(12)

AD A104324

AD

MEMORANDUM REPORT ARBRL-MR-03117

(Supersedes IMR No. 680)

SECONDARY MUZZLE FLASH AND BLAST OF THE BRITISH 81-mm, L16A2, MORTAR

George E. Keller

July 1981

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

81 9 18 061

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MEMORANDUM REPORT ARBRL-MR-03117	2. GOVT ACCESSION NO. AD-A104	3. RECIPIENT'S CATALOG NUMBER 324
4. TITLE (and Subtitle) SECONDARY MUZZLE FLASH AND BLAST OF THE BRITISH 81-mm, L16A2, MORTAR		5. TYPE OF REPORT & PERIOD COVERED Memorandum Report, Feb 80 — May 80 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) George E./Keller		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Ballistic Research Laboratory ATTN: DRDAR-BLI Aberdeen Proving Ground, MD 21005		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1L161102AH43
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Armament Research & Development Command U.S. Army Ballistic Research Laboratory ATTN: DRDAR-BL Aberdeen Proving Ground, MD 21005		12. REPORT DATE JULY 1981 13. NUMBER OF PAGES 45
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This report supersedes Interim Memorandum Report No. 680 dated April 1980.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Muzzle Flash
Muzzle Blast
Propellant
Interior Ballistics
Mortars

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

The British 81-mm, L16A2, Mortar, using six increments of MK3 propellant, has occasional rounds which cause intolerable overpressures at crew locations. The pressure-time records for the offending rounds show that the problem is associated with secondary muzzle flash, which is known to cause excessive overpressure in artillery and naval weapons also. Our calculations, designed to simulate the present mortar conditions, support the observations that the mortar flashes every time it is fired.

(over)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

The British have observed that either the addition of 1% chemical flash suppressant to the propellant or the addition of a two-caliber, conical suppressor eliminates the flash. These observations are combined with our calculations to provide a new basis for flash prediction for mortar systems. Several approaches to the flash problem of this mortar are considered, the best of which is the use of a cooler propellant, M6, as a replacement for the British propellant.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

I. INTRODUCTION

It has been known for some time that the energy dissipated in the secondary muzzle flash of a large caliber weapon causes an overpressure blast wave which can equal or even exceed the primary blast of the weapon[1,2]. Thus, when pressure-time traces for the British 81-mm, L16A2, mortar, using six increments of MK3 propellant, showed a considerable secondary blast, the offending rounds were dubbed "flashers", even though all rounds fired had a secondary flash.

Ballistic Research Laboratory (BRL) involvement in the secondary blast problem of this weapon began with a request from the Director of the Human Engineering Laboratory that we see what could be done to suppress the flash. A record of that telephone conversation is attached as Appendix A.

An actual pressure-time record for the weapon is shown in Figure 1. The location of the pressure gauge was about where the gunner would stand. The primary blast overpressure of about 34 kPa (5 psi) is bad enough, but the secondary blast peak of about 83 kPa (12 psi) is intolerable. For only about one in ten rounds is the measured secondary blast actually larger than the primary blast, but the effect of even that small percentage is shown in Figure 2. According to MIL-STD-1474B(MI), the gunner must remain behind the Z curve shown in Figure 2. The present Surgeon General's policy is to draw the Z curve using data from the worst case. Here, the worst case is due to a "flasher", and the result is that the gunner is not able to get behind the Z curve before the weapon fires. Thus, at the time that this report is being written, the Surgeon General would not issue a Safety Certification for the weapon.

This report covers our investigation of the problem of the secondary flash and secondary blast of the British L16A2 Mortar. It documents considerations of several alternative approaches to secondary flash (and blast) elimination. It incorporates the British findings[3] relative to flash suppression via chemical suppressant added to the propellant and via a conical suppressor. (Because of the use of existing interior ballistic models and flash models, almost all of the work was done in English units. Conversion to S.I. units was made for this report. Chronological details of this work are contained in BRL Laboratory Notebook BLP-79-451.)

---

[1] *G. SooHoo, "Gun Blast Experiments with an 8"/51 Gun," NSWC/DL Technical Note TN-T-1/75, February 1975.*

[2] *E. Bluestone, "First Letter Report of Development Test (DTII), Howitzer, 8-Inch, Full-Tracked, M110E2 Modified (Muzzle-Blast Overpressure Phase)," TECOM Project No. 2-WE-200-110-007, 23 March 1978.*

[3] *C. Wright, Program Review of the I81-mm Mortar System, Dover, NJ, 7 May 1980. Unpublished.*

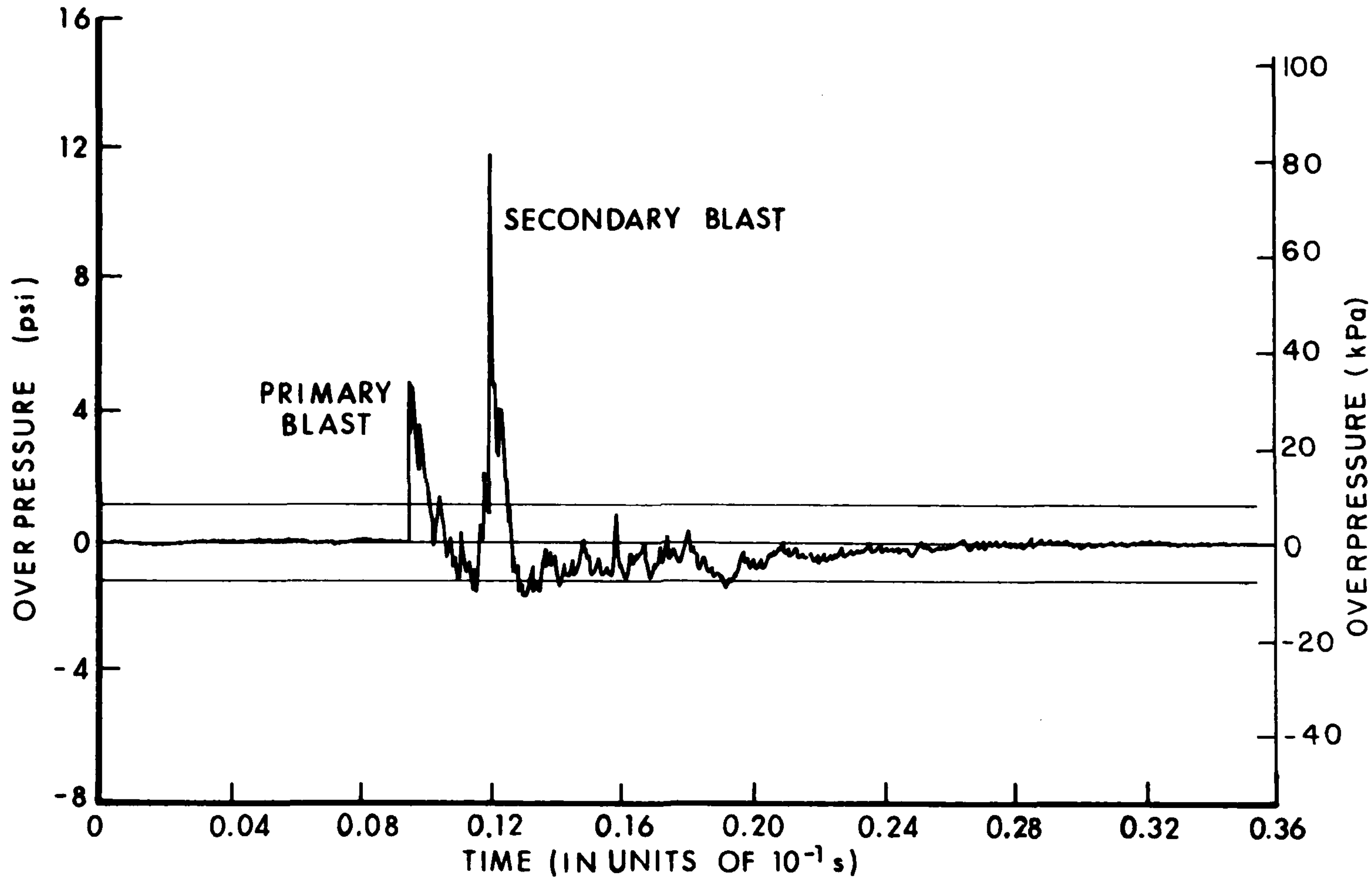

Figure 1. Pressure-Time Curves for the British Mortar.
MTD Test Round 41, a "Flasher".

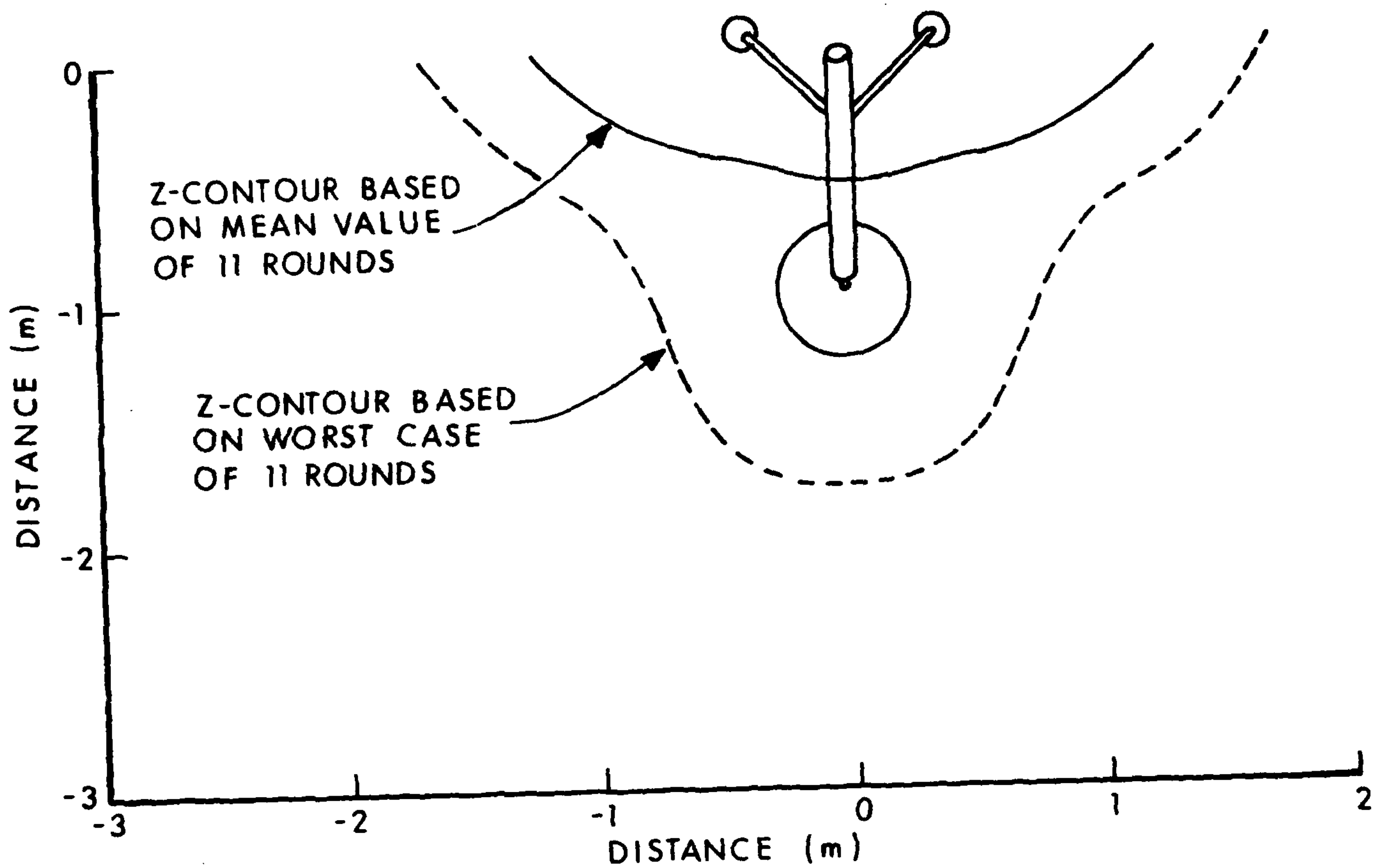

Figure 2. The Effect of Overpressure on Z Curves. 81-mm, L16A2, Mortar; Charge 6; MK3, Ground-Mounted.

II. THE PROBLEM AND BRITISH SOLUTIONS

Our first understanding was that the mortar only flashed about one time in ten firings. In fact, it was quickly established that it flashes every time it is fired, but that only one time in ten is the measured secondary blast larger than the primary blast. Thus, it was suggested that interior ballistic calculations be done for the system, followed by flash-prediction calculations, to see if the weapon should be expected to flash every time, and to see what could be done to stop the flashing.

From Materiel Testing Directorate (MTD) personnel it was learned that the projectile weighed 4.04 kg (8.9 lb) and that the mortar tube was 1.21 m (47.5 in.) long. Personnel of the Physical Measurements Section of MTD carefully measured the projectile behind the obturator. From the volume of the round behind the obturator and the base-to-obturator distance, we calculated a chamber volume of 1.063×10^6 mm^3 (64.88 $in.^3$). The calculations further implied that there are 118 mm (4.66 in.) of "full-bore shell" behind the obturator, which was added to the length of the projectile travel for all interior ballistic calculations.

Propellant specifications were obtained from the British specification covering Propellant - Ball Powder. There, we learned that the nitrogen content is 13.2%, diphenylamine between 0.85 and 1.5%, calcium carbonate between 0.2 and 0.6%, and graphite between 0.1 and 0.3%. The propellant granules are 0.30 to 0.41 mm (0.012 to 0.016 in.) in diameter.

Such a propellant is so similar to the U.S. M10 propellant that M10 propellant characterizations were used for the first interior ballistic (IB) calculations. These were performed with the Baer-Frankle model[4], as later modified by Deas and Lynn[5]. The final British specification states that with a charge of 0.121 kg (0.266 lb), a muzzle velocity of 286.5 m/s (940 ft/s) must be achieved with pressures not exceeding 77.2 MPa (11,200 psi). MTD personnel have measured 290 m/s and 72.4 MPa under those conditions. Using M10 propellant characteristics, our simulations gave 288 m/s and 75.4 MPa for the British weapon. These are close enough to the measured values that we used them as the reference calculations for this investigation. The results of the calculation for full charge (all six increments, totaling 0.121 kg) are shown in Appendix B. Thermodynamic values for these calculations were obtained using Blake[6], Version 203.3, at a loading density which gave peak pressures appropriate to this mortar system.

---

[4] *P.G. Baer and J.M. Frankle, "The Simulation of Interior Ballistic Performance of Guns by Digital Computer Program," BRL Report No. 1183, December 1962. AD #299 980.*

[5] *R.W. Deas and F.R. Lynn, "A Thermodynamic Model of Interior Ballistics," Report in preparation.*

[6] *E. Freedman, "Blake - A Ballistic Thermodynamic Code Based on Tiger," Proceedings of the International Symposium on Gun Propellants, Dover, NJ, October 1973, p. 1.10-1.*

The interior ballistic model yields muzzle temperature, pressure and velocity and the other muzzle exit characteristics necessary for flash prediction. In the manner of Carfagno[7], and using the calculational procedures developed by May and Einstein[8], a flash prediction calculation was made, and it is shown in Appendix C. This procedure calculates several relevant temperatures as a function of R, the fraction of entrained air in the mass of the mixture. Here T8 is the estimated temperature of the muzzle gas/air mixture after it is reheated by the primary shock. When T8 exceeds experimentally determined ignition limits, flash is likely to occur. Note that for this mortar, the maximum T8 is 1204 K. The column labeled T3 is the temperature of the muzzle gas/air mixture if a mechanical suppressor prevents shock reheating of the mixture. The maximum T3 for this basic calculation is 997 K.

One cannot overemphasize the fact that experimental work is still underway to validate the temperature predictions of available interior-ballistic models, and, while the flash predictions of the May-Einstein technique correlate well with observations, the temperature values inferred have not been validated. As a result, one speaks of the "temperatures" (T8's) and uses them as guidance in the prediction of flash, but the actual values of the temperatures have not yet been validated with measurements. An alternative approach to the calculation of the relevant temperatures, underway at this writing, promises improved predictions in the future. E. Schmidt outlines a quasi-two-dimensional approach to the calculation of near-muzzle gas temperatures and pressures[9].

From the work of Carfagno[7], as supplemented by observations reported in May and Einstein[8], one can construct a table of muzzle gas/air mixture

---

[7] *S.P. Carfagno, "Handbook on Gun Flash," Franklin Institute Report, Contract No. DA-36-034-514-ORD-78RD, November 1961, AD #327 051.*

[8] *I.W. May and S.I. Einstein, "Prediction of Gun Muzzle Flash," ARBRL-TR-02279, March 1980, AD A083888.*

[9] *E.M. Schmidt, "Gun Muzzle Flash and Associated Pressure Disturbances," submitted to the AIAA, December 1980.*

temperatures to use as a guide for predicting whether reignition of the mixture will lead to secondary flash in artillery systems, as follows:

TABLE 1. FLASH PREDICTION FOR ARTILLERY WEAPONS

Flash Suppressant	Occurrence of Secondary Flash		
%	Regularly	Unpredictable	Never
0	900 K	800 K	700 K
1	1125 K	1025 K	925 K
2	1225 K	1125 K	1025 K

It should be emphasized that these values and the flash observations come from studies of large caliber guns, for which the muzzle gas/air mixture is heated for a longer time than it is for mortars. Since it is known that a lengthening of the heating time of an air/fuel mixture causes the temperature required for ignition to be lower, the mixture temperatures required for reignition of mortar gases should be higher than those shown in Table 1.

The recent British observations[3] permit just such a table to be constructed for mortars. The British observed that a conical suppressor, two calibers in length and two calibers in diameter at the front, eliminated flash from ten of ten rounds fired. An IB calculation, which assumes that the conical device increases the gun's volume and thus the effective travel of the projectile in the gun, is included as Appendix D and a flash prediction as Appendix E. Assuming that the suppressor works by moving the normal shock downstream enough that shock reheating of the mixture does not lead to reignition, T3 is the relevant temperature, and the peak T3 is seen to be 953 K. If one combines that with the observations on the standard system, which had a peak T8 of 1204 K, of flash without suppressant and no flash with 1% suppressant, the following table is offered for future mortar flash prediction:

TABLE 2. FLASH PREDICTION FOR MORTARS

Flash Suppressant	Occurrence of Secondary Flash		
%	Regularly	Unpredictable	Never
0	1150 K	1050 K	950 K
1	1375 K	1275 K	1175 K
2	1475 K	1375 K	1275 K

Table 2 maintains the temperature differences from Table 1, but shifts all temperatures an equal amount. One would still expect a mortar with no suppressant and with a calculated peak T8 of 1204 K to flash every time, as has been observed in this case.

Carfagno[7] has pointed out that leakage of propellant gases around a mortar projectile could lead to rather different mixing and heating taking place at the muzzle of the mortar. However, he does not attempt to quantify the differences, and they are not included in any calculations in this report.

It has been suggested that the effectiveness of the conical suppressor arises from its cooling of the propellant gases. While one cannot state categorically that this is not the case, it is unlikely for the following reason. The May-Einstein flash prediction scheme starts with the stagnation temperature of the muzzle gases as they exit the muzzle. The conical suppressor should lead to an isentropic expansion of the muzzle gases, lowering the temperature and pressure while raising the gas velocity, but the stagnation temperature is not changed by such an isentropic process. Thus, a flash prediction for the case of an added conical suppressor should be similar to that for a bare muzzle. A better understanding of the muzzle gas temperature, pressure, and velocity after a conical suppressor, achieved by either models or measurements, would permit a more definitive statement about flash predictions for this case.

III. OTHER PROPOSED CURES

A. Charge Reduction

As an interim measure, while working on a solution to the blast problem, limited training with the weapon might be made possible by firing with a reduced charge. Appendices F and G document IB and flash-prediction calculations for the case of just one increment of MK3 propellant used in the present mortar. With a T8 of 1391 K, the mortar should still flash every time. However, while no data have been found to support the idea, less fuel may lead to a secondary flash and blast of reduced intensity, perhaps sufficiently reduced to permit training with the weapon.

B. Longer Tube

One method of improving the ballistic performance of the present system would be to lengthen the mortar tube, so that more energy is extracted from the propellant, with the result that both muzzle temperature and pressure are reduced. Appendices H and I document calculations for a mortar whose tube has been extended by 0.254 m (10 in.). We see that muzzle conditions are somewhat improved, but the muzzle gas/air temperature T8 is only 45 K less than that of the standard system. This system should still flash every time. On the other hand, this modified weapon has a higher muzzle velocity, and therefore a greater range, than the standard system.

C. Alternative Propellants

Several cooler propellants were considered as alternatives to the British propellant being used in the L16A2.

1. M31. M31, with a flame temperature of about 2600 K, was an early candidate for a replacement propellant. We calculated that an equal weight of M31 would provide nearly equal muzzle velocities. However, the heterogeneous nature of M31 would make it very difficult, if not impossible, to manufacture the propellant in the physical size needed.

2. M1. M1 was considered, with its flame temperature of about 2427 K. Unfortunately, M1 burns both coolly and slowly, and no reasonable combination of charge weight and propellant size could be found to yield useful ballistic performance.

3. M6. M6 was considered, because it is a homogeneous propellant and has a low flame temperature (2556 K). Appendix J is the full-charge calculation for M6 used in the British mortar; only the propellant has been changed. As before, the thermodynamic values used for these calculations were obtained from Blake[6], Version 203.3, at a loading density which gave peak pressures appropriate to this mortar system. Note that 13% more propellant was used. It is our opinion that there is room for such an increase. The propellant size is reasonable, 0.381-mm (0.015-in.) diameter. Both the calculated maximum tube pressure and the calculated muzzle velocity are nearly identical to the M10 benchmark values. Best of all, the flash calculation, reproduced as Appendix K, predicts a muzzle gas/air mixture temperature of only 954 K. Such a mixture would not be expected to flash.

D. Summary of Characteristics of Alternative Systems

Predicted muzzle velocities and muzzle gas/air mixture temperatures for the several alternative systems which have been investigated are shown in Table 3.

TABLE 3. PREDICTED MUZZLE VELOCITIES AND PEAK MIXTURE TEMPERATURES

	M10 Std Tube 6 Increments	M10 Conical Suppressor 6 Increments	M10 Std Tube 1 Increment	M10 Long Tube 6 Increments	M6 Std Tube 6 Increments
Muzzle Velocity	288 m/s	304 m/s	98 m/s	299 m/s	288 m/s
Peak Mixture Temperature	1204 K	953 K (T3)	1391 K	1159 K	954 K

IV. CONCLUSIONS

1. It is not surprising that the present British 81-mm, L16A2, Mortar using 6 increments of MK3 propellant flashes every time. Our calculations combine with the British observations of flash suppression for this system to show that it is quite reasonable to expect it to flash every time.

2. Interior ballistic calculations, flash-prediction calculations, and observations have been combined to produce a new table for flash prediction for mortar systems.

3. Adding a tube extension of perhaps 0.254 m (10 in.) would improve the performance of the weapon somewhat, but it would not be expected to eliminate the secondary flash (and/secondary blast).

4. Changing to a cooler propellant, such as M6, could eliminate secondary flash and the associated (sometimes severe) overpressures, while maintaining comparable ballistic performance. Such a change would eliminate the weight penalty that goes with a conical suppressor and the smoke penalty that goes with the use of a chemical suppressant.

V. ACKNOWLEDGMENTS

This report, while it has but one author, is the product of the work of many people. Figure 1 is the product of the Materiel Testing Directorate of USATECOM (Messrs. S. Walton, D. Lacey, and C. Herud). Figure 2, which so clearly illustrates the effect of having to cope with secondary flash and its associated secondary blast, came from the Human Engineering Laboratory (Messrs. G. Garinther and B. Cummings). The patience of Dr. E. M. Schmidt, Launch and Flight Division, BRL, is acknowledged, as he introduced me to the complexities of muzzle flows. I thank my many colleagues in the Applied Ballistics Branch (especially Drs. I. W. May and T. C. Minor and Messrs. A. W. Horst, T. R. Trafton, and P. G. Baer) for their patient instruction in the science and art that is interior ballistics.

REFERENCES

1. G. SooHoo, "Gun Blast Experiments with an 8"/51 Gun," NSWC/DL Technical Note TN-T-1/75, Feb 75.

2. E. Bluestone, "First Letter Report of Development Test (DTII), Howitzer, 8-Inch, Full-Tracked, M110E2 Modified (Muzzle-Blast Over-Pressure Phase)," TECOM Project No. 2-WE-200-110-007, 23 March 1977.

3. C. Wright, Program Review of the I81-mm Mortar System, Dover, NJ, 7 May 1980, Unpublished.

4. P.G. Baer and J.M. Frankle, "The Simulation of Interior Ballistic Performance of Guns by Digital Computer Program," BRL Report No. 1183, December 1962, AD #299 980.

5. R.W. Deas and F.R. Lynn, "A Thermodynamic Model of Interior Ballistics," Report in preparation.

6. E. Freedman, "Blake - A Ballistic Thermodynamic Code Based on Tiger," Proceedings of the International Symposium on Gun Propellants, Dover, NJ, October 1973, pp. 1.10-1.

7. S.P. Carfagno, "Handbook on Gun Flash," Franklin Institute Report, Contract No. DA-36-034-514-ORD-78RD, November 1961, AD #327 051.

8. I.W. May and S.I. Einstein, "Prediction of Gun Muzzle Flash," ARBRL-TR-02229, March 1980, AD A083888.

9. E.M. Schmidt, "Gun Muzzle Flash and Associated Pressure Disturbances," submitted to the AIAA, December 1980.

APPENDIX A.

RECORD OF TELEPHONE CONVERSATION WHICH LED TO THIS WORK

TELEPHONE OR VERBAL CONVERSATION RECORD

For use of this form, see AR 340-15; the proponent agency is The Adjutant General's Office.

DATE
12 Feb 80

SUBJECT OF CONVERSATION
81-mm Mortar

INCOMING CALL

PERSON CALLING	ADDRESS	PHONE NUMBER AND EXTENSION
G. Keller	DRDAR-BLP	278-3423
PERSON CALLED	**OFFICE**	**PHONE NUMBER AND EXTENSION**
J. Weisz, Director, HEL	DRXHE-D	278-3883

OUTGOING CALL

PERSON CALLING	OFFICE	PHONE NUMBER AND EXTENSION
PERSON CALLED	**ADDRESS**	**PHONE NUMBER AND EXTENSION**

SUMMARY OF CONVERSATION

1. As a result of conversations involving Dr. Weisz, Dr. Murphy, Dr. Eichelberger, J. Hurban, and J. Frankle, I called Dr. Weisz. He said that the US plans to buy the British 81-mm mortar. I got the impression that this procurement is a "first", a showpiece RSI action. Unfortunately, the mortar has a blast problem. Specifically, it flashes "sometimes", and there is a much larger secondary blast associated with the secondary flash (as has been observed for some time in artillery pieces). The Surgeon General now insists on using "worst case" data for blast safety specifications - the secondary blast has caused him to stop present troop testing of the weapon system. Cold weather testing is stopped in Alaska, with only a few weeks of time left for testing. OT testing is also stopped. HEL has formed a blast committee, including G. Kahl from BRL, and the committee will address the problem.

2. In the meantime, Dr. Weisz said Dr. Eichelberger said BRL had a solution to the flash problem - a standard flash suppressant such as potassium sulfate. Dr. Weisz wondered what BRL could do, in coordination with MTD perhaps, that could get the testing going again. Don Lacey from MTD was with Dr. Weisz when he talked with GEN Sheraton and should know details. I said I would call Laçey and be in touch with Dr. Weisz.

George E. Keller

GEORGE E. KELLER
Applied Ballistics Branch
Interior Ballistics Division

Routing:
1. Artly Prop Team Ldr, ABB, IBD
2. ~~Chief, ABB, IBD~~
3. Chief, IBD, BRL
4. Director, BRL

CF:
Mr. J. Hurban, IBD, BRL
Dr. G. Kahl, LFD, BRL
Dr. E. Schmidt, LFD, BRL
Dr. C. Murphy, LFD, BRL

DA FORM 1 APR 66 751 REPLACES EDITION OF 1 FEB 55 WHICH WILL BE USED.

APPENDIX B.

INTERIOR BALLISTIC CALCULATION TO SIMULATE PRESENT BRITISH L16A2 MORTAR

GUN TYPE: 81-MM MORTAR, BRITISH	TRAVEL: 39.6 IN
CHAMBER VOLUME: 64.88 CU IN	TIME STEP: .100 MS
GROOVE DIAMETER: 3.205 IN	LAND DIAMETER: 3.205 IN
GROOVE/LAND RATIO: 1.000	BORE AREA: 8.068 SQ IN
TWIST: NONE	EXPANSION RATIO: 5.9
PRESSURE GRADIENT: LAGRANGIAN	EROSIVE COEFF: .0000000
PROJECTILE: BRITISH	PROJ WT: 8.900 LB

ENGRAVING & FRICTIONAL RESISTANCE [KPSI] VS. TRAVEL [IN]

TRAVEL:	0.00
RESISTANCE:	.10

PROPELLANT	BLK POWDER	M10
WEIGHT [LB]	.00024	.266
IMPETUS [FT-LB/LB]	96000.	347665.
FLAME TEMP [K]	2000.	3042.
ALPHA	0.0000	.8650
BETA	50.000000	.000826
GAMMA	1.250	1.233
COVOL [CU IN/LB]	30.000	29.780
DENS [LB/CU IN]	.06000	.06033
GRAIN TYPE	CORD	SPHERE
GRAIN LEN [IN]	.2000	-------
GRAIN DIAM [IN]	.1000	.0140
IGNITION CODE	0	0
THRESHOLD VALUE	0.00000	0.00000

M10, STD TUBE, THERMO FOR LOW LOADING DENSITY

CONDITIONS AT:	MAX PR	MUZZLE	PROP 1 BURNT	PROP 2 BURNT
TIME [MS]	3.50	7.74	1.00	5.75
BR PRES [KPSI]	10.93	1.92	.15	4.07
MN PRES [KPSI]	10.88	1.91	.15	4.05
BS PRES [KPSI]	10.77	1.89	.15	4.01
MEAN TEMP [K]	2890.	1970.	2997.	2294.
TRAVEL [IN]	2.4	39.6	0.0	18.6
VEL [FPS]	319.	944.	0.	793.
ACCEL [G'S]	9657.	1587.	31.	3510.
FR BRNT PROP 1	1.000	1.000	1.000	1.000
FR BRNT PROP 2	.798	1.000	.008	1.000

APPENDIX C

FLASH-PREDICTION CALCULATION FOR
PRESENT BRITISH L16A2 MORTAR

M10, STD TUBE, THERMO FOR LOW LOADING DENSITY

AMBIENT TEMP IN DEG K = 295.0
SPECIFIC HEAT, CONST P= .24
SPECIFIC HEAT, CONST V = .171
AMBIENT PRESSURE IN PSI = 14.70
MUZZLE VELOCITY, FT PER SEC = 944.0
PROJECTILE WEIGHT IN POUNDS = 8.9
GUN VOLUME IN CUBIC INCHES = 383.0
MUZZLE PRESSURE IN PSI = 1890.0
MUZZLE TEMPERATURE IN K = 1949.0
PROPELLANT FORCE = 347665.0
FLAME TEMPERATURE = 3042.0
SPECIFIC HEAT RATIO = 1.233
CHARGE WEIGHT IN POUNDS = .266

R	P4	T3	T4	T5	T8
0.00	212.08	778.48	1936.41	1169.35	1169.35
.05	181.94	822.72	1886.43	1164.43	1183.50
.10	156.37	862.77	1833.99	1157.37	1194.10
.15	134.49	898.34	1778.88	1148.21	1200.91
.20	115.60	929.09	1720.87	1136.95	1203.65
.25	99.18	954.67	1659.72	1123.56	1202.02
.30	84.82	974.67	1595.13	1107.97	1195.66
.35	72.22	988.66	1526.76	1090.04	1184.23
.40	61.11	996.15	1454.23	1069.60	1167.29
.45	51.28	996.60	1377.06	1046.40	1144.40
.50	42.58	989.40	1294.69	1020.09	1115.04
.55	34.85	973.88	1206.39	990.18	1078.64
.60	27.99	949.28	1111.22	955.95	1034.56
.65	21.90	914.76	1007.87	916.30	982.09
.70	16.51	869.34	894.36	869.38	920.41
.75	11.75	811.95	767.36	811.70	848.59
.80	7.58	741.34	620.40	735.44	765.60
.85	3.99	656.09	437.80	617.71	670.23
.90	.97	554.59	166.58	347.56	561.10

APPENDIX D

INTERIOR BALLISTIC CALCULATION FOR THE PRESENT SYSTEM WITH A TWO-CALIBER, CONICAL SUPPRESSOR

GUN TYPE: 81-MM MORTAR, BRITISH
CHAMBER VOLUME: 64.88 CU IN
GROOVE DIAMETER: 3.205 IN
GROOVE/LAND RATIO: 1.000
TWIST: NONE
PRESSURE GRADIENT: LAGRANGIAN
PROJECTILE: BRITISH

TRAVEL: 54.6 IN
TIME STEP: .100 MS
LAND DIAMETER: 3.205 IN
BORE AREA: 8.068 SQ IN
EXPANSION RATIO: 7.8
EROSIVE COEFF: .0000000
PROJ WT: 8.900 LB

ENGRAVING & FRICTIONAL RESISTANCE [KPSI] VS. TRAVEL [IN]

TRAVEL:	0.00
RESISTANCE:	.10

PROPELLANT	BLK POWDER	M10
WEIGHT [LB]	.000	.266
IMPETUS [FT-LB/LB]	96000.	347665.
FLAME TEMP [K]	2000.	3042.
ALPHA	0.0000	.8650
BETA	50.000000	.000826
GAMMA	1.250	1.233
COVOL [CU IN/LB]	30.000	29.780
DENS [LB/CU IN]	.06000	.06033
GRAIN TYPE	CORD	SPHERE
GRAIN LEN [IN]	.2000	-------
GRAIN DIAM [IN]	.1000	.0140
IGNITION CODE	0	0
THRESHOLD VALUE	0.00000	0.00000

M10 WITH TWO-CALIBER, CONICAL SUPPRESSOR

CONDITIONS AT:	MAX PR	MUZZLE	PROP 1 BURNT	PROP 2 BURNT
TIME [MS]	3.50	9.03	1.00	5.75
BR PRES [KPSI]	10.92	1.34	.15	4.05
MN PRES [KPSI]	10.87	1.34	.15	4.03
BS PRES [KPSI]	10.76	1.33	.15	4.00
MEAN TEMP [K]	2888.	1822.	2997.	2284.
TRAVEL [IN]	2.4	54.6	0.0	18.6
VEL [FPS]	319.	996.	0.	791.
ACCEL [G'S]	9648.	1071.	31.	3498.
FR BRNT PROP 1	1.000	1.000	1.000	1.000
FR BRNT PROP 2	.798	1.000	.008	1.000

APPENDIX E

FLASH-PREDICTION CALCULATION FOR THE PRESENT SYSTEM WITH A TWO-CALIBER, CONICAL SUPPRESSOR

M10 WITH TWO-CALIBER, CONICAL SUPPRESSOR

AMBIENT TEMP IN DEG K = 295.0
SPECIFIC HEAT, CONST P= .24
SPECIFIC HEAT, CONST V = .171
AMBIENT PRESSURE IN PSI = 14.70
MUZZLE VELOCITY, FT PER SEC = 996.0
PROJECTILE WEIGHT IN POUNDS = 8.9
GUN VOLUME IN CUBIC INCHES = 504.0
MUZZLE PRESSURE IN PSI = 1330.0
MUZZLE TEMPERATURE IN K = 1808.0
PROPELLANT FORCE = 347665.0
FLAME TEMPERATURE = 3042.0
SPECIFIC HEAT RATIO = 1.233
CHARGE WEIGHT IN POUNDS = .266

R	P4	T3	T4	T5	T8
0.00	190.17	771.74	1799.00	1108.99	1108.99
.05	164.30	809.78	1753.00	1103.44	1121.06
.10	142.07	844.02	1704.71	1096.07	1129.90
.15	122.81	874.22	1653.96	1086.92	1135.28
.20	106.03	900.05	1600.52	1075.96	1136.95
.25	91.31	921.21	1544.15	1063.14	1134.62
.30	78.34	937.32	1484.59	1048.37	1128.00
.35	66.88	948.00	1421.52	1031.53	1116.74
.40	56.72	952.80	1354.55	1012.44	1100.46
.45	47.68	951.23	1283.24	990.86	1078.75
.50	39.63	942.75	1207.04	966.44	1051.15
.55	32.46	926.73	1125.24	938.72	1017.12
.60	26.06	902.51	1036.90	906.98	976.10
.65	20.37	869.31	940.71	870.12	927.41
.70	15.32	826.27	834.64	826.27	870.33
.75	10.85	772.39	715.26	771.80	804.00
.80	6.93	706.55	575.74	698.37	727.49
.85	3.55	627.49	399.38	580.90	639.68
.90	.73	533.71	129.00	291.43	539.34

APPENDIX F

INTERIOR BALLISTIC CALCULATION FOR MORTAR WITH STANDARD TUBE, ONE CHARGE INCREMENT

GUN TYPE: 81-MM MORTAR, BRITISH
CHAMBER VOLUME: 64.88 CU IN
GROOVE DIAMETER: 3.205 IN
GROOVE/LAND RATIO: 1.000
TWIST: NONE
PRESSURE GRADIENT: LAGRANGIAN
PROJECTILE: BRITISH

TRAVEL: 39.6 IN
TIME STEP: .100 MS
LAND DIAMETER: 3.205 IN
BORE AREA: 8.068 SQ IN
EXPANSION RATIO: 5.9
EROSIVE COEFF: .0000000
PROJ WT: 8.900 LB

ENGRAVING & FRICTIONAL RESISTANCE [KPSI] VS. TRAVEL [IN]

TRAVEL:	0.00
RESISTANCE:	.10

PROPELLANT	BLK POWDER	M10
WEIGHT [LB]	.00024	.044
IMPETUS [FT-LB/LB]	96000.	347665.
FLAME TEMP [K]	2000.	3042.
ALPHA	0.0000	.8650
BETA	50.000000	.000826
GAMMA	1.250	1.233
COVOL [CU IN/LB]	30.000	29.780
DENS [LB/CU IN]	.06000	.06033
GRAIN TYPE	CORD	SPHERE
GRAIN LEN [IN]	.2000	-------
GRAIN DIAM [IN]	.1000	.0140
IGNITION CODE	0	0
THRESHOLD VALUE	0.00000	0.00000

M10, STD TUBE, INCREMENT 1

CONDITIONS AT:	MAX PR	MUZZLE	PROP 1 BURNT	PROP 2 BURNT
TIME [MS]	13.00	25.49	1.00	-----
BR PRES [KPSI]	1.19	.32	.01	-----
MN PRES [KPSI]	1.19	.32	.01	-----
BS PRES [KPSI]	1.19	.32	.01	-----
MEAN TEMP [K]	2860.	2075.	2392.	-----
TRAVEL [IN]	2.7	39.6	0.0	-----
VEL [FPS]	112.	321.	0.	-----
ACCEL [G'S]	971.	176.	0.	-----
FR BRNT PROP 1	1.000	1.000	1.000	-----
FR BRNT PROP 2	.590	.966	.001	-----

APPENDIX G

FLASH-PREDICTION CALCULATION FOR MORTAR WITH STANDARD TUBE, ONE CHARGE INCREMENT

M10, STD TUBE, INCREMENT 1

AMBIENT TEMP IN DEG K = 295.0
SPECIFIC HEAT, CONST P= .24
SPECIFIC HEAT, CONST V = .171
AMBIENT PRESSURE IN PSI = 14.70
MUZZLE VELOCITY, FT PER SEC = 321.0
PROJECTILE WEIGHT IN POUNDS = 8.9
GUN VOLUME IN CUBIC INCHES = 383.0
MUZZLE PRESSURE IN PSI = 320.0
MUZZLE TEMPERATURE IN K = 2075.0
PROPELLANT FORCE = 347665.0
FLAME TEMPERATURE = 3042.0
SPECIFIC HEAT RATIO = 1.233
CHARGE WEIGHT IN POUNDS = .044

R	P4	T3	T4	T5	T8
0.00	108.84	1159.33	2026.47	1388.14	1388.14
.05	96.94	1179.39	1972.48	1373.79	1390.58
.10	86.13	1195.57	1915.78	1357.85	1389.53
.15	76.29	1207.61	1856.13	1340.20	1384.73
.20	67.33	1215.19	1793.29	1320.74	1375.91
.25	59.15	1217.99	1726.96	1299.30	1362.78
.30	51.68	1215.63	1656.80	1275.69	1344.99
.35	44.85	1207.71	1582.43	1249.65	1322.19
.40	38.60	1193.78	1503.38	1220.86	1293.96
.45	32.89	1173.33	1419.10	1188.92	1259.85
.50	27.67	1145.81	1328.90	1153.26	1219.36
.55	22.90	1110.60	1231.90	1113.11	1171.92
.60	18.55	1066.99	1126.94	1067.34	1116.91
.65	14.59	1014.20	1012.34	1014.20	1053.62
.70	11.00	951.34	885.58	950.71	981.23
.75	7.76	877.40	742.32	871.20	898.85
.80	4.86	791.23	573.99	762.72	805.44
.85	2.31	691.54	359.74	586.33	699.81
.90	.12	576.80	28.99	106.29	580.61

APPENDIX H

INTERIOR BALLISTIC CALCULATION FOR MORTAR WITH 0.254-m (10-in.) TUBE EXTENSION

GUN TYPE: 81-MM MORTAR, BRITISH	TRAVEL: 49.6 IN
CHAMBER VOLUME: 64.88 CU IN	TIME STEP: .100 MS
GROOVE DIAMETER: 3.205 IN	LAND DIAMETER: 3.205 IN
GROOVE/LAND RATIO: 1.000	BORE AREA: 8.068 SQ IN
TWIST: NONE	EXPANSION RATIO: 7.2
PRESSURE GRADIENT: LAGRANGIAN	EROSIVE COEFF: .0000000
PROJECTILE: BRITISH	PROJ WT: 8.900 LB

ENGRAVING & FRICTIONAL RESISTANCE [KPSI] VS. TRAVEL [IN]

TRAVEL:	0.00
RESISTANCE:	.10

PROPELLANT	BLK POWDER	M10
WEIGHT [LB]	.00024	.266
IMPETUS [FT-LB/LB]	96000.	347665.
FLAME TEMP [K]	2000.	3042.
ALPHA	0.0000	.8650
BETA	50.000000	.000826
GAMMA	1.250	1.233
COVOL [CU IN/LB]	30.000	29.780
DENS [LB/CU IN]	.06000	.06033
GRAIN TYPE	CORD	SPHERE
GRAIN LEN [IN]	.2000	-------
GRAIN DIAM [IN]	.1000	.0140
IGNITION CODE	0	0
THRESHOLD VALUE	0.00000	0.00000

M10, LONG TUBE, THERMO FOR LOW LOADING DENSITY

CONDITIONS AT:	MAX PR	MUZZLE	PROP 1 BURNT	PROP 2 BURNT
TIME [MS]	3.50	8.61	1.00	5.75
BR PRES [KPSI]	10.93	1.50	.15	4.06
MN PRES [KPSI]	10.87	1.49	.15	4.04
BS PRES [KPSI]	10.77	1.48	.15	4.00
MEAN TEMP [K]	2889.	1867.	2997.	2287.
TRAVEL [IN]	2.4	49.6	0.0	18.6
VEL [FPS]	319.	982.	0.	792.
ACCEL [G'S]	9651.	1208.	31.	3502.
FR BRNT PROP 1	1.000	1.000	1.000	1.000
FR BRNT PROP 2	.798	1.000	.008	1.000

APPENDIX I

FLASH-PREDICTION CALCULATION FOR MORTAR WITH 0.254-m (10-in.) TUBE EXTENSION

M10, LONG TUBE, THERMO FOR LOW LOADING DENSITY

AMBIENT TEMP IN DEG K = 295.0
SPECIFIC HEAT, CONST P= .24
SPECIFIC HEAT, CONST V = .171
AMBIENT PRESSURE IN PSI = 14.70
MUZZLE VELOCITY, FT PER SEC = 982.0
PROJECTILE WEIGHT IN POUNDS = 8.9
GUN VOLUME IN CUBIC INCHES = 464.0
MUZZLE PRESSURE IN PSI = 1480.0
MUZZLE TEMPERATURE IN K = 1854.0
PROPELLANT FORCE = 347665.0
FLAME TEMPERATURE = 3042.0
SPECIFIC HEAT RATIO = 1.233
CHARGE WEIGHT IN POUNDS = .266

R	P4	T3	T4	T5	T8
0.00	196.68	775.56	1843.92	1129.48	1129.48
.05	169.57	815.50	1796.62	1124.07	1142.17
.10	146.36	851.52	1746.98	1116.75	1151.53
.15	126.33	883.35	1694.79	1107.54	1157.33
.20	108.93	910.68	1639.85	1096.44	1159.29
.25	93.70	933.18	1581.92	1083.40	1157.14
.30	80.32	950.46	1520.71	1068.32	1150.56
.35	68.52	962.11	1455.90	1051.09	1139.19
.40	58.07	967.69	1387.11	1031.53	1122.65
.45	48.79	966.68	1313.88	1009.39	1100.51
.50	40.54	958.53	1235.65	984.32	1072.29
.55	33.20	942.59	1151.72	955.85	1037.45
.60	26.66	918.17	1061.14	923.27	995.39
.65	20.85	884.46	962.60	885.47	945.43
.70	15.69	840.57	854.09	840.58	886.81
.75	11.13	785.48	732.20	785.02	818.66
.80	7.14	718.03	590.24	710.63	740.00
.85	3.69	636.90	411.84	593.07	649.70
.90	.81	540.57	141.23	310.30	546.47

APPENDIX J

INTERIOR BALLISTIC CALCULATION FOR BRITISH MORTAR WITH M6 PROPELLANT

GUN TYPE: 81-MM MORTAR, BRITISH	TRAVEL: 39.6 IN
CHAMBER VOLUME: 64.88 CU IN	TIME STEP: .100 MS
GROOVE DIAMETER: 3.205 IN	LAND DIAMETER: 3.205 IN
GROOVE/LAND RATIO: 1.000	BORE AREA: 8.068 SQ IN
TWIST: NONE	EXPANSION RATIO: 5.9
PRESSURE GRADIENT: LAGRANGIAN	EROSIVE COEFF: .0000000
PROJECTILE: BRITISH	PROJ WT: 8.900 LB

ENGRAVING & FRICTIONAL RESISTANCE [KPSI] VS. TRAVEL [IN]

TRAVEL:	0.00
RESISTANCE:	.10

PROPELLANT	BLK POWDER	M6
WEIGHT [LB]	.00024	.300
IMPETUS [FT-LB/LB]	96000.	316860.
FLAME TEMP [K]	2000.	2556.
ALPHA	0.0000	.7090
BETA	50.000000	.003380
GAMMA	1.250	1.257
COVOL [CU IN/LB]	30.000	32.060
DENS [LB/CU IN]	.06000	.05700
GRAIN TYPE	CORD	SPHERE
GRAIN LEN [IN]	.2000	-------
GRAIN DIAM [IN]	.1000	.0160
IGNITION CODE	0	0
THRESHOLD VALUE	0.00000	0.00000

M6 WITH STD TUBE

CONDITIONS AT:	MAX PR	MUZZLE	PROP 1 BURNT	PROP 2 BURNT
TIME [MS]	2.70	6.95	1.00	5.75
BR PRES [KPSI]	10.79	1.91	1.26	2.91
MN PRES [KPSI]	10.73	1.90	1.25	2.90
BS PRES [KPSI]	10.62	1.88	1.24	2.87
MEAN TEMP [K]	2413.	1593.	2553.	1747.
TRAVEL [IN]	2.4	39.6	.0	26.5
VEL [FPS]	319.	945.	6.	869.
ACCEL [G'S]	9513.	1574.	1021.	2474.
FR BRNT PROP 1	1.000	1.000	1.000	1.000
FR BRNT PROP 2	.755	1.000	.065	1.000

APPENDIX K

FLASH-PREDICTION CALCULATION FOR BRITISH MORTAR WITH M6 PROPELLANT

M6 WITH STD TUBE

AMBIENT TEMP IN DEG K = 295.0
SPECIFIC HEAT, CONST P= .24
SPECIFIC HEAT, CONST V = .171
AMBIENT PRESSURE IN PSI = 14.70
MUZZLE VELOCITY, FT PER SEC = 945.0
PROJECTILE WEIGHT IN POUNDS = 8.9
GUN VOLUME IN CUBIC INCHES = 383.0
MUZZLE PRESSURE IN PSI = 1880.0
MUZZLE TEMPERATURE IN K = 1576.0
PROPELLANT FORCE = 316860.0
FLAME TEMPERATURE = 2556.0
SPECIFIC HEAT RATIO = 1.257
CHARGE WEIGHT IN POUNDS = .300

R	P4	T3	T4	T5	T8
0.00	219.45	584.52	1566.19	901.18	901.18
.05	186.53	625.60	1527.26	903.05	917.90
.10	159.14	663.28	1486.40	902.92	931.74
.15	136.04	697.33	1443.43	900.89	942.51
.20	116.35	727.48	1398.19	897.01	949.98
.25	99.41	753.43	1350.46	891.28	953.89
.30	84.73	774.86	1300.02	883.69	953.98
.35	71.92	791.42	1246.59	874.15	949.94
.40	60.69	802.70	1189.84	862.55	941.44
.45	50.81	808.27	1129.38	848.72	928.10
.50	42.08	807.62	1064.73	832.41	909.50
.55	34.35	800.23	995.27	813.23	885.18
.60	27.51	785.45	920.17	790.63	854.62
.65	21.44	762.61	838.22	763.72	817.23
.70	16.08	730.92	747.58	730.93	772.34
.75	11.36	689.48	645.03	689.15	719.21
.80	7.23	637.29	524.11	631.01	656.97
.85	3.69	573.18	368.72	533.59	584.65
.90	.76	495.83	122.87	276.42	501.12

DISTRIBUTION LIST

No. of Copies	Organization
12	Commander Defense Technical Info Center ATTN: DDC-DDA Cameron Station Alexandria, VA 22314
1	Commander US Army Materiel Development and Readiness Command ATTN: DRCDMD-ST 5001 Eisenhower Avenue Alexandria, VA 22333
2	Commander US Army Armament R&D Command ATTN: DRDAR-TSS Dover, NJ 07801
9	Commander US Army Armament R&D Command ATTN: DRDAR-LCA W. Benson H. Fair D. Downs K. Russell L. Schlosberg S. Westley S. Bernstein P. Kemmey C. Heyman Dover, NJ 07801
1	Commander US Army Armament R&D Command ATTN: DRDAR-LCE, R. Walker Dover, NJ 07801
2	Commander US Army Armament R&D Command ATTN: DRDAR-SCA, L. Stiefel B. Brodman Dover, NJ 07801
1	Commander US Army Armament R&D Command ATTN: DRDAR-LCB-I, D. Spring Dover, NJ 07801
5	Commander US Army Armament R&D Command ATTN: DRDAR-QAR-Q, J. Rutkowski G. Allen J. Donner P. Seraro D. Adams Dover, NJ 07801
2	Commander US Army Armament R&D Command ATTN: DRCPM-CAWS, F. Menke H. Noble Dover, NJ 07801
1	Commander US Army Armament R&D Command ATTN: DRDAR-LCW-A, M. Salsbury Dover, NJ 07801
1	Commander US Army Armament R&D Command ATTN: DRDAR-LCS, J.W. Gregorits Dover, NJ 07801
1	Commander US Army Armament R&D Command ATTN: DRDAR-LCU, A. Moss Dover, NJ 07801
1	Commander US Army Armament R&D Command ATTN: DRDAR-LC, J.T. Frasier Dover, NJ 07801
1	Commander US Army Armament R&D Command ATTN: DRDAR-XM Dover, NJ 07801

DISTRIBUTION LIST

No. of Copies	Organization
1	Commander US Army Armament Materiel Readiness Command ATTN: DRDAR-LEP-L, Tech Library Rock Island, IL 61299
1	Commander US Army Watervliet Arsenal ATTN: SARWV-RD, R. Thierry Watervliet, NY 12189
1	Director US Army ARRADCOM Benet Weapons Laboratory ATTN: DRDAR-LCB-TL Watervliet, NY 12189
1	Commander US Army Aviation Research and Development Command ATTN: DRDAV-E 4300 Goodfellow Blvd. St. Louis, MO 63120
1	Director US Army Air Mobility Research and Development Laboratory Ames Research Center Moffett Field, CA 94035
1	Commander US Army Communications Research and Development Command ATTN: DRDCO-PPA-SA Fort Monmouth, NJ 07703
1	Commander US Army Electronics Research and Development Command Technical Support Activity ATTN: DELSD-L Fort Monmouth, NJ 07703

No. of Copies	Organization
1	Commander US Army Missile Command ATTN: DRSMI-R Redstone Arsenal, AL 35809
1	Commander US Army Missile Command ATTN: DRSMI-YDL Redstone Arsenal, AL 35809
1	Commander US Army Natick Research and Development Command ATTN: DRXRE, D. Sieling Natick, MA 01762
1	Commander US Army Tank Automotive Research and Development Command ATTN: DRDTA-UL Warren, MI 48090
2	Commander US Army Materials and Mechanics Research Center ATTN: DRXMR-ATL Tech Library Watertown, MA 02172
1	Commander US Army Research Office ATTN: Tech Library P.O. Box 12211 Research Triangle Park, NC 27706
1	Director US Army TRADOC Systems Analysis Activity ATTN: ATAA-SL, Tech Library White Sands Missile Range, NM 88002

DISTRIBUTION LIST

No. of Copies	Organization	No. of Copies	Organization
1	Chief Naval Research ATTN: Code 473, R.S. Miller 800 N. Quincy Street Arlington, VA 22217	2	Commanding Officer Naval Ordnance Station ATTN: P.L. Stang C. Smith Indian Head, MD 20640
1	Commander Naval Sea Systems Command ATTN: SEA-62R2, J.W. Murrin National Center, Bldg. 2 Room 6E08 Washington, DC 20360	1	Program Manager AFOSR Directorate of Aerospace Sciences ATTN: L.H. Caveny Bolling AFB, DC 20332
3	Commander Naval Surface Weapons Center ATTN: Code G33, J.L. East D. McClure Code DX-21 Tech Library Dahlgren, VA 22448	2	AFRPL (DYSC) ATTN: D. George J.N. Levine Edwards AFB, CA 93523
2	Commander Naval Surface Weapons Center ATTN: S.J. Jacobs/Code 240 Code 730 K. Kim/Code R-13 Silver Spring, MD 20910	1	AFATL/DLDL ATTN: O.K. Heiney Eglin AFB, FL 32542
1	Commanding Officer Naval Underwater Systems Center Energy Conversion Dept. ATTN: Code 5B331, R.S. Lazar Newport, RI 02840	1	Aerodyne Research, Inc. Bedford Research Park ATTN: V. Yousefian Bedford, MA 01730
2	Commander Naval Weapons Center ATTN: Code 388, R.L. Derr C.F. Price China Lake, CA 93555	1	Aerojet Solid Propulsion Co. ATTN: P. Micheli Sacramento, CA 95813
1	Superintendent Naval Postgraduate School Dept. of Mechanical Engineering ATTN: A.E. Fuhs Monterey, CA 93940	1	Atlantic Research Corporation ATTN: M.K. King 5390 Cherokee Avenue Alexandria, VA 22314
		1	AVCO Corporation AVCO Everett Rsch Lab Div ATTN: D. Stickler 2385 Revere Beach Parkway Everett, MA 02149
		1	Calspan Corporation ATTN: E.B. Fisher P.O. Box 400 Buffalo, NY 14221

DISTRIBUTION LIST

No. of Copies	Organization
1	General Applied Sciences Labs ATTN: J. Erdos Merrick & Stewart Avenues Westbury Long Island, NY 11590
1	General Electric Company Armament Systems Dept. ATTN: M.J. Bulman, Room 1311 Lakeside Avenue Burlington, VT 05402
1	Hercules, Inc. Allegany Ballistics Laboratory ATTN: R.B. Miller P.O. Box 210 Cumberland, MD 21502
1	Hercules, Inc. Bacchus Works ATTN: K.P. McCarty P.O. Box 98 Magna, UT 84044
1	Hercules, Inc. Eglin Operations AFATL/DLDL ATTN: R.L. Simmons Eglin AFB, FL 32542
1	IITRI ATTN: M.J. Klein 10 W. 35th Street Chicago, IL 60615
1	Lawrence Livermore Laboratory ATTN: M.S. L-355, A. Buckingham P.O. Box 808 Livermore, CA 94550
1	Olin Corporation Badger Army Ammunition Plant ATTN: R.J. Thiede Baraboo, WI 53913

No. of Copies	Organization
1	Olin Corporation Smokeless Powder Operations ATTN: R.L. Cook P.O. Box 222 St. Marks, FL 32355
1	Paul Gough Associates, Inc. ATTN: P.S. Gough P.O. Box 1614 Portsmouth, NH 03801
1	Physics International Company 2700 Merced Street Leandro, CA 94577
1	Princeton Combustion Research Lab., Inc. ATTN: M. Summerfield 1041 US Highway One North Princeton, NJ 08540
1	Pulsepower Systems, Inc. ATTN: L. C. Elmore 815 American Street San Carlos, CA 94070
1	Rockwell International Corporation Rocketdyne Division ATTN: BA08 J.E. Flanagan 6633 Canoga Avenue Canoga Park, CA 91304
1	Science Applications, Inc. ATTN: R.B. Edelman 23146 Cumorah Crest Woodland Hills, CA 91364
1	Scientific Research Assoc., Inc. ATTN: H. McDonald P.O. Box 498 Glastonbury, CT 06033

DISTRIBUTION LIST

No. of Copies	Organization
1	Shock Hydrodynamics, Inc. ATTN: W.H. Anderson 4710-16 Vineland Avenue North Hollywood, CA 91602
3	Thiokol Corporation Huntsville Division ATTN: D. Flanigan R. Glick Tech Library Huntsville, AL 35807
2	Thiokol Corporation Wasatch Division ATTN: J. Peterson Tech Library P.O. Box 524 Brigham City, UT 84302
2	United Technologies ATTN: R. Brown Tech Library P.O. Box 358 Sunnyvale, CA 94088
1	Universal Propulsion Company ATTN: H.J. McSpadden 1800 W. Deer Valley Road Phoenix, AZ 85027
1	Battelle Memorial Institute ATTN: Tech Library 505 King Avenue Columbus, OH 43201
1	Brigham Young University Dept. of Chemical Engineering ATTN: M. Beckstead Provo, UT 84601
1	California Institute of Tech 204 Karman Lab Mail Stop 301-46 ATTN: F.E.C. Culick 1201 E. California Street Pasadena, CA 91125

No. of Copies	Organization
1	California Institute of Technology Jet Propulsion Laboratory ATTN: L.D. Strand 4800 Oak Grove Drive Pasadena, CA 91103
1	Case Western Reserve University Division of Aerospace Sciences ATTN: J. Tien Cleveland, OH 44135
3	Georgia Institute of Tech School of Aerospace Eng. ATTN: B.T. Zinn E. Price W.C. Strahle Atlanta, GA 30332
1	Institute of Gas Technology ATTN: D. Gidaspow 3424 S. State Street Chicago, IL 60616
1	Johns Hopkins University Applied Physics Laboratory Chemical Propulsion Information Agency ATTN: T. Christian Johns Hopkins Road Laurel, MD 20810
1	Massachusetts Institute of Technology Dept. of Mechanical Engineering ATTN: T. Toong Cambridge, MA 02139
1	Pennsylvania State University Applied Research Lab ATTN: G.M. Faeth P.O. Box 30 State College, PA 16801

DISTRIBUTION LIST

No. of Copies	Organization
1	Pennsylvania State University Dept. of Mechanical Engineering ATTN: K. Kuo University Park, PA 16802
1	Purdue University School of Mechanical Engineering ATTN: J.R. Osborn TSPC Chaffee Hall West Lafayette, IN 47906
1	Rensselaer Polytechnic Inst. Department of Mathematics ATTN: D.A. Drew Troy, NY 12181
1	Rutgers State University Dept. of Mechanical and Aerospace Engineering ATTN: S. Temkin University Heights Campus New Brunswick, NJ 08903
1	SRI International Propulsion Sciences Division ATTN: Tech Library 333 Ravenswood Avenue Menlo Park, CA 94024
1	St^vens Institute of Technology ıson Laboratory ATTN: R. McAlevy, III Hoboken, NJ 07030
1	University of California Los Alamos Scientific Lab ATTN: T3, D. Butler Los Alamos, NM 87554
1	University of Southern California Mechanical Engineering Dept. ATTN: OHE200, M. Gerstein Los Angeles, CA 90007
1	University of California, San Diego AMES Department ATTN: F.A. Williams P.O. Box 109 La Jolla, CA 92037
1	University of Illinois Dept. of Mechanical Engineering ATTN: H. Krier 144 MEB 1206 W. Green Street Urbana, IL 61801
1	University of Massachusetts Dept. of Mechanical Engineering ATTN: K. Jakus Amherst, MA 01002
1	University of Minnesota Dept. of Mechanical Engineering ATTN: E. Fletcher Minneapolis, MN 55455
2	University of Utah Dept. of Chemical Engineering ATTN: A. Baer G. Flandro Salt Lake City, UT 84112
1	Washington State University Dept. of Mechanical Engineering ATTN: C.T. Crowe Pullman, WA 99163

Aberdeen Proving Ground

Dir, USAMSAA
ATTN: DRXSY-D
DRXSY-MP, H. Cohen
Cdr, USATECOM
ATTN: DRSTE-TO-F
STEAP-MT, S. Walton
G. Rice
D. Lacey
C. Herud

DISTRIBUTION LIST

No. of Copies	Organization
	Dir, HEL ATTN: J. Weisz G. Garinther D. Hodge B. Cummings
	Dir, USACSL Bldg. E3516, EA ATTN: DRDAR-CLB-PA

USER EVALUATION OF REPORT

Please take a few minutes to answer the questions below; tear out this sheet, fold as indicated, staple or tape closed, and place in the mail. Your comments will provide us with information for improving future reports.

1. BRL Report Number ________________________

2. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which report will be used.)

____

3. How, specifically, is the report being used? (Information source, design data or procedure, management procedure, source of ideas, etc.) ________________________

4. Has the information in this report led to any quantitative savings as far as man-hours/contract dollars saved, operating costs avoided, efficiencies achieved, etc.? If so, please elaborate.

____

5. General Comments (Indicate what you think should be changed to make this report and future reports of this type more responsive to your needs, more usable, improve readability, etc.) __________

6. If you would like to be contacted by the personnel who prepared this report to raise specific questions or discuss the topic, please fill in the following information.

Name: ________________________

Telephone Number: ________________________

Organization Address: ________________________

— — — — — — — — — FOLD HERE — — — — — — — — —

Director
US Army Ballistic Research Laboratory
Aberdeen Proving Ground, MD 21005

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO 12062 WASHINGTON, DC
POSTAGE WILL BE PAID BY DEPARTMENT OF THE ARMY

Director
US Army Ballistic Research Laboratory
ATTN: DRDAR-TSB
Aberdeen Proving Ground, MD 21005

— — — — — — — — — FOLD HERE — — — — — — — — —