RDTR No. 145
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HIGH INTENSITY TAMP-CAST ILLUMINATING FLARE

(Summary Report July 67-December 68)

U. S. NAVAL AMMUNITION DEPOT
CRANE, INDIANA

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HIGH INTENSITY TAMP-CAST ILLUMINATING FLARE
(Summary Report July 67-December 68)

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ABSTRACT

The development of a high intensity tamp-cast illuminating flare is described. The flare produced a luminous intensity of 25 million candles for over two minutes. A brief discussion is included concerning the binder systems used to make the tamp-cast flares along with the assembly of a capability for testing the flares. Summary data of flare tests related to this work is included.

INTRODUCTION

The exploratory development of an illuminating flare whose luminous intensity is 25 million candles was undertaken about June 1966 under MIPR PG-6-58. The first year's progress was reported by reference (1). During the first year, it was demonstrated that a flare with a luminous intensity of 25 million candles could be built. As a result of this, the work was continued with a new goal.

The next phase of the work from July 67 to October 68 was directed toward the building of a flare which would not only provide a luminous intensity of 25 million candles but also would do this for a two minute period or more. This then is the phase of work which is reported herein.

The new goal and binder improvements which became known during this period caused the work effort to be divided into several smaller units. These are:

Part I Build a flare with a luminous intensity of 25 million candles for two minutes

Part II Evaluate improved binder system

Part III Provide minimum capability for testing the flares,

Part IV Perform flare tests relevant to this flare program.

These are the major subdivisions of the work during this period which are discussed in the text of this report.

PART I

25 MILLION CANDLE FLARE

Purpose

The purpose of this report is to describe the development effort which led to the fabrication of an illuminating flare candle which generates a luminous intensity of 25 million candles for two minutes or more.

Background and Review

In order to orient the reader it is useful to include some of the background which leads to the concept of tamp-casting and to review the progress of the work prior to the start of this report period. With this in mind, we can start with a review of the state-of-the-art of flare pressing.

During the manufacture of a conventional illuminating flare, the composition is normally consolidated into the flare container at a pressure near ten thousand psi. Furthermore, when it is necessary to make flares with a large cross-sectional area, extremely large presses are required in order to achieve the 10,000 psi consolidation force. Thus, the size of the candle that can be made is often limited by the size of press which is available. For example, a press of about 200 tons is required to consolidate the composition into an 8-inch diameter flare. Larger flares would require correspondingly larger presses.

Since the consolidation operation becomes more complex as the size of the equipment increases, it becomes increasingly attractive from an economical standpoint to eliminate the consolidation operation. This can be achieved if the composition can be "cast" into the candle container instead of pressed. The tamp-casting method is the technique chosen to make candles in this program. Generally, the composition will not flow and therefore is tamped at pressures near 50 psi. For purposes of this report, the process of tamping and later polymerization of the composition is what is known as tamp-casting a flare candle.

In an effort to attain outputs of 25 million candles, flares were first made in the normal solid cylindrical shape. It was estimated that flares of sufficient diameter and size could be made which would provide the required 25 million candle output. Prototypes of such flares were tested. They were burned in cigarette fashion. Two important characteristics of the experiment became evident: First, the luminous intensity output was found to degrade as the diameter of the candle increased. At the start of this program this degradation function was not defined. Further discussion may be found in reference (1). The other benefit that came from this phase of the work was the development of the techniques required to process the composition. During the manufacture of the solid candles, various mixing, tamping, and casting techniques were tried. In addition, different composition formulas were used. All of this led to the preparation of candles which were suitable for performance testing.

During the early phases it was learned that it was necessary to burn about five pounds of composition per second in order to generate luminous intensities of 25 million candles. This in turn requires the burning of large composition surface areas in order to obtain the desired output. Since this would require candles of extremely large diameters if they were made as a solid cylinder, another approach was taken. Candles were made which had a star-shaped cavity in the center of the grain. The purpose of the star cavity was to present a larger surface area for burning. This idea is based on computations developed for the burning of propellant grains of various star configurations.

Candles were made with a star-shaped cavity completely through the center of the candle. When the candle is ignited, the flame exits from both ends of the candle. This produces equal but opposing forces thereby eliminating any major propulsion effect. It was also decided to suspend the candle in a horizontal position which causes the flames to develop horizontal to the surface of the ground. In this manner, a larger projected cross-sectional surface area of the flame is presented to the ground surface.

This double star candle design was used successfully to generate the required luminous intensity of 25 million candles.

All of the candles prepared the first year were tested at the MAPI site. In general, the MAPI site may be described as a polar arrangement of about 56 photocells on the ground each of which views the candle suspended about 80 feet in the air. The cells are arranged such that the flare is viewed from all aspects. Eight cells were added to the MAPI system during the latter part of this phase. The cells were placed at greater distances from the flare in order that the entire flame could be viewed by the cells. Additional details about the MAPI site may be found in references (1), (2), (3), (4) and (5).

The 25 million candle output requirement was first demonstrated by both candles MAPI No. 426 and MAPI No. 463. In each case, about five pounds per second of composition is burned. Also, the computations show that efficiencies in (cd-sec)/g generally range from ten to twelve thousand. See Table II, page 14 of Volume I to reference (1). This is only about one-fourth of the efficiency achieved when compared to the standard pressed illuminating composition in a four-inch size. Although these efficiencies are low, it was shown in the next year's work that they could be improved considerably by utilizing more efficient binder systems.

Two different binder systems were utilized to make the double star candles. We noticed that the silicon resin system has the characteristic of burning much faster than did the epoxy-polyglycol system for comparable composition formulas. See references (10), (11) and (12) for more information about these binders. Both of these resin systems have the very desirable characteristic of a very low exotherm during the polymerization reaction. Generally, their pot life is about eight hours which permits adequate time for the casting process. After the candle is cast, it is placed in an oven at around 150-170°F for 24 hours or more to cause the cure. During this curing period, the exotherm is almost unnoticeable. This characteristic is extremely important from a safety standpoint, in particular when it is necessary to cure large section candles. Because the exotherm is low, there is less danger of exceeding the decomposition temperature of any of the flare ingredients.

The first phase proved that a luminous intensity of 25 million candles could be generated by a pyrotechnic illuminating flare. Furthermore, the information gathered during this phase of the program indicated that considerable improvement could be made by increasing the efficiency of this system. From this start, the effort progressed toward the goal of a two minute flare producing a luminous intensity of 25 million candles and a higher efficiency composition.

Experimental

By the end of the first year it had been demonstrated that from a single source it is possible to produce a luminous intensity of 25 million candles. From this data it was apparent that a two minute burning time candle could be made provided the diameter of the candle was about 20 inches. From other information available, it was estimated that such a candle would weigh in the neighborhood of 500 pounds. This weight was more than the original test facility could tolerate. Secondly, the flames from these candles extend to about 15 feet on either side of the candle while burning at peak intensity. The photocells viewing this flame must see the entire flame if reliable data is to be obtained. Also, all the intensity computations are based on the premise that the source is a point source. Certainly a photocell at a distance of eighty feet from a 20-30 foot long flame can not be considered to be viewing a point source. For this reason and that of the weight limitation, it was necessary to provide a test facility with a larger capability. That effort will be discussed Part III.

While the improved test site was being prepared, further tests were planned. These mainly involved the adjustment of the formulas as well as the evaluation of an improved binder system which recently had become available as reported in reference (6). This improved system is also described in Part II of this report. To perform these tests and still stay within the weight limitations, candles were made in a twelve-inch diameter size. These small test samples were used to establish the burning rate for a given composition. That information was used to scale up into a larger version the latter of which to be tested on the improved test site when that became available.

The summary sheet, Table I, on the next page compares data for a series of candles which were prepared during the intervening six to eight months. MAPI 659 and 665 show two flares each with a different binder. One flare had an efficiency of about 12,000 cd-sec/gm and the other about 10,000 cd-sec/gm. Had we not learned about the improved epoxy-polyester system about this time we probably would have conducted further tests on the MAPI 659 formula which in turn eventually would have been scaled up. Since however the improved resin system was showing great promise, tests were immediately conducted to determine its usefulness in the double star cast flare system. After it was determined that the material could be processed, flares MAPI 706 and 709 were made from this material. Additional details about the flare fabrication process can be found in Appendix I, Volume II of reference (1). More information about these candles is also included in the Table I.

TABLE I

12.0" DIAMETER DOUBLE-STAR CAST FLARES

19 February 1969

MAPI Test No.	657	658	659**	665	706	709	B1
Magnesium %	36	55	53	56	57	57	57.5
(granulation)	18	15	17	17	17	17	17
Sodium Nitrate %	50.0	31	33	30	30.5	30.5	30.5
(particle size)	150 μ	150 μ	150 μ	***	***	30μ	30μ
Binder* %							
Silicone	14	--	--	14	--	--	--
Epoxy-Polyglycol	--	14	14	--	--	--	--
Epoxy-Polyester	--	--	--	--	12.5	12.5	12.0
Luminous Intensity ($x10^6$cd)	4.0	17.5	10.0	14.4	>22.5	24.7	~25
Burning Time (sec)	128	45	75	51	71	73	138
Efficiency ($x10^3$ cd-sec/g)	4.8	8.0	12.0	10.0	21.7	22.4	~15
Burning Rate (in/sec)	0.02	0.06	0.04	0.05	0.04	0.04	0.05
Burning Rate (sec/in)	42.6	15	25	17	23.6	24.3	19.7
Burning Rate ($x10^3$g/sec)	0.85	2.1	0.84	1.44	1.04	1.10	1.80
Density (g/cm^3)				1.44	1.42	1.57	1.41
Composition Weight ($x10^3$g)	108.9	97.6	62.6	73.6	73.6	80.5	234
(lbs)	240	215	138	162	162	177	516
Composition Length (in)	42.1	44.2	26.2	29.8	30.5	30.3	33.4 ****

* Silicone formula: Sylgard 182 mix.
Epoxy-Polyglycol formula: 62% QX 3812 and 38% DER 732.
Epoxy-Polyester formula: 81.89% Foamrez F-17-80, 17.0% ERL-0510, and 1.11% Iron Linoleate.

**Denotes 6-point star; all others are 4-point stars.

***50% 30 micron and 50% 150 micron.

**** This unit is 20 inches diameter.

The most important performance characteristics resulting from the tests of MAPI 706 and 709 was the fact that in each case the luminous intensity was near the required 25 million. Both units showed a luminous efficiency of about 22,000 cd-sec/gm which is almost double what had been accomplished previously with other binders. This bonus performance was one which would later make the goal much easier to meet. From this point, the scale-up proceeded.

Based on the successful test of candles MAPI 706 and 709, a twenty-inch diameter candle MAPI B1 was made using the epoxy-polyester binder system and the formula shown in Table I. The test of that candle showed that the unit produced an average luminous intensity of 25 million candles for a period of 138 seconds. Thus the goal of this phase had been met.

The flare MAPI B1 was not what one might consider to be a perfect candle. It did not burn as smoothly as had been desired. As a matter of fact, at about 45 seconds into the burn, the flare started to discharge chunks of composition while burning. This suggested that there might be cracks in the composition or there might be an inadequate bond between the composition and the case. From later investigations, it appears that the latter was the condition that existed. Some of these problems will be discussed in Part II of this report. This partial chunking of the composition from the candle while burning undoubtedly accounted for the reduced efficiency (15,000 cd-sec/gm) recorded for this unit. Even in the light of the reduced efficiency, however, the unit did meet the minimum requirements of the test.

Figure 1 shows a plot of luminous intensity as a function of burning time for Flare MAPI 709. It is easy to see that it is nearly 30 seconds before the unit reaches the required 25 million candles intensity. It should be noted that this unit contained a star cavity which had four points. Previous experiments with these flares have shown that a peak intensity can be reached more quickly if certain changes are made. The time to peak intensity can be increased by using a faster burning composition which sometimes can be achieved by utilizing a finer granulation of magnesium. Another means of achieving a faster time to peak is to start with a six point star cavity instead of a four point star. For further information about the behavior of the star cavities, the reader is referred to Appendix II of Volume II of reference (1).

Either of these techniques can be used independently of the other or, if one chooses, both can be incorporated into one candle. When the latter is used, the time to peak will be extremely fast. It had been considered during this program that such a modification might be utilized to advantage. If this had been

FIGURE 1

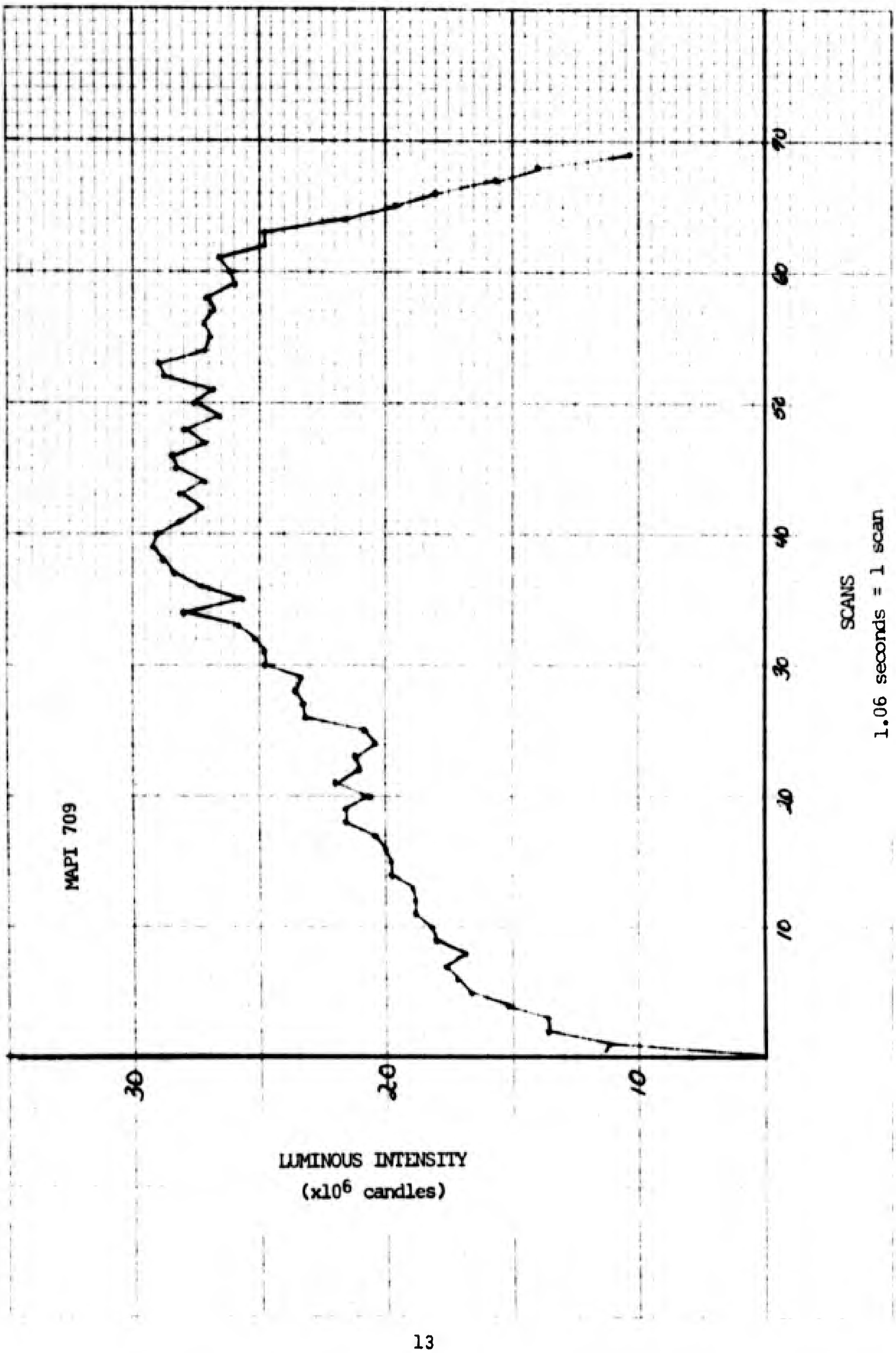


FIGURE 1

done, the flare would probably start out with a very high intensity which would gradually taper to a lower intensity. For example it might start out averaging near 30 million and taper to an average of 20 million as the burn progressed. Such a characteristic might be used to advantage since the high intensity portion of the burn would probably correspond to initiation of the flare at high altitude. As the flare drops in altitude there would also be a decrease in luminous intensity; the net result of which would be constant illumination on the ground. Such a condition is considered to be advantageous from a tactical standpoint.

Conclusion

During this phase it was demonstrated that a luminous intensity of 25 million candles can be delivered by a single pyrotechnic illuminating flare over a period of more than two minutes. An improved binder system was utilized to prepare this flare. MAPI B1, which weighed 516 pounds was tested on the improved MAPI site. This test not only proved that the flame met the minimum requirements set for the program but it also proved the versatility and acceptability of the improved test facility.

PART II

BINDER STUDY

Purpose

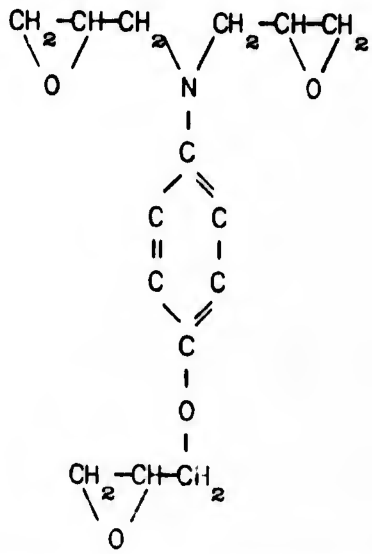
The object of this phase of the project was to determine the usefulness of an epoxy-polyester binder system for making the star-cavity tamp-cast candles.

Discussion

It has already been mentioned in PART I that during the program a seemingly improved binder system was being evaluated in flare systems. References (1) and (6) contain data about the early applications of this material. Because of the promise that the material showed in other areas, it was tried in this program as well. The results of this effort are described herein.

The formula for the epoxy-polyester system used to tamp-cast the double star cavity candles, consists of about 81.89% Formrez F17-80 polyester resin, 17.0% ERL-0510 epoxy resin, and 1.11% iron linoleate. See reference (7) for information about the use of these materials for pressing flares.

The epoxy resins ERLD-0500 and ERL-0510 are both products of Union Carbide Corporation manufactured under U.S. Patent 2,951,825. The idealized structure is:



The two products are triglycidyl derivaties of para-amino phenol. ERLD-0500 is the reaction product of para-amino phenol and epichlorohydrin in the presence of caustic. Like all such products, ERLD-0500 contains some polymeric material with pendant hydroxyl groups. Commercially produced, ERLD-0500 has a viscosity of 2000 to 5000 cP* at room temperature. The presence of hydroxyl groups in the material produces some catalytic effects and hence shortens potlife. To overcome this, the ERLD-0500 is molecularily distilled to produce a product known as ERL-0510 which is essentially the monomeric triglicidyl derivative of para-amino phenol.

It is a pale straw-colored liquid with a viscosity of 400 to 700 cP*.

*From Union Carbide Product Data sheets. cP = centipoise.

Formrez F17-80 is a carboxyl terminated polyester produced by Witco Chemical Company. Its emperical formulation and typical analysis is:

Emperical Formulation

$C_{1.6}\ H_{2.55}\ O_{1.0}$

Typical Analysis

Hydroxyl, No.	3.0
Acid No. **	72.0
Moisture, %	0.04
Viscosity, cP @ 25°C	40,000

**milligrams KOH per gram of sample

Source data and information about the remaining ingredients such as magnesium, sodium nitrate, and iron linoleate may be found in Table II.

No difficulties were experienced in using this binder system in early applications. The resins were first tried in small solid cylindrical candles made by a tamp-cast method. After the small units showed acceptable performance, MAPI candles 706 and 709 were made. The latter two candles are the first units containing a star cavity which were made with the improved epoxy-polyester resin system. Although no difficulties were noticed at the time, the problems which were later to arise quite

TABLE II

List of Materials

Formrez F17-80 Carboxyl terminated polyester resin	Witco Chemical Co. 75 E. Walker Drive Chicago, Illinois 60601 Phone: 312-346-2960
Epoxy Resin ERL-0510 Thiokol Chemical Corp. Specification TWS-RM-1003	Union Carbide Corp. 230 North Michigan Ave. Chicago, Illinois 60601 Phone: 312-346-3300
Epoxy Resin ERLD-0500 Thiokol Chemical Corp. Specification TWS-RM-64	Union Carbide Corp. Plastics Division 2330 Victory Parkway Cincinnati, Ohio 45206 Phone: 513-272-0202
Iron Linoleate Thiokol Chemical Corp Specification TWS-RM-1002	Harshaw Chemical Co. 1945 East 97th St. Cleveland, Ohio 44106 Phone: 216-721-8300
Sodium Nitrate	Davies Nitrate Co. P.O. Box 306 Metuchen, N.J. 08840
Magnesium Atomized grades	Valley Metallurgical Processing Co. Essex, Connecticut 06426

prominently may have been present but in a reduced form. In any event, as pointed out in Part I, MAPI 706 and 709 performed satisfactorily.

When this work was completed, MAPI B1 Candle was made. This 20 inch diameter unit was a direct scale-up of MAPI 706 and 709. It was here that potlife problems were first experienced. That is, the material had a tendency to set up while in the mixer (15-30 minutes) as compared to what previously had been a four hour potlife at ambient temperature.

Originally there did not seem to be any correlation between the behavior of the composition used to make MAPI 706 and 709 and that used to make MAPI B1. It had however been noted that, the first units were made during the Winter period (relatively low humidity) as compared to MAPI B1 which was made during the Spring of the year (high humidity). Although this feature may have played a role in the difficulties which were experienced, it does not seem to be the sole source of the main problem.

Another change was noticed between MAPI 706, 709 and MAPI B1. The first two units were made with a magnesium from a different shipment than was used to make the third unit. Although the granular size in all three units was the same and the material was from the same manufacturer, it now appears to be very likely that the magnesium in the two shipments had surface conditions which made them different in some way.

About this time it was learned that the Thiokol Chemical Corporation was also having similar difficulties to that just described. Mainly the difficulty shows up in an extremely short potlife. The problem then becomes one of finding out the source of this short potlife. After discussion with representatives of the Thiokol Chemical Corporation and with manufacturers of the individual ingredients and resins it appears that the problem may generally be described as follows:

The Formrez F17-80 is reported to have an acid number of 72. In this material there apparently is residual succinic anhydride which is used in the process of manufacturing the resin. When moisture is allowed to come into the presence of the anhydride, that material converts to succinic acid. The acid is then available to react with the magnesium which in turn causes gassing and a catalysis of the polymerization reaction. At this point the reader should not conclude that moisture is the only source of the problem. It is suggested that the problem may also exist in the absence of moisture for the reasons that will soon become apparent.

It was also learned through experience that the problem is aggravated when magnesium of very small particle size is used as compared to the coarser materials. This observation suggests that the problem is associated with the condition of the magnesium surface or with its surface area. The other observation which was made concerning magnesium is that magnesium formed into a ball by a milling process is less reactive than magnesium manufactured by the process of atomization. This relationship seems to hold for a given particle size of magnesium. Once again, this suggests that the surface condition of the magnesium is relatable to the potlife problem.

During the investigations conducted into this problem, several persons had hypothesized that the magnesium oxide surface coating on the magnesium was the cause of the shortened potlife because magnesium oxide is a known catalyst for the polymerization reaction. The presence of varying quantities of oxide coating on the magnesium would explain the differences between the magnesiums prepared by the two different processes as well as the observation that fine magnesium is more reactive than is coarse magnesium. The latter results from a higher surface area which in turn would correspond to a greater amount of available magnesium oxide. If this is the case, the problem becomes one of eliminating the magnesium oxide surface condition, controlling it, or avoiding it completely.

Several methods have been suggested. Chemical neutralizers or agents that would block the activity of the magnesium oxide were suggested as additives to the resin. Another suggestion is to avoid the use of atomized magnesium in favor of the seemingly less reactive material which had been formed into a ball by milling. Another suggestion involves treatment of the magnesium to remove the oxide coating. All of these techniques may be successful in varying degrees. What the ultimate answer turns out to be will undoubtedly depend on the circumstances surrounding the processing and manufacturing of the item involved. These problems were not pursued further in this program because at the time that the problem came to light, the major goal of the program had been reached. Consequently, the problem was not pursued to its solution.

Conclusions

During this phase it was demonstrated that an improved polyester-epoxy resin system could be used successfully for tamp casting large star cavity flare candles. The processing procedures brought to light several problems that are associated with the use of this material. Only partial solutions have been found for this problem, although the problem itself seems to have been identified. The major conclusions reached from this phase is that flares made with this binder system have a better efficiency than those made with the binder systems tested earlier and that if the system is to be continued in this use, the means must be found to control the process to the extent that premature polymerization of the composition no longer occurs.

PART III

TEST CAPABILITY

Purpose

The purpose of this part of the report is to describe the test capability that was assembled to support this flare program.

Introduction

It has been mentioned previously in Part I that the original test facility was not capable of suspending the candle weights which would have to be tested. Secondly, it was learned that the flames from the candles being prepared in this program extend to about 15 feet on either side of the candle while burning at peak intensity. It is also clear that the photocells viewing this flame must see the entire flame if reliable data is to be obtained. It is also important to notice that all of the intensity computations are based on the assumption that the radiator is a point source. Certainly a photocell at a distance of 80 feet from a 20 to 30 foot long flame cannot be considered to be viewing a point source. For this reason and that of the weight limitation, it was deemed necessary to provide a test facility with a larger capability. Such a capability was assembled during this program.

Discussion

The site for the new capability was chosen adjacent to an existing pyrotechnic test area and within sight of the old MAPI test area. Eleven acres of land were cleared in the center of which two 300 foot towers were installed at a distance of 300 feet apart. Sixteen photocells were scattered over the eleven acres in an array varying in distance between 100 feet to 400 feet from ground zero. All of these cells view a region between the towers at about 250 feet in the air where the test unit is normally suspended. The towers have the strength necessary to suspend weights up to 2500 pounds for significant periods of time. See Figure 2 for the site layout. Figure 3 is aerial view.

The details of the electronics of this improved capability as well as the sensing head calibration are given in reference (8). Generally, the procedure is as follows: During a time span of about one second, all of the sixteen photocells are sequencially sampled one time. The intensity of each of the sensing heads at the time it is sampled is recorded on magnetic tape. That information, along with calibration data, information concerning the sensing heads, and the geometric location in relation to the test unit is converted to digital form for analysis by computer. Such a procedure permits the computation of luminous intensity for each

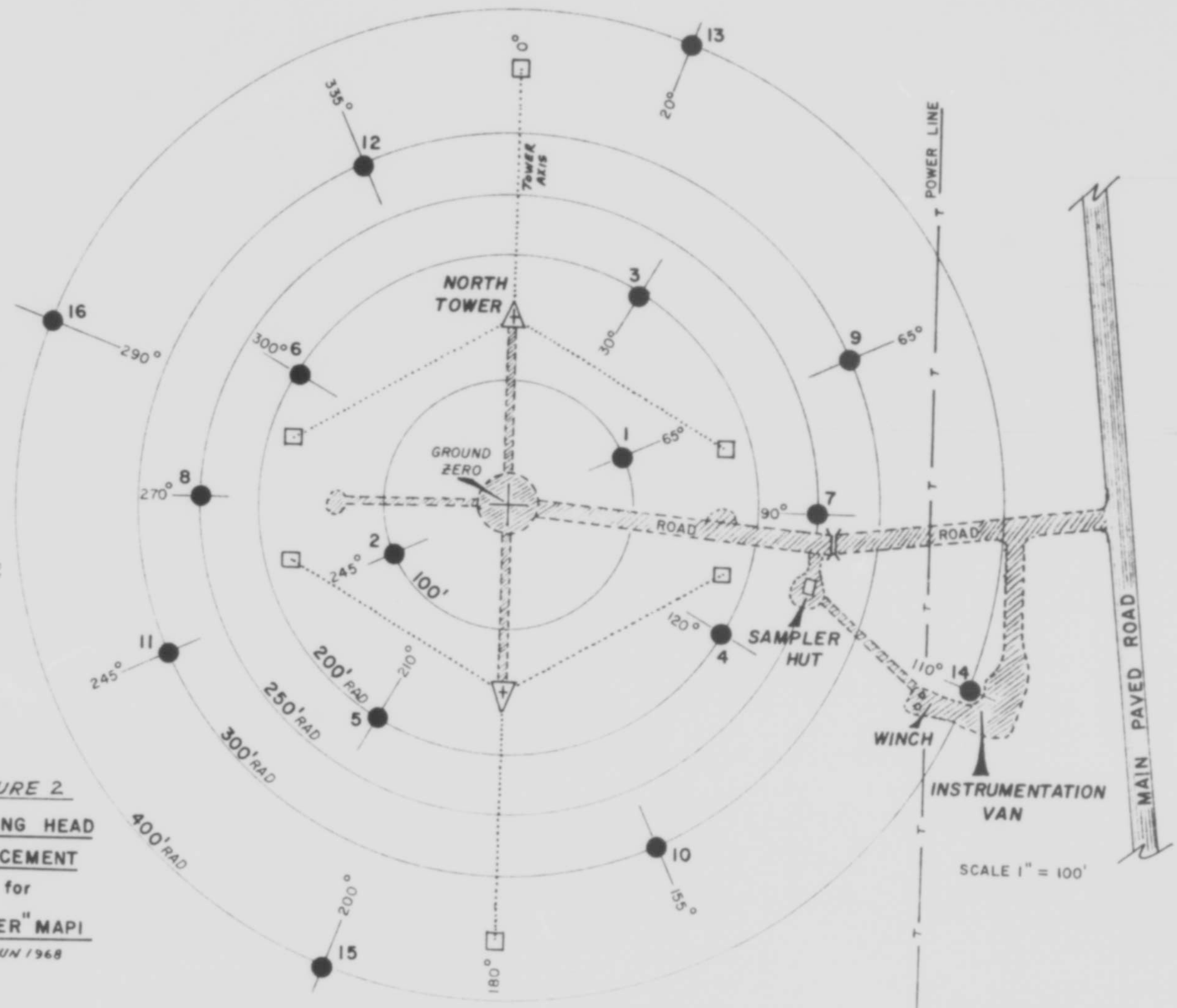


FIGURE 2

SENSING HEAD PLACEMENT for "SUPER" MAPI

3 JUN 1968

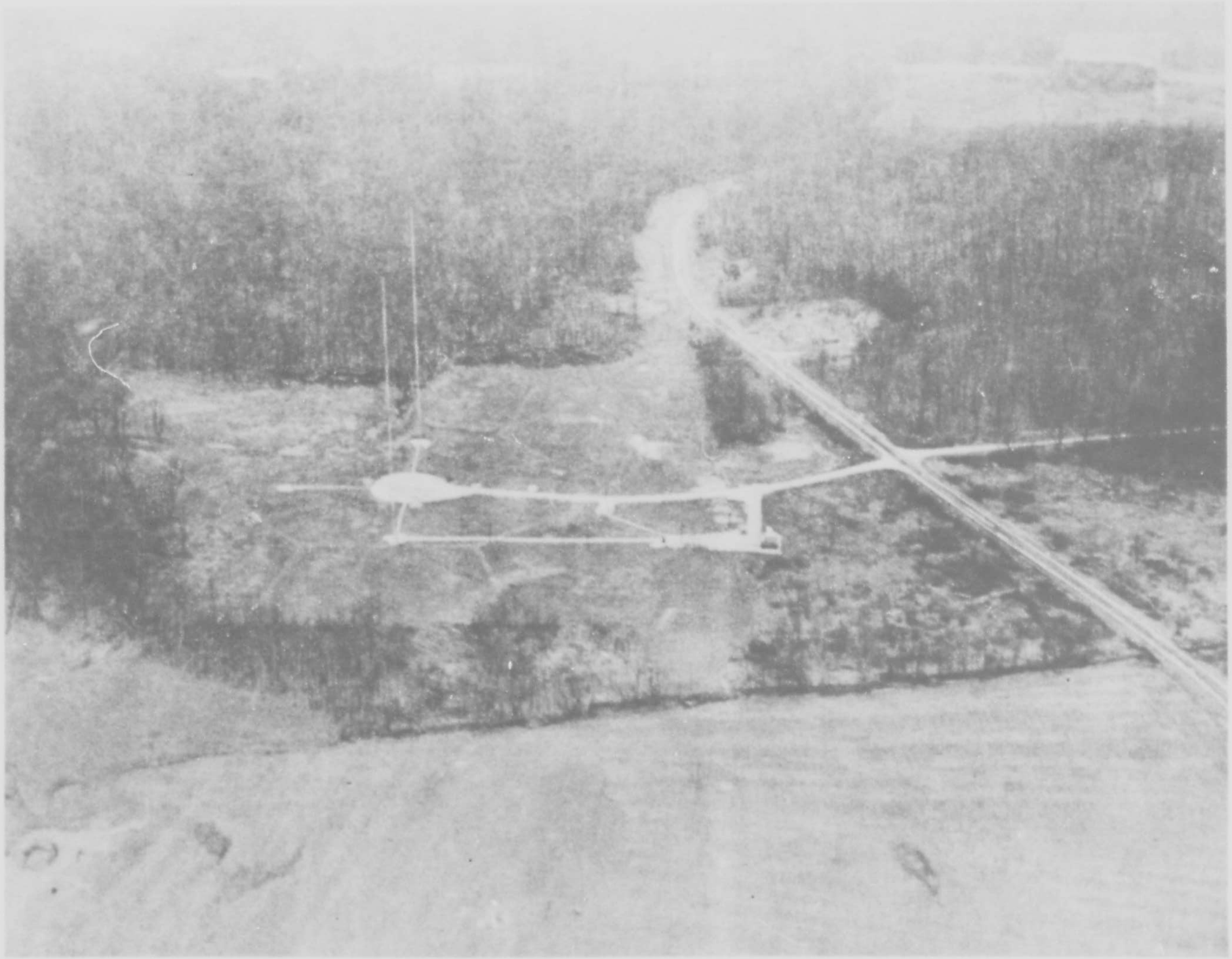


FIGURE 3

Aerial view of "SUPER" MAPI

sensing head during each second of burning time. With this information one can assess the directional performance of the unit. For example: intensities directly below the flare may be compared to some other region of the test site. Additionally one is able to assess the degree to which the smoke generated by the unit interferes with the ground illumination in any region of the test site.

Conclusions

The improved test capability which later became known as the "Super-MAPI Area" has been utilized successfully for the test of flares. The site is operational.

PART IV

RELATED FLARE TESTS

Purpose

Four major tests were performed which are directly related to the work described in this report. The summarized results of those tests are included.

First Test

Twelve short Briteye Flares designated as the MLU-44/B made by the Bermite Powder Company were tested on the regular MAPI site. It should be emphasized that the units were damaged in various ways. Therefore, optimum performance was not expected. The results do, however, show what efficiency level can be expected. Table III is the summarized data.

TABLE III

MLU 44/B BRITEYE FLARES MADE BY BERMITE

MAPI Test 1 December 67

Data from SCC-650 Computer 1/6/69

MAPI #	Burning (1) Time (sec)	Luminous Intensity ($x10^6$ candles)	Luminous Efficiency (cd.sec)/g
676	177	4.23	33,600
677	185	4.10	34,700
678	192	4.42	37,900
679	13	3.55	
680	133	4.77	29,000
681	166	4.68	34,900
682	73	5.15	
683	176	4.64	36,600
684	190	4.46	37,900
685	182	4.24	34,700
686	156	4.92	34,300
687	163	4.51	33,000

(1) The burning time is the period between the time when the unit reaches 750,000 candles at the start of the burn and the time when the unit first drops below 750,000 candles at the end of the burn. The first 10 seconds of the burn are not used to compute the luminous intensity.

Second Test, LUU-3/B

Twenty-four cast LUU-3/B flares made by the Thiokol Chemical Corporation (TCC) were received for test on the regular MAPI site. Twenty-two of the units were included in this test. The remaining two flares were held for the third test (26 April). All of these flares were made for the U.S. Air Force Armament Laboratory, Eglin Air Force Base by TCC under a development contract. The flares had been subjected to a variety of environmental, durability, and safety tests prior to this test. A matter to be considered in comparing the pressed Briteye MLU-44/B to the tamp-cast LUU-3/B is that the LUU-3/B is cast into an aluminum case and the MLU-44/B is pressed into a non-metal case. This is known to account for some of the performance differences. The details of the TCC work in developing these flares may be found in reference (9). Table IV is a summary of the MAPI test data.

TABLE IV

LUU-3/B FLARE TEST
MAPI Test 29 March 68
Data from SCC-650 Computer 11/20/68

MAPI # (1)	Burning (2) Time (sec)	Luminous Intensity ($x10^6$ candles)	Luminous Efficiency (cd-sec/g)
718	281	3.99	33,400
719	285	3.92	33,300
720	371	2.97	37,300
721	380	2.60	32,600
722	recorder failure		
723	364	2.56	31,400
724	360	3.22	39,200
725	225	5.19	38,600
726	336	3.62	40,100
727	330	3.82	41,700
728	316	3.90	40,800
729	303	3.93	39,800
730	307	3.20	33,300
732	279	4.66	45,900
734	293	4.38	45,000
735	340	3.80	43,000
736	334	3.94	44,300
737	280	4.47	44,500
738	305	4.27	45,100
739	317	3.96	42,700
741	286	4.85	41,300
742	297	4.31	45,200
743	294	4.87	50,600
744	267	4.63	43,700
745	312	4.27	45,600
746	252	4.90	36,800

(1) #718, 719, 741 and 746 are pressed MLU-44/B flares made by NAD Crane. The remainder are cast MLU-44/B flares made by Thiokol Chemical Corporation.

(2) The burning time is the period between the time when the unit reaches 750,000 candles at the start of the burn and the time when the unit first drops below 750,000 candles at the end of the burn. The first 10 seconds of the burn are not used to compute the luminous intensity.

Third Test, LUU-3/B

Two LUU-3/B flares were held out from the 29 March series. This was done to get a second comparison of the LUU-3/B to the pressed standard Briteye. These two units along with six Briteye Flares were tested on 26 April 1968 after recalibration of the MAPI instrumentation. Generally, the trends indicated by the second test were repeated. Table V is a summary of that data.

TABLE V

LUU-3/B FLARE TEST
MAPI Test 26 April 1968
Data from SCC-650 Computer May 1969

MAPI (1) Number	Burning (2) Time (sec)	Luminous Intensity ($x10^6$ candles)	Luminous Efficiency (cd-sec/gm)
671	282	4.99	39,000
672	278	4.71	37,000
673	280	4.82	38,100
674	289	4.54	44,500
675	308	4.38	38,100
676	recorder failure		
677	311	4.26	45,100
678	307	4.42	38,300

(1) #671, 672, 673, 675, 676, and 678 are pressed MLU-44/B flares made by NAD Crane. #674 and 677 are cast LUU-3/B flares made by Thiokol Chemical Corporation.

(2) The burning time is the period between the time when the unit reaches 750,000 candles at the start of the burn and the time when the unit first drops below 750,000 candles at the end of the burn. The first 10 seconds of the burn are not used to compute the luminous intensity.

Fourth Test, LUU-2/B

Five 4.5 inch diameter LUU-2/B flares made by the Thiokol Chemical Corporation (TCC) under contract to the Air Force Armament Laboratory were tested in the Photometric Tunnel. These units, like the 8 inch diameter LUU-3/B, were cast into an aluminum case. For purposes of comparison, the LUU-2/B flares were tested along with paper cased MK 45 production line flares and MK 45 size pressed "special" experimental flares. Reference (6) is a report of the early development of the LUU-2/B. Table VI is a summary of the test results.

TABLE VI

LUU-2/B TEST RESULTS

Test Date 22 Nov 68 in Photometric Tunnel

Item	Luminous Intensity (10^6 candles)	Burning Time (seconds)	Weight (grams)	Efficiency (cd.sec/gm)
1 Special	1.83	204	6800	55,200
2 Special	1.87	204	6800	56,100
3 Special	1.58	265	7704	54,500
4 Production	1.69	234	7641	51,200
5 LUU-2/B	1.55	279	9158	47,200
6 Special	1.56	272	7699	51,700
7 Production	1.79	217	7645	50,900
8 LUU-2/B	1.50	277	9221	45,300
9 Special	1.51	263	7708	51,800
10 Production	1.50	214	7627	42,400
11 LUU-2/B	1.48	281	9131	45,500
12 Special	1.58	253	7663	52,500
13 Production	1.62	240	7645	51,000
14 LUU-2/B	1.58	275	9158	47,700
15 Special	1.59	259	7672	53,700
16 Production	1.77	228	7604	53,100
17 LUU-2/B	1.56	275	9140	47,100

	Candles Average	Time Average	Efficiency Average
Special X (1,2)	1.85	205	55,700
Special (3,6,9,12,15)	1.54	262	52,900
Production (4,7,10,13,16)	1.68	226	49,700
LUU-2/B (5,8,11,14,17)	1.53	277	46,600

Conclusions

These data show that the tamp-cast flares, both 5" and 8", are relatively efficient as light producers. There data along with other information related to these test flares were submitted to the Air Force Armament Laboratory.

Note added in proof: See reference 13 by Northrop Carolina, Inc. concerning pressed and cast systems in a candle about 2.5 inch diameter and 11 inches long. See reference 14 by Thiokol Chemical Corporation concerning the development of an 8 inch cast flare.

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13. ABSTRACT

The development of a high intensity tamp-cast illuminating flare is described. The flare produced a luminous intensity of 25 million candles for over two minutes. A brief discussion is included concerning the binder systems used to make the tamp-cast flares along with the assembly of a capability for testing the flares. Summary data of flare tests related to this work is included.

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