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OOAMA

AIRMUNITIONS TEST REPORT

SHELF & SERVICE LIFE TEST OF ROCKET MOTORS, M16E3 FOR MACE (MGM-13A)

2705th AIRMUNITIONS WING
OGDEN AIR MATERIEL AREA
UNITED STATES AIR FORCE • HILL AIR FORCE BASE, UTAH

SHELF AND SERVICE LIFE TEST OF

ROCKET MOTORS, M16E3 FOR MACE (MGM-13A)

by

Alden T. Arbon

PUBLICATION REVIEW

This report has been reviewed and is approved

Alex D. Peresich

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Chief
Service Engineering Division
2705th Airmunitions Wing

MARCH 1964

2705TH AIRMUNITIONS WING
OGDEN AIR MATERIEL AREA
AIR FORCE LOGISTICS COMMAND
UNITED STATES AIR FORCE
Hill Air Force Base, Utah

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The conclusions and recommendations in this report are not to be considered directive in nature. This type information becomes official only when published in Technical Orders or other applicable Air Force publications.

Qualified requesters may obtain a copy of this report from DDC, Cameron Station, Alexandria, Virginia 22314.

ADMINISTRATIVE DATA

PURPOSE:

This test is one phase of a long range program designed to determine the maximum combined service and shelf life of the M16E3 Rocket Motor for the MGM-13A Missile. This test was to determine if an extension from the present 60 months life was possible.

MANUFACTURER:

Thiokol Chemical Corp, Wasatch Division, Tremonton, Utah

MANUFACTURER'S TYPE OR MODEL NUMBER:

Rocket Motor, Solid Propellant, M16E3, FSN 1336-741-2060-V174

DRAWINGS AND SPECIFICATIONS:

Thiokol Chemical Corp, Model Specification TUS-60-192, Aug 60
Rocket Motor Drawing, Thiokol U-8987
Pyrogen Drawing, Thiokol DU-6670

QUANTITY OF ITEMS TESTED:

Five motors were used in this test

SECURITY CLASSIFICATION:

Unclassified

DATE TEST COMPLETED:

15 December 1963

TEST CONDUCTED BY:

OOAMA (OOYT 2705th Airmunitions Wing)

Test Director: Richard O. Miller, Captain, USAF

Project Engineer: Alden T. Arbon, Electrical Engineer

DISPOSITION:

All metal parts generated were inspected and certified inert in accordance with Technical Order 11C3-1-3 and HAFBR 136-2 and delivered to the Redistribution and Marketing Division.

ACKNOWLEDGEMENTS:

The author wishes to acknowledge the help and assistance of 2d Lt Schmeil and SSgt Poole NCOIC in accomplishment of this test.

ABSTRACT

These tests were accomplished to determine the feasibility of extending the combined service and shelf life of the M16E3 Rocket Motor for the MGM-13A Missile System. Inspection, both visual and radiographic, along with static firing was accomplished on five motors, age 60 months. Tests were conducted at -30°F and +160°F. X-ray examination revealed several small propellant defects. These defects did not have an adverse effect on performance. One motor, which was not considered a representative sample of the inventory, leaked at the forward end. No malfunctions occurred in the other motors and ballistic parameters were within specification limits. It is recommended that the combined service and shelf life of the M16E3 Rocket Motor be extended to 6-1/2 years provided continuous vigilance is maintained on the exudate condition.

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INTRODUCTION

The number and size of solid propellant rocket motors in the Air Force have been increasing at a very rapid rate and it has therefore become more important that the maximum serviceable life of these units be known and fully utilized. Factors such as high reliability and instant readiness have been and still are the prime advantages of the solid propellant motor. These factors must be preserved. To this end the 2705th Airmunitions Wing is performing service engineering and surveillance tests on the explosive components for the MGM-13A and B Mace Missiles.

From the results of this program, it is hoped that corrective measures for alleviating any adverse aging manifestations may be determined early and thus lengthen the serviceable life of the operational units.

The project covered in this report is part of a continuing surveillance test program and was established to determine the feasibility of an extension in combined service and shelf life of the M16E3 Booster beyond the present 60 months. The motors tested have been installed on Mace missiles deployed in Germany. They have been periodically removed and re-installed during maintenance cycles. No accurate record is available on the total time installed; however, these motors were subjected to field handling, use and storage, and are representative of all motors of similar age.

Static firing facilities located at Hill Air Force Base are limited to firing of rocket motors with a propellant weight of approximately 300 pounds. There is a safety limitation because of buildings in the vicinity of the firing stand that are used for maintenance work. In the event of a malfunction (pressure burst of a large rocket motor) it would be possible for fragments to reach the vicinity of these buildings.

Therefore, it is necessary to conduct tests on the larger motors on the Hill Air Force Range 6404 which is located approximately 45 miles west of Hill Air Force Base. To temperature condition motors prior to static firing, a portable temperature conditioning oven has been procured. This oven has been designed so that it can be transported to the range on a flat-bed truck. It is operated by a portable electrical generator. The oven has a dual capability of temperature conditioning motors either to very high or very low temperatures.

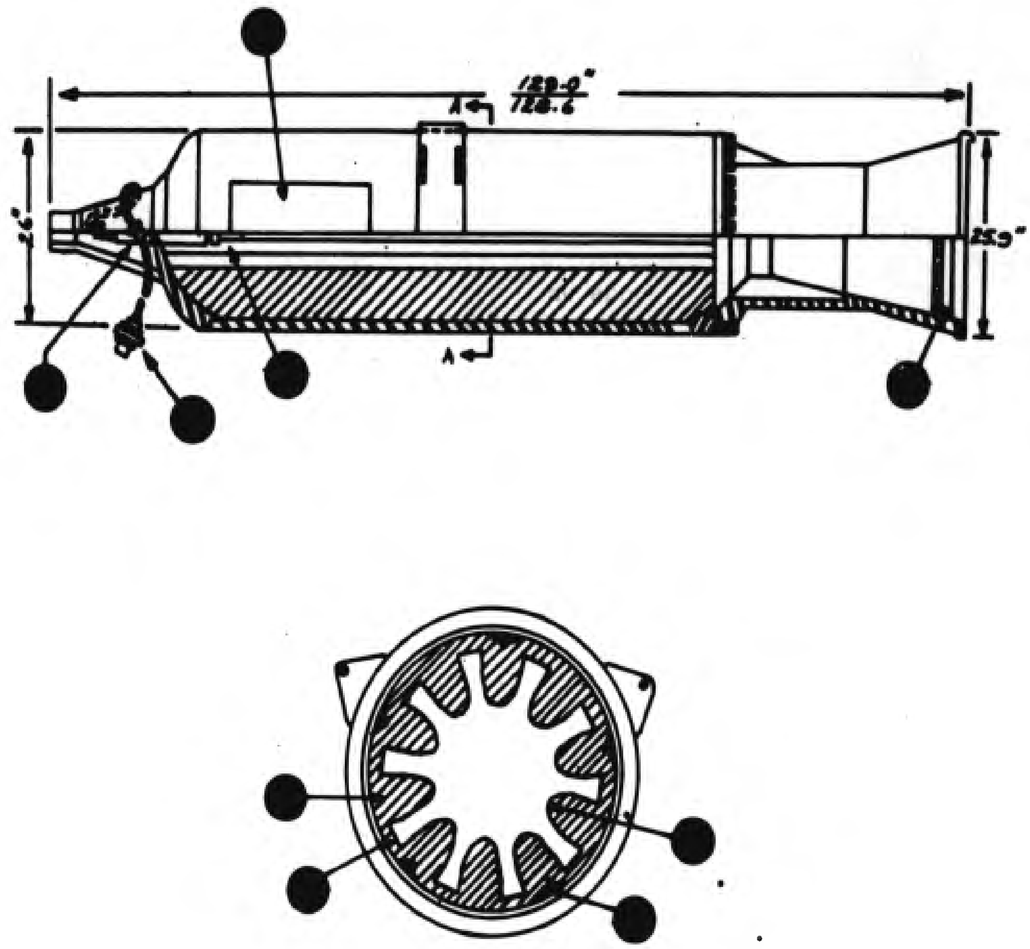
DESCRIPTION

The M16E3 Rocket Motor was designed by Thiokol Chemical Corporation for the MGM-13A Weapon System. It produces 101,000 pounds nominal thrust for 2.62 seconds when conditioned to +70°F. The complete booster system consists of the following four major components: motor assembly, pyrogen, safe-arm device and cable assembly.

The motor chamber is fabricated from AISI 4130 steel. The thrust adapter and nozzle are fabricated from AISI 1020 steel. Dimensions of the motor are shown in Figure 1. The TU-P-140 Pyrogen consists of a steel mixed-flow nozzle, steel adapter, and loaded case assembly. Figures 2 and 3 show a cutaway view of the unit and its loaded case assembly. Figures 2 and 3 show a cutaway view of the unit and its loaded case assembly. The safe/arm device TU-SA-140 consists of a rotary solenoid-driven arming mechanism, two squibs and a pyrotechnic pellet charge assembly as shown in Figure 4.

The cable assembly used with the M16E3 Motor is a 12-conductor type with cable support clip and cable connectors.

A summary of explosive components used with the MGM-13 System is given in Table 1.



SECTION A-A

(1) Labels, 180° apart

(2) Cable Assembly

(3) Pyrogen Unit

(4) Safe-Arm Device

(5) Nozzle Closure

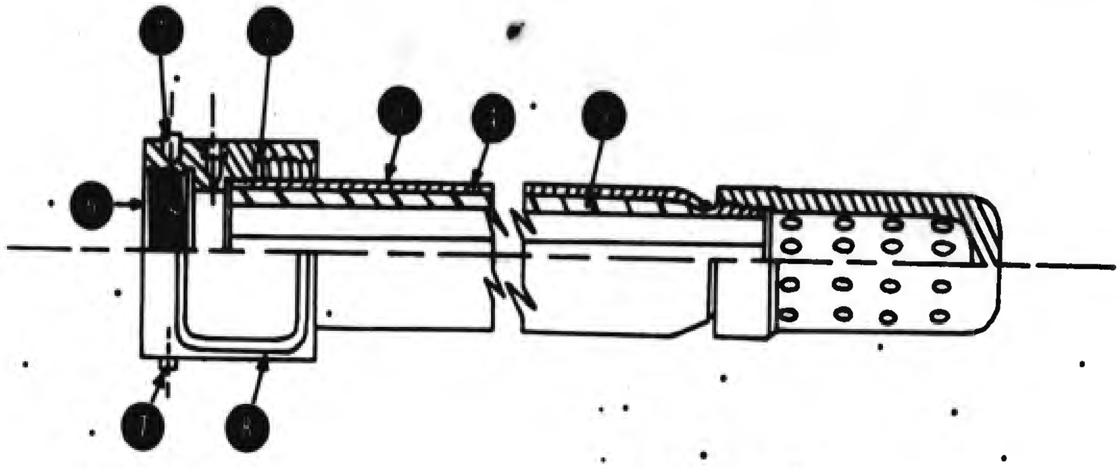
(6) Propellant

(7) Web

(8) Star Point

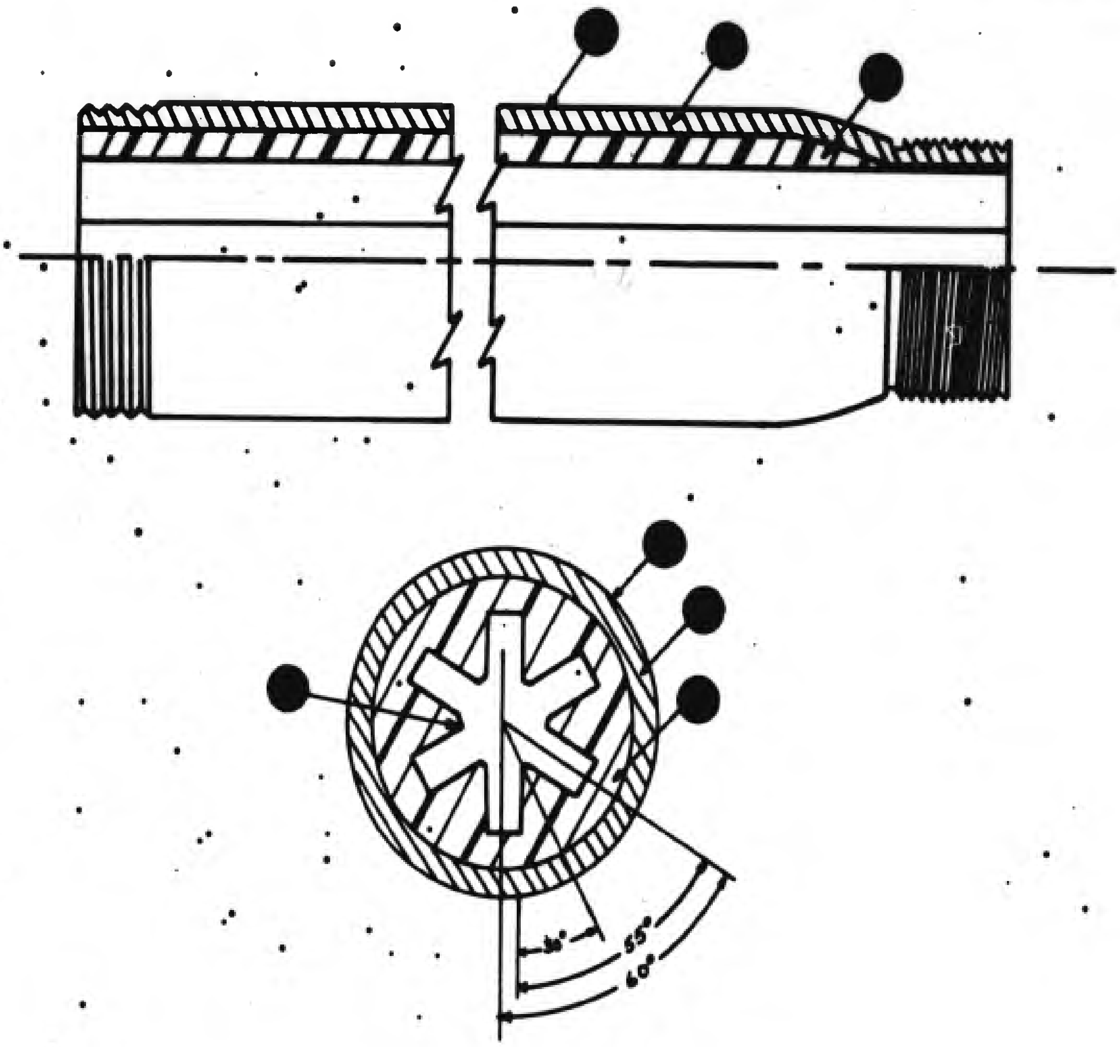
(9) Inhibitor

FIGURE 1. Rocket Motor, M16E3 Showing Dimensions and Important Parts.



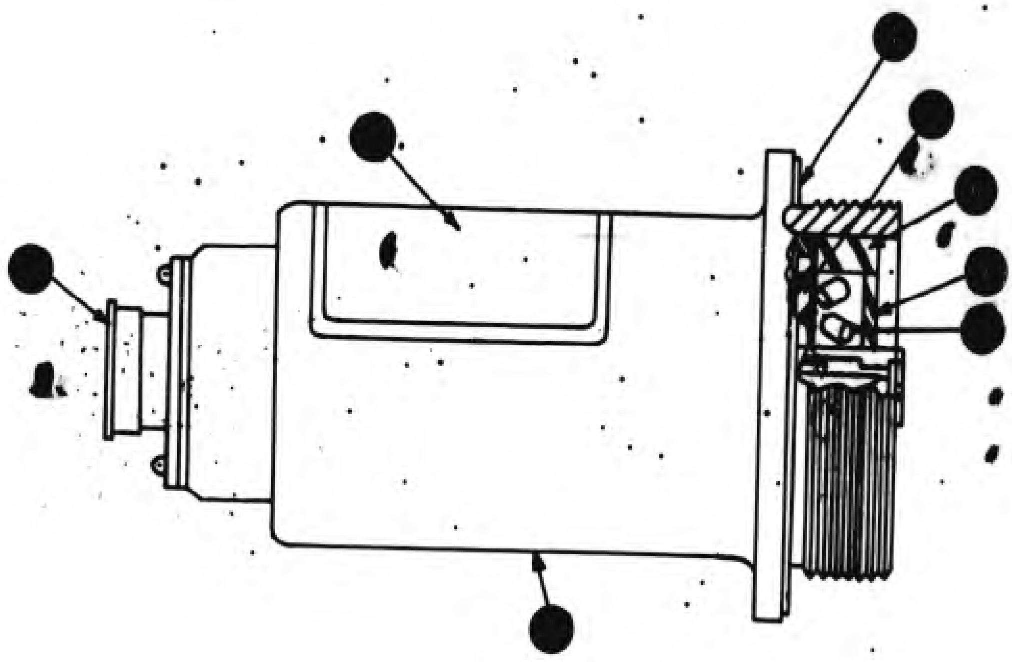
(1) Pin
(2) Gasket
(3) Case
(4) Liner
(5) Propellant
(6) Dust Cap
(7) Pin
(8) Adapter

FIGURE 2. Pyrogen Unit, TU-P-140, Cutaway View.



(1) Case
(2) Liner
(3) Propellant
(4) Star Point
(5) Case
(6) Liner
(7) Propellant

FIGURE 3. Pyrogen Unit, TU-P-140, Loaded Case Assembly.



(1) Dust Cap

(2) Label

(3) Arming Mechanism Case

(4) Gasket

(5) Disc

(6) Cylinder

(7) Cover

(8) Initiator Charge

FIGURE 4. Safe-Arm Device, TU-SA-140 for M16E3 Motor.

ITEM NOMENCLATURE	QUANTITY PER MISSILE	
	MGM-13B	MGM-13C
Rocket Motor, M16E3	1	1
Pyrogen Unit, TU-P-140	1	1
Safe/Arm Device, TU-SA-140	1	1
Cap, Blasting Electric E-80	0	4
Cap, Blasting Electric E-81	0	6
Detonating Cord	0	46 Ft 6 In
Squib, Electric, M-76, Mod 1	6	20
Relay, Time Delay, Squib-Operated, Part No. OM373C	0	2
Squib, Rapid Fire, Test Set, Cable Disconnect, 200X-6-134, OA-AN10-3-(2.7)2(7B1), OA-AN10-3-7B1	1	0

TABLE 1. Explosive Components Used on the TM-76A and B.

A summary of the physical characteristics of the M16E3 Rocket Motor is contained in Table 2.

TECHNICAL DATA	DIMENSION (Inches)
Length of Complete Unit	129.00
Motor Case Outside Diameter	26.00
Maximum Diameter Over Aft Attachment Lugs	33.50
Throat Diameter	10.96
Exit Cone Diameter	25.00
NOMINAL WEIGHT OF ROCKET MOTOR PARTS	**WEIGHT (Pounds)**
Motor Case Assembly including slivers	1005
Nozzle	520
Propellant	1400
Liner	10
Pyrogen Unit	15
Nozzle Closure Plate	5
TOTAL WEIGHT	2955

TABLE 2. Physical Characteristics of the M16E3 Rocket Motor.

The TU-P-140 Pyrogen unit weighs 15.39 pounds, 2.05 of which is propellant. Performance characteristics of the TU-SA-140 safe/arm device are in Table 3.

NOMENCLATURE	REQUIREMENT
Solenoid Actuation	28 Volts DC
Squib Firing Circuit	28 Volts DC
Maximum No-Fire Per Squib or 2 in Parallel	1.0 Ampere
Minimum All-Fire	1.8 Amperes
Resistance (Safe Position) between pins "H" & "L"	3.2 ± 0.5 Ohm
Single Circuit Between (Pins "A" & "B" - Squib No. 2) (Pins "C" & "D" - Squib No. 1)	0.22 ± 0.10 Ohm

TABLE 3. Performance Characteristics of the TU-SA-140 Safe/Arm Device.

The propellant used in the M16E3 is the T-35 Polysulfide type. Table 4 gives the composition of T-35 propellant as nominal per cent by weight and the function of each ingredient.

INGREDIENT	NOMINAL PERCENTAGE	FUNCTION
Ammonium Perchlorate with conditioner	70.17	Oxidizer
Liquid Polymer, Ethyl Formal Polysulfide, Medium Viscosity	21.48	Fuel - Binder
Di (Butoxydiethoxy) Methane	2.39	Plasticizer
Ferric Oxide	2.00	Burning - rate Catalyst
Para-Quinone Dioxime	1.60	Curing Agent
Magnesium Oxide, Calcined	1.01	Additive to increase strength at temperature extremes
Diphenylguanidine	0.795	Curing Accelerator
Sulfur	0.015	Curing Accelerator

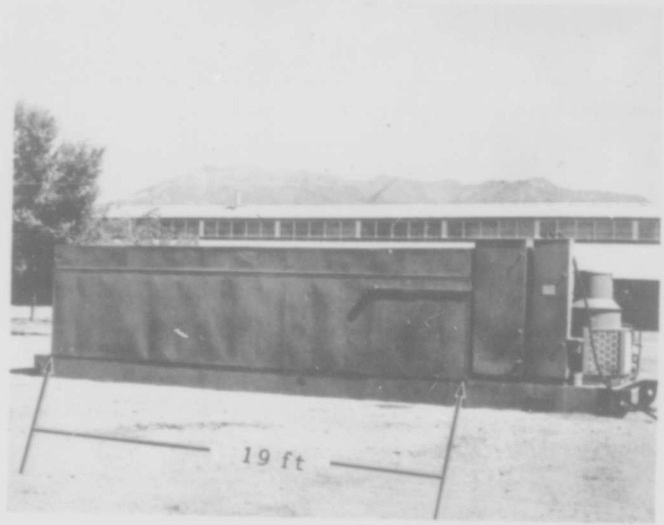
TABLE 4. Propellant T35 Composition.

TEST PROCEDURES

Five motors (aged 69, 68, 68, 60 and 59.5 months) were subjected to a thorough visual and X-ray examination prior to temperature and static tests.

Temperature conditioning was accomplished using the portable environmental unit shown in Figure 5. Motors were held in the oven for a minimum of 44 hours before firing.

Test firing was accomplished using the set-up as shown in Figures 6 and 7.



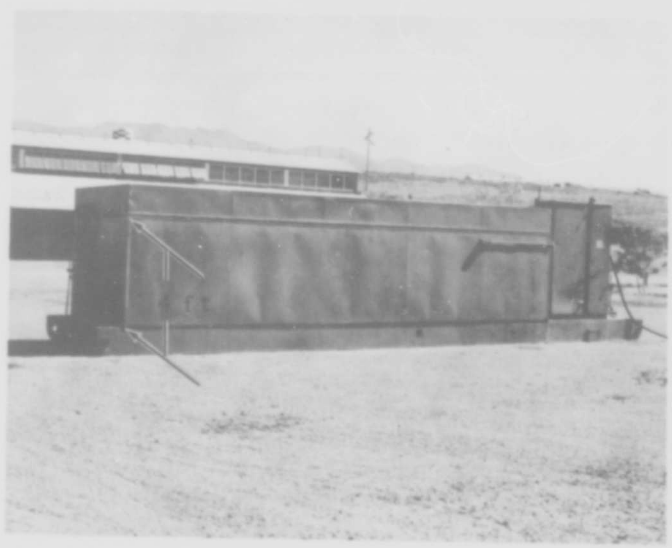


FIGURE 5. Portable Temperature Conditioning Equipment.

1 Thrust Transducer - 200,000 pound

2 Fastax Camera w/Fragment Shield

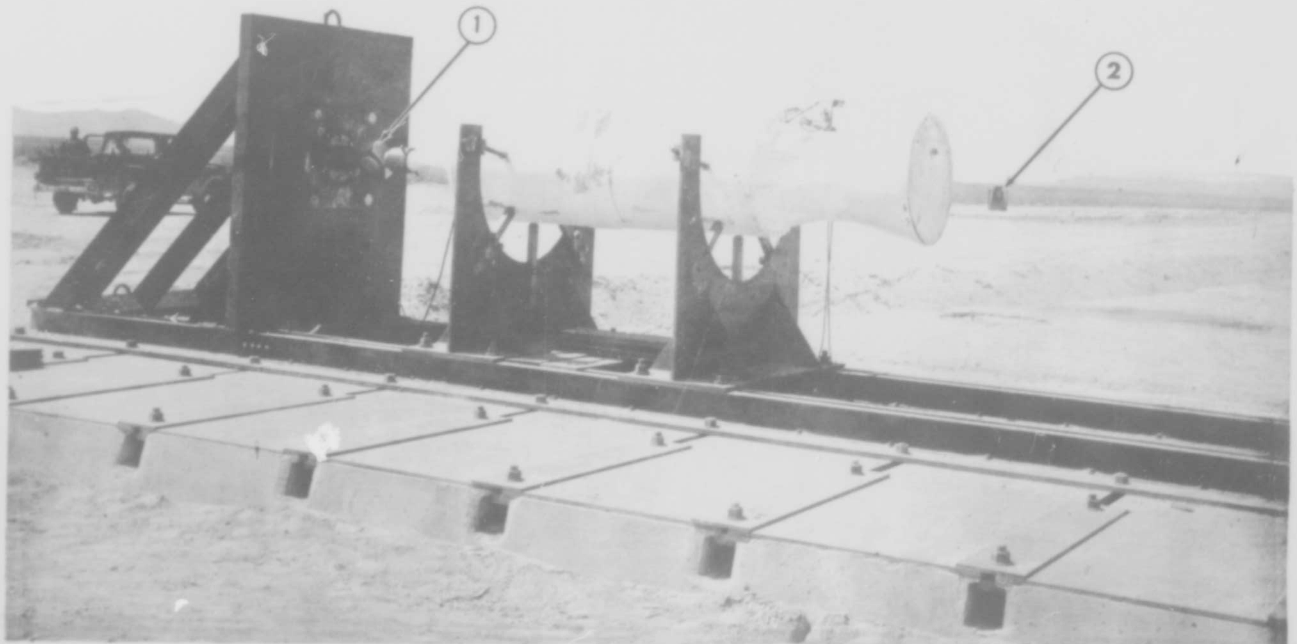


FIGURE 6. M16E3 Motor in Static Firing Stand (Hill Air Force Range 6404).

A. Improper Ignition.

B. Pressure Leak in Forward End.

FIGURE 7. Malfunctioning Motor.

TEST RESULTS

VISUAL INSPECTION

A white crystalline, salt-like substance had exuded on the star points of Motor Number 10. A small patch of substance would reflect a flashlight beam in the valleys of Motor Number 1. Both of these motors had not been modified due to rusted end caps.

RADIOGRAPHIC INSPECTION

The five motors were X-rayed using 2 MEV General Electric machines using AA type X-ray film. Motor Number 15 showed no defects. Motor Number 14 showed two voids: one 5/8 Inch by 3/4 Inch, and one 9/16 Inch by 2 Inches. These defects were similar to defects found in motors tested earlier.

STATIC TESTING

One of the five motors did not perform satisfactorily during static testing, however, this motor was partially damaged prior to the test. Details are discussed later in this report. Three cold motors exceeded the specification requirement for total impulse. This is considered a desirable factor. One cold motor exceeded the limit for ignition delay by 0.16 seconds. This is not considered a significant discrepancy.

Motor serial numbers 15 and 14 were shipped in from Germany and conditioned at -30°F. These motors fired within all ballistic specifications except they exceeded total impulse maximum (Figure 8). This is considered desirable.

Two motors, serial numbers 10 and 1, were received with frozen head end caps. Considerable pounding and cutting with a hacksaw was necessary to loosen the cap to allow a pyrogen to be installed; however, the threads of both motors were damaged in this operation. Motor Number 10, conditioned at +30°F, performed within specification limits except for total impulse and ignition delay.

DEFINITION OF PARAMETERS FOR FIGURE 8

Ignition Time (t_i). Ignition time is the time from switch closure until 10 per cent of the maximum thrust is attained.

Action Time (t_a). Action time begins when pressure has risen to 10 per cent of its maximum value and ends when it has fallen to 10 per cent of its maximum value.

Burning Time (t_b). Burning time begins at the same point as does the action time and ends when the pressure begins to drop sharply near the end of burning. This point is defined by marking tangents to the equilibrium portion of the curve and to the decay portion of the curve. The angle between these tangents is bisected by a line extending to the curve. A vertical line dropped from the point where the bisecting line cuts the curve indicates the end of burning time.

Ignition Delay (t_d). Ignition delay is the time from switch closure (t_o) to 4000 pounds thrust.

Pressure, Average Chamber ($\bar{P}_c$). The average chamber pressure is the area under the pressure-time curve between the limits of action time divided by the action time (t_a).

Thrust, Average ($\bar{F}$). Average thrust is the total impulse divided by action time.

Impulse, Total (I). Total impulse is the area under the thrust-time curve within the limits of action time.

Impulse, Specific (I_{sp}). Specific impulse is the total impulse divided by the motor propellant weight.

Ignition Interval (t_{pi}). Ignition interval is the time from switch closure (t_o) to 90 per cent maximum pressure. This parameter was not calculated for this report.

Effective Exhaust Velocity (V_e). Obtained by multiplying the specific impulse by 32.2 ft/sec^2.

Average Burning Rate (B_r). Obtained by dividing the web thickness by the burn time.

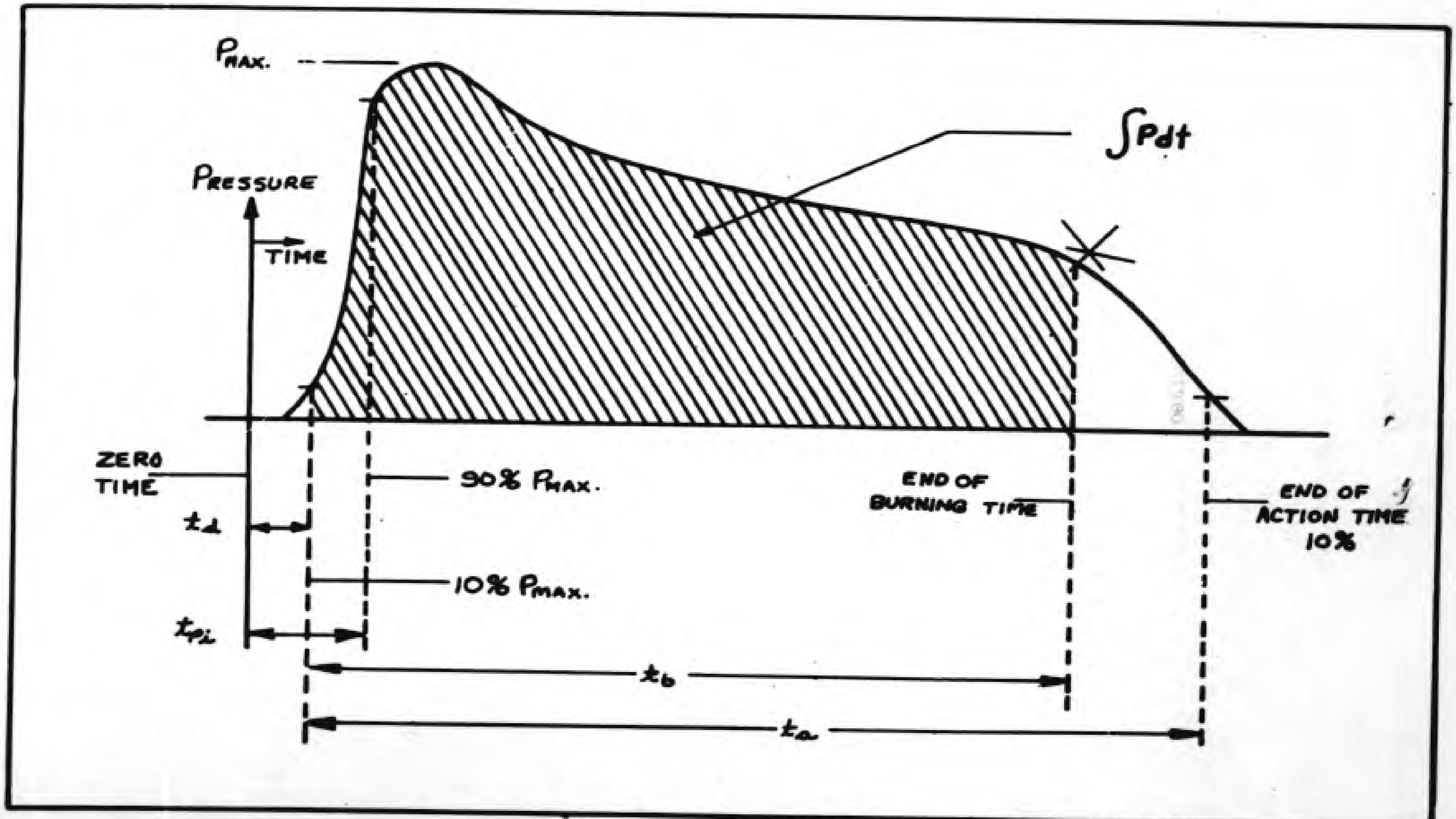


FIGURE 8. Definition of Parameters for the M16E3 Rocket Motor.

Motor Number 1 developed an exhaust gas leak in the forward end. This motor was conditioned at +160°F. The leak was in two cuts through the pyrogen threads. High speed films showed a large cloud of black smoke pouring from the nozzle all during the extra long ignition delay time (1.61 seconds). This motor produced enough total impulse, but chamber pressure was low, due in part to pressure leak in forward end. The average thrust was lower than the specified minimum. The motor was a nonrepresentative sample because of pyrogen thread damage (Figures 7 and 9). The data was not used for service life extension.

Table 5 is a summary of performance specifications for the M16E3 Rocket Motor.

PARAMETER	-30°F	+160°F
*Thrust, Average (Min) Pounds	69,500	106,000
*Thrust, Average (Max) Pounds	130,000	130,000
Total Impulse, (Min) Pounds·Sec	256,750	266,000
Total Impulse, (Max) Pounds·Sec	281,000	290,000
Burn Time, (Min) Seconds	2.200	2.200
Burn Time, (Max) Seconds	3.400	3.400
Ignition Delay, (Min) Seconds	-	-
Ignition Delay, (Max) Seconds	0.500	0.500

TABLE 5. Performance Ratings for the M16E3 Rocket Motor.

*Thrust Values are for Sea Level.

Table 6 contains manufacturer's data for the Air Force Motors tested. Table 7 is a summary of ballistic data for Air Force firings.

Test system accuracy is ± 2 per cent; therefore, thrust values for the +160°F motors in Table 7 may actually be within these limits.

FIGURE 9. Typical Test Preparation.

M16E3 ROCKET MOTOR					
	LOT 1 S/N 15	LOT 1 S/N 14	LOT 4 S/N 10	LOT 4 S/N 1	LOT 2 S/N 2
Manufacturer's Date	2-7-58	2-7-58	10-30-58	12-12-58	4-2-58
Case Number	S-646	S-607	S-594	S-588	S-650
Nozzle Number	S-646	S-607	S-594	S-588	S-658
Propellant Weight	1369	1374	1382	1379	1375
TU-P-140 PYROGEN					
Manufacturer's Date	*	6-27-61	7-28-61	7-28-61	*
Serial Number	*	0232	301	29	*
Lot	*	THO-004	THO-005	THO-005	*
Sub Lot	*	*	043	43	*
TU-SA-140 SAFE/ARM					
Lot	THO-003	THO-006	THO-003	THO-005	THO-006
Manufacturer's Date	4-28-61	7-8-61	5-5-61	5-22-61	7-8-61
Serial Number	63	204	0099	122	211

TABLE 6. Manufacturer's Data for the Air Force Motors Tested.

* Not recorded due to obstructions after installation.

MOTOR	LOT 4 NO. 10	LOT 1 NO. 14	LOT 1 NO. 15	LOT 2 NO. 2	LOT 4* NO. 3	LOT 4** NO. 1	SPECIFICATION LIMITS	
Age (Months)	60	68	68	69	56	59.5		
Conditioning (°F)	-30	-30	-30	+160	+160	+160	-30	+160
Action Time (Sec)	3.457	3.47	3.53	2.51	2.91	3.36		
Burn Time (Sec)	2.79	3.18	3.21	2.28	2.46	2.77	2.2 Min 3.4 Max	2.2 Min 3.4 Max
Time Delay (Sec)	.661@	.368	.43	.14	0.28	1.61@	.5	.5
Pressure Peak (Psi)	662	635	635	824	858	585**		
Average (Psi)	560	623	554	755	736	407**		
Thrust Peak (Lbs)	107,250	97,500	97,500	117,000	129,000	106,500		
Average (Lbs)	92,046	88,390	84,633	106,751	103,148	79,800@	71,170 Min# 131,500 Max	107,670 Min# 131,750 Max
Total Impulse	318,205	306,700	298,756	267,946	300,368	268,352	256,750 Min 281,000 Max	263,000 Min 290,000 Max

TABLE 7.

@ Out of Specification
* Data from OOY-TR-63-753 for Comparative Purposes Only
** Considered Bad Sample Due to Exhaust Gas Leak
\# Thrust Corrected for Altitude (4200 Feet)

CONCLUSIONS

1. The defects found during the radiographic inspection had no significant effect on the performance of the motors.

2. Rocket Motors, M16E3 will perform satisfactorily for more than 69 months when functioned within temperature limits of -30°F and +160°F.

RECOMMENDATIONS

It is recommended that the combined service and shelf life of the M16E3 Rocket Motor be extended to 78 months, provided observations be made frequently to see that exudation from the motor propellant grain does not worsen. Further, recommend that tests be conducted on motors over 78 months old as soon as samples can be obtained.

DISTRIBUTION LIST

3 Dep, The Inspector General, Director of Aerospace Safety (Dep, TIG for Safety), Hq USAF (AFIAS-G2), Norton AFB, Calif
1 Hq USAF (AFSSS-AE), Wash 25, DC
2 AFLC (MCSWT and MCIA-E), Wright-Patterson AFB, Ohio
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3 Cml Prpln Info Agcy, The John Hopkins Univ, Applied Physics Lab, (Patrick J. Martin, Asst Gp Suprv), 8621 Georgia Ave, Silver Spring, Md
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1 586th Tactical Missile Gp, APO 109, New York, NY
1 587th Tactical Missile Gp, APO 130, New York, NY
2 AFPR (1 cy to Martin Co TM-76 Program Ofc), Martin Co, Baltimore,Md
2 AFPR, (1 cy to Thiokol Chemical Corp), Thiokol Chemical Corp, Brigham City, Utah
2 WRAMA (WRW), Robins AFB, Ga

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2705th Airmunitions Wing (OOAMA), Hill Air Force Base, Utah
SHELF AND SERVICE LIFE TEST OF ROCKET MOTORS, M16E3 FOR MACE (MGM-13A), by Alden T. Arbon, March 1964, 21p incl. figures and tables.
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These tests were accomplished to determine the feasibility of extending the combined service and shelf life of the M16E3 Rocket Motor for the MGM-13A Missile System. Inspection, both visual and radiographic, along with static firing was accomplished on five motors, age 60 months. Tests were conducted at $-30^{\circ}F$ and $+160^{\circ}F$. X-ray examination revealed several small propellant defects. These defects did not have an adverse effect on performance. One motor, which was not considered a representative sample of the inventory, leaked at the forward end. No malfunctions occurred in the other motors and ballistic parameters were within specification limits. It is recommended that the combined service and shelf life of the M16E3 Rocket Motor be extended to 6-1/2 years provided continuous vigilance is maintained on the exudate condition.

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1. Rocket Motors

I. Alden T. Arbon

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AD

2705th Airmunitions Wing (OOAMA), Hill Air Force Base, Utah
SHELF AND SERVICE LIFE TEST OF ROCKET MOTORS, M16E3 FOR MACE (MGM-13A), by Alden T. Arbon, March 1964, 21p incl. figures and tables.
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