JANNAF SLOW COOK-OFF CONSORTIUM WORKSHOP FINDINGS

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ABSTRACT

This report summarize the slow cook-off consortium workshop that was held during the Dec 2015 Joint Army Navy NASA Air Force (JANNAF) Programmatic and Industrial Base (PIB)/Propellant and Explosives Development and Characterization (PEDCS)/Safety and Environmental Protection (SEPS)/Structures and Mechanical Behavior (SMB)/Rocket Nozzle meeting. The goal of the meeting was to provide an update on policy changes that are being investigated and to identify gaps/methods to address gaps in knowledge as they pertain to slow cook-off. A secondary goal of the workshop was also to begin preparing a position for the munitions safety information analysis center (MSIAC) meeting that was held in Atlanta in April 2016. An initial survey was sent out prior to the meeting to focus discussion. Gaps in policy, modeling & simulation, and testing were identified along with potential methods to address the gaps.

INTRODUCTION

The slow cook-off test has received a significant amount of scrutiny since it was first proposed. The hazard classification community utilizes the slow cook-off test for hazard classification of hazard division 1.2.3. It is utilized to evaluate an ordnance item to a slow heating response.[1] However, in the insensitive munition community the slow cook-off rate has been very controversial. Prior slow cook-off workshops were held that focused on the origin of the heating rate and the validity of the rate as being either the worst case scenario or if it should be the most likely rate encountered.[2-3]

The slow cook-off test is defined in STANAG 4382 2nd Edition. Two types of heating rates are defined in the test series. The standard test defines a ramp rate of 5ºC per minute to a preconditioning temperature of 50ºC for eight hours or until the item reaches thermal equilibrium, whichever occurs first. Following the preconditioning, the test item is then subjected to a gradual increase in temperature of 3.3ºC per hour until reaction. The second method is a tailored test, where preconditioning is not required, rather utilize a heating rate based on the analysis of the appropriate heating rate for the item. If no analysis was done, then a default rate of 25ºC per hour will be used. It is important to note that the tailored test is not applicable for hazard classification purposes. In the United States (US), the use of the tailored test requires increased levels of approval to utilize over the 3.3 ºC per hour rate. The test item will be placed in an insulated disposable oven where the difference in air temperature between the inlet and exit does not exceed 5ºC. The oven will be constructed so that it offers the least possible confinement. The air gap between the oven and the item is a minimum of 200 mm to allow for air circulation. Four thermocouples in the oven will monitor the air temperature. The response of the item will be evaluated by the air blast overpressure, witness plate, fragmentation, photography, and video response.[4]

The goal of the workshop that was held in December 2015 at the JANNAF meeting in Salt Lake City Utah was to review the current status of modeling, testing, and policy as they relate to slow cook-off, identify gaps in knowledge, and methods to address these gaps. In addition, it was also to prepare the US for the upcoming MSIAC meeting that was being held in Atlanta Georgia at the end of April. Prior to the meeting, a survey was sent out as pre-work to members of the JANNAF Propulsion System Hazard Subcommittee (PSHS) cook-off panel to identify gaps in knowledge and to focus efforts in the workshop.

WORKSHOP PRE-WORK

A week before the workshop, an email was sent out to 59 people from the department of defense, department of energy, industry, and academia inviting them to take part in a survey and provided information on the upcoming JANNAF cook-off workshop. The participants were invited to also forward the invite to other interested parties. The participants that were selected were members of the JANNAF cook-off panel. The survey was hosted on survey monkey and consisted of nine questions that were mostly multiple choice with an option to expand on their comments if desired. The survey was free for use and had limited functionality compared to paid resources. The first three questions were demographic in nature. These quantified what the individual's primary interest in slow cook-off was, their experience level, and what business sector/service does the individual belong to. The next question inquired on their belief on how well the slow cook-off community understood a range of topics such as decomposition chemistry to confinement effects. The next three questions asked the respondent to evaluate how well the community is able to predict/model various conditions, determine specific parameters through testing, and what items should influence slow cook-off policy. The remaining two questions were open ended that asked what the biggest gap in knowledge was in slow cook-off phenomenology was and what the most critical policy issue was as it relates to slow cook-off.
The questions and tabulated responses can be found in the appendix.

The overall response to the survey was very low. Prior to the meeting, only 8 people responded to the survey for a response rate of 13.6%. The survey link was resent out after the meeting to solicit an increased response rate. The survey was sent out to a total of 85 people and was left open for two months following the meeting. A total of 17 people responded to the survey. However, three of the respondents only did the demographic questions. Therefore, only 14 people were considered with a respondent rate of 16.5%. It should be noted that 14 people completed the majority of the survey, a few of the respondents did not answer the open ended questions.

The demographics of the survey can be seen in Figures 1-3. Figure 1 shows the organization affiliation who took part in the survey. The majority of the participants were from the Navy. The "other" affiliates were from Department of Defense Office of Secretary of Defense and Naval Ordnance Safety and Security Activity (NOSSA). The participants who took part in the survey were mainly interested in three areas: modeling, policy, and small scale testing, as seen in Figure 2. Experience level for looking at slow cook-off was mostly focused at either greater than 20 years or 2-5 years, seen in Figure 3.

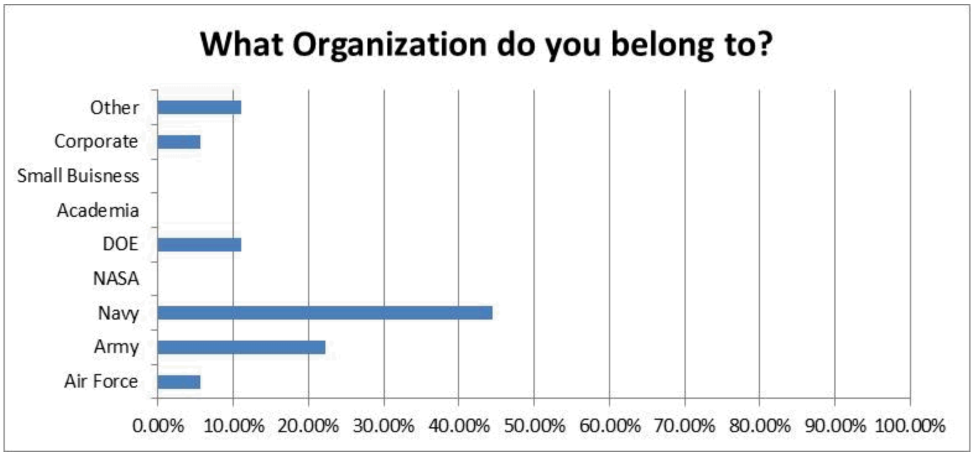

Figure 1. Organization Affiliation

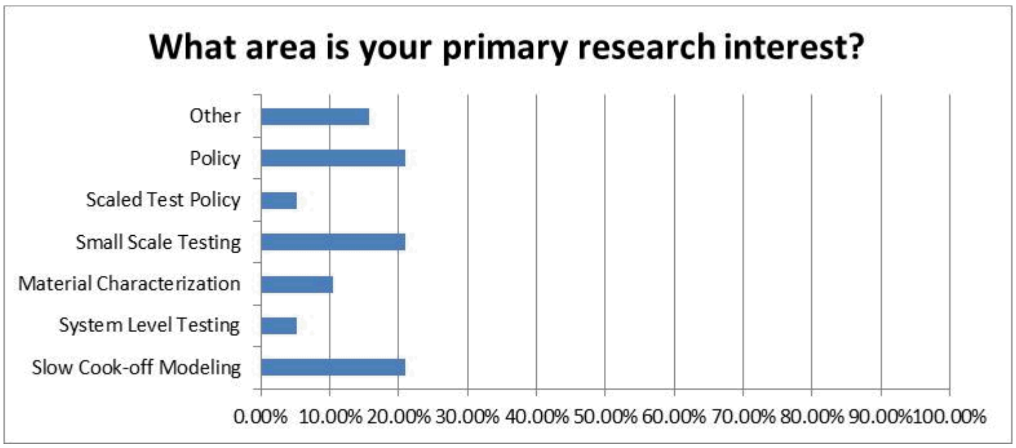

Figure 2. Participant Research Interest

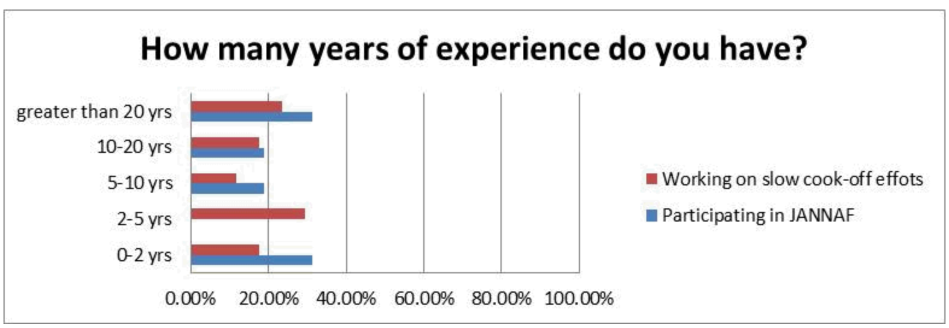

Figure 3. Participant Experience level

The participant was asked to evaluate how well the community understood 7 topics as seen in Figure 4. The first two parts of the question was to evaluate how well the community understood ammonium perchlorate (AP) and nitramine decomposition. The majority of the respondents felt that nitramine decomposition was fairly well understood with small gaps. Ammonium perchlorate was viewed as not well understood. The causes of reaction violence, confinement effects, heating rate effects, energetic physical state at cook-off and case/liner/insulation state at cook-off were not well understood or viewed as having large gaps in knowledge. Other areas that were brought up that were commented on that had gaps in knowledge were solid state chemistry, confinement, location of ignition as a function of heating rate and system geometry, conductive and convective burning as a function of pressure, thermal damage, and propellant binder effects.

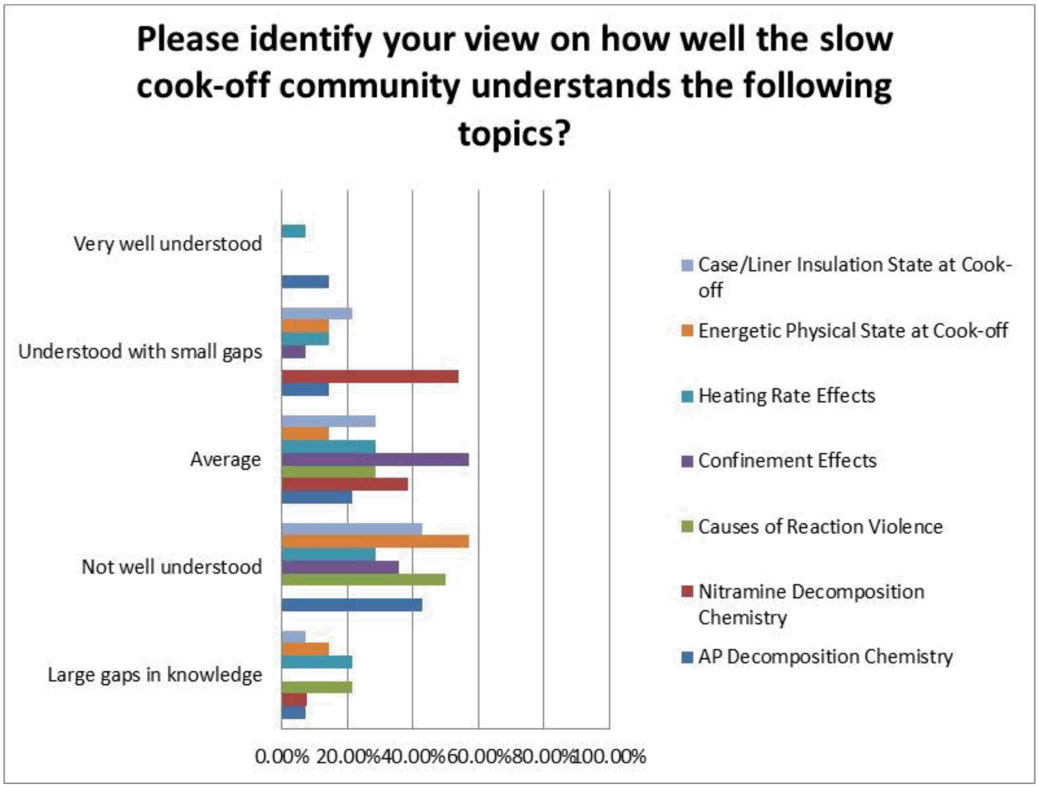

Figure 4. Knowledge Assessment

Figures 5 and 6 assess how well the participants believed the community can model and test various slow cook-off phenomenon. Generally, the community believes that the time to reaction and temperature at reaction can be predicted modestly well to accurately. Prediction of reaction violence and influence of heating rate on reaction violence are the items that the participants felt cannot be predicted at this point. On the testing front, the determination of system level response based on subscale testing and material condition at or near cook-off are the parameters that the participants felt cannot be currently determined by testing.

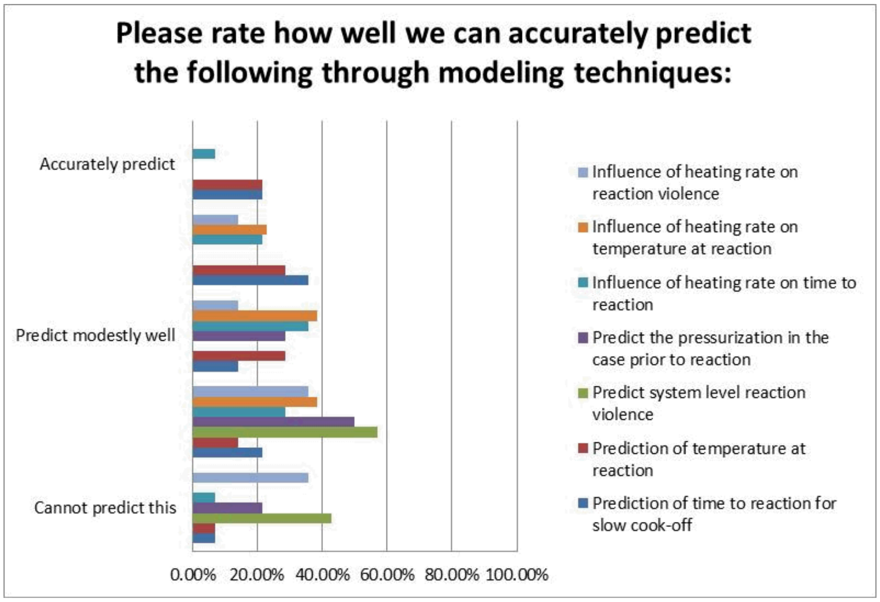

Figure 5. Modeling Assessment

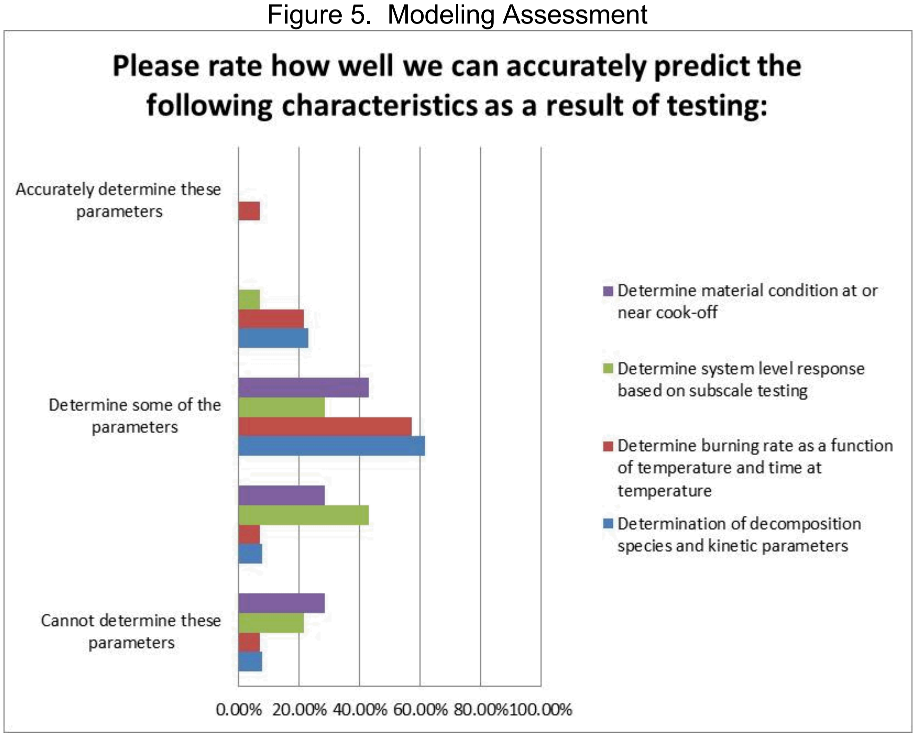

Figure 6. Testing Assessment

The participants viewed having a heating rate as the most likely situation encountered as slightly more important than using a heating rate that is the worst case scenario. This brings up the need for the threat hazard assessment (THA). In addition, the participants viewed it important to very important to have small scale data with system level data to determine overall reaction violence. Finally, they believed that cost should not be a driver in determining policy updates.

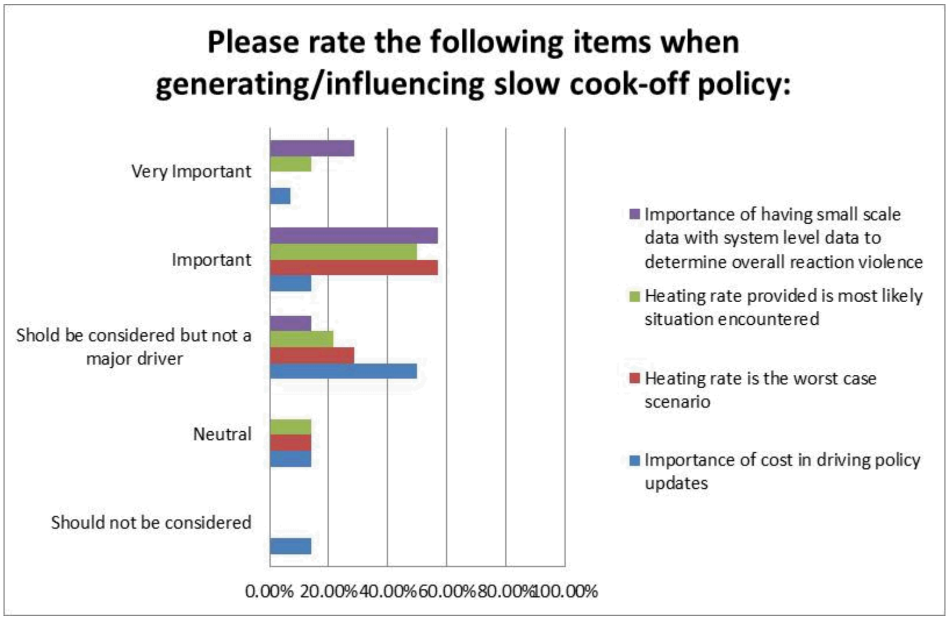

Figure 7. Items that influence Policy

The final two questions were open ended questions asking the participant what is the biggest gap in knowledge in terms of slow cook-off phenomenology and the most critical policy issue. The biggest gap in knowledge in terms of slow cook-off phenomenology is the ability to predict reaction violence. Other topics that were brought up were scaling, AP-based reactions, representing thermally damage evolution with burning rate enhancement, and linking reaction violence definitions to science. The most critical policy issue that was brought up was the heating rate. Other policy issues that were mentioned were funding to help the testers and modelers to better understand what is occurring, utilizing modeling more to understand what is happening with the munition, and utilizing one type of test to understand the system.

The results of the survey were utilized to help shape the presentations and discussions at the workshop.

WORKSHOP

The slow cook-off consortium workshop took place on December 7-8, 2015 as a PSHS workshop being held in conjunction with the JANNAF PIB/PEDCS/SEPS/SMB/Rocket Nozzle meeting that was being held in Salt Lake City Utah. The workshop lasted one and a half days.

Day 1

The workshop started on Monday afternoon with 47 participants. All the presentations from the workshop are available for distribution if desired. Plenary presentations began the workshop. The first presentation reviewed the previous JANNAF workshops that were held in 2011 and 2012 focused on the slow cook-off heating rate. In this, the potential basis for the 3.3ºC heating rate was discussed along with the issue that the program offices are building munitions to pass the test even though the rate might be unrealistic and depending on the munition and scenario could not lead to the most violent reaction. The second presentation was an overview of the international meeting on slow cook-off (technical cooperation program (TTCP)). A three year effort is currently ongoing to look at slow cook-off and which is the best rate. The US and United Kingdom are the major participants. The US effort was focused on the first year looking at modeling the different heating rates and types of heating (forced vs. natural convection). The second year compared the models to the testing with the third year being focused on all up rounds. The third and fourth presentations of the plenary were focused on the current status of testing and modeling. These outlined where the presenter's thoughts were on what the current gaps in testing and modeling.

Following the plenary sessions, the group was broken up into three areas; testing, modeling, and policy. The goal of the break-out sessions was to expand on the gaps that were identified in the plenary and the survey. The modeling break-out session had nine participants. These participants were from the Army, Navy, Department of Energy, and a prime contractor. The testing break-out session had eleven participants from the Army, Navy, Air Force, and prime contractor. Six people from the Navy, Army, and Air Force participated in the policy break-out session. It should be noted, each break-out session also identified potential gaps in the other two areas. These gaps were then rolled up into each particular session.

Policy Break-out Session

The policy break-out session addressed both potential gaps in policy and methods that could be done to alleviate/address the gaps. Three main gaps were identified by the participants. The first gap that was identified was the appropriateness of the heating rate. As alluded to previously, what should the heating rate be: should the heating rate be worst case scenario, most likely scenario, or item's response to low temperature heating. If the heating rate is changed the following questions were considered: how will the body of data that has been generated using the 3.3°C per hour compare to the new standard, will previously tested items need to be tested at the new rate, ordnance items worst case scenario; the most likely response will vary for each ordnance item so what is the rate that will be used? Will the IM/DDESB de-harmonize with respect to slow cook-off since DDESB did not want to change the heating rate? The potential near term way forward proposed by the group was to increase the number of tests currently run. Perform two slow cook-off tests per THA and one at 3.3°C/hr (based on the response, assess the need for a second test). In the out years, utilize models and subscale tests to predict reaction violence so that two slow cook-off tests could be run per THA and assess at the 3.3°C per hour based on the modeling results. The challenge with this method will be OSD/DDESB approval for this recommendation.

The second gap that was identified by the group was oven configuration/design. The STANAG does not define how the oven is constructed. The oven should not drive the reaction of the system. For example, if material flows out of the munition via a vent plug or other types of venting mechanisms, the oven should be constructed so that the material does not fall onto a heating element that ignites the material and can cause either a more reactive or mild reaction. The oven fragments should also be used as secondary evidence only. Finally, the soak conditions should be tailored so that the reaction occurs during the day to enhance the video evidence.

The third gap identified was the maximum temperature requirement for US tests. If an ordnance item does not react by the defined temperature (365°C) it is considered as having no reaction. This requirement for US tests is currently not found in the STANAG. If the number was based upon limitations of standard test equipment to a maximum temperature or reasonable ability to maintain ramp, should consider adding to STANAG, if other rationale, than consider dropping as a requirement for US tests.

Additional gaps that were brought up by either the modeling or testing side were scoring, aging, and cost. Currently, the method that the slow cook-off test is scored is qualitative in nature. To better predict a system level response based on both models and lab-scale/subscale testing will require more quantitative metrics. Current slow cook-off testing is also done on pristine munition. How does age effect the response of the munition. Finally, how will cost play a role in improving the slow cook-off test.

Testing Break-out Session

The second break-out session was focused on addressing gaps in testing. The testing group had a general question for the modeling group about what types of data do they need and to what fidelity do they need it. The testing gaps that were identified were broken out into three main areas: lab scale, subscale, and system level testing gaps. The lab scale testing gaps were under three main areas. The first area is what is the physical/chemical state of the energetic as a function of temperature and time at temperature. There is a lack of data for the energetic as the item heats up. The majority of the data that is collected is at ambient or at slightly elevated temperatures. It is important to know the porosity, permeability, surface area, decomposition products, thermal diffusivity/conductivity, and burning rate as a function of temperature and time at temperature. It has been seen for a given energetic material that the burning rate can increase four times the elevated temperature burning rate when the material sits at temperature for greater than 3 hrs. This data would be invaluable to provide the modelers so that they can accurately predict what is occurring to predict reaction violence. Another gap that was brought up at the lab scale level is the physical/chemical state of the inert items (case, liner, and insulation). The majority of lab scale data that is generated is on the energetic. Understanding the influence of these items is also importance. The last major lab scale gap that was brought up was what is the correct heating rate to use, should the heating rate be scaled for the sample size. A milligram sample might need a different heating rate versus a gram or kilogram sample. Previous work has shown difficulty in developing kinetic parameters based on lab scale testing. Could the issue be the rate at which the heat is applied does not match subscale or full scale rates?

Subscale testing gaps were the next area to be identified. Similar gaps were identified that were found in the lab scale testing gaps such as the correct heating rate as a function of item size and physical/chemical properties as a function of both temperature and time at temperature. At the subscale level, understanding how confinement effects these properties is also important. Since the material is confined, the reactions may catalyze and potentially lead to more violent reactions. As a result of confinement, understanding how the system pressurizes and how the porosity changes over time is important in modeling reaction violence. There is a gap in the ability to visualize/quantify the material at or near cook-off. How does quenching the material influence/change its physical/chemical properties once the item reaches cook-off temperatures. In determining reaction violence, what items should be measured at the subscale level. What is the influence of critical diameter as a result of thermal damage? There is a strong desire to utilize small/subscale tests to predict large/system level response. What components should be measured to inform formulators, modelers, and system designers on how the item/energetic will behave. How do you scale the tests to be able to predict a system level response? How does the soak influence the overall response? Does the test have the capability of capturing thermal paths like the full scale system. How applicable are the current subscale tests to different types of material (explosives, propellants (gun, rocket, etc.), pyrotechnics).

Gaps in system level was the last area addressed by the testing group. Many of the gaps that were previously mentioned in the policy section was also identified by the testing group. For example, applicability to real world, the lack of documentation for the construction of the oven so that it will not influence in the test or the response of the item and the US upper temperature limit requirement. Another gap associated with the oven is how natural versus forced convection play a role in the item's response. How uniform does the temperature need to be throughout the oven so dead spots should not exist? Once the oven fails how complete is the reaction? The question was raised if we can have a standardized test. We have a large variety of munitions that are different sizes and weights. Current testing requirements are acceptable for small munition but for the large munition, the soak temperatures are never reached prior to ramped heating. The gap size between the oven wall and item might be too much for smaller munitions but not enough for larger munitions. The way the test is scored was also a gap that was identified. The desire to have more quantitative metrics. Therefore the potential to increase the amount of instrumentation on the test. What types of instrumentation would provide more quantitative metrics that the modelers could use to validate their reaction violence predictions. How does the instrumentation change with a logistical configuration where the item might be in a launcher which is in a storage container. How does various components influence the full scale reaction? Many times the motor is tested separately than the warhead. If both have been thermally damaged what is the overall reaction?

Modeling Break-out Session

The third break-out session addressed gaps in modeling. Similar gaps were identified in the modeling session as both the policy and testing areas. The lack of material properties at high temperature, accurate representation of heating rate (how well is it controlled and tests that capture heat rate accurately), and the need for more quantitative data in determining reaction violence response. Would wall strain rate or a stochastic representation of the fragmentation be more appropriate in determining the response type in a model? It was concluded that the modeling tools are available however there are gaps in terms of when is the correct one to apply and how to parameterize the models, if single-physics tests are acceptable, integrated tests, or a mixture of both. The ability to scale the models is also difficult. For example, utilizing the same kinetic scheme to match the small, intermediate, and full scale response is difficult. In addition what level of the system is appropriate to sufficiently model the response. How does the "mass effect" get taken into account? Larger munitions tend to be more violent, the cause of this is still being debated. How can models be used as a tool to inform the design process to get a "good answer?"

Addressing which model to apply will depend on the energetic. Looking at three types of energetics: plastic bonded explosives (PBXs), melt cast, and composite propellants, each system has different properties that needs to be taken into account and the different heat transfer mechanisms. The PBXs will need to consider cracking, thermal damage evolution (such as changes in porosity, permeability, and surface area), venting/pressure effects, and chemistry. The composite propellant will be similar to the PBXs however, AP chemistry complexities will also need to be considered along with binder effects (such as swelling, crosslinking/hardening, particle debonding, and effects of minor constituents on binder behavior).   Melt cast energetics have liquid phase behavior that must be considered such as flow (can be 2-phase), dissolution, and chemistry effects that is accelerated which cannot be extrapolated.

The ability to accurately model thermal damage evolution is also a gap. How to accurately characterize thermal damage (connected porosity, surface area, etc.) and how it evolves as the energetic is soaked and heating. Accurately representing the interaction between the ingredients (e.g. dissolution of the RDX by TNT in Comp B leads to faster reactions than would otherwise be expected for either ingredient alone) and the representation of the binder.

Day 2

Participation dropped for the second part of the workshop to thirteen people. The first part of the second day was out-briefing the gaps identified in the break-out sessions. Following the out-briefs, it was decided that the members remaining from the testing group and the modeling group would pick what they felt was the most important gaps and the remaining participants would come together to find potential ways to address the gaps. Following the roundtable for potential solutions, a brief was given on the potential rewrite of STANAG 4382 into AOP 4382. The workshop was then concluded with an out-brief planned for the MSIAC meeting in Atlanta in April and the PSHS meeting in May.

Potential Solutions for Modeling Gaps

The modeling gaps were down selected to three main items: thermal damage evolution, thermally induced swelling, and measurable parameters for correlation of cook-off response. To accurately model thermal damage evolution, the modelers need data on porosity/permeability/surface area as a function of heating rate/temperature/confinement history to help parameterize the models (e.g. convection combustion models). In addition, heated/damaged material burning rates (via either combustion bomb and/or pressurized stand burner) are also needed. These inputs would then be inserted into an appropriate model (such as convective burning) to address thermal damage evolution. Adapting a polymer foam chemistry and mold-filling models to hydroxyl-terminated polybutadiene (HTPB) propellants would be attempted to try to predict thermally induced swelling of propellants. The correlation of cook-off response with a category I-V (detonation, partial detonation, explosion, deflagration, and burn) would require additional testing. The suggestion was to add addition instrumentation to the item so that the strain rate at wall, internal pressure in the energetic, etc. would be correlated with the reaction violence score.

Potential Solutions for Testing Gaps

Gaps were identified for each scaled test. The gaps that were identified were chosen based on the needs from the modeling team. In the lab scale testing the desire for material properties at and along the way to cook-off was addressed. To obtain the thermal diffusivity/conductivity data at higher temperatures could be obtained by backing it out from the SITI thermocouple data. Decomposition product determination would be to utilize a gas chromatograph/mass spectrometer to measure/identify the off-gases. Care must be taken to ensure the lines are uniformly heated to prevent condensing in the lines. Products may continue to react as they go through the system so intermediate species may not be determined. It was suggested to talk to Dr. Jeffrey Kay from Sandia Livermore for pressure rate influences on decomposition species and how to best collect the data. Temperature time history for the strength of the case could also be data mined to improve the fidelity of the models.

The subscale gaps that were addressed was the visualization/quantification of the item at or near cook-off and what should be measured in a subscale test to predict reaction violence. Two techniques were brought up that would allow for the visualization/quantification at or near cook-off. The first technique is the use of x-ray. Flash x-ray and real time radiography can be used to probe what is occurring in the item as it gets closer to its cook-off temperature. Consideration must be given to the case and propellant material since flash and other radiography techniques can only penetrate a specified distance based on the power level. The x-ray technique can also be used to measure the pressure generation in the item by visually seeing the bubble/gas propagation. The pressure can be backed out if permeability and gas pressurization data can be measured. Another option to visualize what is occurring near cook-off is to rapidly quench the material prior to the reaction. However, the concern with this method is that additional damage may occur to the material due to the rapid temperature drop. Strains and near field/inside pressure time history should be measured to determine reaction violence at the subscale level. The number of fragments and state of the material (porosity, etc.) should also influence how reaction violence should be predicted.

The major gap that was addressed at the system level was improving the instrumentation to obtain more quantitative metrics for scoring the reaction violence at the system level. Assigning measurable quantities to the reaction types 1-5 (detonation, partial detonation, explosion, deflagration, and burn) based on the addition of diagnostic tools is the first step. It was suggested to measure pressure in the oven, internal to the system (in-bore) if possible and near field pressures. The utilization of planar Doppler velocimetry (PDV) and high speed video for fragment velocity. To determine wall strain-rate utilize Moriee fringes, digital image correlation (DIC) photo geometry (speckle pattern), or stamp dots to see the expansion of the case. Metallurgical fragment analysis can also be used to determine the reaction type. Some challenges exist to adding additional instrumentation. The slow cook-off test will cost more and will take longer time to set up. Program Offices and the ranges will need to see the benefits of adding the extra instrumentation. It will need to be shown that the added instrumentation will lead to a better informed score and in the long run could lead to reduced costs. The added instrumentation will help the modelers match their model to the various reaction types. This will enable the exploration of other conditions that may be examined as was proposed earlier in the policy session without the need for additional testing.

SUMMARY

A slow cook-off consortium workshop was conducted at the JANNAF PEDCS meeting in Dec 2015 at Salt Lake City, Utah. Forty seven people from the DoD, DOE, academia, and industry participated in the meeting. The focus of the meeting was to provide an update to the community on the current status of slow cook-off policy, testing, and modeling. Gaps and potential ways to address the gaps in the three areas were identified at the workshop. Prior to the workshop a survey was sent out to focus the workshop on what the community viewed as the largest gaps in testing, policy, and modeling.

The first day of the workshop had plenary sessions on current status of policy discussions, modeling, and testing. In these sessions, the presenters identified potential gaps in testing, modeling, and policy. Break-out session then occurred where the gaps were expanded upon.

On the second day, the break-out sessions were debriefed to the group. A decrease in the number of participants was observed. Methods to collect the data to fill a few of the gaps in modeling and testing were suggested by the group. Due to time constraints not all of the gaps were addressed. Following the group discussion on addressing the gaps, a brief was presented on the potential for a possible rewrite of STANAG 4382 into an allied ordnance publication (AOP) where potential changes were discussed.

The results of the slow cook-off consortium workshop were then presented at the MSIAC meeting on the Science of Cook-off that occurred in Atlanta, Georgia on April 25-29, 2016.

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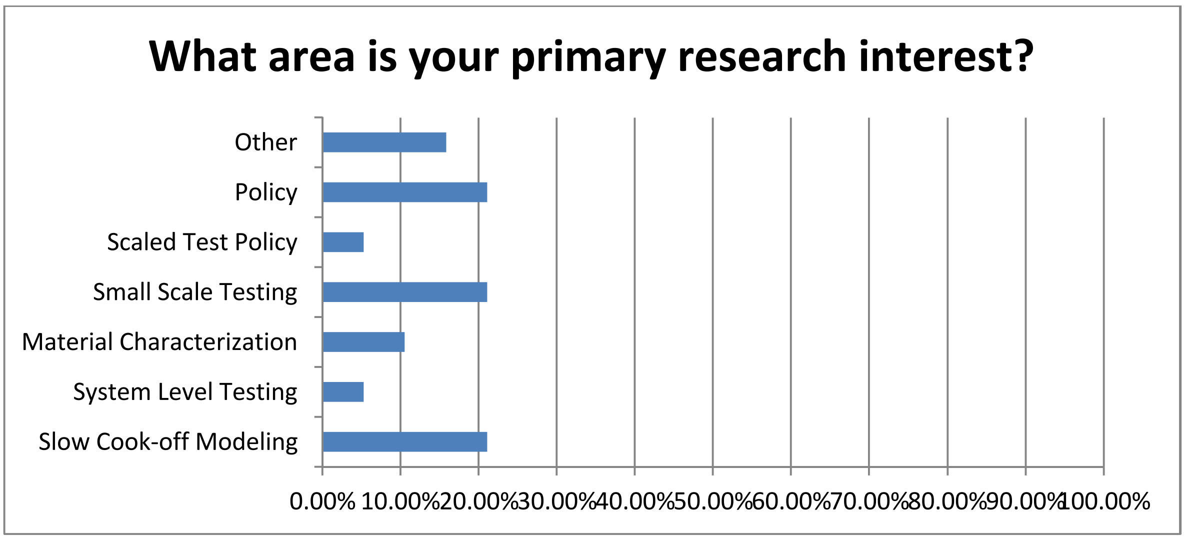
3. Fuchs, B.E. and Clark K.A. “Slow Cook-off Rate Determination Workshop.” 59th JANANAF Propulsion Meeting, 41st SMB, 37th PEDCS, 28th RNT, 26th SEPS Joint Subcommittee Meeting. Colorado Springs. CO. April 2012
4. STANAG 4382 Ed. 2, “Slow Heating, Munitions Test Procedures,” North Atlantic Treaty Organization (NATO), 15 April 2003.

Appendix 1: Survey Results

1.) What area is your primary research interest?

	Responses	Percentages
Slow Cook-off Modeling	4	21.05%
System Level Testing	1	5.26%
Material Characterization	2	10.53%
Small Scale Testing	4	21.05%
Scaled Test Policy	1	5.26%
Policy	4	21.05%
Other	3	15.79%
Total	19	100.00%

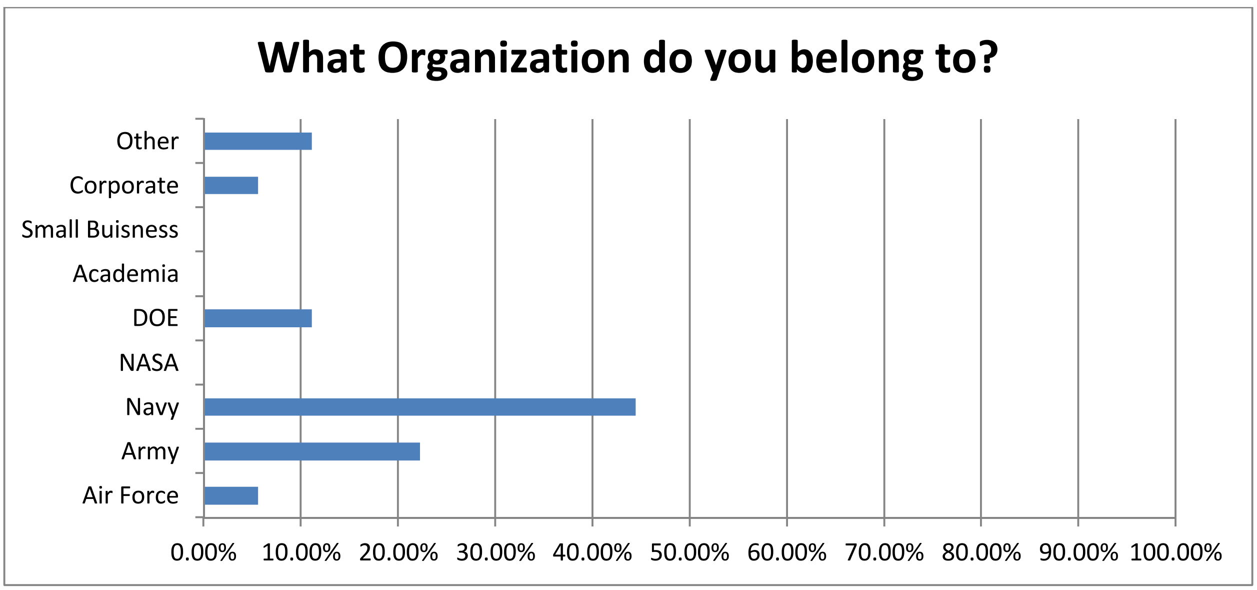


Other:
All of the above.
and small scale testing
Proper slow cook-off modeling requires all of the above except policy

2.) What Organization do you belong to?

	Responses	Percentages
Air Force	1	5.56%
Army	4	22.22%
Navy	8	44.44%
NASA	0	0.00%
DOE	2	11.11%
Academia	0	0.00%
Small Buisness	0	0.00%
Corporate	1	5.56%
Other	2	11.11%
Total	18	100.00%

Other:
DOD OSD
NOSSA



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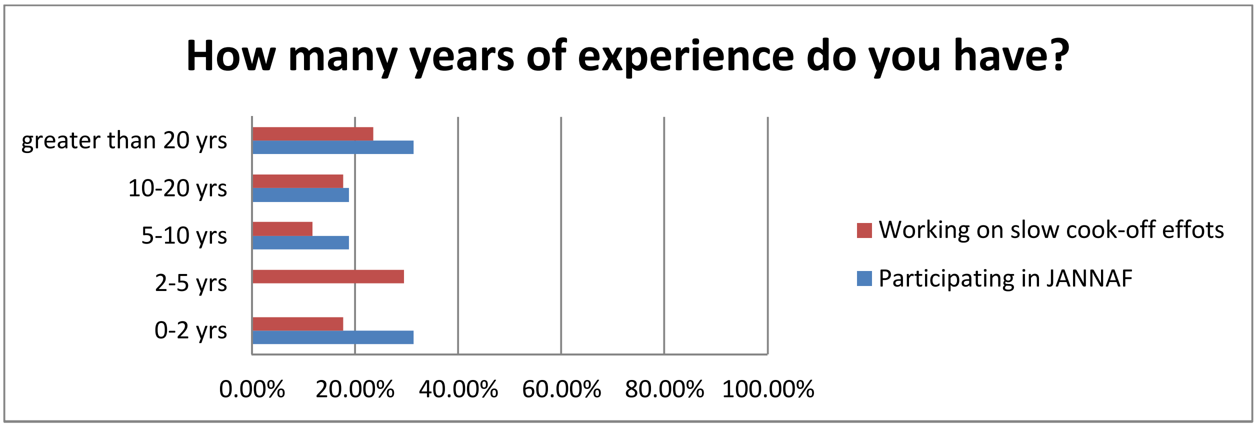
3.) How many years of experience do you have?

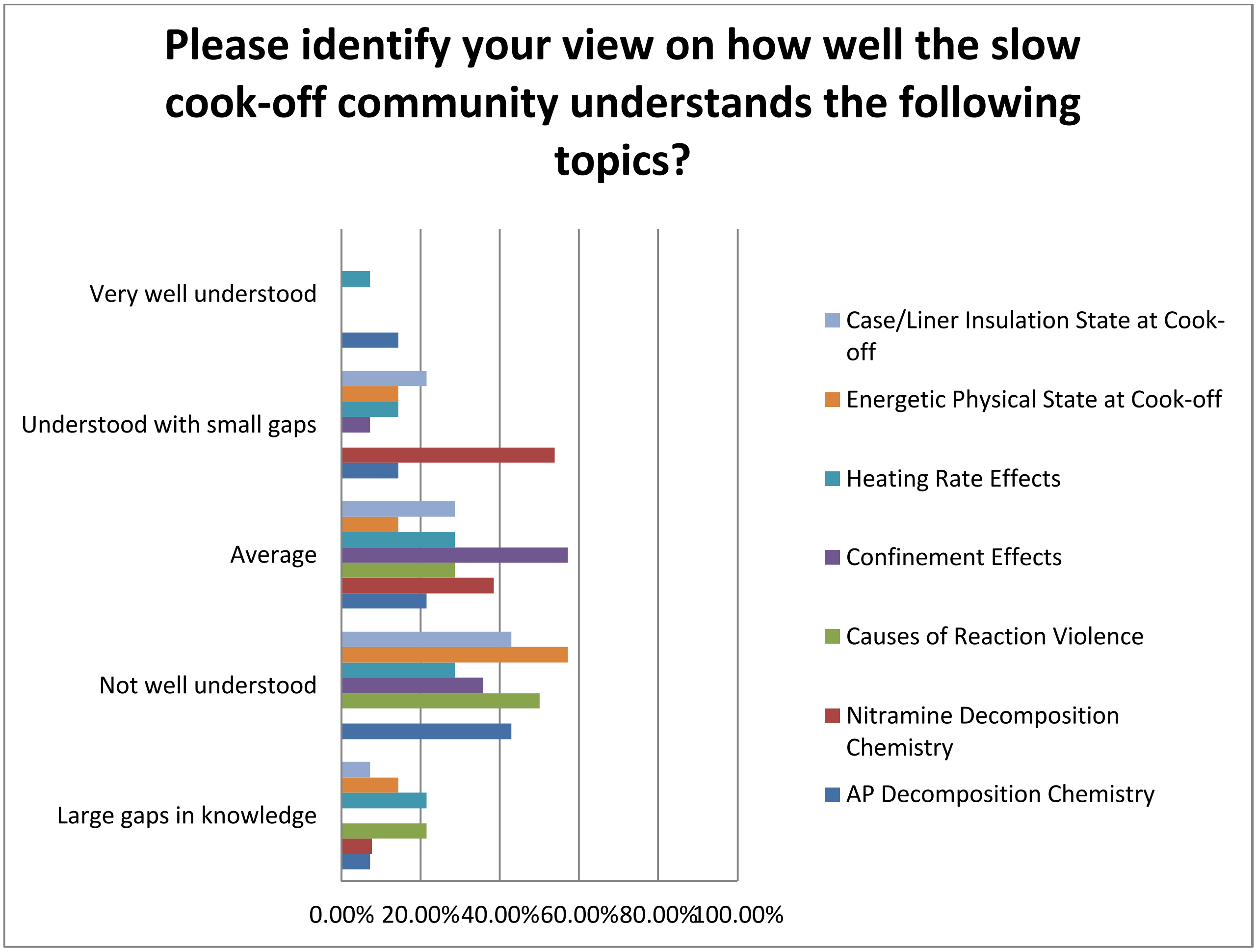
	0-2 yrs	2-5 yrs	5-10 yrs	10-20 yrs	greater than 20 yrs	Total
Participating in JANNAF	5	0	3	3	5	16
Percentage	31.25%	0.00%	18.75%	18.75%	31.25%	100.00%
Working on slow cook-off efforts	3	5	2	3	4	17
Percentage	17.65%	29.41%	11.76%	17.65%	23.53%	100.00%



4.) Please identify your view on how well the slow cook-off community understands the following topics?

	Large gaps in knowledge	Not well understood	Average	Understood with small gaps	Very well understood	Total
AP Decomposition Chemistry	1	6	3	2	2	14
Percentage	7.14%	42.86%	21.43%	14.29%	14.29%	100.00%
Nitramine Decomposition Chemistry	1	0	5	7	0	13
Percentage	7.69%	0.00%	38.46%	53.85%	0.00%	100.00%
Causes of Reaction Violence	3	7	4	0	0	14
Percentage	21.43%	50.00%	28.57%	0.00%	0.00%	100.00%
Confinement Effects	0	5	8	1	0	14
Percentage	0.00%	35.71%	57.14%	7.14%	0.00%	100.00%
Heating Rate Effects	3	4	4	2	1	14
Percentage	21.43%	28.57%	28.57%	14.29%	7.14%	100.00%
Energetic Physical State at Cook-off	2	8	2	2	0	14
Percentage	14.29%	57.14%	14.29%	14.29%	0.00%	100.00%
Case/Liner Insulation State at Cook-off	1	6	4	3	0	14
Percentage	7.14%	42.86%	28.57%	21.43%	0.00%	100.00%

Comments:
(A) AP decomposition has been studied and studied, but there are some things that are still not well understood (solid-state chemistry in general is less well understood than gas or liquid chemistry since topology can matter, etc.) (B) Propellant binder effects (swelling, crosslinking, stiffening) are not well understood in my opinion and this was not in the list; (C) confinement in the above can mean both mechanical (e.g. inertial) confinement and “gas-tightness” (does pressure build up or not.)
Location of ignition as a function of heating rate and system geometry; conductive and convective burning as a function of pressure, thermal damage state of energetic.



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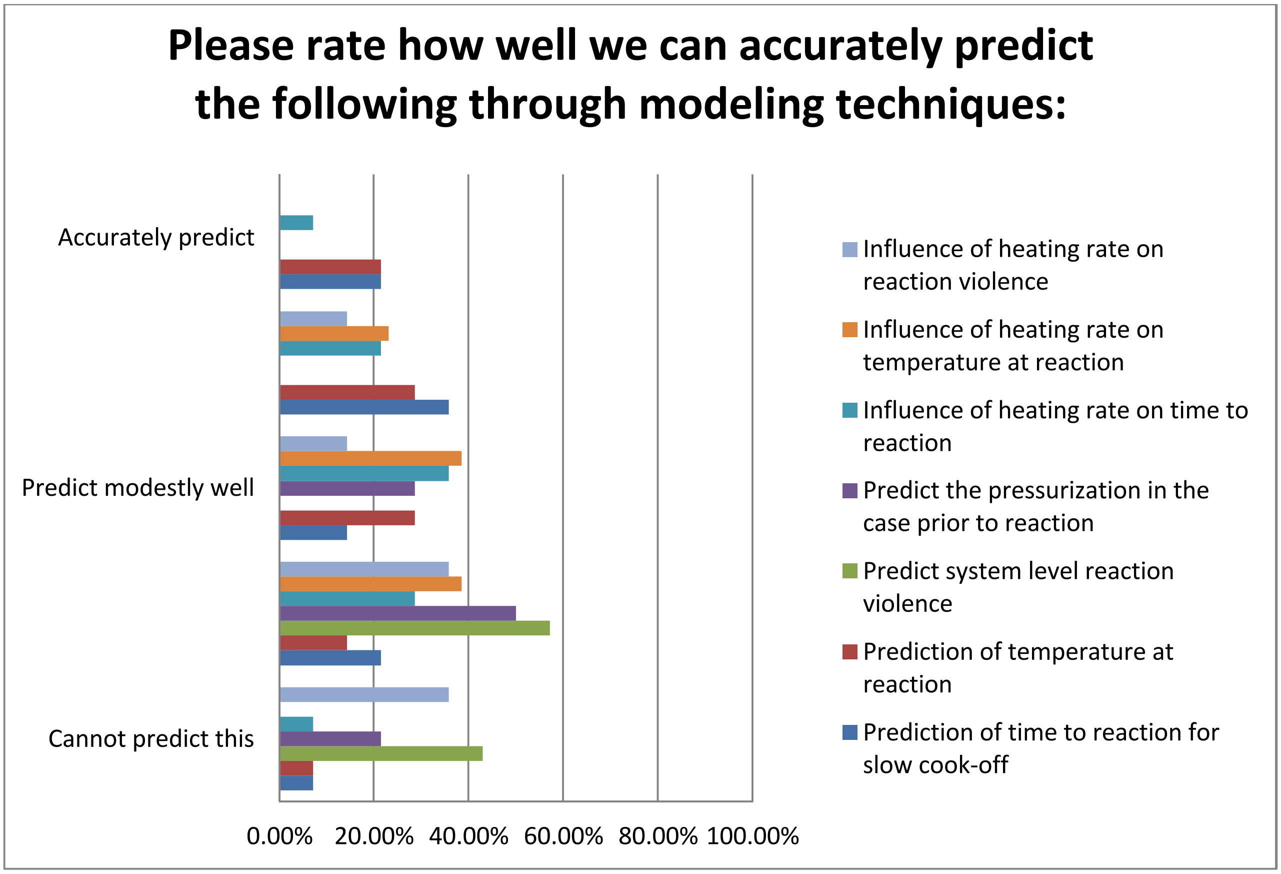
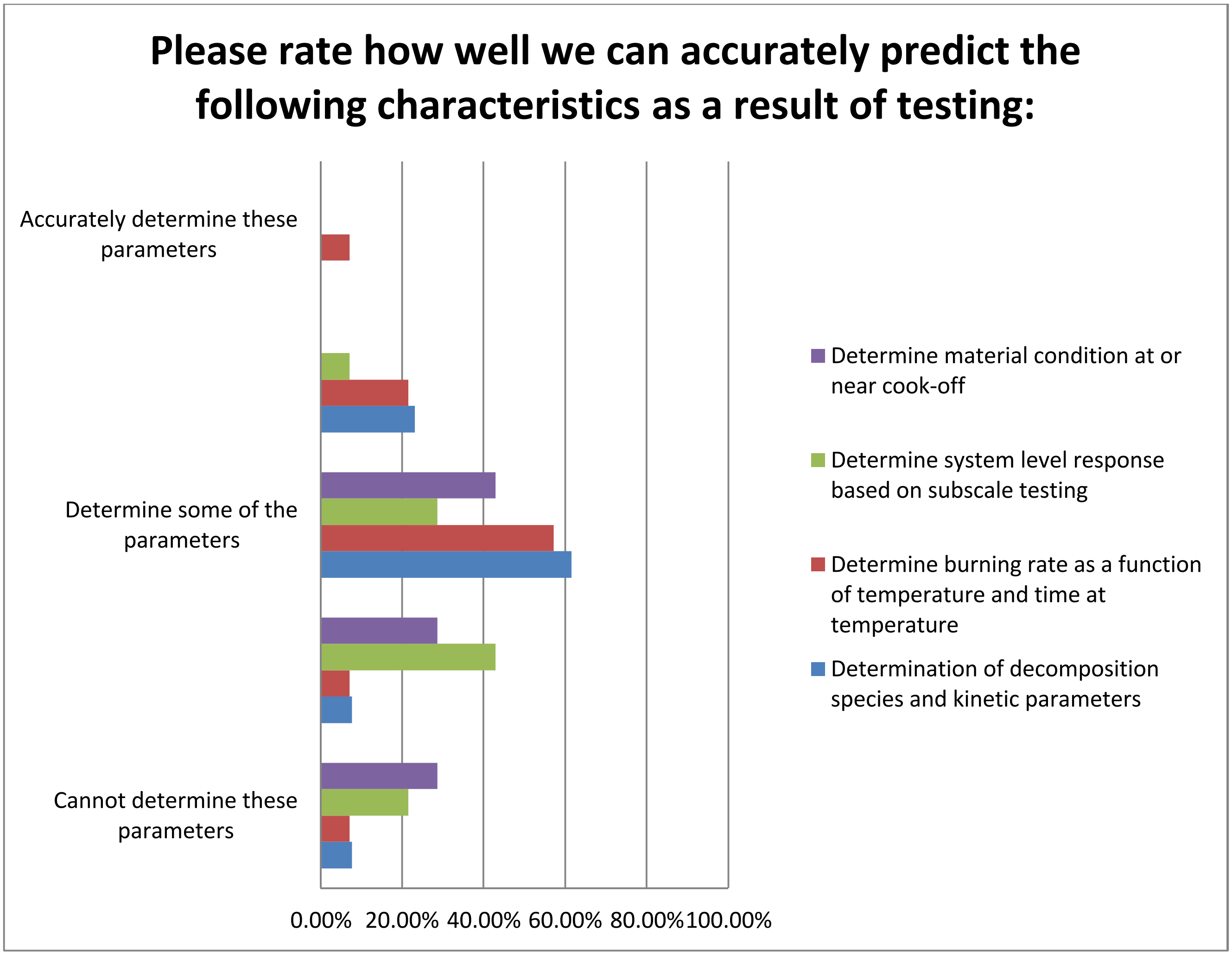
5.) Please rate how well we can accurately predict the following through modeling techniques:

	Cannot predict this		Predict modestly well		Accurately predict	Total
Prediction of time to reaction for slow cook-off	1	3	2	5	3	14
Percentage	7.14%	21.43%	14.29%	35.71%	21.43%	100.00%
Prediction of temperature at reaction	1	2	4	4	3	14
Percentage	7.14%	14.29%	28.57%	28.57%	21.43%	100.00%
Predict system level reaction violence	6	8	0	0	0	14
Percentage	42.86%	57.14%	0.00%	0.00%	0.00%	100.00%
Predict the pressurization in the case prior to reaction	3	7	4	0	0	14
Percentage	21.43%	50.00%	28.57%	0.00%	0.00%	100.00%
Influence of heating rate on time to reaction	1	4	5	3	1	14
Percentage	7.14%	28.57%	35.71%	21.43%	7.14%	100.00%
Influence of heating rate on temperature at reaction	0	5	5	3	0	13
Percentage	0.00%	38.46%	38.46%	23.08%	0.00%	100.00%
Influence of heating rate on reaction violence	5	5	2	2	0	14
Percentage	35.71%	35.71%	14.29%	14.29%	0.00%	100.00%


Please rate how well we can accurately predict the following through modeling techniques:
Accurately predict
Predict modestly well
Cannot predict this
0.00%
20.00%
40.00%
60.00%
80.00%
100.00%
Influence of heating rate on reaction violence
Influence of heating rate on temperature at reaction
Influence of heating rate on time to reaction
Predict the pressurization in the case prior to reaction
Predict system level reaction violence
Prediction of temperature at reaction
Prediction of time to reaction for slow cook-off

6.) Please rate how well we can accurately pedict the following characteristics as a result of testing:

	Cannot determine these parameters		Determine some of the parameters		Accurately determine these parameters	Total
Determination of decomposition species and kinetic parameters	1	1	8	3	0	13
Percentage	7.69%	7.69%	61.54%	23.08%	0.00%	100.00%
Determine burning rate as a function of temperature and time at temperature	1	1	8	3	1	14
Percentage	7.14%	7.14%	57.14%	21.43%	7.14%	100.00%
Determine system level response based on subscale testing	3	6	4	1	0	14
Percentage	21.43%	42.86%	28.57%	7.14%	0.00%	100.00%
Determine material condition at or near cook-off	4	4	6	0	0	14
Percentage	28.57%	28.57%	42.86%	0.00%	0.00%	100.00%



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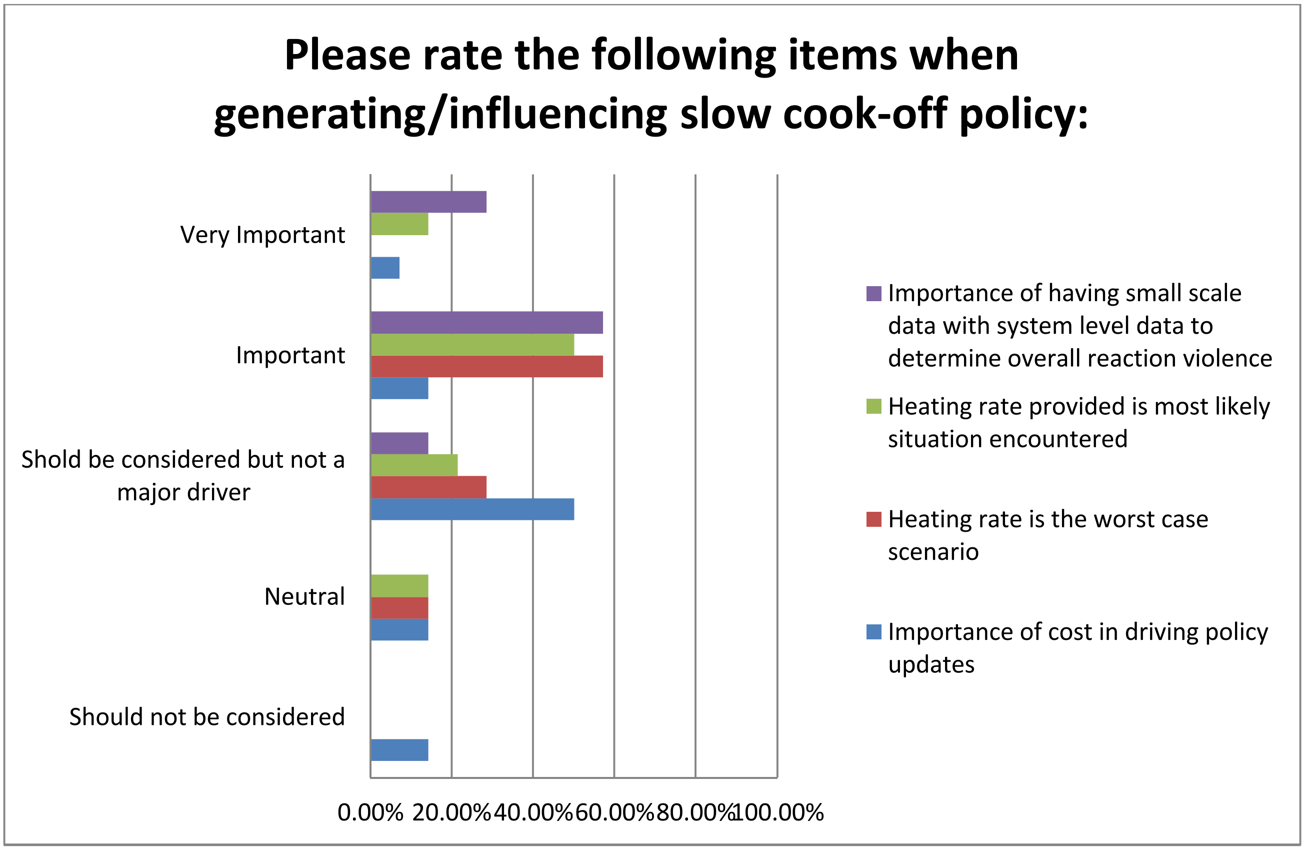
7.) Please rate the following items when generating/influencing slow cook-off policy:

	Should not be considered	Neutral	Shold be considered but not a major driver	Important	Very Important	Total
Importance of cost in driving policy updates	2	2	7	2	1	14
Percentage	14.29%	14.29%	50.00%	14.29%	7.14%	100.00%
Heating rate is the worst case scenario	0	2	4	8	0	14
Percentage	0.00%	14.29%	28.57%	57.14%	0.00%	100.00%
Heating rate provided is most likely situation encountered	0	2	3	7	2	14
Percentage	0.00%	14.29%	21.43%	50.00%	14.29%	100.00%
Importance of having small scale data with system level data to determine overall reaction violence	0	0	2	8	4	14
Percentage	0.00%	0.00%	14.29%	57.14%	28.57%	100.00%



Q8: What do you view as the biggest gap in knowledge in terms of slow cook-off phenomenology?

Predicting violence; realistic heating rates in cookoff scenarios
12/30/2015 11:58 AM View respondent's answers

relate good modeling to reactions
12/14/2015 12:20 PM View respondent's answers

Why containerizing an AP-based motor causes the reaction to go from Type III to Type I.
12/14/2015 7:43 AM View respondent's answers

I am fairly new to this area, but I think there should definitly be more cohesion between experimentalist and modelers. Both are a very important piece to the puzzle if greater understanding is the goal. I think designing experiments with modelers in mind would be a helpful thing. Certain parmeters would be useful in order to help guide modelers and to have fundamental data that can be used to help validate model predictions.
12/14/2015 7:23 AM View respondent's answers

There are not as many gaps in knowledge as there are gaps in capabilities.
12/11/2015 7:33 AM View respondent's answers

understanding how it scales
12/11/2015 7:02 AM View respondent's answers

prediction of reaction violence
12/10/2015 3:24 PM View respondent's answers

Accurate quantification of reaction violence
12/1/2015 5:55 PM View respondent's answers

quantifying the terms used in reaction violence. we need definitions that are more strongly based on science.

11/30/2015 11:44 AM View respondent's answers

Developing the methodology for representing thermally driven damage evolution and the associated burn rate enhancement. We know this happens, but it is not clear how to quantify this and/or model it. It may be that damage evolution is dependent on the type of energetic system. And it may be in part due to the behavior of the so-called "inert" constituents (binders, etc.) of energetic materials.

11/30/2015 10:52 AM View respondent's answers

Post-ignition reaction violence up to the worse-case scenario of DDT.

11/30/2015 10:32 AM View respondent's answers

Q9: What do you view as the most critical policy issue with slow cook-off?

Agreeing to a more realistic heating rate and gaining approval for testing a rates more likely for a particular munition

12/30/2015 11:58 AM View respondent's answers

heating rate

12/14/2015 12:20 PM View respondent's answers

Heating rate.

12/14/2015 7:43 AM View respondent's answers

Funding is always an important issue. To do more experiments and design better models there should be funding dedicated with that goal in mind. This would give experimentalist the funding to pursue more fundamental experiments, and do more runs under more conditions. This in turn can help guide modelers who can then attempt to model some of the more uncertain aspects of slowcookoff.

12/14/2015 7:23 AM View respondent's answers

Modeling simulations should be integrated better into engineering design and policy decisions. This requires a change in mindset since the ability to produce accurate quantitative predictions are a long way off. I believe informed decisions can be made using the qualitative aspects of our existing computational capabilities both in design and assessment.

12/11/2015 7:33 AM View respondent's answers

Using the tests to hazard classify

12/11/2015 7:02 AM View respondent's answers

Testing to THA.

12/10/2015 3:24 PM View respondent's answers

Testing a broad range of ordnance items both in size and function, with a single test criteria.

12/1/2015 5:55 PM View respondent's answers

evaluation of a system without considering the specific conditions in which the system becomes hazardous.

11/30/2015 11:44 AM View respondent's answers

It is my understanding that most systems fail the slow cook-off test. But the test as performed may not be realistic for real world conditions--it is an over-test. So if a system DOES happen to pass the SCO test it is probably "good to go." But other systems may also be "good to go" in terms of real world application but fail SCO. So we resort to waivers, etc. If there is going to be a waiver, then why bother do the test? On the other hand, the other reason to maintain current SCO methodology is that there is a history (so there are data to compare with).