TECHNICAL REPORT NO. 74-28

40MM FLOATING FLARE

by

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Munitions Branch

March 1974

Final Report

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U. S. ARMY LAND WARFARE LABORATORY
Aberdeen Proving Ground, Maryland 21005

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	40mm Marker		

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The 40mm Floating Flare Cartridge is a fixed round for the M79 and M203 grenade launchers for nighttime target or position marking in inundated areas, mud, or snow. These yellow, green, and red flares are identifiable for approximately 90 seconds from a range exceeding 3000 meters at an altitude of 1000 feet on a clear night. These cartridges were developed in response to a need expressed in Vietnam, which later was formalized by inclusion in a Materiel Need (QMR) for 40mm signals. Engineering design tests have been conducted and field evaluation is scheduled in Alaska.

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PREFACE

Troops in the field currently do not have a standoff capability for marking a target or position in inundated areas during the hours of darkness. This need was evident in Vietnam and was expressed in the MACV Significant Problem Areas Report (May 1972 and previous editions). It later was formalized by inclusion of 40mm Floating Flare Cartridges in the Materiel Need (Engineering Development) (QMR) for Signals, Ground, 40mm Weapon Launched.

This development was conducted under LWL Task No. 02-F-71, 40mm Floating Flare, Department of Army R & D Project No. 1P763701D718. Development contractors were Northrop Carolina, Inc., Asheville, NC and Chemtronics Division of Airtronics, Inc., Swannanoa, NC. Engineering Design Tests were conducted by AAI Corporation, Cockeysville, MD and test facilities of General Environments Corporation, Hartwood, VA and H. P. White Laboratory, Bel Air, MD were used.

The author acknowledges the aid received from numerous personnel of these companies . . . especially Mr. Lee A. Wieder of NCI, Mr. Peter D. Evanoff of NCI and Chemtronics, Mr. Donald W. Renfroe of Chemtronics, and Mr. Matthew G. Popik of AAI. The consultation and assistance received from various personnel of the Munitions Branch of LWL, especially Mr. Joseph N. Ruff, also is acknowledged.

TABLE OF CONTENTS

	Page
REPORT DOCUMENTATION PAGE (DD FORM 1473)	iii
PREFACE	iv
INTRODUCTION	3
DESCRIPTION	5
DEVELOPMENT HISTORY	12
Contract No. DAAD05-71-C-0191	12
Feasibility Tests	13
Contract No. DAAD05-72-C-0179	14
Engineering Design and Safety Evaluation Tests	15
Discussion	16
CONCLUSIONS	18
RECOMMENDATIONS	19
REFERENCES	20
APPENDICES:	
A. Military Characteristics	A-1
B. Feasibility Report (Excerpts)	B-1
C. Development Report (Excerpts)	C-1
D. Engineering Design Test Plan	D-1
E. Environmental and Physical Testing Report (Excerpts)	E-1
F. Flight Testing Report (Excerpts)	F-1
G. Recoil Measurements Report (Excerpts)	G-1
DISTRIBUTION LIST	21

INTRODUCTION

Troops in the field currently do not have a standoff capability for marking a target or position in inundated areas. This need was evident in Vietnam where forces operating in swampy, inundated terrain often were faced with the serious problem of marking the location of friendly and enemy position for aerial observers. The available marking devices, AN/M8 and M18 Smoke Grenades, submerged upon water impact, thus reducing or eliminating their marking capability. Also, the maximum standoff distance for standard grenades is 30 to 40 meters when hand thrown from an exposed standing position. A small floating marker was needed that could be launched from an existing weapon to a standoff range of 250 or 300 meters. The signal would have to be visible and identifiable from a range of at least one mile and would have to function long enough for the observer to pinpoint the position being marked. This need was expressed in the MACV Significant Problem Areas Report, May 1972 (page II-25) and several previous issues (Reference 1).

In response to the original expression of this need, a 40mm Floating Smoke Marker Cartridge was developed for daytime signalling under LWL Task No. 01-F-68, 40mm Target Marker (Floating), TMF-1. When the TMF-1 cartridge is fired from the M79 or M203 Grenade Launcher at an elevation of 32° to 35°, the marker has a range of approximately 300 meters. At 5-1/2 seconds after firing, a pyrotechnic delay element ignites the first-fire mix inside the marker. The combustion gases cause the marker assembly to separate from the projectile body and inflate the ballute (balloon-parachute). The ballute retards the flight of the marker assembly, causes it to impact in the desired orientation, and provides flotation on water or prevents burying in mud or snow. Smoke is emitted from the marker for 60 to 90 seconds and the red and yellow smoke signals are identifiable by an airborne observer from an aerial slant range of more than two miles on a clear day. After completion of Engineering Design Tests, 500 cartridges (yellow and red) were shipped to Vietnam for field evaluation by the RVN Combat Development and Test Center. The evaluation was favorable, "Very appropriate . . . for the Vietnam battlefield," with the only disadvantage being that "Smoke ejection time and smoke density are insufficient to provide easy observation in bad weather." For development and test details refer to the development reports (References 2 and 3).

In November 1969, the contractor suggested that a floating flare cartridge for a nighttime signaling marker might be feasible. A tentative list of military characteristics was formulated (Appendix A), a task was established in July 1970, and a feasibility development contract was signed in December 1970.

The need for floating 40mm markers was formalized in 1972 by inclusion of the following 40mm cartridges in the approved Department of Army Materiel Need (Engineering Development) (QMR) for Signals, Ground, 40mm Weapon Launched (Reference 4):

1. Light producing signals

    a. Red floating flare
    b. Yellow floating flare
    c. Green floating flare

2. Smoke producing signals

    a. Red floating target marker
    b. Yellow floating target marker
    c. Green floating target marker

DESCRIPTION

The 40mm Floating Flare Cartridge (Figures 1, 2 and 3) is a fixed round for the M79 and M203 grenade launchers for nighttime target or position marking in inundated areas, mud or snow. The external configuration is similar to the M583 White Star Parachute Cartridge, the 40mm Target Marker (Floating) TMF-1, and other 40mm signals now being developed under the same Materiel Need. Cartridge length is 5-1/4 inches and weight is 9-1/2 ounces. The two major assemblies comprising the complete round are the cartridge case and the projectile (Figure 4). The cartridge case assembly includes the case, the primer, and the propelling charge. The projectile assembly includes the body, marker, and ogive assemblies. The body assembly includes the body housing, the delay assembly, and a bearing plate. The marker assembly (Figure 5) which telescopes into the body assembly, consists of a loaded canister subassembly and a chimney/ballute subassembly. The canister subassembly includes the canister, an insulating liner, the ignition (first-fire) composition, and the flare composition. The chimney/ballute subassembly consists of the chimney, the ballute, which is made up from several pieces, an asbestos disc, and interfacing materials. The base of the canister is crimped into a groove on the chimney. The ogive assembly consists of the ogive and an O-ring. A snap joint on the ogive locks the ogive to a groove in the projectile body housing, thereby retaining the other components inside the projectile assembly.

The functioning sequence is shown in Figure 6. When the flare cartridge is fired, the primer flash ignites the propelling charge, which expels the projectile from the grenade launcher in a ballistic path toward the target. The flame from the propelling charge also ignites the pyrotechnic delay charge in the base of the projectile. The delay charge burns through in approximately 5-1/2 seconds and, spitting flame through the chimney, it ignites the first-fire (ignition) mix on the base of the flare composition in the canister. The resultant pressure generated inside the projectile body releases the snap joint on the ogive and then ejects the marker assembly from the body assembly. The combustion gases immediately inflate the ballute, which then acts as an aerodynamic decelerator, slowing the marker assembly as it descends with the loaded metal canister in a nose-down attitude. The marker impacts so gently that it usually does not submerge; furthermore, it will not bury itself in soft mud. After the marker lands on water, snow or mud, the inflated ballute supports the canister in an upright orientation, keeping it afloat. Meanwhile, the combustion has transferred from the first-fire mix, through an intermediate mix, to the flare composition and flame issues from the chimney, which extends from the combustion chamber (canister) through the center of the ballute.

The maximum projectile range is 280 meters, which is obtained when using a launch angle of 32° to 35°. The flare signal colors are red, yellow, and green. On a clear night, the flare signal is identifiable for an aerial slant range exceeding two miles. Burn time of the flare is 80-100 seconds. Average recoil impulse is 3.33 lb-sec.

Figure 1. 40mm Floating Flare Cartridge

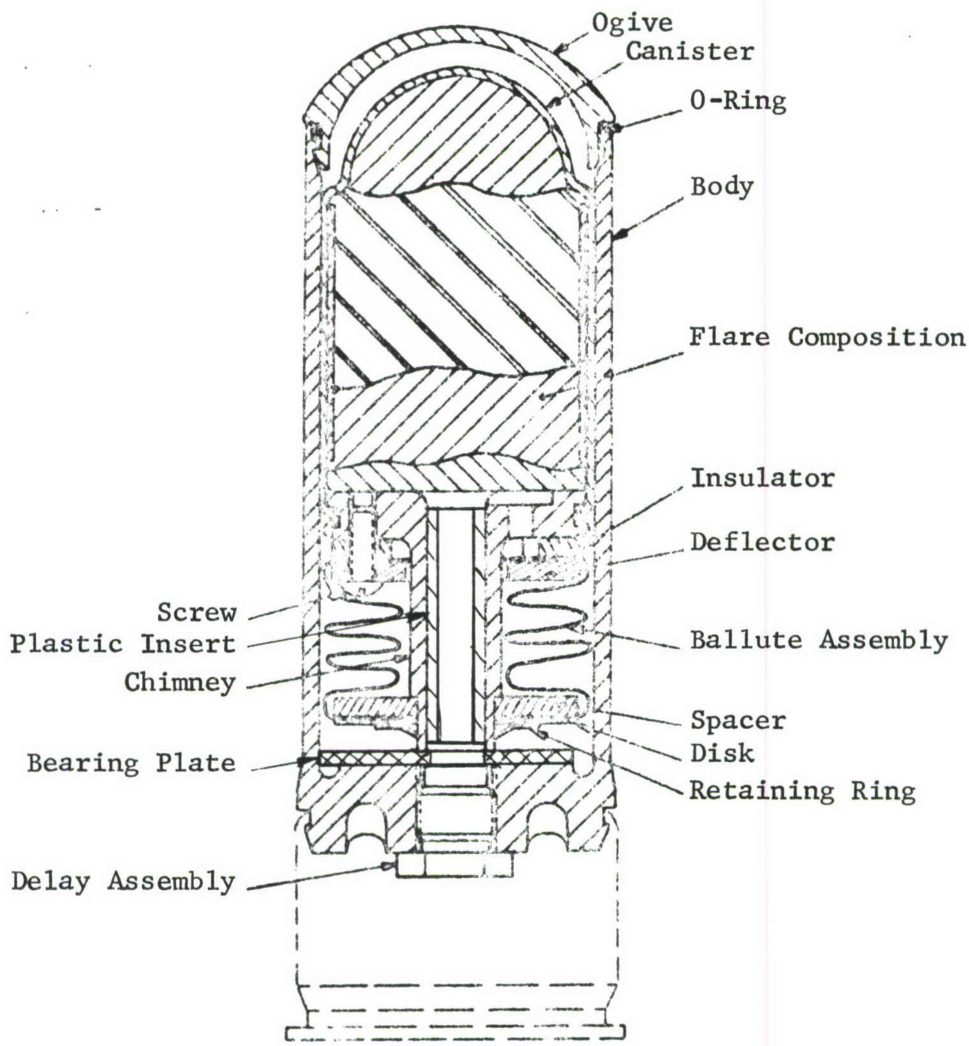

Figure 2. Cross Section of 40mm Floating Flare Cartridge

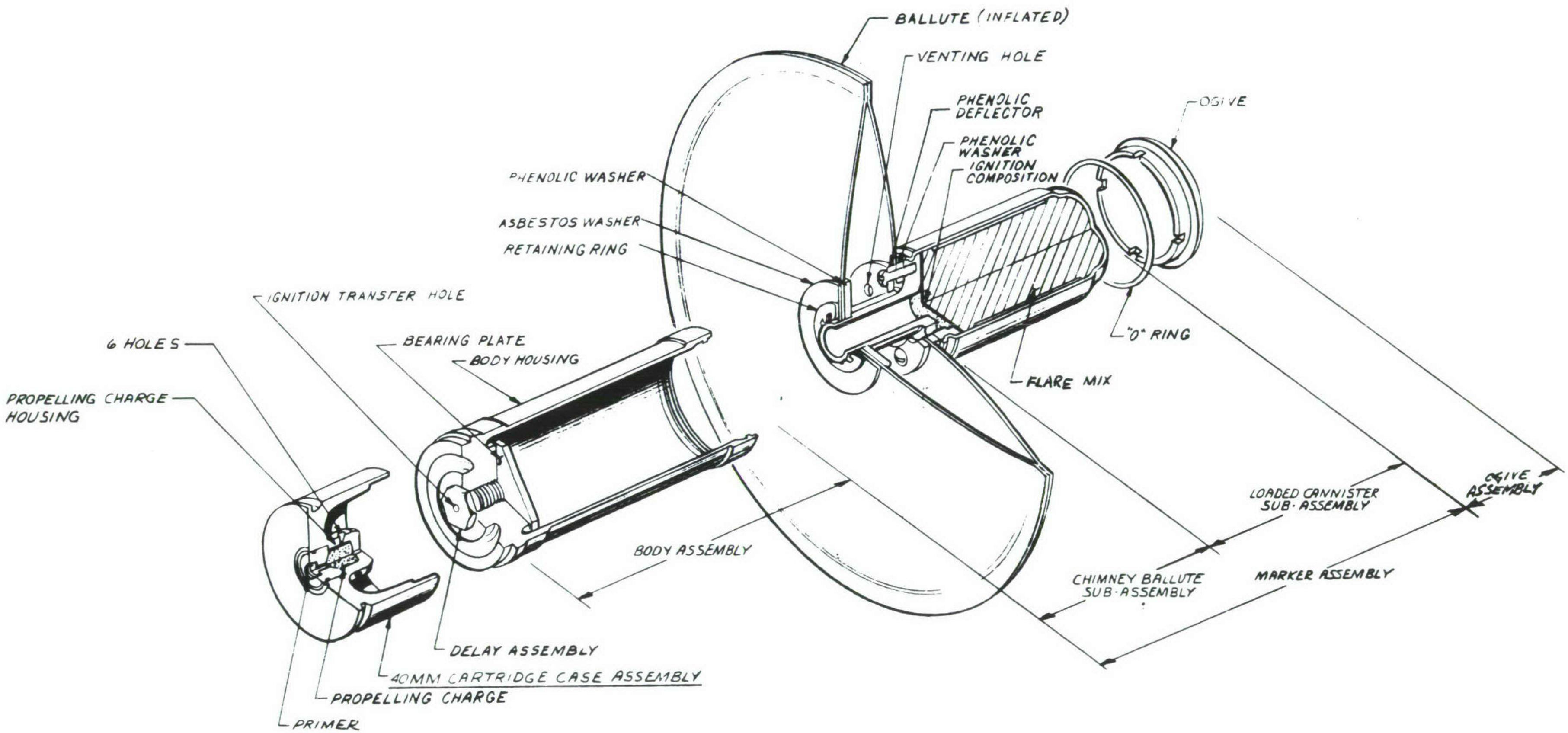

Figure 3. Exploded View, 40mm Floating Flare Cartridge

Figure 4. 40mm Floating Flare Cartridge Case and Projectile

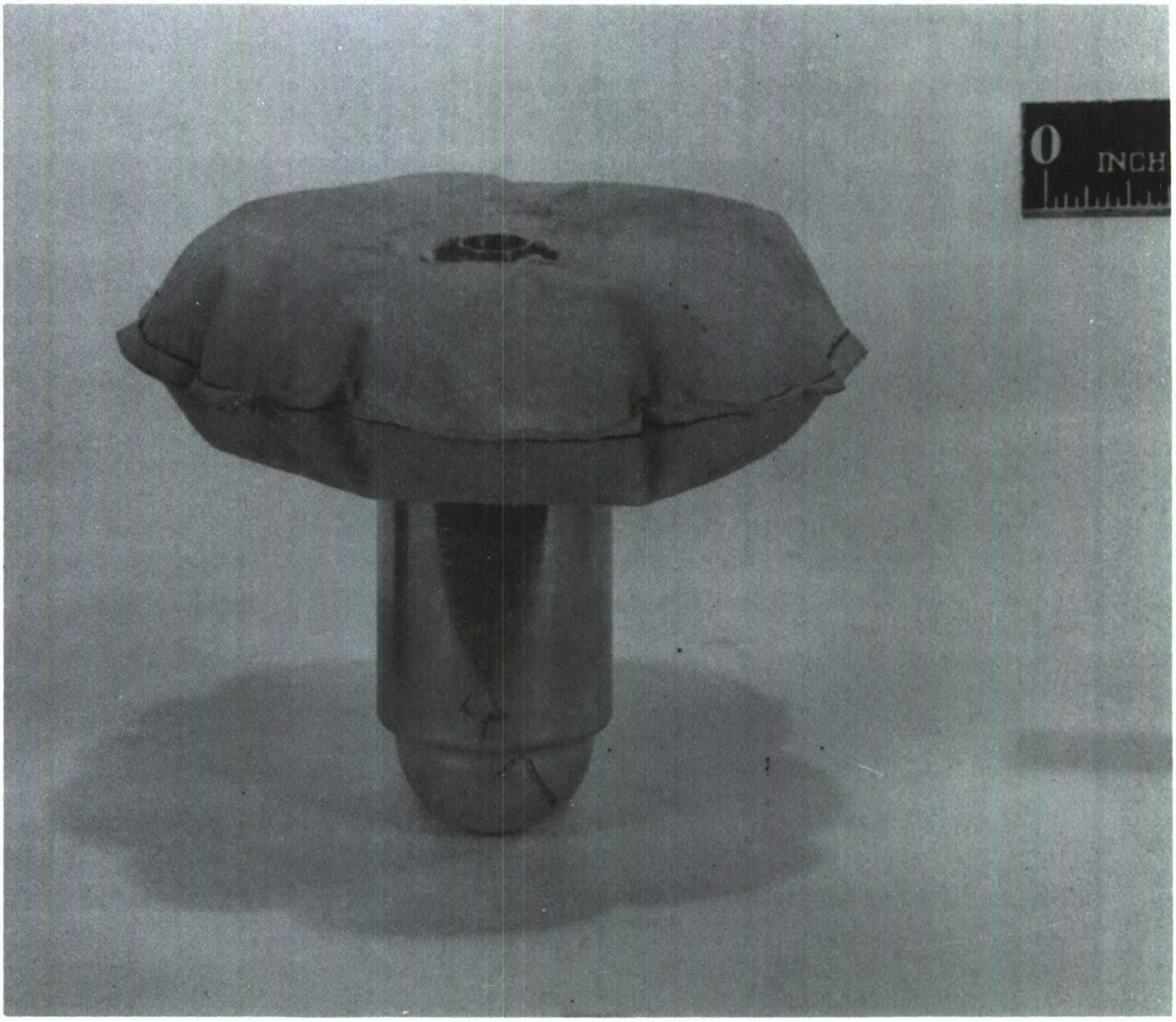

Figure 5. Marker Assembly, 40mm Floating Flare Cartridge

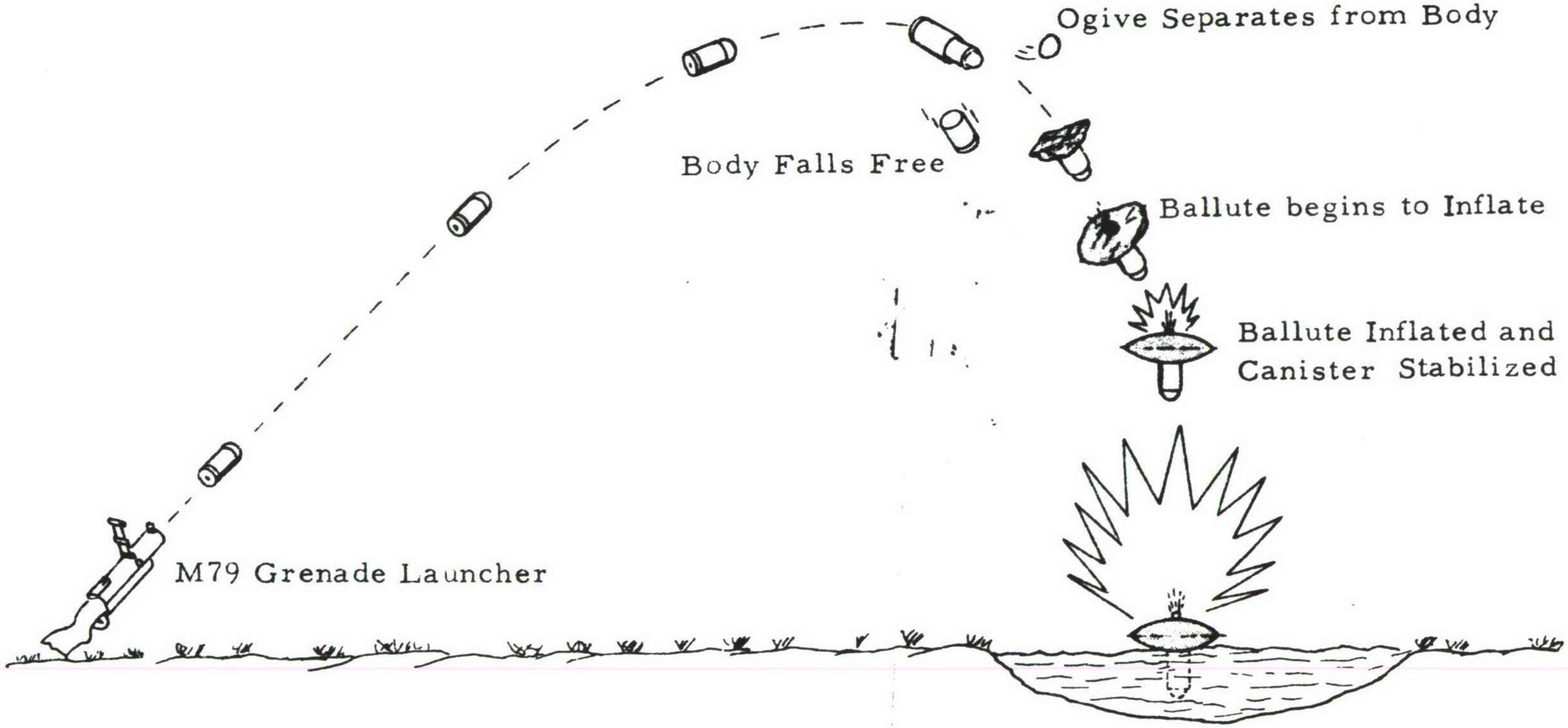

Figure 6. Functioning Sequence, 40mm Floating Flare Cartridge

DEVELOPMENT HISTORY

Contract No. DAAD05-71-C0191

This contract was let to Northrop Carolina, Inc., Asheville (Swannanoa), NC in December 1970 to develop a 40mm floating flare for nighttime target or position marking in inundated areas. This cartridge was to be designed for use with the 40mm Grenade Launchers M79 and M203. It was to be designed with a pyrotechnic delay element to separate the payload from the projectile housing during flight and with a retardation/flotation device to slow the descent rate of the payload prior to surface impact and to provide flotation upon water. It was to have an external configuration similar to that of the 40mm Floating Target (Smoke) Marker Cartridge and to use the maximum number of hardware components common to that smoke cartridge and other cartridges under development by the US Army Materiel Command's Project Manager for Selected Ammunition. The basic scope of this contract included design, development, and test of yellow, green, and red flares followed by acceptance tests of 15 flare cartridges and subsequent delivery of 75 flare cartridges for government testing. Appendix A states the military characteristics governing this development.

During the course of this development, the contractor underwent a company reorganization and the contract was subcontracted to Chemtronics, a Division of Airtronics, Inc., which leased the NCI facilities at Swannanoa, NC.

The contractor developed yellow, green, and red flare compositions that could be adapted to the basic hardware of the 40mm Floating Target (Smoke) Marker Cartridge, TMF-1. A binder investigation was conducted and cellulose acetate plasticized with triacetin was selected. Color producers selected were strontium nitrate (red), sodium nitrate (yellow), and barium nitrate (green). Burn time was found to be a sensitive function of the nitrate/ammonium perchlorate ratio, the binder content, and magnesium particle size.

Ballute development also was a major effort. The material used in the TMF-1 could not withstand the higher temperatures generated by the flare mixes. A silicone-coated glass fabric proved to be suitable. It also was necessary to switch from aluminum to steel for the chimney of the marker assembly.

A total of 144 static development tests, 75 ballute development tests, 15 feasibility demonstration tests, 66 environmental tests, and 9 delivery acceptance tests were conducted by the contractor prior to delivery of 75 cartridges to USALWL.

Excerpts from the contractor's final report (Reference 5) on this contract effort are presented in Appendix B. The contractor's test plan is presented as Appendix A of that report; the other appendixes to the contractor's report have been withdrawn.

Feasibility Tests

Night tests of feasibility items were conducted on 12 Aug 71 to evaluate night visibility. Weather conditions included clear skies, seven miles visibility, and wind northerly at 2 to 5 miles per hour. Altitude of observation aircraft varied from 500 feet to 2000 feet above the ground.

Red and yellow flares were observed at all ranges out to five miles with the color being readily identifiable. The green flare could only be observed out to a range of two miles with the color not being identifiable beyond a range of 1500 meters. Of the three flares observed, the yellow flare was by far the brightest. When the three colors were deployed in close proximity, the yellow flare precluded identification of the red and green flares beyond 1500 meters.

Production of flame in the desired colors averaged close to 90 seconds, which is listed as essential in the military characteristics. Thirty-one of the 36 cartridges fired performed as expected, with the ballute effectively retarding the fall of the payload and then keeping it afloat throughout the burn time. Four of the 5 failures appeared to be failures of the first-fire mix (expulsion charge) to properly transfer to the main composition; however, expulsion occurred and the ballutes were inflated. The cause of the other failure could not be discerned because of the darkness and the inability to recover the hardware.

The pilot and other observers agreed that the red and yellow flares were satisfactory as a marker for aircraft, but the green flare was unsatisfactory. While the yellow and red flares far exceed the essential observation distance characteristic of 3000 meters as specified in the military characteristics, the green flare could be seen only approximately half the required distance.

As previously indicated, the development contractor, NCI/Chemtronics, had conducted additional feasibility tests, including the testing of 66 cartridges in conjunction with General Testing Laboratories. Testing included storage and transit conditions; transportation and aircraft vibration; rainfall, sea salt fallout, sand and dust, and other operational conditions; and bullet impact. These special test conditions did not appear to have any significant effect on performance.

It was concluded that feasibility had been demonstrated. Excellent performance had been obtained from the red and yellow flares but additional development was necessary to improve the output of the green formulation. Color quality and flame output of the green flare and improvement of ignition transfer from the first-fire mix to the main flame composition would be investigated prior to fabrication of cartridges for Engineering Design Testing (EDT).

Upon being informed of the unsatisfactory performance of the green flare, the contractor conducted an independent investigation in an effort to improve the color quality of the green signal. Ten formulations were tested. Six cartridges were then fabricated and demonstrated at Aberdeen Proving Ground in September 1971. All six functioned properly and could be seen at ranges of 3000 meters or more. The flame size had been increased and the color was identifiable as green, although appearing as a greenish white at the longer ranges. It was concluded that, although a significant improvement had been demonstrated, additional effort was needed to achieve a deeper green.

Contract No. DAAD05-72-C-0179

This contract was let to Chemtronics in February 1972 to continue the development of the 40mm Floating Flare, especially to improve the color output of the green flare and to improve the transfer from the first-fire (ignition) mix to the main flare mix (all colors), followed by the fabrication of quantities for EDT and field evaluation. The principal development effort was to be directed toward providing a "greener" green flare, with "stoplight green" as the development goal. The investigation could include consideration of using a shorter signal duration to determine if an acceptable tradeoff could be achieved. The design and performance goals were the same as those stated in Contract No. DAAD05-71-C-0191 except for the environmental requirement, which was extended to include Categories 1, 2, 5, and 6, AR70-38, dated 5 May 1969 instead of just Category 2, Wet-Hot. Operation under all environmental categories continued to be desired. This contract was divided into three phases. Phase I included the aforementioned development efforts followed by fabrication and delivery of a quantity of forty (40) flare cartridges (20 green, 10 red, and 10 yellow) to demonstrate the improvements that had been achieved. Following Government evaluation of these items, Phase II included the effecting of any necessary design changes followed by manufacture and delivery of 300 cartridges (100 of each color) for EDT. Following completion of EDT, Phase III included the effecting of any necessary design changes followed by manufacture and delivery of 1188 cartridges (396 of each color) in accordance with the approved technical drawings.

The contract objectives were achieved and a total of 1528 cartridges were delivered to the Government as scheduled.

The green flare composition was sufficiently improved that this flare was visible and recognizable to a range in excess of 3000 meters for approximately 90 seconds, as were the red and yellow flares. The 90-second burn time was achieved with all colors after a modification of the red composition that increased its burn by about 10 seconds.

Reliability (all colors) was improved by increasing the quantity of first-fire (ignition) mix from 2.25 grams to 3.00, by reducing the amount of teflon in the ignition mix by 75%, and by incorporating a 4-gram intermediate mix composed of 50% ignition mix and 50% flare mix. During the final test series of 53 cartridges, there were not failures attributable to this segment of the ignition train. The two failures that occurred were attributed to failures of the pyrotechnic delay.

Additional improvements in performance and reliability were achieved by changing to a full-length plastic chimney insert. This insert eliminated slag accumulation in the chimney during burning, thereby providing smoother burning (a more uniform flame) and preventing overpressurization of the ballute, which formerly had caused ruptures and premature sinking. As a further improvement, the break strength of the thread used to stitch the ballute was increased from 1.2 pounds to 3 pounds.

More than 400 units were tested during this program. These included green-flare-composition laboratory static tests, night visibility tests, and development and qualification tests. Outdoor tests involved both static tests in water and flight tests using an M79 Grenade Launcher.

Details on the development effort on this contract are presented in the contractor's final report (Reference 6); excerpts are presented as Appendix C.

Engineering Design and Safety Evaluation Tests

A test plan for Engineering Design and Safety Evaluation tests (Appendix D) was formulated based on the LWL Military Characteristics (Appendix A), the approved Materiel Need (QMR) (Reference 4), and an engineering test plan for 40mm signal cartridges (Reference 7).

This testing actually was divided into three phases, all coordinated by AAI Corporation and witnessed by Government personnel. The environmental and physical testing was conducted by General Environments Corporation, Hartwood, VA. The principal firing tests were conducted by AAI personnel at the General Environments facility. The recoil tests were conducted by AAI and H. P. White personnel at H. P. White Laboratories, Bel Air, MD.

The environmental and physical testing included sequential rough handling (seven-foot package drop, loose cargo, and five-foot item drop), high humidity, waterproofness, vibration, forty-foot package drop, and high and low temperature storage. Pre-test examination revealed no apparent indication of deterioration and/or damage of the test articles as a result of transport. After the seven-foot drop of the rough handling sequence, it was found that the nose caps of all 88 cartridges had been loosened or had completely separated from the cartridge housing. All were replaced prior to continuing testing. The nose caps were again loosened or separated during the loose cargo sequence of rough handling and were again replaced prior to continuing. A few of the cartridges experienced small dents at the forward rim of cartridge housing near the nose cap during the five-foot individual drop test. These were the only visible damages resulting from the environmental conditioning. The cartridges in the forty-foot drop did not explode and were safe to handle afterwards (actually, they later were test fired from an M79 Grenade Launcher). Additional information on these tests is presented in Appendix E. The detailed report on these tests is Appendix A of Technical Note No. LWL-CR-02F71B (Reference 8).

Performance testing was conducted using a 40mm Grenade Launcher M79. The launch angle for the flight tests was 45°. The performance testing included evaluation of delay times, burn times, range, flight characteristics, flotation characteristics, altitude at functioning, and recoil impulse. During testing there were no misfires at launching and all launchings were normal, presenting no hazard in that respect. Three major types of malfunctions occurred: (1) failure to function in flight (9%), (2) failure to eject the flare after functioning (6%), (3) failure to remain afloat after normal ejection and impact in water (14%). With a total of 187 cartridges fired during the flight tests, these three types of failures combined to produce an overall failure rate of 29%.

Serious failure rates were observed with the high humidity group and those conditioned and fired at extreme temperatures of -70° and +160°F. Meanwhile the failure rates at -45° and +125°F were approximately the same as with the control rounds (ambient conditions). Of the 71% that operated normally, the flare color and brightness were generally good. Those flares that floated on the side (included in the 14% failure rate) usually had poor color or visibility (these were daytime firings). In some cases the ballute did not inflate properly during flight and the marker sank upon impact with water; these markers generally burned underwater and often surfaced during mid-burn. In other cases a section of the seam at the ballute perimeter opened or the ballute was damaged by hot slag; these markers generally turned on their sides. It also was observed that a fire hazard does exist when the marker lands in dry grass or brush. Additional information on the flight tests is presented in Appendix F. The detailed report on these tests is Technical Note No. LWL-CR-02F71B (Reference 8).

Recoil impulse was measured for 63 cartridges fired horizontally from an M79 Grenade Launcher mounted in a ballistic pendulum. The functioning of the flare was not evaluated during these firings. The average recoil impulse was 3.33 lb-sec (3.28 at -50°F, 3.33 at ambient, and 3.39 at 145°F). Results of the ballistic pendulum tests are presented in Appendix G. This complete test report is Appendix B of Technical Note No. LWL-CR-02F71B (Reference 8).

Discussion

The 40mm Floating Flare Cartridge has been demonstrated at Ft. Benning and in Alaska; the 40mm Floating Smoke Marker Cartridge was demonstrated simultaneously. No formal comments were received from Ft. Benning but observers indicated that they liked these items. However, the following comments were made in a subsequent letter from the US Army Combat Development Command, (CDC-CS-MS-IN) Ft. Belvoir, VA to HQDA (DAFD-SDY), Washington, DC dated 8 Feb 73, which recommended deletion of these two signals from the Materiel Need (Reference 4):

"Combat Developments Command has recently re-examined the need for the pyrotechnic ammunition listed in the . . . (Materiel Need) . . . and has concluded that the floating flares and floating target markers can be eliminated without adversely affecting ground combat operations. While there may be some instances in which the floating smoke or floating flares would provide an advantageous capability, these occurrences are considered to be too uncommon to warrant significant RDTE expenditures and/or wide-spread issue. It appears that the application of such floating pyro-technics is very limited and considerable reduction in the cost and pro-liferation of military hardware can be achieved if they are deleted from the MN."

However, the demonstration in Alaska, which followed correspondence between US Army, Alaska, and USALWL, received very favorable comments. The following statement has been extracted from a letter from USARAL (ARACD) to USALWL dated 29 Jun 73, subject: Land Warfare Laboratory Evaluations in USARAL:

"During the period 19-23 March 1973 members of the USARAL staff observed evaluations of three items developed by LWL. The . . . 40mm floating signals (smoke and flare) were evaluated at Fort Richardson . . . The 40mm floating signals (smoke and flare) fired from the M-79 remained on the surface of the snow and were visible at ranges far in excess of the standard grenades that quickly sink into the snow and become obscured. It is suggested that the 40mm floating signals be nominated for test by the Arctic Test Center. USARAL is submitting a Proposed Required Operational Capability (PROC) for a non-submersible smoke grenade."

In addition, the following comments were included in the Monthly Liaison Activities Report, 1-31 Mar 73, from the CDC Liaison Officer (ATFE-L-AA) to USACDC dated 2 Apr 73:

"On 22 March I observed an evaluation of . . . floating flares and smoke grenades (can be fired from the M79 or M203 launchers) at Fort Richardson. The snow in the impact area varied from 2-4 feet deep. Surface was soft but beginning to bind from warm weather. Out of about two dozen fired, not a single round sank more than four inches into the soft surface. The sinkage 'hole' was the diameter of the flotation collar and in all cases, the smoke and flare discharge tubes were clear and totally free from snow. In several instances the yellow smoke rounds 'fluttered' or tumbled during descent. They still landed 'upright' and functioned normally in the snow. About six of the other type rounds bounced upon impact and landed several inches to as much as two feet from the original point of impact. However, in every instance of bounce, the round remained upright and functioned normally. The flotation collar worked beautifully. The conclusion is that this type of munition should be available for use in the field where water, deep mud, tundra or snow can extinguish or mask standard munitions of this type and render them useless."

In response to the USARAL letter, a proposed evaluation plan for the 40mm Floating Flare Cartridge has been submitted through the US Army Test and Evaluation Command to the US Army Arctic Test Center. Approximately 900 cartridges have been offered for this evaluation.

The technical data package and the remaining cartridges have been turned over to the Office of the Project Manager for Selected Ammunition, US Army Materiel Command, which is located at Picatinny Arsenal, Dover, NJ.

CONCLUSIONS

Red, yellow, and green 40mm Floating Flare Cartridges for firing from the M79 and M203 Grenade Launchers have been developed for use for nighttime target or position marking in inundated areas, mud, or snow. They have a maximum range of 280 meters, a signal burn time of 80 - 100 seconds, and a visual recognition distance exceeding 2 miles on a clear night. External configuration is similar to the 40mm White Star Parachute Cartridge M583 developed under the same Materiel Need. Recoil impulse averages 3.33 lb-sec.

The basic program objectives (see Military Characteristics, Appendix A) have been met except for reliability. Performance of the cartridges that functioned properly exceeded the stated requirements. Maximum commonality of parts was achieved with other signals developed under the Materiel Need (Reference 4). During the final contractor tests prior to LWL's engineering design tests (EDT) a reliability of 96% was achieved with all failures attributable to the pyrotechnic delay assembly. However, during EDT the overall reliability was only 71%, which is less than the 85% requirement stated in the Materiel Need. The failure rate was serious for the extreme temperature (-70^{o} and $+160^{o}F$) and high humidity groups. A failure rate of 9% could be attributed directly to failure of the pyrotechnic delay assembly, which is a standard component of other 40mm pyrotechnic signals. Poor ignition transfer gave a 6% failure rate and could be attributable to a weak output of the delay assembly or a poor first-fire mix. The flotation failure rate of 14% was primarily caused by inadequate construction of the ballute periphery. These failure problems can be solved.

It is concluded that the 40mm Floating Flare Cartridge is safe for handling and use. Approximately 900 cartridges have been offered for field evaluation in Alaska. An additional 300 cartridges have been turned over to the US Army Materiel Command's Project Manager for Selected Ammunition.

RECOMMENDATIONS

1. The construction of the ballute should be investigated to achieve greater strength and sealing along its periphery.

2. The reliability of the standard pyrotechnic delay assembly should be improved.

3. To prevent separations during rough handling, packaging improvement should be investigated; if this is unsatisfactory, a more durable fastening method that still will release quickly upon internal pressurization will be needed at the ogive/body interface.

4. Field evaluation in Alaska during both winter and summer seasons should be completed.

5. Following the completion of field evaluation, an In-Process Review should be conducted to review the results of the development effort and field evaluations and to determine whether to continue development or to delete the floating signals from the Materiel Need.

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* Copies of these Technical Notes may be borrowed from the APG Technical Library, STEAP-TL, Aberdeen Proving Ground, MD 21005.

APPENDIX A

MILITARY CHARACTERISTICS

APPENDIX A

8 July 1970

MILITARY CHARACTERISTICS FOR 40MM FLOATING FLARE

1. REQUIREMENT:

a. Provide U. S. Army units conducting airmobile assaults and other military activities the capability of reliably marking, with a variety of colored flare markers, inundated areas during the hours of darkness.

b. Source of Requirement:

(1) MACV Significant Problem Areas, May 1970, Page 32.

(2) MACV Significant Problem Areas, Nov 1969, Page 27

2. OPERATIONAL AND ORGANIZATIONAL CONCEPTS:

a. Operational Concept: Infantry companies, airmobile companies and command and control personnel would utilize this device to mark landing zones, enemy positions, and reference points on inundated areas to facilitate military operations during the hours of darkness.

b. Organizational Concept: It is envisioned this item would be available to using units through normal supply channels for the class of supply.

3. JUSTIFICATION AND PRIORITY:

a. Reason for the Requirement: Troops in the field currently do not have the capability of marking a target or position on inundated areas during the hours of darkness with a standoff capability.

b. Priority for Requirement: Priority Grouping II; Reference: MACV Significant Problem Areas, dated May 1970.

4. CHARACTERISTICS:

a. Performance Characteristics: (Essential) The floating flare marker shall be capable of reliable delivery from the M79 and M203 Grenade Launchers.

(1) Number of major components in this unit, (Essential) One (1).

(2) Maximum/minimum weights - To be determined during development.

(3) Cubic measurements (Essential) - Same as 40mm Floating Smoke Marker.

(4) Environmental requirement (Essential) Wet-Hot (AR 70-38); (Desired) All climatic conditions.

(5) Paradrop (Essential) - Yes.

(6) Assembly/disassembly time (Essential) - None.

(7) Power requirements (Essential) - None.

(8) Transportability (Essential) - Man-air transportable.

(9) Observation distance requirement (Essential) - 3,000 meters from a minimum altitude of 1,000 feet.

(10) Expendable (Essential) - Yes.

(11) Performance requirements:

(a) (Essential) Impact insensitive to small arms fire.

(b) (Essential) Operate under all conditions of weather and on inundated areas.

(c) (Essential) Visible for a minimum of 1½ minutes.

(d) (Essential) 95% reliability in inundated areas.

(e) Range (Essential) 250 meters; (Desired) 300 meters.

(f) Colors (Essential) Red, green and yellow flares will be provided.

(12) Storage (shelf life) (Essential) five years.

b. Maintenance Concept: (Essential) Require no maintenance other than visual inspection prior to use.

c. Human Engineering Characteristics: (Essential) Require no special training and complete safety in operation; AR 602-1 dated 4 March 68 and AR 385-16 dated 11 Feb 67.

d. Priority of Characteristics: Reliability, performance.

5. PERSONNEL CONSIDERATIONS: Introduction of this item into the Army inventory will require no additional personnel spaces in TO&E of tactical units.

DATE 9 July 1970

APPROVED: [signature]
for LUCIEN E. RISING
COL, GS
Chief, Military Opns Division

APPENDIX B

FEASIBILITY REPORT (EXCERPTS)

APPENDIX B

Excerpts from

TECHNICAL NOTE NO. LWL-CR-02F71

40mm FLOATING FLARE FEASIBILITY

Final Report
Contract No. DAAD05-71-C-0191

by

Peter D. Evanoff
Project Manager, Chemtronics
Northrop Carolina, Inc.
Asheville, North Carolina

February 1972

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U. S. ARMY LAND WARFARE LABORATORY
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TABLE OF CONTENTS

		Page
ABSTRACT		iii
FOREWORD		v
INTRODUCTION		1
CONCLUSIONS		4
DEVELOPMENT		5
1.	General	5
2.	Binder Investigation	5
3.	Red Flare Compositions	6
4.	Yellow Flare Compositions	8
5.	Green Flare Compositions	10
6.	Flame Temperature	13
7.	Temperature Sensitivity	16
8.	Ballute Development	16
9.	Feasibility Demonstration	17
ENVIRONMENTAL TESTS		19
DELIVERY ROUNDS		20
Appendix A	Program Plan	24
Appendix B	Data Sheets for Red Flare Composition Tests	29
Appendix C	Data Sheets for Yellow Flare Composition Tests	38
Appendix D	Data Sheets for Green Flare Composition Tests	44
Appendix E	Feasibility Demonstration Test Results	53
Appendix F	Environmental Testing of Cartridge 40mm Floating Flare	55
Appendix G	Environmental Flight Test Results	74

TABLE OF CONTENTS (continued)

		Page
Appendix H	Delivery Rounds Data	81
Appendix I	Improved Green Flare	83

LIST OF FIGURES

		Page
Figure 1	Burning Time of Red Flare Compositions with Polyvinylchloride Binder as a Function of Strontium Nitrate and Ammonium Perchlorate Content	7
Figure 2	Burning Time of Red Flare Compositions with Cellulose Acetate Binder as a Function of Strontium Nitrate and Ammonium Perchlorate Content	9
Figure 3	Burning Time of Yellow Flare Compositions with Cellulose Acetate Binder	11
Figure 4	Burning Time of Yellow Flare Compositions with Cellulose Acetate Binder (Granulation 16 Magnesium)	12
Figure 5	Burning Time of Green Flare Compositions as a Function of Ammonium Chloride and Ammonium Perchlorate Content	14
Figure 6	Burning Time of Green Flare Compositions with Cellulose Acetate Binder as a Function of Barium Nitrate and Ammonium Perchlorate Content	15
Figure 7	Cross Section Drawing 40mm Flare	21
Figure 8	40mm Floating Flare Sequence of Operation	22

INTRODUCTION

The objective of this program was the development of a floating flare for nighttime target or position marking in inundated areas.

The following design characteristics were included in the development goals:

a. The 40mm Floating Flare shall be developed as a 40mm cartridge with all components assembled as a single unit.

b. The flare shall be designed for delivery from both the M79 and the M203 Grenade Launchers.

c. The design shall incorporate the 40mm Cartridge Case XM195 for the launch system.

d. Flare colors required are red, green, and yellow.

e. The design shall incorporate a floatation device of the ballute type, which shall be fabricated from a material capable of withstanding the high temperatures of the gases produced by the burning flare.

f. The cubic measurements of the unit shall be the same as those of the 40mm Floating Smoke Marker and the final assembly length shall not exceed 5-1/4 inches.

g. The projectile and total cartridge weights shall be determined during development and, once determined, these weights shall be consistent.

h. The cartridge shall be man-air transportable and be safe for paradrop delivery.

i. The cartridge shall be expendable.

The following performance characteristics were included in the development goals:

a. The recoil momentum produced by the flare cartridge shall not exceed 4.0 lb-sec when fired from the M79 Grenade Launcher.

b. The flare cartridge shall be capable of operating and functioning under environmental condition "wet-hot," Category 2 of AR 70-38; operation under all environmental categories is desired but not essential.

c. The flare delay element (fuze) shall initiate the signal-emitting pyrotechnic before impact.

d. Ballute inflation shall be complete between the time of separation of the payload from the projectile body and impact onto the surface of the water.

e. The flare shall be capable of floating and functioning on mud or water of any depth and under all weather conditions.

f. The flare shall have a range capability of not less than 250 meters; a range of 300 meters is desirable.

g. The pyrotechnic mix shall produce a visible signal for a minimum of 1-1/2 minutes as measured from the time of payload ignition (at separation from the projectile body) to burnout after impact; the signal intensity and color shall be relatively uniform during the burn interval.

h. The flare signal shall be visible and the color identifiable from an observation distance of at least 3000 meters and from a minimum altitude of 1000 feet on a clear night.

i. The flare shall operate with 95 percent reliability in inundated areas.

j. The flare cartridge should be impact insensitive to small arms fire.

k. The flare cartridge shall have a storage shelf life of a minimum of five years.

The development goals also included the following:

a. Human Engineering Characteristics: require no special training and complete safety in operation.

b. Maintenance Concept: require no maintenance other than visual inspection prior to use.

c. Priority of Characteristics: reliability performance.

The program plan outline is presented in Appendix A.

CONCLUSIONS

The major program objectives were achieved. A target marker was developed which 1) is capable of launch from either the M79 or M203 40mm Grenade Launcher, 2) is capable of floatation in swamp or water-covered areas, 3) has an external configuration similar to the 40mm Floating Smoke Marker, and 4) contains a flare-emitting pyrotechnic element, a delay element that ignites the flare before impact, and a floatation device.

The specific development goals were met with the following three exceptions:

1. The burn time of the red signal is 80 seconds rather than 90 seconds.

2. The green signal is not color identifiable at a range greater than 2200 meters compared to the goal of 3000 meters.

3. Overall reliability was less than 95 percent.

It is believed that the first two shortcomings noted above can be improved by composition and/or internal mechanical component modifications. A significant improvement in the visibility of the green signal was made at the conclusion of the program by modifying the composition. The problems with the green flare were the principal causes of the reliability shortcoming. The reliability can be improved by improving ignition transfer from the first-fire to the composition mix.

DEVELOPMENT

1. GENERAL

Red, yellow, and green flare mix compositions compatible with the 40mm Target Marker (TMF-1) were developed in the initial phase of the program. This phase established basic formulations and those characteristics which would require modification of the TMF-1 design. A program test plan (Appendix A) also was prepared at that time.

A binder selection was made for the three colors following an evaluation of two binder systems. Pressing conditions were standardized to simplify formulation evaluation. Candles were pressed to length at 16,000-pound force and the weight was allowed to vary. Following formulation evaluation, the pressing conditions were optimized and candle weights established during flight tests for ballute development.

2. BINDER INVESTIGATION

An investigation was conducted to develop a pressable low-temperature-cure polyvinylchloride binder. A polyvinylchloride (PVC) dispersion resin plasticized with diethylphthalate (DEP) in a ratio of 7 parts PVC to 3 parts DEP was found to produce a damp, pressable composition when loaded with 70 to 75 percent strontium nitrate, magnesium powder and ammonium perchlorate. The compositions cured at temperatures less than 150°F.

However, large batches, i.e. 500 grams, processed with this binder produced wet putty-like material which was not suitable for pressing and cured to solid masses in 24 hours on standing at room temperature.

Reduction of the DEP concentrations to 23 percent of the binder gave dry pressable compositions. However, this modified binder was not suitable for red flame compositions because of poor flame color quality and high burning rates.

An alternate binder consisting of cellulose acetate (CA) plasticized with triacetin (TA) in the ratio of one to one was then investigated. This binder produced dry-to-damp compositions which were readily pressable and with flames of equal or superior color quality to those of the polyvinylchloride binder.

3. RED FLARE COMPOSITIONS

Thirty-one flare compositions were evaluated in the TMF-1 unit to develop a suitable flame color and burning rate. Twenty-four of these compositions contained the polyvinylchloride binder (PVC-DEP) and seven contained the cellulose acetate binder (CA/TA). A summary of the compositions investigated is given in Appendix B (test results).

a. Polyvinylchloride Binder

Burn time, color, and processability were evaluated for the PVC/DEP compositions as functions of binder, magnesium, ammonium perchlorate, strontium nitrate, and potassium nitrate content; and magnesium particle size. The following effects were observed in the evaluation tests.

Burn time was found to be most sensitive to binder and magnesium content. Increasing magnesium content from five to ten percent at the expense of binder reduced burn time to one-half its original value.

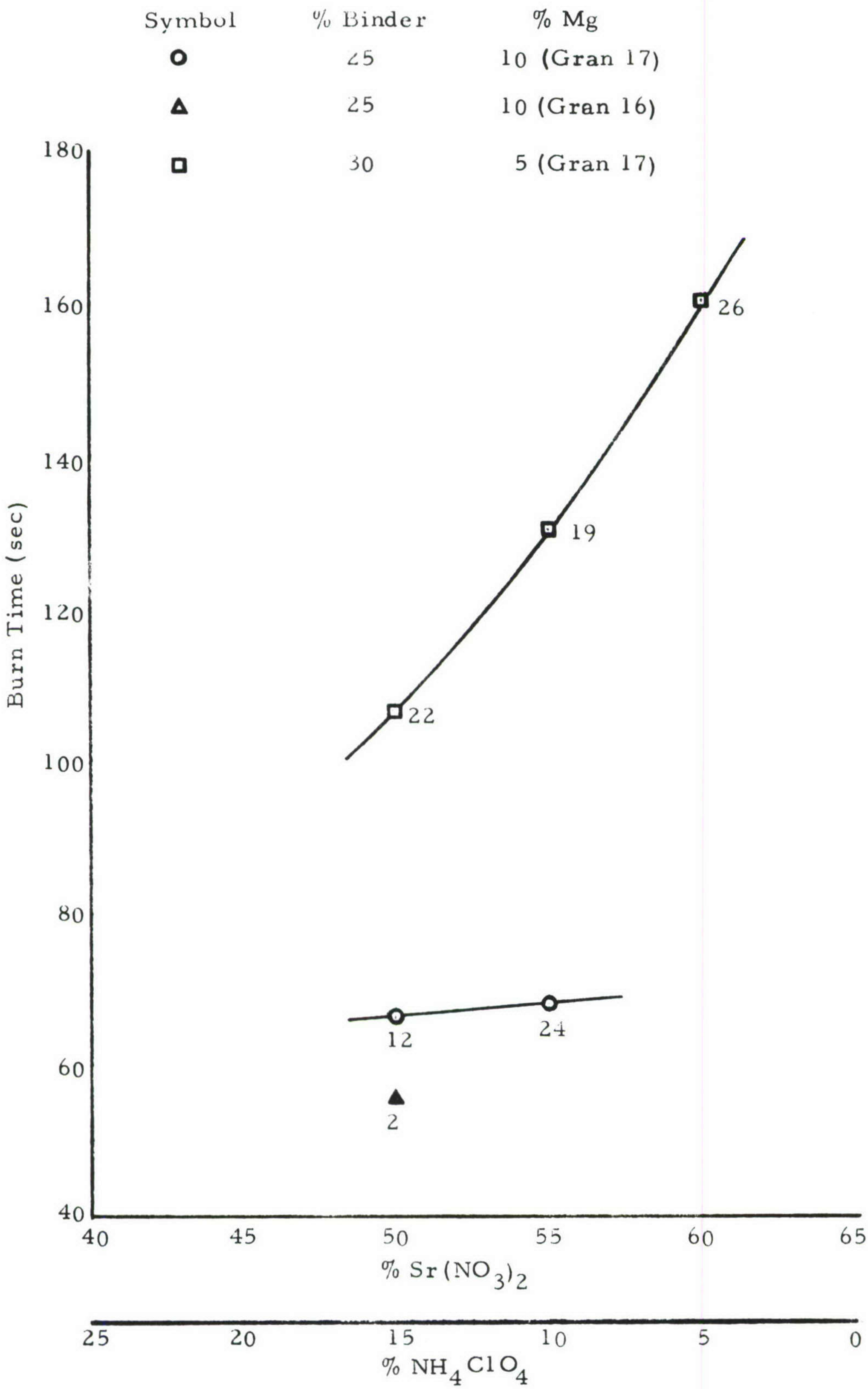
Burn time was also found to be a function of magnesium particle size. Burn time was increased over 20 percent by increasing the average particle size of the magnesium from 22 microns (Granulation 16) to 200 microns (Granulation 17).

Increasing strontium nitrate content at the expense of ammonium perchlorate was observed to increase burn time particularly with 30 percent binder content composition. Less or no effect was observed with compositions containing 25 percent binder.

Each of the above effects are shown graphically in Figure 1.

The substitution of potassium nitrate for strontium nitrate was found to significantly reduce the quality of the red flame. The strontium nitrate compositions containing at least ten percent ammonium perchlorate produced a red flame of good quality.

FIGURE 1 - Burning Time of Red Flare Compositions with Polyvinylchloride Binder as a Function of Strontium Nitrate and Ammonium Perchlorate Content



Compositions containing 10 to 15 percent ammonium perchlorate, 5 percent magnesium and 25 percent or more binder with a 7-to-3 ratio of polyvinylchloride to diethylphthalate approached castability.

Composition R-19 was found to best satisfy the burn time, color quality, processability, and ballute inflation requirements for the polyvinylchloride red flame compositions.

b. Cellulose Acetate Binder

Burn time, color, and ballute inflation characteristics were evaluated for pressed CA/TA compositions as functions of binder, magnesium, strontium nitrate, and ammonium perchlorate content and magnesium and ammonium perchlorate particle size.

Burn time as a function of strontium nitrate and ammonium perchlorate content is shown in Figure 2. Unlike the polyvinylchloride compositions, burn time was found to decrease with increasing strontium nitrate with the cellulose acetate binder.

The cellulose acetate composition which best achieved the program goals was R-29 which consists of:

Ingredient	Weight %
Strontium nitrate (Grade 3)	50.0
Ammonium perchlorate (50μ)	15.0
Magnesium (Granulation 16)	5.0
Cellulose acetate	15.0
Triacetin	15.0

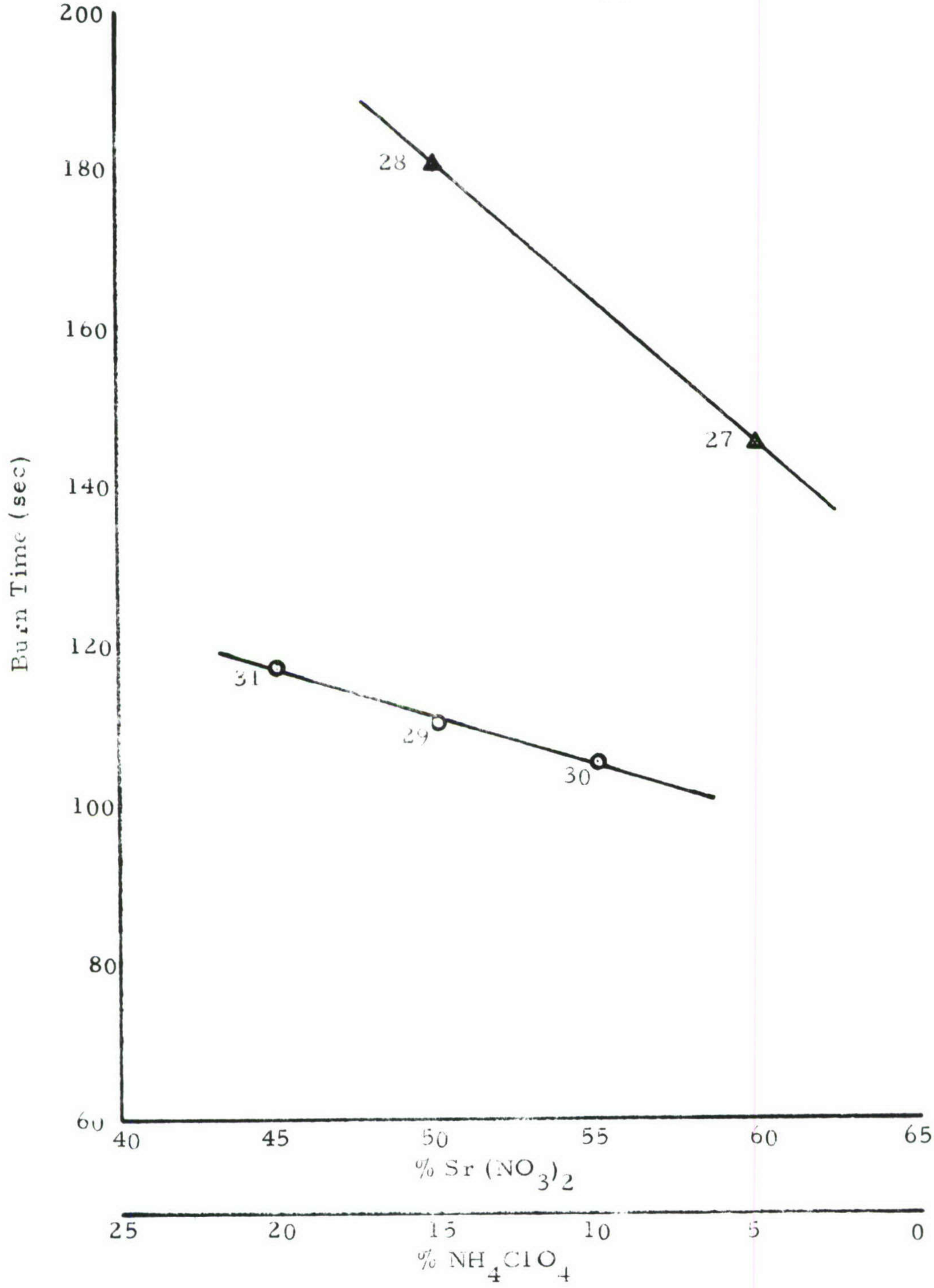
This composition was tested in twelve TMF-1 units in water to confirm a static burn time of 110 seconds. The flame from night tests was recognizable as a red light from a distance of 600 meters. This composition was suitable for flight, visibility, and temperature sensitivity testing.

4. YELLOW FLARE COMPOSITIONS

Twenty-two yellow flare compositions with the cellulose acetate binder were tested. The compositions and test results

FIGURE 2 - Burning Time of Red Flare Compositions with Cellulose Acetate Binder as a Function of Strontium Nitrate and Ammonium Perchlorate Content

Symbol	% Binder	% Mg
o	30	5 (Gran 16)
▲	30	5 (Gran 17)



are summarized in Appendix C. The effects of binder content at three levels, i.e. 25, 30 and 35 percent, magnesium particle size, i.e. Granulations 16 and 17, and total oxidizer content were investigated.

The effects of composition on burn time in the TMF-1 unit are shown graphically in Figures 3 and 4. Burn time was found to be a sensitive function of sodium nitrate/ammonium perchlorate ratio, binder content, and magnesium particle size.

Compositions containing Granulation 17 magnesium or less than 45 percent sodium nitrate gave unstable flames which were easily extinguished.

Burning times in excess of 110 seconds and stable combustion were achieved with compositions containing Granulation 16 magnesium, 30 percent binder and at least 45 percent sodium nitrate.

A yellow flame composition, Y-13, which was readily recognizable at 600 meters as a bright yellow light and burned stably for 140 seconds in the TMF-1 unit is given below.

Ingredient	Weight %
Sodium nitrate (30 μ)	50.0
Ammonium perchlorate (50 μ)	10.0
Magnesium (Granulation 16)	10.0
Cellulose acetate	15.0
Triacetin	15.0

This composition was suitable for flight, visibility, and temperature sensitivity testing.

5. GREEN FLARE COMPOSITIONS

Seventy-four green flare compositions were tested. Twenty-eight of these compositions contained the polyvinylchloride binder and the remainder the cellulose acetate binder. The compositions and test results are summarized in Appendix D.

The large number of tests resulted from the difficulty in achieving good color quality, stable combustion, and burn times greater than 90 seconds with the same composition. This

FIGURE 3 - Burning Time of Yellow Flare Compositions with Cellulose Acetate Binder

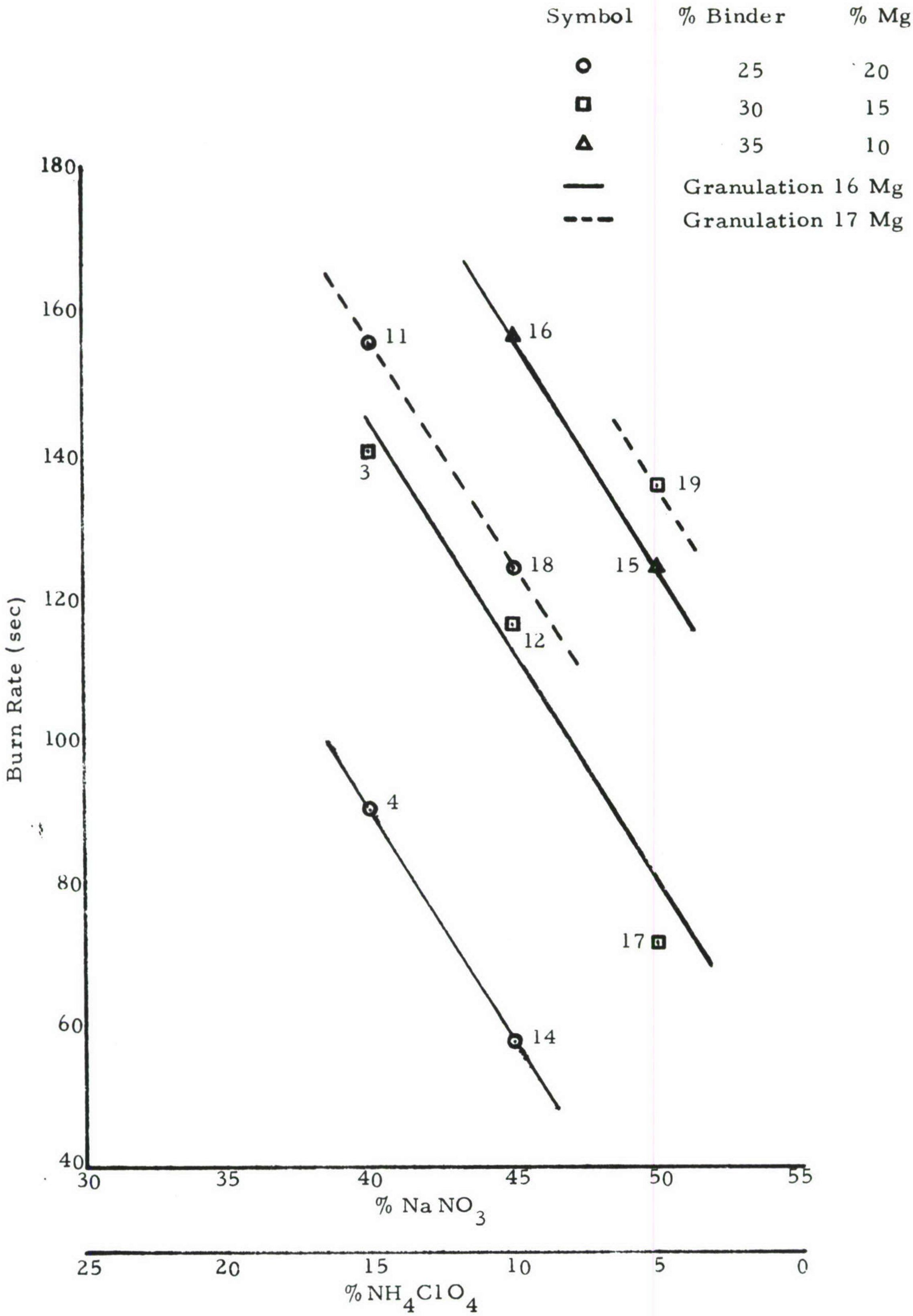
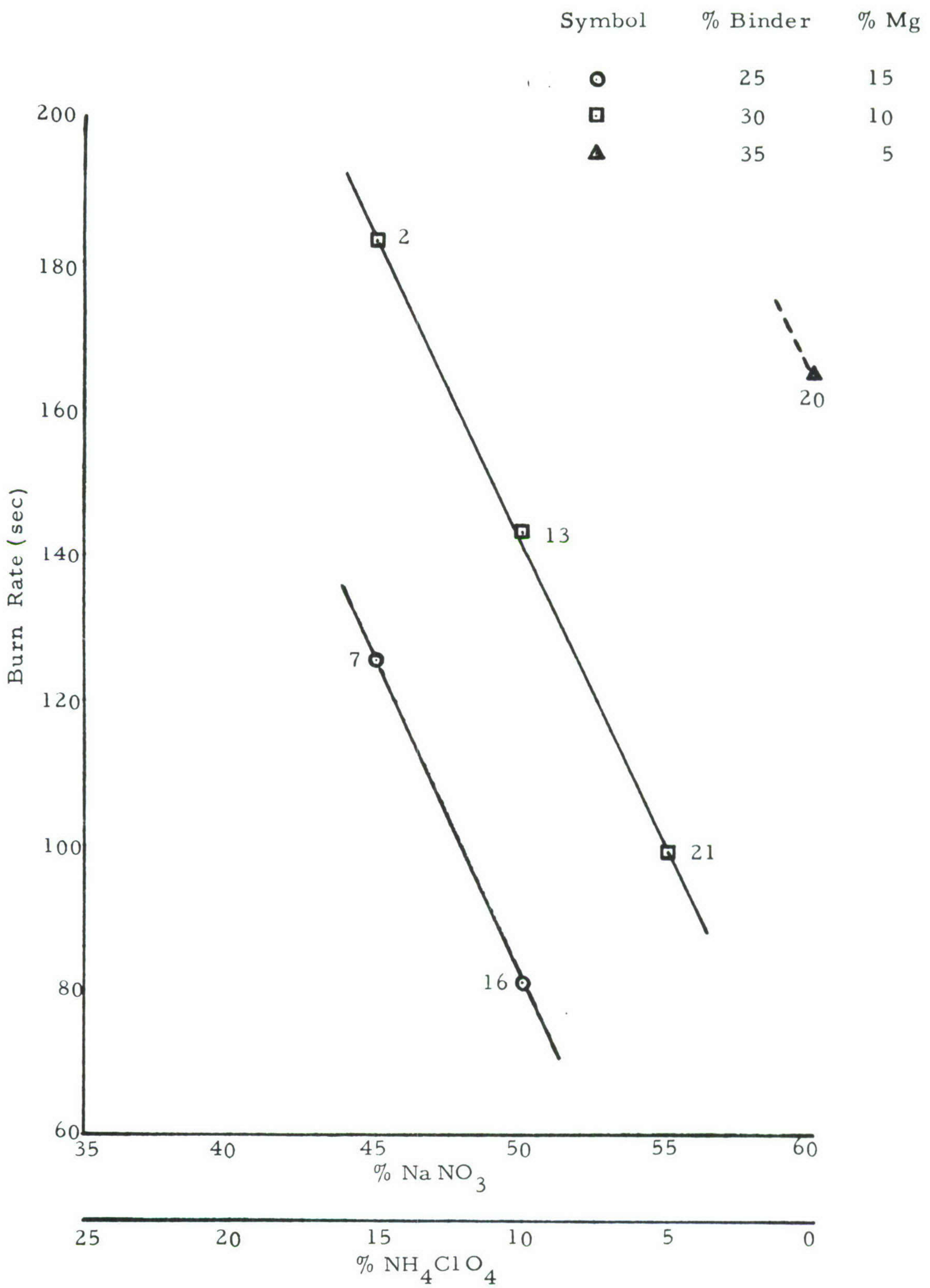


FIGURE 4 - Burning Time of Yellow Flare Compositions with Cellulose Acetate Binder

(Granulation 16 Magnesium)



problem stems from the difficulty in forming barium monochloride which produces the green flame in the combustion zone. The use of ammonium perchlorate and barium chloride in the compositions aid in formation of barium monochloride in the flame but barium chloride is difficult to vaporize and large amounts of barium chloride led to combustion instability and heavy slag. Boron and potassium perchlorate were also investigated in the compositions with limited success.

A solution to the problem was found with the use of ammonium chloride in combination with ammonium perchlorate. Ammonium chloride decomposes at a relatively low temperature and provides a source of chlorine for the barium. Ammonium chloride also increased burn time to an acceptable value as shown in Figure 5. Burn time of compositions containing a ammonium chloride was found to be relatively insensitive to barium nitrate content as shown in Figure 6. This permits low quantities of barium nitrate to be used in the composition and results in low slag formation.

The composition given below burns 120 to 125 seconds in the TMF-1 unit and produces the best quality green flame of the compositions investigated.

Ingredient	Weight %
Barium nitrate (JAN-B-162)	35.0
Ammonium chloride	5.0
Ammonium perchlorate (50 μ)	30.0
Magnesium (Granulation 17)	5.0
Cellulose acetate	12.5
Triacetin	12.5

Laboratory tests showed some yellow in the flame which may have been due to emission from the steel chimney used. While this composition was suitable for flight testing, further composition investigation was conducted to improve color intensity.

6. FLAME TEMPERATURE

The flame temperature for each color composition was measured by embedding thermocouples in the mix and observing the temperature profile as the surface burned past the thermocouple location. Maximum temperatures observed were:

FIGURE 5 - Burning Time of Green Flare Compositions as a Function of Ammonium Chloride and Ammonium Perchlorate Content

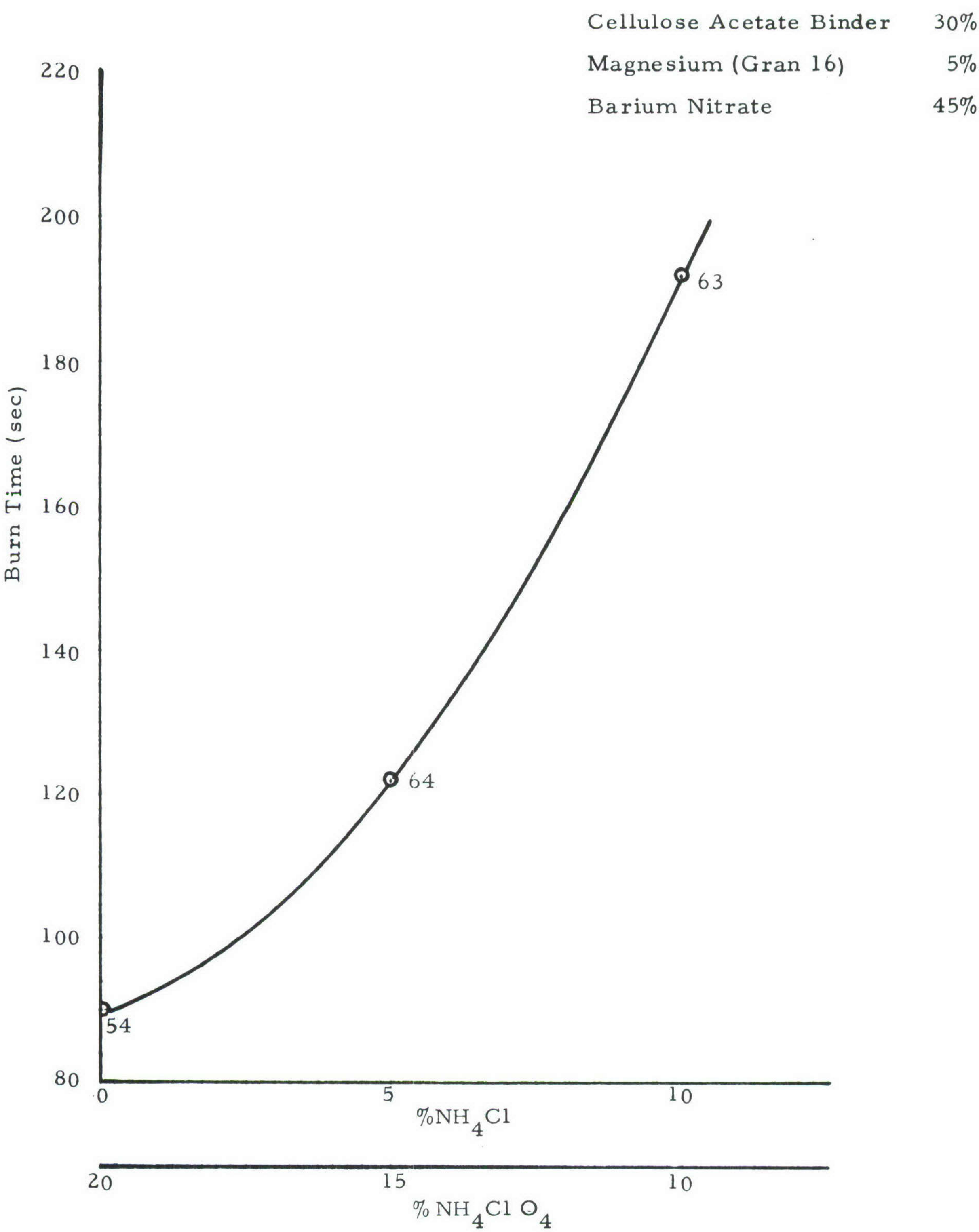
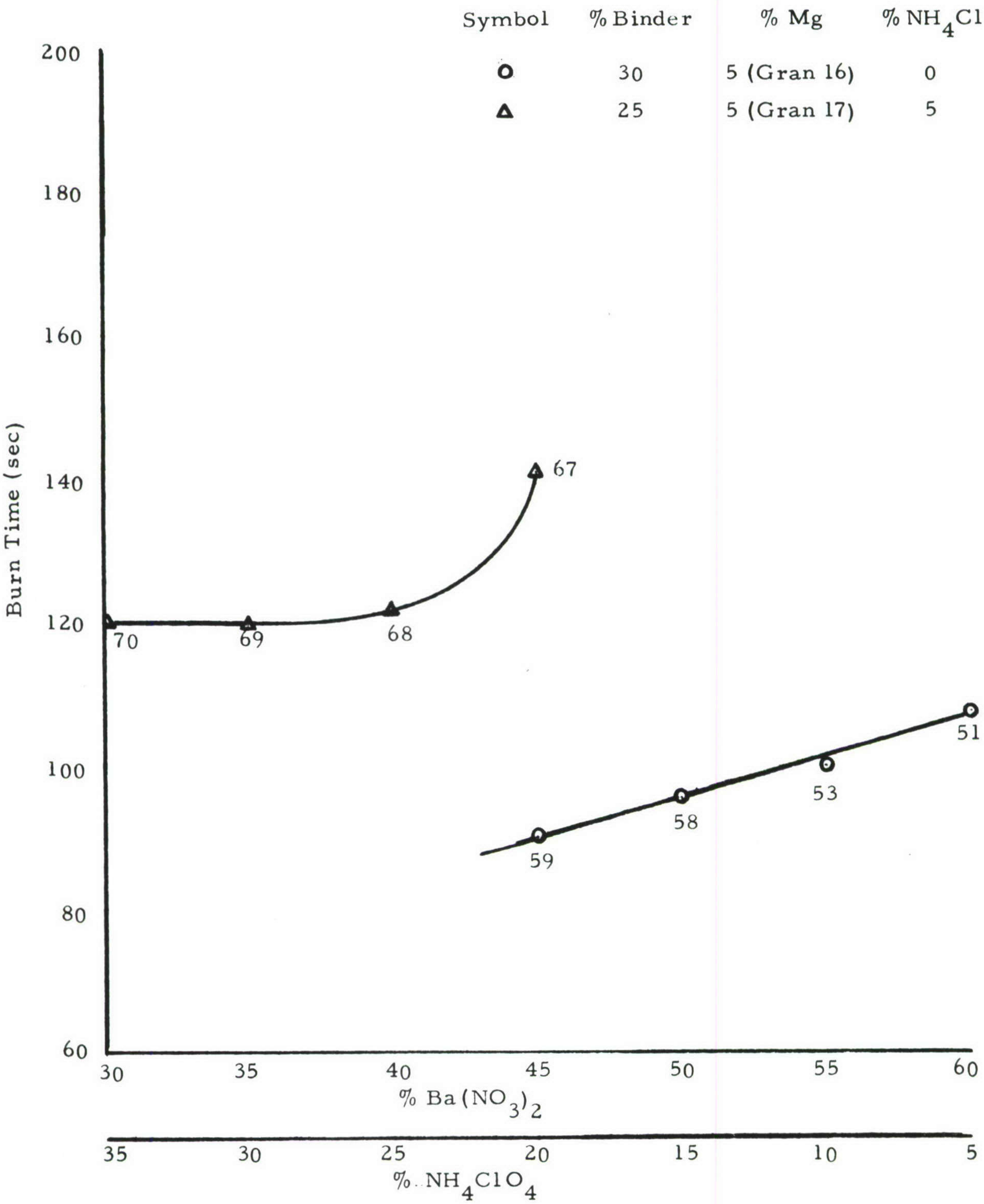


FIGURE 6 - Burning Time of Green Flare Compositions with Cellullose Acetate Binder as a Function of Barium Nitrate and Ammonium Perchlorate Content



Red (Test R-29)	2288°F
Yellow (Test Y-13)	2247°F
Green (Test G-69)	2343°F

These temperature measurements were used to aid in the selection of chimney and ballute materials. The values indicated that a steel chimney would be more adequate than the aluminum chimney of the TMF-1 design.

7. TEMPERATURE SENSITIVITY

Candles of each color, i.e., R-39 to R-42, Y-33 to Y-36, G-80 to G-83, were tested in water after four hours conditioning at the temperature extremes, -65°F and +165°F.

Burning time was not measurably affected by condition temperature. Ignition, however, was found to be less reliable at -65°F. Two candles, a yellow and a green, did not ignite after conditioning at the lower temperature.

8. BALLUTE DEVELOPMENT

Glass fabric was chosen as the basic material for the ballute on the basis of the flame temperatures of the flare compositions. Neoprene and silicone rubbers were evaluated as sealant coatings for the glass fabric.

Neoprene-coated glass was found inadequate. This material was easily ripped and was combustible in the exhaust gas environment of the flares.

Silicone-coated glass, however, was found to be a suitable ballute material. Both 5- and 7-mil fabric thicknesses were evaluated. The 7-mil fabric, RM-7 made by 3M, was the tougher of the two and was chosen for flight tests.

Holes were burned or ripped in the underside of RM-7 ballutes of the TMF-1 design during ignition in the initial flight tests. This problem was eliminated by doubling the ballute thickness on the bottom side. A modified packing technique was necessary to incorporate the additional ballute material into the unit. The technique which proved successful consisted of using vacuum for packing the ballute and rolling the edges of the material inward. With this technique, the ballute and flare canister were inserted into the body more readily than the TMF-1 design packed by the original procedure.

Two design modifications were required to insure firm ballute inflation during ignition. These were 1) a plastic insert in the chimney and 2) a reduced press pressure for the flare composition. The plastic orifice in the chimney results in a larger quantity of gas flow into the ballute during ignition. The orifice subsequently is melted, thus exposing the full chimney area following floatation of the unit. The reduced press pressures increased the gas flow rate. Burn times were also reduced but maintained a time of 110 seconds.

9. FEASIBILITY DEMONSTRATION

Eighteen rounds were tested in the feasibility demonstration phase in the presence of the Contract Technical Supervisor. Two rounds of each color were tested at night and six of each color during daylight hours. The test results are given in Appendix E.

The tests demonstrated the ability of the rounds to:

1. Sustain a flame and/or reignite after submergence in water.

2. Achieve a minimum range of 250 meters when launched at an angle of 35 degrees.

3. Burn a minimum of 90 seconds with green and yellow. The red flare burned 79 to 85 seconds.

Some effort was expended following these tests to eliminate flame pulsation with the yellow flare and increase the burning time of the red unit. The limited development effort produced no suitable improvement in the burning time of the red flare but a modification of the yellow composition resulted in smoother combustion.

The flare compositions and pressing conditions shown in Table I were frozen for the environmental tests.

TABLE I - FLOATING FLARE COMPOSITIONS

Color	Red	Yellow	Green
Composition (Wt. %)			
$Sr(NO_3)_2$	40.0	---	---
$NaNO_3$	---	45.0	---
$Ba(NO_3)_2$	---	---	30.0
NH_4ClO_4 (50 microns)	30.0	15.0	35.0
Magnesium (Gran 16)	5.0	15.0	5.0
NH_4Cl	---	---	5.0
Cellulose Acetate	12.5	12.5	12.5
Triacetin	12.5	12.5	12.5
Composition Weight (grams)	70	60	60
Pressing Force (lbs)	10,000	5,000	5,000

ENVIRONMENTAL TESTS

Sixty-six rounds were built and tested according to the plan outlined in Table I of Appendix A.

The groups I and II environmental conditioning was performed by General Testing Laboratories, Inc. The environmental test report is given in Appendix F. The flight tests of these rounds and the control units of Group VI were performed at Chemtronics and witnessed by the Contract Technical Supervisor. The results of these tests are given in Appendix G. The environmental conditioning had no adverse effects on the functional characteristics of the units.

Six units were subjected to bullet impact tests. The flare compositions were found to be insensitive to bullet impact. However, impact in the first-fire or delay resulted in ignition of these components and subsequently the flare mix. The flare composition extinguished following ejection after first-fire ignition from bullet impact. Following bullet impact of the delay, the canister ejected and the composition burned normally.

Night and day observation tests were performed with five units of each color. Observation was made from an aircraft flying at 1000 feet above ground level. The flames could be seen at ranges less than 2000 meters in daylight. At night, the red and yellow flares were visible and the color identifiable from a range greater than 3000 meters. The green flare was not color distinguishable from a range greater than 1000 meters, however.

DELIVERY ROUNDS

Eighty-four delivery rounds were manufactured with the flare compositions shown in Table I. Nine of these rounds were tested for acceptance. The acceptance test results are given in Appendix H.

Two of the three green rounds tested did not ignite due to lack of transfer energy from the first-fire to the flare composition. The green rounds were rebuilt with a layer between the first-fire and the flare composition that consisted of a mixture of the two. Three of the new green rounds were tested and successful ignition transfer was achieved. Burn times were short for these three rounds when the units sank because reused ballutes did not give proper floatation.

Twenty-five rounds of each color were delivered to the Land Warfare Laboratory for testing. The red and yellow units gave acceptable performance. The red and yellow signals were visible and color identifiable at a range exceeding 3000 meters and an altitude of 1000 feet. However, the color of the green units could not be recognized beyond a range of 1000 meters.

The green flare composition was then modified to the formulation given below and six rounds demonstrated at LWL. The modified formulation resulted in a significant improvement in the visible range, i.e., greater than 3000 meters, but was not color identifiable beyond 2200 meters. The green signal modification test results are given in Appendix I.

	Weight %
$Ba(NO_3)_2$	35.0
NH_4ClO_4 (400 μ)	20.0
NH_4Cl	10.0
Magnesium (Gran 16)	10.0
Cellulose Acetate	12.5
Triacetin	12.5

A cross section of the 40mm Floating Flare round is shown in Figure 7. The operational sequence is shown in Figure 8.

APPENDIX A - PROGRAM PLAN

(Test Plan for 40mm Floating Flare as prepared during initial planning of feasibility program.)

1. DEVELOPMENT TESTS

One hundred forty-four static tests of the flare formulation (forty-eight for each color) and seventy-five ballute tests are planned during the development phase of the program which ends in Week 17. Approximately fifteen flight tests (included in the seventy-five ballute tests) will be conducted at four strategic points throughout this phase to ascertain system compatability with M79 launching to increase confidence in the ability of the floating flare to pass the feasibility demonstration tests. The remaining ballute tests will be conducted statically in conjunction with flare formulation tests.

In evaluating the flame composition performance, the important characteristics will be ignition at temperature extremes, flare color, plume size, burn rate, and ability to sustain and reignite after splashing or submergence in water.

Initially, flame compositions in all three colors (red, yellow, and green) will be evaluated in the TMF-1 hardware using a chimney and canister but without the ballute. The grains will be ignited with a boron-potassium nitrate-teflon-laminac first fire pressed onto the grains which in turn will be ignited with a quick-match fuse cord. The flame composition tests for each color will evaluate binder content (nine tests), magnesium content (nine tests), magnesium particle size (nine tests), and nitrate content (nine tests). The two binder candidates are polyvinyl chloride and cellulose acetate plasticized with triacetin. Both are known to give pressable compositions with adequate mechanical properties and flame characteristics. As each flare formulation is finalized, tests at -65° and $+165^{\circ}F$ will be performed to determine burn rate and flare sustainment characteristics (twelve tests).

The results of each test conducted throughout the development, feasibility, and environmental and delivery acceptance will be recorded on a data sheet. Serialization of all units will begin with the initial flare formulation tests and continue through the delivery acceptance tests. The serial number will consist of the first letter of the color tested and sequential test numbers.

Thermocouple measurements at the chimney exit and burning surface will be made to obtain the flame temperatures of the red, yellow, and green flare formulations. This information will be used in selecting ballute materials with adequate mechanical properties to withstand the high temperatures of the flare combustion products. A total of five static ballute tests is planned for each color during the finalization of the flare formulation. Ballutes will also be tested in the sixty flight tests throughout the finalization of the flare formulation development.

2. FEASIBILITY DEMONSTRATION TESTS

Fifteen 40mm Floating Flare rounds (five of each color -- red, yellow, green) will be fabricated for the feasibility demonstration phase of the program. These tests will be witnessed by the Contract Technical Supervisor at NCI. The units will be fired from the M79 grenade launcher at ambient temperatures into a lake. Color films made during development will be available for review at this time. The objective of these tests is to determine the ability of the round to 1) sustain a flame, and/or reignite after submergence in water, 2) achieve a minimum range of 250 meters when launched at an angle of approximately 35 degrees, and 3) burn a minimum of 90 seconds for each of the three required colors (red, yellow, and green). Fired hardware will be recovered for subsequent inspection to determine the ability of the ballute material to survive throughout the entire burn time.

Upon completion of these tests, a design review will be conducted at NCI by LWL and NCI representatives. Approval of the feasibility demonstration test results will constitute a design freeze and will allow fabrication of the sixty-six environmental units to be started. Deficiencies encountered during these tests will be thoroughly reviewed by both LWL and NCI, and all necessary modification and retesting will be mutually agreed upon at that time.

3. ENVIRONMENTAL TESTS

A total of sixty-six units (twenty-two of each color) will be tested according to the proposed test matrix outlined in Table I.

TABLE I

	Group					
	I	II	III	IV	V	VI
Storage and transit conditions diurnal cycle (per Table 2-3, AR-70-38)	21					
Operational conditions diurnal cycle (per Table 2-3, AR-70-38)		15				
Rain fall (Per 2-8 Category 2, Wet-Hot AR-70-38)		15				
Sea salt fallout (per MIL-STD-810B, Method 509)		15				
Sand and dust (per MIL-E-5272C ASG, 4.11.3 Procedure III)		15				
Transportation and aircraft vibration (MTP 4-2-804)	21					
Bullet impact			6			
Day observation				6		
Night observation					9	
Control units (no environments)						9
Functional testing (total of 66 units)	21	15	6	6	6	9

The twenty-one Group I units and one inert unit will be packaged in an M2A1 Ammunition Box. This is the configuration in which the 40mm units would be subjected to the vibration and diurnal cycling of storage and transit conditions. The fifteen unpackaged units in Group II will be subjected to a diurnal cycle of operational conditions, rainfall, sea salt fallout, and blowing sand and dust conditions.

Six units (two of each color) have been designated for bullet impact tests. These units will be suspended vertically from a wire in front of a dirt embankment and then impacted with a 30-06 rifle slug fired at a distance of approximately 50 feet. Photography equipment will be available to record results of any units that ignite. Still photographs will be taken of units that successfully withstand this test.

Both day and night observation tests will be performed on a total of fifteen units (five of each color). These fifteen units will not be fired from the grenade launcher but will be ignited statically with a quickmatch fuze and placed in a water-filled container for the burning duration at the NCI test site.

The aircraft will fly at a minimum altitude of 1000 feet above ground level in a circular flight pattern range of 3000 meters. Photographs will be taken from the aircraft during the observation tests to document acquisition distances. Six units are planned for day observation tests and nine for night observation.

The remaining nine units are control units and therefore will not be subjected to any environments other than ambient storage.

The storage and transit conditions diurnal cycle, operational conditions diurnal cycle, and rainfall requirements will be per Category 2, Wet-Hot of AR-70-38. For sea salt fallout, it is proposed to use MIL-STD-810B, method 509 which subjects the unpackaged units to a salt concentration of approximately 1740 $gm/m^2/yr$ for 48 hours. It is also proposed to use MIL-E-5272C (ASG) 4.11.3, Procedure III sand and dust tests, to meet the blowing sand and blowing dust requirements in Category 4, Hot-Dry, plus the wind requirements in Category 2, Wet-Hot of AR-70-38. This test will subject unpackaged units to a dust concentration of 0.1 to 0.25 grams per cubic foot, at a temperature of 77°F and an air velocity of 2500 ± 500 feet per minute for a duration of three hours. The transportation and aircraft vibration tests will be conducted on packaged units per MTP 4-2-804, Curve A of Figure A-5.

At the conclusion of these tests, a joint LWL and NCI conference will be held to analyze all test results, data and photo coverage. Approval of this phase will permit the delivery unit fabrication to start.

4. DELIVERY ACCEPTANCE TESTS

With the approval of the environmental tests, a total of eighty-four units (twenty-eight of each color) will be fabricated for delivery. Nine of these rounds (three of each color) will be randomly selected for NCI acceptance testing. It is planned to function these nine rounds the same as the feasibility rounds in Week 25. Operational data will be recorded for each round and will be submitted with the load sheets on the seventy-five delivery rounds. NCI quality assurance personnel will witness these tests. LWL personnel may witness these tests, if they desire to do so.

APPENDIX C

DEVELOPMENT REPORT (EXCERPTS)

APPENDIX C

Excerpts from

TECHNICAL NOTE NO. LWL-CR-02F71A

40mm FLOATING FLARE DEVELOPMENT

Final Report
Contract No. DAAD05-72-C-0179

by

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TABLE OF CONTENTS

		Page
ABSTRACT		iii
FOREWORD		v
INTRODUCTION		1
CONCLUSIONS		6
HARDWARE DESIGN		7
1.	General	7
2.	Body	7
3.	Ballute	7
4.	Ogive	8
5.	Delay	8
6.	Chimney	8
FLARE COMPOSITIONS		10
1.	General	10
2.	Ignition Composition	10
3.	Intermediate Charge	11
4.	Flare Mix	11
TEST RESULTS		13
1.	Baseline Tests	13
2.	Green Flare Additive Tests	13
3.	Phase I Development and Qualification Tests	24
4.	Phase II Development and Qualification Tests	26
5.	Phase III Development and Qualification Tests	27
Appendix A	Baseline Green Flare Data	29
Appendix B	Test Series 1 - Green Flare Composition Data	31
Appendix C	Test Series 2 - Green Flare Composition Data	43
Appendix D	Night Visibility Green Flare Test Data	49
Appendix E	Test Series 3 - Flare Composition Data	53
Appendix F	Phase I Development and Qualification Test Data	70
Appendix G	Phase II Development and Qualification Test Data	88
Appendix H	Phase III Development and Qualification Test Data	93

HARDWARE DESIGN

1. GENERAL

The changes made to the design of the hardware during this contract effort are discussed in detail in the subsequent paragraphs.

2. BODY

The body called for in the data package and used previously on the Floating Flare round is made per Drawing 9245765. This body is not considered the standard now due to upgrading of the manufacturing tooling. The body's reduced barrel O.D. is now formed during or immediately after the basic impact extrusion operation. Formerly this reduced barrel diameter was made by a secondary machining operation. The only dimensional change in the new body is the taper angle between the forward land and barrel. This surface is now a blend versus the 30 degree angle used on the old design. With agreement of the LWL project officer, the purchase order for the bodies was amended to reflect the new standard configuration and an alteration notice (AN) was written against the assembly drawing, 040091000, allowing the optional use of alternate Picatinny Arsenal bodies 9243900 or 9255778.

3. BALLUTE

The vendor that was punching out the ballute pieces reported difficulty in preventing tearing between the I.D. and the three screw holes. From a review of the design, it appeared that the I.D. on the -2 and -3 components could be reduced from .720 + .030 inches to .65 - .05 inches. This would increase the material web between the I.D. and the three screw holes from a minimum of .025 inches to a minimum of .07 inches. In addition, the three .12 R cutouts in the I.D. didn't appear to offer any advantage to the design. Therefore, the I.D. was redimensioned and the .12 R cutout deleted on the drawing.

Because of random failures in the ballute stitched seam resulting in premature sinking, the thread size was changed from 70/2 per V-T-276 Type IA2 to 30/3 per V-T-276, Type IA1. In addition, the stitching per inch was reduced from a minimum of 25 to 15 to 20 because the closer stitched seam damaged the ballute material.

4. OGIVE

After several discussions with previous program officials and the ogive vendor, it was concluded that the ogives supplied on previous programs were made by blending 0 percent and 40 percent glass filled Lexan. The drawing calls for a 10 percent glass content in the Lexan. It was noted on the previous programs that there was a large variation in the rigidity of the ogives. This variation causes problems in the retention of the ogive in the gun barrel and subsequent ejection at delay burnout. The vendor stated that the reason for the blending of 0 percent material with 40 percent material was the fact that it was cheaper for small orders and the lead time from the material supplier for preblended material was excessive. The material supplier was contacted and asked about the advisability of a molder blending glass filled Lexan with unfilled Lexan. He said it would not work because different surface coatings are used on filled and unfilled materials. These coatings prevent proper mixing of the materials in a mold. Another problem was the ogive drawing 040055013 called for green colored Lexan by the designation MVCL 6167. The proper callout for natural colored 10 percent glass filled Lexan is 500-131.

5. DELAY

In an attempt to use as many standard components as possible in the 40MM Flare the Picatinny 40MM delay was evaluated. This delay proved highly successful and was used throughout the program. An AN was submitted on the top assembly drawing number 040091000 to allow the use of the Picatinny Arsenal delay 9243885.

Only one problem was encountered with the delays on this program and that was traced to a manufacturing technique. These delays failed to ignite the flare mix first fire. X-ray examination showed a thin layer of delay output charge between the two pressed increments. Apparently the press ram was inadvertantly depositing some of the output mix from the previous delay onto the top of the first increment of the next delay. Twenty new delays were made with the operator wiping the ram clean after pressing each delay. Tests of these delays showed the problem was corrected by this new procedure.

6. CHIMNEY

Probably the most significant improvement in performance of the hardware was made by the simplest design change. Two modes of ballute failures were observed. The most common failure was caused by slow inflation of the ballute immediately after ejection from the body. The aerodynamic forces caused the relaxed ballute to curl around the orifice of the chimney and thereby allowing the hot flame of the flare to burn a hole in the top of the ballute. The other mode of failure was simply an overpressure of the ballute stitching. All the colored flares experienced pressure increases during the early phases of burning due to slag accumulating in the chimney. The problem was especially severe with the green units and often resulted in failure of the ballutes and subsequent sinking.

In an effort to determine the reason for the slag accumulation in the chimney, units were made and flight tested with the plastic insert in the chimney extended the full length of the chimney. It was expected that the slagging would get worse due to a theory that the char of the insert acted as a catalyst for the solid components of the exhaust gases. However, the opposite occurred. The extended insert eliminated the slag accumulation and caused the ballutes to inflate faster. The char of the insert apparently prevented the char from bonding to the wall of the chimney. This change was incorporated on the Phase II and Phase III delivery rounds.

FLARE COMPOSITIONS

1. GENERAL

The flare charge design consists of an ignition starter mix, an intermediate mix and the main flare charge, all pressed simultaneously in the listed order.

The charge is a single end burner 1.29 inches in diameter and 2.19 inches in length. The following table shows a comparison between the various colored flares.

	Red	Yellow	Green
Ignition Composition Weight (gm)	3	3	3
Intermediate Charge Weight (gm)	4	4	4
Flare Mix Weight (gm)	65	56	65
Burning Surface Area (Sq. In.)	1.30	1.30	1.30
Pressed Density (gm/cc)	1.80	1.57	1.80
Average Burn Time (Sec)	88	100	88
Average Burn Rate (In/Sec)	.025	.022	.025
Press Pressure (lbs/sq. in.)	10,000-15,000	5000	5000

The three charge components were developed through an extensive series of tests listed in the Appendixes and discussed in Section IV. Details of the chosen elements of the flare charges are discussed in the following paragraphs. Note that the intermediate charge was not used in the previous feasibility program and the yellow flare mix was not changed during this program.

2. IGNITION COMPOSITION

The Boron Potassium Nitrate ignition mixture gave generally excellent results throughout the duration of the program. However, the initial weight of 1.0 gram used on the first units was increased to 3 grams early in the program to improve the ejection of the ogive and to decrease the inflation time of the ballute. Late in the program reproducible ignition of the ignition charge became a problem and the teflon binder was reduced to aid this problem. The two compositions are given in the following table.

Components	Percent by Weight Old	New
Boron	19.2	22.6
Polytetrafluoroethylene	18.2	4.6
Potassium Nitrate	57.6	67.8
Lupersol DDM	.05	.05
Resin Polyester	4.95	4.95

3. INTERMEDIATE CHARGE

Because some ignition transfer failures between the ignition composition and the flare mix occurred in the earlier feasibility program, an intermediate charge was used during this program. The intermediate mixture consisted of a blend of 50 percent by weight ignition charge and 50 percent by weight flare mix. Initially only two grams of mix were used, however during this program this was increased to three grams then to four grams as a result of random ignition transfer and ballute inflation problems

4. FLARE MIX

The primary technical objective was to improve the color quality of the green flares. The baseline formulation, which served as the performance standard, was developed late in the previous feasibility program. Initially twenty six additives were tried, however all of the additives reduced the flare burn time considerably below the 90 second requirement or caused excessive chuffing or were too high in flame temperature. Another problem which occurred with some of the additives was incompatibility with other mix ingredients. In fact the additive that gave the best color improvement, chromic chloride, sometimes reacted with the magnesium during mixing and pressing. After the additives failed to produce the desired results of increasing both intensity and color quality, the baseline formulation was optimized. This optimization resulted from a decrease in the barium nitrate by 10 percent, a removal of the ammonium chloride, and a 5 percent increase in both the ammonium perchlorate and binder and a 10 percent increase in the magnesium content. Both the baseline (old) formulation and the new formulation are given in the following table:

Components	Percent by Weight Old	New
Barium Nitrate	35	25
Ammonium Perchlorate (Class 7)	20	25
Cellulose Acetate	12.5	15
Triacetin	12.5	15
Magnesium	10 (22μ)	20 (350μ)
Ammonium Chloride	10	--

The red flare composition carried over from the previous program burned 15 seconds short of the requirements. Therefore, a modification was made to the formulation which brought the time up to the required 90 seconds. The ammonium perchlorate content was reduced 5 percent and the magnesium content was increased 5 percent. In addition, the magnesium particle size was increased from 22 microns to 350 microns. Both the old and the new formulations are listed below for comparison.

Components	Percent by Weight Old	New
Strontium Nitrate	40	40
Ammonium Perchlorate (Class 3)	30	25
Magnesium	5(22μ)	10(350μ)
Cellulose Acetate	12.5	12.5
Triacetin	12.5	12.5

The use of the new formulation initiated in Phase II of this program and performed satisfactorily throughout the balance of the program.

No changes were made to the yellow flare mix during this program. For reference, the yellow flare mix formulation is as follows:

Components	Percent by Weight
Sodium Nitrate (Class 2)	45
Ammonium Perchlorate (Class 3)	15
Magnesium (22μ)	15
Cellulose Acetate	12.5
Triacetin	12.5

This formulation performed satisfactorily throughout the program.

TEST RESULTS

1. BASELINE TESTS

To check out the green baseline composition and the intermediate igniter mix between the ignition charge and the main charge, two static tests were conducted. The test results shown in Appendix A verified the results reported in the previous feasibility program.

2. GREEN FLARE ADDITIVE TESTS

The color additives for the green flare were investigated in three separate series. The first series screened all candidate additives by simply adding two additives to the base formulation and replacing the binder. The second test series screened the best additives from series 1 by replacing one component of the basic formulation with the additive. Several additives and components were evaluated in test series 3 by multiple substitution into the basic formulation. Evaluation was carried out by static daytime tests, static night tests for range determination and daytime flight tests.

a. Test Series 1 - Additives Screening

(1) Objective

The objective of this series was to screen additives which were incorporated in the basic formulation to determine the effect on color quality.

(2) Test Method

The additives were incorporated into the basic formulation, replacing binder - 10 percent additive for 10 percent binder. Twenty-six additives, listed in Table I, were tested. Color and burn time were recorded. The most promising additives were then tested in the basic formulation by adding 10 percent to the total formulation. All candles were tested in water without a ballute. The basic formulation is as follows:

TABLE I - ADDITIVES

Cupric Nitrate	Nickel Nitrate
Cupric Chromate	Nickel
Cuprous Chloride	Nickel Chloride
Cupric Acetate	Titanium
Cuprous Oxide	Zinc
Copper	Zinc Chloride
Chromium	Borium Chromate
Chromic Chloride	Boron
Ammonium Dichromate	Zirconium
Chromic Acetate	Picric Acid
Boric Acid	Potassium Permanganate
Tetrachloro-P-Benzaquinone	Tin
Nickel Acetate	Bronze

Component	Percent by Weight
Barium Nitrate	35.0
Ammonium Perchlorate 400 Micron	20.0
Ammonium Chloride	10.0
Magnesium, Mesh $\frac{200}{325}$	10.0
Cellulose Acetate	12.5
Triacetin	12.5

(3) Results

From this series, the following compounds were selected for further investigation in test series 2:

Chromic Chloride, Chromic Acetate, Chromium Metal, Ammonium Dichromate, Titanium, Zirconium Nickel, Nickel Acetate and Nickel Chloride.

A shoot off of the first four additives which were the most effective was conducted. The most effective additive was chromic chloride. However, the effect was not as great as expected. All raw date is shown in Appendix B.

(4) General Observations

This series indicates some color improvement can be obtained with additives. Generally, the additives which improve color quality also increase burn rate. Chromic chloride, when damp, reacts with magnesium; therefore, the magnesium should be coated (chromalized) to prevent this reaction. Nickel nitrate was found to be incompatible in the basic formulation.

b. Test Series 2 - Additives Substituted for One Component

(1) Objective

The objective was to further investigate the color improvement properties of the additives selected in test series 1.

(2) Test Method

The additive replaced one component, totally or partially, that most closely related to the additive; i.e., chromic chloride replaced ammonium chloride, chromium replacing magnesium, etc. The effect of each additive on color and burn time was compared to the control baseline formulation.

(3) Results

The results of test series 2 indicated that some color improvement may be obtained from certain additives. The best additives are listed as follows:

Chromic Chloride
Chromic Acetate
Chrome Metal

Intensity of the flare improved color to some extent, at the expense of shorter burn time.

Removal of the phenolic liner insulator tended to improve the color by reducing the amount of yellow seen in the plume with approximately 10 to 15 percent loss of burn time when tested in water. Raw data on this test series are shown in Appendix C.

c. 3500-Meter Night Visibility Tests

(1) Objective

The two major objectives of this test group were to determine if chromic chloride additive gives a more recognizable color than the control baseline formulation, and to determine if a more intense flare is more recognizable than the basic formulation.

(2) Test Method

Each test formulation was compared directly to the basic formulation. Each unit was tested without a ballute in water. The observation area was 3500 meters distant and 300 meters above the test sight. Weather was clear with a slight haze; visibility was greater than 10 miles.

(3) Results

Thirty-five hundred (3500) meter night visibility tests showed chromic chloride additive to improve the color when compared to the control. A deep rich "stop light" green was observed. The intensity was less than that of the control formulation, and neither one was really adequate.

The more intense burning formulations such as the polyvinyl chlorides were definitely recognizable as green. The color quality was about equal to the control units, but more intense. Boric acid additive improved the color to some extent, while reducing burn rate significantly. However, color improvement from boric acid was not as great as that from chromic chloride.

These intense formulations were used for intensity only. They are not suitable for the 40MM floating flare because of high flame temperatures, excessive slagging properties and drastic reductions of burn time. The data from the night visibility test are presented in Appendix D.

d. Test Series 3 - Multiple Substitution

(1) Objective

The objective of this series was to determine the effects multiple substitution of components and additives on the basic formulation's color quality and burn time.

(2) Test Method

Additives including boron, chromic chloride, polyvinyl chloride, potassium perchlorate, and teflon were substituted for various ingredients in the basic formulations. In addition, the granulation size of both the magnesium and ammonium perchlorate was varied and the effects noted. The burn time was recorded by a stop watch and the intensity by a photocell.

(3) Results

The primary results of this test series is shown on the graphs of Figure 3 through 6 and the raw test data is presented in Appendix E. Figure 3 is a plot showing the effect of magnesium and ammonium perchlorate particle sizes on intensity. The optimum particle size for ammonium perchlorate is 400 microns, while the optimum size for magnesium appears to be above 400 microns. This is one reason why 400 micron ammonium perchlorate and 350 microns magnesium is being used on the new green formulation.

Figure 4 shows the effect of magnesium percent on the intensity measurement. The family of curves was generated by substituting magnesium for various components in the basic formulation. Note that light intensity is very sensitive to the magnesium content and that the substitution of granulation 16 (22 microns) magnesium for ammonium chloride gives the greatest intensity.

The above is the reason why ammonium chloride was dropped from the formulation in favor of more magnesium.

Granulation 16 magnesium had to be changed to granulation 18 in order to maintain the proper burn time. This will be discussed later in the report.

The effect on intensity and burn time of varying the amount of barium nitrate is shown in Figure 5. The effect is not as great as the variations in magnesium content.

Figure 6 shows the influence of magnesium on burn time. Note that a two percent increase in magnesium reduces the burn time approximately ten seconds. Another significant fact obtained from Figure 6 is that approximately a 30-second burn time increase was obtained by using 350 micron size magnesium instead of the 22 micron size of the control formulation. Because of the short duration problem mentioned above, 350 micron magnesium was finally selected.

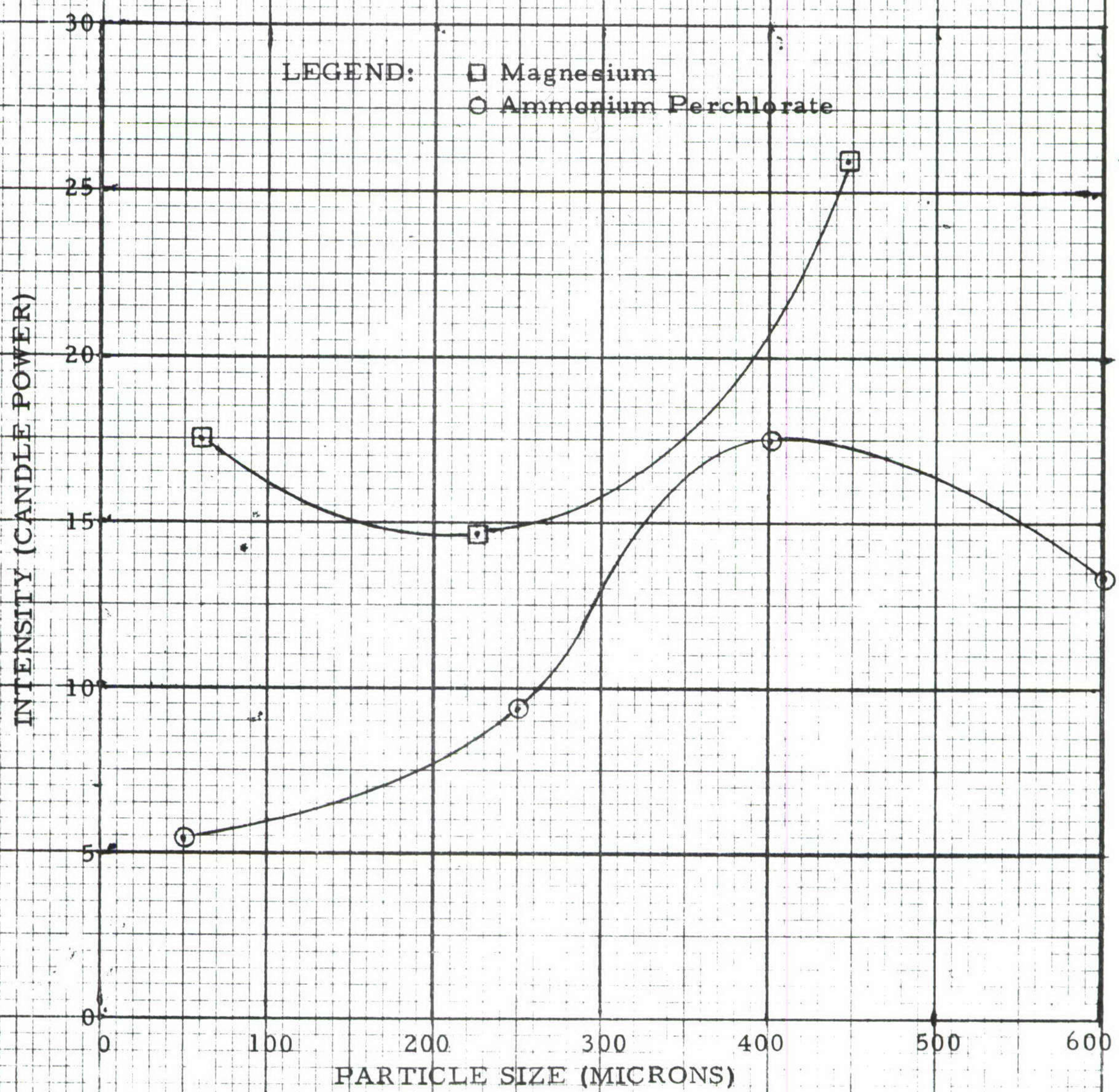

Figure 3 - Intensity as a Function of Particle Size

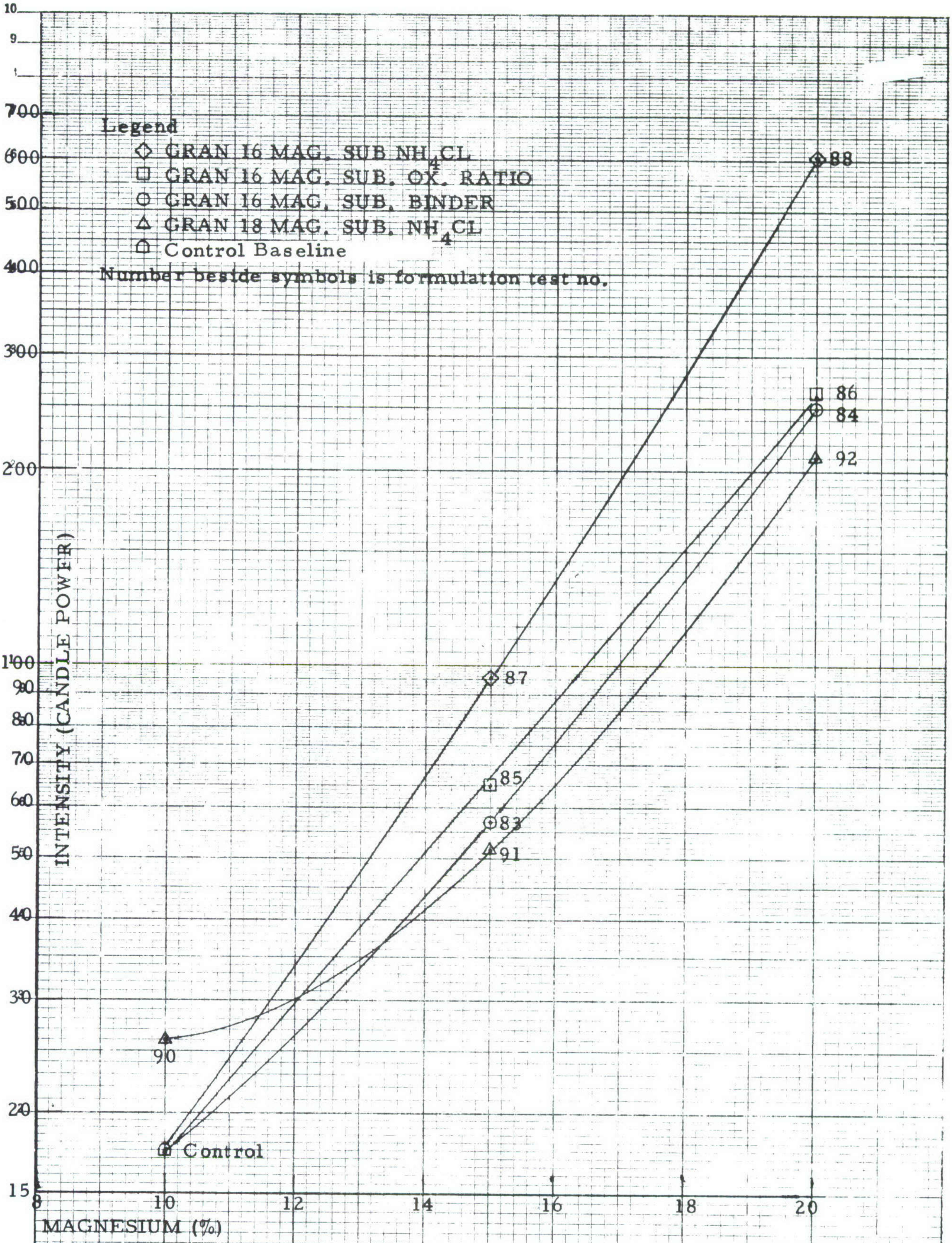

Figure 4 - Intensity as a Function of Magnesium Content

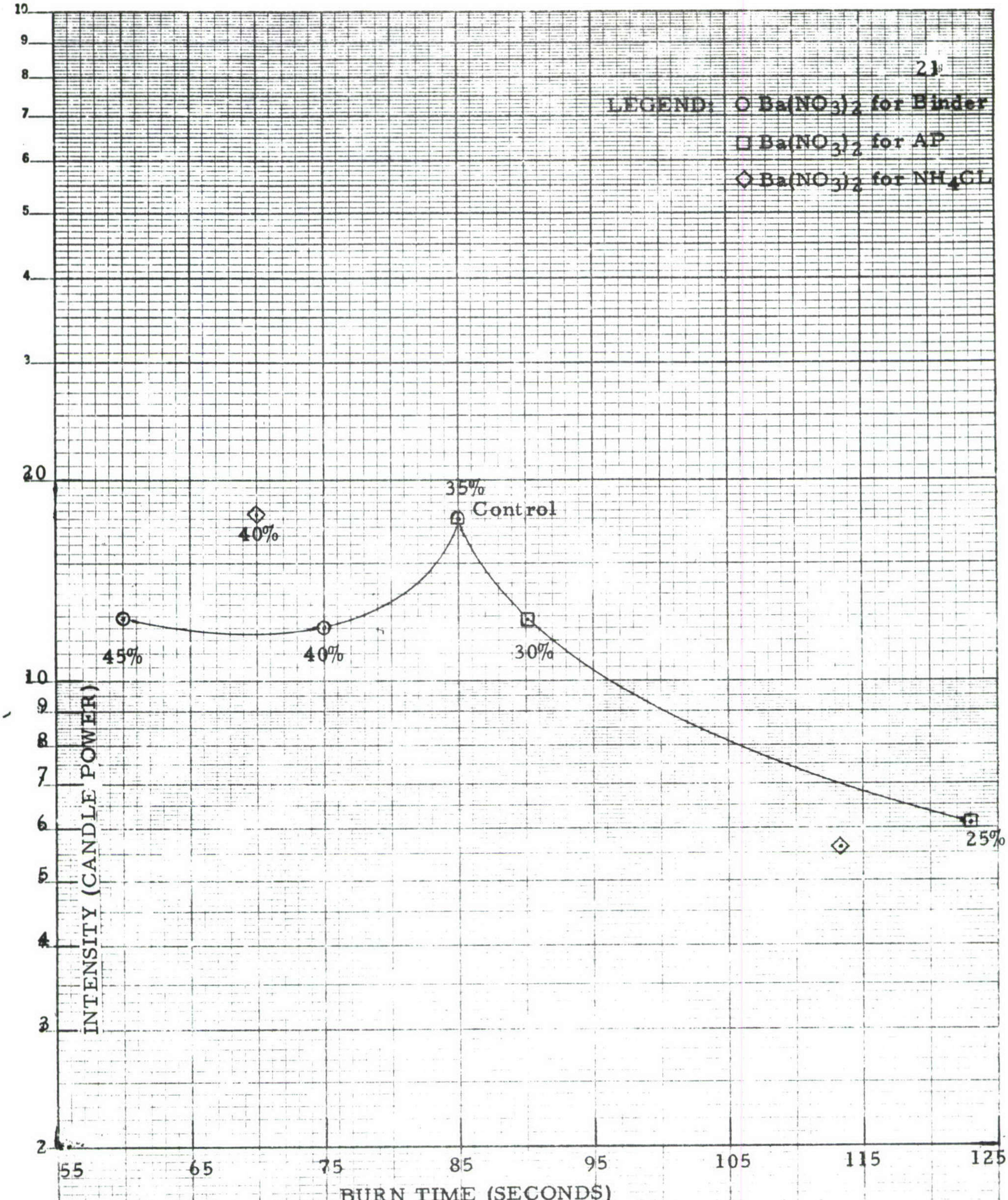

Figure 5 - Effects of Varying $Ba(NO_3)_2$ Content

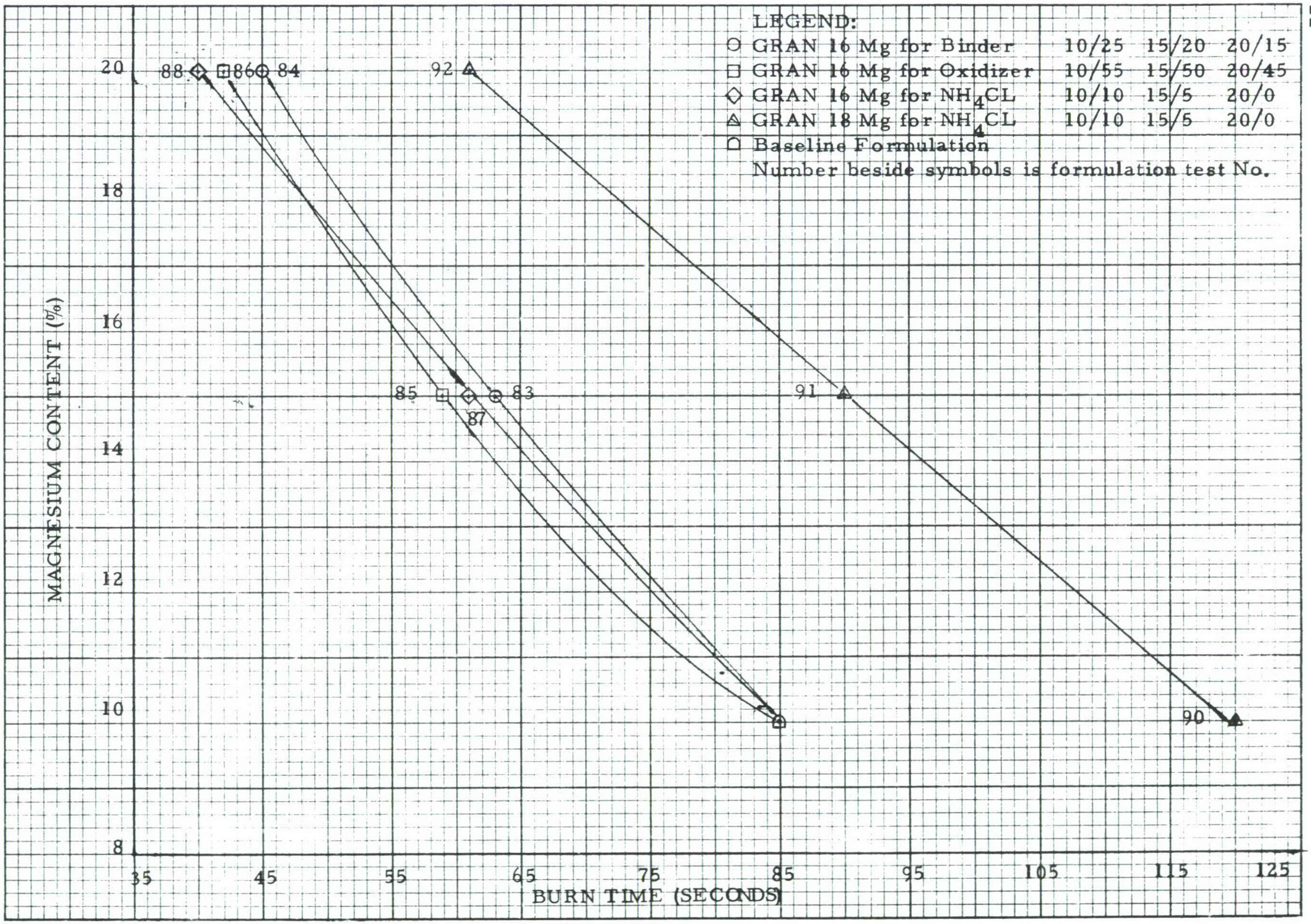

Figure 6 - Burn Time as a Function of Magnesium Content

Pressing pressure was evaluated in test series 119 through 122. By increasing the quantity of mix from 60 grams to 70 grams while maintaining the same charge volume, the burn time increased approximately 5 to 7 seconds. Therefore, the compaction pressure is not considered critical.

The use of a chrome plated chimney to prevent iron off of the chimney from entering the gas stream was evaluated in Test 149. The advantage of the plating was not significant.

In summary, the formulation that gave the best combination of intensity and burn time uses less barium nitrate, more ammonium perchlorate, magnesium, and binder than the baseline mix. This formulation also has no ammonium chloride coolant. Both the baseline formulation and the new formulation are listed below for comparison.

	Percent by Weight	
	Baseline	New
Barium Nitrate	35.0	25.0
Ammonium Perchlorate (400μ)	20.0	25.0
Magnesium	10.0 (22μ)	20.0 (350μ)
Cellulose Acetate	12.5	15.0
Triacetin	12.5	15.0
Ammonium Chloride	10.0	0

3. PHASE I DEVELOPMENT AND QUALIFICATION TESTS

The projectile tumbling problem, which had occurred randomly in previous flight tests, was solved by switching to a relatively new gun barrel. As shown by the data sheets in Appendix F, tumbling did not occur after the newer gun barrel was used.

Sinking rarely occurred after increased stitching on the ballute was used. Thereafter, sinking usually could be attributed to a ballute that had been pinched or cut during assembly.

The next test series, 209 through 214, showed an ignition problem in transferring from the delay to the first fire layer. This was the first tests of the second lot of delays and therefore the delays were suspect. In fact, in test 211 the unit was recovered and the delay had expelled a portion of the tungsten composition into the projectile body. X-ray examination of the delays showed the presence of delay first fire between the two increments of tungsten composition. The delay vendor was contacted to correct the problem.

In order to circumvent the delay problem and continue testing, five green units were fabricated with one gram of FFG black powder in the first fire and five standard green units were fabricated at the same time as control rounds. However, the black powder did not aid the first fire ignition and ogive ejection because of the delay problem. Two out of the five rounds containing the black powder were duds. The test results and data are shown in Appendix F. Serial numbered rounds 216, 218, 220, 222 and 224 had the black powder additive in the first fire. The other five units, 215, 217, 219, 221, and 223 were built like the previous units without any black powder in the first fire. One dud was experienced from this group.

Ten green units were fabricated to evaluate the new, carefully made delays. The flare ingredients were dried overnight at 150°F. The ten rounds were assemblied and flight tested. All ten units functioned satisfactorily proving the new delay pressing procedure. The data on the flight tests of these ten rounds are shown in Appendix F (S/N 225 through 234).

Ten additional green units were fabricated and tested to checkout a new batch of 120 delays. These units (S/N 235 through S/N 244) also were used to verify the assembly technique of a new technician.

As can be seen from the data in Appendix F, the delays functioned normally with time ranging from 5 to 5.8 seconds. However, the technician inadvertantly left out the plastic orifice in the chimney. The first four units were fired into water and tumbling was observed after flare ejection. Normally when this occurs the ballute has a hole or a ripped seam. To determine the specific nature of the failure, unit 239 was fired onto land and recovered. The stitched seam on the ballute's outer circumference was broken. The remaining five units were disassembled and rebuilt with the plastic orifice. All of these five rounds functioned normally. Although the reason why the lack of an orifice causes ballute seam damage was not fully understood the effect was extreme.

Green units 245 to 254 were fabricated and tested to check out a new batch of first fire and to evaluate the effect of a cut ballute on flotation performance. From the data shown in Appendix F, only 6 out of 10 functioned satisfactory. However the units with the cut ballutes functioned adequately. The ejection of the flare from the projectile body was sluggish which is a problem associated with the combined effects of delay venting, first fire combustion, chimney orifice insert and ogive joint. In order to aid in determining the cause of the failure, five units from the same batch were disassembled and inspected. These units, 255 to 259 were found to have been assembled correctly and were reassembled with different ogives to see if ogive ejection was the source of the problem. Ogives on units 255 and 256 were replaced with white ogives, a design which was used on the previous program. 257 and 258 were repacked with new ogives of the current configuration. 259 was repacked with the original ogive. As shown in the appendix only one unit failed to function properly. Unit 257 which had been repacked with a new ogive sank. Even though this test series showed that the ogive could be a contributor in the sinking problem it is one of the most difficult elements in the chain to modify. Lack of quantative data on slot configuration, glass content and lip design make the ogive release force the most difficult to evaluate analytically. Therefore, it was decided that a review of the first fire should be made. Previous batches of first fire were made with the ingredients unscreened. The first fire batch for units 245 to 259 was made by screening the ingredients in an attempt to get more uniform mixture. Ten green units were made by the earlier process and flight tested. As shown by the data sheets for units 260 to 269 all units functioned normally. This successful test series tended to prove that the method of first fire processing was the cause of the previous sinking problems.

Units 270 to 301 were fabricated and tested for the qualification of the green flare batches. The test results were not perfect but satisfactory.

A special static test series was conducted with green flare units 302 to 307. Zinc, cadium and nickel plated chimneys were used to see if color quality would be affected. No effect was noted.

Because of random ballute seam failures, the thread size was increased from a number 50 to a number 40 for the subsequent units. Units 308 to 331 were qualification tests for all three colors. Because two out of five red units on the last batch failed, the batch was rejected. It was observed that the red units tended to flame out in flight tests. To observe this phenomenon more closely, two units from the same defective batch were burned in the laboratory. Units 332 and 333 functioned normally with the flame standing off from the chimney. However, because of the poor flight tests, the batch was rejected. The new batch was tested with units 334 to 337. Since only one unit sank, the batch was accepted. It was speculated that a hole burned in the ballute may have caused the unstable descent and sinking of that one unit.

Two units, 338 and 339, were made in the laboratory to determine if a longer-burning-duration flare could be achieved with a modified red formulation. The magnesium particle size and quantity was increased from 22 microns and 5 percent to 350 microns and 10 percent. The ammonium perchlorate content was reduced from 30 percent to 25 percent. The last unit burned 91 seconds, which is a substantial improvement over what was previously achieved. Both the old and the new formulation are listed below for comparison.

Components	Percent by Weight Old	Percent by Weight New
Strontium Nitrate	40	40
Ammonium Perchlorate (50μ)	30	25
Magnesium	5 (22μ)	10 (350μ)
Cellulose Acetate	12.5	12.5
Triacetin	12.5	12.5

4. PHASE II DEVELOPMENT AND QUALIFICATION TESTS

Green units 340 to 350 were fabricated and tested for Phase II qualification. However, as shown in Appendix G, four units had trouble in ejecting the slag buildup in the chimney. During the course of the subsequent investigation an attempt was made to isolate the source of the slag buildup. One theory was the char from the plastic chimney insert acted as a catalyst causing the solid exhaust products to condense out on the inside of the chimney. Therefore, to check out this theory, three units (S/N 351, 352 and 353) were static tested with the plastic insert the full length of the chimney. This was expected to cause an increase in the slag accumulation. However, the opposite occurred, there was no slagging of any kind and all three units burned smoothly. Flight tests conducted on green units numbers 354 to 363 also verified that the longer insert eliminates the slag buildup in the chimney. One reason that the longer insert may have prevented slagging is the hot char layer that the insert creates prevents condensation of the solid exhaust products. In addition, the char surface may prevent a strong bond of the solid products to the chimney.

Units 364 to 373 were flight tests for red color qualification. All units performed very satisfactory. All ten red units also employed the longer insert in the chimney and the new formulation.

The qualification units for the yellow (374 to 381) also performed quite satisfactory with the full length plastic chimney insert. Unit 382 was an extra red unit that was tested with the yellow rounds and it too functioned normally.

5. PHASE III DEVELOPMENT AND QUALIFICATION TESTS

Because of doubts about the exact specification for the ammonium perchlorate used in two of the colors, a sieve analysis was performed on three samples. This granulation analysis was conducted in accordance with method 201.1 of MIL-STD-1234 and the results are given below.

		% Passing thru Sieve			% Retained on Sieve		
		Sample			Sample		
U.S. Sieve	Microns	1	2	3	1	2	3
100	149	100	100	100	0	0	0
140	105	96	95	95	4	5	5
200	74	74	72	70	26	28	30
325	44	69	71	69	31	29	31

From the above analysis it appears that the ammonium perchlorate sometimes referred to as 50 micron size should be specified as Grade B, class 3 of MIL-A-192.

Phase III qualification started with eighteen green rounds (383 to 400), however as shown by the test data in Appendix H only eleven functioned satisfactory. Seven rounds failed to eject at delay burnout and two of these rounds vented through the delay causing the rounds to go propulsive. From past experience it was immediately concluded that these failures were caused by the slowness of the ignition mix. This problem had occurred before and was solved by very careful control of the manufacturing procedure. However, because of the reoccurring ignition problem it was decided to reduce the binder content. The ignition charge has two different binders, lupersol DDM/polyester and teflon. In addition, the binder quantity is quite high, over twenty three percent. Therefore, five rounds (401 to 405) were made and tested using an ignition mix with twenty five percent less teflon. Two rounds functioned satisfactory, one ejected and burned under water and two rounds went propulsive. Units 406 to 408 were fabricated and tested to determine the effect of no teflon in the ignition mix. All three of these rounds performed normally except that all three sank immediately after burnout. It was concluded that the greater pressurization rate of the ignition mix without teflon must have ruptured the ballutes. If this was the case then premature sinking could occur. Therefore, five rounds (409 to 413) were manufactured with seventy five percent less teflon in the ignition charge and test fired. As shown in Appendix H all but one round experienced good ejection and flotation. One unit had a delay failure which could not be assigned as an ignition failure. To confirm the success of the above tests and to complete qualification of the green flares, Units 414 to 426 were fabricated and tested with seventy five percent less teflon in the ignition mix. All but one round performed normally. The one failure was believed to have been caused by a delay failure since no spit was seen from the delay at the proper ejection time.

Units 427 to 446 were flight tests for red color qualification. All twenty units performed very satisfactory.

Units 447 to 461 were flight tests for yellow color qualification. All of these rounds functioned completely as shown in Appendix H.

APPENDIX D

ENGINEERING DESIGN TEST PLAN

APPENDIX D

TEST PLAN
for
ENGINEERING DESIGN (SAFETY EVALUATION) TEST
of
40mm FLOATING FLARE, LWL Task 02-F-71

1. Rough Handling Tests: Eighty-eight (88) flare cartridges (29 red, 29 yellow, and 30 green) will be subjected to sequential rough handling as described in MTP 4-2-602. Items will be withdrawn at various stages of the sequence and fired for performance data as described in Paragraph 8 and recoil data as described in Paragraph 9.

a. The Seven-Foot Packaged Drop Test shall be conducted as indicated in Appendix E of MTP 4-2-602. First, repackage the flare cartridges so that each M2A1 Ammunition Box contains a sampling with a 7-8-7 color distribution. Then place two M2A1 boxes in each of two wire-bound boxes. Condition one box at -50°F and the other at +145°F for sufficient time to assure complete temperature stabilization. Drop each package in the following cartridge orientations: horizontal, base down, nose down, 45° base down, and 45° nose down. Pull one cartridge of each color from each M2A1 box for performance tests and an equal number for recoil tests.

b. The Loose Cargo Test shall be conducted as indicated in Appendix A of MTP 4-2-602 with the exception that loose packages are used rather than loose cartridges. Add cylinders of equivalent size and weight to compensate for the cartridges removed following the seven-foot packaged drop test. Omit the wire-bound boxes from the test. Repeat the temperature conditioning of the previous test. Bounce one M2A1 box for each temperature condition parallel to, and the other box perpendicular to, the longitudinal axes of the flare cartridges. Pull one cartridge of each color from each M2A1 box for performance tests and an equal number for recoil tests.

c. The Five-Foot Drop Test shall be conducted as indicated in Appendix D of MTP 4-2-602. Repeat the temperature conditioning of the previous tests. Conduct five-foot drop tests of 10 cartridges from each M2A1 box as follows: drop 2 cartridges of different colors so as to impact in a horizontal orientation, 2 base down, 2 nose down, 2 45° base down and 2 45° nose down. Submit one cartridge of each color from each M2A1 box for recoil tests; submit the balance (7 per box) for performance tests.

2. High Humidity, Steady State Test: Condition eighteen (18) flare cartridges (6 of each color) in accordance with MTP 4-2-820, Paragraph 6.2.1. After conditioning at 120°F and 95% relative humidity for 360 hours, return to standard conditions and examine the test items, recording any evidence of materiel deterioration. After examination, withdraw one cartridge of each color for recoil tests (Paragraph 9) and fire the other 15 at ambient temperature (+50° to +90°F) for performance data (Paragraph 8).

3. Waterproofness Test: After precise weighing, submerge twelve (12) flare cartridges (4 of each color) in 3 feet of fresh water at $70^{o}F \pm 5^{o}F$ for 2 hours. After removal from the water, wipe off moisture, allow to air-dry for approximately 1 hour, and again weigh each cartridge. Approximately 4 hours after removal from the water, fire 6 cartridges (2 of each color) from an M79 Grenade Launcher at ambient temperature ($+50^{o}$ to $+90^{o}F$), recording performance data (Paragraph 8). Approximately 48 hours after removal from the water, fire the remaining 6 cartridges. Note: If any cartridges show an increase in weight as a result of immersion, alternate them between the two tests with the one showing the greatest increase being placed in the 48-hour group, the next greatest increase in the 4-hour group, etc.

4. Vibration Test: Twenty-four (24) flare cartridges (8 of each color) will be subjected to a Laboratory Vibration Test, as described in MTP 4-2-804, to simulate 1000 miles of 2-wheel trailer transport and one hour of aircraft flight. Six (6) cartridges (2 of each color) will be placed in each of 4 M2A1 Ammunition Boxes along with dummy weights to simulate the actual gross weight and packing of the box. Precondition 2 boxes at $-50^{o}F$ and then test with the 2 boxes positioned so as to provide testing along 2 axes. Precondition the other 2 boxes at $+145^{o}F$ and then also test in 2 axes. Record data as indicated in the MTP. After examination, fire 12 cartridges (4 of each color) at ambient temperature ($+50^{o}F$ to $+90^{o}F$) for performance data (Paragraph 8). Set aside the remaining 12 cartridges for recoil tests (Paragraph 9).

5. Forty-Foot Drop Test: Eighteen (18) flare cartridges (6 of each color) will be subjected to the Forty-Foot Drop Test as described in MTP 4-2-601. Three (3) cartridges (1 of each color) will be placed in each of 6 M2A1 Ammunition Boxes along with dummy weights to simulate the actual gross weight and packing of the box. These boxes will be packages in 3 wire-bound boxes. One box will be dropped from a height of forty (40) feet to impact on a steel plate in a bottom down orientation; the second in a top down orientation; and the third in a top corner down orientation. The criteria for passing the test is that the signals neither burn nor detonate on impact and that they be safe to handle for disposal purposes. Inspect for damage to packaging, damage to contents (if visible), signs of spillage of propellant or flare compositions, and indications of burning or detonation. Photograph damage to test items.

6. High-Temperature Storage and Operation: Thirty-six (36) flare cartridges (12 of each color) will be subjected to cycled exposure for 7 days according to the following daily schedule:

(1) Six (6) hours at $+94^{o}F$, 15 to 20% relative humidity.

(2) Six (6) hours increasing to $+160^{o}F$, less than 5% relative humidity.

(3) Four (4) hours at $+160^{o}F$, less than 5% relative humidity.

(4) Eight (8) hours decreasing to $+94^{o}F$.

After the exposure period, the temperature will be raised to +125°F and maintained for 16 hours. Twelve (12) cartridges (4 of each color) will be removed (one at a time), examined, and fired (as soon as possible) for performance data (Paragraph 8). Six (6) additional cartridges (2 of each color) will be removed (one at a time), examined, and fired (as soon as possible) for recoil data (Paragraph 9). The temperature will then be raised to +160°F and maintained for 8 hours. Twelve (12) cartridges (4 of each color) will be removed (one at a time), examined, and fired (as soon as possible) for performance data. The final 6 cartridges will then be removed (one at a time), examined, and fired (as soon as possible) for recoil data. (Note: This test is based on the diurnal cycles for the hot-dry category of AR 70-38; it is similar in design to that described in MTP 4-2-131 with the exception that the extreme temperature range has been made more severe.)

7. Low Temperature Storage and Operation: Thirty-six (36) flare cartridges (12 of each color) will be stored for 3 days at -70°F. At the end of this period, 12 cartridges (4 of each color) will be examined and fired for performance data (Paragraph 8). These rounds will be removed one at a time and fired as soon as possible after removal. An additional 6 cartridges (2 of each color) will be removed (one at a time), examined, and fired (as soon as possible) for recoil data (Paragraph 9). The temperature will then be raised to -45°F and maintained for 24 hours. Twelve (12) cartridges (4 of each color) will be removed (one at a time), examined, and fired (as soon as possible) for performance data. The remaining 6 cartridges (2 of each color) will be removed (one at a time), examined, and fired (as soon as possible) for recoil data. (Note: This test is based on diurnal cycles for the extreme cold category of AR 70-38; it is similar in design to that described in MTP 4-2-131 with the exception that the extreme temperature range has been made more severe.)

8. Performance Measurements: Performance data will be recorded for the firing of one hundred sixty-nine (169) flare cartridges (56 red, 56 yellow, and 57 green) from an M79 Grenade Launcher at an elevation of approximately 45° toward an impact area covered by a minimum of 4 inches of water throughout the range interval from 250 to 325 meters. Markers should be placed at 10-meter intervals to permit observation of range to impact. The cartridges to be fired shall be selected from those that have undergone various conditioning treatments as follows: one of each color from each M2A1 box from the seven-foot packaged drop test (4x3), one of each color from each M2A1 box from the loose cargo test (4x3), seven from each M2A1 box from the five-foot drop test (4x7), five of each color from the high humidity test (5x3), four of each color from the waterproofness test (4x3), four of each color from the vibration test (4x3), eight of each color from the high temperature storage test (8x3), eight of each color from the low temperature test (8x3), and ten control rounds of each color (10x3). All firings will be conducted at ambient temperature (+50° to +90°F) except those involving the high and low temperature storage tests; those rounds will be fired as soon as possible after removal from the conditioning chamber. (Note: During these tests, it would be desirable to have 50% of the rounds from the vibration test fired from the M203 Grenade Launcher attached to the M16A1 Rifle.) The following measurements and observations will be recorded:

a. Round identitication number, color, and prefiring conditioning information.

b. Delay time (time from launch to function) to the nearest 0.1 second using a stopwatch.

c. Burn time (time of visible signal of desired color) to the nearest second using a stopwatch.

d. Range to impact in meters.

e. Projectile flight characteristics...stable; wobbled; tumbled; etc.

f. Altitude at function...near apex; descended 1/3; descended 2/3; just before impact; underwater; etc.

g. Flotation characteristics...OK; on side; barely afloat; sank; etc.

h. Unusual observations...projectile stuck in launcher bore; unusually loud or soft ejection (function); holes identified in ballute after recovery; etc.

9. Recoil Impulse Measurements: The firing impulse will be measured for a total of sixty-nine (69) signal cartridges (2 of each color) using the ballistic pendulum method described in MTP 3-2-059 and firing them from the M79 Grenade Launcher. The cartridges to be fired will be selected from those that have undergone various conditioning treatments as follows: one of each color from each M2A1 box from the 7-foot packaged drop test (4x3), one of each color from each box from the loose cargo test (4x3), one of each color from each box from the 5-foot drop test (4x3), one of each color from the high humidity test (1x3), four of each color from the vibration test (4x3), four of each color from high temperature storage (4x3), four of each color from low temperature storage (4x3), and two control signals of each color (2x3). Determine and record the recoil impulse in lb-sec for each round fired.

10. Shoulder Firing: If the recoil measurements are below 3.5 lb-sec, a minimum of two of the control rounds of each color should be shoulder fired from the M79 Grenade Launcher during the course of the Performance Measurements (Paragraph 8). Comments of the gunner should be recorded.

APPENDIX E

ENVIRONMENTAL AND PHYSICAL TESTING REPORT (EXCERPTS)

APPENDIX E

Excerpts from Contractor's Report on Environmental and Physical Testing (Appendix A of Technical Note No. LWL-CR-02F71B, Report of Test on Engineering Design and Safety Evaluation of 40mm Floating Flare, June 1973)

REPORT ON ENVIRONMENTAL TESTING OF 40mm FLOATING FLARE FOR AAI CORPORATION

A. A. Ellis
General Environments Corporation
Hartwood, Virginia 22471

April 1973

3.0 Test Results

3.1 Seven Foot Drop Test

The wire bound wood boxes were broken open, the M2A1 boxes were deformed and the plastic windshields in the forward end of the 40MM Floating Flares were dislodged on impact as a result of the drop test from a height of seven (7) feet.

3.2 Loose Cargo Test

Abrasion of the finish on the M2A1 boxes and the plastic windshields in the forward end of the 40MM Floating Flares were dislodged as a result of the loose cargo (bounce) test with a duration of five (5) minutes on each of six (6) faces of the M2A1 boxes.

3.3 Five Foot Drop Test

Denting of the 40MM Floating Flares resulting from the drop test from a height of five (5) feet is documented in Table IV.

3.3 Five Foot Drop Test (continued)

TABLE IV

Flare No.	Orientation	Temperature (^oF)	Result
13	Horizontal	-50	Dent nose & base
14	Base down	-50	Dent base
15	Nose Down	-50	Dent nose
16	45° Base Down	-50	Dent base
17	45° Nose Down	-50	Dent nose
18	Horizontal	-50	Dent nose & base
19	Base Down	-50	Dent base
20	Nose Down	-50	None
21	45° Base Down	-50	Dent base
22	45° Nose Down	-50	Dent nose
35	Horizontal	-50	Dent nose & base
36	Base Down	-50	Dent base
37	Nose Down	-50	None
38	45° Base Down	-50	Dent base
39	45° Nose Down	-50	Dent nose
40	45° Nose Down	-50	Dent nose & base
41	45° Base Down	-50	Dent base
42	Nose Down	-50	None
43	Base Down	-50	None
44	Horizontal	-50	Dent base
57	Horizontal	145	Dent base
58	Base Down	145	None
59	Nose Down	145	Dent nose
60	45° Base Down	145	Dent base
61	45° Nose Down	145	None
62	Horizontal	145	Dent base
63	Base Down	145	None
64	Nose Down	145	None
65	45° Base Down	145	Dent nose
66	45° Nose Down	145	Dent nose
79	Horizontal	145	None
80	Base Down	145	None
81	Nose Down	145	Dent nose
82	45° Base Down	145	Dent base
83	45° Nose Down	145	Dent nose
84	45° Nose Down	145	Dent nose
85	45° Base Down	145	Dent base
86	Nose Down	145	Dent nose
87	Base Down	145	None
88	Horizontal	145	None

3.4 High Humidity (Steady State)

There was no apparent indication of deterioration and/or damage to the 40MM Floating Flares as a result of the high humidity test exposure.

3.5 Waterproofness Test

There was no apparent indication of deterioration and/or damage to the 40MM Floating Flares as result of the waterproofness test. Test articles weight prior to and after testing is documented in Table V.

TABLE V

Flare No.	Weight before (gr)	Weight after (gr)	Gain (gr)
107	277.80	277.88	0.08
108	280.30	280.30	-
109	271.85	271.90	0.05
110	276.50	276.50	-
111	278.80	278.80	-
112	271.10	271.15	0.05
113	276.30	276.32	0.02
114	280.10	280.10	-
115	269.70	269.72	0.02
116	276.00	276.00	-
117	280.20	280.20	-
118	271.85	271.85	-

3.6 Vibration Test

There was no apparent indication of deterioration and/or damage to the 40MM Floating Flares as a result of the vibration test exposure.

3.7 Forty Foot Drop Test

The wire bound wood boxes were broken open and the M2A1 boxes deformed on impact, however there was no apparent indication of deterioration and/or damage to the 40MM Floating Flares as a result of the drop test from a height of forty (40) feet.

3.8 High Temperature Storage Test

There was no apparent indication of deterioration and/or damage to the 40MM Floating Flares as a result of the high temperature storage test exposure.

3.9 Low Temperature Storage Test

There was no apparent indication of deterioration and/or damage to the 40MM Floating Flares as a result of the low temperature storage test exposure.

3.10 Performance Firing Test

General Environments Corporation did not have control of the performance test to be conducted by AAI Corporation representatives. The acquisition of data and test results during firing of the 40MM Floating Flares was the responsibility of AAI Corporation and therefore is not incorporated as a part of this report.

APPENDIX F

FLIGHT TESTING REPORT (EXCERPTS)

APPENDIX F

Excerpts from

TECHNICAL NOTE NO. LWL-CR-02F71B

REPORT OF TEST ON ENGINEERING DESIGN AND SAFETY EVALUATION OF 40mm FLOATING FLARE

Final Report
Work Assignments No. 2 and No. 10
Contract No. DAAD05-73-C-0214

by

Matthew G. Popik
AAI Corporation
Baltimore, MD 21204

June 1973

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

U. S. ARMY LAND WARFARE LABORATORY
Aberdeen Proving Ground, Maryland 21005

TABLE OF CONTENTS

SECTION			PAGE
I.	GENERAL DATA		1
	A.	Purpose of Test	1
	B.	Description of Test Samples	1
	C.	Disposition of Test Samples	6
II.	ABSTRACT		8
III.	REFERENCES		11
IV.	FACTUAL DATA		12
	A.	Test Apparatus and Equipment	12
	B.	Environmental Test Procedures	12
	C.	Performance Measurement Set-Up and Procedure	12
	D.	Results of Tests	16
	E.	Test Data	21
APPENDIX	A.	Environmental Conditioning	34
APPENDIX	B.	Recoil Measurements	107

IV. FACTUAL DATA

A. Test Apparatus and Equipment

1. M79 Grenade Launcher, 40mm, Serial No. 7943
2. Adjustable Elevation Table
3. Mount, M79 Grenade Launcher
4. Gunner's Elevation Quadrant
5. Environmental Conditioning Apparatus (See Appendix A)

B. Environmental Test Procedures (See Appendix A)

C. Performance Measurement Set-Up and Procedure

The pond at the Hartwood, Virginia site of General Environments Corporation was used as the target area for testing the 40mm Floating Flares. The pond irregularly shaped, measured approximately 60 meters long and 30 meters wide. White nylon lines were placed across the pond at 10 meter intervals to visually establish range at impact. The launcher location was originally established at a point 240 meters from the front of the pond. During testing, however, wind conditions necessitated the establishment of a second firing position 25 meters closer to the pond. Therefore, during testing, all rounds were fired from a distance of either 240 meters or 215 meters from the pond depending upon the wind conditions. Figure 5 is a illustration of the pond showing the marker line locations.

The M79 launcher was fired from a mount clamped to an adjustable elevation table which was weighted to prevent movement during firing. The elevation for all firings was set at 45^{o} and checked with a gunner's quadrant prior to firing each environmental group and with each relocation of the firing site.

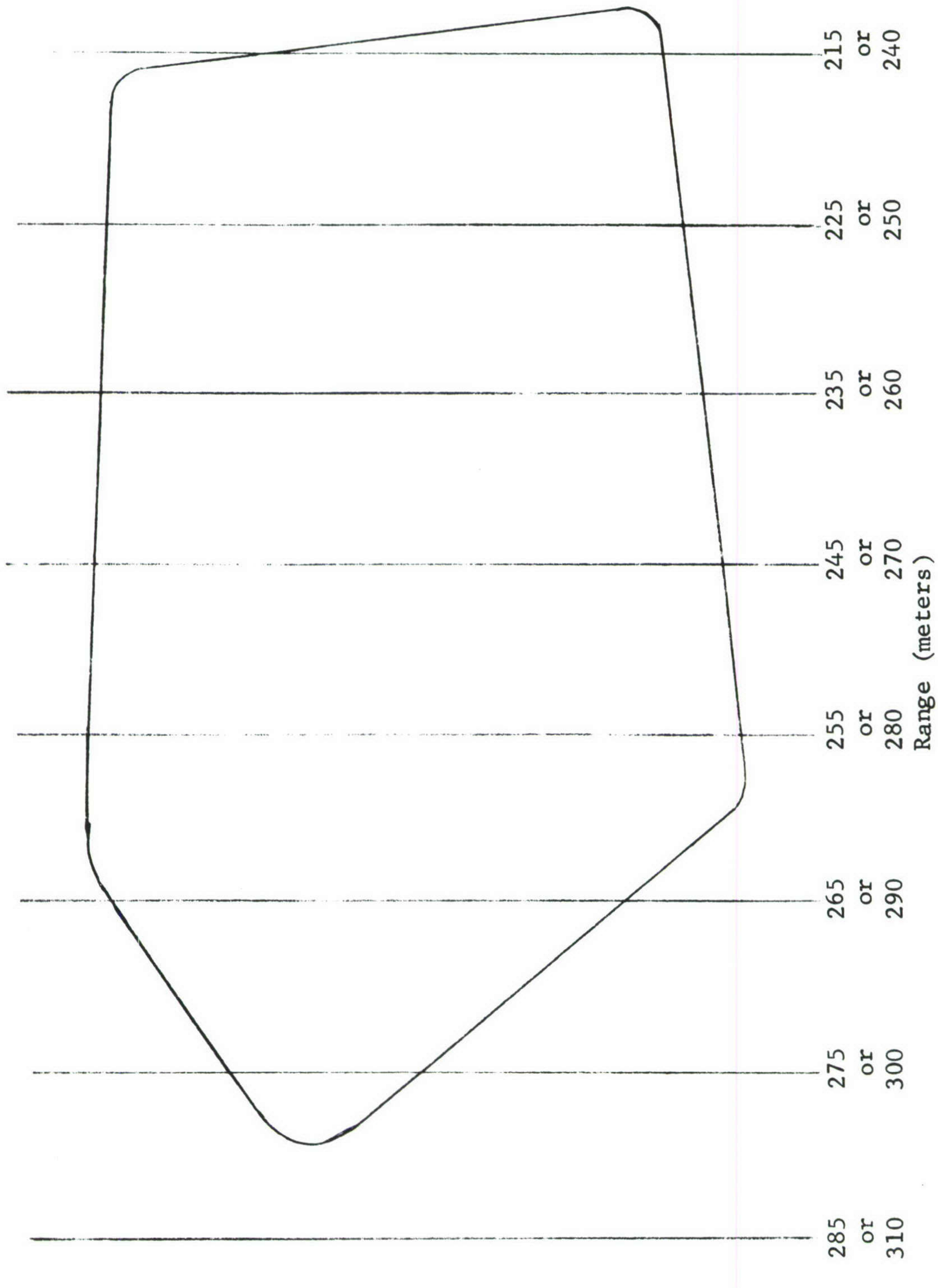

Figure 5. Target Pond

All test firing was conducted by AAI personnel. There was one man at the launcher site and two observers at the pond to record delay time and burn time and to observe the general operation of the flares. Communication was established between the gunner and the observers with hand-held transceivers.

Delay time was measured using a stop-watch held by one of the downrange observers. At firing, the gunner's tranceiver was left open so the observers could hear his countdown. At the instant the firing lanyard was pulled, the gunner signaled "fire" at which time the stop-watch was started. The watch was stopped at the sound of functioning or ejection. Since the observers were approximately 70 to 80 meters away from the projectile in flight at ejection, there would be about a 1/4 second error in timing the event based on the sound. To compensate for this 1/4 second delay, the start of the watch was delayed by a small amount after the signal of "fire" from the gunner was received.

The burn time was measured by the second observer using a stop-watch and he also observed flotation characteristics using binoculars. Only the visible signal time is reported. For those that sank, continued burn underwater is not reported as burn time.

All test firing was coordinated with the requirements of the environmental testing. Performance data was recorded for the firing of one hundred-eighty-seven (187) flare cartridges (63 green, 62 red and 62 yellow). The cartridges to be fired were selected from those that had undergone various treatments as follows:

- one of each color from each M2A1 box from the seven-foot packaged drop test (4x3)
- one of each color from each M2A1 box from the loose cargo test (4x3)
- seven from each M2A1 box from the five-foot drop test (4x7)
- five of each color from the high humidity test (5x3)
- four of each color from the waterproofness test (4x3)
- four of each color from the vibration test (4x3)
- six of each color from the forty-foot drop test (6x3)
- eight of each color from the high temperature storage test (8x3)
- eight of each color from the low temperature storage test (8x3)
- ten control rounds of each color (10x3)

All rounds were fired at ambient temperatures (45^{o} to 60^{o} F) except those in high and low temperature storage tests; those were fired as soon as possible after removal from the conditioning chamber. They were removed three at a time and carried to the launch site in an insulated container.

Since the wind greatly effected accuracy and range, it was necessary to use control rounds occasionally to readjust the aim as weather conditions changed. As a result, 8 control rounds missed the pond while appearing to have functioned normally so that flotation characteristics could not be evaluated for those rounds.

D. Results of Performance Tests

After the seven-foot drop of the rough handling sequence, it was found that the nose caps of all 88 cartridges had been loosened or had completely separated from the cartridge housing. All were replaced prior to continuing testing. The nose caps were again loosened or separated during the loose cargo sequence of rough handling and were again replaced prior to continuing. A few of the cartridges experienced small dents at the forward rim of cartridge housing near the nose cap during the five-foot individual drop test. These were the only visible damages resulting from the environmental conditioning.

The cartridges in the forty-foot drop did not explode and were safe to handle afterwards. These cartridges were later test fired at the request of the government Project Officer.

Table I contains a summation of the test data including averages of times and ranges for the environmental groups. The delay times averaged include those cartridges which functioned audibly even though ballute ejection did not occur. This occurred in 17 tests. Burn time averages do not include those flares which burned part of the time or completely underwater but only those which floated normally and those which impacted on hand. The land and water burn time averages are listed separately. Range averages do not include those flares which did not function or eject but only those which functioned and ejected normally. In the floatation data, those listed as "sank" include those that submerged for a significant portion of the burn as well as those which sank completely and burned underwater.

TABLE I. AVERAGES OF RESULTS FOR ENVIRONMENTAL GROUPS

NO. FIRED	CONDITIONING	DELAY TIME (NO.)	BURN TIME (NO.)	RANGE (NO.)	FLOTATION	FUNCTION BUT NO EJECTION	NO FUNCTION
30	Control	5.5 sec (29)	87 sec (18) water 74 sec (8) land	262M (28)	2 sank 2 on side of (20)	2	0
6	7 Ft Drop; $-50^{\circ}F$	5.7 sec (6)	85 sec (5) water	242M (6)	1 sank of (6)	0	0
6	7 Ft Drop; $145^{\circ}F$	5.4 sec (6)	86 sec (5) water	246M (6)	1 sank 1 on side of (6)	0	0
6	7 Ft Drop; loose cargo; $-50^{\circ}F$	5.2 sec (6)	85 sec (5) water 78 sec (1) land	246M (6)	5 ok of (5)	0	0
6	7 Ft Drop, loose cargo; $145^{\circ}F$	5.3 sec (6)	87 sec (4) water 83 sec (2) land	240M (6)	4 ok of (4)	0	0
14	7 Ft Drop; loose cargo, 5 Ft drop; $-50^{\circ}F$	5.4 sec (12)	85 sec (10) water	248M (12)	2 sank of (12)	0	2
14	7 Ft Drop; loose cargo; 5 Ft Drop; $145^{\circ}F$	5.3 sec (13)	86 sec (8) water 79 sec (4) land	250M (13)	1 sank 1 on side of (9)	0	1
15	High Humidity	5.7 sec (13)	80 sec (6) water 92 sec (1) land	260M (11)	4 sank of (10)	2	2
6	Waterproofness, 4 Hr.	5.2 sec (6)	86 sec (4) water	265M (5)	1 sank of (5)	1	0

TABLE I. (CON'D)

NO. FIRED	CONDITIONING	DELAY TIME (NO.)	BURN TIME (NO.)	RANGE (NO.)	FLOTATION	FUNCTION BUT NO EJECTION	NO FUNCTION
6	Waterproofness; 48 Hr.	5.3 sec (6)	95 sec (3) water 79 sec (1) land	256M (6)	1 sank of (5)	0	0
6	Vibration; -50°F	5.2 sec (6)	83 sec (4) water	253M (5)	1 sank of (5)	1	0
6	Vibration; 145°F	5.1 sec (5)	83 sec (5) water	241M (5)	5 ok of (5)	0	1
18	40 Ft. Drop	5.4 sec (18)	86 sec (12) water 83 sec (5) land	262M (17)	2 on side of (12)	1	0
12	High Temp. 125°F	5.5 sec (11)	80 sec (8) water 66 sec (1) land	278M (11)	2 sank 1 on side of (10)	0	1
12	High Temp. 160°F	5.5 sec (8)	75 sec (5) land	220M (5)	None in Water	3	4
12	Low Temp. -70°F	5.9 sec (12)	88 sec (4) water 78 sec (1) land	267M (6)	1 sank of (6)	6	0
12	Low Temp. -45°F	5.7 sec (12)	89 sec (9) water 78 sec (1) land	261M (11)	1 sank of (10)	1	0
Total 187	All	5.47 (175)	86 sec (110) water 78 sec (30) land	256M (159)	19 sank 7 on side of (130)	17	11

Of the 187 test firings conducted with the 40mm Floating Flare, 11 flares failed to function and 17 functioned but failed to eject the ballute/flare assembly. Combined, these 28 failures produced a function/ejection failure rate of 15.0%. The highest percentage of this type of malfunction occurred during high and low temperature testing. The firings at 160°F yield 4 "no functions" and 3 "no ejections" of the 12 for a function/ejection failure rate of 58%. Firings at -70°F produced 6 "no ejections" of the 12 tested for a failure rate of 50%.

Of the 130 flares tested which impacted in water, 19 sank completely or for a significant portion of the burn and 7 floated on the side producing poor color. The 19 that sank are considered flotation failures and yield a failure rate of 14.6%.

By combining the three major types of failures which are (1) no function, (2) function but no ejection, and (3) those that sank, an overall failure rate of 29.6% was experienced during performance testing for all those tested including control rounds. The individual failure rate for each environmental group is listed below in Table II.

TABLE II. FAILURE RATES FOR ENVIRONMENTAL GROUPS

CONDITIONING	NUMBER TESTED	FAILURE RATE
Control	30	16.7%
Rough Handling (-50° & 145°F)	52	21.5%
High Humidity (120°F)	15	66.6%
Waterproofness	12	28.3%
Vibration (-50° & 145°F)	12	26.7%
40 Foot Drop	18	5.6%
High Temp. (125° & 160°F)	24	53.3%
Low Temp. (-70° & -45°F)	24	47.9%

Delay time for the control group averaged 5.5 seconds. In most cases, the delay times for the environmental groups were within 0.3 seconds of this, mostly on the low side. The longest delay times were recorded for those flares fired at -70°F which averaged 5.9 seconds from launch to functioning.

Burn time was significantly effected by whether the flare burned in water or on land. The cooling effect of water produced longer burn times than those that impacted on land. Also, those on land burned hotter, often melting the aluminum shell. The average burn times for the control group were 87 seconds in water and 74 seconds on land. The averages for all those tested were 86 seconds in water. Low temperature conditioning did not effect burn time but high temperature (125°F) conditioning and firing while hot shortened burn time by about 6 to 8 seconds.

Table III contains the average burn times for the different colors for comparison to each other. They are separated into two groups; those that burned in water and those that burned on land. The averages combine the burn times for all environmental groups including the control group.

TABLE III. AVERAGE BURN TIMES FOR EACH COLOR

	IN WATER			ON LAND		
	GREEN	RED	YELLOW	GREEN	RED	YELLOW
BURN TIME (SEC.)	83	83	91	76	78	80
NO. AVERAGED	31	45	34	11	8	11

Range was significantly effected by wind conditions due to the altitude at which normal functioning occurred. When the ballute opened, deceleration occurred so that with no wind, the flare fell straight down. With a moderate breeze (6 mph), however, the range could be extended or decreased, depending on direction by 15 to 25 meters. With a launch angle of 45^{o} and with no wind, a range of about 260 meters could be expected. The environmental conditioning which most effected range was that of high temperature ($160^{o}F$). Although these were tested during a moderate head wind of about 6 mph, the resulting average range of 220 meters indicated a loss of about 40 meters, a greater range decrease than expected.

Most cartridges tested were stable in flight. About 10% of those fired appeared to wobble in flight between launch and functioning but the slight instability did not effect range or operation.

There were no misfires at launch as all cartridges fired and the cases were extracted normally.

E. Test Data

Included in this section is a tabulation of the performance firing test results for all environmentally conditioned cartridges and for the control cartridges. Presented are pre-firing conditioning for each round; delay time, burn times, range, flight characteristics, flotation characteristics, and any unusual observations. Unless otherwise specified, the altitude at functioning was 1/8 to 1/3 descended from the apex of the trajectory. The burn time is that of the actual visible signal.

All test firing was conducted at General Environments Corporation, Hartwood, Virginia from 29 March 1973 to 6 April 1973.

APPENDIX G

RECOIL MEASUREMENTS REPORT (EXCERPTS)

APPENDIX G

Excerpts from:

LETTER REPORT ON RECOIL MEASUREMENTS OF 40mm FLOATING FLARE CARTRIDGE
June 1973
(Appendix B of Technical Note No. LWL-CR-02F71B, Report of Test on Engineering Design and Safety Evaluation of 40mm Floating Flare, June 1973)

The objective of this work assignment was to conduct ballistic pendulum tests on the 40MM Floating Flare cartridges remaining from performance tests conducted by AAI Corporation.

The test rounds had been previously conditioned during the performance testing phase (refer to LWL Technical Memorandum No. LWL-CR-02F71B), withdrawn, and saved for subsequent recoil tests.

A later test requirement specified additional temperature conditioning prior to recoil testing and firing while the cartridges were at temperature. In all, 63 cartridges were test fired for recoil: 21 green, 21 red, and 21 yellow. In most cases, each cartridge was conditioned at the temperature it had been subjected to previously.

To measure recoil, the M79 launcher was mounted on a ballistic pendulum suspended by vertical wires. At firing, as the pendulum recoiled rearward, the vertical movement from rest to the rearwardmost position was noted and recorded for each cartridge. From this, and using the weight of the recoiling mass, the energy and recoil impulse were calculated.

All testing was performed at H.P. White, Bel Air, Maryland, with AAI supervision on 18 June 1973.

The general operation of all cartridges were normal at launch. The operation of the flare projectile was not evaluated during these tests. The average recoil impulse values which resulted are as follows:

Overall average	-	3.33 lb-sec
Average at -50°F	-	3.28
Average at ambient	-	3.33
Average at 145°F	-	3.39

Enclosed is a tabulation of the test results listing environmental conditioning for each round and the calculated values for recoil energy and recoil impulse.

RECOIL TEST DATA

NO.	COLOR	PREVIOUS CONDITIONING	CONDITIONING FOR RECOIL TESTS	TEST RESULTS RECOIL ENERGY (FT-LBS)	RECOIL IMPULSE (LB-SEC)
4	Green	(-50°F) {7-Foot	-50°F	17.77	3.02
5	Red	Drop	-50°	19.84	3.14
6	Yellow		Ambient	13.63	2.65
10	Green	{Loose Cargo	-50°	19.84	3.19
11	Red	Axis Paral.	-50°	17.08	2.96
12	Yellow		Ambient	22.60	3.41
20	Red	5-Foot Drop, Nose	-50°	18.46	3.08
21	Yellow	45° Base	-50°	17.08	2.96
22	Green	Axis Paral. 5-Foot Drop, 45° Nose	Ambient	21.91	3.36
26	Red		-50°	19.84	3.19
27	Yellow		-50°	21.22	3.30
28	Green		Ambient	22.60	3.41
32	Red	Axis Perpen.	-50°	22.60	3.41
33	Yellow		-50°	21.91	3.36
34	Green		Ambient	21.91	3.36
42	Yellow	5-Foot Drop, Nose	-50°	19.15	3.14
43	Green	, Base	-50°	19.84	3.19
44	Red	(-50°F) Axis Perpen. 5-Foot Drop, Horiz.	Ambient	23.98	3.51
48	Yellow	(145°F)	145°F	19.15	3.14
49	Green		145°	21.22	3.30
50	Red		Ambient	Missed Reading	
54	Yellow	{Loose Cargo	145°	21.91	3.36
55	Green	Axis Paral.	145°	24.67	3.56
56	Red		Ambient	20.53	3.25
64	Green	5-Foot Drop, Nose	145°	23.29	3.46
65	Red	, 45° Base	145°	23.29	3.46
66	Yellow	Axis Paral. 5-Foot Drop, 45° Nose	Ambient	18.46	3.08
70	Green		145°	21.91	3.36
71	Red		145°	19.84	3.19
72	Yellow		Ambient	19.84	3.19
76	Green	Axis Perpen.	145°	23.98	3.51
77	Red		145°	26.05	3.66
78	Yellow		Ambient	22.60	3.41
86	Red	5-Foot Drop, Nose	145°	23.98	3.51
87	Yellow	{7-Foot , Base	145°	22.60	3.41
88	Green	(145°F) Drop Axis Perpen. 5-Foot Drop, Horiz.	Ambient	23.98	3.51
104	Green	High Humidity	Ambient	20.53	3.25
105	Red			22.60	3.41
106	Yellow	High Humidity	Ambient	21.22	3.30
122	Green	Vibration (-50°F) Axis Paral.	-50°F	26.05	3.66
123	Red			26.74	3.71
124	Yellow	Axis Paral.		21.22	3.30
128	Green	Axis Perpen.		21.91	3.36
129	Red		-50°F	24.67	3.56
130	Yellow	(-50°F) Axis Perpen.	Ambient	22.60	3.41
134	Green	(145°F) Axis Paral.	145°F	21.91	3.36
135	Red			20.53	3.25
136	Yellow	Axis Paral.		22.60	3.41
140	Green	Axis Perpen.		22.60	3.41
141	Red		145°F	23.29	3.46
142	Yellow	Vibration (145°F) Axis Perpen.	Ambient	24.67	3.56
173	Green	High Temperature Storage (125°F)	145°F	21.91	3.36
174	Red		145°	19.84	3.19
175	Yellow		Ambient	21.22	3.30
176	Green		Ambient	23.29	3.46
177	Red		-50°	18.46	3.08
178	Yellow	(125°F)	-50°	23.98	3.51
191	Green	(160°F)	145°	21.22	3.30
192	Red		145°	23.29	3.46
193	Yellow		Ambient	21.91	3.36
194	Green		Ambient	22.60	3.41
195	Red		-50°	25.36	3.61
196	Yellow	High Temperature Storage (160°F)	-50°	19.15	3.14

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