

DISTRIBUTION STATEMENT A. Distribution Unlimited. Other requests shall be referred to US Army RDECOM-ARDEC, Picatinny Public Affairs Office, Bldg. 1, Picatinny Arsenal, NJ 07806-5000

DESTRUCTION NOTICE- For classified documents, follow the procedures in DoD 5200.22-M, National Security Industrial Program Manual, Chapter 5, Section 7. For unclassified, limited documents, destroy by any method that will prevent disclosure of contents or reconstruction of the document.



U.S. Army Research, Development and Engineering Command



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Development of
Environmentally Friendly
Insensitive Pyrotechnic
Munitions with Enhanced
Battlefield Performance

Jesse J. Sabatini, Ph.D.
ARDEC Pyrotechnics Technology and
Prototyping Division
jesse.sabatini@us.army.mil

Report Documentation Page		Form Approved OMB No. 0704-0188
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.		
1. REPORT DATE NOV 2011	2. REPORT TYPE	3. DATES COVERED 00-00-2011 to 00-00-2011
4. TITLE AND SUBTITLE Development of Environmentally Friendly Insensitive Pyrotechnic Munitions with Enhanced Battlefield Performance		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER	
	5e. TASK NUMBER	
	5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army RDECOM-ARDEC,Pyrotechnics Technology and Prototyping Division,Building 1515,Picatinny Arsenal,NJ,07806-5000		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited		
13. SUPPLEMENTARY NOTES Presented at the Partners in Environmental Technology Technical Symposium & Workshop, 29 Nov ? 1 Dec 2011, Washington, DC. Sponsored by SERDP and ESTCP.		
14. ABSTRACT Over the past decade, Armament Research, Development and Engineering Center (ARDEC) has been involved in many environmental remediation programs in an effort to address the pressing environmental concerns of many pyrotechnic munitions in the U.S. Army's arsenal. Recent development of environmentally benign variants of the M115A2 ground burst projectile simulator, the M116A1 hand grenade simulator, the M117, M118, and M119 booby trap simulators, the M274 2.75? rocket smoke charge, and the battlefield effects simulator are noteworthy examples of previous success stories. The most recent success stories, such as the development of environmentally conscious red green and white light-emitting pyrotechnic illuminants will be discussed in detail. Specifically discussed will be the use of high-nitrogen compounds as a potassium perchlorate replacement toward the successful prototype development of M126A1 red star and M195 green star illuminants, the development of a barium-free variant of the M159 white star illuminant, and development of barium-, perchlorate- and chlorine-free green illuminants. The use of boron carbide toward the development of barium-, perchlorate- and chlorine-free green light emission will be discussed in significant detail due to its novel usage, and far-reaching potential in military and civilian pyrotechnic applications. The comparable/reduced sensitivities of the developed illuminants to various ignition stimuli, and their enhanced battlefield performances compared to the environmentally questionable formulations are also of significant importance. Ongoing pyrotechnic environmental remediation programs at ARDEC to be mentioned include areas pertaining to anthraquinone-free yellow smoke munitions for signaling purposes perchlorate- and barium-free IM-28 incendiary compositions, and the development of perchlorate- and barium chromate-free pyrotechnic delay fuzes for multi-purpose applications.		

15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 16	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

DEVELOPMENT OF ENVIRONMENTALLY FRIENDLY INSENSITIVE PYROTECHNIC MUNITIONS WITH ENHANCED BATTLEFIELD PERFORMANCE

DR. JESSE SABATINI

U.S. Army RDECOM-ARDEC, Pyrotechnics Technology and Prototyping Division
Building 1515
Picatinny Arsenal, NJ 07806-5000
(973) 724-8449
jesse.sabatini@us.army.mil

Over the past decade, Armament Research, Development and Engineering Center (ARDEC) has been involved in many environmental remediation programs in an effort to address the pressing environmental concerns of many pyrotechnic munitions in the U.S. Army's arsenal. Recent development of environmentally benign variants of the M115A2 ground burst projectile simulator, the M116A1 hand grenade simulator, the M117, M118, and M119 booby trap simulators, the M274 2.75" rocket smoke charge, and the battlefield effects simulator are noteworthy examples of previous success stories.

The most recent success stories, such as the development of environmentally conscious red, green and white light-emitting pyrotechnic illuminants will be discussed in detail. Specifically discussed will be the use of high-nitrogen compounds as a potassium perchlorate replacement toward the successful prototype development of M126A1 red star and M195 green star illuminants, the development of a barium-free variant of the M159 white star illuminant, and development of barium-, perchlorate- and chlorine-free green illuminants. The use of boron carbide toward the development of barium-, perchlorate- and chlorine-free green light emission will be discussed in significant detail due to its novel usage, and far-reaching potential in military and civilian pyrotechnic applications. The comparable/reduced sensitivities of the developed illuminants to various ignition stimuli, and their enhanced battlefield performances compared to the environmentally questionable formulations are also of significant importance.

Ongoing pyrotechnic environmental remediation programs at ARDEC to be mentioned include areas pertaining to anthraquinone-free yellow smoke munitions for signaling purposes, perchlorate- and barium-free IM-28 incendiary compositions, and the development of perchlorate- and barium chromate-free pyrotechnic delay fuzes for multi-purpose applications.



Overview



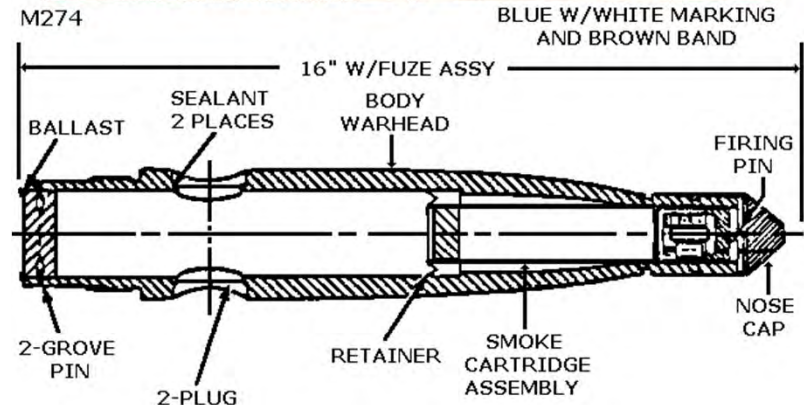
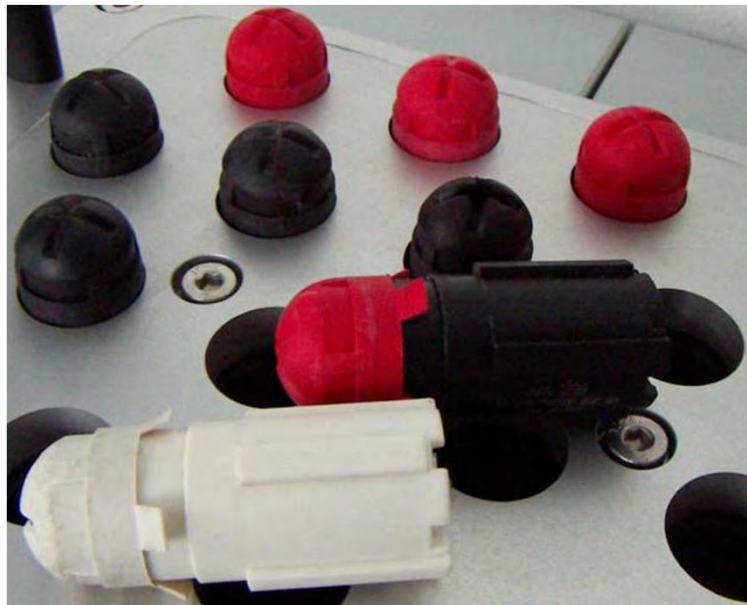
- Past success stories within ARDEC's Pyrotechnics Technology & Prototyping Division
- Environmentally Friendly Battlefield Illumination Development
 - High-nitrogen technologies for battlefield illumination
 - Barium- and chlorine-free green light-emission
 - Barium-free white light-emission
- Sensitivities of successful battlefield illuminants
- Other ongoing environmental initiatives within ARDEC Pyro
 - 0.50 caliber armor-piercing incendiary
 - Yellow smoke hand-held signaling
 - WP and HC smoke replacement
 - Pyrotechnic delay fuze development



Past Success Stories



- M115A2 ground burst projectile simulator
- M116A1 hand grenade simulator
- M117 (flash bang), M118 (illum), and M119 whistling booby trap simulators
- M274 2.75" training rocket smoke charge
- Battlefield effects simulator



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Visible Light Illuminants



- **Hand-held signals** (6), 40mm illuminants (5), 60/81/120mm mortars, 105/155mm artillery, 2.75” rocket.
- Can hand-held signal munitions be developed that burn longer and/or brighter?
 - Longer burning munitions can reduce bulk load of the item upon redesign
 - Brighter burning munitions have both military and civilian importance

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



KP-Free Formulations



M126A1 Control		Formulation A		Formulation B	
Component	Wt %	Component	Wt %	Component	Wt %
Sr(NO ₃) ₂	39.3	Sr(NO ₃) ₂	39.3	Sr(NO ₃) ₂	39.3
Mg 30/50	14.7	Mg 30/50	29.4	Mg 30/50	35.4
Mg 50/100	14.7	PVC	14.7	PVC	14.7
PVC	14.7	Sr(MNT) ₂	9.8	Sr(MNT) ₂	3.8
KClO ₄	9.8	Epon 813/Versamid 140	6.8	Epon 813/Versamid 140	6.8
Laminac 4116/Lupersol	6.8				

Identification	Burn Time (sec)	Luminous Intensity (cd)	Dominant Wavelength (nm)	Spectral Purity (%)
M126A1 Control	54.0	15,194.9	613.1	88.6
Formulation A	63.3	16,285.0	612.5	89.9
Formulation B	55.1	24,490.1	612.7	91.6



KP-Free Formulations



Formulation	Impact [J]	Friction [N]	ESD [J]	Thermal Onset [°C]
M126A1 Control	8.8	80	>0.25	264.6
A	10.8	160	>0.25	235.1
B	10.8	>360	>0.25	231.2



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



KP-Free Formulations



M195 Control

Component	Wt %
Ba(NO ₃) ₂	48
Mg 30/50	22
Dechlorane Plus (DP)	15
KClO ₄	10
Laminac 4116/Lupersol	5

Identification	Burn Time (sec)	Luminous Intensity (cd)	Dominant Wavelength (nm)	Spectral Purity (%)
M195 control	55.0	5,832.0	562.3	65.3
Formulation C	59.3	6,608.7	564.6	69.4
Formulation D	58.1	6,104.6	563.2	69.9

- Formulations do not contain DP



KP-Free Formulations



Formulation	Impact [J]	Friction [N]	ESD [J]	Thermal Onset [°C]
M195 Control	6.9	120	>0.25	622.0
C	11.8	>360	>0.25	583.6
D	8.8	>360	>0.25	559.0



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Barium-Free Illuminants



M159 Control

Components	Wt %
Barium Nitrate	49.5
Magnesium 30/50	29.5
Strontium Nitrate	16.5
Laminac 4116/Lupersol	5

Formulation E

Component	Wt %
Mg 30/50	29.5
NaNO ₃	65.5
Epon 813/Versamid 140	5

Formulation	Burn Time (sec)	Luminous Intensity (Cd)	Dominant Wavelength (nm)	Spectral Purity (%)
Mil-Spec	6.5 min.	25,000 min.	575±10	50 max.
M159 control ^a	7.6	26,160.0	584.2	49.6
E^b	13.1	38,872.5	588.5	87.6

a] 21.4 g consolidated in 1 increment at 2,450 kg.

b] 21.4 g consolidated in 3 increments at 6,818 kg.



Barium-Free Illuminants



Formulation **F**

Component	Wt %
Mg 30/50	34.5
NaNO ₃	60.5
Epon 813/Versamid 140	5

Formulation **G**

Component	Wt %
Mg 30/50	39.5
NaNO ₃	55.5
Epon 813/Versamid 140	5

Formulation **H**

Component	Wt %
Mg 30/50	44.5
NaNO ₃	50.5
Epon 813/Versamid 140	5

Formulation	Burn Time (sec)	Luminous Intensity (Cd)	Dominant Wavelength (nm)	Spectral Purity (%)
M159 control	7.6	26,160.0	584.2	49.6
F	10.9	50,622.7	588.7	88.4
G	9.1	68,805.8	588.1	85.7
H	8.5	76,731.2	588.2	86.7

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Barium-Free Illuminants



Formulation	Impact [J]	Friction [N]	ESD [J]	Thermal Onset [°C]
M159 Control	11.8	240	>0.25	287.6
H	11.1	>360	>0.25	265.8



M159 Control



Formulation **H**



Boron Carbide Illuminants



M125A1 Control	
Components	Weight %
Barium Nitrate	46
Magnesium 30/50	33
Polyvinyl Chloride	16
Laminac 4116/Lupersol	5

Formulations I and J.	
Components	Weight %
Potassium Nitrate	83
Amorphous Boron or Boron Carbide	10
Epon 828/Epikure 3140	7

Formulation	Burn Time (sec)	Luminous Intensity (cd)	Dominant Wavelength (nm)	Spectral Purity (%)
M125A1 Control	8.2	1,357.4	562.3	61.5
I	2.3	1,706.5	563.7	55.0
J	9.7	1,403.3	561.9	52.0



Boron Carbide Illuminants



Formulation	Impact [J]	Friction [N]	ESD [J]	Thermal Onset [°C]
J	>63.7	>360	>9.4	403.5



M125A1 Control



Formulation J



Formulation **K**



Other Ongoing Programs



- Yellow Smoke Signaling
- 0.50 Caliber Armor Piercing Incendiary
- WP and HC Replacement
- Environmentally Friendly Delay Fuzes



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Acknowledgements



■ Funding:

- Environmental Quality Technology (EQT)
- Ordnance Environmental Program (OEP)
- SERDP/ESTCP Program
- US Army, Picatinny Arsenal, NJ

■ Collaborators:

- Dr. Reddy Damavarapu, US Army, RDECOM-ARDEC
- Dr. Thomas Klapötke, Department of Chemistry, Ludwig-Maximilians University (LMU, Munich, Germany)
- United States Military Academy (West Point, NY)
 - COL Ronald K. Hann Jr. and CDT James M. Raab
- Fort Benning Infantry School