

## Operation and Fueling (O/F) Workgroup Meeting Notes from March 23, 2017 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), **Cindy Heil** (Alaska), John Wakefield (Vermont), **Lisa Herschberger** (Minnesota), Anne 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), Roger Purinton (Jotul), Jill Mozier (EPA contractor, meeting note taker)

### Primary Conclusions from Meeting:

- Assuming the new meeting day and time works for everyone, the workgroup (WG) meetings will likely be switched to every-other-Friday at 1 pm. This decision is not yet final.
- The EPA-funded species testing by Mark Champion has finished and results will be forthcoming as soon as the data spreadsheet is finalized.
- The draft 1-day integrated run testing protocol (a.k.a. "ASTM-in-a-day") was presented to the WG. Testing under a more finalized version of this protocol will be performed by Mark Champion under a project managed by Lisa Rector. The 1-day protocol compresses all 4 phases of ASTM's test into a single day's run and includes Start-up, followed by the High Fire phase, followed by the Medium Fire phase and ending with the Low Fire phase. Equivalency factors would be applied to correlate the 1-day test results back to the compliance standard in place under the NSPS.
- Trial loading densities used for each phase were 1 lb/ft for kindling, 3 lb/ft for start-up, 5 lb/ft for high fire, 5 lb/ft for medium fire, and as much fuel will fit in the firebox for the low fire. It was noted that the loading densities for the start-up and perhaps the kindling phases may be too low/small.
- Regarding piece size, WG members seemed to agree that it was reasonable for the protocol to call for small pieces for the High Fire load, medium to large pieces for the Medium Fire load and a jigsaw size mixture of small, medium and large pieces for the Low Fire load (i.e., as much as would fit in the firebox for the Low Fire).

- Air settings were set fully open for start-up and the high fire phase, at medium open for the medium phase and at the lowest air settings for the low-fire phase. It was noted that, when burning cordwood, the low air settings on a stove designed to crib wood may be too low, as cordwood burns at a lower burn rate at a given air setting (compared to crib wood) and therefore more air may be required at the low burn for cordwood.
- The end of the low fire test is tentatively defined as 90% fuel consumption or no weight change after 30 minutes. WG members expressed support for defining the end of ASTM-in-a-day's high and medium fire phases in terms of percentage of coal bed burned down, instead of in rigid timeframes (e.g., 1- and 2-hour burn requirements), in order that the protocol be as flexible as possible to work for a wide range of stoves without requiring exceptions or allowing loopholes.

#### **To-Do List:**

- Lisa Rector will e-mail everyone about upcoming meeting days and times.
- Lisa will post to Basecamp PDFs and eventually a spreadsheet of data from EPA's crib and cordwood species testing performed by Mark Champion. WG members should review the data and provide input to Lisa and to EPA.
- Lisa will post to Basecamp her slides regarding the 1-day integrated run "ASTM-in-a-day" protocol she's working on via testing by Mark Champion and will also eventually post photos.

#### **Highlights from Meeting:**

- Lisa Rector opened the workgroup (WG) meeting, noting that John Crouch, Bob Lebens, Adam Baumgart-Getz, Amanda Aldridge and Cindy Heil couldn't join the call. Lisa also noted that many lab folks appeared to be missing from the call. The following WG participants were present on the call: Lisa Rector, Kelli O'Brien, Gregg Achman, John Barnes, Stef Johnson, Lisa Herschberger, Randy Orr, Rick Curkeet, Bob Ferguson, Rod Tinnemore, John Wakefield, Roger Purinton, Tom Butcher, Jill Mozier plus others who joined later or did not identify themselves.
- Lisa's webinar slide showed the agenda for the day to be: the [upcoming] call schedule; a brief overview of EPA's work; and a review discussion of the 1-day protocol.
- Regarding scheduling of future meetings, Lisa noted that neither she nor John Crouch are available for the two regular April meetings and that Thursdays in general were problematic. Lisa therefore suggested Fridays at 1 pm and asked if anyone had problems with that day and time. Lisa Herschberger replied she will have problems some of time with Fridays at 1pm. Lisa Rector and Lisa Herschberger will talk one-on-one regarding a work-around.
- Lisa Rector noted that she has not yet posted data from the EPA-funded species testing that Mark Champion did. Mark has finished that testing and Lisa will post PDFs of the White Birch, Red Maple and Red Oak runs to Basecamp. Mark is currently cleaning-up and finalizing his Excel spreadsheet of data and other testing information and that too will be posted, once cleaned up. Lisa asked WG members to review the postings on the species testing. Lisa noted that EPA

welcomes WG members' input after they dig into the data. Lisa also noted that, probably on the next call, EPA will present some of that information.

- Lisa recapped that the WG was starting to get into the definition of burn rates [on the last call]. Lisa suggested that laying out what an alternative protocol may look like could aid the discussion. To that end, Lisa noted that during today's meeting, she will go over the testing work she's doing with Mark Champion, in order to show the WG what one alternative protocol looks like. Lisa asked if there were any other items for discussion, but the group had none.
- Regarding the 1-day protocol, Lisa explained that she [NESCAUM] is trying to develop an integrated run, which builds on the ASTM method as well as the TEOM data being collected in a multitude of labs. **The 1-day protocol compresses all 4 phases of ASTM's test into a single day's run** (i.e., "ASTM-in-a-day"). The run consists of multiple burn rates and loading weights and doesn't burn the fuel charge down to 0 weight. Lisa clarified that the NSPS's 2 g/hr (cordwood limit) or 2.5 g/hr (crib limit) would not apply directly to the results of this 1-day test, but rather equivalency factors would be applied to correlate the 1-day test results back to the compliance standard in place under the NSPS. Rod Tinnemore asked the meaning of the 2 and 2.5 g/hr and Lisa replied that 2 g/hr refers to the NSPS' Step 2 [2020 limit] using crib and 2.5 g/hr refers to the Step 2 [2020 limit] using cordwood. Below is an overview of the integrated run:

## Overview of Integrated Run



- Multiple burn rates
  - Multiple loading events
  - Does not burn to zero weight
  - Equivalency factors **MUST** be developed
- Lisa noted that she was at Mark Champion's lab yesterday, testing to determine what aspects of the protocol are doable and not doable. Lisa noted that she has questions about some parts of her draft protocol, but would like to run through it first for the WG and then come back to seek input and answer questions.
  - Lisa noted that the first piece is the **Start-up Phase**. Mark had Lisa build a fire like she would have at home and then translated those loads into loading densities. Air settings were fully open. Lisa used 6 pieces of crumpled newspaper then loaded small, dry kindling on top of that.

Lisa used the same species for kindling as used in the load. The kindling load resulted in a loading density of 1 lb/cubic foot. The starter load fuel was placed on top of the kindling. Lisa noted that they started with 2 lb/cubic foot but, about 15 minutes into the burn, Lisa noted that she wanted to add more fuel. Therefore, Lisa and Mark decided to increase the density to 3 lb/cubic foot, whether all at once or at any interval during the startup phase. Regarding the parameters for the door and poking/stirring, the door can be open for 5 minutes and poking/stirring is unlimited during startup (the cold start run). Lisa noted that the end of the start-up phase is currently defined as when the coal bed reaches 15% of the high fire fuel charge. [Note: this is cut-off in the below screenshot.]

## Start Up Phase

- Set air settings fully open
  - Startup load
    - Crumple newspaper
    - Load kindling - log cabin style for this test
      - Loading density: 1 lb per cubic foot for dry kindling
      - Species and Size: no restrictions
    - Load starter fuel: all starter fuel can be added at once or added at any interval
      - Loading density: 3 lb per cubic foot
      - Size: ~2 inch round cross sectional equivalent
  - Start fire
    - Door can be open for up to 5 minutes
    - Unlimited poking and stirring during cold start run
  - End of start-up phase d
- 
- Next, is the **High Fire Phase**. Below is a photo of the load used for the high fire phase. Because the load is not being burned down to 0 in this protocol, half of ASTM's 10 lb/cubic foot was used (5 lb/cubic foot). Lisa explained that another load would not fit in the stove, if 10 lb/cubic foot had been used as the starting load, since it is only being burned down to 50%. For the high fire phase, Lisa and Mark used 3 pieces of wood and closed the door immediately. No stirring or poking is allowed during the 1-hour high fire. Lisa requested feedback on whether small or large wood pieces should be used and how the high fire should be defined.
- 
- Lisa noted that the proposed protocol is high fire for only 1 hour. Part of the reasoning for the 1-hour burn is that TEOM data (showing real-time PM) reveals that 90% of the PM is captured in the first 45 minutes. Therefore, sampling really only needs to be performed for 1 hour, according to Lisa. Lisa underscored however that an equivalency factor will need to be figured out to translate back to burning down to 0%, as done in Method 28.

## High Fire Phase

- Open door and load high fire load
  - Loading density: 5lb per cubic ft
  - Size: TBD
    - Questions - small or large pieces
- Door closed immediately
- No stirring or poking
- Test ends at after one hour from loading



- Next, is the **Medium Fire Phase**. Lisa noted that, for the medium fire phase, the wood is loaded in the firebox at 5 lb/cubic foot. This is the same density as the high fire, so the resulting volume is little less than 10 lb/cubic foot, because wood from the high fire is left in the firebox in addition. Lisa explained that, even though a lot burned during the high fire phase, all of the wood did not go down into coals; there are still chunks. Lisa also noted that she had questions for the WG about the proper piece sizes for the medium fire. Below is Lisa's slide for the Medium Fire Phase.

## Medium Fire Phase

- Open door and load medium fire load
    - Loading density: 5lb per cubic ft
    - Size: TBD for definition
      - Piece size recommendations?
  - Door closed immediately
  - Set air settings to medium position
  - One stirring and poking event can occur when there is no visible flame
  - Test ends at after two hours from loading
    - Stove should be able to burn at medium setting for 2 hours. Thoughts on this recommendations?
- Lisa explained that the doors are closed immediately for the medium fire. However, Lisa had to open the doors to stir and poke the fire, as there were no flames. The fire re-lit after this. Lisa explained that the medium fire is currently defined as 2 hours from time of loading, but that Lisa

would like WG feedback on this. She defined the end of the medium fire as 2 hours after loading because it seems reasonable that the unit could be at medium for 2 hours. Lisa noted however that perhaps the end point could be based on 50% of the fuel charge being consumed. Lisa further noted that she is still trying to figure out what the end of test definition should be.

- Next and last, is the **Low Fire Phase**, which is summarized in the below screenshot of Lisa's slide. Lisa noted, that after 2 hours, the coal bed was a little less than 15% [of the 5 lb/cubic foot loading density weight]. For the low fire, the prescribed loading density is essentially to load the firebox with as much wood as it'll take. Lisa allowed room for the tube and noted that she and Mark had used birch for this initial test run.

## Low Load Phase

- Open door and load low fire load
    - Loading density: as much as can be loaded without adequate clearance for tubes
    - Size: TBD for definition
  - Recommend door closed immediately
    - could remain open for 5 minutes
  - Air settings can be modified in the first 10 minutes of the test but must be at low load rate by minute 10:00
  - Test end
    - after 90% of fuel consumed
      - Needs definition
    - no weight change after 30 minutes.
- Lisa noted, that after closing the door, she had the air settings at high [open fully] for 5 minutes before closing them down to the low air setting. The end of the test was defined as when 90% of the fuel is consumed (which, Lisa noted, still needs to be defined further) or no weight change after 30 minutes. Lisa further noted that they were still deciding how to define the end of the low fire test and were looking at TEOM data to determine how long to sample to ensure all of the PM was captured. Lisa explained that they may allow one of the low fire runs to proceed all the way to the end (100% fuel consumption) in order to standardize the burn time, but PM measurements wouldn't necessarily have to be taken the entire time. Lisa noted that they were "still at the top of the funnel" in terms of determining the protocol and that this was the first attempt at the "ASTM-in-a-day" protocol. Lisa asked the WG if there were any questions.
  - John Barnes (from New York) asked if loading as much wood as possible for the low burn rate was to simulate an overnight burn. Lisa replied yes, that was the purpose, but clarified that she and Mark had not taken filter measurements yet. So far, they have just been trying to see if the protocol is reasonable. To that end, they simply laid out 10 lb/cf worth of fuel charge on the ground and then subtracted out the pieces that did not fit (one piece). Lisa noted that she, as the novice did the loading, in an effort to simulate what the homeowner would do [in the "real world"].

- In response to a question from John Barnes regarding the ratio of [time] at the high burn rate versus the middle burn rate, Lisa explained that she didn't have time to parse the data yet and it was done as one integrated run. John clarified that he wanted to understand why 1 hour was selected for the high burn and 2 hours was chosen for the medium burn. Lisa explained that those duration choices were about the amount of fuel in the stove and how people generally operate stoves. Lisa noted that the stove couldn't burn for 2 hours on 5 lb/cf [for the high burn rate test] without going to nothing [no fuel left]. The idea behind the 2 hours for the medium burn is that this seems a reasonable time that people would burn at a medium setting. That is, a stove could sustain a medium fire for 2 hours and, furthermore, this 2-hour medium burn also provides good conditions to go to the low fire load/test. Lisa noted that they could have ended the medium burn test at 1 hour, but then the fire would need to keep burning before going into the low fire load/test.
- John Barnes wondered if perhaps the manufacturer would/should specify a load based on their design. Lisa replied that they were still in the process of determining the appropriate protocol.
- Lisa noted that one of the things she is grappling with, having the luxury of seeing EPA's [species] data [based on both crib and cordwood], is whether or not cordwood generally burns at a lower burn rate than crib wood at the same air settings, everything else being equal. Lisa further noted that EPA's species testing seems to indicate this, at least based on the pre-NSPS stove that EPA used for its species testing. Lisa would like to know if that would also hold true for a cleaner, NSPS-certified stove.
- Bob Ferguson replied that, based on the testing done [by himself and for ASTM, for example] this is true even with very modern stoves – that is, at the same air settings, cordwood burns at a lower burn rate than crib wood. Bob noted that this general experience/fact is based on using [the relatively high] ASTM loading densities. Bob explained that there's not enough air spacing [in the firebox when loaded with cordwood] and more air would be required in the stove than the cordwood load allows, in order to get to the higher crib-based burn rates.
- Lisa noted that a high fire [open, high air settings] with cordwood could be similar [in burn rate] to a medium fire [medium air settings] on crib. Therefore, as Lisa and Mark do cordwood testing and develop a cordwood protocol on an NSPS-certified stove that was tested for cribs, Lisa wondered if that should be determined/accounted for in some way.
- Bob Ferguson explained that [this differential in burn rates on cordwood versus crib wood] shows up most at the lower burn rates, that is, when stoves are set to the lowest air/burn settings. Bob noted that it probably occurs less on high because, as the fire gets going, there is less fuel weight with cordwood, depending on when the test is ended. If the test doesn't end until 100% of fuel consumption, then the charcoal tail is impactful. Bob noted that the long tail is much more of a problem with cordwood than with crib. On cordwood, the long tails is doubling the length of the test. Bob explained that it takes approximately the same amount of time to burn the last 10% of cordwood as it takes to burn the first 90% of the fuel (on high fire). It's not a linear process, but low fire shows the most difference, according to Bob. Lisa noted that this

was the same phenomenon that occurred during EPA's species testing on the pre-NSPS Vigilant stove.

- Lisa noted that one question that she and Mark had at end of the first trial day of testing was whether the stove's air setting designed for the lowest burn using crib wood should be used when burning cordwood. Or, should she and Mark adjust the air settings to achieve a similar low burn rate on cordwood that was achieved using crib [which would require that the air settings be opened some amount to allow in more air than the lowest setting, as cordwood would require more air to burn at the same burn rate as cribs]. Lisa clarified that it was a ridiculously low burn rate [using cordwood and the lowest crib settings].
- Bob Ferguson replied that, in his experience, fires burning cordwood at less than 1 kg/hr went out and so that air setting may have to be adjusted. Bob noted that ASTM handled that by requiring an 8-hour burn, but of course an 8-hour burn is to be avoided in an integrated run. Bob noted that there are many stoves where the fire will go out when burning cordwood on the lowest air setting designed for crib wood [certification test]. Bob concluded that he didn't have an answer for Lisa, but there is a big difference [in burn rates between crib and cordwood].
- Stef Johnson noted that Lisa would not find a prescriptive one-size fits all [for the cordwood protocol]. Therefore, Stef suggested that it may be better to be descriptive and look for a performance basis for defining the load rather than being prescriptive.
- Lisa noted that this meant playing with the stove [that is, adjusting the lowest air setting]. Moving forward, if a stove is designed to burn cordwood, it wouldn't be designed as stove designed to burn crib. Lisa wondered therefore how to design a protocol for a cordwood stove while using a stove designed for crib wood.
- Stef replied that he understood the conundrum and that an additional challenge is that there will exist many different stove designs. Therefore, the test method probably cannot be hard coded, since there is no one size fits all. Rather than defining the burn rates, Stef suggested considering defining the conditions that the test has to meet – for example, describe the operating criteria.
- Bob Ferguson noted that ASTM had looked into this on a particular stove and determined that the air setting that delivered a 1 kg/hr burn rate while burning a 12 lb/cf cordwood load, would have delivered about twice that burn rate (2 kg/hr) if burning crib wood. Bob noted that this was approximate and was based on one stove. Bob further noted that he agreed with Stef that there will be differences [among stoves]. Bob suggested considering that the protocol require burning X% of fuel or no more than X% of fuel, in order to allow some flexibility to accommodate stove-to-stove variation, but at the same time provide some basic performance description. Bob concluded that this is especially difficult to define after only one day of testing.



- Lisa replied that she and Mark will go back to the drawing board, regarding the cordwood protocol. Lisa suggested that the WG go back to the beginning, the first slide, to see if anyone had any questions on the proposed start-up.
- Lisa noted that Bob Ferguson had noticed that Lisa and Mark were using a lot less kindling in their draft cordwood ASTM-in-a-day protocol than ASTM's method does. Lisa asked if they were using about half of what the ASTM method calls for. Bob Ferguson confirmed that Lisa and Mark used about half of ASTM's start-up load. Bob noted that Lisa's and Mark's stove did look a little thin at start-up and the stove may have been happier with more kindling. Bob further noted that 1 lb/cf of kindling will look thin in some stoves, depending on the size of the hearth. Lisa agreed and noted that the amount used wasn't determined scientifically. Lisa further noted that she would use more starter fuel on the next run/step and may ultimately decide to go to more kindling, perhaps ending up in same the place as ASTM.
- Bob Ferguson noted that Lisa's and Mark's kindling density in their draft protocol was close to what ASTM requires. Bob explained that ASTM's requirement is based on fuel weight. Therefore, a 20% [of fuel load weight] metric for the kindling results in a loading density of 2 lb/cf for kindling and then 3 lb/cf for the start-up fuel. Bob suggested that Lisa start obtaining photo documentation so that people can see what the loads look like. Bob noted that the stove should maintain relatively clean glass and that the load could be seen this way and also with the door open. This way, Bob noted, people can see if the volume passes the reasonable test. Lisa noted that she had photos but wanted to clear those photos with Mark before showing. Bob suggested that Lisa decide where to take photos to avoid having too many photos, but that visual cues are helpful to stimulate discussion among the group.
- Since there were no questions from the WG on the start-up phase, Lisa went on to see if the WG had any questions regarding the high fire phase. Lisa noted that, for the high fire, she and Mark lowered the loading density to 5 lb/cf and wondered if they should go back to 7 lb/cf, in order to be closer to what Method 28R calls for. Lisa noted that she was agnostic about this decision. Lisa also asked the WG if they should be using small or large pieces in the high fire phase, or perhaps a mix of both.
- John Barnes asked in response what the homeowner/consumer would most likely do.
- Lisa explained that she and Mark used pieces that were twice the size of the starter fuel, but not the biggest pieces, with the rationale that the coal bed is not yet established when going to a high fire right after start up. Therefore, a homeowner wouldn't use the big pieces yet and Lisa decided to use small and medium size pieces, with not specific size definition. Lisa noted that her recommendation would be for the pieces to be on the smaller size for the high fire phase.
- Regarding the medium fire, Lisa again displayed the medium fire slide for the WG, and noted that she recommended larger pieces for this phase, because there is a better-established coal bed at this point. Therefore, the homeowner/consumer is more likely to use bigger pieces.

- Rod Tinnemore asked for confirmation that Lisa doesn't yet have a way of defining piece size. Lisa confirmed that she did not yet, but would have to determine a definition.
- Lisa noted that, for the low fire phase, she and Mark used a mix of piece size to get as many pieces into the firebox as would fit.
- Rod noted that the smaller loading density [used in Lisa's and Mark's draft protocol] does provide more flexibility for the smaller firebox sizes, since there are smaller stoves out there on the market. So, as stated, the protocol is not running the risk of the load not being able to fit into the firebox, whereas that's not a risk going upwards in firebox size. Lisa noted that was a good point and further noted that they were using a medium firebox for testing currently, but would need to go to smaller and larger fireboxes.
- Randy Orr noted that it's reasonable for the protocol to call for small pieces for the High Fire load, medium to large pieces for the Medium Fire load and a jigsaw size mixture of small, medium and large pieces for the Low Fire load.
- Lisa noted that she would post the "ASTM-in-a-day" (i.e., multiple burn rates and load weights in one consolidated/integrated run) protocol to Basecamp and asked WG members for feedback regarding variables or directions that Lisa and Mark may not have yet considered.
- Rod Tinnemore commented, regarding the 2-hour medium burn, that it's difficult/problematic to have an external factor [static requirement] applied to all stoves. Rod noted that other factors need to be examined to determine something other than a rigid timeframe. Lisa agreed and noted that she and Mark had discussed whether setting a rigid timeframe was providing loopholes for some stoves and hurdles for other stoves. Rod noted that he'd like not to build in [a need for] exceptions, but rather make the protocol as flexible as possible to work for a wide range of stoves.
- Lisa noted that, as an alternative [to a rigid time requirement], she is considering instead that the protocol call for burning down the coal bed to a percentage of the fuel load. Stef Johnson noted that he thinks that's a good metric. Lisa clarified that she's thinking about the protocol calling for burning down the coal bed by 50% from the High Fire to the Medium Fire and then by 25% from the Medium Fire to the Low Fire. However, Lisa noted that she's trying to balance those percentages so that the test doesn't go too long.
- There were no further comments or questions. Lisa noted that she and John Crouch would get back to the WG after reviewing their schedules. Lisa will post this presentation to Basecamp along with photos (with Mark's permission). Lisa will also post PDFs of EPA's species testing to Basecamp.
- Meeting adjourned