM – including Tom Morrissey as well as US Stove, Hearth & Home, Blaze King, and Ben Myron – and a number of these results were reported during the ASTM meetings.

- Tom Morrissey noted that the only accredited labs to have used the draft ASTM CTM were Ben Myron and Rick Curkeet. Tom pointed out that OMNI didn't use it, neither did Dirigo nor Polytests. So actual lab work/testing hasn't been done with the method, according to Tom. Rick Curkeet noted that the reason is because the draft ASTM CTM is not a standardized test. Tom replied that that's not relevant because both Rick and Bob have made the claim that the ASTM CTM has been extensively vetted, yet [Tom noted that] he's never seen spreadsheet with actual data. Bob noted that Tom has been on the distribution list and that information was provided through the distribution list.

- Lisa Rector asked Bob Ferguson if he could share the full test reports for the company's and labs that ran the full ASTM tests, not merely the supporting data, but rather the full lab reports from the multiple tests through their stoves. Tom Morrissey confirmed that is what he would like as well. Tom noted that one must essentially take it on faith that there is high variability and that the results are not reproducible, but Tom doesn't necessarily believe that.

- Lisa offered to check Basecamp's site for the ASTM data Bob posted and then send it to Bob to ensure it's the full list of data available. Then Lisa will post the data to the Operation & Fueling Workgroup's Basecamp site. Bob noted that the data is from the testing/work done by Mark Champion on 5 stoves during the course of development to exercise the method. Bob further noted that he did not use the word "vet" pertaining to this testing.

- Tom Morrissey clarified that there is no public knowledge about how many tests have been done, who did it, what the results were, and who paid. Tom noted that Mark Champion's data was summary data, but not test data. Tom asserted that if this method is to be discussed as a serious method, then actual spreadsheet data needs to be seen. Lisa Rector noted that she will touch base with Tom Morrissey after the meeting and see what there is to post to Basecamp, as the O/F workgroup will need to start digging into the weeds.

- John Crouch asked the group to post questions for Rick to Basecamp or, if a state regulator, to send any questions to Bob Lebens or Lisa Rector.

Bob Ferguson's ASTM Cordwood Test Method Development Discussion (continued from 2 weeks ago):

- Bob started going through his slides entitled "A Discussion of the Development of the Proposed ASTM Cordwood Test Method for Room Heaters – Part 3". Bob noted that he would move quickly through the slides in an attempt to finish and would discuss: the medium and low fire test categories of the procedure, the test method outputs, the summary test report and the method's annexes (including efficiency and heat output using CSA B415.1-10 and the method for single burn rate heaters). Note: Bob's presentation slides are posted to Basecamp.

- Regarding the low and medium fire nominal test fuel load density (9.6.3), Bob noted that the test fuel load density evolved to 12 lb/ft^3 of UFV, as previously discussed. An exception is included consistent with the high fire exception discussed earlier. This exception to the load density requirement was added rather than adopting an unproven sliding scale to accommodate small or atypical fireboxes. (Bob added that sliding scales are difficult to vet.) The exception is: if it is physically impossible to achieve the minimum 12 lb/ft^3 (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. (Bob added that sometimes this much wood will simply not fit in the firebox due to a number of reasons including unusually shaped fireboxes, etc.) This exception must be fully documented and the load density that is achieved reported. This is recognition that for some fireboxes 12 lb/ft^3 won't be achievable, especially if the 10 lb/ft^3 requirement was not achieved for the high fire run. Bob noted that the 12 lb/ft^3 represents at 73% increase in load weight over EPA M28.

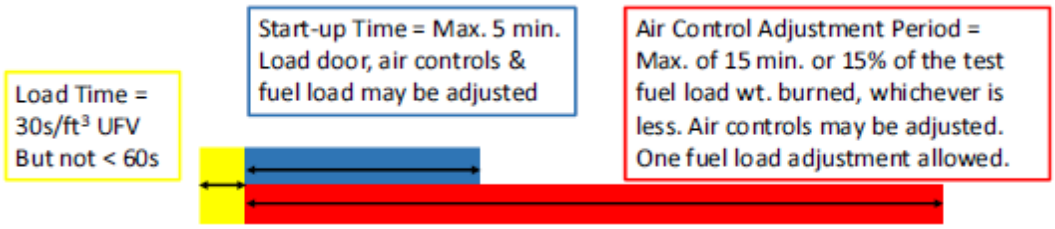
- Regarding the starting charcoal bed weight (9.6.4), Bob noted that this is defined as 10 – 20% of the test fuel load weight and is based on testing and observations by Mark Champion – that is, the appearance of the charcoal bed plus adequate space for the test fuel load. The low and medium fire load time (9.6.5) is based on 30 seconds per ft^3 UFV, but not less than 60 seconds. For the low and medium fire test run start-up time (9.6.6), the load door and air controls may be in any position as recommended in the manufacturer's written instructions for up to five minutes after the maximum allowed load time. Fuel adjustments may be made as needed to ensure ignition of the test fuel load.

- Regarding the low and medium fire air control adjustment period (9.6.7), Bob noted that up to 15 minutes after the maximum load time is allowed, or until 15% of the test fuel load weight is burned. Combustion air controls may be adjusted to ensure ignition of the test fuel. Bob noted that there was much discussion by the Task Group about this optional extra time. Without this option, it was observed that some test run fires simply died out. It takes more time to get the large mass of the test fuel load to ignite in a sustainable fashion.

- Regarding that test fuel pieces can be adjusted once during this period (9.6.8), Bob noted that this was described earlier in the high fire section. (Bob re-iterated that homeowners would likely adjust fuel if a wood piece fell on a glass door, for example.) The practice of fuel adjustment will be self-limiting because: wood consumption could be accelerated causing a failure to meet a low burn rate; fuel adjustments can increase PM since emissions controls (door, bypass, flow path) get interrupted (and stirring up fly ash during load adjustment); and emissions are sampled

during this period, so no PM is being missed. Test fuel load may also be adjusted once during the test run but only after 60% of the test fuel load weight AND 10-minutes have lapsed with a measurable weight loss.

- The following diagram capture the allowable load times, controls adjustment and fuel adjustments:



- Regarding the medium and low fire test run start (9.6.9), Bob noted that emission and efficiency sampling begins immediately before the test fuel load is added. The test fuel load is added in accordance with the manufacturer's written instructions. The full test fuel load must be in the stove by the end of the fuel loading period.

- Regarding the medium and low fire test run completion (9.6.12), Bob noted that the primary criteria is that the test run ends when 100% of the test fuel load weight is consumed. However an exception was added that if the fire goes out, at least 90% of test fuel load weight has been consumed AND there has been no measurable weight loss for at least 30 minutes, then this alternatively marks test run completion. During testing, it was observed that combustion could cease before the full test fuel load weight was consumed, even when the charcoal/fuel bed was adjusted once as allowed in the method. Invalidation of the test run would result if 100% test fuel load consumption were the only requirement.

- Bob noted that further rationale for special test-end criteria include: the fact that cordwood burns very differently than spaced crib fuel and dead zones can occur late in the test run where combustion simply ceases; visually, the stoves were at the end of their burn cycle even though there was remaining test load weight; and the Task Group discussion was about what was reasonable and whether a test run should be invalidated only because all the fuel wasn't consumed. Regarding the last point, it was recognized that essentially 100% of the PM will be accounted for with a test run potentially stopped at or beyond 90% consumption. This 90% cut-off point was directly based on the data and observations. Bob further noted that most if not all of PM has been released by then, so this alternative/special test-end criteria results in shortening the test run and saving a perfectly valid run.

- Bob noted that of course, there are risks for the manufacturer if the stove stops burning before the full test fuel load weight is consumed. The burn duration or burn rate requirement may not have been achieved and the emission rate will be higher due to the shorter test duration. This risk was the trade-off for saving an otherwise perfectly valid and representative test. Bob noted

that since fires can go out in the field before all the wood is burned, this is not an unrealistic end point.

- Regarding the low fire test category (9.7), the primary combustion air will be at the lowest setting at all times after the air control adjustment period has lapsed (9.7.1). Automatic controls allowed to operate as designed. The low fire test run duration must be at least 8 hours, reflective of an unattended overnight burn. However, the minimum burn rate achieved cannot exceed 1.5 kg/h dry basis. This was in recognition of needing to limit the minimum burn rate for heaters with very large fireboxes.

- If a heater cannot achieve the 8-hour burn duration, a minimum burn rate ≤ 1.15 kg/h must be achieved. This was in recognition of needing a limit for heaters with small fireboxes where 8 hours is simply not possible or even intended. This section of the draft ASTM CTM was the result of significant discussion of various options. The key guiding principle was that an overnight burn is a key consumer demand. Once it was generally agreed that meant a minimum of 8 hours, the issues with larger and smaller stoves surfaced and lead to the additional requirements noted above.

- Regarding the medium fire test category (9.8), This section defines a methodology that ensures that the burn rate from medium fire test runs will be in the lower half of the overall burn rate range. Once the high fire burn rate and low fire burn rate have been determined, the mid-point can be calculated. The medium fire burn rate must be below that mid-point. It also includes the need for the air control actuator to be set in the lower half of the consumer controllable range (whether a lever, knob or otherwise). This makes the air control setting to achieve a medium heat output more logical from a visual perspective. Requiring the medium fire test run to fall in the lower half of the operating range is in recognition of the fact that consumers operate much of the time at lower heat outputs (burn rates).

- In the ASTM Task Group discussion, it was noted that by allowing a High Fire test run to continue to 100% fuel consumption, the resultant burn rate could meet the Medium Fire definition. In other words, a medium fire test run could be achieved with the air at the highest setting, just because of the long charcoal tail. Additional test runs were conducted to help inform the Task Group on this issue. It was agreed that achieving two different burn rate categories with the same air setting was not desirable and the requirement to set the air control no higher than the visual mid-point of the control range was added.

- Regarding other requirements common to low, medium and high fire tests (that is, applicable to all test categories) and pertaining to auxiliary equipment operation (primarily convective air fans), the auxiliary equipment should be operated in accordance with the manufacturer's written instructions. That is, automatic systems are allowed to operate as designed. Since the fan "on" condition has always been presumed to be the worst case from a PM emission perspective but is probably the best case for efficiency, defining the appropriate operating conditions for the test runs generated some protracted Task Group discussion. The conclusion reached by the Task Group was to require the convection air fan to be operated for all test runs

if it is optional or included equipment. The consensus was that this represents the worst case for PM which has a passing grade -- whereas efficiency is simply measured and reported. To address the possible impact on efficiency, it was agreed that a statement should be required in the owner's manual indicating that overall efficiency may be lower without a fan installed or if the fan is installed but not used.

- Regarding overall efficiency measurements, for all test runs, including the high fire with cold start, the efficiency measurements are made on a hot-to-hot basis. This is consistent with the way the CSA B415.1 efficiency determination was designed and eliminates the need to insert a number of exceptions to the CSA efficiency spreadsheet. Direct comparisons were made for the same test run including and excluding the cold start part of the high fire test. The efficiency differences observed were small enough to garner Task Group support to proceed using the CSA B415.1 procedure without modification or exceptions. (Bob noted that the hot-to-hot basis for the high fire efficiency determination means efficiency is being measured during a different time period than emissions are being measured.)

- Regarding test method outputs, Bob noted that the High Fire PM Emission Rate (g/h) and PM Factor (g/kg) includes kindling and start-up emissions, test duration and total fuel burned. The test run duration is from ignition of kindling to the end of the test run. The High Fire PM per MMBtu output applies the CSA B415.1 overall efficiency (hot-to-hot) to the total fuel burned (including kindling and start-up fuel) and the total emissions including the cold start. This is adjusted to a per million Btu output basis. The Low and Medium Fire PM Emission Rate (g/h) and PM Factor (g/kg) are based on total hot-to-hot emissions, test run duration and total fuel burned. The Low and Medium Fire PM per MMBtu output is based on the hot-to-hot CSA B415.1 Overall Efficiency, the total weight of test fuel burned over the test run, and the total PM emissions over the test run. This is also adjusted to a per million Btu output basis.

- The weighted average results apply a 40%-40%-20% (Low Fire-Medium Fire-High Fire) weighting to all relevant parameters (e.g., PM emission rate and overall efficiency). The 40-40-20 weighting is based on extensive analysis of PM results from EPA certified stove models. Bob noted that EPA's enhanced database represents a large number of certified stoves. ASTM utilized the original enhanced certified stove database. This was part of the method development process for ASTM E2780. Various alternative data weighting options were compared to the burn rate probability weighting that is part of EPA M28. The 40-40-20 weighting provided a good match with the advantage of simplifying the weighting. This simplification was supported by all Task Group members.

- Regarding the draft ASTM CTM's 40-40-20 average weighting scheme for emissions, Bob showed a number of slides (see slides 20 through 24 on Bob's Part 3 presentation on Basecamp) including:
    - A graph on slide 20 is entitled *40 - 40 - 20 Weighting vs. EPA M28 - All QC'd Cat & NC Data ≤ 4.5 g/hr M28, With Data Falling Within <1.15, 1.15 - 1.75 and Maximum Burn Rate Ranges*. Bob noted this line-fitting was from a group of 96 certified models comparing EPA weighting vs 40-40-20.

- Regarding the datapoints that did not fall so neatly on the fitted line, Bob noted that ASTM analyzed those individual profiles. The graphs on slides 21 and 22 examine what caused those differences and reveal why some of this difference is occurring with these stoves. The graphs slides 21 and 22 are entitled *Selected Emission Profiles and 40-40-20 Weighting Results, Ave. Emissions = (0.4 X Ave. Low (<1.15 kg/hr) + 0.4 X Ave.Med (1.15-1.75 kg/hr) = 0.2 X Ave.High (>1.75 kg/hr)*.
- Slide 23 is a table from January 2010 (updated May 2016) entitled *Comparison of M28 Weighted Average Emissions vs 40-40-20 Weighting for Fixed Burn Rate Ranges and Percentage Based on Burn Rate Ranges*. Bob noted that the last column of data in this table is no longer relevant.
- Slide 24 is a bar chart entitled *EPA M28 Weighting When Grouped into ASTM E2780 <1.15, 1.15-1.75 and >1.75 Burn Rate Ranges*. Bob noted that good 40-40-20 averages result if one takes the averages of all stoves, both those close and far away from the fitted line, and group M28 data into burn rate categories.

- The combined 80% weighting of the low and medium fire results satisfies the recognition that homeowners operate their stoves at lower burn rates (heat output) a significant portion of time. In light of the inclusion of the cold start to the high fire test run, the 20% weighting still seems appropriate and in-keeping with consumer practices. Weighted averages provide the consumer with a single number rating which simplifies the comparison of different stove models.

- Regarding the wood heater cordwood test summary, the concept of including a Summary Test Report was proposed as a means to help ensure standardization in the way the test laboratories report key information about the wood heater tests conducted using the cordwood test method. The summary report is in an interactive Excel spreadsheet format that: contains active cells where information and data are entered, contains locked cells where standardized calculations determine the various parametric results, ensures calculations and reporting are consistent, and that will be available from ASTM as an adjunct to the method. This test summary has received broad support within the ASTM Task Group. Bob further noted that the Task Group noticed that there is a variety of ways information is provided based on a bunch of different summaries from different EPA testing labs. The Task Group thought standardization would be helpful, especially now that test reports are published on websites. Hence the idea of the Excel spreadsheet.

- Bob walked through an example entry on the Excel spreadsheet (see slides 27 through 30 on Basecamp). Regarding slide 27, Bob noted that the spreadsheet requires general information plus lots of photos. These photos show how the stove was set up and also what the typical fuel load looked like. Bob emphasized that photos are required for each test run. Bob explained regarding slide 28 that anything in yellow is an input, anything not in yellow is calculated. The summary [based on its formulas/programming and calculations] realizes whether it's a low, medium or high fire test and knows, for example, where to put "NA". Regarding slide 29, Bob noted that the difference between the 2 trains is captured the in average. The spreadsheet will automatically recognize the # of columns and adjust the calculations accordingly. Slide 30 shows the calculated results.

- Regarding the Cordwood Test Method Annexes, Annex A1 is the WOOD HEATER THERMAL EFFICIENCY AND HEAT OUTPUT DETERMINATION. This provides the information for the application of the CSA B415.1-10 efficiency and heat output determination to the cordwood method. It adds the option for using weight average fuel property values (C-HO, HHV and Ash Content) for mixed species test fuel loads. (Bob noted that this is what Rick Curkeet discussed in his presentation regarding the Ultimate Analysis.) Annex A1 explains the need to subtract the weight of any unburned portion of the test fuel load from the fuel weight values input in to the calculation spreadsheet. Bob noted that it expects 0 weight, but if there's some fuel left this annex will tell you how to subtract that out.

- Regarding Annex A2. SINGLE BURN RATE HEATER FUELING AND OPERATION, Bob noted that since there are no user-operated controls (no changes in air settings), the procedure requires two test runs (no Medium Fire Test) based on a High Fire Protocol with Cold Start and a Low Fire Protocol (hot-to-hot). The data from both test run categories are averaged to determine the overall average PM and CO emissions and overall efficiency.

- Bob concluded his presentation and thanked everyone for their patience.

- John Crouch reminded everyone that all 3 of Bob's presentations on the draft ASTM CTM were posted to Basecamp. John asked the group to please review and send lists of questions to Lisa and Bob Lebens or to post questions directly to Basecamp. Bob Ferguson also offered that it was fine for people to call him directly with questions, if they prefer that to posting questions. Rick Curkeet may also be called directly for questions on his presentation (which is also posted to Basecamp).

- John noted that on November 3rd there will be a presentation regarding 3 stoves tested to the beReal method and to EPA's method. John asked the group to let John and Lisa know if more presentations are needed (e.g., for CSA B415).

- **Meeting adjourned.**