EVALUATION OF THE MC 3125 PARACHUTE
SHROUD CUTTER

C. A. Campos

DEVELOPMENT DIVISION

MARCH 1977

For
Sandia Laboratories
Albuquerque, New Mexico
P.O. No. 03-2685

&

Process Development
Endeavor No. 202

Mason & Hanger-Silas Mason Co., Inc.
Pantex Plant

P. O. BOX 30020
AMARILLO, TEXAS 79177
806-335 1581

operated for the
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
under
U. S. GOVERNMENT Contract EY 76 C 04 0487

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

27
7-13-77
25 D NTS

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights.

Printed in the United States of America
Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy **\$3.50**; Microfiche \$2.25

EVALUATION OF THE MC 3125 PARACHUTE SHROUD CUTTER

C. A. Campos

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

ABSTRACT

This is the second of two reports (C. A. Campos, MC 3125 ALSC Cutting Ability Development, MHSMP-76-29, April-June 1976) which describes the test fire program to evaluate the ability of the Sandia-furnished HNS/ALSC to sever Kevlar parachute shroud lines. The test program consisted of firing MC 3125 simulators, including some with MC 3132 detonators. Imposed environments included high humidity, high and low temperatures, and thermal shock cycles. Additional tests were done to investigate the effects of bending the HNS/ALSC and 18 wedge bar tests were done to establish a method of qualifying HNS/ALSC materials.

Included herein are areas of work which support the Sandia-funded work but are performed using Process Development funds. These areas in general cover the development of test techniques to support Sandia-funded work. Major items are a lot qualification test technique being developed and the investigation into the effects of bending the ALSC.

INTRODUCTION

HNS aluminum-linear-shaped-charge (ALSC) was tested for ultimate use as a cutter of 53.4 kN tensile Kevlar parachute shroud lines and two 2.4 mm packing shroud lines. Of particular interest was the effect humidity may have on the cutting ability of ALSC. Special emphasis was placed on providing a 98% relative humidity environment at 52 C, and it was found that moisture appears to have a deleterious effect on cutting ability.

The tests have shown that the ALSC adequately cuts the Kevlar shroud lines but that special precautions must be taken to prevent extreme moisture saturation of the shroud lines immediately prior to use.

RELATIVE HUMIDITY TESTS

Three tests were devised to further evaluate the performance of ALSC on cutting Kevlar in a high humidity environment. The primary difference from former tests was the operating procedures followed in handling of the test units during and after humidity exposure. In these tests, a plastic bag used to seal moisture around the unit after removal from the humidity chamber was left open during the soak period as before; however, the test units were elevated off the bottom of the bag and extra care taken to avoid contact with the sides.

There were two configurations tested. In one case a full ring MC 3125 simulator and EX-12 detonator were

MASTER

assembled with twelve 53.4 kN tensile FRL No. 5034-146-5 shroud lines. Detonation velocity was not measured on this test. Fig. 1 illustrates the second type of test unit configuration wherein a full ring was saw-cut into 120 degree segments. Aside from the different number of shroud lines tested (three each segment), the full ring simulator and segmented units were identical.

- (a) 2.54 mm ALSC standoff to shroud lines.
- (b) Timing switches used on segmented units only.
- (c) Anvil - Backing for shroud line cutting and witness plate. Holding steel fixtures not shown.

Fig. 1. Humidity Test Assembly

SHOTS 1 AND 2 - FULL RING SIMULATORS

Det. Vel.	Not Measured
Humidity	98% RH, 20 hours at 52 C
Final Temp.	Shot 1 - 4 hours at 85 C Shot 2 - 4 hours at -54 C
Cutting	100%

All shroud lines were successfully cut in these tests. Also, the new procedural steps in testing the units appeared to indicate that prior failures were due to over-test in humidity, i.e., water was allowed to accumulate on the shroud lines.

SHOT 3 - SEGMENTED

Det. Vel.	(1) 7.11 km/sec (2) 7.12 km/sec (3) 7.09 km/sec
Humidity	98% RH, 20 hours at 52 C
Final Temp.	4 hours at 85 C
Cutting	100%

All three units were assembled on the same holding fixture with three shroud lines each. Three timing switches recorded detonation velocity. During the 4-hour environmental conditioning at 85 C the shroud lines possibly experienced some drying. This was purposely specified.

SHOT 4 - SEGMENTED

Det. Vel.	(1) 7.09 km/sec (2) 7.09 km/sec (3) 7.10 km/sec
Humidity	None
Temperature	4 hours at -54 C
Cutting	100%

All three units were again mounted on the same holding fixture, so that the same temperature would be experienced. Humidity was purposely omitted from the environmental exposure for this test.

DETONATION VELOCITY EFFECTS DUE TO BENDING ALSC

These tests were designed to evaluate the effects of bending 5.3 g/m ALSC on detonation velocity. Fig. 2 shows

the two approaches used to accomplish this. The difference in the two approaches is the distance measurement between the timing switches. A technique introduced in the first report consisted of employing plastic shim stock foil on the side-detonation shots. These foil strips are placed along the ALSC groove and holes punched at the pin locations. Gaps between holes were then measured. In the other shots, a jig was fabricated for each different radius to place the pins consistently into position.

Table I gives the detonation velocities measured. The first four shots using a 76.2 mm radius are inconsistent with the shots using the jig measuring technique. In any event, there does not seem to be a substantial change in velocity until the radius reaches 25.4 mm. This change should not affect cutting ability since the MC 3125 radius is 152.4 mm.

ALSC Side-Detonation

ALSC End-Detonation

Table I. Detonation Velocity Effects Due to Bending ALSC

Shot No.	Radius (mm)	Distance Measured	Detonation Velocity (km/sec)
1	76.2	Shim Stock	7.13
2	76.2	Shim Stock	7.16
3	76.2	Shim Stock	7.17
4	76.2	Shim Stock	7.20
5	152.4	Jig	7.04
6	127.0	Jig	7.09
7	127.0	Jig	7.04
8	101.6	Jig	7.04
9	101.6	Jig	7.04
10	76.2	Jig	7.06
11	76.2	Jig	7.06
12	50.8	Jig	7.09
13	50.8	Jig	7.09
14	25.4	Jig	6.89
15	25.4	Jig	6.93
16	25.4	Jig	6.92

NOTE: Shots fired at ambient temperature ALSC core loaded at 5.3 g/m.

Fig. 2. ALSC in Bent Configuration

LOT QUALIFICATION

There were two basic reasons for performing these series of tests. The first was to establish a method for qualifying lot shipments of HNS/ALSC. Secondly, by use of this technique, its effectiveness was to be demonstrated on the lot shipment on hand. The setup is illustrated in Figs. 3 and 4.

Aluminum spacers were machined to provide a standoff of 2.54 mm for cutting the shroud lines, leaving a standoff of 4.70 mm between the ALSC and the aluminum witness plate. Six each tests were done at -54 C, ambient, and 82 C.

Kevlar shroud lines were positioned as shown to obtain go, no-go cutting information. The test results showed a successful cut of all lines including one 26.6 kN Kevlar shroud line included at each temperature.

Detonation velocity for each test was measured. Only a small increase in detonation velocity at -54 C was noted but was not considered significant.

RUPTURE ABILITY

The design of the witness plate served two purposes. Zone 1 in Fig. 3 represents the region used to measure rupturing ability of the ALSC. This measurement is given as rupture thickness. Table II gives the results for velocity and rupture. Sub-lot, as shown, designates the particular shipment available for testing at the time. Sub-lot numbers are used to explain the feasibility of this technique as a method for qualifying HNS/ALSC. The results show some inconsistencies in rupture thickness. To obtain more consistent results it appears the ALSC must maintain alignment over the witness plate by providing adequate backing for the ALSC.

- 1 Zone for measuring depth of penetration.
- 2 Zone for measuring depth of cut.
- 3 Wedged witness plate - 6061 T6 aluminum.
- 4 Aluminum shape charge (ALSC).
- 5 Timing switches - 0.991 mm diameter coated with 0.127 mm Parylene (distance set with gaged jig).
- 6 Rupture thickness.

Fig. 3. Proposed ALSC Lot Qualification Technique

Fig. 4. Proposed ALSC Lot Qualification Assembly

Table II. Qualification Tests and Rupture Results

Shot No.	Sub-Lot No.	Core Load (g/m)	Temperature (C)	53.4 KN Line Cut (%)	71.2 KN Line Cut (%)	Velocity (km/sec)	Thickness of Rupture (mm)
1	None	5.31	Ambient	3 (100)	-	7.05	5.23
2	5766	6.22	Ambient	2 (100)	1 (100)	6.99	4.52
3	5776	5.97	Ambient	3 (100)	-	6.98	5.23
4	5777	6.20	Ambient	3 (100)	-	6.96	4.42
5	5778	5.06	Ambient	3 (100)	-	6.97	4.83
6	5779	6.02	Ambient	3 (100)	-	6.98	5.21
7	None	5.31	-54	3 (100)	-	7.09	4.32
8	5766	6.22	-54	3 (100)	-	7.10	4.78
9	5776	5.97	-54	2 (100)	1 (100)	7.01	4.57
10	5777	6.20	-54	3 (100)	-	7.00	4.72
11	5778	5.96	-54	3 (100)	-	7.09	4.52
12	5779	6.02	-54	3 (100)	-	7.01	4.32
13	None	5.31	82	2 (100)	1 (100)	6.99	5.36
14	5766	6.22	82	3 (100)	-	6.97	5.48
15	5776	5.97	82	3 (100)	-	6.95	5.26
16	5777	6.20	82	3 (100)	-	6.95	5.18
17	5778	5.96	82	3 (100)	-	7.01	5.18
18	5779	6.02	82	3 (100)	-	7.01	5.18

CUTTING ABILITY

Zone 2 in Fig. 3 represents the region used to measure cutting depth of ALSC into a witness plate. Cutting depth here is defined as the depth which ALSC can cut into an adequately supported target. In this particular application an aluminum plate was

used. A dial indicator was utilized to take a total of nine readings per specimen at approximately every 6 mm along a 50 mm sample. These measurements show an irregular pattern left on the witness plate. Figs. 5, 6 and 7 show the pattern of each witness plate.

Fig. 5. ALSC Cutting Profile into Aluminum (-53.9 C, ALSC Standoff 4.70 mm)

Fig. 6. ALSC Cutting Profile into Aluminum (Ambient Temperature, ALSC Standoff 4.70 mm)

Fig. 7. ALSC Cutting Profile into Aluminum (82 C, ALSC Standoff 4.70 mm)

The plot in Fig. 8 shows the effect of temperature on the cutting depth. These data should be used only to anticipate the increased cutting depth into aluminum as a function of temperature since ALSC confinement and standoff affect the cutting. Furthermore, the temperature effects may be attributed either to the witness plate or the ALSC itself or both. No attempt has been made to differentiate between them.

Fig. 8. Depth of cut due to Temperature (Standoff at 1.70 mm)

THERMAL SHOCK

Performance of the MC 3125 was further evaluated following exposure of twelve units to three 4-hour thermal shock cycles of -54 to 85 C. After cycling, three units were tested at -54 C, three at ambient, three at 52 C (98%

RH) and the last three at 85 C. Fig. 9 illustrates the assembled MC 3125 destruct-test unit. Normally, two detonators are fired simultaneously. In these studies, only one MC 3132 detonator was used for each unit with alternating mounting positions to study propagation through the lap joints from both sides.

NOTE: All anvils assembled with two 3/32 packing shroud lines 180° apart and 90° from detonator.

Fig. 9. Thermal Shock Test Assembly

Detonator current and voltage traces were recorded utilizing one dual-trace Tektronix 556 oscilloscope. Fig. 10 shows the circuit for the current supply used to provide the required 5-ampere, 7-millisecond step function for the MC 3132 detonator.

^aCable resistance was compensated in calculations.

Fig. 10. MC 3132 Detonator Voltage/Current Monitor Schematic

A pin switch coated with 0.013 mm layer of Parylene was positioned in the ALSC groove 90 degrees from the detonator. This provided a stop-count trigger pulse to a counter. The function time given in Table III is that time from the detonator trigger pulse to the timing switch pulse.

Indications are that the function times were acceptable within an expected time of 1 ms. Figs. 11 and 12 are included to show the oscilloscope traces for current and voltage.

Test results appear to confirm the MC 3125 cutter's ability to function

Table III. Results of Function Time Measurements

Shot No.	Sub-Lot No.	Final Temperature (C/RH)	Function Time (μs)	Detonation Current Peak (amp)	Bridgewire Time		Bridgewire Resistance ^b (Ω)
					Time A ^a (μs)	Time B ^a (μs)	
1	5778	-54	1042.2	5.26	807.4	978.5	1.09
2	None	-54	954.7	5.00	872.5	959.3	1.07
3	5779	-54	992.2	4.58	685.1	942.2	1.32
4	5778	82	674.3	4.35	618.6	663.2	1.23
5	5777	82	689.3	4.30	621.0	660.7	1.26
6	5766	82	683.3	4.66	609.1	782.8	-
7	5776	Ambient	-	5.33	747.8	780.6	-
8	None	Ambient	746.0	6.09	674.5	710.5	-
9	5779	Ambient	874.4	5.30	811.6	830.6	-
10	None	RH	-	4.98	600.0	703.0	1.09
11	5776	RH	707.2	4.80	635.4	682.5	1.15
12	5777	RH	-	4.04	577.3	613.2	1.37

^aRefer to figure for time reference. Values measured from scope traces.

^bValues calculated from voltage and current records.

Sub-Lot 5778, Shot No. 1

Sub-Lot None, Shot No. 2

Sub-Lot 5779, Shot No. 3

Sub-Lot 5778, Shot No. 4

Sub-Lot 5777, Shot No. 5

Sub-Lot 5766, Shot No. 6

NOTE: Sweep Speed at 0.3 ms/cm. Voltage trace at 5 volt/cm and current at 0.5 volt/cm.

Fig. 11. MC 3132 Detonator Hot Wire Monitor

Sub-Lot 5776, Shot No. 7

Sub-Lot None, Shot No. 8

Sub-Lot 5779, Shot No. 9

Sub-Lot None, Shot No. 10

Sub-Lot 5776, Shot No. 11

Sub-Lot 5777, Shot No. 12

NONE: Sweep Speed at 0.3 ms/cm. Voltage trace at 5 volt/cm and current at 0.5 volt/cm. Shot No. 8 sweep at 0.7 ms/cm.

Fig. 12. MC 3132 Detonator Hot Wire Monitor

properly after exposure to thermal shock. However, three units which received a final soak of 52 C (98% RH) prior to testing failed to cut 100% of the shroud lines as shown in Figs. 13, 14 and 15. A close investigation was made to resolve these failures. All test units except Shot No. 12 were equipped with one uncoated 71.2 kN shroud line. In addition, all units were equipped with two 2.4 mm packing shroud lines. The 71.2 kN shroud line may be expected to fail after absorbing more moisture than one which has a protective coating as indicated in Shots 10 and 11.

An attempt was made to randomly position the packing shrouds around the lap joint, since a report^a on a lap joint study had disclosed a potential failure zone around the lap joint. Shot No. 10 confirmed this conclusion. It is recommended that the location of the shrouds must avoid this region.

^aTo be published by Mason & Hanger Development Division

- ① 71.2 kN uncoated shroud line - 60% cut only. Explanation for failure attributed to excess moisture absorption by uncoated shroud line.
- ② 2.4 mm thick shroud line failure point - 90% cut line. Blank spot on anvil behind failure point.

Fig. 13. Shot No. 10 (Final Environment 52 C, 98% RH)

- ① 71.2 kN uncoated shroud line - 85% cut only. Explanation for failure attributed to excess moisture absorption by uncoated shroud line.

Fig. 14. Shot No. 11 (Final Environment 52 C, 98% RH)

- ① 53.4 kN shroud line failure point - 95% cut only. No blank spot on anvil detected. No explanation for failure could be determined.

There was no 71.2 kN shroud line tested on this shot.

Fig. 15. Shot No. 12 (Final Environment 52 C, 98% RH)

SUMMARY

Results are summarized as follows:

1. High and low temperatures have not been shown to adversely affect the cutting of the tested shroud lines. Detonation velocity is not significantly affected.

2. It has been shown that shroud line cutting is not affected after exposure to high humidity, but a failure may be risked if the shroud line is allowed to accumulate excessive water. The limits have not been examined.
3. The MC 3132 detonators performed as expected following thermal shock conditioning. Test results show the function time to be within acceptable limits.
4. The lot qualification test technique did show inconsistencies in the data; however, the problems are understood and future work will be expended to correct for them. This technique is being proposed for manufacturing lot qualification. Two major results can be presently obtained which include depth of rupture and cutting depth.
5. It was shown in the lot qualification tests that cutting depth and depth of rupture increase with temperature.
6. It was necessary to investigate the effects bending ALSC might have on the detonation velocity since cutting ability is a function of velocity. Test results have shown that detonation velocity is not significantly affected by bending the ALSC to as small as 50 mm in radius.