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REPLACEMENT OF FIRST FIRE COMPOSITION IN M127A1 GROUND ILLUMINATION SIGNAL

Russell N. Broad

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A study was conducted to replace the first fire composition in the M127A1 ground illumination signal. The original first fire composition contained tetranitrocarbazole, a sole source material, and barium nitrate, a toxic material. Program costs were minimized by choosing a presently used first fire composition as a replacement. A data base of such compositions was created. It was used to pick candidate replacement compositions. The compositions were loaded into illuminant assemblies and tested statically. Results from this test showed that Starter Mix (SM) XXV was the best candidate composition. It was loaded into complete signals that underwent ballistic testing. Signals with SM-XXV met all applicable Military specification requirements. The success of the program justified the approach of choosing a currently used first fire composition.

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INTRODUCTION

The pyrotechnic first fire compositions covered by MIL-P-48240 are used on a wide range of colored signals and illuminating projectiles. There are three of these compositions, each formulated to give a distinctive color. Table 1 give the formulations for these compositions. TNC is a common constituent of these compositions. TNC was first synthesized in the late 1800s and found use in pyrotechnics in World War II (ref 1). Picatinny Arsenal investigated its use as a first fire constituent in the early 1950s (ref 2). It is considered an explosive material. Upon ignition it produces considerable energy and essentially gaseous products. These properties enable the first fire compositions to ignite illuminating and signal compositions. The first fire compositions are either pressed on top of, or brushed onto, the surfaces of illuminating and signal compositions pressed into canisters or sleeves. The first fire compositions are initiated by expelling charges or ignition compositions. Through the years, the first fire compositions have given reliable, consistent performance.

In the early 1990s, the availability of TNC became uncertain because its sole producer did not want to manufacture it anymore. Although another company picked up production, availability could not be guaranteed. TNC has no commercial market and the military market has declined dramatically. The resulting low demand make its production marginally profitable. Thus, there is little motivation to continue its production. This situation led to execution of an engineering study to eliminate use of TNC. A secondary purpose of the engineering study was the replacement of barium nitrate in the igniter compositions. This material is in two of the pyrotechnic first fire compositions. Like all water soluble barium salts, it has high acute toxicity. Further, disposal of waste containing it is relatively expensive because it cannot be landfilled. This report describes the results of the engineering study.

TECHNICAL APPROACH

One approach to remove TNC could have been reformulating the first fire compositions without it. This would have resulted in novel compositions. The approach taken, however, was replacement of the three first fire compositions with a pyrotechnic composition that was presently being used on other items. The advantages of this approach follow. First, it minimized testing required for qualification since a presently used composition had a history associated with it. This included functioning performance in various end items, environmental considerations, cost and data on storage stability, safety, thermodynamics, and kinetics. Second, manufacturing procedures and drawings already existed for the composition. Third, use of one first fire composition would simplify manufacturing since one batch of composition could be used for various items, regardless of the items' signal or illumination colors.

One possible drawback to this approach was the elimination of first fire compositions that were tailored to the illuminating or signal composition color. Several individuals knowledgeable in the field use the colored signals revealed that the color of the first fire flash was insignificant in affecting an observer's ability to distinguish illuminant or signal colors. The flash of the first fire is of very quick duration (<500 ms) compared to the burn time of the illuminants or signals (>25 sec). Thus, elimination of the color requirement for the first fire compositions was of no concern and this approach was pursued.

The program was conducted in three phases. First, other presently used pyrotechnic compositions were identified and pertinent data was collected on them. For maximum flexibility, we did not confine our search to only igniter and first fire compositions (henceforth we will use the term first fire to apply to igniter compositions as well). A data base was created from which the best candidate compositions were selected. Second, static functioning tests were performed on illuminant assemblies which contained the candidate first fire compositions and the standard first fire compositions. These tests determined if the candidate replacement compositions would have any adverse affect on the static requirements for the illuminating assemblies. Third, items were loaded with both the candidate replacement composition and the standard first fire composition, and underwent first article ballistic testing.

RESULT

Composition Data Base/Selection of Candidate Compositions

Identification of presently used first fire compositions was begun by generating a list of drawings that contained words igniter, ignition, and first fire in their titles. These drawings were then obtained. A second source for such compositions was reference 3. This procedure ensured that the vast majority of, if not all, presently used first fire compositions were identified. With this information, a minimal data base that included first fire formulations and common names was created. Further information was then added. This included impact, electrostatic and friction sensitivity data, hazard class, heat of reaction, autoignition temperature, burn rate, cost per pound, and qualitative ranking of toxicity. Not all of his data could be obtained for every composition. The data base is shown in table 2. The references for the various data are cited in the table.

Criteria were developed to select the most promising candidate replacement compositions. Criteria included toxicity, cost, sensitivity, availability of constituents, history of problems, and burning characteristics. It was decided to eliminate those that would be least likely selected. The first criterion for elimination was presence of acutely toxic or carcinogenic constituents. This included barium, lead salts, and chromates. This consideration eliminated many of the compositions shown in table 2 as candidates. The remaining compositions were eliminated because of safety or processing issues, autoignition temperatures exceeding 500°C (ref 4), or other considerations such as cost. Since the first fire compositions are in contact with the flash from expelling charges for short duration's, they must reach their autoignition temperatures quickly. This is more easily accomplished if the autoignition temperature is relatively low. The remaining compositions, which were chosen as candidates, were Starter Mix XXV, IM-6, and I-548 (no. 10, 34, and 40, respectively in table 2). Table 3 shows further detail on these compositions.

Static Tests of Candidate Compositions

Composition I-548 was dropped from consideration because the required grade of calcium resonate could not be obtained easily. Only starter Mix XXV and IM-6 were evaluated statically. Table 4 is a matrix of assembly types and quantities statically tested. Assemblies with the standard first fire compositions served as controls. The choice of assemblies was based upon the items planned for the qualification tests. In turn, the choice of items was based upon what items would be in production during the duration of the program.

The required parts for the assemblies were ordered and tooling was fabricated for loading the assemblies. The Pyro Systems Branch of the U.S. Army Armament Research, Development and Engineering Center (ARDEC), Picatinny Arsenal, New Jersey mixed all the pyrotechnic compositions and loaded all the assemblies used in the static tests. The Branch also conducted all the static tests in its own flare tunnel. Table 5 is a roll up of averaged static test parameters for the assembly/first fire combinations tested.

The efficiency data shows that SM-XXV offers significantly better performance over IM-6 for the M125A1 and M127A1, while the IM-6 is much better for the M158. They are nearly equal for the M583A1. SM-XXV was better than the standard first fire for all items except the M583A1. Here, the standard was approximately 13% higher. Based on this static data, as well as SM-XXV's lower cost, we decided to test SM-XXV in the ballistic testing.

Ballistic Testing for Prove Out of New First Fire Composition

In consultation with ARDEC's Product Assurance and Test Directorate, a test plan was drafted for ballistic testing. The ballistic test consisted of functioning tests at conditioning temperatures specified in the military specifications. Additionally, some illuminant assemblies from the lot used for the ballistic test were statically tested. Quantities were per first article requirements. This minimal amount of testing was justified since changing the first fire would in no way affect the hardware and other energetic material fills in the item.

The ballistic tests were conducted by Thiokol Corporation at Longhorn Army Ammunition Plant (LHAAP). During the time period in which static testing at ARDEC concluded and ballistic tests begun, numerous production lines were closed at LHAAP. Startup of these lines exclusively for this program would have been prohibitively expensive. Consequently, only the M127A1 signal experienced ballistic testing.

Thiokol loaded the items per the technical data package requirements and performed testing per the Scope of Work. Table 6 shows their static burn data. The candlepowers measured at LHAAP were higher than ours; this was due to differences in the tunnels and test procedures. As expected, the candlepower achieved with SM-XXV was higher then FF-I. Since exact illuminant weight data was unavailable, efficiencies are not reported. Table 7 presents the ballistic (flight) data. The data shows that aside from two failures at 70°F, all signals met the requirements. One failure was non-expulsion of the signal; the other, failure of the round to expel. Neither was related to first fire function. The only ballistic parameter that could have been possibly affected by the change in first fire was the burn time. The differences between the signals with FF-I and SM-XXV for this parameter were small and within the standard deviations at all temperatures.

CONCLUSIONS

The success of the project vindicated the selected approach. Choosing a presently used igniter composition kept the cost and technical risks of the program as low as expected. The need for extensive testing above first article requirements was eliminated.

RECOMMENDATIONS

Other items incorporating igniter compositions with sole source, toxic, or environmental/ objectionable constituents should be evaluated for igniter replacement. Programs to achieve this objective would be of minimal scope since they would have the data base of igniters generated in this program as a starting point.

Table 1
Formulations for pyrotechnic first fire compositions

Constituent	Requirements	Nominal weight percent		
		Type I	Type II	Type III
Barium nitrate	MIL-B-162 Average particle size ≤ 20 μ	50	---	50
Strontium nitrate	MIL-S-20322 Grade A or B	---	50	--
Tetranitrocarbazole	MIL-T-13723	10	10	10
Silicon	MIL-S-230 Average particle size ≤ 10 μ	20	16	13
Zirconium hydride	Commercial	15	15	20
Polyvinyl chloride	MIL-P-20307	---	5	3
Laminac 4116 + 1% Lupersol DDM catalyst	Commercial	5	4	4
Color requirement		Yellow	Red	Green

Table 2
Database for first fire and pyrotechnic compositions

Table 2 Database for first fire and pyrotechnic compositions

No	Fuel (Percent):	Oxidant (Percent):	Additive (Percent):	Binder (Percent):	Solvent (Percent)	Type of Comp.	Cost $/Lb	E.Sta.(J) Uncon/Con (BM)	Fric.P Steel/F	Impact PA,(")	BR As Shown	Heat ofRec Cal/g	Ig.Temp Degrees C Auto/DTA	Compat Gr/Haz (DOD)	Toxicity
1	Lead Azide					Exp		0.007	Exp/Exp	4 -5					
2	Nitrocellulose					Exp		0.049j	Burns/	3-5			160	D /1.1	Not Toxic
3	PETN					Exp		.06 /.21	Cra./NR	6				/1.1	
4	TNT					Exp		.06 /4.4	NR/NR	14		1060	/D475	/1.1	
5	RDX					Exp		>11.03	Exp/NR	8		1240	260 (5s)	/1.1	
6	Black Powder					Exp	3.00	12.5/0.8	Snp/NR	16		684	288 (5s)	/1.1	
7	98.5-99 RDX		<1.5 St.Acid			Exp.		11.025	Cra./NR	8 -12			190	/1.1	
8	30 Charcoal	70 KN03				St.MIXII	3.24	0.75 BM	NR/NR	@10 NR	1.9s/mg	980	418	G /1.3	MOD.
9	83.3 Dry Mix Dry Mix (#9): 26/4/13;Si/C/Al BinderSolu(#9):	35/22;KN03/Fe203		16.7 B.Solu 6 NC	94Acetone	StartMix	2.35 2.71 0.59	1.25	NR/NR	15 BOE	0.3s/mg		401	G /1.3 D /1.1	MOD Slight
10	26/13/4;Si/Al/C	35/22;KN03/Fe203				~~St.MixII~~ StMixXV	2.71	1.25 1.5 BM	NR/NR	15 BOE	5.0s/in	1186	421	/1.3	SLIGHT
11	60 Dry Mix Dry Mix (#11): 16.8/10;S/C.Starch BinderSolu(#11):	43.2/30;KC103/NaHC03		40 B.Solu. 4 NC	96Acetone	St.MixVI	0.46 0.42 0.51	1.15	NR/NR NR/NR	28 BM 3.2BOE	>1 s/mg 25 s/in	946	182 216	G /1.1	SLIGHT
12	35 pts Sb	35/30pts;CaSi2/KC104		66pts(8 NC	92 Ace.)				NR/NR	15 BOE	13s/in	1812	446	/1.3	
13	40 Al	30/30;Ba(N03)2/KC104				PFP-555				26		2147	700 (5s)		
14	23/15; Al / S	62 Ba(N03)2				Flash		NR @.25	Cr/	22 ERL				D /1.1	SL-MOD.
15	91 Bk.Powder	9 Al				Flash	3.09	0.225	NR/NR	14	0.2s/mg		344	D /1.1	MOD.
16	34/26; Mg/Al	40 KC104				PFP-I	7.53	3.2/<0.73	Snp/NR	27 -36			762	D /1.1	TOX
17	25.5/12.8; Mg/Al	25.5/28.1;BaCr04/KCl		8.1Viton A	B.Acetate	FF	22.4	0.0125	CD/CD	6			380	A /1.1	TOXIC CAR.SUS
18	50/50; FF/Flare FF: 10 B Flare: 65 Mg	90 BaCr04 28 Teflon		7 Hycar	MEK or Acetone	FF.Flare iDP-906	8.89 10.1 7.60	0.051 0.0034	CB/CB CB/CB	12 12 16	0.6s/in	480	550 615 400	G /1.3 /1.1 G /1.3	MOD CAR.SUS. SL.- MOD.
19	DryMix & B.Solu. Dry Mix (#16): 25/25; Ti/Si Binder Solu:	25/25; Fe304/Pb304		(10.9 NC	89.1 Acetone)	FF.VII	1.31 0.77	0.875	NR/NR NR/NR	15 BOE	3.0s/in 3.0s/in	360 360	>762 762	G /1.3	MOD
20	30 W	55/10;BaCr04/KC104	5 D.earth	Viton A		FFMix			NR/NR				391	/1.3	
21	25/25; Si/Ti	50 Pb304	(Graphite	NC	Acetone)	FF.MixX	1.29	1.625	NR/NR	NR @15	0.3s/mg	275	780	G /1.1	MOD
22	10 B	90 Pb02			E.Acetate	FF.PComp	7.90	0.0125	CB/CB	2			327	A /1.1	MOD

Table 2
(cont)

Table 2 Database for first fire and pyrotechnic compositions

No	Fuel	Oxidant	Additive	Binder	Solvent	Type	Cost	E.Sta.(J)	Fric.P	Impact	BR	Heat	Ig.Temp	Compat	Toxicity
	(Percent):	(Percent):	(Percent):	(Percent):	(Percent)	of Comp.	$/Lb	Uncon/Con (BM)	Steel/F	PA,(")	**As Shown	ofRec Cal/g	Degrees C Auto/DTA	Gr/Haz (DOD)	******Ref
23	33 Bk Powder Red Pyro Comp.: 2/17; Mg,Gran11 Mg,Gran 4	67 Red Pyro. Comp. 13/21.4;NaNO3/KClO4	6.5 Hexachl'b. 7.5 Gilsonite 2.8 Graphite			FFfM131S								D /1.1	MOD CAR.SUS
24	30 Ti	70 Fe203				FF30MixV	1.09	N/R	Cr/NR	10 BOE	6.5s/in		659	G /1.3	SLIGHT
25	FF: I,II & III, I:20/15; Si/ZrH2 II:16/15; Si/ZrH2 III:30/20;Si/ZrH2	TNC Pyro.Comp.: 50 Ba(NO3)2 50 Sr(NO3)2 50 Ba(NO3)2	10TNC 10TNC; 5PvCl 10TNC; 3PvCl	5 Lam.4116 4 Lam.4116 4 Lam.4116		FF:I,II, III FF:I FF:II FF:III	3.78 3.67 3.64	9.76	Cra/NR	26	8.6s/in 12 s/in 12 s/in	680	476	D /1.1	MOD CAR.SUS TOXIC CAR.SUS
26	TNC, FFIII(Slurry)		Pluronic F68	Cel.Nitrate		FFM125A1									
27	TNC, FFI(Slurry)		Pluronic F68	Cel.Nitrate		FF127A1									
28	TNC, FFII(Slurry) or 16 BPowder,Cl-8	84 TNC FFII (Slurry)	Pluronic F68 Pluronic F68	Cel.Nitrate Cel.Nitrate	MEK	FF158A1 FFM158A1									
29	TNC, FFI (Not A or 1g B powder Ig. Pwd.: 19 B	Slurry) 3g Ignition Pwd.(Not 18/58;Ty IV Tef/KNO3	A Slurry)	5 P.ester		FFM583A1 FFM583A1	3.78 11.4 14.2								
30	20 Si	80 Pb304		1.8 (10 NC	90 Ace.)	FFM201A1	0.82		NR/NR	>15BOE	4.4s/in	335	371	/1.3	TOXIC
31	10 Si	90 Pb304		1.8 (10 NC	90 Ace.)	FFMix	0.65		NR/NR		1.5s/in	256		/1.3	TOXIC
32	25 B VAAR is no longer	75 KNO3 being produced. An	old quotation	1 VAAR @ $19.00 /	lb. was	I-SpMix used for	19.3 cost	0.124	CB/NR	10	2.3s/in	1594	414/431.2	/1.1	MOD.
33	50 Si	20/30; PbO2/CuO				Igniter	1.67			15		380	476		TOXIC
34	40 Si	54 KNO3		6 Viton A		IM-6	3.82	> 1	> 2477 ft. lbs	> 49.6	11.6in/		673.5	G	MOD
35	65 Zr	25 Fe203	10 D.Earth	VAAR added		I-A1A	>69	0.0024	CB/NR	24	.06s/mg	550	427	G/1.3	Slight
36	21 Zr	79 BaCrO4				DP-162	25.6	0.0013	PB/NR	23	1.0s/in	396	418	/1.1	CAR.SUS
37	19 B	58/18; KNO3/TFE		5 Lam4116		SI-282		0.283	Spk/NR	9			NR(5sec)	D/1.1	MOD.
38	23.1 B	70.7 KNO3	0.5PluronicF68	5.7 Lam4116		Igniter		1.0BM	NR	13		1600	400/565	D /1.1	MOD
39	16.5 Mg	80.5 BaO2	2/1;CaRes/Graphite			I-527	1.95	1.25	Sps/NR	23			375	G /1.3	CAR.SUS
40	15.0 Ty-III Mg(Gran	65.0 SrO2	7/13; TyI/TyII Ca Resinate			I-548		0.05 BM	Spks/NR	8			239		MOD
41	6 Mg (Gr.12) I-136: 10 Ca Res.	94 I-136 90 SrO2				I-194 I-136	5.97	0.25 0.05	Snps/NR Snps/NR	35ERL 16	.5s/mg		287 280	G /1.1 G/1.1	Slight Slight

Table 2
(cont)

Table 2 Database for first fire and pyrotechnic compositions

No	Fuel (Percent):	Oxidant (Percent):	Additive (Percent):	Binder (Percent):	Solvent (Percent)	Type of Comp.	Cost $/Lb	E.Sta.(j) Uncon/Con (BM)	Fric.P Steel/F	Impact PA,(")	BR **As Shown	Heat ofRec Cal/g	Ig.Temp Degrees C Auto/DTA	Compat Gr/Haz (DOD)	Toxicity ******Ref
42	5 B	95 BaCr04				DP.T-10	7.15		CB/NR	>40	1.9s/in	265	553/675	/1.1	CAR.SUS
43	10 B	90 BaCr04				DP-479	10.1	0.02	CB/CB	12	0.7s/in	480	615/705	/1.1	CAR.SUS
44	10 B	90 BaCr04		1 VAAR (See record #32)		DP-879	9.70	0.25	CB/NR	24	1.5s/in	463	560	/1.1	CAR.SUS
45	15 B	85 BaCr04				DP-523	13.2		CB/NR	26	1.5s/in	502	/645	/1.1	CAR.SUS
46	19 B	81 BaCr04				DP.T-10	15.7	0.50	CB/NR	10	2.0s/in	276	656	/1.1	CAR.SUS
47	15 B	44/41; BaCr04/Cr203				DelayMix	13.9				4.5s/in				CAR.SUS
48	14 B	44/42; BaCr02/Cr203				DelayMix	13.2				6.5s/in				CAR.SUS
49	13 B	41/44; BaCr02/Cr203				DelayMix	12.5				8.5s/in				CAR.SUS
50	50 W	40/10; BaCr04/KC104				DelayMix	7.27		NR/NR	22 BOE	12s/in	233	270	/1.3	Car.SUS
51	20 W	70/10; BaCr04/KC104				DelayMix	5.68				41s/in				CAR.SUS
52	9 70/30ZnNi alloy &17 30/70ZnNi alloy	60/14; BaCr04/KC104				DP-1415, TyII	17.9		CB/NR	>40	6.0s/in	521	325	/1.3	CAR.CUS TOXIC
53	3 70/30 ZnNi alloy &23 30/70ZnNi alloy	60/14; BaCr04/KC104				DP-1415, TyIII	16.6		CB/	>40	11s/in	521	325	/1.3	CAR.SUS TOXIC
54	55 MN	45 PbCr04				DP.D16	1.07				2.2s/in	230			CAR.SUS
55	33 Mn	30/37; BaCr04/PbCr04				DP.D16B	1.99		NR/NR	15 BOE	8.4S/in	256	460		CAR.SUS
56	32.8 Mn	37/30.2;BaCr04/PbCr0				DP.D16C			NR/NR	15 BOE	13s/in	262		/1.3	CAR.SUS
57	28 Zr	72 Pb02				DelayMix	22.5				<.5s/in				Toxic
58	5/31;Zr/Ni	42/22; BaCr04/KC104				DP.T-2	10.5				6.5s/in				CAR.SUS
59	5/17;Zr/Ni	70/8; BaCr04/KC104				DP.HP-25	9.71				18 s/in				CAR.SUS
60	32-58 W	32-56 BaCr04 & 10-14 KC104		VAAR (See record #32)		Delay P.	7.04 Avg. w/oB	11.03	NR/	36			270		MOD
61	53 Zr	21/26; KC104/Mo03				SI-98						1174	372		
62	48.7 Zr	31.3/20; Mo03/Cr203				SI-113	54.1	0.00018	CB/CB	34	0.8s/in	605	400	G/1.3	Low
63	40 Zn;20 Al	20 KC104;20 KN03				PFP-600	3.82 Avg.	>50		14			700	G /1.3	MOD
64	60-67 Al	33-40 KC104				PFP-600	5.9	0.37	CB/NR	24		2284		D /1.1	
65	22.5/10; Al(Fl.)/S	64/3.5; KC104/SbS2				M-80									

Table 2
(cont)

Table 2 Database for first fire and pyrotechnic compositions

No	Fuel (Percent):	Oxidant (Percent):	Additive (Percent):	Binder (Percent):	Solvent (Percent)	Type of Comp.	Cost $/Lb	E.Sta.(j) Uncon/Con (BM)	Fric.P Steel/F	Impact PA,(*)	BR **As Shown	Heat ofRec Cal/g	Ig.Temp Degrees C Auto/DTA	Compat Gr/Haz (DOD)	Toxicity ******Ref
66	40.0 Zr	60 BaCrO4										502			
67	M1 Propellant					Propel't		11.03	NR/NR	4 -6				C /1.1	
68	M9 Propellant					Propel't		5.2	Snp/NR	2 -3				C /1.1	
69	M30 Propellant					Propel't		>12.5	NR/NR	4				C /1.1	
70	42 30/50 Mg	44 Sr(NO3)2	7 Declarane	7 VAAR (See record #32)		III,RT		>50	Cra/NR	19			344	D /1.1	High
71	48-65 20/50 Mg	31-47.5 NaNO3		4-4.5 VAAR (See record #32)		FY-1450		11.82	NR/NR	21			/518	D /1.1	MOD
72	75 30/50 Mg	10 Teflon		15 Viton A	Acetone	III.F,IR	9.00	11.025	NR/NR	18			400	A /1.3	Sl.- MOD.
73	50 30/50 Mg	38 NaNO3		5 Lam4116	Acetone	FY-1444	4.28	11.025	NR/NR	19		1456	640	/1.1	SL-MOD
74	65.9 30/50 Mg	34 NaNO3				FY-1192							610		
75	46% 20/50 Mg	45 NaNO3		9 Lam4116	Acetone	FY-1451		11.02	NR/NR	20			431	A/	
76	65 Mg	28 TFE		7 Hycar	MEK or Ac	III.F.IR	7.60	11.025	NR/NR	16			400	G /1.3	SL-MOD
77	Opt. Fuel: 33 Mg 30/50 of: a.Ty-I(Sp.14067)or b.Ty-III(Sp.382C)or c.Ty-IV,El,Sp.14067	46 Ba(NO3)2, Cl-2 (30um)	16 PvCl	5 Lam4116		III.M125		11.02							
78	Opt. Composition: 66 Mg30/50TyI(14067	29 NaNO3		5 Lam4116		III.M127		11.02							
or	65 Mg30/50TyI(14067	31 NaNO3		4 VAAR		III.M127		11.02							
79	33 Mg30/50TyI 14067	48 Sr(NO3)2,GrB	15 PvCl	4 VAAR		III.M158		11.02							
80 &	28 Mg30/50TyI 14067 20 Mg50/100El 14067	41 NaNO3,GrB,Cl-2		11Lam4116		III.583		11.02							

DATA COLLECTION:

The thermal and sensitivity data were collected from HCSDS statements, from a DTIC Technical Report, #AD-E400- 496, entitled, A Compilation of Hazard and Test Data for Pyrotechnic Compositions by Fred L. McIntyre, and from two laboratory reports: one entitled Development of Igniter Compositions for High Altitude Ignition of Illuminants, Propellants etc. by C.Knapp et.al. and a second entitled Compilation and Evaluation of Ignition Temperature Parameters and Differential Thermal Analysis for Pyrotechnic Barium Chromate - Boron Systems by S Gordon and E. D. Crane.

In order to expedite the collection of burning rate data, sources were used that presented the data in two different units. Some of these rates were calculated from HCSDS statements which presented burning times for 20 mg of loose composition. The remainder of these rates were collected for pressed compositions on a linear basis in seconds /inch. The common practice is to load delays at pressures between 20,000 and 40,000 psi.

The toxicity and compatibility data were collected from HCSDS statements and from a Noyes Publication:Handbook of Toxic and Hazardous Chemicals, 1981.

Cost data was collected from the latest editions of the monthly Chemical Marketing Reporter published by the Schnell Publishing Company of New York and by direct contact with users and Manufacturing Companies.

Finally, a few propellants and explosives were used for comparison.

Table 2
(cont)

Abbreviations

E. Sta. = Electrostatic
J = Joules
Fric. P = Friction
BR = Burning rate
Ig. Temp = Ignition temperature
Compat = Compatibility
Comp = Composition
Uncon = Unconfined
Con = Confined
F = Fiber
PA = Picatinny Arsenal
Rec = Recation
DTA = Differential thermal analysis
Gr = Group
Haz = Hazard
BM = Bureau of Mines
Exp = Explodes
Cra, Cr = Crackles
NR = No reaction
St. = Stearic
Snp, Snps = Snaps
St. = Starter
Mod = Moderate
B = Binder
BOE = Bureau of Explosives
Solu = Solution
Nc = Nitrocellulose
pts = parts
Ace = Acetone
Tox = Toxic
Sl-Mod = Slight to moderate
ERL = Energetics Research Laboratory
Bk. = Black
B.Acetate = Butyl Acetate
CD = Complete detonation
CAR. SUS = Carcinogen suspect
MEK = Methyl Ethyl Ketone
CB = Complete burning
D.earth = Diatomaceous Earth
E. Acetate = Ethyl acetate
Pyro = Pyrotechnic
Hexachl'b = Hexachlorobenzene
TNC = tetranitrocarbazole
PvCl = Polyvinyl chloride
LAM = Laminac
Cel = Cellulose
Pwd. = Powder
Ty = Type
Tef = Teflon
P.ester = Polyester
CaRes = Calcium resinate
Sps, Spks, Spk = Sparks
Pb = Partial burn
Propel't = Propellant
TFE = tetraflouroethylene
Cl = Class
Sp = Specification
El = Ellipsoidal
Opt = Optimal

Table 3
Candidate first fire compositions

Constituent	Requirements	Nominal weight percent		
		SM-XXV	IM-6	I-548
Silicon	MIL-S-230 Grade II, Class C	25.7	40.0	---
Potassium nitrate	MIL-P-156 Class I	34.6	54.0	---
Charcoal	JAN-C-178 Class D	4.0	---	--
Aluminum powder	MIL-A-512 Type II, Grade C, Class 4	12.8	---	---
Red iron oxide	MIL-I-275 Grade D	21.7	---	---
Nitrocellulose	MIL-N-244 Grade D	1.2	---	---
Viton A	Commerical	---	6.0	---
Strontium peroxide	MIL-S-612 Grade B	---	---	65.0
Calcium resinate	MIL-C-20470 Type II	---	---	7.0
Calcium resinate	MIL-C-20470 Type I	---	---	13.0
Magnesium powder	MIL-M-382 Type III, Granulation 12	---	---	15.0

Table 4
Static tunnel (ARDEC) data for various illuminant assemblies

Assembly for	First Fire	# Assemblies	Burn Time, sec	Average Candlepower	Average Efficiency candle-gram/sec	Average Color Value
M125A1 Green Star	FF-III	10	5.1±0.3	5516±1040	2347±430	0.42±0.02
Cluster Ground	IM-6	10	5.6±0.5	4196±1165	1924±471	0.41±0.01
Illumination Signal	SM-XXV	10	5.4±0.5	5962±991	2677±282	0.41±0.00
M158 Red Star	FF-II	10	4.2±0.4	19349±3696	6811±1257	0.54±0.01
Cluster Ground	IM-6	10	4.8±0.4	21177±2897	8511±1533	0.54±0.01
Illumination Signal	SM-XXV	10	4.6±0.5	20323±1193	7717±717	0.53±0.00
M127A1 White Star	FF-I	10	37.9±1.5	76788±4367	34302±2084	0.05±0.00
Parachute Ground	IM-6	10	39.0±1.2	56962±1734	26275±8204	0.04±0.00
Illumination Signal	SM-XXV	10	38.6±0.8	80780±5359	36784±2806	0.05±0.00
M583A1 White Star	FF-I	10	26.0±2.9	110631±4513	36827±3874	N. A.
40mm Parachute	IM-6	10	21.0±4.6	112867±16744	32251±3358	N. A.
Cartridge	SM-XXV	10	23.2±2.4	106327±11498	32369±2655	N. A.

Table 5
Static tunnel (LHAAP) data for standard and candidate illuminant assemblies

Assembly	First fire	No. assemblies	Average burn time, sec	Average candlepower
M127A1	FF-I	20	34.0 ± 0.8	114,100 ± 5,890
M127A1	SM-XXV	20	31.0 ± 0.9	135,100 ± 9,010

Table 6
Ballistic data for signals conditioned at -65°F

		M127 with FF-I	M127 with SM-XXV	Requirements
	# Fired	16	16	16
	# Functioned	16	16	16
Altitude, feet	Average	715±38	700±76	None
	Maximum	805	784	None
	Minimum	652	433	None
Angle, degrees	Average	6.0±3.2	11.0±9.1	≤25
	Maximum	14	44	None
	Minimum	2	3	None
Chute Delay, seconds	Average	0.82±0.08	0.82±0.15	None
	Maximum	0.92	1.29	5
	Minimum	0.66	0.63	None
Burn Time, seconds	Average	37.0±1.3	37.0±1.2	None
	Maximum	39.1	38.7	None
	Minimum	34.1	35.1	25

Table 7
Ballistic data for signals conditioned at 70°F

		M127 with FF-I	M127 with SM-XXV	Requirements
	# Fired	32	32	32
	# Functioned	32	30	32
Altitude, feet	Average	815±34	821±42	>725
	Maximum	889	916	None
	Minimum	719	743	500
Angle, degrees	Average	4.0±2.4	4.0±2.4	≤12
	Maximum	10	9	30
	Minimum	1	1	None
Chute Delay, seconds	Average	0.72±0.06	0.74±0.09	None
	Maximum	0.91	0.95	5
	Minimum	0.64	0.59	None
Burn Time, seconds	Average	32.9±1.2	32.5±0.8	None
	Maximum	34.7	34.9	None
	Minimum	30.6	30.5	25

Table 8
Ballistic data for signals conditioned at 165°F

		M127 with FF-I	M127 with SM-XXV	Requirements
	# Fired	32	32	32
	# Functioned	32	32	32
Altitude, feet	Average	828±34	845±25	None
	Maximum	886	916	None
	Minimum	684	803	None
Angle, degrees	Average	4.0±2.5	4.0±2.4	None
	Maximum	10	8	None
	Minimum	1	0	None
Chute Delay, seconds	Average	0.67±0.08	0.69±0.10	None
	Maximum	0.83	1.06	None
	Minimum	0.53	0.56	None
Burn Time, seconds	Average	31.2±1.3	30.6±1.3	None
	Maximum	35.1	33.8	None
	Minimum	28.8	28.4	None

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