Mitigating Potential Single-Point-Failure in the Chain of Materials Supply of Densified Basic Magnesium Carbonate for Smoke Generation

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ABSTRACT

Densified Basic magnesium carbonate (DBMC) is widely used in military for smoke generation, such as in M18/M83 smoke grenades, M8 smoke pot, battlefield effect simulator (BES) and other miscellaneous pyrotechnic sub-components. It is mainly a coolant through a multi-stage decomposition to produce desirable smokes without flaming. It also has unique properties, such as particle size, density, that are essential to the Glatt Mixer process. However, domestic production (Rohm&Haas) has long ceased, and the army currently relies on a sole foreign source, Dead Sea Bromide of Israeli, for the supply of the material. Consequently, there is a high chance of single-point failure (SPF) in the chain of material supply. The aim of this work is to identify, evaluate and establish alternative sources/suppliers of BMC to mitigate the potential source single point failure. Among six supply sources identified for assessment, the BMC samples from Lehmann and Voss of Germany and Melox Chemicals of India more closely resemble the material currently used in the Army in terms of their physiochemical and thermal properties as outlined in military spec MIL-DIL-11361E. The heavy metals and other trace constituents were also

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	2. REPORT TYPE	3. DATES COVERED
21 APR 2011	**Technical**	**12-10-2010 to 21-04-2011**

4. TITLE AND SUBTITLE
Mitigating Potential Single-Point-Failure in the Chain of Materials Supply of Densified Basic Magnesium Carbonate for Smoke Generation None

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Zhaohua Luan; Gary Chen; Lyle Miller; Michael Whittaker; Raymond Cutler

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research, Development and Engineering Center (ARDEC),Building 3124,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

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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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INTRODUCTION

Densified basic magnesium carbonate (DBMC) is a compound containing magnesium carbonate, MgCO3, magnesium hydroxide, and water. It exists in two different forms with distinct particle morphologies, one is known as light phase with a 4:1:4 chemistry, $4MgCO_3 : 1Mg(OH)_2 : 4H_2O$, and another referred as heavy phase 4:1:5 with higher water content, $4MgCO_3 :1Mg(OH)_2 : 5H_2O$. Weight loss for these two phases upon heating is slightly different, 58.5 % and 56.9 % for heavy and light respectively.

Upon heating, DBMC loses water and then carbon dioxide, the rapid release of these gases aids in smoke generation. For this very reason, the Army currently uses DBMC for smoke generation in a variety of weapon systems such as M18/M83 smoke grenades, M8 smoke pot, battlefield effect simulator (BES) and other miscellaneous pyrotechnic sub-components with an annual usage of over 25 metric tons. It functions as a coolant through a multi-stage decomposition to produce desirable smokes without flaming. However, the domestic DBMC production by Rohm&Haas has long ceased and the Dead Sea Bromide of Israeli is currently the Army's sole DBMC supplier. Consequently, there is a potential single-point failure (SPF) in the chain of materials supply for those crucial weapon systems, and there is an urgent need for alternative supplier to mitigate such a risk.

MATERIALS AND TEST PROTOCOLS

No U. S. suppliers were identified. Among six potential BMC suppliers under consideration, two are in Europe, Lehmann & Voss (L&V, Germany) and Solvay (Italy), and three are from India, Melox, Osian and Shree. Shree's material was clearly out of the specification in terms of density and, therefore, not further evaluated. The Army provided its DBMC material as Army control.

Two sets of tests were conducted against Army material specification for DBMC, MIL-DTL-11361E. Physical and thermal analysis was carried out at a contract lab located at 2425 South 900 West, Salt Lake City, Utah 84119, while trace and heavy metal analysis were performed at ARDEC laboratory at Picatinny Arsenal.

RESULTS AND DISSCUSSIONS

Physical and thermal analysis

As shown in Table 1, the physical properties of all DBMC materials under consideration vary greatly with sample L&V of Germany and Melox of India most closely resembles the Army spec in terms of density and particle size. Sample Osian of India and Solvay of Italy are clearly out of the spec. The Solvay material is actually a Light grade and the Osian material is in too fine particles.

Table 1. **Physical Characteristics of Densified Basic Magnesium Carbonate Samples.**

Supplier	Density (g/cc)		Surface Area	Particle Size (μm)	
	Bulk	Tap	(m^2/g)	Water	Alcohol
MIL Spec	(n/a)	0.2-0.6	(n/a)	7-20	(n/a)
Army	0.35	0.57	11.4	11.9	14.1
L & V(#2)	0.37	0.64	10.1	14.7	14.2
L & V(#1)	0.38	0.69	16.2	18.9	20.7
Melox	0.20	0.46	20.9	7.3	9.6
Osian	0.11	0.29	23.7	0.8	25.1
Solvay	0.08	0.19	33.2	0.4	8.6

As far as thermal properties, shown in Table 2, all materials give almost the same MgO content as these are all food grade materials, but not in endothermic characteristics even the Army control. L&V of Germany provided two materials, with the second material very close to the Army control. Melox material is currently used by Indian Army for smoke generators. It meets most specifications, but has very different particle morphology than what the Army currently uses.

Table 2. Thermal Properties of Densified Basic Magnesium Carbonate Samples.

Supplier	Moisture Content (%)	MgO Content (%)	Endotherms 1st	Endotherms 2nd
MIL Spec	1.0 max	40.0-43.5	235-250°C	435-450°C
Army	0.76	42.9	260°C	454°C
L & V(#2)	1.15	45.0	285°C	469°C
L & V(#1)	0.73	43.6	272°C	466°C
Melox	2.12	43.3	276°C	441°C
Osian	-0.13	42.3	264°C	440°C
Solvay	0.67	43.5	285°C	454°C

L&V appears to be the best choice as a second supplier to the Army as their surface area and bulk density values are closest to the material presently being used, while Meltox ranks second for down selection.

Trace and heavy metal analysis

BMC materials from three supply sources, L&V, Melox and Osian were selected for additional test. Table 3 shows material solubility and total MgO content of selected materials in comparison with that of Army control sample and Mil Spec.

As can be seen from the data on Table 3, the material L&V 2 and Melox pass the solubility test, while Osian fails both solubility test in HCl and the water. As for MgO content, the data from all samples tested are generally in the range specified in Mil Spec.

Table 3. Material Solubility and Total MgO Content of Selected BMC Materials

Materials	**Solubility (wt%)**		**Assay as MgO (wt%)**
	HCl solution	**Water**	
Army control	0.009	0.16	40.6, 41.1
L&V(2)	0.002	0.07	43.1, 42.8
Melox	0.019	0.22	42.7, 41.6
Osian	0.048	0.68	40.4, 40.8
Mil Spec	0.02 max	0.50 max	40 -43.5

Table 4 gives trace and heavy metal analysis results. None of materials tested contained significant amount of heavy metals such as arsenic, lead, mercury, barium, bismuth, cadmium chromium, and well within Mil Spec.

However, the Mil Spec is not consistent in term of Iron content. Table 1 in paragraph 3.2 of the Mil Spec gives an upper limit of 0.02 %, while the paragraph 4.4.6.2 gives an upper limit of 0.002 %. The analysis procedure calls for preparing a solution of 10 ppm in iron. Using that solution in the manner described will give an upper limit of 0.002 %. LgV 500 seemed high than the limit of 0.002 %, but well below the limit of 0.02 %. The iron contents for other samples are within the Mil Spec.

Table 4. Trace and Heavy Metal Content of Selected BMC Sample Materials.

Materials	**Trace or Heavy Metal**								
	Calcium	**Iron**	**Arsenic**	**Lead**	**Mercury**	**Barium**	**Bismuth**	**Cadmium**	**Chromiu**
Control	0.06	0.0015	0	1.5	0	0.35	0.25	0.58	2.5
L&V(2)	0.20	0.0036	0	0.9	0	0.35	0.14	0.47	2.0
Melox	0.45, 0.44	0.0013	0	1.7	0	0.31	0	0.45	0.14
Osian	0.11	0.0015	0	1.4	0	1.1	5.3	0.50	0.20
Mil Spec	0.45 max	0.002	2 max	10 max	20 max	20 max	20 max	20 max	20 max

Analysis for calcium was performed using atomic absorption spectroscopy. The spec method was very tedious, and did not appear reliable. The army control, LgV500, and Osian pass easily. The Melox is in borderline. The test was repeated in duplicate with similar results.

CONCLUSIONS AND RECOMMODATIONS

While no material is an exact duplicate of the Army control in terms of physiochemical characteristics, at least two of the BMC materials investigated, L&V(2) and Melox closely resemble what was specified in Mil Spec, and might work as well as BMC material from the Dead Sea Bromide.

It is therefore recommended that the BMC materials from L&V and Melox should be considered as potentially viable source of material supply, and be further assessed for performance data in weapon systems such as M18 smoke grenades.

As a footnote, The Mil Spec, MIL-DTL-11361E, appears written based on material currently in use, and too restrictive or otherwise too narrowly defined. It should be revised with more updated information.

ACKNOWLEDGEMENTS:

Authors thanks Kerry Henry-PM-JS, John Blackmer-PM-JS, Derek Dereiter-PM-CCS and Jessica A Perciballi-ARDEC for project management support.

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