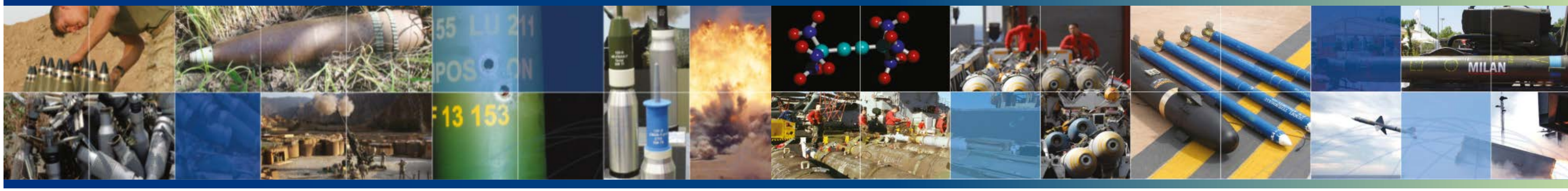
MSIAC Munitions Safety Information Analysis Center

Supporting Member Nations in the Enhancement of their Munitions Life Cycle Safety



STANAG 4382
Slow Heating Survey and Historical Review

Insensitive Munitions and Energetic Materials Technology Symposium

Portland, OR, USA – April 2018

Ernie Baker
TSO Propulsion Technology
+32.(0)2.707.54.47
e.baker@msiac.nato.int

MSIAC Office
+32.(0)2.707.54.16
info@msiac.nato.int
http://www.msiac.nato.int

Outline

- Background
- Process / Questionnaire
- Analysis
- Test Setup Photos
- Historical Events Review

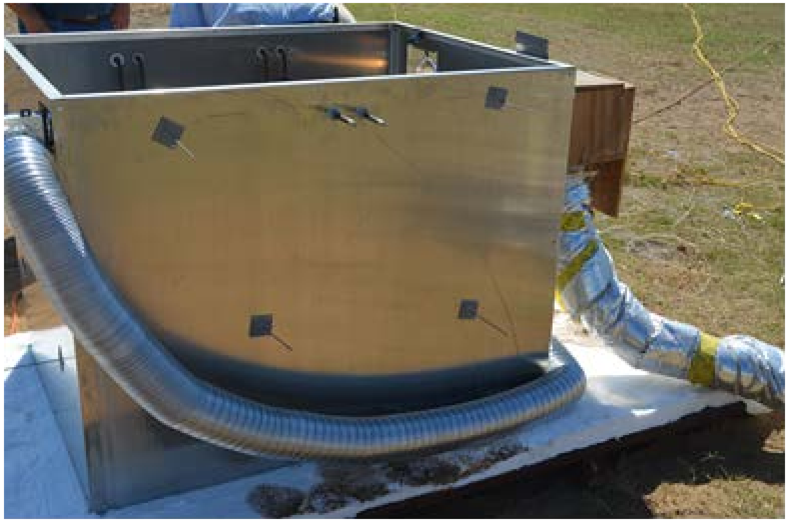
Background

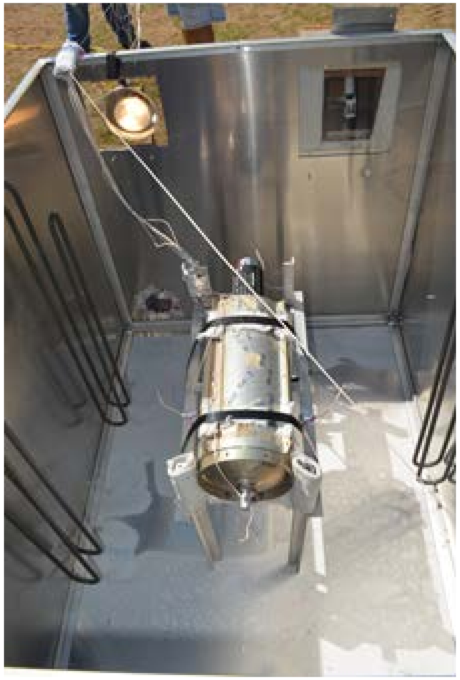
- In 2015, MSIAC initiated a survey of STANAG 4240 (Fast Cook-off Test) that led to a list of recommendations to update the document.
- NATO AC/326 SG/B has tasked MSIAC to initiate the same type of survey for STANAG 4382 (Slow Heating Test).
- MSIAC was subsequently tasked to review actual events heating rates and durations.

Baker, E.L., "An International Review of the Slow Heating Test", MSIAC Report O-177, June 2017

Stated aim of the test

Determine the reaction of munitions to the slow application of heat which is in contrast to that occurring during fast cookoff tests. Although not necessarily intended as such, this slow heating may result from indirect exposure to fire.





Procedure

- MSIAC has written a survey related to the Slow Cook-off Test
- The survey was reviewed by the custodian of STANAG 4382 (USA)
- The survey was sent to the nations
- After reception & analysis of the answers and other related documents, MSIAC is summarizing the results in a report.

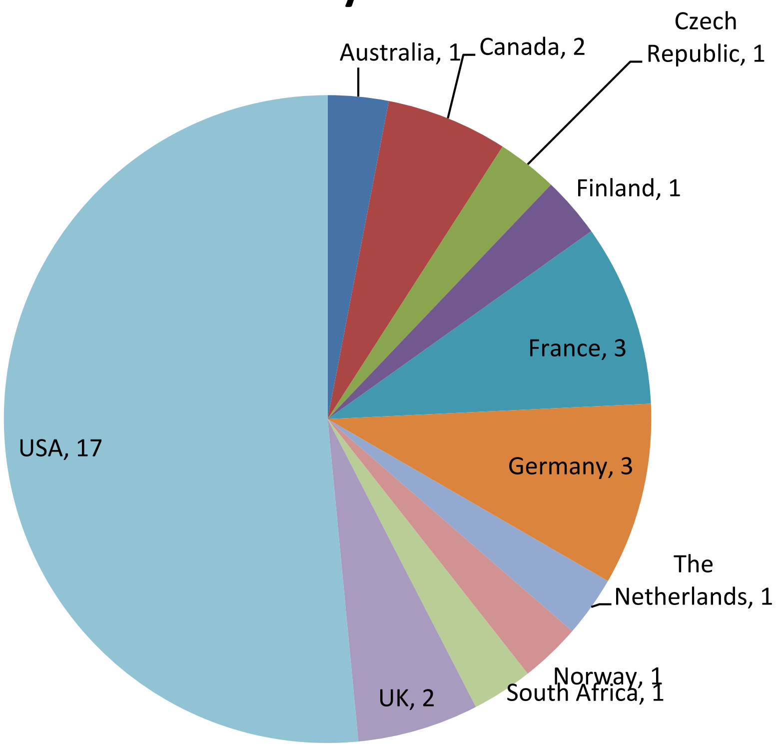
MSIAC

Origin of the answers

Supporting Munitions Safety

- 34 responses from 11 nations.
- 62/38 government / private

Answers by nations



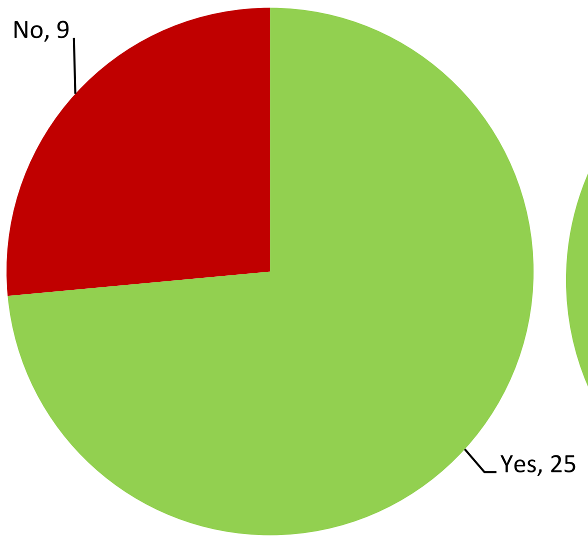
THANK YOU

for the number and the quality of your answers

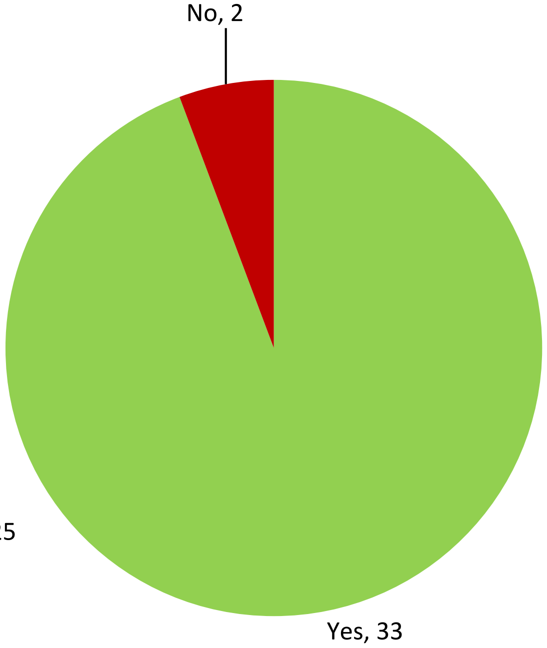
Country	Organisation	Status
DOS	Australia	gov
DRDC Valcartier	Canada	gov
GD-OTS Canada	Canada	private
AC/326	Czech Republic	gov
Test Firing Center	Finland	gov
AC/326 - DGA	France	gov
NEXTER Munitions	France	private
Airbus Safran Launchers	France	private
WTD91	Germany	gov
MBDA Systems	Germany	private
MBDA Systems	Germany	private
Centre of Excellence Weapons and Ammunition	Netherlands	gov
AC/326	Norway	gov
AC/326	South Africa	gov
Bofors Test Center	Sweden	private
QinetiQ	United Kingdom	private
BAE Systems	United Kingdom	private
US Army AIMB	United States of America	gov
NSWC Dahlgren D	United States of America	gov
Redstone (Army)	United States of America	gov
Eglin Air Force	United States of America	gov
Eglin Air Force	United States of America	gov
AFLCMC/EBDP	United States of America	gov
NAWC China Lake	United States of America	gov
NSWC Dahlgren D	United States of America	gov
NSWC Dahlgren D	United States of America	gov
NAWC China Lake	United States of America	gov
NAWC China Lake	United States of America	gov
DDESB	United States of America	gov
YPG ATC	United States of America	gov
NAWC China Lake	United States of America	gov
NSWC Crane	United States of America	gov
NSWC Crane	United States of America	gov
NSWC Crane	United States of America	gov

Test Purpose

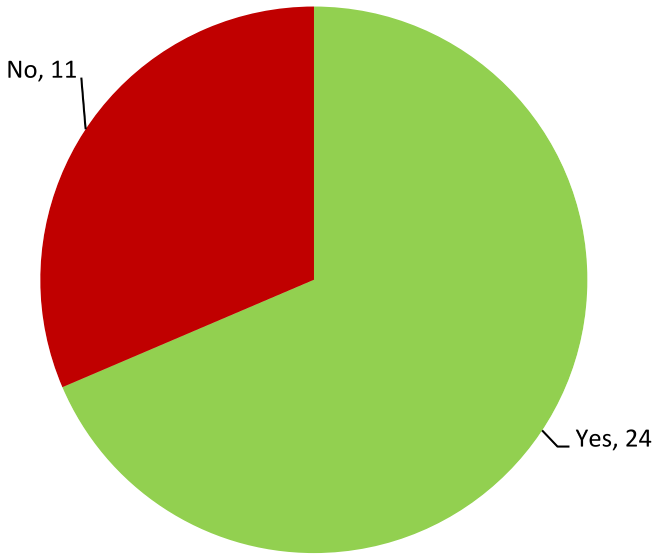
To provide an extreme heating rate different from the FCO.



To characterize the munition being tested.

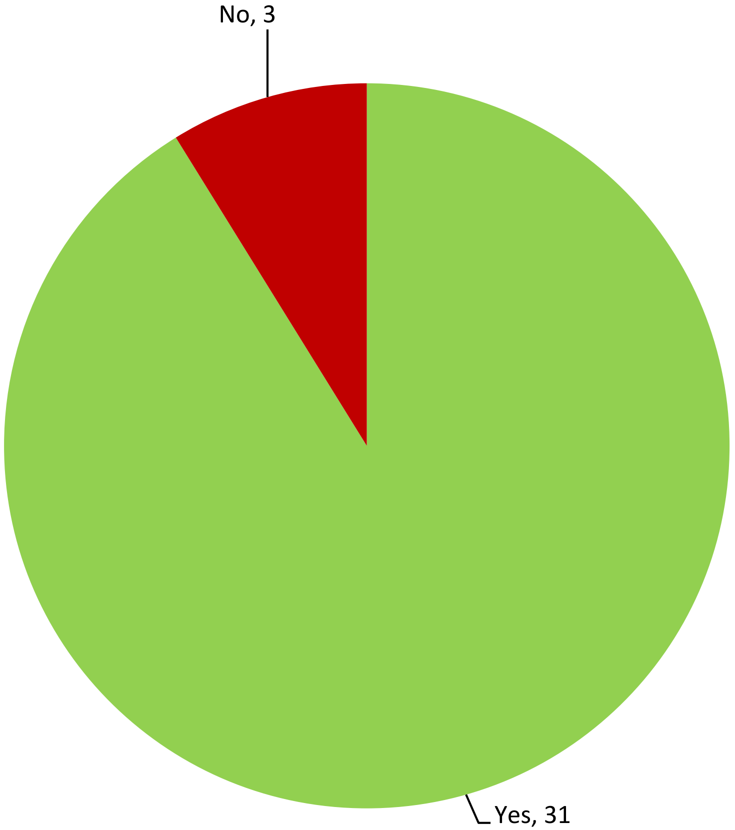


To simulate a real life accident scenario.



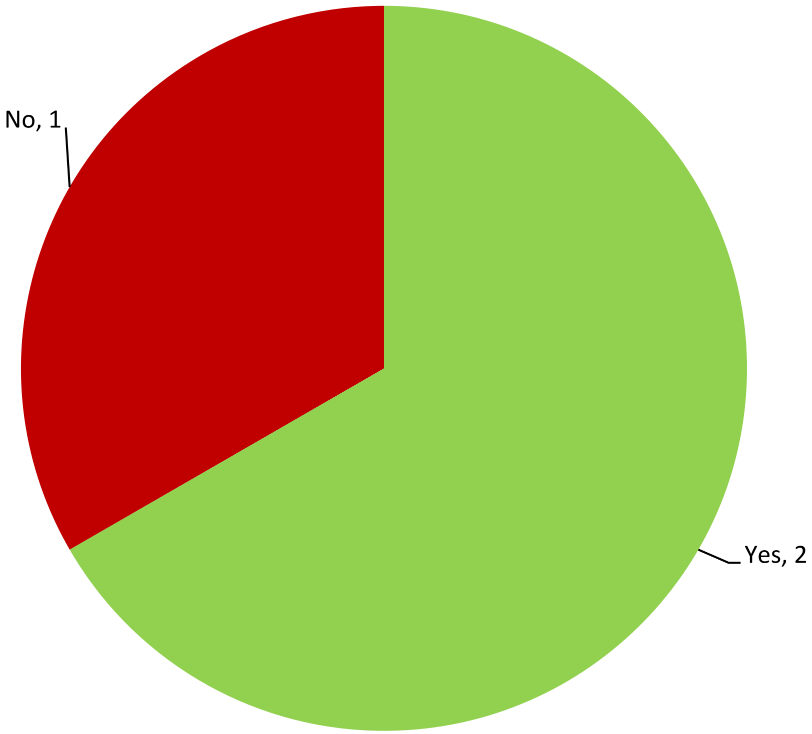
Test Procedure

Do you conduct your SCO tests as required by the STANAG 4382 primary test procedure?



Germany: WTD91-320
France: AFNOR NF T70-515

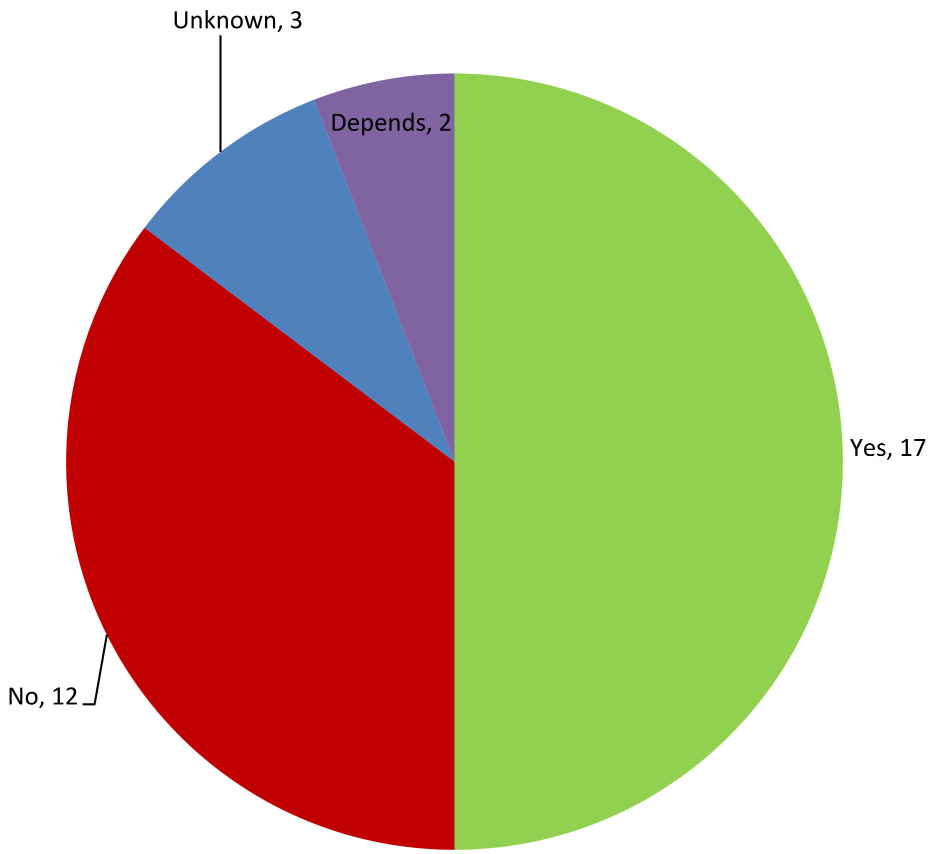
Do you have a nationally approved test procedure to carry out the slow heating test?



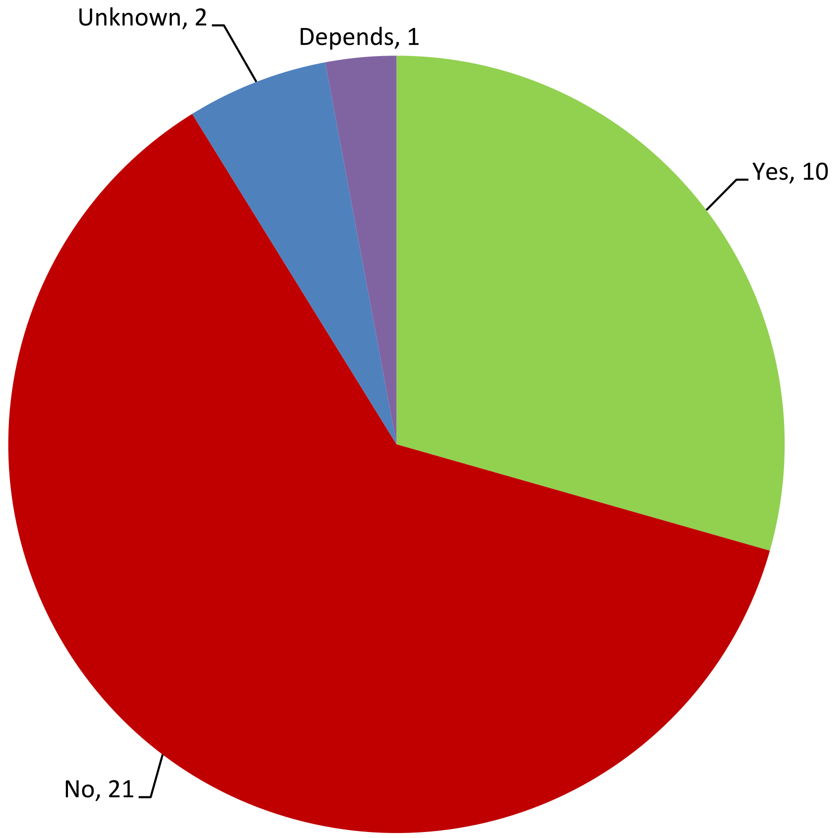
NAWCWD: code 47300D
NSWC Crane: CR-JXRN-RD-P-1196E

Heating Rate

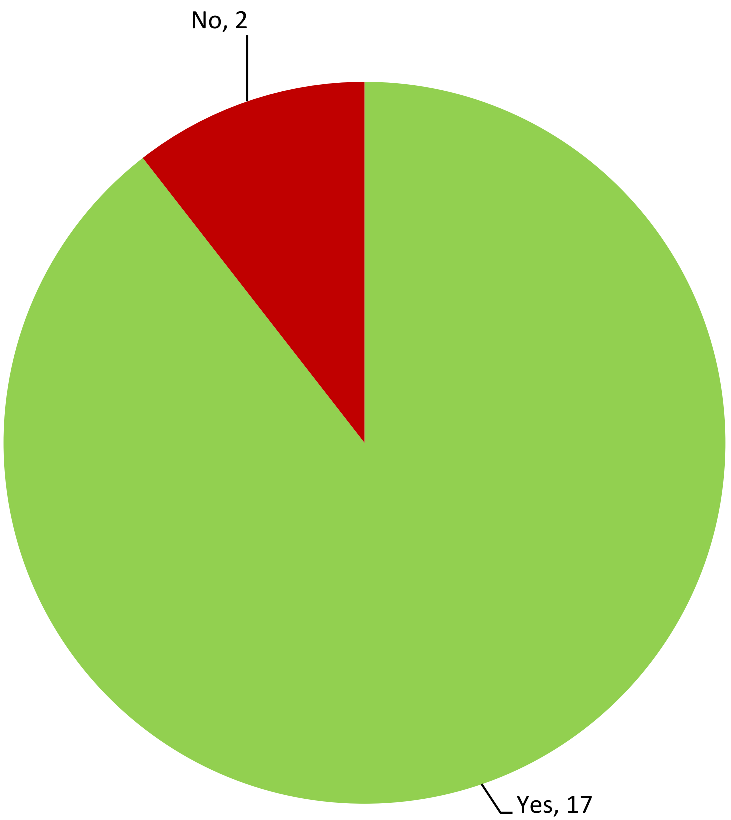
Should the slow heating rate be changed?

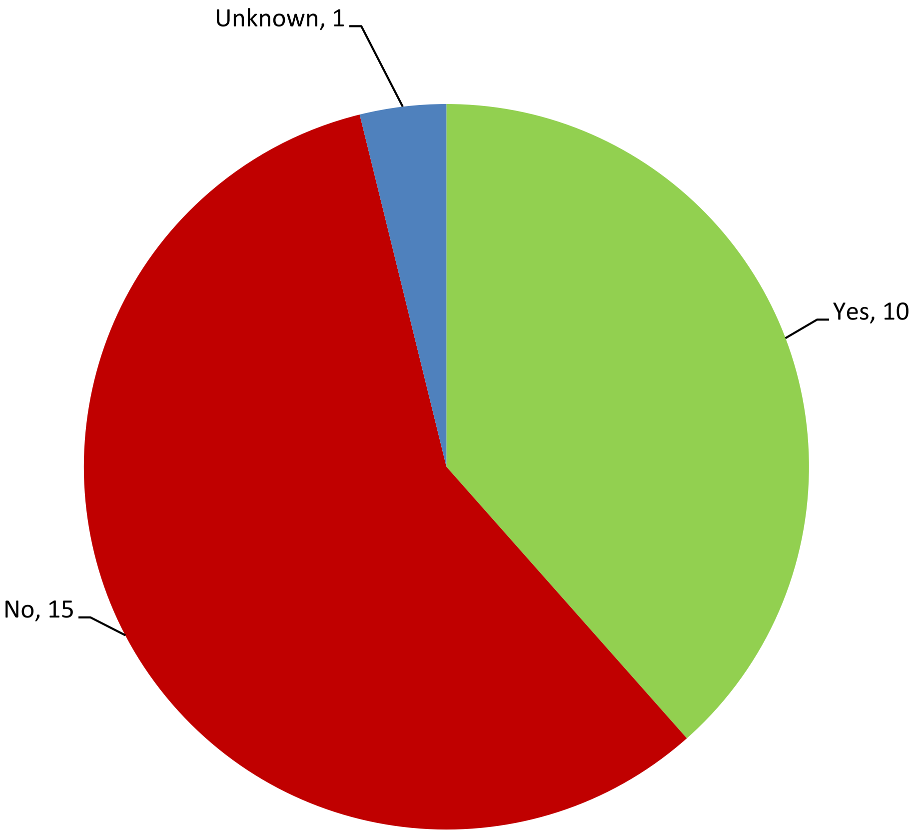


Should item size be a consideration in defining a slow heating rate?



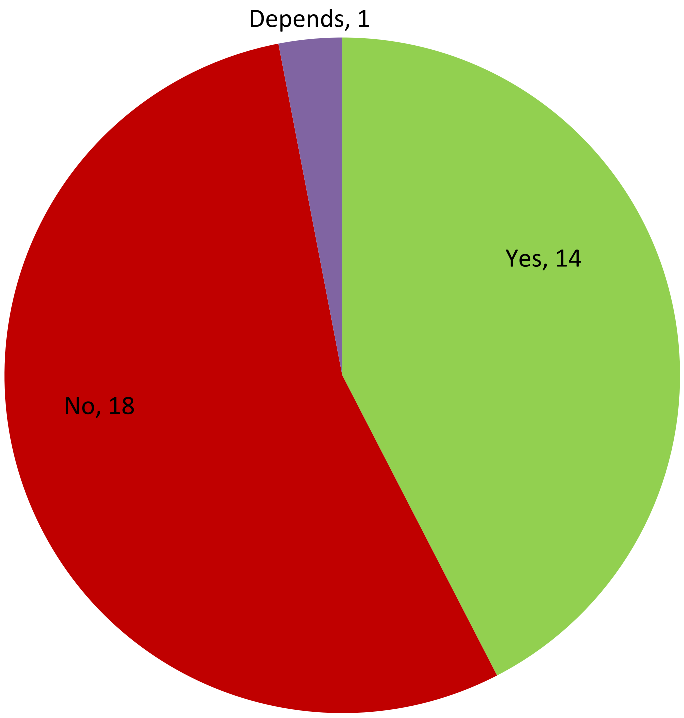
Oven Design


Do you have equipment to force the airflow?
No, 2
Yes, 17


Do you provide protection for any energetic material exuded out of the item being tested?
Unknown, 1
Yes, 10
No, 15

Oven Standardization

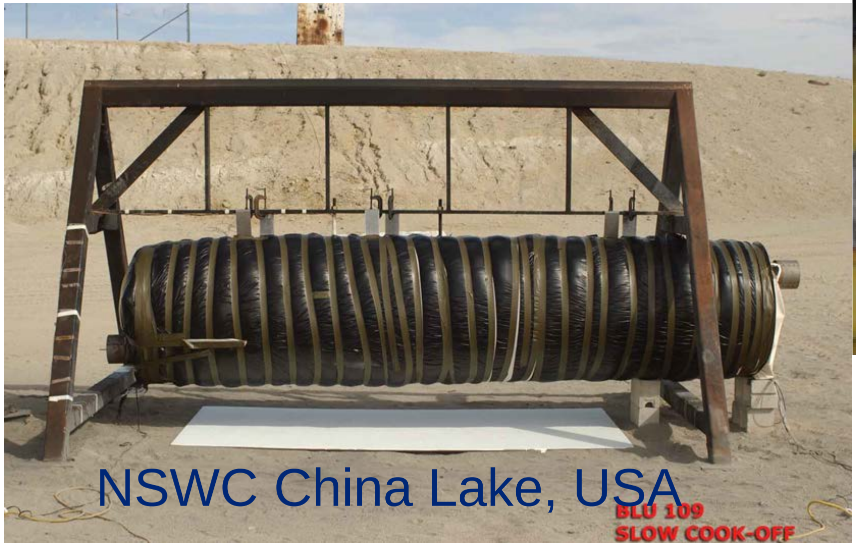
Should we standardize the oven design?



- Different munition types require different considerations.
- Differing sizes of munitions required different sized ovens.
- Some items need to be restrained to prevent flight in case of a strong propulsive reaction.

At least recommendations and guide to a well designed oven to avoid blast wave absorption, fragment location into the oven and secondary fragments.

Test Setup Photos



NSWC China Lake, USA



KCW&M, Netherlands



Finnish Defence Forces, Finland


Bundeswehr Germany


YPG, US Army


Redstone Test Center, USA

Test Setup Photos

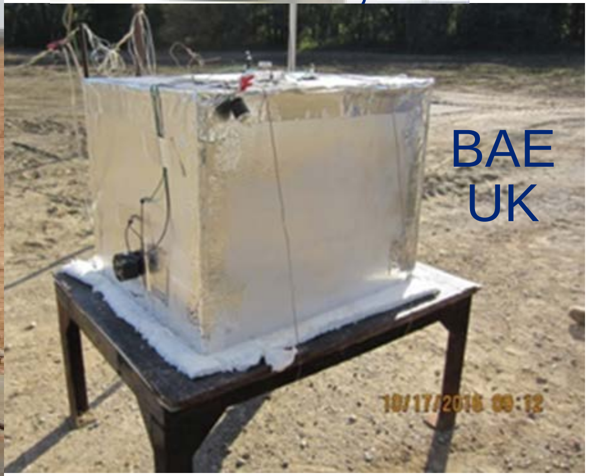

NEXTER France


GD-OTS, Canada


Redstone Test Center, USA


Airbus Safran Launchers, France

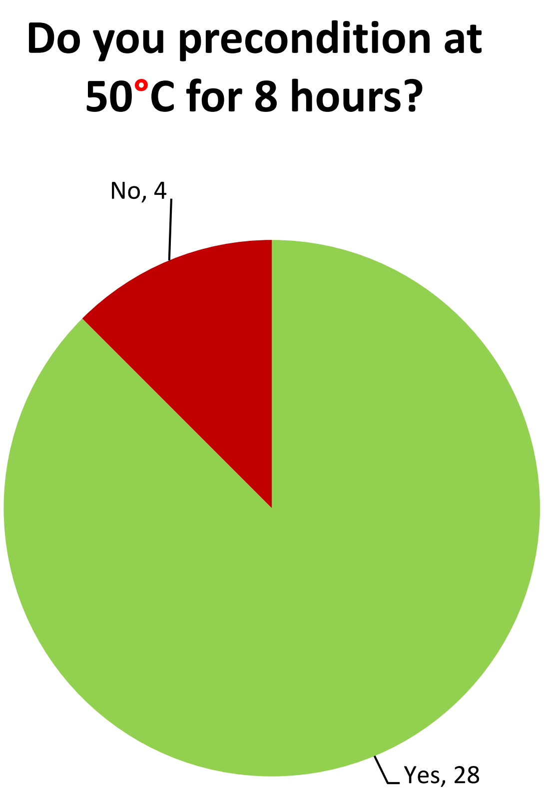

Qinetiq UK

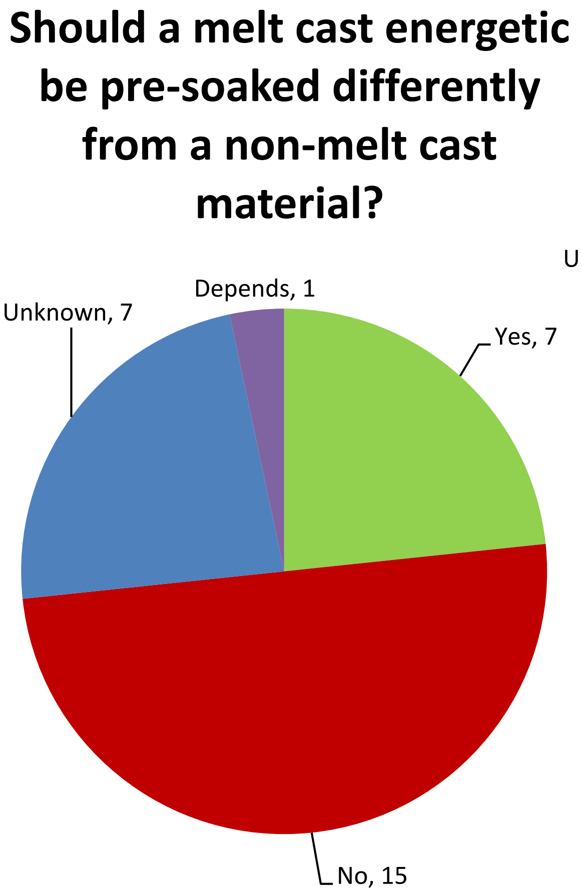


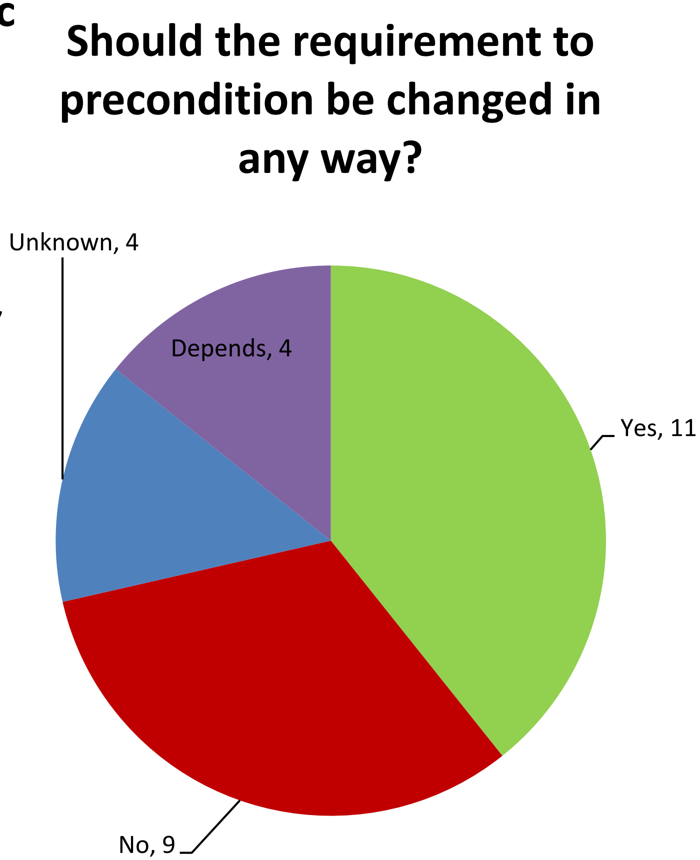
BAE UK

Many different designs!

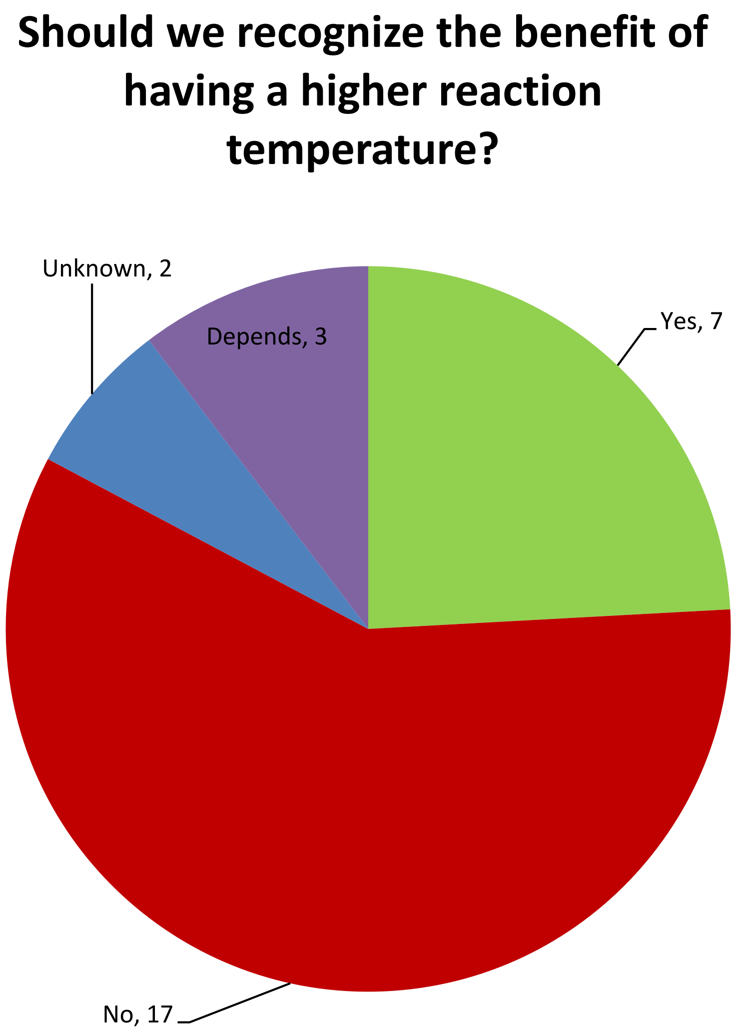
Temperature Preconditioning

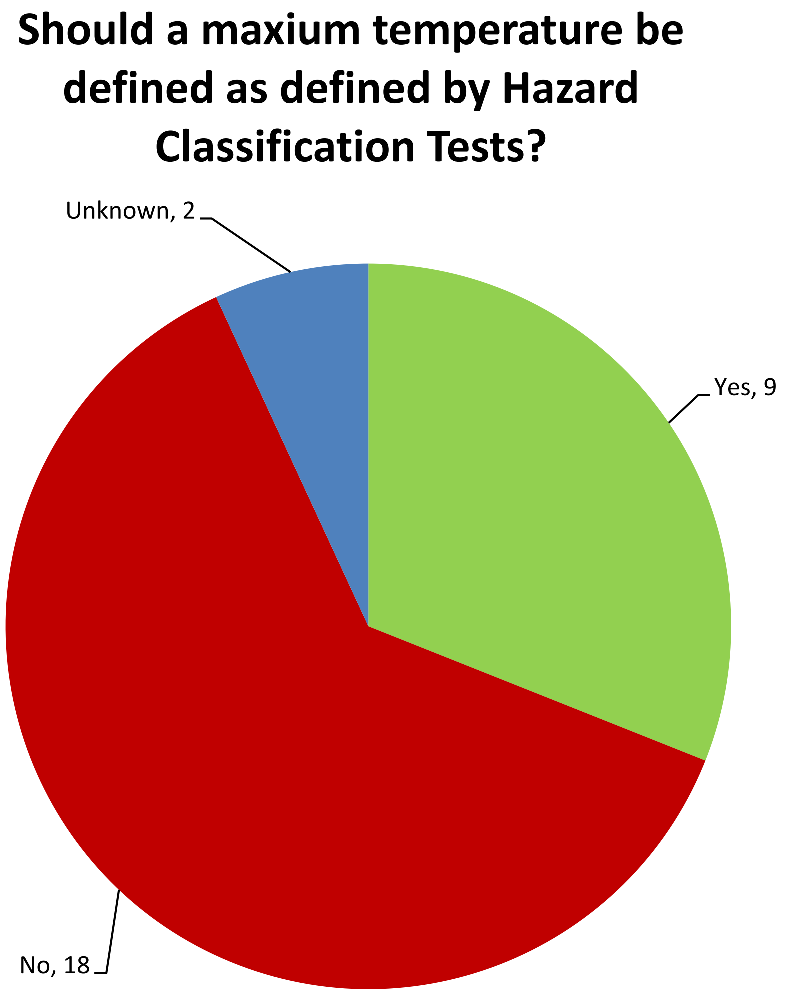






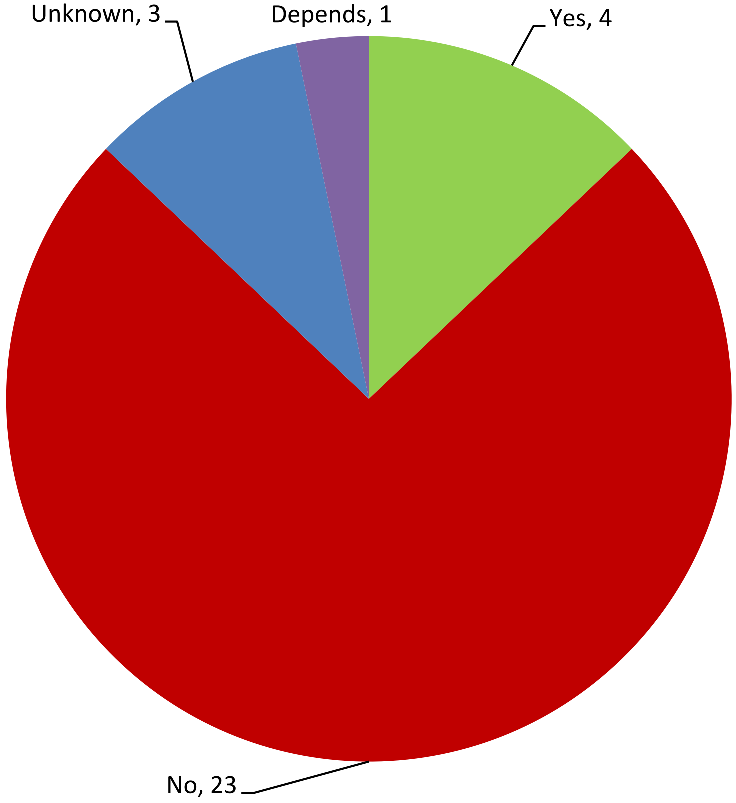
Reaction Temperature



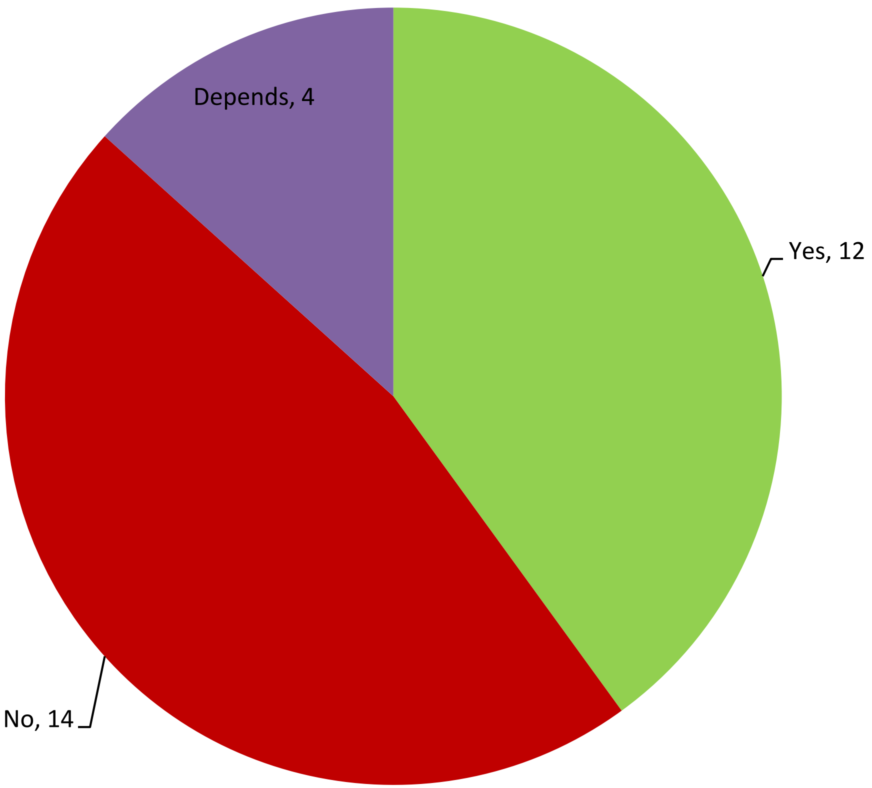


Melting and Propulsion

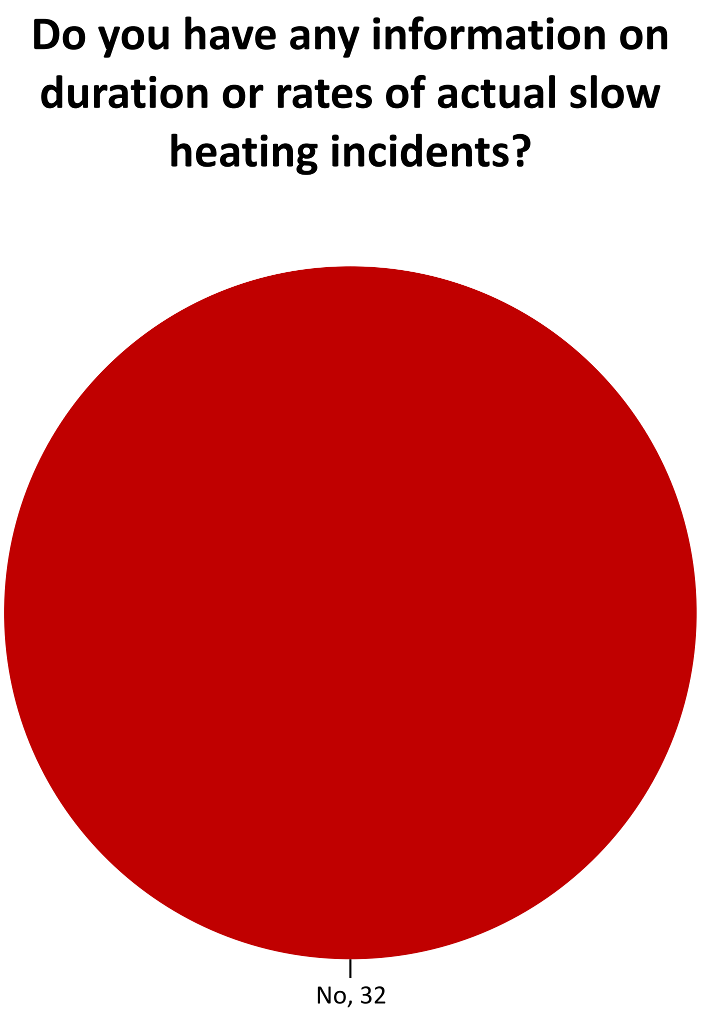
Should the melting of energetics during a test affect the testing requirement?



Do you restrain the test item in case of risk of propulsion?



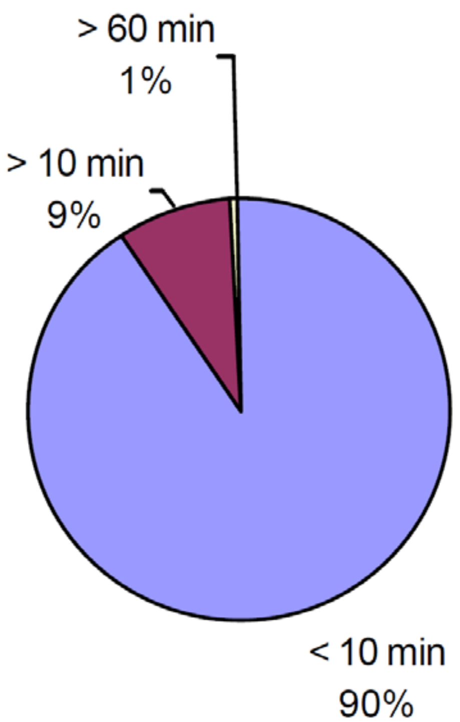
Actual Events Heating Rates



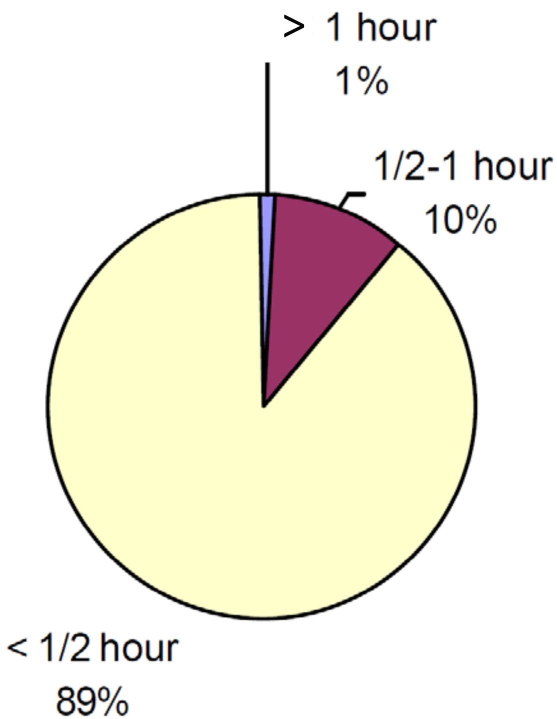
Historical Events Review

- During the AC/326 SG/B SH CWG meeting, 10-11 April 2017, MSIAC was asked to obtain and share any available historical information from the MSIAC safety database regarding real-life slow heating events and potential thermal threats.
- F. Peugeot, “Assessing Thermal Threats” MSIAC Technical Report L-097 published in 2003.
- A search of MAD-X provided no applicable information
- A report search resulted in a large number of references
- K. Hunt from OSD provided further references
- Dr. David Hubble from NSWCDD, USA did a similar study, along with supporting fire modeling. He had very similar results and conclusions

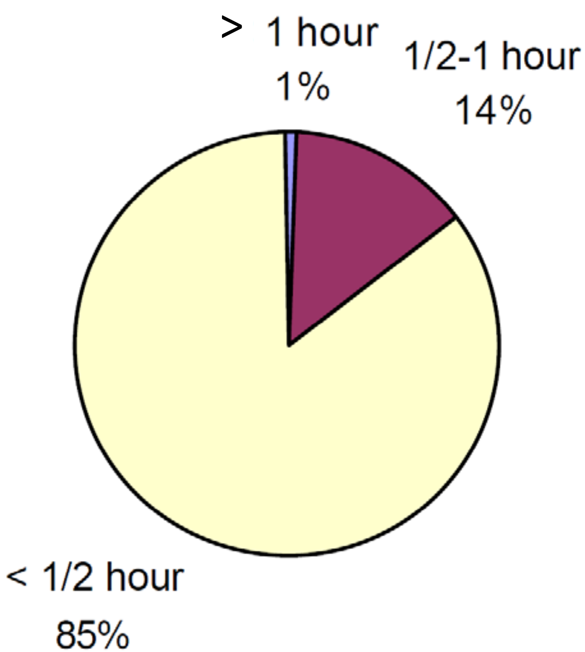
Historical Duration Data



UK Navy statistics related to ship fire duration (1989)



US truck transport statistics related to fire duration (1969)



US rail transport statistics related to fire duration (1969)

Real world durations have relatively short durations
-5 events identified to be longer than 1 day

"Cookoff – a UK naval perspective", I. Wallace, Proceedings of the NIMIC 1993 Workshop on Cookoff, paper TP-5 (1993)
"Probability of transportation accidents", W. Brobst, Transportation Branch, US Atomic Energy Commission, F 192092 (1972)

Historical Data

- there exist a wide variety of heating rates
- these rates depend on many factors
  - direct exposure: fire size
  - indirect exposure: adjacent compartment size

Order of magnitude of the maximum temperature and the heating rate

Heating Source	• Torching • EM Burning • Exhausts • Pyrotechnics	• Fuel Fire • Wood fire • Propane burner • Building Fire	• Hot Breach • Gun Battlecarry • Launcher • Nuclear plant • Aircraft debris • Remote fire • Aerodynamic Heating • **Adjacent compartment fire**	• Solar Heating • Steam leak
Regime	Fast Cookoff (FCO)		Intermediate Cookoff (ICO)	Slow Cookoff (SCO)
Temperatures (Order of magnitude)	1000 to 2000 °C	~1000 °C	100 to 300 °C	~ 100 °C
Heating rates (Order of magnitude)	50 to 100 °C/sec	1 to 20 °C/sec	**25°C/hr to 50 °C/min**	< 20 °C/hr

NATO AC/326 SG/B Slow Heating Custodial Working Group is using this information as part of the process to update STANAG 4382

Backup Information

- Backup

References

"Analysis of Heating Rates for the Insensitive Munitions Slow Cookoff Test", Fontenot J.S., Jacobson M., NWC TM 6278, Naval Air Warfare Center China Lake, California (1988)
"Navy Insensitive Munitions and Shipboard Fire Protection Workshop", NAWC China Lake, California (1995)
"Summary of NIMIC 1993 Workshop on Cookoff", Stokes B.B., Fitzgerald-Smith J. DeFourneaux M., Kernen P., NIMIC-BS-307-94, (1994)
"Threat Hazard Assessment for Insensitive Munitions", Victor, A., Presented at NIMIC Hazards Analysis Workshop (1996)
"Exploring cookoff mysteries", A. Victor, JANNAF Propulsion Systems Hazards Subcommittee meeting (1994)
"Insensitive Munitions Threat Hazard Assessment of the PAC-3 Missile System", Victor Technology, Final Report, US Restricted (1994)
"AMRAAM rocket motor slow cookoff mitigation", J. Gross, NAVY IM/Shipboard fire protection workshop (1995)
"2.75-Inch rocket system slow cookoff heating rate", H. Gokee, NAVY IM/Shipboard fire protection workshop (1995)
"In-Bore Measurement of 120-mm Ammunition Temperatures", Kolasa, Gregory M.; Flyash, Boris, Technical report ARCCD-TR-01001 (2001)
"Characteristics if liquid fuel fire and gas burner heating", E. Lundstrom, Proceedings of the NIMIC 1993 Workshop on Cookoff, paper TP-8 (1993)
"Slow cookoff analysis", E. Lundstrom, Proceedings of the NIMIC 1993 Workshop on Cookoff, paper TP-7 (1993)
"Measured temperatures of solid rocket motors dump stored in the tropics and desert-Part 4. Tropics", Naval Air Systems Command, NWC TP 5039, Part 4 (1989)
"Preliminary analysis of the heating of ordnance in ship magazines due to a fire in an adjacent compartment", J. Mansfield, NAWCWPNS TP 8186 (1996)
"Ordnance heating rates in shipboard magazines", C. Doolan, DSTO-TR-1188 (2002)
"Computer simulation of the thermal effects on a concentric canister missile launcher with a fire in an adjacent compartment", G. Null, Naval Postgraduate School Thesis, ADA337018 (1997)
"Modelling of the HMAS Westralia fire", S. Kennett, G. Gamble, J. De Li, DSTO -TR-0698 (1998)
"Propellant fires in a simulated shipboard compartment: Project HULVUL Phase III, G. Back, R. Darwin, J. Scheffey, Naval Research Laboratory NRL/MIU6180 --99-8394 (1999)
"Phénomènes thermiques induits par un accident de munition à bord d'un navire", A. Fournier, C. Lallemand, AGARD-CP-511, paper 22 (1992)
« A preliminary model for heat transfer from an uncontained solid rocket propellant burn », W. Gill, L. Kent, N. Keltner, W. Schimmel, JANNAF Propulsion Systems Hazards Subcommittee, pp.297 - 302 (1994)

References

"Cookoff – a UK naval perspective", I. Wallace, Proceedings of the NIMIC 1993 Workshop on Cookoff, paper TP-5 (1993)
"Standoff distance effect on cookoff of ordnance stowed in MDCS ship cargo holds", O. Heimdahl, L. Bowman, Twenty-ninth DoD Explosives Safety Seminar (2000)
"Measurement of the size, duration and thermal output of fireballs produced by a range of pyrotechnics", R. Wharton, J. Harding, A. Barratt, R. Merrifield, 21rst international pyrotechnics seminar, pp.916-931 (1995)
"Probability of transportation accidents", W. Brobst, Transportation Branch, US Atomic Energy Commission, F 192092 (1972)
"Heat feedback to the fuel surface in pool fires", A. Hamins, S. Fischer, T. Kashiwagi, M. Klassen, J. Gore, Combustion science and Technology, vol.97, n°1-3, 37 -62 (1994)
"Temperatures in flames and fire", Dr. Vytenis Babrauskas, Fire Science and Technology Inc. (1997)
"Improved real-scale fire measurements having meaningful uncertainty limits", W. Pitts, in "Workshop on Fire: Testing measurement needs: Proceedings", W. Grosshandler, Building and Fire Research Laboratory (2001)
"An international survey of computer models for fire and smoke", R. Friedman, Journal of Fire Prot. Engr, 4 (3), pp.81-92 (1992)
"State of the art in zone modeling of fires", W. Jones, International Fire Protection Seminar, 9th. Engineering Methods for Fire Safety, pp. 126 pp (2001)
"Zone computer fire models for enclosures", W. Dalton in DiNenno, SFPE Handbook of Fire Protection Engineering 2nd Edition, Chapter 7, Section 3, 3, pp.148 -151 (1997)
"CFAST, the consolidated model of fire growth and smoke transport", Richard D. Peacock, Glenn P. Forney, Paul A. Reneke, Rebecca M. Portier, Walter W. Jones, National Institute of Standards and Technology Technical note 1299
"Fire environments typical of Navy ships", D. Leblanc, Thesis, submitted to the Faculty of the Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Master of Science in Fire Protection Engineering (1998)
"United Nations Recommendations on the transport of dangerous goods, Manual of tests and criteria", Third revised edition (1999)
"Center for the simulation of accidental fires and explosions, Annual Report, October 2000 to September 2001, submitted to the DoE LLNL under subcontract B341493, D. Pershing (2001)
"Modeling of Buildings, houses… fires", http://UoC-Fire Engineering.htm
"Fire Hazard Assessment", R. Bukowski, in SFPE Handbook of Fire Protection Engineering, Section 11, Chapter 7 (1997)

MSIAC

Supporting Munitions Safety

References

"Simplified fire growth calculations", E. Budnick, D. Evans, H. Nelson in SFPE Handbook of Fire Protection Engineering, Section 11, Chapter 10 (1997)

"Simulation of the dynamics of the fire at 3146 Cherry Road NE, Washington D.C., May 30, 1999", D. Madrzykowski, R. Vettori, Buildings and Fire Research Laboratory, National Institute of Standards and Technology, NISTIR 6510 (2000)

"A study of heat transfer in liquid pool fires from steady burning through boilover", W.R. Guinn, Paper for Fire Protection Engineering -520

"Appropriate Slow Cookoff Heating Rates", R. Frey, Army Research Laboratory, 18 April 2000.

Threat Hazard Analysis prepared for Program Executive Office for Theater Air Defense, Booz-Allen & Hamilton, Inc.; 26 November, 1996.

"Realistic Safe-Separation Distance Determination for Mass Fire Hazards", T. Boggs, K.P. Ford, J. Covino, NAWCWD TM 8668, March 2013.

"Ammunition Accident at the Evangelos Florakis Naval Base, Zygi, Cyprus 11 July 2011", T.N. Taylor, MSIAC Report O-150 Rev. 1, September 2014.

"Ammunition Depot Explosions", A. Wilkinson, SAS Conventional Ammunition in Surplus Book 15 Chapter 13.

"Dangerous Depots: The Growing Humanitarian Problem Posed by Aging and Poorly Maintained Munitions Storage Sites Factsheets", Fact Sheet produced by the U.S. Department of State's Bureau of Political-Military Affairs, Summer 2010

"Major Ammunition Accidents—1917 to 2009" compiled by Colonel George Zahaczewsky, U.S. Army (Retired). Colonel Zahaczewsky Former Director of the U.S. Department of Defense's Humanitarian Demining Research & Development Program

"Recent Explosive Events in Ammunition Storage Areas," a report of 137 incidents released in June 2007 by the South Eastern and Eastern Europe Clearinghouse for the Control of Small Arms and Light Weapons (http://www.seesac.org).

"Environmental Monitoring of Stored Ammunition in South Korea (1995-1997)", U.S. Army Defense Ammunition Cener, Report No. 94-28-1, July 1997.

Acknowledgment: Thanks to Kathryn Hunt, US OSD for further information and references on fire events.