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**EVALUATION OF ALTERNATE FUEL AND BINDER MATERIALS
IN HAND HELD SIGNALS ILLUMINANT COMPOSITIONS**

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**U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND
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13. ABSTRACT An investigation was conducted to explore the feasibility of replacing atomized magnesium fuel and laminac binder in the hand held signals illuminant compositions with alternate fuel and binder materials without compromising performance characteristics. The illuminant compositions for M127A1 white star and M126A1 red star were selected as technology demonstration candidates. Alternate fuel materials tested include several commercially available atomized aluminum (ALCAN X-65, AEE-AI 104), high energetic nanomicon size aluminum powder (ALEX aluminum), magnesium-aluminum alloy powders (50/50) and ground magnesium powders (Reade RMC 305 and RCM 366). Alternate binder materials tested include environmentally compatible polyester polyurethane resin (CA-398 NLV), polyvinyl acetate resin (AYAF), vinyl alcohol acetate resins (POLIVIC S 202 and S 505) and hydrogenated nitrile elastomer (ZETPOL 2010). The performance criteria used for evaluation were luminous output (candlepower), burn time (seconds), and chromaticity color characteristics (dominant wavelength-DWL and saturation purity). Test data indicate that the luminous output (candlepower) and burn time with these new binder samples were generally comparable or higher than the minimum required values (candlepower 90,000 and burn time 25 sec for M127A1, candlepower 10,000 and burn time 50 sec for M126A1). The chromaticity characteristics including dominant wavelength and saturation purity values with these binder samples were within the acceptable CIE standard values for M126A1 red star. Further testing with the new binder materials, particularly with AYAF and POLIVIC S 505, are needed to optimize binder concentration in the compositions followed by a full-scale evaluation through end item function testing. The performance characteristics with the ground magnesium (Reade RMC 305 and RMC 366) fuel pellet samples were generally comparable or higher than the minimum required values. All the aluminum sample pellets and most of magnesium-aluminum alloy sample pellets did not provide sufficient luminous output (candlepower) or burn time or both. Limited compressive strength data with the new binder materials in illuminant compositions indicate that there is sufficient strength to hold the ingredients in the compositions and provide a homogeneous mixture.					
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INTRODUCTION

The study on magnesium fuel alternatives and binder material alternatives for munitions (simulators, illuminating signals, and flares) is a part of a broad-base program to develop and demonstrate safe, reliable, and environmentally acceptable pyrotechnic munitions. A report (ref. 1) has been issued recently citing a successful demonstration of an alternate fuel material (atomized aluminum) to replace the current atomized magnesium fuel in trip flare illuminant composition. The report also includes a successful demonstration of replacement of environmentally incompatible barium chromate-boron mixture with environmentally compatible potassium nitrate-boron mixture in the first fire composition for trip flare system. The same concept has been extended to the present study where it explores the possibility of replacing magnesium fuel in Hand Held Signals' illuminant compositions without compromising the performance characteristics. In addition, environmentally compatible alternate binder materials were investigated (ref. 2) to replace Laminac 4116 binder, which is presently used in the compositions. Laminac is a polyester base resin that cross-links to a thermoset copolymer with a vinyl monomer, styrene. Lupersol DDM-9 serves as a catalyst for the polyester resin cross-linking and contains methyl ethyl ketone peroxide (MEKP). There are several issues involved with the use of this system. First, both, the carrier solvent-styrene and MEKP are toxic materials and are extremely hazardous to health and environment. Load plants have complaints about these materials. Secondly, the cross-linking and thermosetting nature of the binder often lead to the volume of consolidation of illuminating compositions to shrink during cure, resulting in inconsistent candle power/burn time and charge fall out during field testing. Thirdly, Laminac has limited pot life when incorporated with the cure agent, forcing manufacturers to blend a mix and press it within a very short time. Finally, this material can be obtained only from a single source and has limited military and commercial market. The overall approach addressed in this program is to explore the use of an alternate fuel and/or binder material without compromising the performance characteristics of the signal system.

OBJECTIVE AND APPROACH

The objectives of the present investigation are twofold: (1) to evaluate the effect on performance by replacing atomized magnesium with an alternate fuel material and (2) to evaluate the effect on performance by replacing Laminac binder material with an alternate binder material in signal illuminant compositions. The study addresses parametric evaluation and performance characteristics with alternate materials including the effects of particle size, fuel-oxidant ratio, binder type and concentration, and additives. The illuminant compositions for the Hand Held Signals (M127A1 White Star-ground-parachute and M126A1 Red Star-ground-parachute) were chosen as technology demo candidates for this investigation. The illuminant compositions consist of primarily atomized magnesium as fuel, different oxidizers/additives to provide required performance and color characteristics for the signal and Laminac as a binder. Figure 1 and table 1 give details respectively of configurations and compositions that are presently used in these systems. The study also evaluates and compares the test data for signal illuminant composition using commercially available ground magnesium instead of Mil-Spec. atomized magnesium as fuel.

MATERIAL SELECTION AND DESCRIPTION

Alternate Fuel Materials

ALEX Aluminum Powder

A new class of high energetic, ultra-fine (nanometers size) aluminum powders (refs. 3 and 4), developed by ARGONIDE Corporation by Elex process where metal wires are heated with an electrical pulse in an inert gas environment, were obtained. The electromagnetic field produced by the pulse contains the metal as the temperature rises beyond 20,000 K at which time there is electric over load. Then the wire, in the form of a plasma, is exploded into aerosols and results in crystalline particles that are approximately 50 to 100 nm in size that are agglomerated. Figure 2 represents the composite of particle size and SEM microphotograph.

Aluminum Powder (AL-104)

Spherical atomized aluminum powder was obtained from Atlantic Equipment Engineers High Purity Metal Powders and Compound. Figure 3 represents the composite of particle size and SEM microphotograph.

Alcan X-65 Aluminum Powder

Alcan spherical aluminum powder, produced by inert gas atomization process, is of uniform particle size and high packing density. Details of specification for this powder is given in the Appendix. Figure 4 represents the composite of particle size and SEM microphotograph.

Magnesium – Aluminum Alloy (50/50) Powders (also referred as “Magnallium”)

Magnesium-aluminum alloy powders obtained per military specification were used. The powders were obtained from Atlantic Equipment Engineers High Purity Metal Powders and Compound and from Skylight corporation. Figure 5a and b represent the composite of particle size and SEM microphotographs.

Ground Magnesium Powders (Reade RMC-305 and RMC-366)

Commercially available ground magnesium powders are mechanically produced from primary magnesium, minimum 99.8% pure per ASTM Specification B92 to sizes ranging from 30 mesh to 100 mesh. Figures 6 and 7 represent the composite of particle size and SEM microphotographs of the powders.

Atomized Magnesium

Atomized magnesium 30/50 type 1 (from Hummel Croton Inc.) and atomized magnesium 50/100 type 1 (from Valley Met Inc.), per Mil-P-14067, were obtained for preparing standard samples. Figures 8 and 9 represent the composite of particle size and SEM microphotographs.

Alternate Binder Materials

A broad-based search from government, industry and academia was applied to gather information on alternate materials for Laminac systems. Potential candidates were selected for evaluation based on the following criteria - environmental acceptability (toxicity characteristics), solubility in solvent, tensile strength, soft point/decomposition temperature (thermal stability), commercial availability, compatibility with pyrotechnic ingredients and requirement for curing/cross-linking. The following are potential new binders resulting from this search. Product specifications for these binders are described in the appendix.

LAMINAC 4116

Laminac is currently in use. Laminac is a polyester base resin that cross-links to a thermoset copolymer with a vinyl monomer, styrene. Lupersol DDM-9 serves as a catalyst for the polyester resin cross-linking and contains MEKP.

CA-398NLV

Morthane CA-398NLV is a high molecular weight hydroxyl-terminated polyester polyurethane resin from Morton International (ref. 5).

AYAF

AYAF is a polyvinyl acetate resin and is a thermoplastic material from Union Carbide (ref. 6).

POLIVIC S 202 – 35%

POLIVIC S 202-35% is a secondary suspending agent for polyvinyl chloride from 3V Inc. It is polyvinyl acetate partially hydrolyzed (mol 47%) in methanol with a random distribution of the hydroxy group along the macromolecule (ref. 7).

POLIVIC S 505 – 35%

POLIVIC S 505 – 35% is a secondary suspending agent for polyvinyl chloride from 3V Inc. It is polyvinyl acetate partially hydrolyzed (mol 30%) in methanol with a random distribution of the hydroxy group along the macromolecule (ref. 7).

Zetpol 2010

Zetpol 2010 from ZEON chemicals Inc. is one of the hydrogenated nitrile elastomers and is in mid-range in terms of acrylonitrile content and saturation (ref. 8).

RESULTS AND DISCUSSION

Particle sizes of various powders used in this study were measured using a laser light scattering technique (Melvern Instrument). A scanning electron microscopy (SEM) was used to obtain the shape of the particles. Test samples (pellets) were prepared per drawing requirements of Hand Held Signals (M126A1-P/N 8797971 & M127A1-P/N 9295010) using kraft tube (Spec # UU-P-268,

convolute wound with dextrine adhesive between layers). The performance characteristic testing on samples includes measurement/calculation of luminous output, burn time, and chromaticity color values. A spectra radiometer device has been used to measure the spectral energy distribution. Electric match (M103 Atlas match) and SI 163 igniter (zirconium-iron oxide base) were used for initiation of pellets. All tests were video taped in order to observe the nature and color characteristics of flame burning and production of any incandescent and/ or un-burnt particles during combustion.

Mechanical Compression Strength

Signal compositions with magnesium as fuel for M126A1 and M127A1 stars were selected to prepare batches with different binders for compression strength evaluation. Dry granules were consolidated (at 6,000 or 9,000 psi.) to small pellets (3/8 in. by 3/8 in.) for testing in an Instron Mechanical Test System. Each pellet after aging (24 or 72 hrs) was compressed by the load cell, starting at one end and continued until it was deformed or crushed. The load (force-lb) at this point was recorded. Five pellets for each composition was tested and the average was computed. Table 2 summarizes pellet strength (load-lb) with the type of binder and its concentration in the composition. The M126A1 samples with Laminac binder produced maximum strength (94.63 lbs.) while samples with other binders produced 62.02 for POLIVIC S505, 73.93 for old VAAR, 68.35 for AYAF and the lowest value, 34.59 for CA-398NLV. In spite of lower strength values for the samples with the new binders, the performance data (fig. 4 - candlepower, burn time) met the standard required values indicating that there is sufficient compressive strength to hold the ingredients intact for these samples. For M127A1 samples, the lower compressive strength values (53.38 with POLIVIC S505 and 37.77 for old VAAR binders) did not affect the performance characteristics (fig. 3 - candlepower, burn time). Environmental conditioning and firing tests needs to be conducted for prove-out and the performance has to be evaluated in full size samples with these new binder materials in the hand held signal systems.

Performance Characteristics

M127A1 White Star

Full size white star pellets were made using different fuel material powders including atomized magnesium (current standard), commercially available ground magnesium (Reade RMC 305 and RMC 366), magnesium-aluminum alloy (50/50) powders, ALEX aluminum, and atomized spherical aluminum powders (from AEE Inc.). The fuel content was increased in some samples to find the effects on performance with increasing concentration. The oxidant in all these samples was sodium nitrate and the binder material was Laminac 4116. The binder concentration was 5% in all these samples while the oxidant concentration was adjusted based on fuel concentration in the pellets. Table 3 summarizes all the data including composition and performance (luminous output, burn time and luminous efficiency values). The luminous output values for tested samples are also reported as a percentage of the minimum required value. The minimum burning requirements for candlepower and burn time are 90,000 candles and 25 sec, respectively. Figure 10 represents luminous output (candlepower) and burn time for all the samples. Magnesium fuel in the standard illuminant composition produces higher luminous output (123% and 133%) for 57% and 66% of atomized magnesium in the samples, respectively, and the luminous efficiencies were 35.6 and 31.6, respectively. The performance data indicate that only ground magnesium samples produce at least minimum (or exceed) required values. The luminous outputs were 98% and 137% and the

luminous efficiencies were 24.6 and 31.7, respectively, for Reade RMC-305 and RMC-366. Other fuel materials samples, either failed to produce the required candlepower or burn time or both values. Magnesium-aluminum alloy samples (with 45%, 55%, 65%, and 70% fuel content) do not meet luminous output requirement in all fuel composition range (luminous output - 54%, 85%, 78%, and 79%, respectively). Only one magnesium-aluminum alloy sample (with 45% fuel) met burn time data (29.9 sec) and the rest of the samples failed to produce the minimum burn time. The luminous efficiencies were 16.1 or lower for these samples. Atomized aluminum fuel (AL-104) samples of various concentrations (45% to 65%) provide less than 50% of candlepower even though they exceed burn time requirements. The addition of tungsten in the fuel (AL-104) for these samples did not improve the performance (luminous outputs were less than 50%). Similarly, high energetic nanometer ALEX aluminum powder samples of various fuel concentrations (45% to 70% range) produced luminous output in the range of 45% to 70% of the required minimum value and burn time in the range of 7.8 to 12.9 sec. These values were less than required standard. Variation in fuel concentration for the ALEX samples (45% to 70%) indicates that a peak was reached at 55% fuel concentration in luminous output while burn time generally decreased with increase in concentration (table 3). During burning/combustion of the pellets, both ejection of bright incandescent particles (molten aluminum or partially burned aluminum for aluminum samples) and smoke were visually observed.

Full-size pellets were made with different binder materials (POLIVIC S505 binder, AYAF binder, and VAAR-old Union carbide binder) using standard magnesium compositions and compared with samples made using Laminac binder. With these new binders, the luminous outputs were relatively high (candlepower in the range of 99,950-110,412 candles) and burn time data met or exceeded the standard required value. The luminous output were 111% for POLIVIC S505 sample, 114% for AYAF sample, 123% for VAAR-old Union Carbide sample, and 133% for Laminac sample, respectively, of the required value. Although the luminous outputs with the new binders were less than with that of Laminac binder sample, they were well above the minimum required value. The luminous efficiencies for these samples were 32.3, 28.1, 32.4, and 31.6, respectively. Since only limited tests were conducted with these binders and with only one concentration, improvement in the performance can be achieved by refinement in binder concentration and improving processing techniques. The later can be achieved by directing efforts to improve wetting characteristics of these alternate binders to ease mixing and granulation and enhancing pellet strength through the addition of plasticizer, such as phosphate.

M126A1 Red Star

Full size red star pellets were made using different fuel material powders including atomized magnesium (current standard), commercially available ground magnesium (Reade RMC 305 and RMC 366), magnesium-aluminum alloy (50/50) powders, and atomized spherical aluminum powders of different particle sizes (AE-104 and X-65 Toyal America). The oxidants in all these samples were strontium nitrate, potassium perchlorate, and polyvinyl chloride and the binder material was Laminac 4116. Table 4 summarizes all the data including composition and performance (luminous output, burn time, luminous and chromacity color coordinate values). The luminous output values for tested samples are also reported as a percentage of the minimum required value. The minimum burning requirements for candlepower and burn time are 10,000 (candles) and 50 sec respectively. Figure 11 represents luminous output (candlepower) and burn time for all the samples. The standard (control) pellet sample (M383, table4) with atomized magnesium produced luminous output of 9,834 candles and burn time of 74 sec. The luminous efficiency was 8.1 for the standard.

The performance data (candlepower and burn time) for the ground magnesium (RMC 305 and RMC 366) samples indicate that they exceed the required value. The luminous outputs were 118% and 118%, burn times were 68 and 64 sec and luminous efficiencies were 8.5 and 8.9, respectively, for Reade RMC-305 and RMC-366. Magnesium-aluminum alloy samples either failed to meet candlepower or burn time or both of the required minimum values. It should be noted that experiments were conducted by eliminating the secondary oxidant (potassium perchlorate) and increasing strontium nitrate concentration in three of magnesium-aluminum alloy samples. For example, magnesium-aluminum alloy samples (with 29% and 32% fuel from Skylighter Inc., with 30% and 32% fuel from AEE) provided luminous output of 38%, 58%, 77%, and 117% of the required value respectively and burn time of 76, 64, 44 and 36 sec, respectively. The results suggest that the smaller mesh size alloy (from AEE) will provide more efficient combustion to yield higher luminous output and shorter burn times. It is possible that performance output can be increased to meet the required value by adjusting the fuel-oxidant ratio of Mg-Al alloy of smaller mesh size (for example, M379, table 4). Atomized aluminum samples (AL-104 and Al X-65 Toyal America), failed totally to meet luminous output of the standard even though they generally exceed burn time requirements. The luminous output values were 7% and 9% only for Al-104 and Al X-65 pellet samples. The addition of tungsten to the sample (M381, table 4) did not improve the performance (luminous output of 6%). It is to be pointed out that during burning/ combustion of the pellets, both the ejection of bright incandescent particles (molten aluminum or partially burnt aluminum) and some smoke were visually observed.

Full size pellets were made with different binder materials (POLIVIC-S 505, POLIVIC-S 202, AYAF, VAAR old, Zetpol 2010, and CA-398NLV) using standard magnesium pellet compositions and compared with the samples prepared with the Laminac binder. With these binders, the luminous outputs were relatively high (candlepower range, 11,000 to 17,775) and burn time data (58 to 67 sec) met or exceeded the standard (50 sec). The luminous outputs were 178% and 149% for two POLIVIC S 505 binder samples, 170% for POLIVIC S 202 sample, 125% for AYAF sample, 159% for VAAR-old Union carbide sample, 146% for Zetpol 2010 sample, 117% for CA-398NLV sample, and 98% for Laminac sample, respectively, of the required value. The luminous outputs with the new binders were relatively higher than those with Laminac binder sample and are well above the minimum required value. The luminous efficiencies were 11.6 and 10.2 for two POLIVIC S 505 samples, 10.8 for POLIVIC S 202 sample, 8.7 for AYAF sample, 10.5 for VAAR-old Union carbide sample, 10.1 for Zetpol 2010 sample, 8.7 for CA-398NLV sample, and 8.1 for Laminac binder sample, respectively. Since only limited tests were conducted with these binders and with only one binder concentration at 3% (with the exception of AYAF binder concentration at 5%), improvement in the performance can be achieved by refinement in binder concentration and improving processing techniques. The later can be achieved by directing efforts to improve wetting characteristics of these alternate binders to ease mixing and granulation and enhancing pellet strength through addition of plasticizer, such as phosphate. The results indicate POLIVIC S 505, POLIVIC S 202 and AYAF binder provide relatively high luminous outputs (table 4) and good pellet strength (table 2) and therefore merit further study.

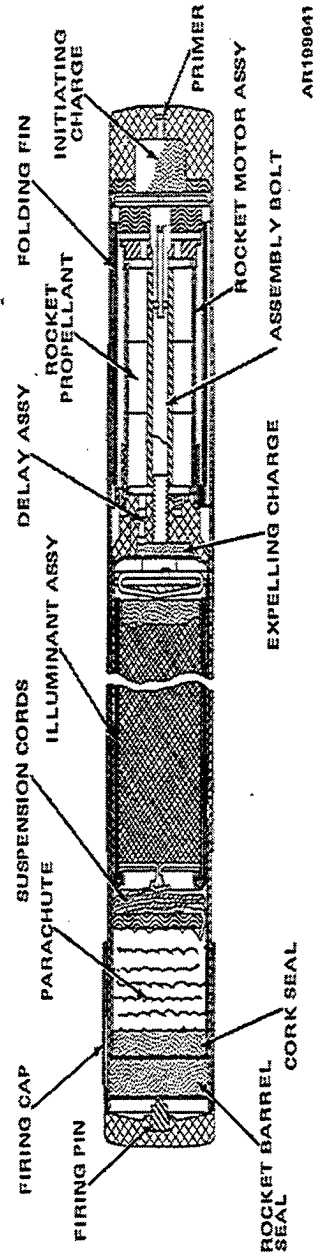
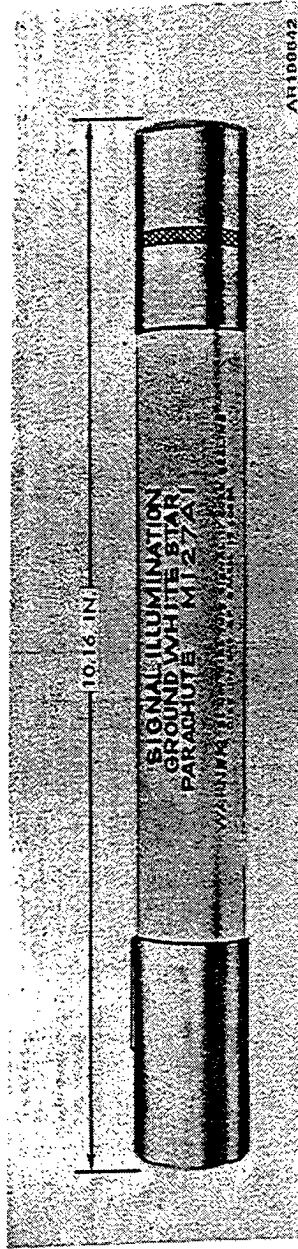
The color characteristic data for M126A1 red star is summarized in table 4. They include the dominant wavelength (DWL), saturation (purity %), and chromaticity diagram coordinates (x and y). The standard CIE (commission internationale d'eclairage) color values are 620 nm \pm 20 nm and 76% min. purity for red. The color values are calculated for those compositions that meet the required luminous output and burn time. For samples with different binders in the composition, the dominant wavelength and saturation purity values were 614 nm and 91% for Laminac, 613 nm and 89% for

AYAF, 610 nm and 85% for POLIVIC S 202, 612 nm, 87% for Zetpol 2010, and 614 nm and 91% for CA-398 NLV, respectively. The DWL values fall within the acceptable CIE values (620 nm \pm 20 nm) and the saturation purity values are well above the standard required. These data indicate that any one of the binders can be used in the illuminant composition for red star provided that they also meet the performance requirements including luminous output and burn time and have sufficient compressive strength to hold all the ingredients in the composition.

SUMMARY AND RECOMMENDATIONS

1. Several new environmentally compatible materials including polyester polyurethane resin (CA-398 NLV), polyvinyl acetate resins (AYAF, POLIVIC S 202, and S 505) and hydrogenated nitrile elastomer (Zetpol 2010) were tested as a potential binder material in the hand held signals (M127A1 White Star-ground-parachute and M126A1 Red Star-ground-parachute) illuminant compositions. The intent is to replace the current Laminac 4116 binder due to several environmental producibility concerns and issues.
2. The luminous output (candlepower) and burn time with these new binders samples were generally comparable or higher than the minimum required values (candlepower 90,000 and burn time 25 sec for M127A1 and candlepower 10,000 and burn time 50 sec for M126A1). The color characteristics (dominant wavelength and saturation purity) of the red star samples were agreeable with the standard CIE values.
3. It should be pointed out that POLIVIC S 505 and S 202 binders are of different version of vinyl alcohol acetate resin (VAAR-manufactured by 3V company) and provide comparable compressive strength relative to the old VAAR (manufactured by Union Carbide Inc.). The old VAAR is being extensively used in many pyrotechnic compositions due to its strong binding characteristics. Unfortunately, it is not available or in limited supplies. POLIVIC S 505, POLIVIC S 202 and AYAF resins would provide alternative choices as binder material.
4. Compressive strength data with new binder materials in illuminant compositions indicated that there is sufficient strength to hold ingredients in the compositions. POLIVIC S 505 and AYAF resins provide comparable compressive strengths and luminous outputs and merit further testing and evaluation for use in end items.
5. The performance results for the new binders are based on limited samples. Additional tests need to be performed to select one or two new binder materials to optimize the binder concentration in the compositions followed by full-scale evaluation through end item function test. Improvement in the processing technique can also be achieved by directing efforts to improve wetting characteristics of these alternate binders to ease mixing and granulation and to enhance pellet strength through the addition of plasticizer, such as phosphate.
6. Several commercially available atomized aluminum (Alcan X-65, AEE-AI), high energetic nanometer aluminum powder (ALEX), magnesium-aluminum alloy powders, ground magnesium (Reade RMC-305 and RMC-366) were tested as fuel material to replace the current atomized magnesium in the signal illuminant compositions.

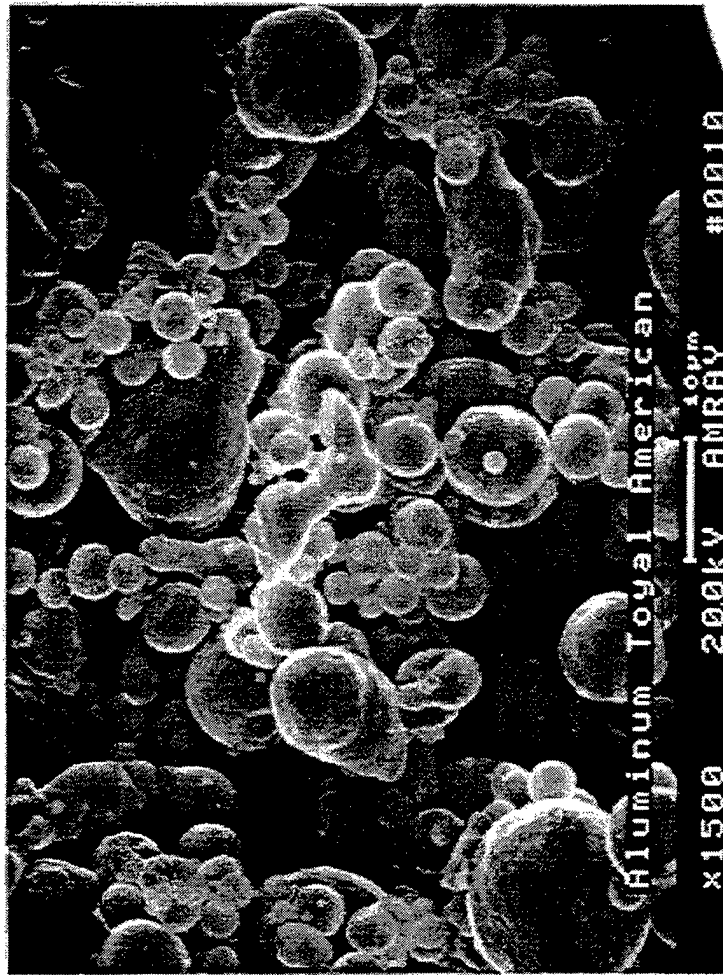
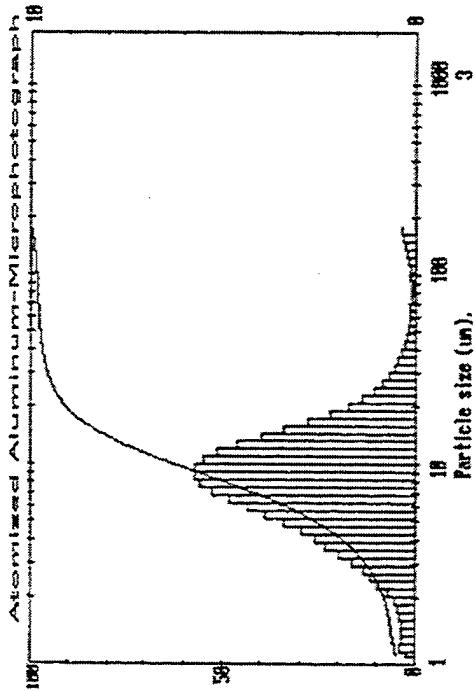
7. The performance characteristics including luminous output (candlepower) and burn time with the ground magnesium (Reade RMC-305 and RMC-366) fuel pellet samples were generally comparable or higher than the minimum required values. Full scale end item function tests and evaluation need to be performed with this commercially available ground magnesium samples for incorporation as alternate fuel material in the specification drawings.
8. All samples with aluminum, as fuel did not provide sufficient luminous output or burn time or both. This indicates that aluminum can not be used as fuel to replace magnesium in the hand held signals illuminant compositions.
9. All samples with magnesium-aluminum alloy, as fuel in M127A1 white star illuminant composition did not provide sufficient luminous output (candlepower) or burn time or both. The samples with magnesium-aluminum alloy as fuel in M126A1 red star (table 4) provided sufficient luminous output or burn time and not both. It is generally possible that by adjusting the fuel-oxidant ratio in the illuminant composition, particularly with smaller size alloy particle size, one can obtain the required luminous output and burn time. This effort needs to be explored further for this system.



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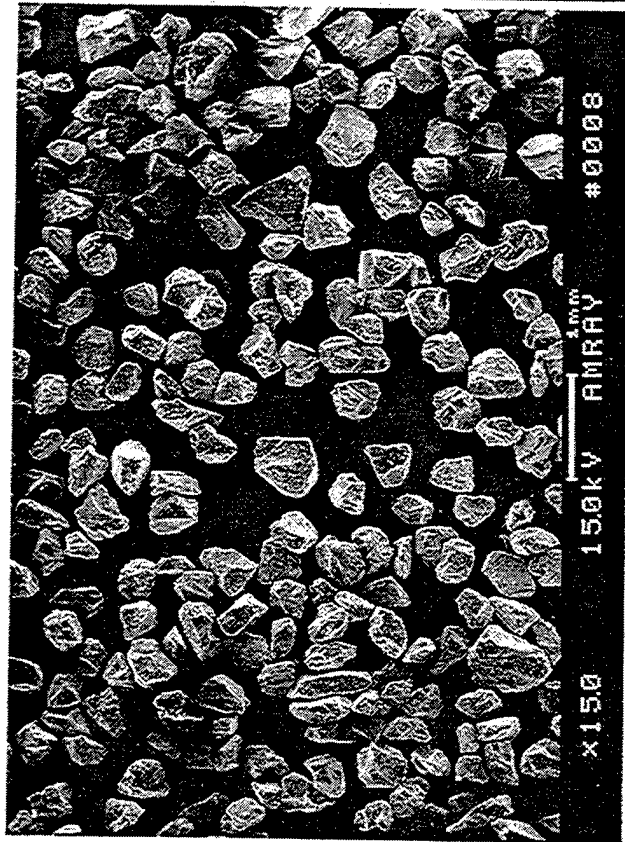
- M127A1 - Atomized Mg + Sodium Nitrate + Laminac Binder; Performance- Candlepower (90000), Burn Time (25 seconds)
- M126A1 - Atomized Mg + Strontium Nitrate + Potassium Perchlorate +Laminac Binder Performance - Candlepower (10000), Burn Time (50 seconds), Red color value (0.54)

Figure 1
Hand held illuminant signals M127A1 white star and M126A1 red star



High Under Size	High Under % Size	High Under x Size	High Under x Size	High Under x Size	High Under x Size	High Under x Size	High Under x Size	High Under x Size	Span
100	100	64.4	98.0	8.65	51.1	2.95	2.2	1.06	2.83
169	99.7	58.7	97.9	7.51	45.5	2.69	18.9	0.96	D(1,3)
186	99.3	57.4	97.7	6.84	40.3	2.45	18.7	0.88	11.86µm
224	99.1	56.7	97.6	6.53	35.4	2.23	17.7	0.80	D(1,2)
113	98.9	44.3	97.3	5.67	31.1	2.03	16.6	0.73	4.66µm
163	98.7	40.4	97.1	5.17	27.2	1.85	15.5	0.68	D(1,0.97)
93.6	98.6	36.8	96.7	4.71	23.8	1.68	14.6	0.58	16.99µm
85.2	98.4	33.5	96.5	4.29	20.9	1.53	13.3	0.53	D(1,0.17)
77.6	98.3	30.5	96.3	3.91	18.2	1.40	12.2	0.50	2.51µm
70.7	98.1	25.3	94.3	3.24	13.8	1.16	9.9	0.38	D(1,0.5)
Source = Sample									
Focal length = 100 mm									
Presentation = std									
Beam length = 2.4 mm									
Residual = 0.199 %									
Dispuration = 0.0463									
Voltag Conc. = 0.0679%									
Sp.S.A = 1.4778 #/cc.									
Shape OFF									

Figure 4
 Atomized aluminum (Toyal America Alcan X-65) -- particle analysis and SEM microphotograph



(a) 15X

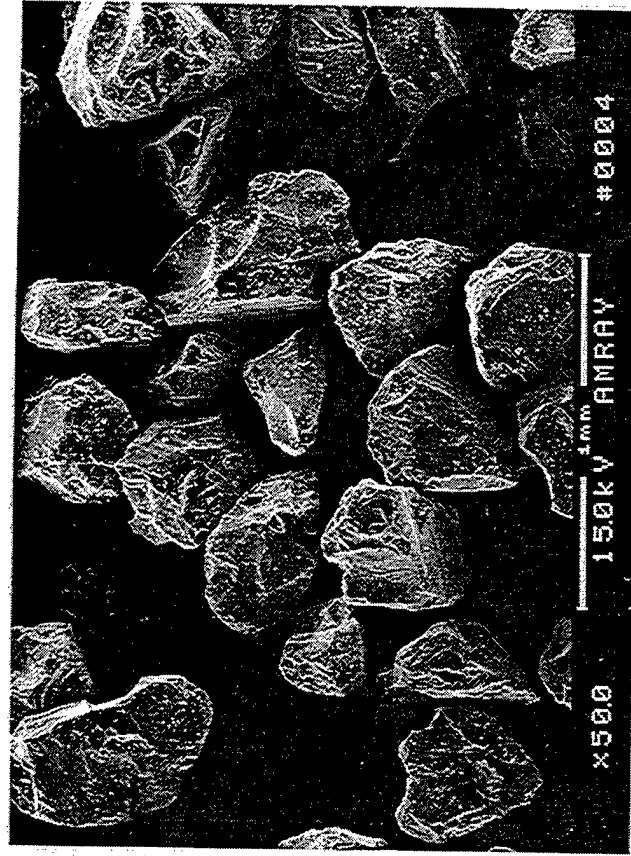
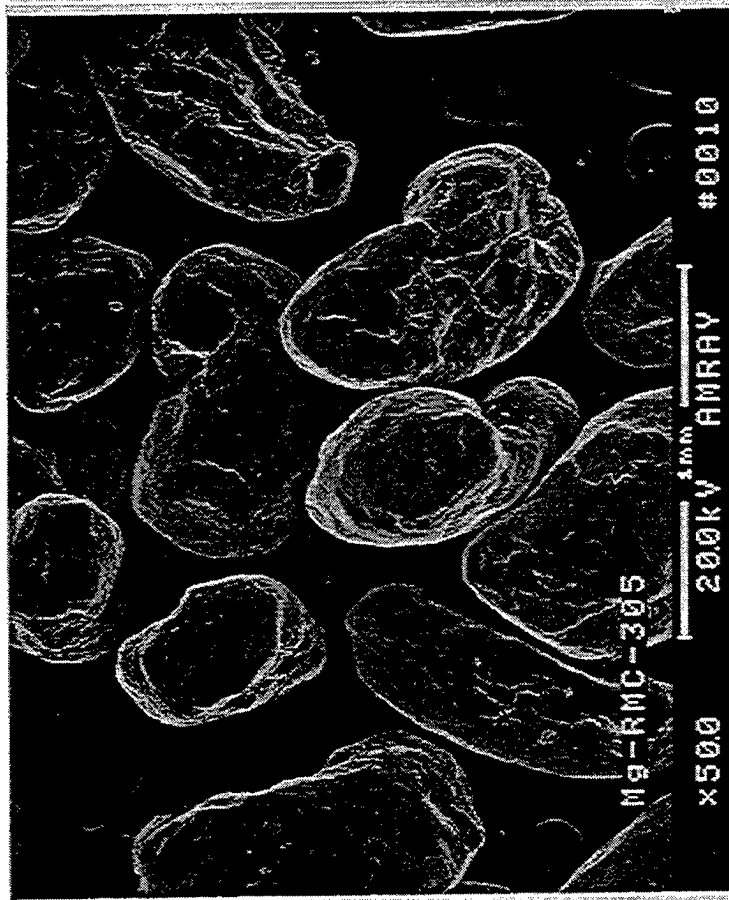
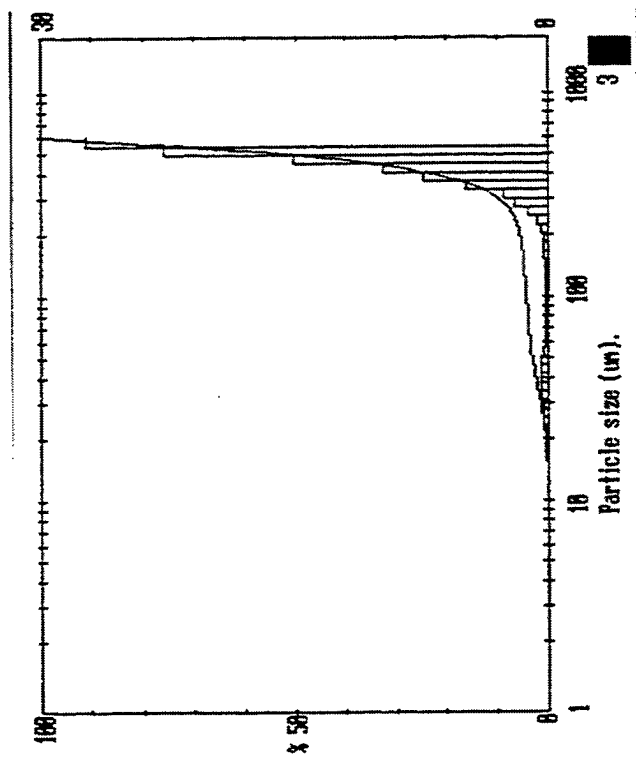


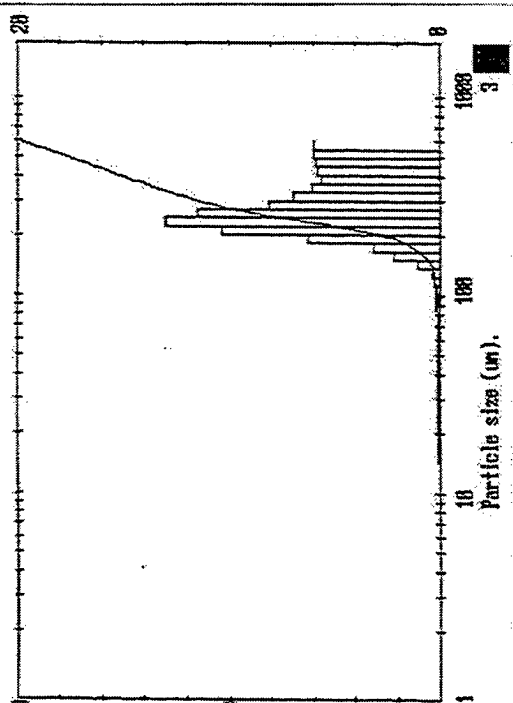
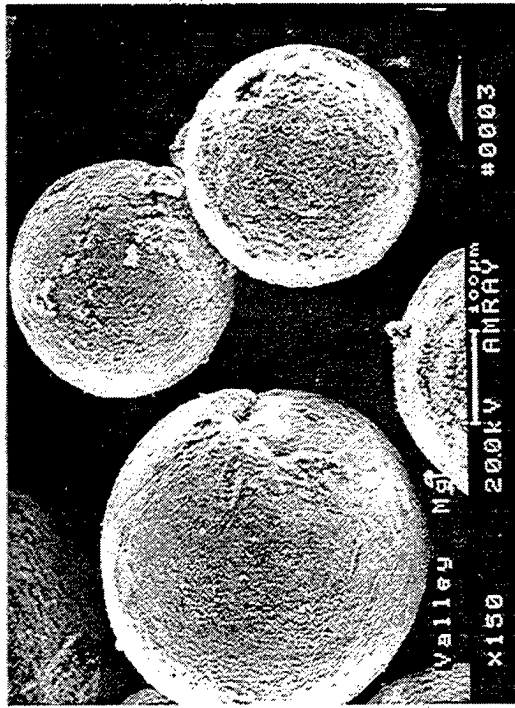
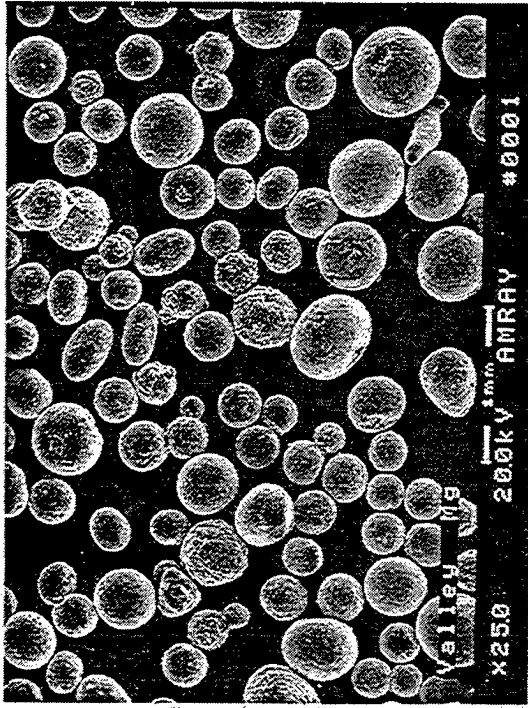
Figure 5b
Mg-AL alloy from Skylighter – SEM microphotograph (particle size, 30-60 mesh or 600 – 250 micron size)



High Under Size	High Under Size	High Under Size	High Under Size	High Under Size	High Under Size	High Under Size	High Under Size	High Under Size	High Under Size	Span	
600	100	184	203	5.6	18.5	23.1	23.1	0.6	7.82	0.0	
544	72.9	166	184	5.3	16.2	21.0	21.0	0.6	7.08	0.0	
493	49.9	151	166	5.1	15.0	19.8	19.8	0.6	6.42	0.0	
446	31.9	137	151	4.9	13.5	17.2	17.2	0.6	5.82	0.0	
404	21.7	124	137	4.6	12.0	15.6	15.6	0.6	5.27	0.0	
366	14.7	112	124	4.4	10.9	14.6	14.6	0.6	4.75	0.0	
332	10.0	102	112	4.2	9.3	13.5	13.5	0.6	4.25	0.0	
301	8.0	92.1	102	4.2	8.2	12.5	12.5	0.6	3.85	0.0	
273	6.8	83.4	92.1	4.2	7.2	11.5	11.5	0.6	3.52	0.0	
247	6.1	75.6	83.4	4.1	6.5	10.5	10.5	0.6	3.22	0.0	
224	6.1	68.6	75.6	4.0	5.5	9.5	9.5	0.6	2.92	0.0	
Source =		Sample		Beam length =		2.4 mm		Model indp		D.V. (0.5)	
Focal length =		300 mm		Residual =		3.100 X		Volume Conc. =		0.49524	
Presentation =		sind		Occupation =		0.1196		Sp.S.H		0.0212 #/cc.	
				Volume distribution				Shape		DFF	

Instruments

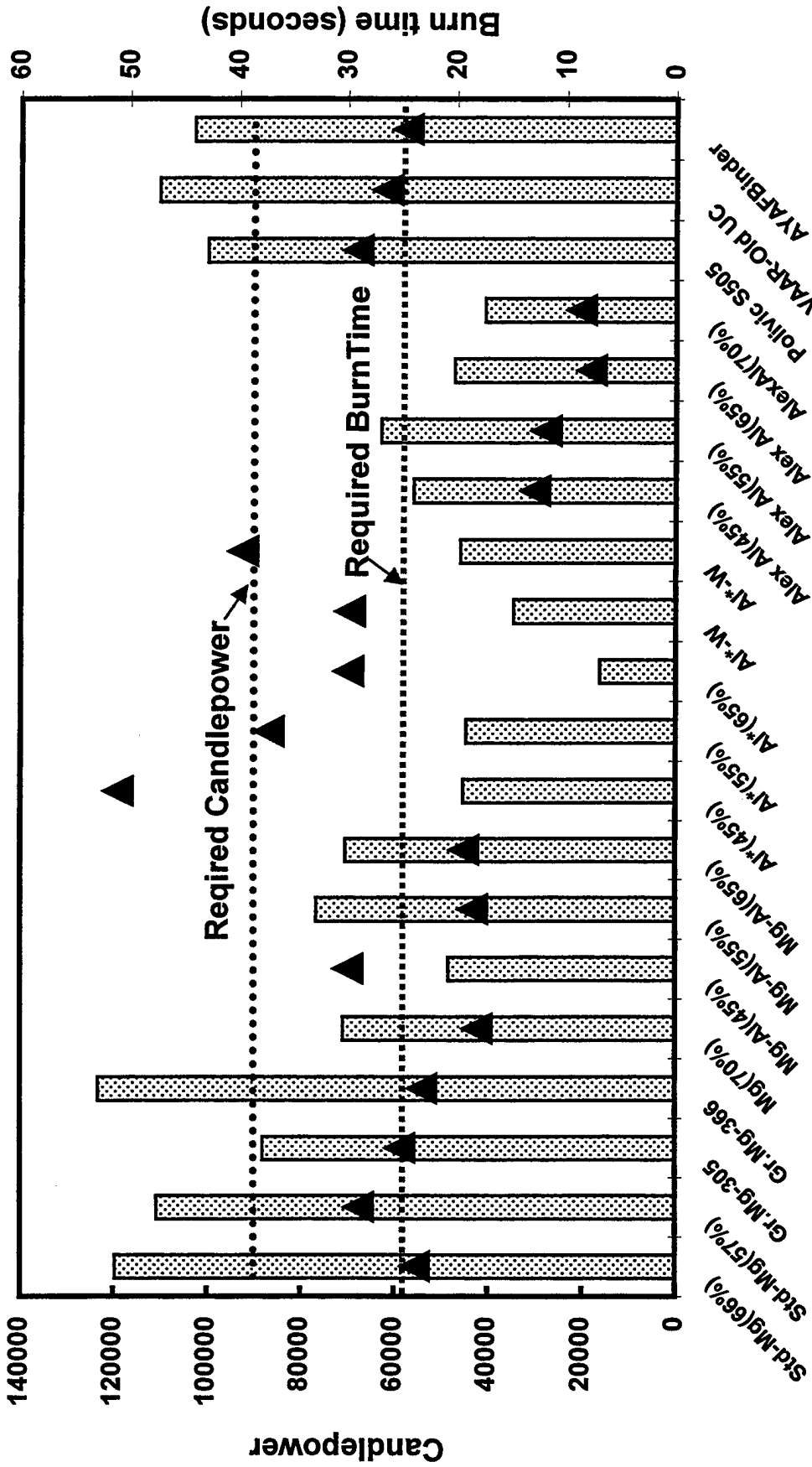
Figure 6
Ground magnesium, ellipsoidal (Reade RMC 305) – particle analysis and SEM microphotograph



High Size	High Under Size	High Under %	High Size	High Under %	High Under %	High Under %	Span: 1.16
500	100	0.0	100	0.0	0.0	0.0	D1: 0.31
250	100	0.0	100	0.0	0.0	0.0	D2: 0.16
100	100	0.0	100	0.0	0.0	0.0	D3: 0.1
50	100	0.0	100	0.0	0.0	0.0	D4: 0.07
25	100	0.0	100	0.0	0.0	0.0	D5: 0.05
10	100	0.0	100	0.0	0.0	0.0	D6: 0.03
5	100	0.0	100	0.0	0.0	0.0	D7: 0.02
2.5	100	0.0	100	0.0	0.0	0.0	D8: 0.01
1.25	100	0.0	100	0.0	0.0	0.0	D9: 0.01
0.625	100	0.0	100	0.0	0.0	0.0	D10: 0.01
0.3125	100	0.0	100	0.0	0.0	0.0	D11: 0.01
0.15625	100	0.0	100	0.0	0.0	0.0	D12: 0.01
0.078125	100	0.0	100	0.0	0.0	0.0	D13: 0.01
0.0390625	100	0.0	100	0.0	0.0	0.0	D14: 0.01
0.01953125	100	0.0	100	0.0	0.0	0.0	D15: 0.01
0.009765625	100	0.0	100	0.0	0.0	0.0	D16: 0.01
0.0048828125	100	0.0	100	0.0	0.0	0.0	D17: 0.01
0.00244140625	100	0.0	100	0.0	0.0	0.0	D18: 0.01
0.001220703125	100	0.0	100	0.0	0.0	0.0	D19: 0.01
0.0006103515625	100	0.0	100	0.0	0.0	0.0	D20: 0.01
0.00030517578125	100	0.0	100	0.0	0.0	0.0	D21: 0.01
0.000152587890625	100	0.0	100	0.0	0.0	0.0	D22: 0.01
0.0000762939453125	100	0.0	100	0.0	0.0	0.0	D23: 0.01
0.00003814697265625	100	0.0	100	0.0	0.0	0.0	D24: 0.01
0.000019073486328125	100	0.0	100	0.0	0.0	0.0	D25: 0.01
0.0000095367431640625	100	0.0	100	0.0	0.0	0.0	D26: 0.01
0.00000476837158203125	100	0.0	100	0.0	0.0	0.0	D27: 0.01
0.000002384185791015625	100	0.0	100	0.0	0.0	0.0	D28: 0.01
0.0000011920928955078125	100	0.0	100	0.0	0.0	0.0	D29: 0.01
0.00000059604644775390625	100	0.0	100	0.0	0.0	0.0	D30: 0.01
0.000000298023223876953125	100	0.0	100	0.0	0.0	0.0	D31: 0.01
0.0000001490116119384765625	100	0.0	100	0.0	0.0	0.0	D32: 0.01
0.00000007450580596923828125	100	0.0	100	0.0	0.0	0.0	D33: 0.01
0.000000037252902984619140625	100	0.0	100	0.0	0.0	0.0	D34: 0.01
0.0000000186264514923095703125	100	0.0	100	0.0	0.0	0.0	D35: 0.01
0.00000000931322574615478515625	100	0.0	100	0.0	0.0	0.0	D36: 0.01
0.000000004656612873077392578125	100	0.0	100	0.0	0.0	0.0	D37: 0.01
0.0000000023283064365386962890625	100	0.0	100	0.0	0.0	0.0	D38: 0.01
0.00000000116415321826934844453125	100	0.0	100	0.0	0.0	0.0	D39: 0.01
0.000000000582076609134672222265625	100	0.0	100	0.0	0.0	0.0	D40: 0.01
0.0000000002910383045673361111328125	100	0.0	100	0.0	0.0	0.0	D41: 0.01
0.00000000014551915228366805556640625	100	0.0	100	0.0	0.0	0.0	D42: 0.01
0.0000000000727595761418340402778125	100	0.0	100	0.0	0.0	0.0	D43: 0.01
0.00000000003637978807091702013890625	100	0.0	100	0.0	0.0	0.0	D44: 0.01
0.000000000018189894035458510069453125	100	0.0	100	0.0	0.0	0.0	D45: 0.01
0.0000000000090949470177292550347265625	100	0.0	100	0.0	0.0	0.0	D46: 0.01
0.00000000000454747350886462751736328125	100	0.0	100	0.0	0.0	0.0	D47: 0.01
0.0000000000022737367544323137586640625	100	0.0	100	0.0	0.0	0.0	D48: 0.01
0.00000000000113686837721615667827303125	100	0.0	100	0.0	0.0	0.0	D49: 0.01
0.000000000000568434188608078339136515625	100	0.0	100	0.0	0.0	0.0	D50: 0.01
0.0000000000002842170943040391695682578125	100	0.0	100	0.0	0.0	0.0	D51: 0.01
0.00000000000014210854715201957978412890625	100	0.0	100	0.0	0.0	0.0	D52: 0.01
0.000000000000071054273576009789892064453125	100	0.0	100	0.0	0.0	0.0	D53: 0.01
0.0000000000000355271367880048949460322265625	100	0.0	100	0.0	0.0	0.0	D54: 0.01
0.00000000000001776356839400244747451611328125	100	0.0	100	0.0	0.0	0.0	D55: 0.01
0.000000000000008881784197001223737275556640625	100	0.0	100	0.0	0.0	0.0	D56: 0.01
0.0000000000000044408920985006118686377778125	100	0.0	100	0.0	0.0	0.0	D57: 0.01
0.0000000000000022204460492500305843188890625	100	0.0	100	0.0	0.0	0.0	D58: 0.01
0.00000000000000111022302462501529215944453125	100	0.0	100	0.0	0.0	0.0	D59: 0.01
0.000000000000000555111512312507646079722265625	100	0.0	100	0.0	0.0	0.0	D60: 0.01
0.0000000000000002775557561562537230398611328125	100	0.0	100	0.0	0.0	0.0	D61: 0.01
0.0000000000000001387778780781268619930556640625	100	0.0	100	0.0	0.0	0.0	D62: 0.01
0.0000000000000000693889390390634399677778125	100	0.0	100	0.0	0.0	0.0	D63: 0.01
0.0000000000000000346944695195317199838890625	100	0.0	100	0.0	0.0	0.0	D64: 0.01
0.00000000000000001734723475976589994194453125	100	0.0	100	0.0	0.0	0.0	D65: 0.01
0.000000000000000008673617379882949970972265625	100	0.0	100	0.0	0.0	0.0	D66: 0.01
0.0000000000000000043368086899414995488890625	100	0.0	100	0.0	0.0	0.0	D67: 0.01
0.00000000000000000216840434497074997744453125	100	0.0	100	0.0	0.0	0.0	D68: 0.01
0.000000000000000001084202172485374998722265625	100	0.0	100	0.0	0.0	0.0	D69: 0.01
0.00000000000000000054210108624268749988611328125	100	0.0	100	0.0	0.0	0.0	D70: 0.01
0.0000000000000000002710505431213437499930556640625	100	0.0	100	0.0	0.0	0.0	D71: 0.01
0.00000000000000000013552527156067187499967778125	100	0.0	100	0.0	0.0	0.0	D72: 0.01
0.0000000000000000000677626357803389374999838890625	100	0.0	100	0.0	0.0	0.0	D73: 0.01
0.00000000000000000003388131789016946874999930556640625	100	0.0	100	0.0	0.0	0.0	D74: 0.01
0.0000000000000000000169406589450847343999967778125	100	0.0	100	0.0	0.0	0.0	D75: 0.01
0.00000000000000000000847032947254236719999838890625	100	0.0	100	0.0	0.0	0.0	D76: 0.01
0.0000000000000000000042351647362711835999967778125	100	0.0	100	0.0	0.0	0.0	D77: 0.01
0.0000000000000000000021175823681355917179999838890625	100	0.0	100	0.0	0.0	0.0	D78: 0.01
0.00000000000000000000105879118406778888999967778125	100	0.0	100	0.0	0.0	0.0	D79: 0.01
0.0000000000000000000005293955920338944449999838890625	100	0.0	100	0.0	0.0	0.0	D80: 0.01
0.0000000000000000000002646977960169472224999967778125	100	0.0	100	0.0	0.0	0.0	D81: 0.01
0.0000000000000000000001323488980084736119999838890625	100	0.0	100	0.0	0.0	0.0	D82: 0.01
0.00000000000000000000006617444900423680999967778125	100	0.0	100	0.0	0.0	0.0	D83: 0.01
0.0000000000000000000000330872245021184049999838890625	100	0.0	100	0.0	0.0	0.0	D84: 0.01
0.000000000000000000000016543612251072024999967778125	100	0.0	100	0.0	0.0	0.0	D85: 0.01
0.00000000000000000000000827180612553611249999838890625	100	0.0	100	0.0	0.0	0.0	D86: 0.01
0.0000000000000000000000041359030627680624999967778125	100	0.0	100	0.0	0.0	0.0	D87: 0.01
0.000000000000000000000002067951531384031249999838890625	100	0.0	100	0.0	0.0	0.0	D88: 0.01
0.00000000000000000000000103397576569201624999967778125	100	0.0	100	0.0	0.0	0.0	D89: 0.01
0.0000000000000000000000005169878828460081249999838890625	100	0.0	100	0.0	0.0	0.0	D90: 0.01
0.0000000000000000000000002584939414230040624999967778125	100	0.0	100	0.0	0.0	0.0	D91: 0.01
0.0000000000000000000000001292469707111500206249999838890625	100	0.0	100	0.0	0.0	0.0	D92: 0.01
0.00000000000000000000000006462348535557500103124999967778125	100	0.0	100	0.0	0.0	0.0	D93: 0.01
0.00000000000000000000000003231174267777750005156249999838890625	100	0.0	100	0.0	0.0	0.0	D94: 0.01
0.00000000000000000000000001615587133888750002578124999967778125	100	0.0	100	0.0	0.0	0.0	D95: 0.01
0.00000000000000000000000000807793566944375000128906249999838890625	100	0.0	100	0.0	0.0	0.0	D96: 0.01
0.000000000000000000000000004038967834721875000064453124999967778125	100	0.0	100	0.0	0.0	0.0	D97: 0.01
0.000000000000000000000000002019483917360937500003222656249999838890625	100	0.0	100	0.0	0.0	0.0	D98: 0.01
0.0000000000000000000000000010097419586804687500001611328124999967778125	100	0.0	100	0.0	0.0	0.0	D99: 0.01
0.0000000000000000000000000005048709793402343750000080566406249999838890625	100	0.0	100	0.0	0.0	0.0	D100: 0.01

Figure 9
Atomized magnesium (Valley Met Inc.) – particle analysis and SEM microphotograph

M127 White Star Signal



Composition-Fuel & Binder Materials

* Al from AEE

Figure 10
Effect of fuel material or binder material on performance – candlepower and burn time

M126 Red Star Signal

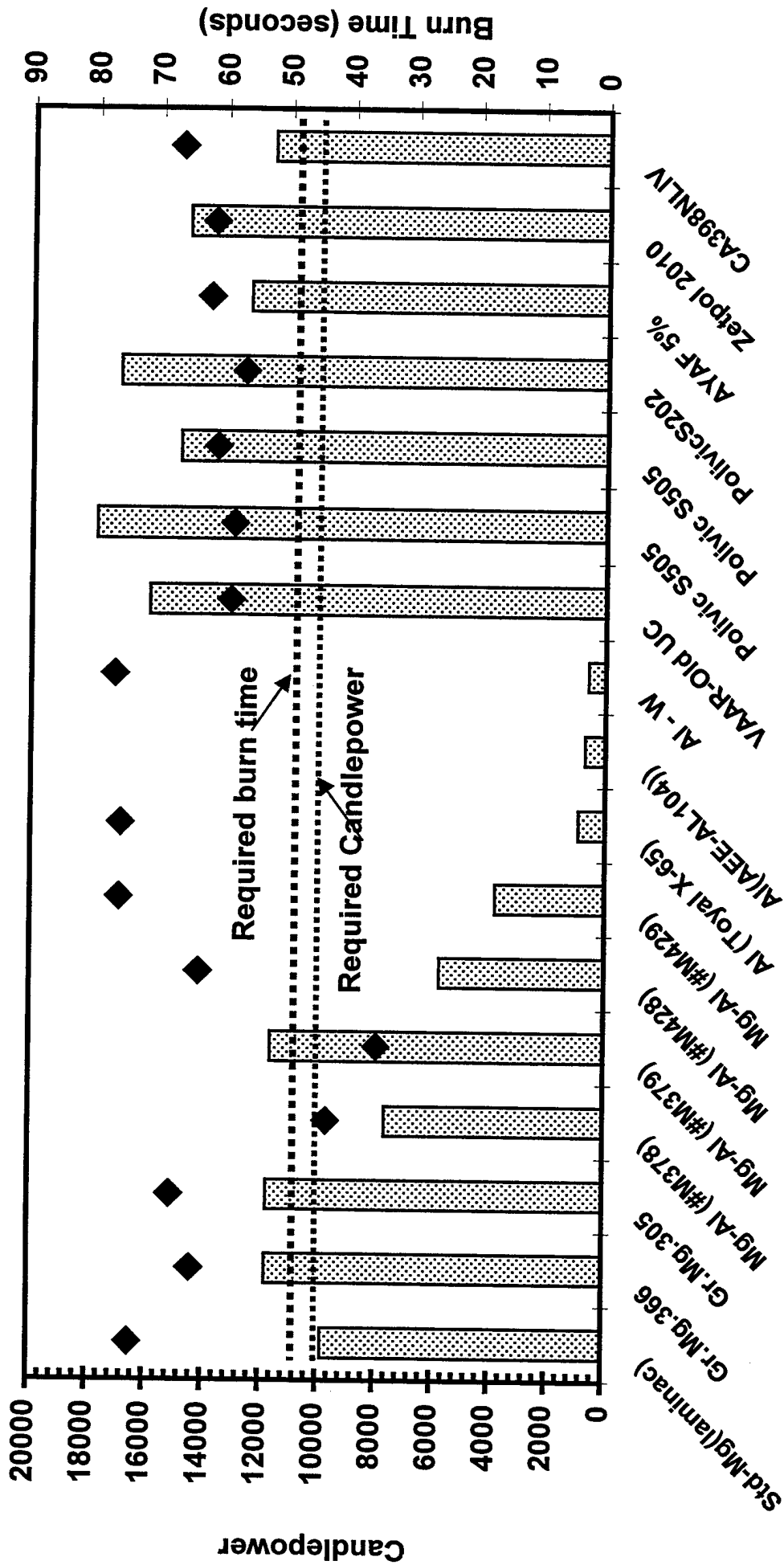


Figure 11
Effect of fuel material or binder material on performance – candlepower and burn time

Table 1
Performance requirements and compositions for Hand Held Signals

<p>M126A1 RED STAR (Illumination, Ground, Parachutes) (PN: 8797971)</p>	<p>M127 WHITE STAR (Illumination, Ground, Parachutes) (PN: 9295010)</p>
<p>Use: Signaling (day/night) Performance: Delay: 5 sec. Candlepower - 10000 MIN Burn Time - 50 seconds MIN RED color value .54 MIN</p> <p>Materials: Atomized Mg (Type I, 30/50) * 14.7% Mg (Type I 50/100) # 14.7% Strontium Nitrate, (size 50 +/-20u, MIL-S-20322) 38.3% Potassium Perchlorate (size 20 +/-5 u, SPEC PA-PD-254) 9.9% Polyvinyl chloride (Mil-P-20307) 14.7% Binder- Laminac 4116, 6.6 % Alternate:* Mg Powder, Type III, Granulation 17-D (SPEC- M-382) or Mg Powder, Ellipsoidal type 30/50 (SPEC Mil-14067)</p>	<p>Use: Signaling (day/night); night time illumination Performance: Delay: 5 sec. Candlepower - 90,000 MIN Burn Time- 25 Seconds MIN</p> <p>Materials: Atomized Mg (Type I, 30/50) 66% Sodium Nitrate, (size 30u) 29% Binder- Laminac 4116, 5 % Alternate: Mg Powder, Type III, Granulation 17-D (SPEC- M-382) or Mg Powder, Ellipsoidal type 30/50, (SPEC Mil-14067)</p>
<p>Illuminant charge 85 grams, press in a minimum of two equal increments at 6000 lbs/sq inch</p>	<p>Illuminant charge 87 grams, press in a minimum of two equal increments at 4000 lbs/sq inch</p>

Table 2
Compression strength data for pellets made with different binders in compositions (Hand Held Signals)

Sample #	Signal Type	Composition	Load-Ibs#	Remarks
M422	White Star M127A1	Atomized Mg, 67% + Sodium Nitrate, 30% Binder, new VAAR (POLIVIC, S505) 3%	53.38*	Pellet (3/8in. by 3/8in.) pressed at 9000 psi
M423	White Star M127A1	Atomized Mg, 67% + Sodium Nitrate, 30% Binder (old VAAR, Union Carbide) 3%	37.77*	Pellet (3/8in. by 3/8in.) pressed at 9000 psi
M430	Red Star M126A1	Atomized Mg (Type 1, 30/50) 15.5% + Atomized Mg (Type 1, 50/100) 15.5% + Strontium Nitrate, 41.0%+ Potassium Perchlorate, 10.0% Polyvinyl chloride, 15.0%+ Binder, new VAAR (POLIVIC, S505) 3%	62.02*	Pellet (3/8in. by 3/8in.) pressed at 9000 psi
M431	Red Star M126A1	Atomized Mg (Type 1, 30/50) 15.5%+ Atomized Mg (Type 1, 50/100) 15.5% Strontium Nitrate, 41.0%+ Potassium Perchlorate, 10.0% Polyvinyl chloride, 15.0% + Binder (old VAAR, Union Carbide) 3%	73.93*	Pellet (3/8in. by 3/8in.) pressed at 9000 psi
M384	Red Star M126A1	Atomized Mg (Type 1, 30/50) 15.5%+ Atomized Mg (Type 1, 50/100) 15.5% Strontium Nitrate, 41.0%+ Potassium Perchlorate, 10.0% Polyvinyl chloride, 15.0% + Binder, AYAF 5%	68.35**	Pellet (3/8in. by 3/8in.) pressed at 6000 psi
M385	Red Star M126A1	Atomized Mg (Type 1, 30/50) 15.5%+ Atomized Mg (Type 1, 50/100) 15.5% Strontium Nitrate, 41.0%+ Potassium Perchlorate, 10.0% Polyvinyl chloride, 15.0%+ Binder, CA-398NLY 3%	34.59**	Pellet (3/8in. by 3/8in.) pressed at 6000 psi
M383	Red Star M126A1	Atomized Mg (Type 1, 30/50) 15.5%+ Atomized Mg (Type 1, 50/100) 15.5% Strontium Nitrate, 41.0%+ Potassium Perchlorate, 10.0% Polyvinyl chloride, 15.0%+ Binder, LAMINAC 6.6%	94.63**	Pellet (3/8in. by 3/8in.) pressed at 6000 psi

* pellets are aged for about 72 hours Values are the average for five samples
 ** pellets are aged for about 24 hours Values are the average for five samples
 # load-lb values are recorded when pellets are deformed or crushed by load cell.

Table 3
M127A1 White Star - Luminous Output, burn time and efficiency

Sample No	Fuel Material	Composition	*Luminous Output (candles)	Burn Time (seconds)	Efficiency (Kcandle. X. sec/gram)
M 413	Hart Metal atomized Mg	Atomized Mg (Type I, 30/50) 66% Sodium Nitrate (USP Double Refined, size 30 micron) 29% Binder Laminac 4116 5%	119642 (133%)	23.78	31.6
M 397	Hart Metal atomized Mg	Atomized Mg (Type I, 30/50) 57% Sodium Nitrate (USP Double Refined, size 30 micron) 38% Binder Laminac 4116 5%	110838 (123%)	28.88	35.6
M 424	Ground Mg, Read RMC 305	Ground Mg 66% Sodium Nitrate (USP Double Refined, size 30 micron) 29% Binder Laminac 4116 5%	88129 (98%)	25.13	24.6
M 425	Ground Mg Read RMC-366	Ground Mg 66% Sodium Nitrate (USP Double Refined, size 30 micron) 29% Binder Laminac 4116 5%	123299 (137%)	23.11	31.7
M 422	Hart Metal atomized Mg	Atomized Mg (Type I, 30/50) 67% Sodium Nitrate (USP Double Refined, size 30 micron) 30% Binder VAAR, Polivic-S505, 3%	99950 (111%)	29.10	32.3
M 423	Hart Metal atomized Mg	Atomized Mg (Type I, 30/50) 67% Sodium Nitrate (USP Double Refined, size 30 micron) 30% Binder VAAR (Union Carbide, old VAAR) 3%	110412 (123%)	26.41	32.4
M 408	Hart Metal atomized Mg	Atomized Mg (Type I, 30/50) 66% Sodium Nitrate (USP Double Refined, size 30 micron) 31% Binder AYAF 3%	102851 (114%)	24.59	28.1
M 398	Aluminum- (AEE- Al 104)	Atomized Aluminum 45% Sodium Nitrate (USP Double Refined, size 30 micron) 50% Binder Laminac 4116 5%	45255 (50%)	50.98	
M 399	Aluminum- (AEE - Al 104)	Atomized Aluminum 55% Sodium Nitrate (USP Double Refined, size 30 micron) 40% Binder Lamina 4116 5%	44621 (50%)	37.19	
M 400	Aluminum- (AEE - Al 104)	Atomized Aluminum 65% Sodium Nitrate (USP Double Refined, size 30 micron) 30% Binder Lamina 4116 5%	16255 (18%)	29.87	
M 410	Aluminum- (AEE - Al 104) + Tungsten	Atomized Aluminum 55% Tungsten 7% Sodium Nitrate (USP Double Refined, size 30 micron) 33% Binder Lamina 4116 5%	34545 (38%)	29.74	

Table 3
(cont'd)

M 401	Aluminum- (AEE - Al 104) + Tungsten	Atomized Aluminum 45%, Tungsten 7% Sodium Nitrate (USP Double Refined, size 30 micron) 43% Binder Lamina 4116 5 %	45854 (51%)	39.60	
M 402	Alex - Aluminum	Atomized Aluminum 45% Sodium Nitrate (USP Double Refined, size 30 micron) 50% Binder Lamina 4116 5 %	55994 (62%)	12.89	
M 403	Alex - Aluminum	Atomized Aluminum 55% Sodium Nitrate (USP Double Refined, size 30 micron) 40% Binder Lamina 4116 5 %	62819 (70%)	11.88	
M 404	Alex - Aluminum	Atomized Aluminum 65% Sodium Nitrate (USP Double Refined, size 30 micron) 30% Binder Lamina 4116 5 %	47145 (52%)	7.76	
M 412	Alex - Aluminum	Atomized Aluminum 70% Sodium Nitrate (USP Double Refined, size 30 micron) 25% Binder Lamina 4116 5 %	40694 (45%)	8.69	
M 405	Mg/Al Alloy (50/50) -AEE (16-72 micron)	Mg/Al alloy, 45% Sodium Nitrate (USP Double Refined, size 30 micron) 50% Binder Lamina 4116 5 %	48372 (54%)	29.88	16.1
M 406	Mg/Al Alloy (50/50) -AEE (16-72 micron)	Mg/Al alloy, 55% Sodium Nitrate (USP Double Refined, size 30 micron) 40% Binder Lamina 4116 5 %	76618 (85%)	18.49	15.7
M 407	Mg/Al Alloy (50/50) -AEE (16-72 micron)	Mg/Al alloy, 65% Sodium Nitrate (USP Double Refined, size 30 micron) 30% Binder Lamina 4116 5 %	70316 (78%)	19.28	15.1
M 411	Mg/Al Alloy (50/50) -AEE (16-72 micron)	Mg/Al alloy, 70% Sodium Nitrate (USP Double Refined, size 30 micron) 25% Binder Lamina 4116 5 %	70825 (79%)	18.06	14.2

PERFORMANCE : Candlepower - 90000 MIN, Burn time 25 seconds MIN; * Percentage Luminous output in parenthesis () is based on minimum valued required
Illuminant Charge, used in test samples 90 grams, press in a minimum of two increments at 4000 PSI
Initiating Charge, Black powder 0.725 gram

Table 4
M126A1 Red Star – Luminous output, burn time, efficiency and color characteristics

Sample No	Fuel Material	COMPOSITION	Luminous Output (candles)	Burn Time (seconds)	Efficiency (k candles X sec/gram)	Color Characteristics
M 383	atomized Mg	Atomized Mg (Type I, 30/50) * 14.7% Mg (Type I 50/100) # 14.7% Strontium Nitrate, 38.3% Potassium Perchlorate 9.9% Polyvinyl chloride 14.7% Binder Laminac 6.6 %	9834 (98%)	74.34	8.1	DWL (nm): 614 Saturation(%): 91 X: 6438 Y: .3228
M 426	Ground Mg Reade RMC-366	Ground Mg 29.5% Strontium Nitrate, 39.3% Potassium Perchlorate 9.8% Polyvinyl chloride 14.7% Binder Laminac 6.7 %	11802 (118%)	64.82	8.5	
M 427	Ground Mg Reade RMC-305	Ground Mg 29.5% Strontium Nitrate, 39.3% Potassium Perchlorate 9.8% Polyvinyl chloride 14.7% Binder Laminac 6.7 %	11775 (118%)	68.02	8.9	
M 378	Mg/Al Alloy (50/50); (from AEE); (16-72 micron size)	Mg/Al alloy, 30% Strontium Nitrate, 40% Potassium Perchlorate, 10% Polyvinyl chloride, 15% Binder Lamina 5%	7650 (77%)	43.66	3.7	
M 379	Mg/Al Alloy (50/50)); (from AEE); (16-72 micron size)	Mg/Al alloy, 32% Strontium Nitrate, 48% Potassium Perchlorate 0% Polyvinyl chloride 15% Binder Lamina 5 %	11656 (117%)	35.80	4.6	
M 428	Mg/Al Alloy (50/50) Skylighter Inc; (30-60 mesh or 600-250 micron	Mg/Al alloy, 32% Strontium Nitrate, 48% Potassium Perchlorate, 0% Polyvinyl chloride, 15% Binder Lamina 5%	5763 (58%)	63.80	4.1	

Table 4
(cont'd)

M 429	Mg/Al Alloy (50/50); Skylighter Inc; (30-60 mesh or 600-250 micron)	Mg/Al alloy, 29% Strontium Nitrate, 48% Potassium Perchlorate, 0% Polyvinyl chloride, 18% Binder Lamina 5%	3830 (38%)	76.22	3.2	
M 382	Aluminum-(AEE- Al 104)	Aluminum, 30% Strontium Nitrate, 40% Potassium Perchlorate 10% Polyvinyl chloride 15% Binder Laminac 4116 5 %	708 (7%)	91.07		
M 381	Aluminum-(AEE- Al 104)	Aluminum, 29%+ Tungsten, 7% + Strontium Nitrate, 36% Potassium Perchlorate 9% Polyvinyl chloride 14% Binder Laminac 4116 5 %	608 (6%)	77.05		
M 380	ToyAl Al (X-65) 6-8 micron size	Aluminum, 30% Strontium Nitrate, 40% Potassium Perchlorate 10% Polyvinyl chloride 15% Binder Laminac 5 %	936 (9%)	76.02		
M 421	atomized Mg	Atomized Mg (Type I, 30/50) * 15.0% Mg (Type I 50/100) # 15.0% Strontium Nitrate, 42.0% Potassium Perchlorate 10.0% Polyvinyl chloride 15.0% Binder VAAR, Polivic-S505, 3.0%	17775 (178%)	58.62	11.6	
M 430	atomized Mg	Atomized Mg (Type I, 30/50) * 15.5% Mg (Type I 50/100) # 15.5% Strontium Nitrate, 41.0% Potassium Perchlorate 10.0% Polyvinyl chloride 15.0% Binder VAAR Polivic-S505, 3.0%	14894 (149%)	61.36	10.2	
M 431	atomized Mg	Atomized Mg (Type I, 30/50) * 15.5% Mg (Type I 50/100) # 15.5% Strontium Nitrate, 41.0% Potassium Perchlorate 10.0%	15912 (159%)	59.13	10.5	

Table 4
(cont'd)

M 384	atomized Mg	Polyvinyl chloride 15.0% Binder VAAR,(Union Carbide) 3.0% Atomized Mg (Type I, 30/50) * 14.7% Mg (Type I 50/100) # 14.7% Strontium Nitrate, 36% Potassium Perchlorate 9% Polyvinyl chloride 14% Binder AYAF 5%	12503 (125%)	62.53	8.7	DWL (nm): 613 Saturation(%): 89 X: .6328 Y: .3280
M 414	atomized Mg	Atomized Mg (Type I, 30/50) * 15% Mg (Type I 50/100) # 15% Strontium Nitrate, 42% Potassium Perchlorate 10% Polyvinyl chloride 15% Binder, Polivic S202 35% - 3 %	16983 (170%)	57.03	10.8	DWL (nm): 610 Saturation(%): 85 X: .6115 Y: .3341
M 415	atomized Mg	Atomized Mg (Type I, 30/50) * 15% Mg (Type I 50/100) # 15% Strontium Nitrate, 42% Potassium Perchlorate 10% Polyvinyl chloride 15% Binder Zetpol 2010 - 3 %	14628 (146%)	61.90	10.1	DWL (nm):612 Saturation(%): 87 X: .6225 Y: .3302
M 385	atomized Mg	Atomized Mg (Type I, 30/50) * 15% Mg (Type I 50/100) # 15% Strontium Nitrate, 42% Potassium Perchlorate 10% Polyvinyl chloride 15% Binder CA-398NLV 3 %	11709 (117%)	66.93	8.7	DWL (nm): 614 Saturation(%): 91 X: .6420 Y: .3239

PERFORMANCE : Candlepower – 10000 MIN, Burn time 50 seconds MIN; Percentage luminous output in parenthesis () is based on minimum value required
Illuminant Charge used in test samples 90 grams, press in a minimum of two equal increments at 6000 PSI; use of surface activeagent such as Fluoronic F-68 is
 authorized to a maximum of 0.5% to improve mixing and blending of illuminant and priming composition
Initiating Charge, Black powder 0.725 gram
Color Characteristics: Dominant Wave Length (DWL): 620 nm +/- 20 nm; 75% min. purity

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3. Technical Information Bulletin, "Elex Energetic Metal Powders – A New Class of Materials," Argonide Corporation, Sanford, FL, 1997.
4. Ivanov, G. V. and Tepper, F., "Activated Aluminum as a Stored Energy Source for Propellants," 4th International Symposium of Special Topics in Chemical Propulsion, Stockholm, Sweden, May 27 – 31, 1996.
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6. Product Information, (SC1127), "Union Carbide Polyvinyl Acetate Resins for Coating and Adhesives," Union Carbide, Specialty Chemical Division, Danbury, CT.
7. Product Information – Technical Information Bulletin, "Polivic S202-35% and Polivic S505-35%," 3V Plastic Additives Division, Charlotte, NC, January 1999.
8. Product Information and Specification – "Zetpol 2010," Zeon Chemicals Inc., Louisville, KY, March 1998.

APPENDIX

PRODUCT/MANUFACTURER'S SPECIFICATIONS OF MATERIALS

Source for Materials and Product Information:

ALEX Aluminum powder: The Argonide Corporation, 240 Power Court, Suite #108, Sanford, FL, 32771-9530, Phone: 407-322-2500

Aluminum powder (AL-104): Atlantic Equipment Engineers- Division of Micron Metals, Inc. Phone: 800-486-2436 or 201-384-5606

Alcan X-65 Aluminum powder: Toyal America, Inc. (Alcan-Toyo America), 1717 North Naper Boulevard, Suite 201, Naperville, IL 60563. Phone: 708-505-2160

Magnesium-Aluminum alloy (50/50) powders: Atlantic Equipment Engineers- Division of Micron Metals, Inc. Phone: 800-486-2436 or 201-384-5606 and Reade Manufacturing Company, Division of Magnesium Elektron, Inc. 100 Ridgeway Boulevard, Lakehurst, NJ 08733, Phone: 732-657-6451; Skylighter, Inc. P.O.Box 480-W, Round Hill, VA 20142-0480, Phone: 540-554-4543

Ground magnesium powders: Reade Manufacturing Company, Division of Magnesium Elektron, Inc. 100 Ridgeway Boulevard, Lakehurst, NJ 08733, Phone: 732-657-6451

Atomized magnesium (30/50) Type 1 and (50/100) Type 1: Hummel Croton Inc., 10 Hamrich Road, South Plainsfield, NJ 07080-4899, Phone: 908-754-1800 or Hart Metals, Inc. P.O.Box 428, Route 209 North, Tamaqua, PA 18252-0128,

CA-398NLV: Morton International, Inc. 1275, Lake Avenue, Woodstock, IL 60098-7499, Phone: 815-338-1800

AYAF: Union Carbide Chemicals and Plastics Company Inc., Speciality Chemicals Division, 39 Old Ridgebury Road, Danbury, CT 06817-0001

POLIVIC S202-35% and POLIVIC S505-35%: 3V Plastic Additives Division, 9140 Arrowpoint Boulevard, Suite120, Charlotte, NC 28273, Phone: 704-522-1763

Zetpol 2010: Zeon Chemicals Inc. 411 Bells Lane, Louisville, KY 40211, Phone: 800-735-3388

Alcan X-65

Spherical Aluminum Powder

Alcan Spherical Aluminum Powders are produced by inert gas atomization. These products are designed for applications where purity, particle size uniformity and high packing density is required.

Spherical Aluminum Powders can be manufactured to comply with all aerospace, military or customer specifications.

Typical Properties

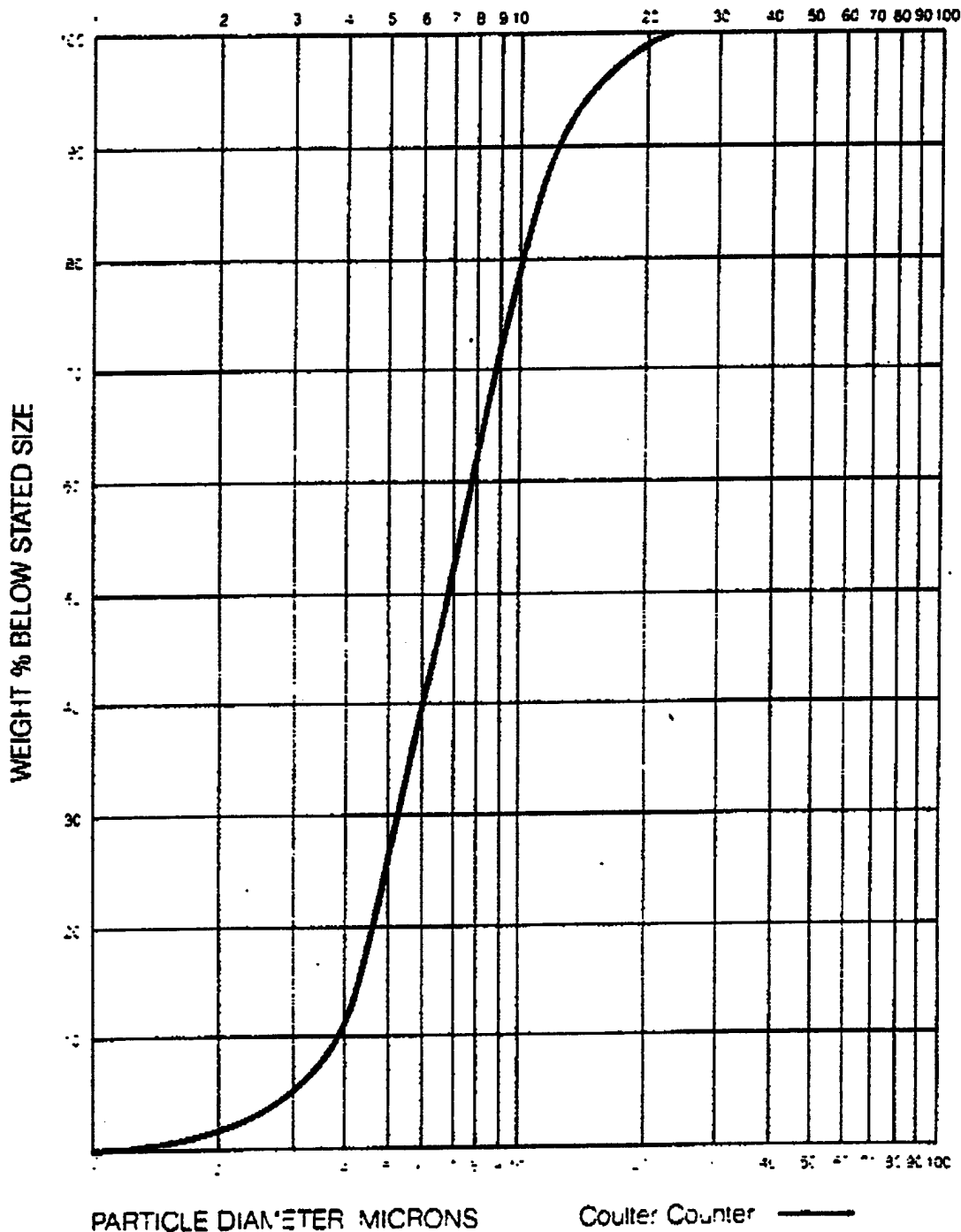
Apparent Density (g/cc)	0.75
Tap Density (g/cc)	1.50
Sieve Analysis % -325 mesh (Wet Test)	99.0% (min)
Average Particle Diameter (Fisher Sub-Sieve Sizer)	4.5 - 9.0 microns
Particle Size Distribution (Coulter)	
10%	3 - 5 microns
50% (Weight Mean Diameter)	5 - 9 microns
90%	10 - 15 microns
Oil & Grease %	.05% (max)
Volatile Matter @ 105°C, WT %	.10%
Surface Area (m ² /g)	0.5
Chemical Analysis %	
	Aluminum 99.00% (min)
	Iron 0.20% (max)
	Silicon 0.12% (max)
Typical Oxide Level (AL ₂ O ₃)	0.8%

ALCAN-TOYO AMERICA



Particle Size Distributions

Alcan X-65 Spherical Aluminum Powder



Morthane® Resins

Technical Information Adhesives and Specialty Polymers

Certificate of Analysis

Customer	U.S. Army Armament Research Dev. Eng.	Customer Order No.	Verbal
Date Shipped	October 8, 1996	Our Order No.	117357
Product	CA-398NLV	Product Code	8844
Run Number	96-9790	Lot(s)	-10

I hereby certify that the above material has the following analysis:

	Lot Number
	96-9790-10
Viscosity, 30%/MEK, cps	376
Mw	48554
Mn	21626
MWD	2.25
Acid Number, mg KOH/g	0.21 (Composite Sample)
Yield, psi	3988 (Composite Sample)
Modulus - 100%, psi	2718 (Composite Sample)
Tensile @ Break, psi	4976 (Composite Sample)
% Elongation	254 (Composite Sample)
Tg, °C	35.6 (Composite Sample)
Hardness, Shore D	80 (Composite Sample)
Density, g/cc	1.16 (Composite Sample)
Pounds Shipped	1



POLIVIC[®] S 202 - 35%

Suspending agent for PVC

(C₂H₅OH)X (C₂H₅OCOCH₃)Y
in methanol/methylacetate

Chemical and physical characteristics

Appearance	Brown yellow liquid
Density (g/cm ³)	Approx. 0.95
Boiling point (°C)	Approx. 60
Freezing point (°C)	Approx. -30
Solubility in water	Coagulates in water
Water content (% W/W)	35
Alkalinity (mg KOH/g)	450
Rate of Hydrolysis (mol %)	47
Dynamic viscosity at 20 °C (mPa.s)	150
	7

Properties

POLIVIC S 202 - 35% is a secondary suspending agent for the manufacture of suspension Polyvinylchloride. It is a polyvinylchloride partially hydrolysed in methanol with a random distribution of the hydroxy group along the macromolecule.

POLIVIC S 202 - 35% controls the process of agglomeration of primary polymer particles inside the VCM droplets: this results in a unique morphology with uniformly distributed pores in the PVC grain. The total volume of pores (porosity) depends on the concentration of POLIVIC S 202 - 35% used in the polymerization process.

Key applicative advantages are:

UNIFORM POROSITY DISTRIBUTION

PVC porosity obtained with POLIVIC S 202 - 35% is uniformly distributed over the entire particle size range.

The total volume of pores, measured by mercury-porosimeter, can be 0.43 cc/g with high molecular weight PVC (i.e. K=70).

IMPROVED PLASTICIZER ABSORPTION

The average pore diameter is larger than without POLIVIC S 202 - 35% which is of particular advantage for plasticizer absorption in various applications. PVC resins produced with POLIVIC S 202 - 35% have average pore diameter of 1 micron instead of 0.5 microns as commonly found without POLIVIC S 202 - 35%.

INCREASE IN VCM CONVERSION

The use of POLIVIC S 202 - 35% avoids the usual problem of porosity decrease as VCM conversion increases.

For K=70 PVC a porosity of 0.43 cc/g can be achieved with a VCM conversion of 91%.

Information contained in this data sheet is based on our present knowledge. However we do not assume any liability for the use of the product. Consequently the product must be tested by the user according to his needs and his production and application conditions. Neither do we assume any responsibility for infringement of third parties patent rights which may arise from the use of the product.

BETTER STRIPPABILITY

Residual VCM on PVC depends on the type and level of PVC porosity. POLIVIC S 202 - 35% allows compliance with the most stringent regulations by achieving low residual VCM.

EASIER PROCESSABILITY

PVC quality achieved by using POLIVIC S 202 - 35% offers the advantage of obtaining PVC with a narrow particle size distribution. The morphology of PVC particles obtained with POLIVIC S 202 - 35% makes the product easier to process and allows manufacture of items (rigid and flexible) with improved properties (i.e. more homogeneous gelation and lower level of fish eyes).

Applications

POLIVIC S 202 - 35% must be used in conjunction with primary suspending agents at concentrations of 0.02-0.10% (active) referred to VCM. POLIVIC S 202 - 35% is used without limitations of PVC suspensions technology (size of reactors, agitation or chemicals: type and nature of initiators or primary suspending agents).

Packaging

POLIVIC S 202 - 35% is available in three different forms:

- Metal drums of 190 kgs net
- Bulk containers (SBC) 1000 kgs
- Chemical tanks up to 23 ton/batch

Transport classification

UN No.	1992
ICAO/IATA	Class 3 (6.1)
IMO	Class 3.2
ADR/RID	Class 3, Item 20b

Toxicological information

The product contains approx. 45% of Methanol and 20% of Methyl acetate. Methanol is classified toxic by inhalation and ingestion. Both solvents are flammable.

Storage and handling

POLIVIC S 202 - 35% is a stable solution. No chemical degradation is expected if this product is stored at room temperature. The organic solvents present form explosive mixture with air, therefore compressed air must NEVER be used to empty or purge tanks of POLIVIC S 202 - 35%.

For further information please refer to safety data sheet.

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3V

Plastic Additives
Division

POLIVIC[®] S 505 - 35%

Suspending agent for PVC

Formula $(C_2H_5OH)_X(C_2H_5OCOCH_3)_Y$
in methanol/methylacetate

Chemical and physical characteristics

Appearance	Brown yellow liquid
Specific gravity (g/cm ³)	Approx. 0.95
Boiling point (°C)	Approx. 60
Freezing point (°C)	Approx. -30
Solubility in water	Coagulates in water
Active content (% W/W)	35
Saponification nr. (mg KOH/g)	535
Degree of Hydrolysis (mol %)	30
Brookfield viscosity at 20 °C (mPa.s)	100
pH	7

Properties

POLIVIC S 505 - 35% is a secondary suspending agent for the manufacture of suspension Polyvinylchloride. It is a polyvinyl acetate partially hydrolysed in methanol with a random distribution of the hydroxy group along the macromolecule. POLIVIC S 505 - 35% controls the process of agglomeration of the primary polymer particles inside the VCM droplets: this results in a unique morphology with uniformly distributed pores in the PVC grain. The total volume of pores (porosity) depends on the concentration of POLIVIC S 505 - 35% used in the polymerization process.

Main applicative advantages are:

UNIFORM POROSITY DISTRIBUTION

The PVC porosity obtained with POLIVIC S 505 - 35% is uniformly distributed over the entire particle size range.

The total volume of pores, measured by mercury-porosimeter, can be 0.43 cc/g with high molecular weight PVC (i.e. K=70).

IMPROVED PLASTICIZER ABSORPTION

The average pore diameter is larger than without POLIVIC S 505 - 35% which is of particular advantage for plasticizer absorption in flexible applications. PVC resins produced with POLIVIC S 505 - 35% have average pore diameter of 1 micron instead of 0.5 microns as commonly found without POLIVIC.

INCREASE IN VCM CONVERSION

The use of POLIVIC S 505 - 35% avoids the usual problem of porosity decrease as VCM conversion increases.

For K=70 PVC a porosity of 0.43 cc/g can be achieved with VCM conversion of 91%.

Information contained in this data sheet is based on our present knowledge. However we do not assume any liability for the use of the product. Consequently the product must be tested by the user according to his needs and his production and application conditions. Neither do we assume any responsibility for infringement of third parties patent rights which may arise from the use of the product.

BETTER STRIPPABILITY

Residual VCM on PVC depends on the type and level of PVC porosity. POLIVIC S 505 - 35% allows compliance with the most stringent regulations by achieving low residual VCM.

EASIER PROCESSABILITY

PVC quality achieved by using POLIVIC S 505 - 35% offers the advantage of obtaining PVC with a narrow particle size distribution. The morphology of PVC particles obtained with POLIVIC S 505 - 35% makes the product easier to process and allows manufacture of items (rigid and flexible) with improved properties (i.e. more homogeneous gelation and lower level of fish eyes.)

Applications

POLIVIC S 505 - 35% must be used in conjunction with primary suspending agents at concentrations of 0.02-0.10% (active) referred to VCM. POLIVIC S 505 - 35% is used without limitations of PVC suspensions technology (size of reactors, agitation or chemicals: type and nature of initiators or primary suspending agents).

Packaging

POLIVIC S 505 - 35% is available in three different forms:

- Metal drums of 190 kgs net
- Bulk containers (SBC) 1000 kgs
- Chemical tanks up to 23 ton/batch

Transport classification

UN No.	1992
ICAO/IATA	Class 3 (6.1)
IMO	Class 3.2
ADR/RID	Class 3, Item 20b

Toxicological information

The product contains approx. 55% of Methanol and 10% of Methyl acetate. Methanol is classified toxic by inhalation and ingestion. Both solvents are flammable.

Storage and handling

POLIVIC S 505 - 35% is a stable solution. No chemical degradation is expected if this product is stored at room temperature. The organic solvents present form explosive mixture with air, therefore compressed air must NEVER be used to empty or purge tanks of POLIVIC S 505 - 35%.

For further information please refer to safety data sheet.



9140 ARROWPOINT BOULEVARD CHARLOTTE, NC 28273
 TEL: 704-523-5252 FAX: 704-522-1763

PVC – Polymerization Additives

POLIVIC SUSPENDING AGENTS

<u>Polivic</u>	<u>Activity</u> (%)	<u>Sap No.</u> (mg KOH / g)	<u>Hydrolysis</u> (Mole %)	<u>Suspension</u>
S 202-35 %	35	445	47	Methanol
S 505-35 %	35	535	30	Methanol
S 404 W	39	395	56	Water
S 432 W	33	380	58	Water
SP-808	20	320	67	Water

ANTIFOULING AGENT

	<u>Activity</u> (%)	<u>Suspension</u>
Everclean 104NS	6	Water

January, 1999

Zetpol®

H N B R

Zetpol® 2010

Product Specification
Date Issued: 3/31/98
Supersedes: 11/01/94

Description: 2010 is a highly saturated copolymer of butadiene and acrylonitrile with high tensile strength, good heat resistance, good chemical resistance to aggressive fluids, and an excellent balance of properties over a wide variation of temperatures.

Packaging: 2010 shall be in the form of dark amber to black-brown colored 25 kg (55.1 lb) bales free from foreign material considered objectionable for normal applications.

Specification	Min.	Max.	Test Procedure No. ⁽¹⁾
<i>Polymer Properties</i>			
Bound Acrylonitrile (%)	34.9	37.5	ZCI-T-010
Ash (%)		0.5	ZCI-T-005
Heat Loss (%)		0.5	ZCI-T-002
Iodine Value (mg/100mg)	8.0	14.0	ZCI-T-004
Mooney Viscosity (ML 1+4 @ 100°C)	78.0	92.0	ZCI-T-003
<i>Test Recipe Properties</i> ⁽²⁾			
Tensile, psi (MPa)	3654 (25.2)	4524 (31.2)	ZCI-T-008
Elongation (%)	350	510	ZCI-T-008
Modulus @ 300% Elongation, psi (MPa)	2088 (14.4)	3248 (22.4)	ZCI-T-008
Hardness (Shore A)	66	74	ZCI-T-009

Special Notes: Refer to MSDS No. 40 for proper handling instructions.

(1) Zeon Test Procedures are available upon request

(2) Test Recipe:

Zetpol 2010	100
Sterling NS (SRF)	40
Zinc Oxide #1	5
Retilox F-40P	5

(3) Shelf Life - retest critical parameters 3 years after the date of manufacture

Reason for Issue: 1) Add MPa values 2) Change test recipe from Peroximon F-40 to Retilox F-40P 3) Add reason for issue section 4) General format updates

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Zeon Chemicals Incorporated, 4111 Bells Lane Louisville, KY 40211 Phone: 800/735-3388, Fax: 502/775-2055

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