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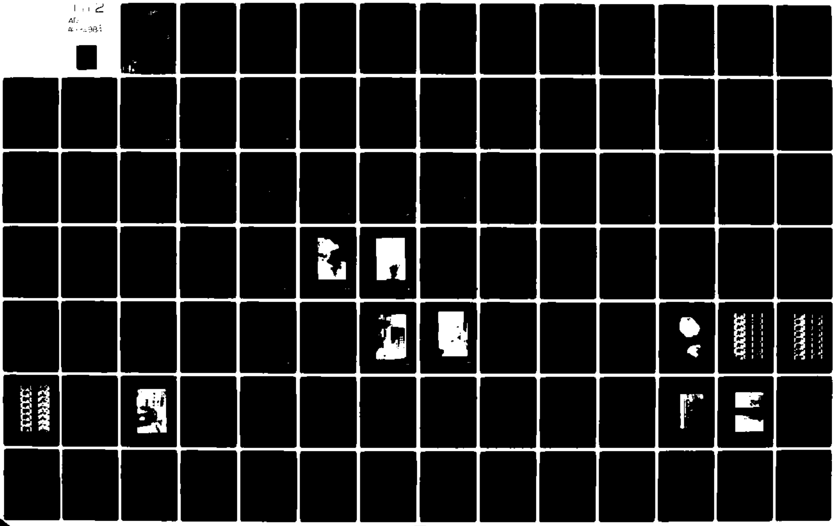

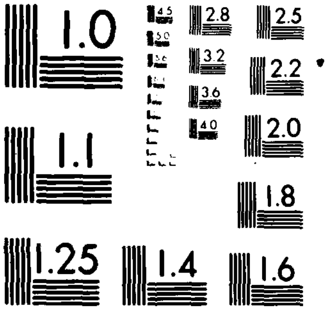

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LEVEL II

[illegible]46 PRACTICE FUZE

Final Report

In Response To:

Contract No. DAAK10-79-C-0040

Prepared For:

Department of the Army
U. S. Army Armament Research
and Development Command
Dover, New Jersey 07801

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July 1980

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[illegible] Associates
[illegible] Canyon Road, San Ramon, California 94583

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XM746 PRACTICE FUZE

11 Final Report

In Response To:
Contract No. DAAK10-79-C-0040

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Prepared For:

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U. S. Army Armament Research
and Development Command
Dover, New Jersey 07801

11 July 1980

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14 MB-R-80/12

PREPARED BY
MBA MBAssociates
Bollinger Canyon Road, San Ramon, California 94583

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1.0 INTRODUCTION

This final report describes MBA development engineering effort and the results achieved under Contract DAAK10-79-0040. The purpose of this effort has been to determine methods for producing a low cost practice fuze along with a spotting charge to provide realistic year round training of military personnel and thereby reduce expenditure of standard service ammunitions. (See Appendix A for requirements as stated in contract).

Static and ballistic testing was conducted with a number of spotting charge candidates, ARRADCOM's desensitized Photoflash, Ordnance Research Inc's Red Phosphate composition and MBA's $TiCl_4$, all of which were loaded into modified P.D., M739 fuzes.

The ARRADCOM SW522 spotting charge produced the most reliable smoke cloud on the target and was the final selected candidate. The use of the P.D., M739 fuze, which is in production, produced the XM747 configuration, which offered a definite cost saving for this program by eliminating the need to manufacture costly hardware.

MBA received a contract modification in February 1980 to load and assemble 576 XM747E2 practice fuzes for testing at Ft. Sill and ARRADCOM.

2.0 BACKGROUND

During the time period between notice of award and contract award ($\sim$1 year), ARRADCOM had made significant progress on an in-house development program for the XM747 (M739) practice fuze and spotting charge; see Figure 1. The ARRADCOM work prior to MBA involvement was as follows:

1. Development of 3 candidate photoflash smoke compositions.
2. Ballistic and lethality testing conducted for the smoke compositions using a modified M557 fuze.
3. Fuzes had been modified and loaded with spotting charges and were sent to Yuma Proving Grounds for testing in late January 1979.

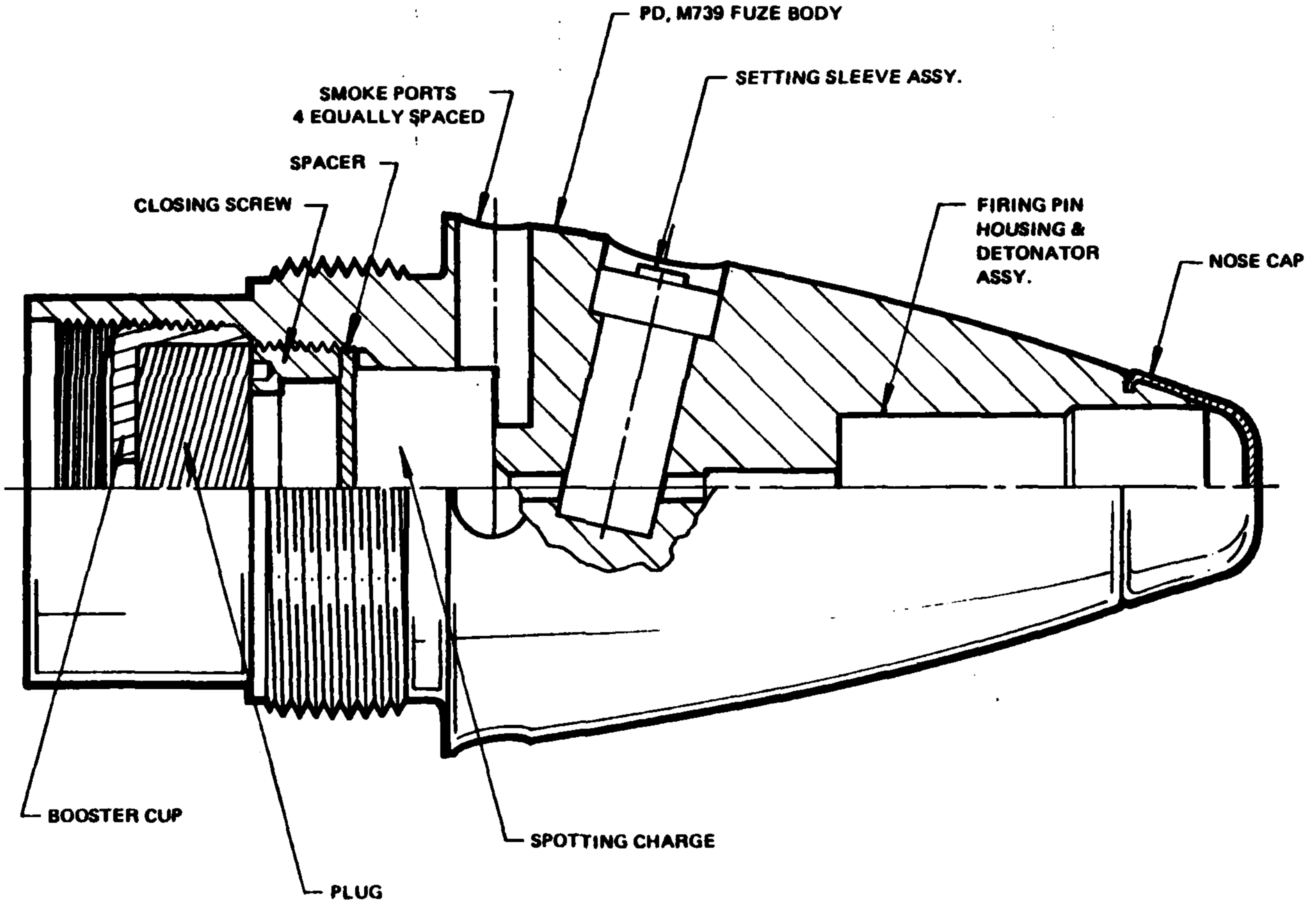


FIGURE 1
ARRADCOM XM747 (M739) PRACTICE FUZE

4. 1,500 P.D., M739 fuzes were being modified by Honeywell for the XM747 fuze program.
5. A plastic mold had been made for the smoke container (see Figures 2A & 2B).
6. Work had been started on a preliminary design for an all plastic version of the fuze (see Figure 3).

With the XM747 fuze development being as far along as it was, it was agreed that MBA would continue the initial effort by analyzing and testing non-conventional spotting charges such as Titanium Tetrachloride ($TiCl_4$ Cold Smoke). MBA would also upgrade the P.D., M739 fuze design and develop an adaptable plastic settable ogive to satisfy the requirements for the XM746 fuze and further develop the low cost all plastic fuze.

3.0 MBA PRELIMINARY CONFIGURATION

A baseline configuration, see Figure 4, was a modified P.D., M739 fuze and the possible use of $TiCl_4$ as a spotting marker, see Table 1 for physical properties, and $BKNO_3$ for the expulsion charge. The $TiCl_4$ was to be contained in either a glass vial and sealed with a teflon cap or an all metal container. The $BKNO_3$ is in granular form and sealed in a plastic container. The plastic settable ogive is set in a radial groove. The O.D. of the groove would be rolled over with sufficient pressure to contain the ogive and let the ogive rotate when a minimum torque of 75-in. lb. is applied. The detonator assembly P/N 9258613 is the standard super-quick detonator.

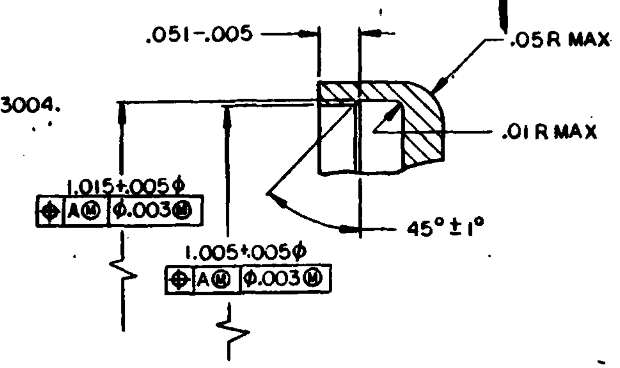
The baseline configuration shown in Figure 5 is an all plastic molded version of the fuze. Its main features are a snap-on settable ogive retained by a square wire spring clip and a friction surface to produce the required torque setting, and 30° aft canted smoke ports. The main features are as follows:

1. A large payload.
2. A short function time due to a decreased length of the spit tube.

DRAWING SIZE C
(ARRADCOMR 76-12)

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
XO	———	———	———

NOTES: —
1 - SPEC MIL-A-2550 APPLIES.
2 - MATERIAL: — POLYETHEYLENE, HIGH DENSITY, THEMOPLASTIC, CONDUCTING, DUPONT ALATHON 2910, BK 55, MEETING REQUIREMENTS OF ASTM D-3004.



DETAIL A
SCALE: 10/1

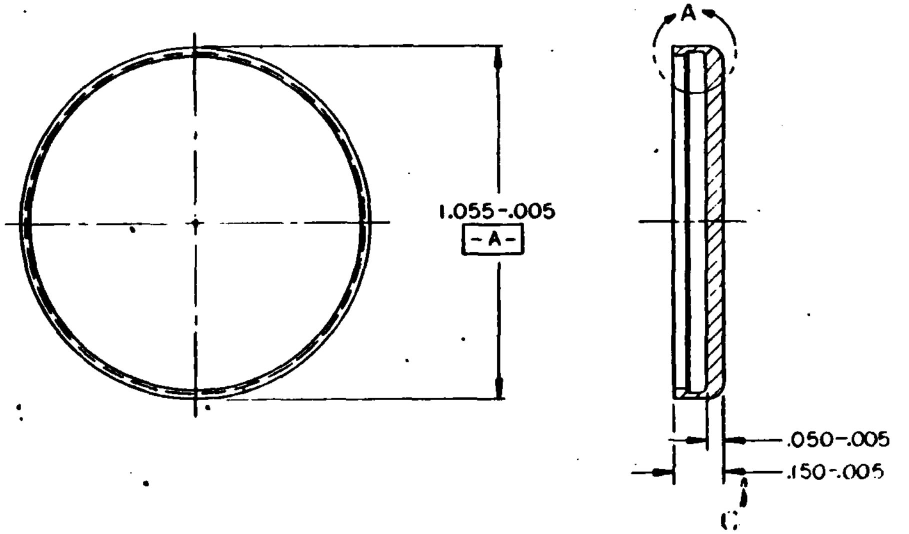


FIGURE 2A

JUN 8 1979

PART NO. 9331829

9331826	FUZE XM747	MECHANICAL PROPERTIES YP TS EL2 RA BH RH	DO NOT SCALE DRAWING UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON DECIMALS ± FRACTIONS ± ANGLES ±
NEXT ASSY	USED ON		
APPLICATION			

ORIGINAL DATE OF DRAWING 79-04-25
DRAFTSMAN M.S.
CHECKER
ENGR
ENGR
ENGR
ENGR

U S ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
DOVER, NEW JERSEY 07801

COVER, SPOTTING CHARGE

SIZE C
CODE IDENT NO 19200
T
9331829
SCALE 4/1
UNIT WT.
SHEET

DRAWING SIZE C
(ARRADCOMR 70-13)

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
XO	—	—	—

NOTES:—
1-SPEC MIL-A-2550 APPLIES.
2-MATERIAL:—POLYETHEYLENE, HIGH DENSITY, THERMOPLASTIC, CONDUCTING, DUPONT ALATHON 2910, BK 55, MEETING REQUIREMENTS OF ASTM D-3004.

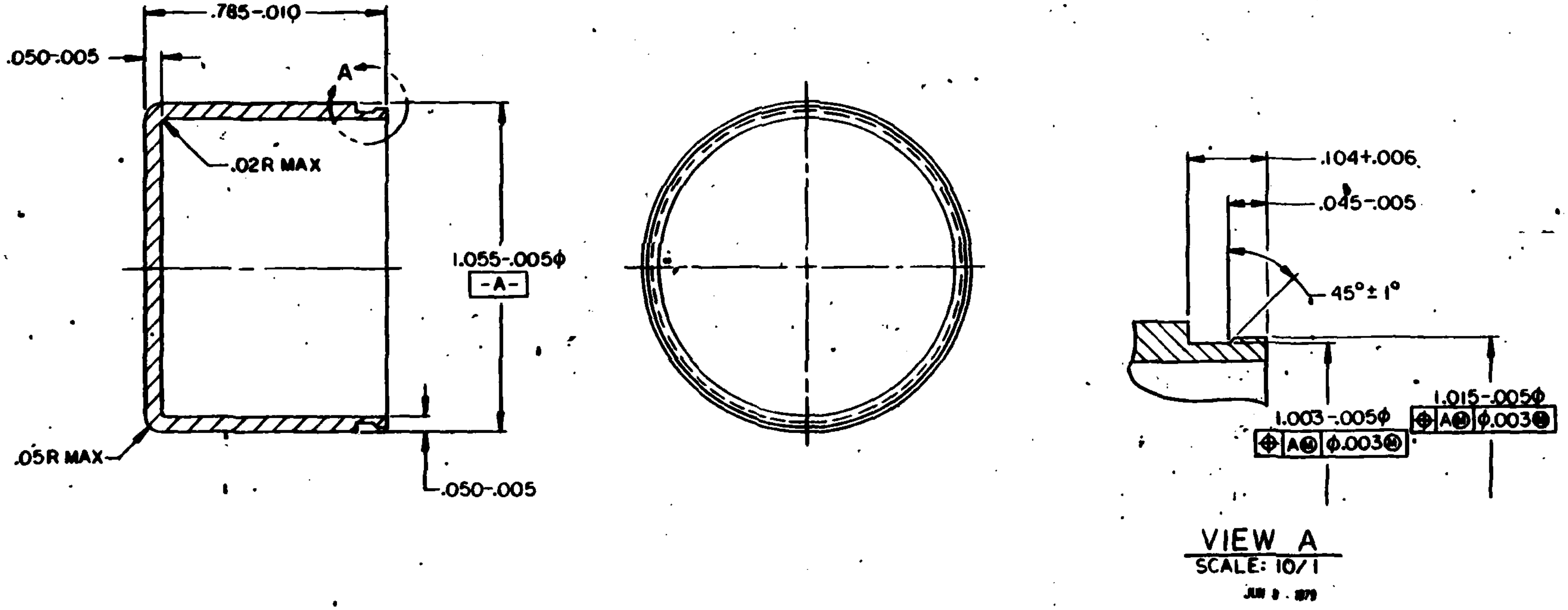


FIGURE 2B

PART NO. 9331828

9331826	FUZE XM747
NEXT ASSY	USED ON
APPLICATION	

MECHANICAL PROPERTIES
YP
TS
EL2
RA
BH
RH

DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS ±
FRACTIONS ± ANGLES ±

ORIGINAL DATE OF DRAWING
79-04-25
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ENGR
ENGR

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DOVER, NEW JERSEY 07801

CUP, SPOTTING CHARGE

SIZE C
CODE IDENT NO. 19200
T
9331828
SCALE 4/1
UNIT WT.
SHEET

ARRADCOM FORM 87 AUG 77 REPLACES SARPA FORM 1040 OCT 75 WHICH MAY BE USED UNTIL EXHAUSTED

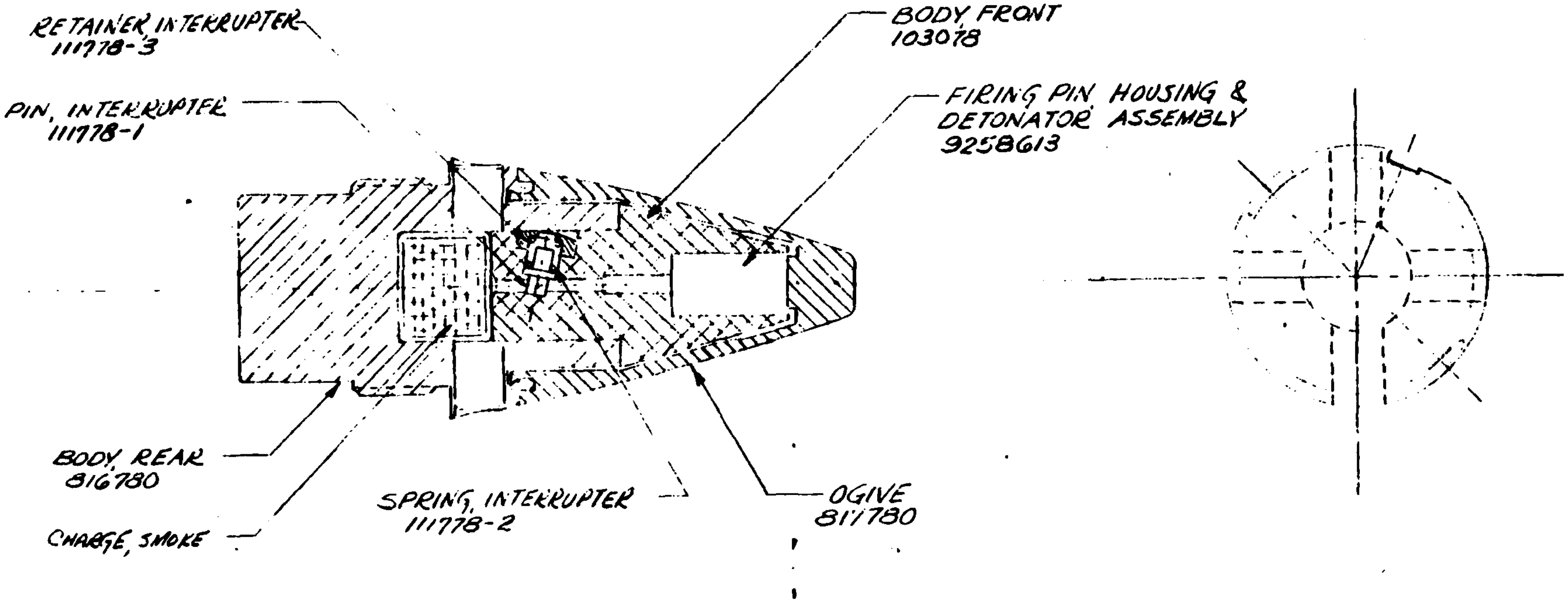


FIGURE 3
PLASTIC PRACTICE FUZE
XM746 PRELIMINARY DESIGN

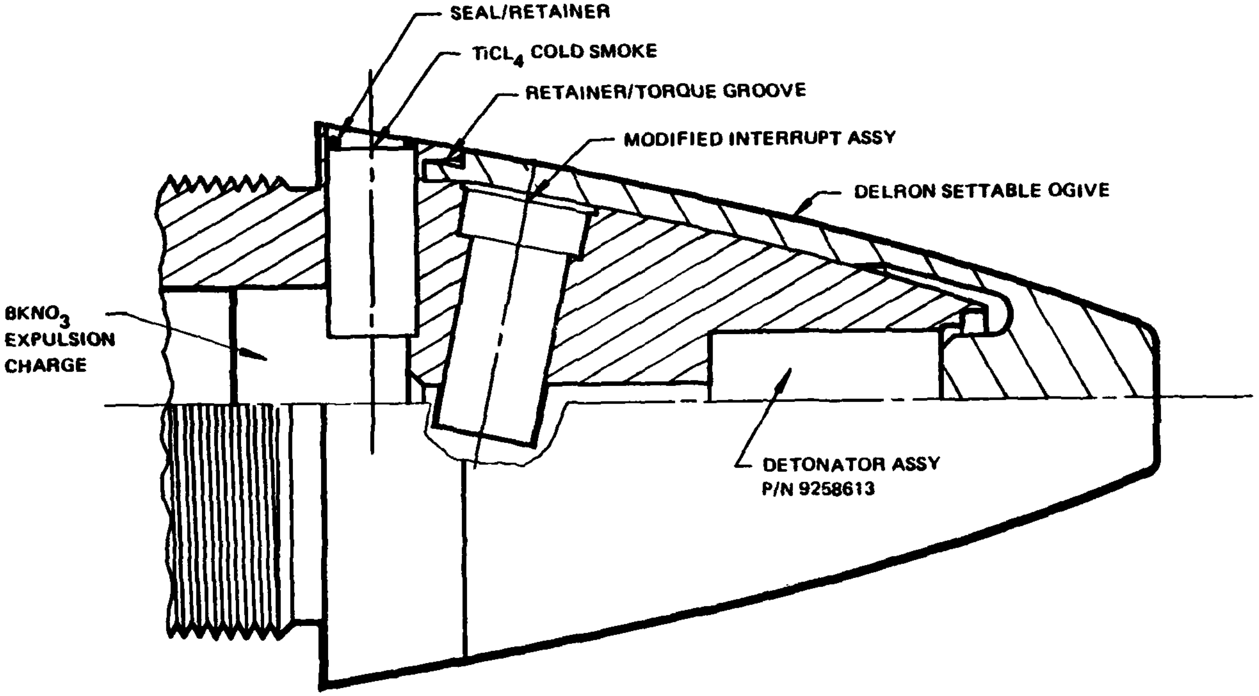


FIGURE 4
MODIFIED PDM739 FUZE

TABLE 1

TITANIUM TETRACHLORIDE - $TiCl_4$

PHYSICAL PROPERTIES

Chemical Formula	$TiCl_4$
Molecular Weight	189.7
Color, Form	clear liquid
Melting Point	-30°C
Boiling Point	136.4°C
Specific Gravity (20°C)	1.726
Density (lbs./gal.)	14.4
Stability	decomposes in the presence of moist air

SPECIFICATIONS (Weston, Michigan Plant)

Titanium, wt.%	25.0 minimum
Chlorine, wt.%	74.0 minimum
Color	50 maximum

Metal Analysis, ppm

Tin (Sn)	10 max.	Chromium (Cr)	5 max.
Aluminum (Al)	10 max.	Antimony (Sb)	5 max.
Iron (Fe)	15 max.	Arsenic (As)	10 max.
Vanadium (V)	10 max.	Lead (Pb)	1 max.
Silicon (Si)	10 max.	Nickel (Ni)	5 max.
Copper (Cu)	5 max.		

SAFETY AND HANDLING

Titanium tetrachloride must be maintained under inert atmosphere. Nitrogen containing less than 10 ppm of oxygen is recommended. Exposure to moisture in the air generates hydrochloric acid and titanium dioxide. Refer to the titanium tetrachloride "Product Safety Information" sheet for safety information, and to the Stauffer brochure "A Guide to Cylinder Unloading."

THE ABOVE INFORMATION REPRODUCED FROM STAUFFER CHEMICALS PRODUCT DATA SHEET

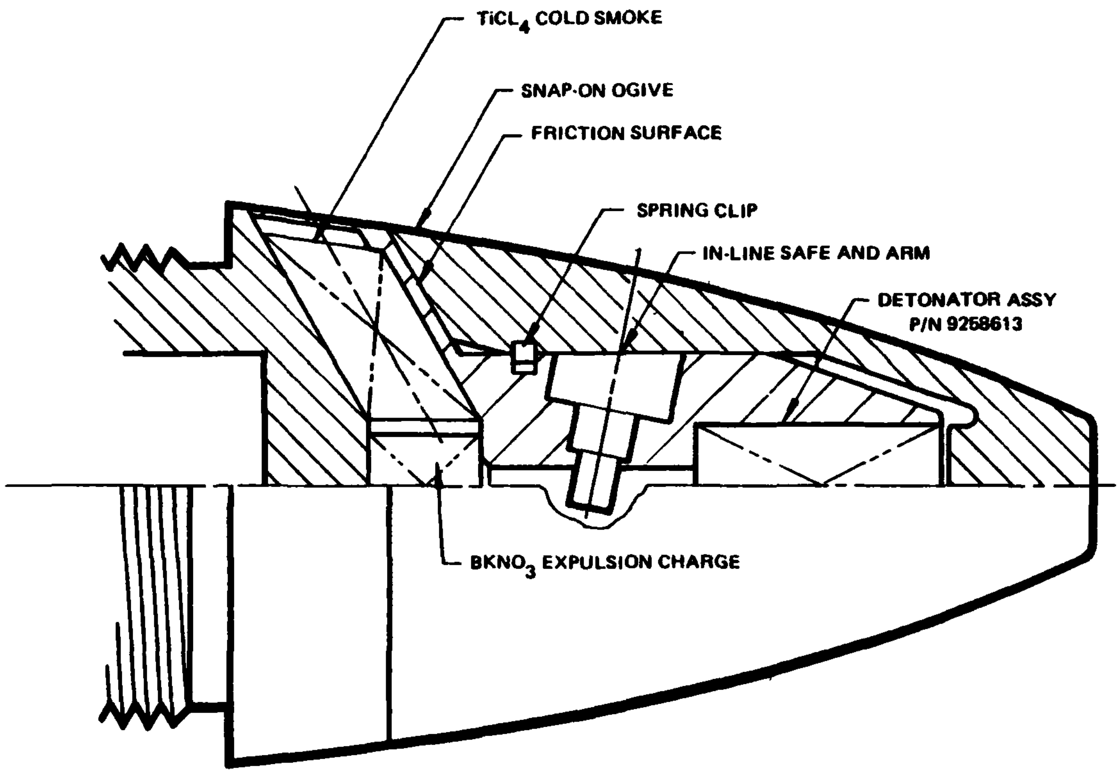


FIGURE 5
XM746 ALL PLASTIC FUZE

3. An increased amount of smoke over the target area due to the force created by the projectile deceleration rate on impact.

3.1 Model

MBA modified a P.D., M739 fuze body to accept a plastic settable ogive, per Figure 4, for a preliminary design model. The model was presented to ARRADCOM for evaluation.

4.0 PROGRAM REQUIREMENT CHANGES

As a result of a meeting held at ARRADCOM in March with users and staff in which the past performance of the practice fuze was reviewed, the following requirement changes were made:

- The range was increased for observer viewing (un-aided eye) to 4,000 meters. This distance was based on infantry being between the impact point and this range. Work on the XM746 version was thereby stopped.

- The general concensus of the users was that there would be sufficient training with tactical ammunition (30%) to preclude the need for an MT type simulated fuze; therefore, only a P.D. configured training fuze was required. Work on the XM746 version was thereby stopped.

- A sound signature was eliminated as a hard requirement but retained as a desired feature to back-up the visible signature.

- The visible signatures observed during ballistic testing in January were generally considered inadequate and further fuze testing was to be conducted with increased capacity smoke charges.

5.0 HARDWARE & ANALYSIS

5.1 ARRADCOM Configurations

The XM747 (M739) fuze assembly, shown in Figure 6, was developed by ARRADCOM. The modified P.D., M739 fuze body has 4 holes (smoke ports) drilled in the rear of the body and consisted of the following unmodified components:

- NOSE CAP P/N 9298909

- CROSS BAR & HOLDER ASSEMBLY P/N 9258622

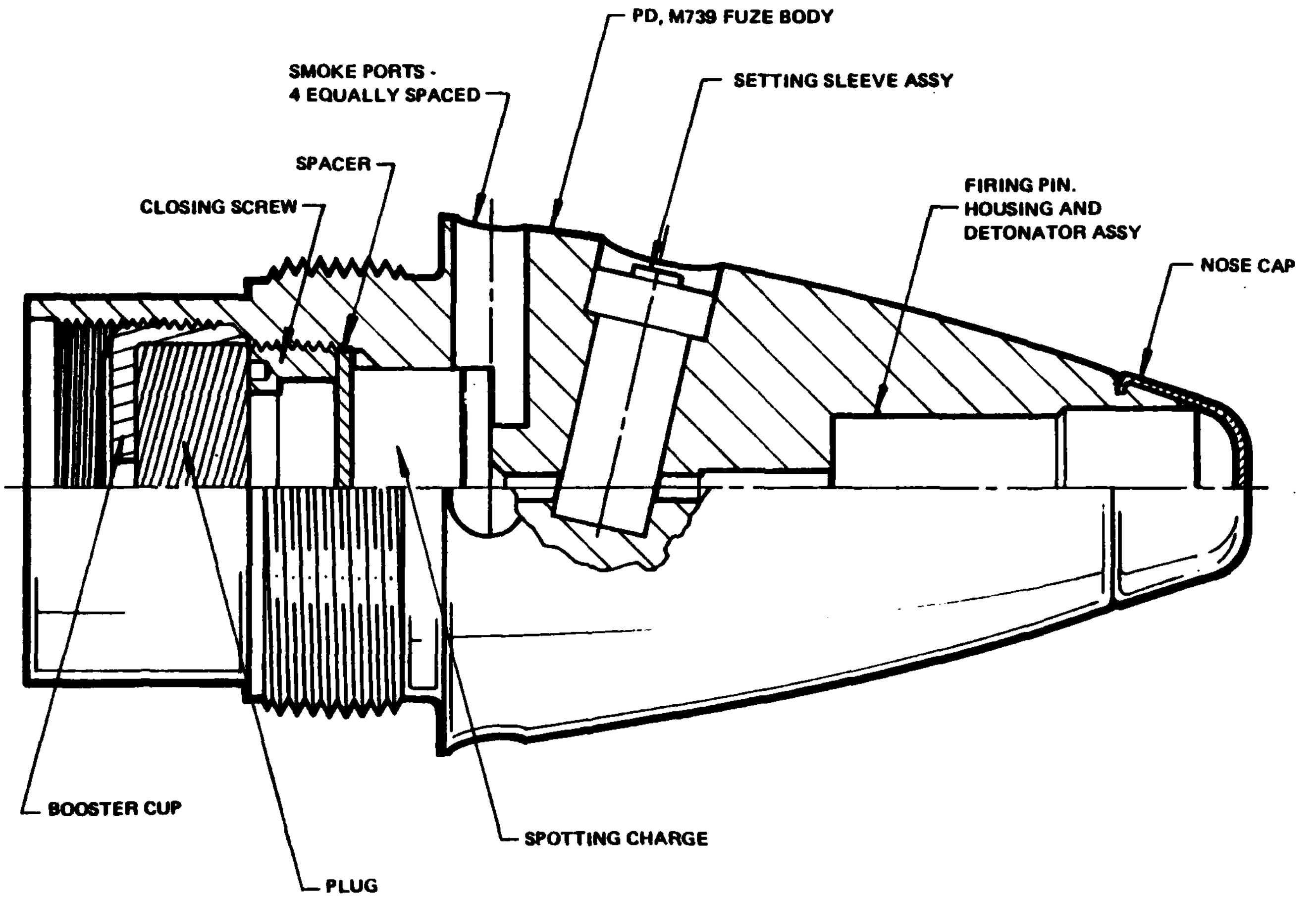


FIGURE 6
ARRADCOM XM747 (M739) PRACTICE FUZE

1480-17051

- FIRING PIN AND HOUSING DETONATOR ASSEMBLY P/N 9258613
- SETTING SLEEVE ASSEMBLY P/N 9258625
- SPACER P/N 9225115
- CLOSING SCREW P/N 9258611
- BOOSTER CUP P/N 9258607

The pyrotechnic spotting charge is loaded into plastic containers (sealed with epoxy), see Figure 7. The assembly is held in place with the closing screw and spacer and contained by the booster cup and plug. The system functions as follows:

The detonator is initiated on impact; the energy from the detonator is transferred down the spit tube penetrating the plastic cup and igniting the spotting charge, which is then expelled through the smoke ports.

The event was designed to take place in less than 2 milliseconds from impact to signal display from the smoke ports.

The design was statically and ballistically tested. The results were poor to non-spotting of the smoke cloud at the target area. In an effort to improve performance, two major configuration changes were made. The first was to increase the length of the spotting charge container by 1.165 inches which increased the spotting charge material by ≈ 58%. The second change was the addition of dimples in the cup and cap to decrease the penetration resistance of the assembly and thereby decrease the function time, see Figures 8A and 8B.

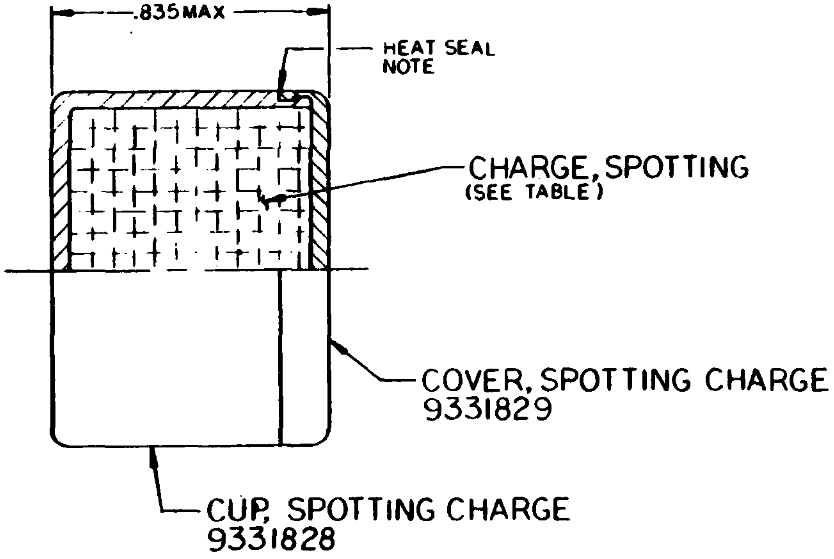
Also, two smoke ports were added to the fuze body, bringing the total to six, see Figure 9. The addition of the holes in the fuze body required spacers in the booster cup to prevent rupturing of the booster cup. This configuration was determined by tests conducted at Yuma Proving Grounds.

The final configuration under this contract involved the removal of smoke ports from the fuze body and addition of four 0.5 inch diameter ports in the 155mm XM804 projectile 19 inches back from the nose.

DRAWING SIZE C
(ARRADCOMR 70-12)

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
XO			

NOTES: —
1 — SPEC MIL-A-2550 APPLIES.
2 —



JUN 8 1979

SEE SEPARATE PARTS LIST 9331826

FIGURE 7

PART NO. SEE TABLE

9331823	FUZE XM747		
NEXT ASSY	USED ON		
APPLICATION			

MECHANICAL PROPERTIES
YP
TS
EL2
RA
BH
RH

DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS ±
FRACTIONS ± ANGLES ±

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U S ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
DOVER, NEW JERSEY 07801

SPOTTING CHARGE
ASSEMBLY

SIZE	CODE IDENT NO		
C	19200	T	9331826
SCALE 4/1	UNIT WT.		SHEET

ARRADCOM FORM 87 AUG 77 REPLACES SARPA FORM 1460 OCT 75 WHICH MAY BE USED UNTIL EXHAUSTED

DRAWING 3423 C
(ARRADCOMR 78-12)

NOTES: —
1 - SPEC MIL-A-2550 APPLIES.
2 - MATERIAL: — POLYETHEYLENE, HIGH DENSITY, THEMOPLASTIC, CONDUCTING, DUPONT ALATHON 2910, BK 55, MEETING REQUIREMENTS OF ASTM D-3004.
3 - COAT ALL SURFACES WITH ANTI-STATIC AGENT.

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
XO	—	—	—
XA	ADDED .125, .025 DIMS & NOTE 3	79-06-11	

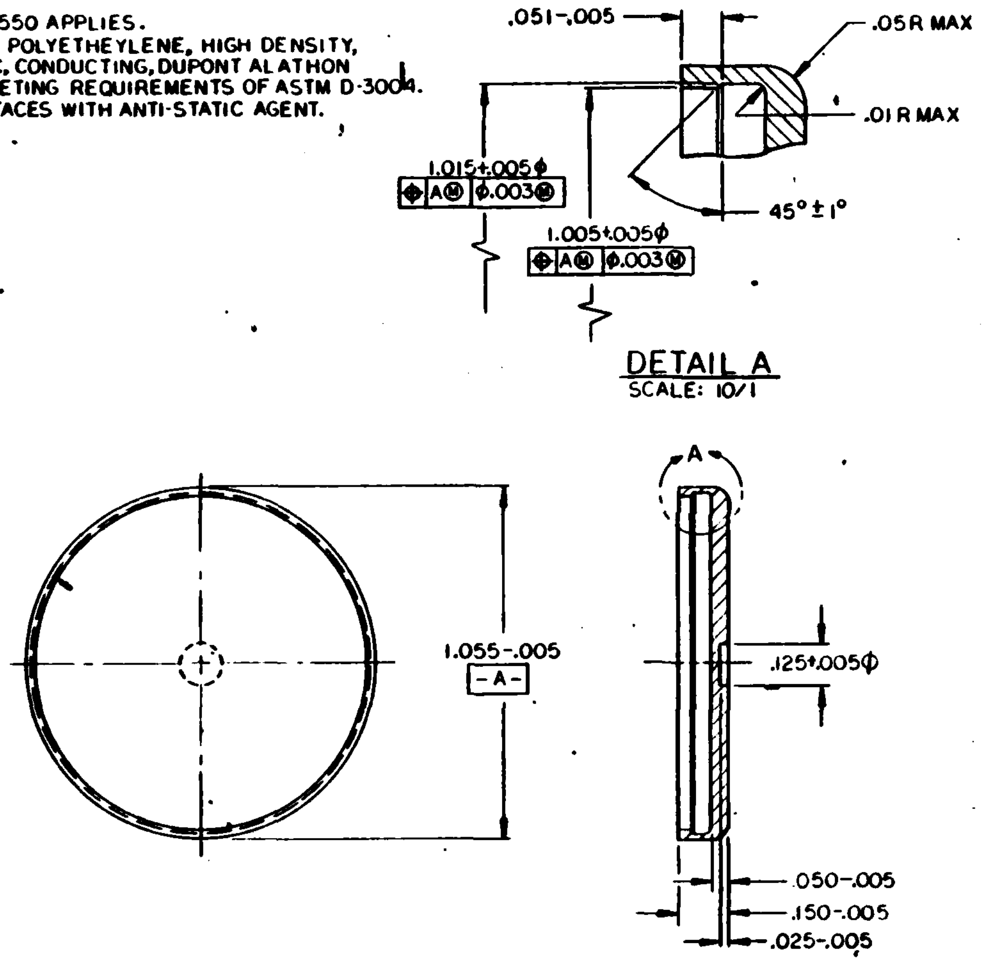


FIGURE 8A

PART NO. 9331829

9331826	FUZE XM747	MECHANICAL PROPERTIES	DO NOT SCALE DRAWING UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
NEXT ASSY	USED ON	YP TS EL2 RA BH BH	TOLERANCES ON DECIMALS ± FRACTIONS ± ANGLES ±
APPLICATION			

ORIGINAL DATE OF DRAWING 79-04-25
DRAFTSMAN M.S. CHECKER
ENGR ENGR
ENGR ENGR

U S ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
DOVER, NEW JERSEY 07801

COVER, SPOTTING CHARGE

SIZE C
CODE IDENT NO 19200
T
9331829
SCALE 4/1 UNIT WT. SHEET

DRAWING SIZE C
(ARRADCOMR 70-12)

NOTES:—
1-SPEC MIL-A-2550 APPLIES.
2-MATERIAL:— POLYETHEYLENE, HIGH DENSITY, THERMOPLASTIC, CONDUCTING, DUPONT ALATHON 2910, BK 55, MEETING REQUIREMENTS OF ASTM D-3004.
3-COAT ALL SURFACES WITH ANTI-STATIC AGENT.

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
XO			
XA	DIM 1.950 WAS .785. ADDED .125, .025 DIMS & NOTE 3.	79-06-11	

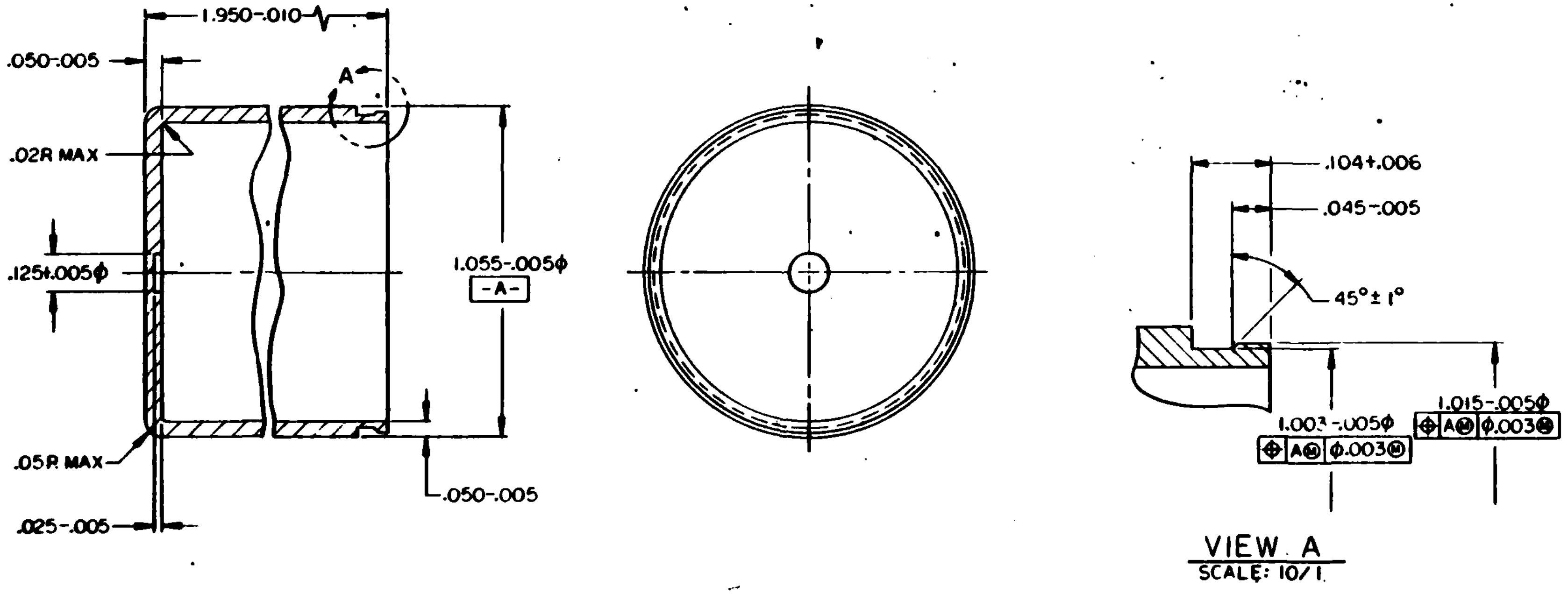


FIGURE 8B

PART NO. 9331828

		MECHANICAL PROPERTIES	
		YP	
		TS	
		ELG	
		RA	
9331826	FUZE XM747	BH	
NEXT ASSY	USED ON	BH	
APPLICATION			

DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS ±
FRACTIONS ± ANGLES ±

ORIGINAL DATE OF DRAWING
79-04-25
DRAFTSMAN MS
CHECKER
ENGR
ENGR
ENGR
ENGR

U S ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
DOVER, NEW JERSEY 07801

CUP, SPOTTING CHARGE

SIZE	CODE IDENT NO		
C	19200	T	9331828
SCALE 4/1	UNIT WT.		SHEET

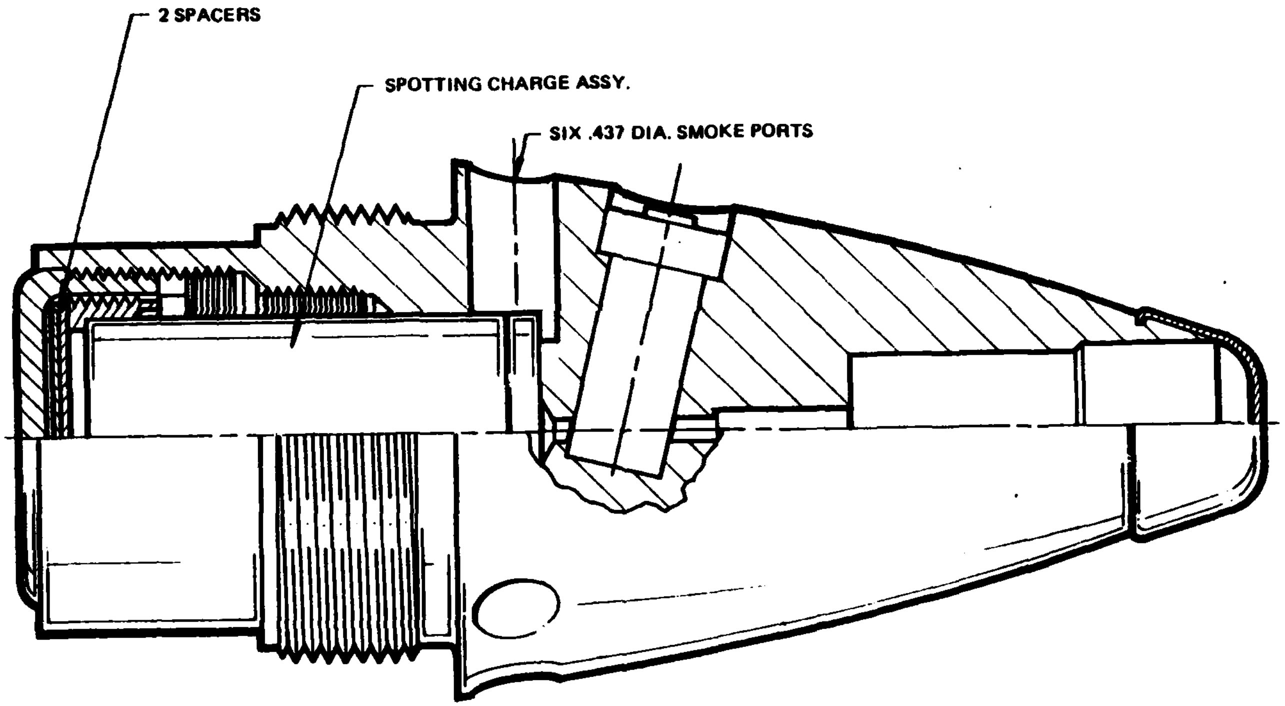


FIGURE 9
6 PORT/INCREASED SPOTTING CHARGE
XM747 FUZE ASSEMBLY

MBA
1480-17052

Initially, the holes were drilled radially but in the final design they were canted 45° to the rear of the projectile, see Figure 10. With this configuration the booster cup base is ruptured and the spotting charge ejects through the projectile smoke ports. The spacers in the booster cup were removed to facilitate the base failure mode. Also considered was a combination of spacers in the booster cup with smoke ports in the fuze body and projectile to eject smoke from both the projectile and fuze, (see Section 6.0 Testing - MBA Static Testing). The final configuration was brought about as a result of the MBA static test and ARRADCOM and MBA's estimate of the worst case and most rapid burial condition for the 155mm projectile, see Figure 11. This condition exists in deeply saturated light sand soils. The ARRADCOM model predicts coverage of the smoke ports located 19 inches back on the projectile 1.8 milliseconds after impact. MBA analysis indicates burial in $\approx$ 2.0 milliseconds.

With the choked flow gases exiting at Mach 1 and the ports canted back 45°, the gases will have a net forward velocity component approximately 1/3 that of the shell at the critical period when they flow into the circular cavity between the shell and ejected from impact.

5.2 ARRADCOM Spotting Charges

For the spotting charge, ARRADCOM developed a family of desensitized photoflash composition (see Table 2) designated as SW Smoke Compositions. The SW522, also described as MOD "E", produced the best smoke cloud and function time and proved to be a relatively safe material to handle (see Table 3 for sensitivity data).

Other spotting charges considered by ARRADCOM were Ordnance Research Inc's (ORI) composition and Baldwin Electronic Inc's (BEI) composition.

The ORI composition, a proprietary composition, proved to be slow in function time and a sensitive material (see Table 3). Variations of the composition were statically and ballistically tested throughout the program.

The BEI composition was subject to one set of ballistic testing in April. The results were poor and it was no longer considered a candidate material.

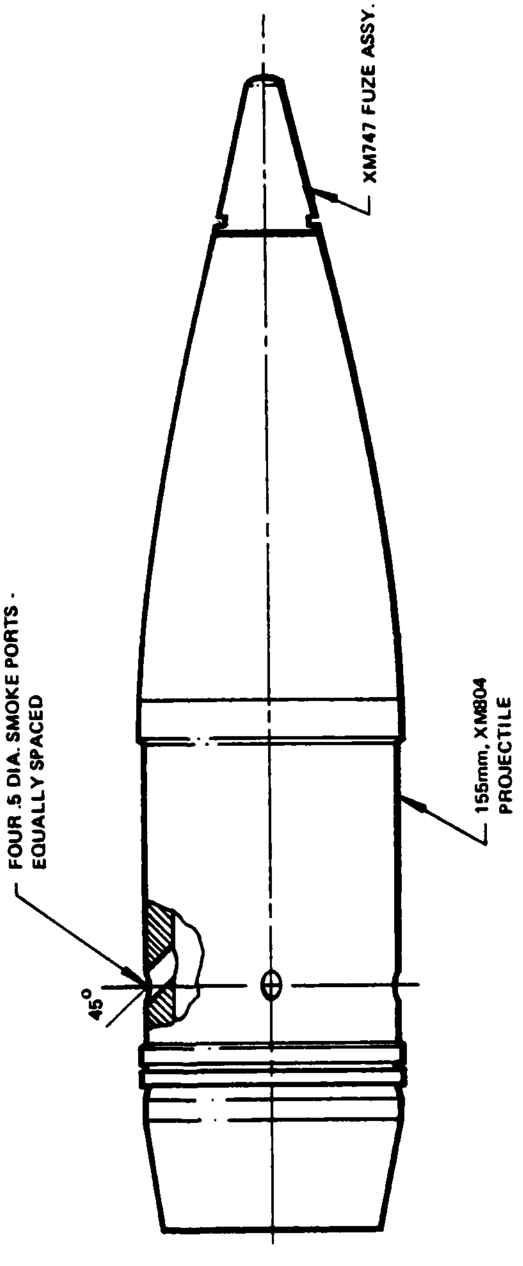
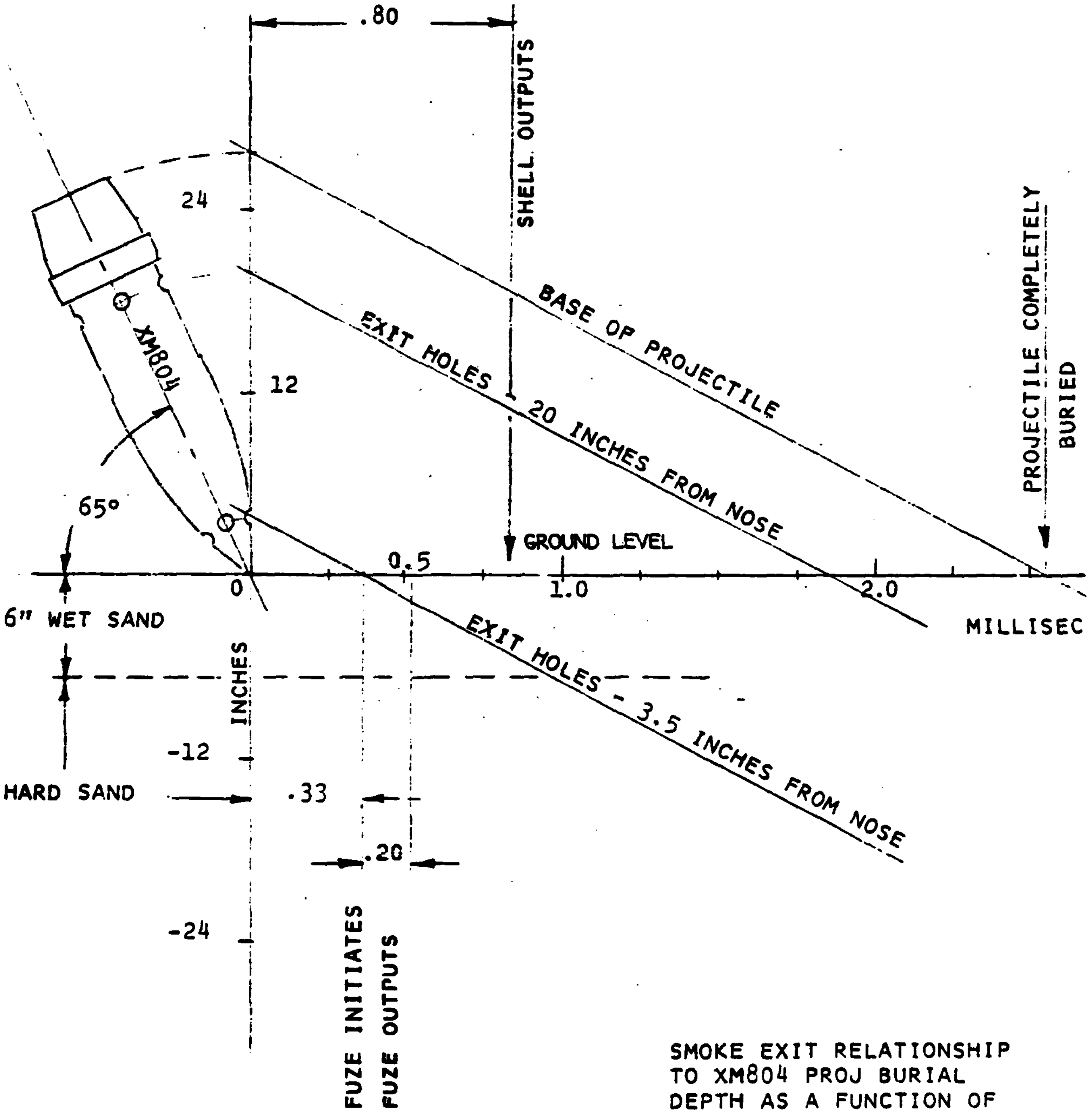


FIGURE 10
PROJECTILE ASSEMBLY



SMOKE EXIT RELATIONSHIP
TO XM804 PROJ BURIAL
DEPTH AS A FUNCTION OF
EXIT HOLE LOCATION

IMP VEL - 900 FT/SEC
IMP ANGLE - 65 DEG
MEDIUM - WET SAND

FIGURE 11

L. POST - ARRADCOM
NOV. 79

TABLE 2

SW SMOKE COMPOSITIONS

COMPOSITION	MIL-P-466 Type III, Class A Photoflash	MOD A SW-59 % by Wt.	MOD B SW-466 % by Wt.	MOD C SW-521 % by Wt.	MOD E SW-522 % by Wt.	Specification
Zinc Dust	—	68.75	75	65	40 ± 1	JAN-Z-365
Potassium Perchlorate	30	18.75	25	25	20 ± 0.5	MIL-P-217A, GrA, C14
Potassium Nitrate	—	12.50	—	—	20 ± 0.5	MIL-P-15613, Class 2
Aluminum (Atomized)	40	—	—	10	20 ± 0.5	MIL-P-14067A, Type II
Barium Nitrate	30	—	—	—	—	

TABLE 3

SENSITIVITY COMPARISON OF PYROTECHNIC SMOKES

CHARACTERISTIC	COMPOSITION		
	SW 522	ORI 'B'	ORI 'C'
Vacuum Stability: Gas Evolved - ML	0.92 40 Hrs @ 120°C	1.88 40 Hrs @ 100°C	11+ Failed - Stopped After 16 hours
Impact Test: (Bruceton 50% F.P.)			
2.5 Kg Wt Drop Ht (cm)	198	96.5*	51*
Std Ball Drop (Prim Expl) (cm)			
Friction Pendulum:			
Fiber Shoe	No Action	Detonates	Burns
Steel Shoe	Cracks, Sparks, Partial Detonation	Burns, Detonates	Cracks, Burns
Electrostatic Sensitivity: @ 0.25 Joules	No Ignition 20 Tries	Ignites Between 0.025 & 0.25 Joules (Failed)**	No Ignition 20 Tries
Ignition Temp: DTA 10°C/Minute Up to 227°C	No Ignition To 700°C Even @ 20°C/Min	No Ignition (In Argon)	Endotherm 54°C Endotherm 64-84°C Endotherm 127°C Exotherm 104-129°C (In Argon)

* Value for RD 1333 Lead Azide is 48-56 CM.

** 0.025 Joules can be carried on human body

5.3 MBA Hardware

The configuration shown in Figures 12A & B, P/N SK40679, is the initial MBA design using $TiCl_4$ for the spotting marker and $BKNO_3$ for an ejection charge. $TiCl_4$ reacts with moisture in the air to produce Titanium Dioxide (TiO_2) and Hydrogen Chloride (HCl). The TiO_2 appears as a dense white smoke while the HCl is rapidly dispersed. Exposure to large quantities of $TiCl_4$ can be harmful; however, the material is primarily considered to be an irritant. While $TiCl_4$ is corrosive, it is compatible with a number of materials, including teflon, epoxy and low carbon steel.

The $TiCl_4$ was loaded into teflon containers and mechanically sealed with an "O" ring (see Figure 13).

To maximize the volume of the $TiCl_4$, a special $BKNO_3$ container was fabricated in lieu of using existing GFE spotting containers (see Figure 14). The ejection charge container was loaded with 3.9 grams of granulated $BKNO_3$ and sealed with epoxy. This configuration, along with SW522 and ORI smoke candidates, was ballistically tested at Yuma Proving Grounds in April and all received low ratings.*

Locating the smoke ports in the projectile body provided the opportunity to increase the $TiCl_4$. Because the SW522 (MOD "E") spotting charge displayed excellent function time and its visual properties would enhance the $TiCl_4$ display, it was decided to use the SW522 composition to expel the $TiCl_4$ and eliminate the $BKNO_3$ expulsion charge.

Two $TiCl_4$ container designs were considered and identified as configurations A & B. The A configuration contained approximately 22 cc of $TiCl_4$ and 47 grams of MOD "E" expulsion charge loaded into the GFE smoke container (see Figure 15). The "A" configuration was rejected due to the fact it projected beyond the rear of the fuze body which would cause packaging problems in the event of a future production program.

The "B" configuration, P/N 116041-500, was designed to be completely contained within the fuze body (see Figures 16A & B). To accomplish this, it was necessary to reduce the $TiCl_4$ spotting charge to 18 cc and

---

* This test series resulted in the decision by ARRADCOM to move the smoke ports to the projectile as well as evaluate fuze/projectile smoke port combinations.

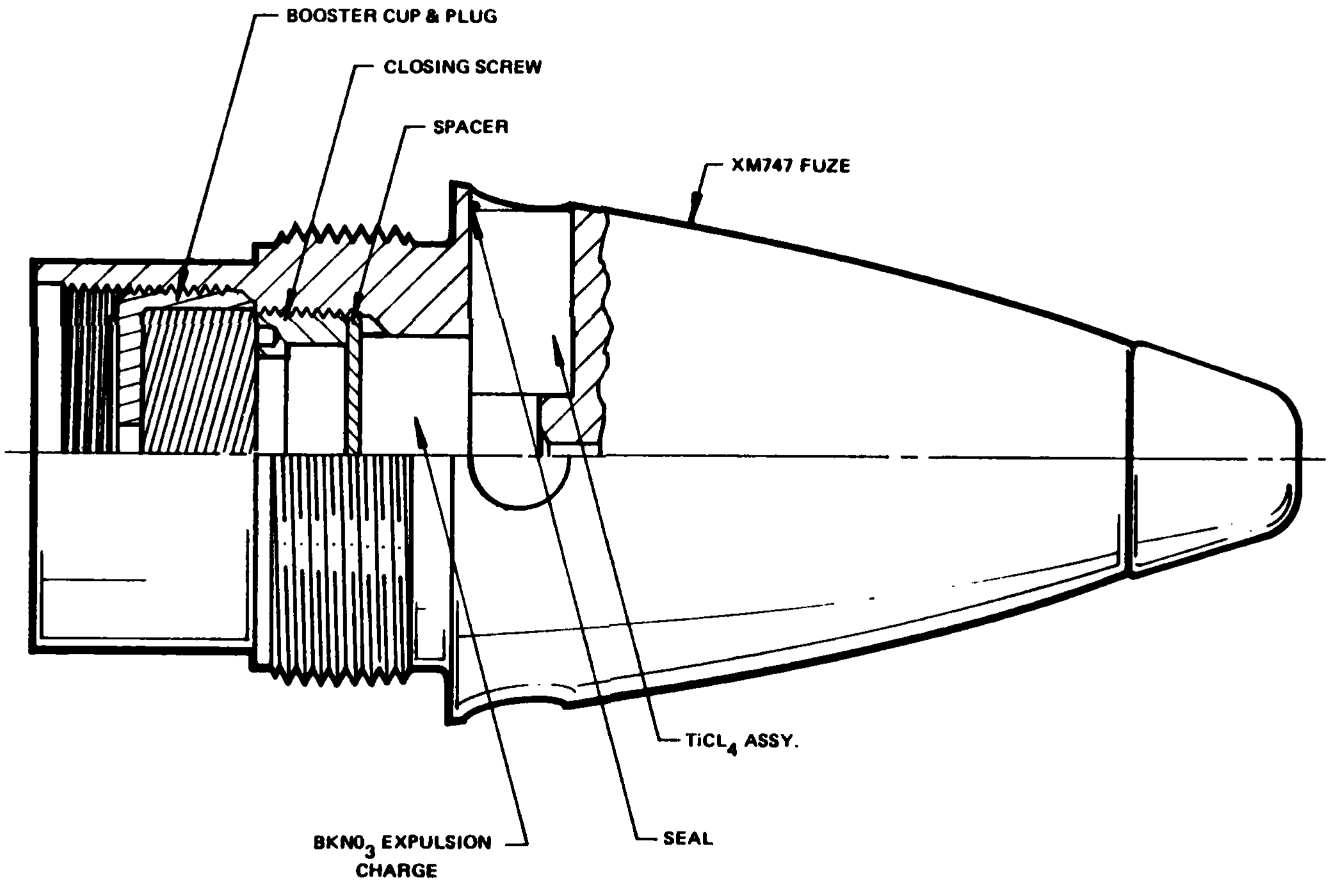
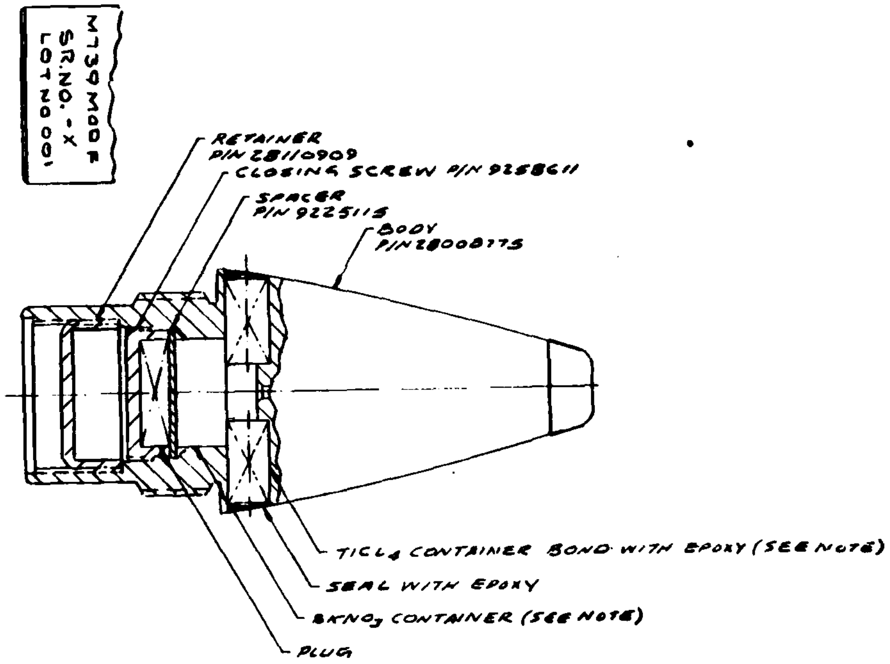


FIGURE 12A
XM747 MBA $TiCL_4$ CONFIGURATION
(P/N SK40679)



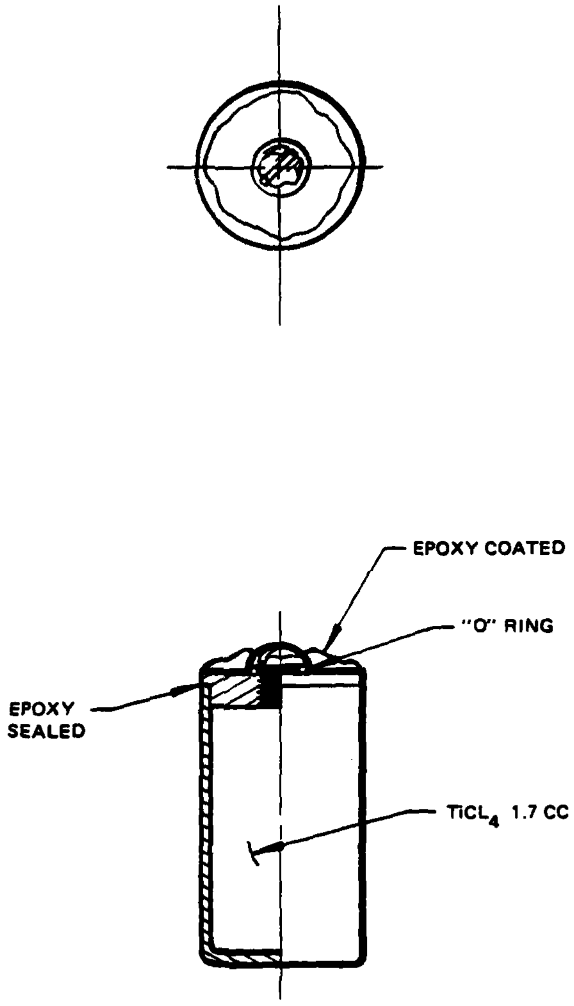
NOTE
SEE SK40678 FOR PART DETAILS

TITLE	FUZE M739 MOD F
DRAWN	4-6-75
DWG SIZE	C
CODE IDENT NO.	27934
DWG NO.	SK40679
SCALE	NONE
RELEASE DATE	4-6-75
SHEET	1

MBAssociates

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMAL ANGULAR
.XX ± ±
.XXX ±
DO NOT SCALE DRAWING

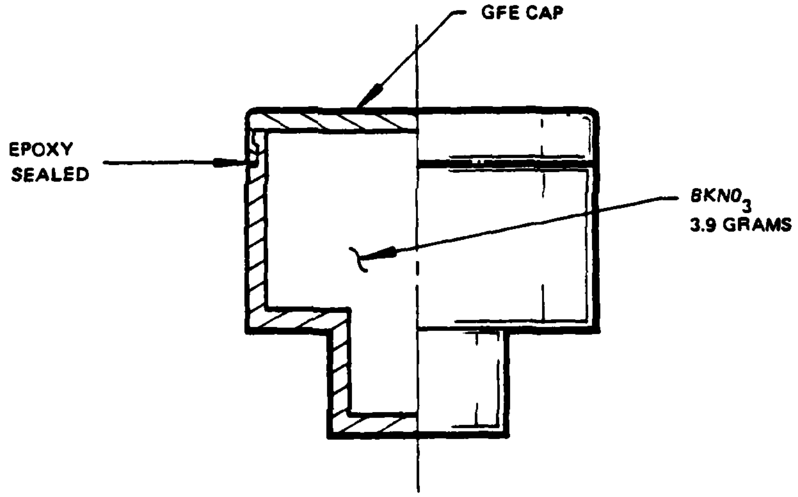
FIGURE 12B



MATERIAL: TEFLON

FIGURE 13
$TiCl_4$ ASSEMBLY

MBA
1480-17054



MATERIAL: DELRON

FIGURE 14
$BKNO_3$ ASSEMBLY

MBA
1480 17055

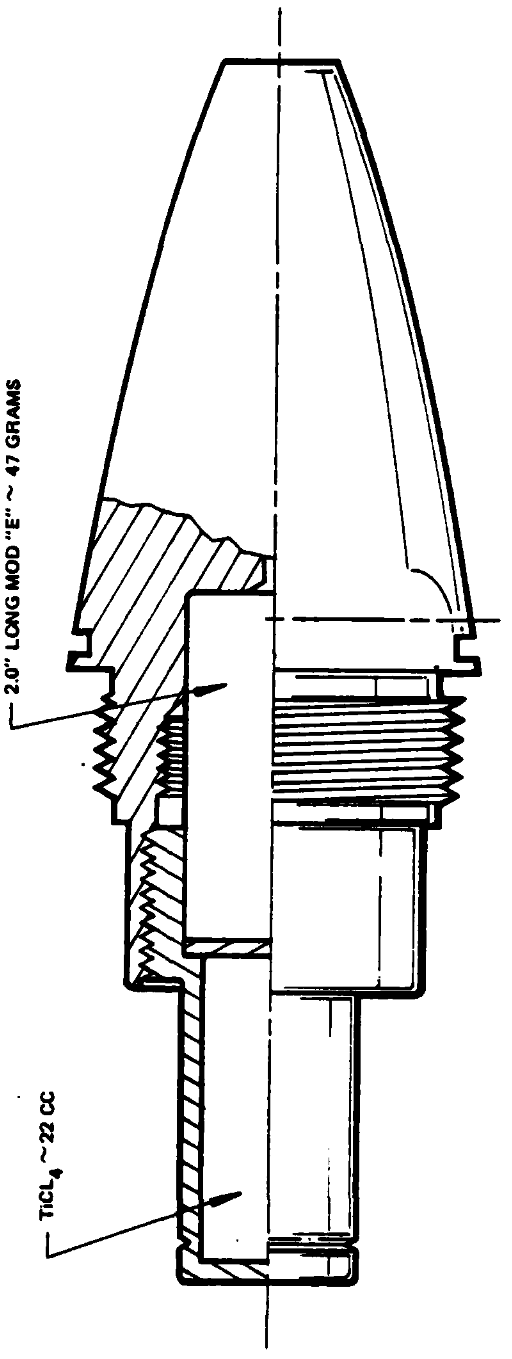


FIGURE 15
TiCL$_4$/MOD "E", CONFIGURATION "A"

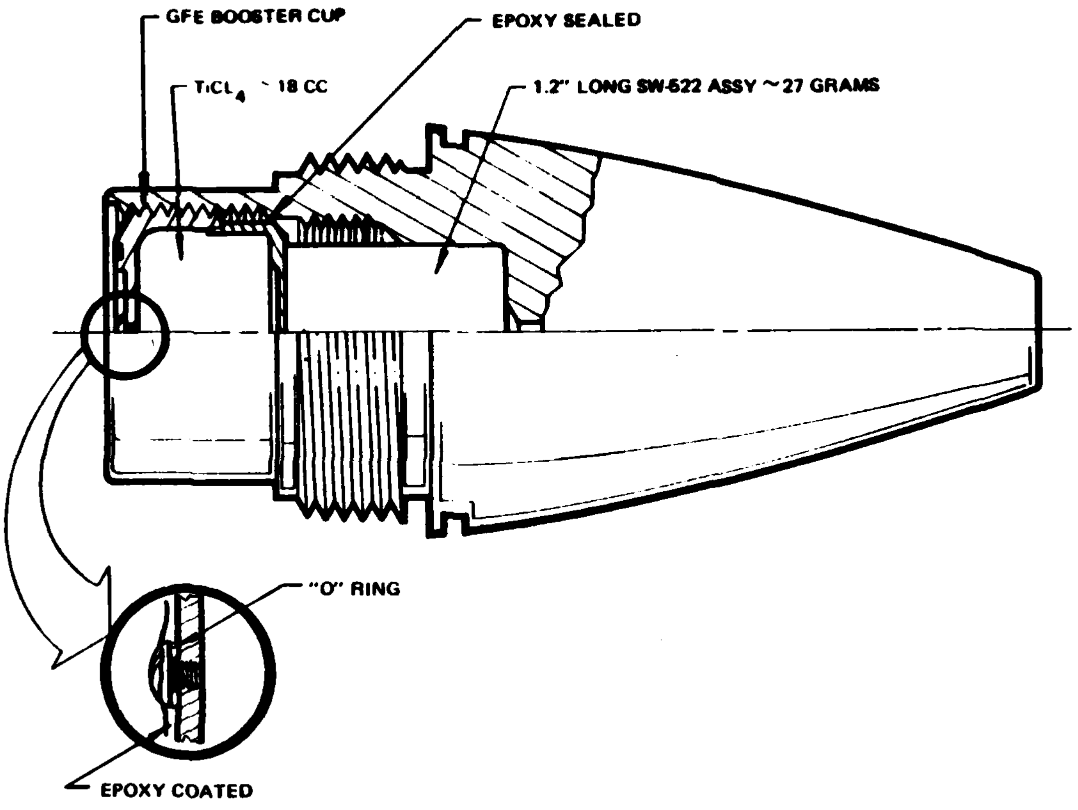
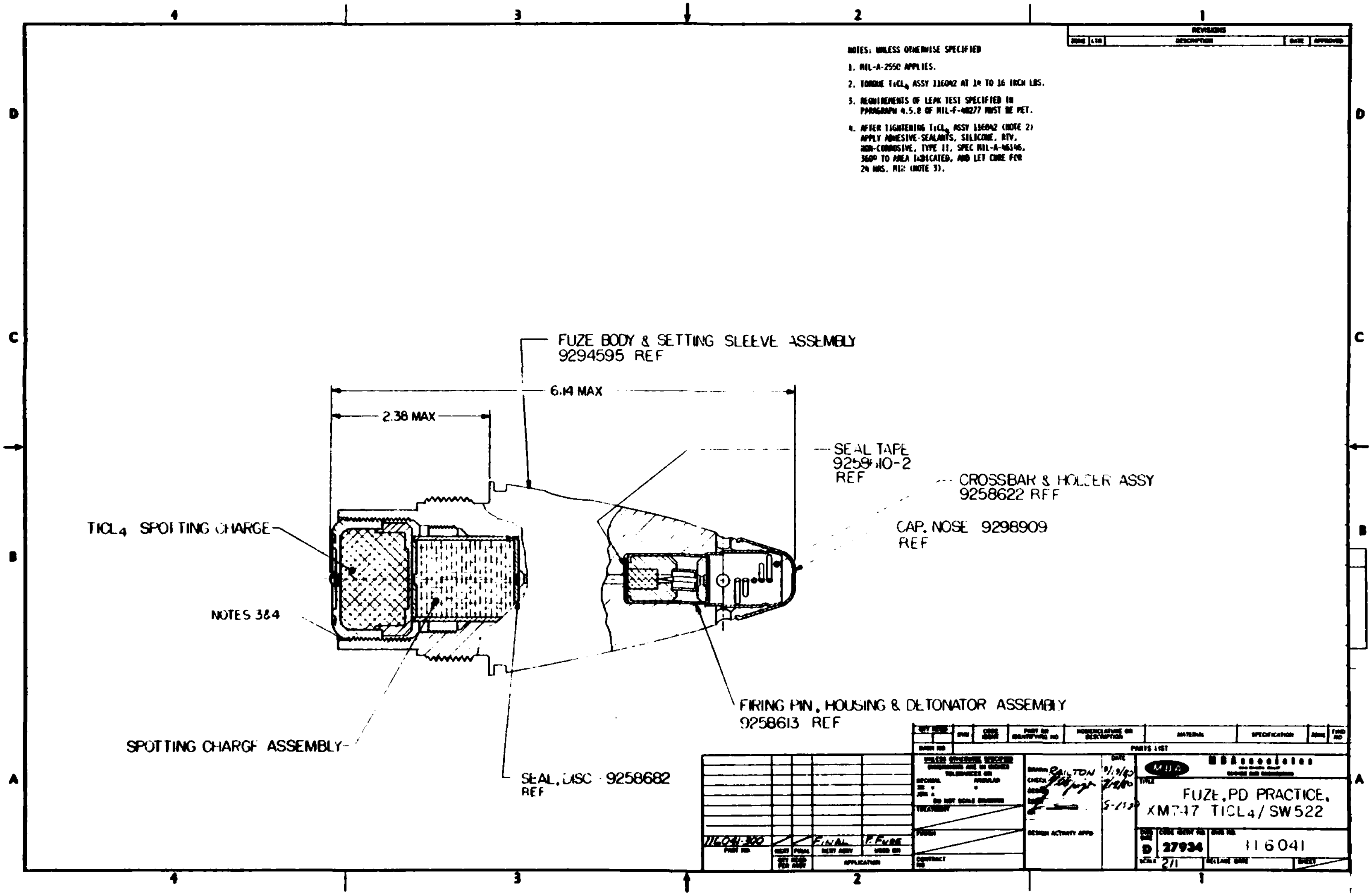


FIGURE 16A
$TiCL_4$/SW-522 CONFIGURATION
(P/N 116041-500)



NOTES: UNLESS OTHERWISE SPECIFIED

1. MIL-A-255C APPLIES.
2. TORQUE TiCl$_4$ ASSY 116042 AT 14 TO 16 INCH LBS.
3. REQUIREMENTS OF LEAK TEST SPECIFIED IN PARAGRAPH 4.5.8 OF MIL-F-48277 MUST BE MET.
4. AFTER TIGHTENING TiCl$_4$ ASSY 116042 (NOTE 2) APPLY ADHESIVE-SEALANTS, SILICONE, RTV, NON-CORROSIVE, TYPE II, SPEC MIL-A-46146, 360° TO AREA INDICATED, AND LET CURE FOR 24 HRS. MIN (NOTE 3).

FIGURE 16B

reduce the SW522 expulsion charge to 27 grams.

The $TiCl_4$ container utilized the GFE booster cup along with a fabricated closure. The fill port was mechanically sealed with an "O" ring and then painted with epoxy sealant. The expulsion charge container was reduced by 3/4 inches. The "B" configuration was statically tested at MBA in September and ballistically tested at Ft. Lewis in December with fair to excellent results (see Section 6.0 for test results).

In an attempt to achieve decreased function time, the standard production fuze cross bar assembly was removed and the firing pin, housing and super-quick detonator assembly were moved forward (see Figure 17), at the suggestion of ARRADCOM. This configuration was ballistically tested at Ft. Sill in June with little, if any, improvement when fired into a soft, muddy target area.

5.4 Analysis for Ballistic Testing

A stress analysis of the critical components, i.e., the booster cup base and the cup/body interface was performed. The results show adequate margins of safety for safe operation (see Appendix B). In lieu of actual data on internal pressure required to separate or fail the cup base during detonation, an unexpected bursting pressure was calculated.

Factors of safety used in the margin of safety calculations were 1.15 applied to the yield allowable and 1.5 applied to the ultimate allowable. These values are standard aerospace practice. Because of the extremely high acceleration forces of set-back loads, the actual margins of safety during normal handling operations are far in excess of hazardous material requirements.

The methods, referenced in the analysis, are standard pracrice and should not cause concern over their validity. As demonstrated in the analysis, the minimum margin of safety occurred at the cup base material thickness transition from 0.040 inches to 0.104 inches. This margin is 0.80 on yield which represents a stress level 80 percent below the material allowable when reduced by the yield factor of safety. The most critical area is therefore approximately twice as strong as required to support the worst case loading.

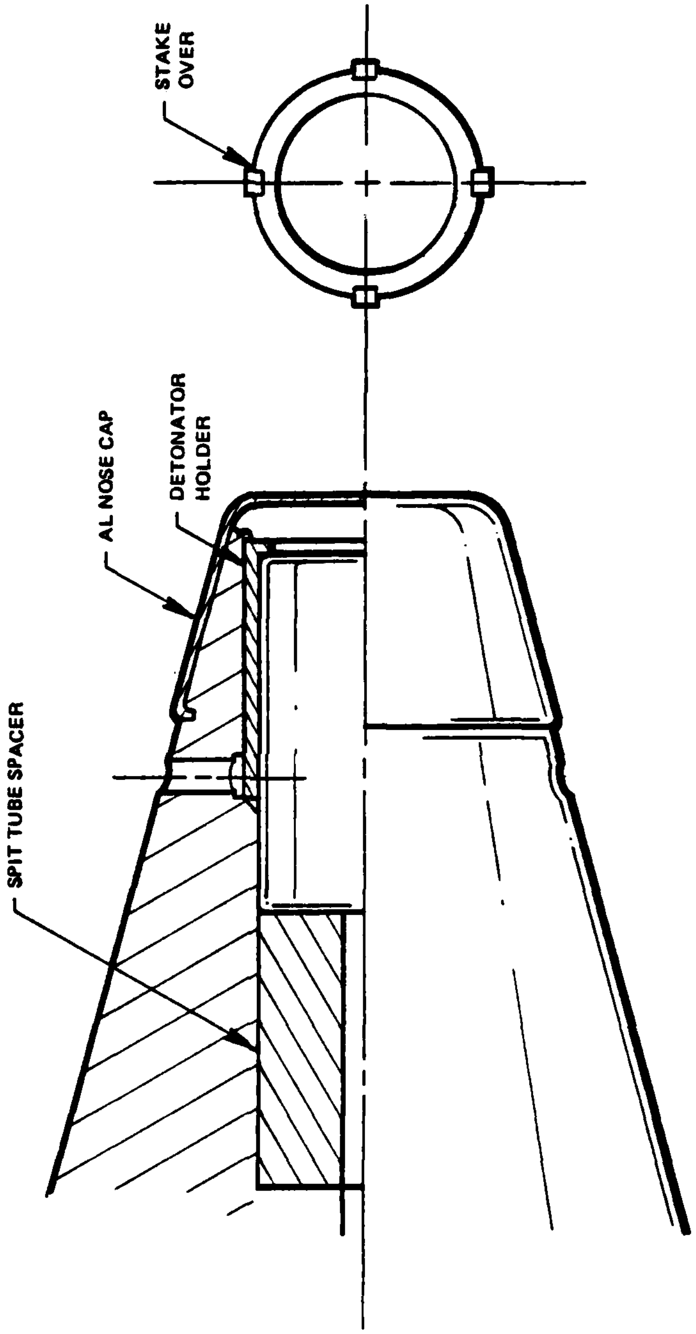


FIGURE 17
FUZE DETONATOR MODIFICATION

The analysis also predicts a bursting pressure of 10,500 psi which appears to be compatible with good performance during the detonation event. Although actual pressures are not known, they are anticipated to be in the order of 20,000 psi, if totally contained. This two to one pressure ratio is comfortable for reliable failure expectation.

6.0 TESTING

6.1 ARRADCOM Tests at Yuma Proving Grounds

ARRADCOM conducted ballistic tests* at Yuma Proving Grounds in late January 1979 to evaluate three ARRADCOM developed spotting charges and photoflash.

The modified M739 (XM747) fuzes containing the spotting charges (see Figure 1) were tested on the XM804 155mm training projectile. Trajectory evaluations were also made for ballistic similitude with the M167 inert projectile with T2 charge and the M557 fuze.

Observers and 16mm and video cameras were stationed at 1,000 to 1,800 meters from the impact area. The spotting charges were rated as poor, as reported by ARRADCOM (see Table 4 for test results, conclusions and recommendations). Ballistic similitude was achieved.

The next set of tests were conducted in late April 1979 at Yuma Proving Grounds. These tests incorporated the following modification to the January hardware. The nose cap was removed from the XM747 (M739) fuze and three charge weights were used in single, double and triple cups. This was accomplished by joining standard cups and assemblying them into the XM747 fuze, with four smoke ports. (See Figure 19 for typical double and triple charge configurations).

Between January and April tests, ARRADCOM modified the smoke compositions designating the new blends MOD "D" (PF 54) and MOD "E" SW522 (see Table 5).

---

* Test information provided by ARRADCOM

TABLE 4

VISUAL FUNCTIONAL RESULTS
XM804 TRNG PROJ w/MOD M739 FUZE

SPOTTER COMPOSITIONS

VISUAL DATA	MOD A SW-59	MOD B SW-466	MOD C SW521	PF(1)	XM804 W/M557	M107 Inert w/T2 Chg & M557
Dust, Flash & Smoke	-	-	-	4	1	35
Dust & Smoke		12	14	6	1	15
Unobserved	6	3	3	-	-	2
Total Fired	8	15	17	10	2	52
Dist to Impact (Avg)	1650M	1450M	1450M	1450M	1300M	1650M
Degree of Visibility (2)	Poor	Poor	Poor	Fair	Poor	Good

(1) PF-Photoflash Charge

(2) Impact areas varied due to ballistic similitude testing of XM804 vs M107 Proj which was conducted at several Zones and QE's. However, visibility of the smoke (A, B & C) compositions were considered poor even when the impact areas were clearly visible, twelve impacts were spotted using a 7 power scope from four different towers. Desert growth 6 to 10 feet high obscured the impact on a few rounds fired.

CONCLUSIONS:

The modified M739 fuzes with four different spotting charge compositons did not meet the LOA visibility requirement of being equal to a fully loaded 105MM, HE projectile.

Visibility by the naked eye of the three smoke compositions "A", "B" and "C" was considered poor, especially at high angles of impact. No flash was observed on any of these smoke compositions during daytime observation. Twelve of the rounds were unobserved even when looking through a 7 power scope.

The fuze with the photoflash composition was more visible than the fuzes with smoke composition. All ten fuzes tested were observed and six out of ten had both flash and smoke. However, the signature produced was not equal to a 105MM HE round. As a matter of fact, the photoflash did not produce a signature as good as the 155MM M107 inert with a T2 supplementaty charge which was fired alternately as a control round.

RECOMMENDATIONS:

The practice fuze impact sensitivity should be increased to provide a level of sensitivity at least equal to the M557 PD Fuze*.

The modified M739 fuzes used in this test were the less sensitive nose cap version. This probably caused the fuze to penetrate the ground slightly before functioning, obscuring the flash and/or smoke.

A larger amount of spotting charge composition should be used to produce more flash and/or smoke for better visibility.

---

* Previous testing of a modified M557 Fuze containing the same photoflash charge had a signature equivalent to the inert 155MM projectile with a T2 supplementary charge.

EXTRACTED FROM TRIP REPORT OF W. ERCK (ARRADCOM) DATED JANUARY 28, 1979.

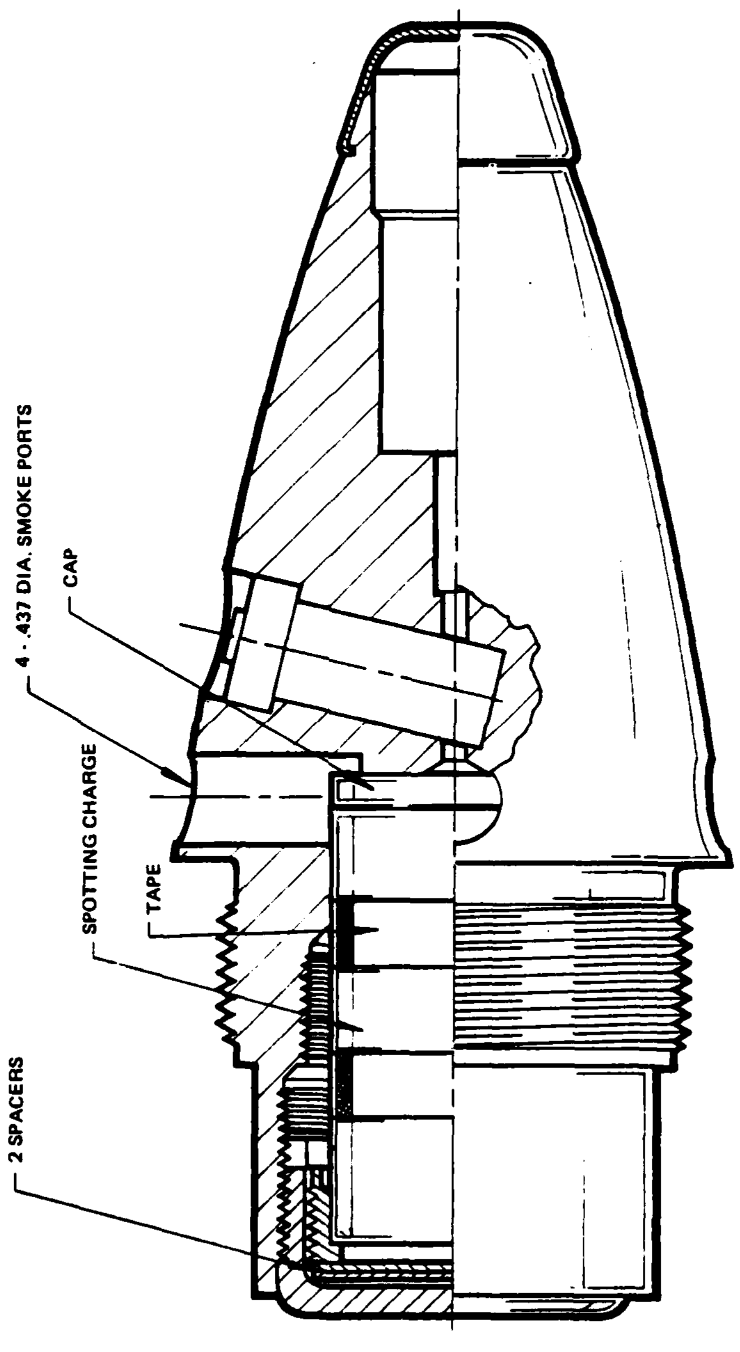


FIGURE 19
XM747 MULTIPLE CHARGE CONFIGURATION

1480-17057

Also submitted for evaluation were two compositions by Ordnance Research Inc. (ORI) and two compositions by Baldwin Electronics Inc. (BEI). The initial $TiCl_4/BKNO_3$ design was the final configuration being evaluated during this test series (see Figure 20).

Static tests were conducted at MBA prior to this Yuma test series to evaluate $TiCl_4$ as a spotting charge. The tests were conducted with 5.8cc of $TiCl_4$ and 2.2gm's of $BKNO_3$ charge contained in a test fixture, (see Figure 21). The daytime testing produced a sizable cloud about 25 ft. high and about 10 ft. in diameter (see Figure 22). The night test produced a base flash with a moderate size greenish cloud (see Figure 23). The event lasted a few seconds.

The ballistic evaluation testing of the spotting charge candidates was conducted over a two day period. The selected test area was flat and consisted of dry desert sand with light brush. ARRADCOM, ORI, Ft. Sill and MBA personnel were present for the tests. Observers were stationed at 2,000; 2,500 and 4,000 meters with video cameras at 2,000 and 4,000 meters.

The XM747 fuzes were assembled to the M107-155mm inert loaded projectiles.

The spotting charges were fired in groups of five the first day and in alternate order the second day for better comparison of the smoke cloud on impact (see Table 6).

Because the target area was dry and sandy a large dust cloud was created at projectile impact making it difficult to distinguish the smoke cloud from the dust. However, the MOD "E" did produce a flash on some impacts, visible at 2,000 meters and with a signature rated by the observers to be somewhat better than the MBA, ORI or BEI spotting charges. Therefore, the MOD "E" was selected for the baseline spotting charge.

TABLE 5

DESCRIPTION OF PYROTECHNIC SMOKE COMPOSITIONS

Ingredient	MOD "D" PF54 % By Wt.	MOD "E" SW522 % by Wt.	Spec.
Zinc Dust		40 ± 1	JAN-Z-365
Potassium Perchlorate		20 ± 0.5	MIL-P-217A, GrA, C14
Potassium Nitrate		20 ± 0.5	MIL-P-15613 Cl 2
Barrium Nitrate	60%		
Aluminum (Atomized)	40%	20 ± 0.5	MIL-P-14067A Type II

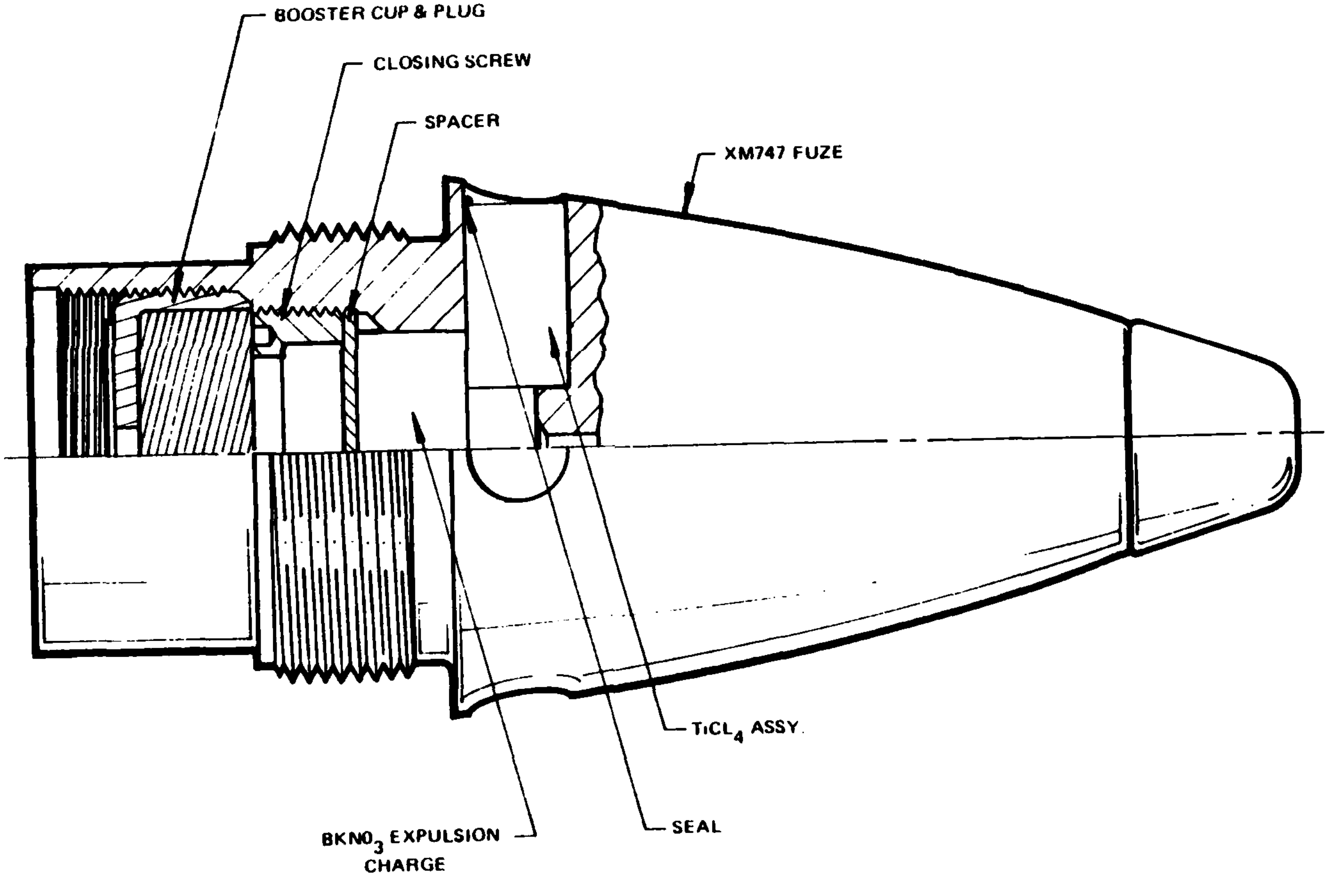
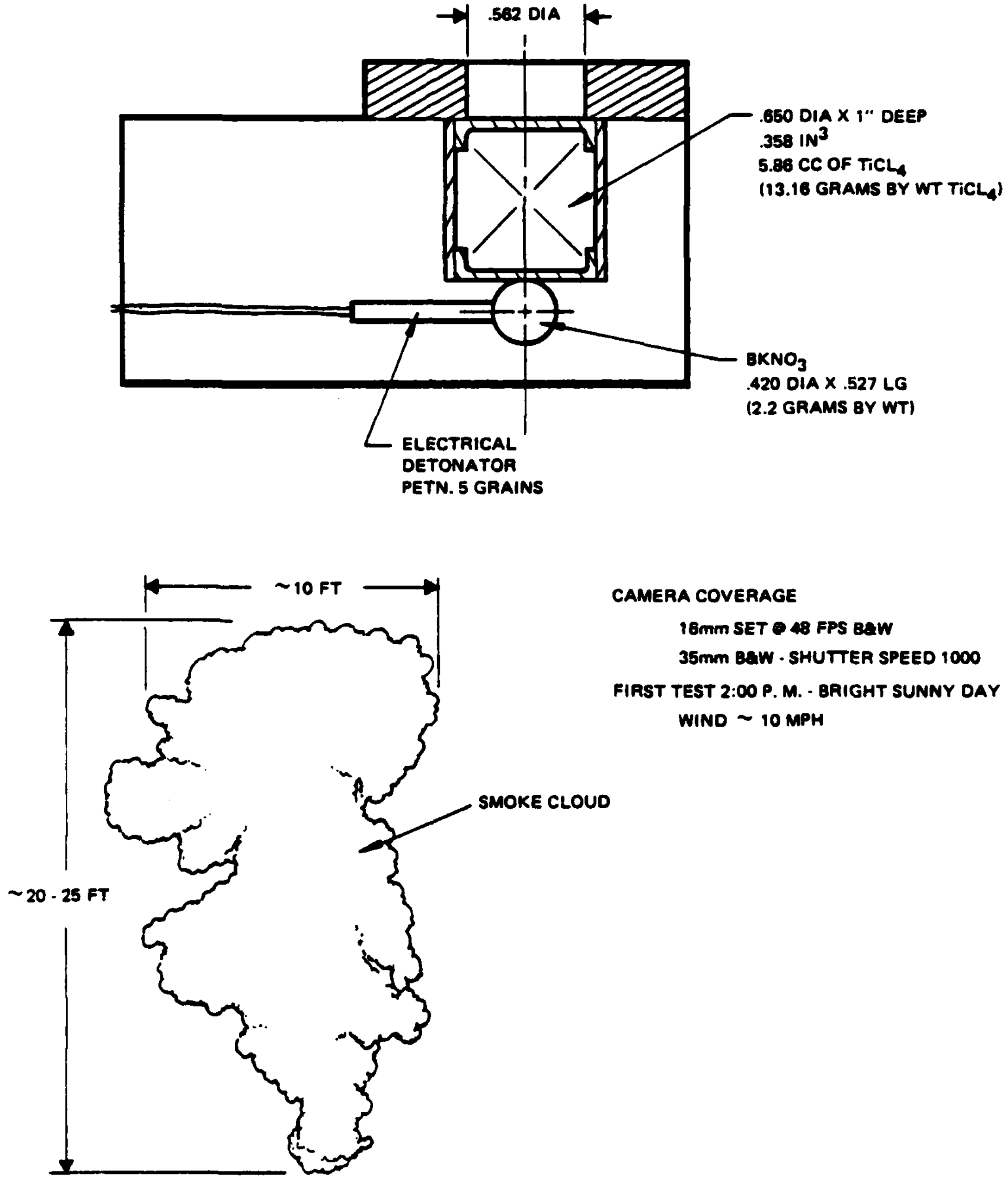


FIGURE 20
XM747 MBA $TiCL_4$ CONFIGURATION



CAMERA COVERAGE

16mm SET @ 48 FPS B&W

35mm B&W - SHUTTER SPEED 1000

FIRST TEST 2:00 P. M. - BRIGHT SUNNY DAY

WIND ~ 10 MPH

FIGURE 21
$TiCL_4$ TEST SET-UP

MBA

0799-16566

FIGURE 22
PRACTICE FUZE SMOKE CLOUD

FIGURE 23
$TiCL_4$ NIGHT TEST

MBA
0799-16574

TABLE 6

TEXT MATRIX

Legend

MOD D - ARRADCOM
MOD E - ARRADCOM

MOD F - MBA

MOD J - ORI
MOD K - ORI

MOD L - MOD "E"/$TiCl_4$

MOD G - BEI
MOD H - BEI

TESTING - YPG 4/23/79

MOD "D" - 5 each
MOD "E" - 5 each
MOD "F" - 5 each
MOD "G" - 5 each
MOD "H" - 5 each
MOD "J" - 5 each
- single charge

MOD "J" - 5 each
MOD "K" - 5 each
- double charge

1. MOD "E" Double Cups
2. MOD "E"
3. MOD "J" Double Cups
4. MOD "J" Triple Cups
5. MOD "K" Double Cups
6. MOD "K" Triple Cups

1. MOD "C" Triple Cups
2. MOD "D" Double Cups
3. MOD "E" Double Cups
4. MOD "C" Triple Cups
5. MOD "J" Double Cups
6. MOD "J" Triple Cups
7. MOD "L" Triple Cups
8. MOD "K" Double Cups
9. MOD "K" Triple Cups
10. MOD "C" Triple Cups
11. MOD "C" Triple Cups

NOTE: MOD "C" $TiCl_4$ with triple MOD "E" charge

TABLE 6 (Continued)

TESTING - YPG 4/24/79

1. MOD "K" Double Cups
2. MOD "K" Double Cups
3. MOD "K" Double Cups
4. MOD "K" Double Cups
5. MOD "K" Double Cups

1. MOD "D" Double Cups
2. MOD "E" Double Cups
3. MOD "J" Double Cups
4. MOD "J" Triple Cups
5. MOD "K" Double Cups
6. MOD "K" Triple Cups

1. MOD "D" Double Cups
2. MOD "E" Double Cups
3. MOD "J" Double Cups
4. MOD "J" Triple Cups
5. MOD "K" Double Cups
6. MOD "K" Triple Cups

1. MOD "D" Double Cups
2. MOD "E" Double Cups
3. MOD "J" Double Cups
4. MOD "J" Triple Cups
5. MOD "K" Double Cups
6. MOD "K" Triple Cups

In addition to the ballistic test, static tests were conducted on the XM747 fuze assembled to the M107 projectile and loaded with a triple charge of approximately 50 grams of MOD "E". The assemblies were tested at AMB -40°F and +140°F. The tests revealed that a minimum of six holes (smoke ports) would be required in the fuze body and two spacers in the booster cup were needed to prevent rupturing of the booster cup. The last day of testing was devoted to checking the aerodynamic effects of the projectile with a premature fuze function. This was accomplished by modifying the M1 delay plunger assembly to achieve an air burst. The air burst fuzes were loaded with double charges of MOD "E" and assembled to 155mm, M107 projectiles. There were no noticable aerodynamic effects caused by early fuze functioning.

A discussion of the range conditions revealed that Ft. Sill would better simulate actual training conditions. It was agreed the further testing of the XM747 fuze with MOD "E" charge would be conducted in June 1979 at Ft. Sill.

6.2 Tests at Fort Sill, Oklahoma

Ballistic testing of 24 - XM747 fuzes loaded with approximately 47 grams of the MOD "E" charge was conducted at Ft. Sill, Oklahoma during June 1979 with the detonator modifications discussed in 5.3.

The day before the scheduled tests, 2.6 inches of rain fell on the impact area (grass land) resulting in an extremely soft, muddy area. As reported by the Ft. Sill personnel, the smoke signal from the test firings into the muddy impact area was smothered by the impact medium and was either minimal or not visible. The balance of the fuzes were fired into a firm hillside yielding reasonably observable signals.

Because of poor results from the Yuma Proving Grounds and Ft. Sill tests, primary reconfiguration as well as minor refinements of the design was agreed on. Four 1/2-inch holes were drilled 7.5 inches from the base of the 155mm XM804 projectile to increase the time from impact smoke port burial (see Figure 25). Also, minor changes were made to the ORI and MOD "E" compositions in an attempt to increase their quickness. The $TiCl_4$ candidate design was modified by increasing the $TiCl_4$ and replacing the $BKNO_3$ expulsion charge with a SW522 charge.

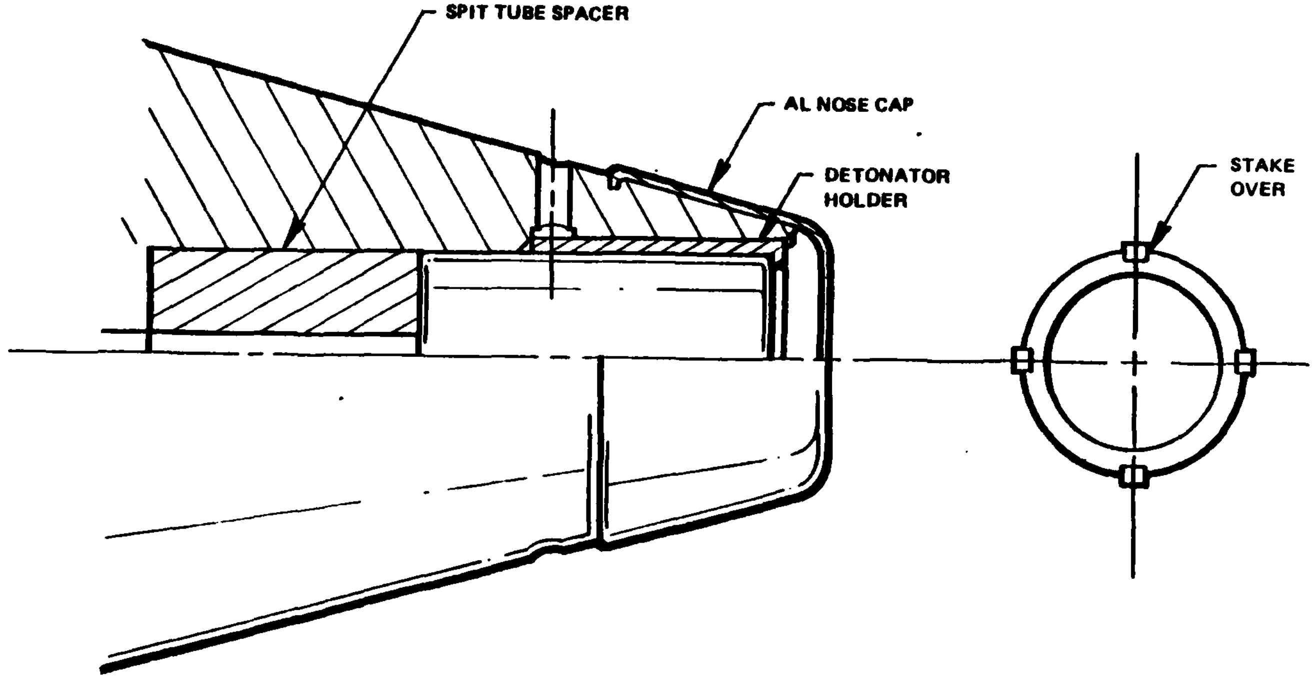


FIGURE 24
FUZE DETONATOR MODIFICATION

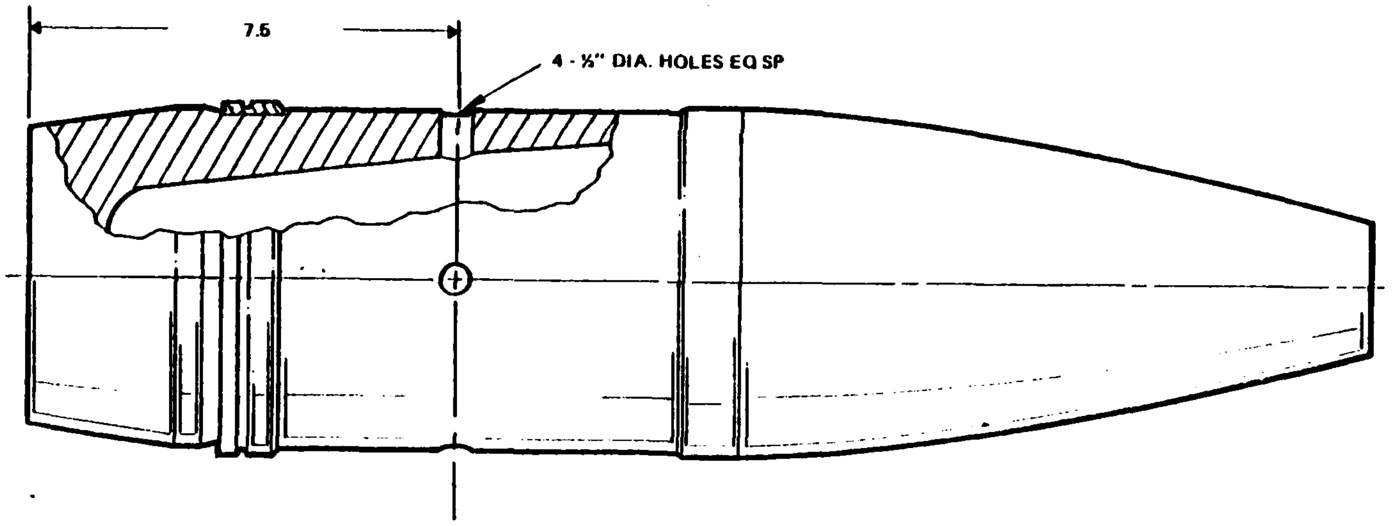


FIGURE 25
M107 (155mm) PROJECTILE

6.3 MBA Static Tests

Static testing of a matrix of the modified designs was conducted at MBA over an eight day period starting on 9 September. The static tests had two objectives. The first was to determine static function times. The second objective was to quantitize smoke cloud size and duration of Ordnance Research Inc's (ORI) Type B and Type C charges, ARRADCOM MOD E and MOD E1 charges and the MBA improved $TiCl_4$ MOD E charge and define the best smoke port configuration. Based on these test results, the best performing ORI and ARRADCOM configuration, along with the $TiCl_4$ configuration, were carried forward for ballistic range testing at Ft. Lewis.

The hardware used in the testing was the M107 (155mm) Projectile and XM747 Fuze. The GFE fuzes were received with six .437 diameter holes. The holes were taped ½-20 and screws were used, as necessary (see Figure 26), to meet the test plan for 0, 3 & 6 holes in the fuze. The projectile had four 0.500 holes drilled radial into the body 7.500 in. from the base (see Figure 25).

MBA blended the ARRADCOM composition MOD E and E1 and loaded the composition into GFE plastic containers (see Figure 27) to ARRADCOM specifications (see Table 7). The ARRADCOM and ORI charges were loaded as shown in Figure 26. Two $TiCl_4$ configurations designated A & B were tested (see Figures 28 and 29). The "A" configuration was rejected as previously discussed, due to a conflict in packaging envelope.

ORI supplied their spotting charge "B" and "C" in sealed containers for the test.

A total of 54 tests of the various spotting charges and smoke port configurations were conducted (see Table 8). The fuzes were assembled to the M107 projectile, placed in a test fixture and fired with an electric squib (see Figure 30).

ARRADCOM and Ft. Sill representatives witnessed the test series and evaluated the spotting charges and hardware configurations.

The instrumentation and equipment used was as follows:

a. Molectron Model PR-100 electric radiometer, amplifier and a CIC Model 5-124 recording oscillograph for energy output of the spotting charge.

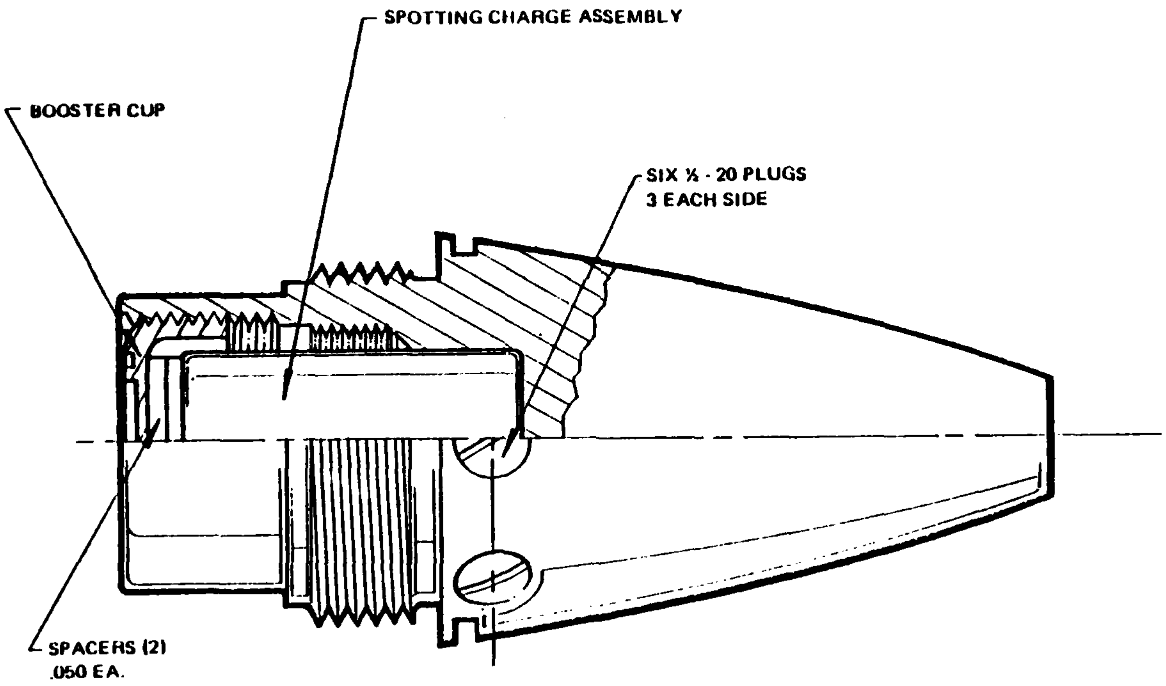
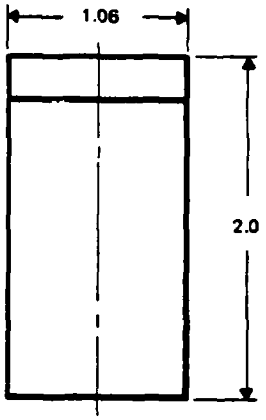
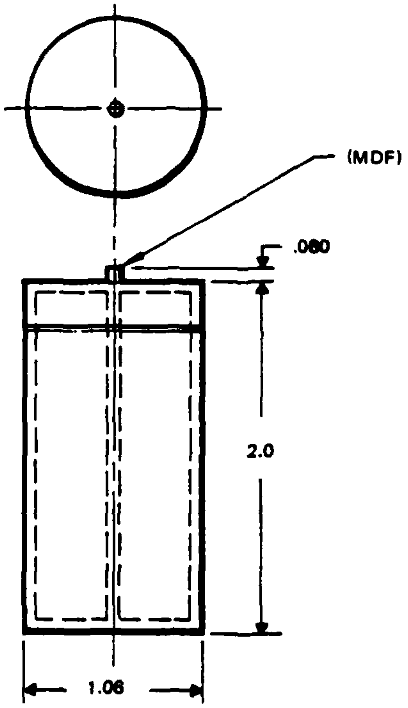


FIGURE 26
XM747 FUZE BODY



MOD E CONTAINER



MOD E1 CONTAINER

FIGURE 27
ARRADCOM CONFIGURATION

MBA
3029-16852

TABLE 7

NOTES:

1. Spec MIL-A-2550 Applies.
2. Load with approximately 48 grams ARRADCOM smoke composition, MOD E, as follows:

INGREDIENT	% BY WT.	PARTICLE SIZE (MICRONS)	SPEC
Zinc Dust	40 ± 1	7 ± 3	JAN-Z-365
Potassium Perchlorate	20 ± 0.5	Per spec	MIL-P-217A, GRA, CL 4
Potassium Nitrate	20 ± 0.5	30 ± 15	MIL-P-156B, CL 2
Aluminum (Atomized)	20 ± 0.5	Per spec	MIL-P-14067A, Type II

3. Advisory: Blend Smoke Composition Ingredients Use Globe or Ball Mill Equipment.
4. Compact Charge, Spotting by Vibrating or Tamping in Cup, Spotting Charge, 9331828.
5. Secure Cover to Cup with 2 part Epoxy.

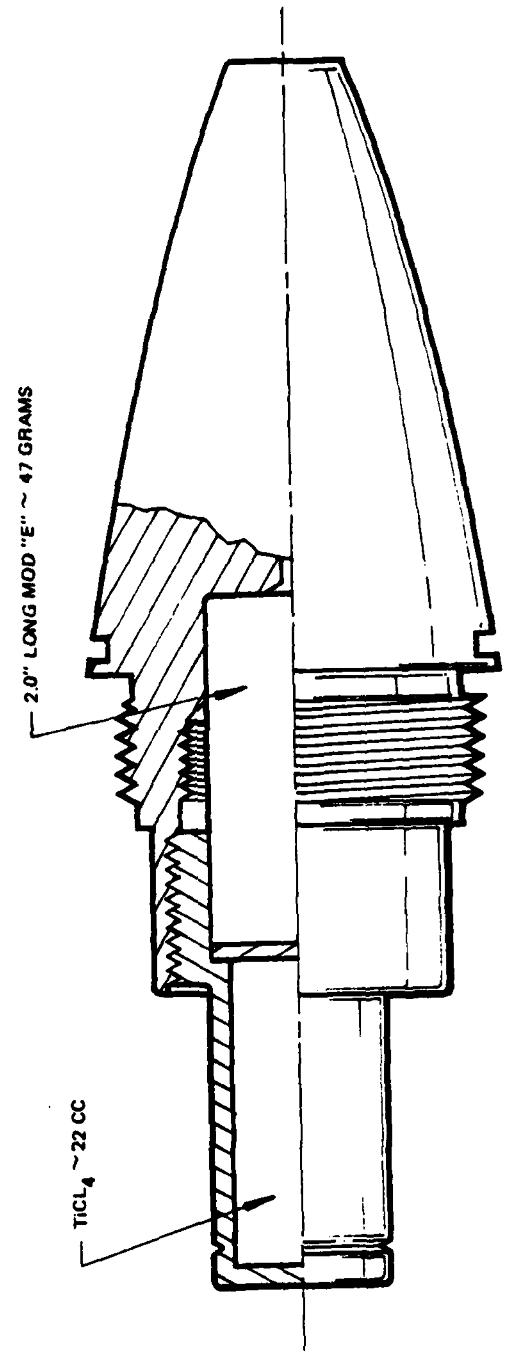


FIGURE 28
TiCL$_4$/MOD "E", CONFIGURATION "A"

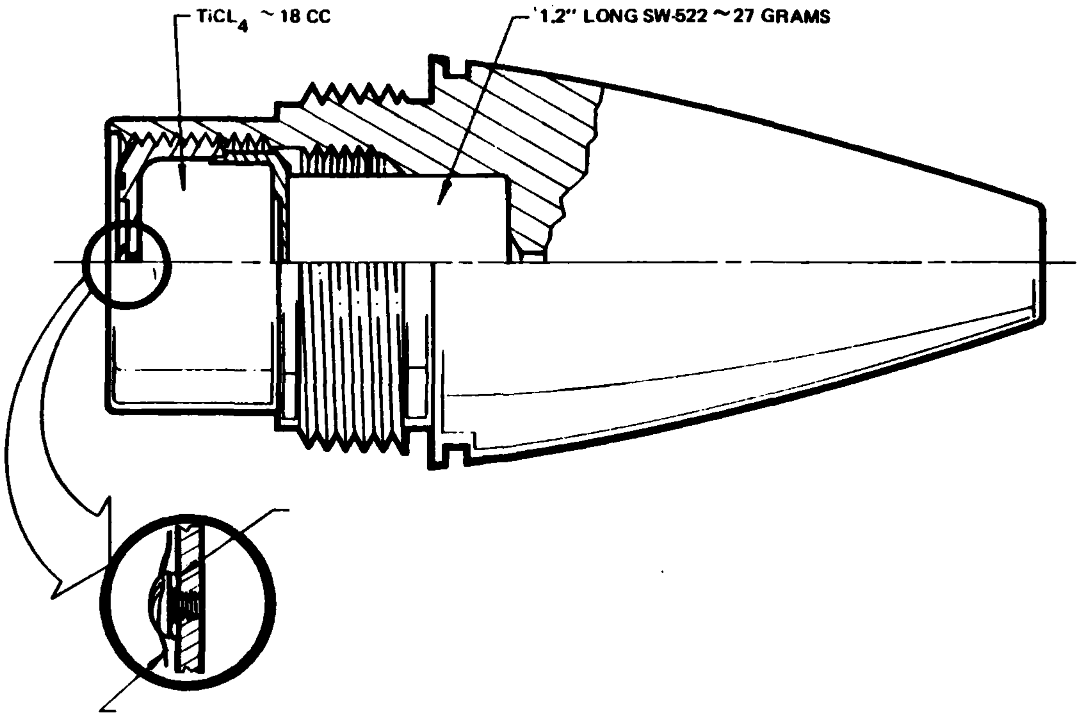


FIGURE 29
TiCL$_4$/MOD "E" CONFIGURATION

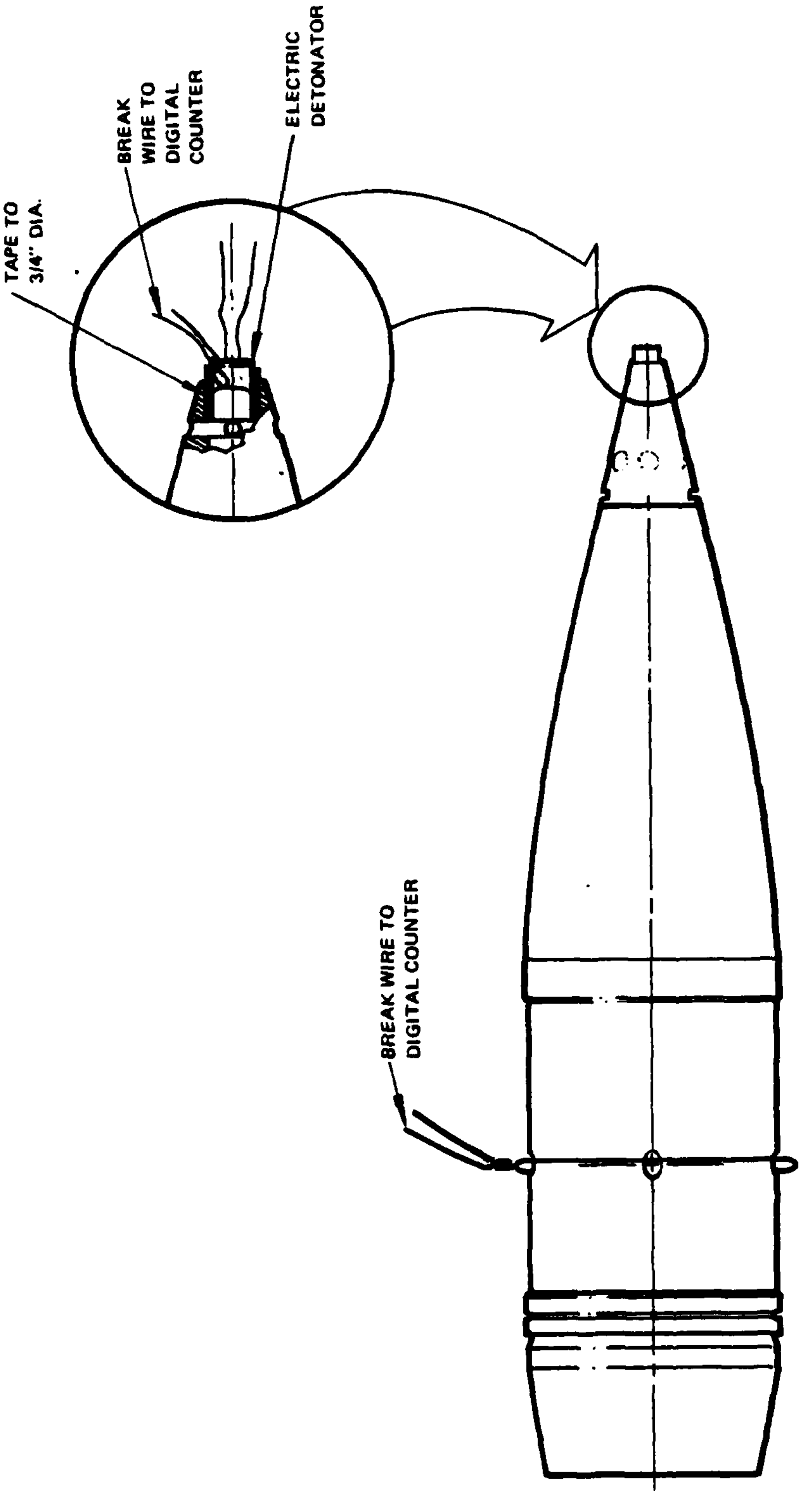


FIGURE 30
TYPICAL VELOCITY SCREEN

b. Hy Cam Hi Speed 16mm camera to record function times.

c. Scoopic 16mm camera for film coverage of the testing.

d. Velocity screens to a digital counter for instantaneous function time read out. See Figure 30 for typical hook-up.

e. Agastat step timer to control function times between cameras and fuze detonation (see Figure 31).

f. Walk-in oven for temperature conditioning of fuzes to -30°F and +130°F for 12 hours (see Figure 32).

The first eleven tests were devoted primarily to selecting the best ARRADCOM and ORI spotting charge configuration.

The fuzes were assembled, as shown in Figure 26, except the six holes were not plugged. Based on previous tests, two 0.050 steel spacers were placed between the booster cup and the spotting charge to prevent rupturing the booster cup base. This was done to insure expelling the total charge out of the fuze ports.

Based on visual observations, review of the 16mm film and examination of function time data, see Table 8, ARRADCOM's MOD "E" was selected over the MOD "E1" because the mild detonating fuze (MDF) in the MOD "E1" did not improve function time. ORI "C" was selected primarily on the basis of more smoke than ORI "B" composition.

A series of tests were conducted to verify the distribution of the spotting charge output between the fuze and projectile ports (see Table 8). It was also necessary during this test series to determine the need, if any, for a 0.050 steel spacer to slightly delay the rupturing of the booster cup and distribute the spotting charge between the fuze and projectile ports. During tests 12, 13, 15 & 17, (see Table 8) the booster cup did not rupture, as planned. Based on these results, it was concluded that the 0.050 spacer be removed for all future tests.

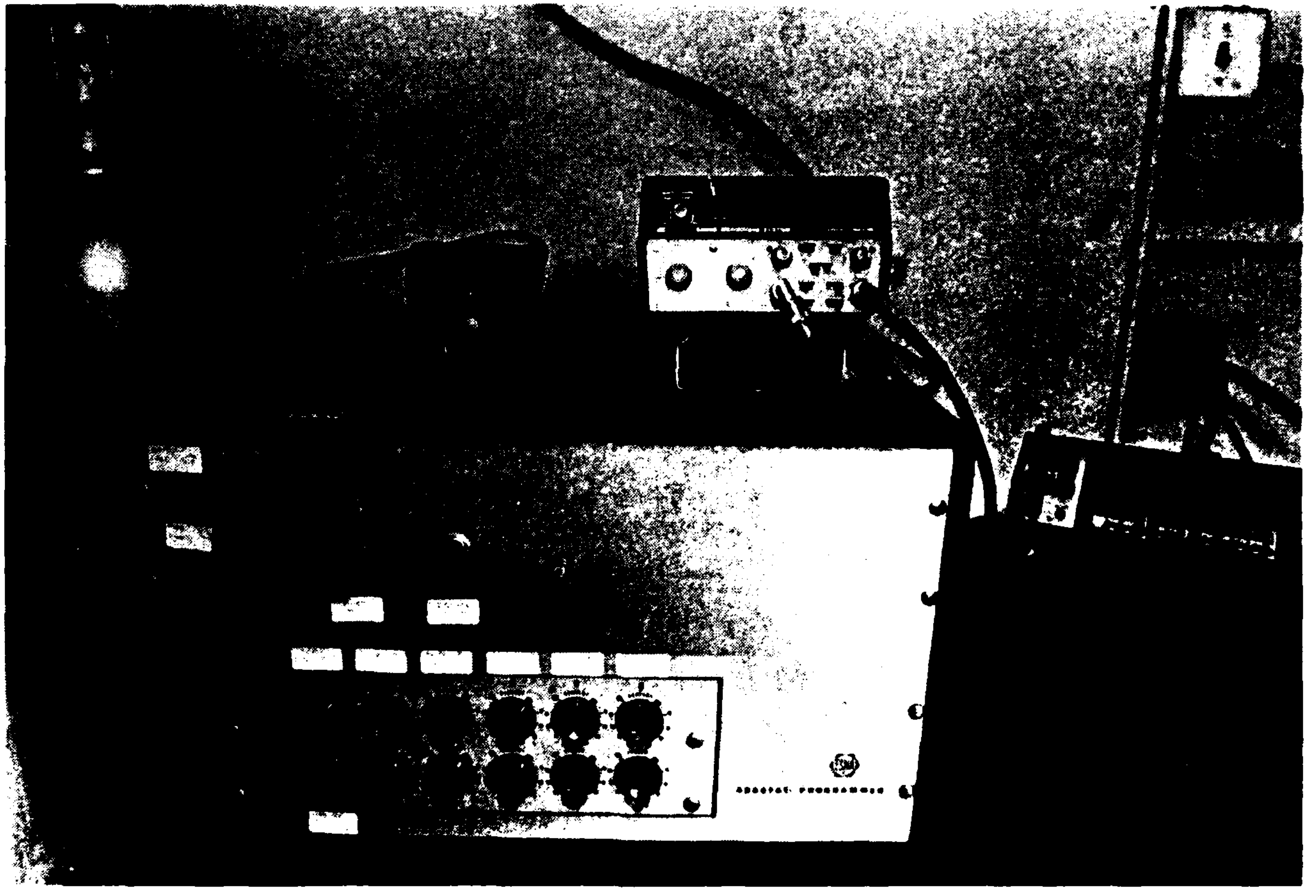


FIGURE 31.
TEST CONTROL MODULE

FIGURE 32
WALK IN OVEN

MBA
3139-16872

TABLE 8

Page 1 of 2

STATIC TESTING PRACTICE FUZE SM747

DATE	DESCRIPTION	TEST No.	SR No.	FUZE TEMP °F	SPOTTING CHARGE	CHARGE VOL. CC/wtGM	TIME MS FUZE BW	TIME MS FUZE FILM	TIME MS PROJ BW	TIME MS PROJ FILM	REMARKS
6-11	6 Hole Fuze - 0 Holes Proj.	1	020	AMB	MOD "E"	44.11	.138	-	-	-	
6-11	6 Hole Fuze - 0 Holes Proj.	2	021	AMB	MOD "E1"	46.95	.195	-	-	-	*Fuze did not function
6-11	6 Hole Fuze - 0 Holes Proj.	3	024	AMB	MOD "E1"	46.3	.173	-	-	-	
6-11	6 Hole Fuze - 0 Holes Proj.	4	022	AMB	ORI "C"	-	.180	-	-	-	
6-11	6 Hole Fuze - 0 Holes Proj.	5	023	AMB	ORI "B"	-	.706	-	-	-	
6-11	0 Hole Fuze - 4 Hole Proj.	6	025	AMB	TICL4/ MOD"E1"	22/46.6	-	-	2.69	-	
9-12	6 Hole Fuze - 0 Hole Proj.	7	026	AMB	MOD "E"	46.6	.188	-	-	-	Configuration "A" cont.
9-12	6 Hole Fuze - 0 Hole Proj.	8	027	AMB	MOD "E1"	47.15	1.32	-	-	-	
9-12	6 Hole Fuze - 0 Hole Proj.	9	028	AMB	ORI "B"	-	.191	-	-	-	
9-12	6 Hole Fuze - 0 Hole Proj.	10	029	AMB	ORI "C"	-	.191	-	-	-	
9-12	6 Hole Fuze - 0 Hole Proj.	11	030	AMB	MOD "E1"	45.7	.174	-	-	-	
9-12	6 Hole Fuze - 4 Hole Proj.	12	031	AMB	MOD "E"	49.0	-	-			Booster cup did not rupture
9-12	3 Hole Fuze - 4 Hole Proj.	13	033	AMB	MOD "E"	46.85	-	-			Booster cup did not rupture
9-12	0 Hole Fuze - 4 Hole Proj.	14	035	AMB	MOD "E"	46.9	-	-			*Fuze did not function
9-12	6 Hole Fuze - 4 Hole Proj.	15	032	AMB	MOD "E"	46.5	-	-			Booster cup did not rupture
9-12	0 Hole Fuze - 4 Hole Proj.	16	043	AMB	TICL4/ MOD"E"	22/47.45	-	-			*Fuze did not function Configuration "A" container
9-13	3 Hole Fuze - 4 Hole Proj.	17	039	AMB	ORI"C"	-	-	.143			Booster cup did not rupture
9-13	0 Hole Fuze - 4 Hole Proj.	18	041	AMB	ORI"C"	-	-	-	-	11.2	
9-13	0 Hole Fuze - 4 Hole Proj.	19	042	AMB	ORI"C"	-	-	-	-	5.07	
9-13	3 Hole Fuze - 4 Hole Proj.	20	034	AMB	MOD "E"	47.55	-	.250	1.678	2.40	
9-13	0 Hole Fuze - 4 Hole Proj.	21	036	AMB	MOD "E"	46.85	-	-	2.160	2.43	
9-13	0 Hole Fuze - 4 Hole Proj.	22	044	AMB	TICL4/ MOD"E"	22/47.5	-	-	2.371	-	Fuze failed at ports Configuration "A"
9-13	0 Hole Fuze - 4 Hole Proj.	23	046	AMB	MOD "E"	46.6	-	-	2.691	-	Fuze failed at ports
9-13	0 Hole Fuze - 4 Hole Proj.	24	045	AMB	TICL4/ MOD"E"	22/47.5	-	-	-	1.84	Configuration "A" container
9-17	0 Hole Fuze - 4 Hole Proj.	25	061	-50°F	ORI "C"	-	-	-	8.591	9.04	
9-17	0 Hole Fuze - 4 Hole Proj.	26	063	-50°F	ORI "C"	-	-	-	6.036	6.57	
9-17	0 Hole Fuze - 4 Hole Proj.	27	047	-50°F	MOD "E"	45.75	-	-	2.495	2.79	*Interrupt not in proper position

TABLE 8 (contd.)

Page 2 of 2

STATIC TESTING PRACTICE FUZE SM747

DATE	DESCRIPTION	TEST No.	SR No.	FUZE TEMP °F	SPOTTING CHARGE	CHARGE VOL CC/$_{wtGM}$	TIME MS FUZE BW	TIME MS FUZE FILM	TIME MS PROJ BW	TIME MS PROJ FILM	REMARKS
9-18	0 Hole Fuze - 4 Hole Proj.	28	059	-30°F	ORI"C"	-			6.00	9.57	
9-18	0 Hole Fuze - 4 Hole Proj.	29	062	-30°F	ORI"C"	-			-	7.95	
9-18	0 Hole Fuze - 4 Hole Proj.	30	060	-30°F	ORI"C"	-			7.747	8.09	
9-18	0 Hole Fuze - 4 Hole Proj.	31	053	-30°F	MOD"E"	47.05			2.496	2.67	
9-18	0 Hole Fuze - 4 Hole Proj.	32	052	-30°F	MOD"E"	46.25			1.620	1.79	
9-18	0 Hole Fuze - 4 Hole Proj.	33	051	-30°F	MOD"E"	48.45			2.232	2.34	
9-18	0 Hole Fuze - 4 Hole Proj.	34	050	-30°F	MOD"E"	47.65			2.065	2.31	
9-18	0 Hole Fuze - 4 Hole Proj.	35	058	-30°F	TICL4/ MOD"E"	22/45.15			2.853	3.21	Configuration "A" container
9-18	0 Hole Fuze - 4 Hole Proj.	36	057	-30°F	TICL4/ MOD"E"	22/45.9			-	4.07	Configuration "A" container
9-18	0 Hole Fuze - 4 Hole Proj.	37	055	-30°F	TICL4/ MOD"E"	22/47.5			-	2.55	Configuration "A" container
9-20	0 Hole Fuze - 4 Hole Proj.	38	076	+140°F	ORI"C"	-			-	-	
9-20	0 Hole Fuze - 4 Hole Proj.	39	078	+140°F	ORI"C"	-			5.908	6.10	
9-20	0 Hole Fuze - 4 Hole Proj.	40	075	+140°F	ORI"C"	-			5.061	5.29	
9-20	0 Hole Fuze - 4 Hole Proj.	41	074	+140°F	ORI"C"	-			5.520	5.94	
9-20	0 Hole Fuze - 4 Hole Proj.	42	077	+140°F	ORI"C"	-			6.661	7.06	
9-21	0 Hole Fuze - 4 Hole Proj.	43	066	+140°F	MOD"E"	48.75			1.223	1.41	
9-21	0 Hole Fuze - 4 Hole Proj.	44	068	+140°F	MOD"E"	45.75			1.892	2.15	
9-21	0 Hole Fuze - 4 Hole Proj.	45	067	+140°F	MOD"E"	46.05			2.922	3.80	
9-21	0 Hole Fuze - 4 Hole Proj.	46	070	+140°F	MOD"E"	49.55			2.180	2.30	
9-21	0 Hole Fuze - 4 Hole Proj.	47	069	+140°F	MOD"E"	46.95			2.746	2.93	
9-28	0 Hole Fuze - 4 Hole Proj.	48	079	AMB	ORI"C"	-				5.59	
9-28	0 Hole Fuze - 4 Hole Proj.	49	080	AMB	ORI"C"	-				6.28	
9-28	0 Hole Fuze - 4 Hole Proj.	50	064	AMB	MOD"E"	47.10				1.64	
9-28	0 Hole Fuze - 4 Hole Proj.	51	065	AMB	MOD"E"	47.05				1.81	
9-28	0 Hole Fuze - 4 Hole Proj.	52	086	AMB	TICL4/ MOD"E"	18/27.86				2.40	Configuration "B" container
9-28	0 Hole Fuze - 4 Hole Proj.	53	087	AMB	TICL4/ MOD"E"	18/26.95				2.62	Configuration "B" container
9-28	0 Hole Fuze - 4 Hole Proj.	54	088	AMB	TICL4/ MOD"E"	18/27.05				3.22	Configuration "B" container

NOTE: ORI"C" & MOD"E" ALL DISPLAYED GOOD SMOKE AND FLASH.
TICL4/MOD"E" EXCELLENT SMOKE FOR LONGER DURATION. GOOD FLASH.

In Tests No. 18 through 24 with the six fuze ports blocked off, five of the cups ruptured (see Figure 33) and two of the fuze bodies (Tests 22 and 24) had tensile failures in the area of smoke port (see Figure 34). The failure was attributed to the modification of the fuze (the addition of the six smoke ports) which removed about 70% of the material in the area of the failure.

The decision was made to remove all the smoke ports from the fuze body partially because of the structural failures but principally as a result of reviewing the high speed films of the tests. These films showed the ports contributed little, if anything, to the onset time or size of the smoke cloud.

In comparing ORI "C" and MOD "E" cloud size and duration, no major difference could be seen; however, the flash seemed to be more intense coming from the ORI "C" charge. The MBA $TiCl_4$/MOD "E" cloud, when compared to ORI "C" and MOD "E", was much more intense and its duration considerably longer, in the order of 15-20 sec. compared to about 5-10 sec. The film clips in Figure 35, A, B & C, show the typical spotting charge of the MOD "E", ORI "C" and MBA $TiCl_4$ exiting from the rear of the projectile shortly after fuze function (MOD "E" at 10.0 MS, ORI "C", 14.0 MS and MBA $TiCl_4$ 11.0 MS).

The temperature testing (-30°F and +130°F) showed no significant change in function time or cloud size as compared to ambient temperature results.

The $TiCl_4$ "B" configuration containers were used in Tests 52, 53 and 54 with no noticable change in cloud size and function time, as compared to the "A" configuration.

As a result of all testing, the smoke port configuration for all candidates for ballistic testing at Ft. Lewis would have four smoke ports located 7.50 inches from the projectile base and canted 45° towards the rear. The XM747 (M739) fuze loaded with the spotting charge candidates would have no smoke ports.

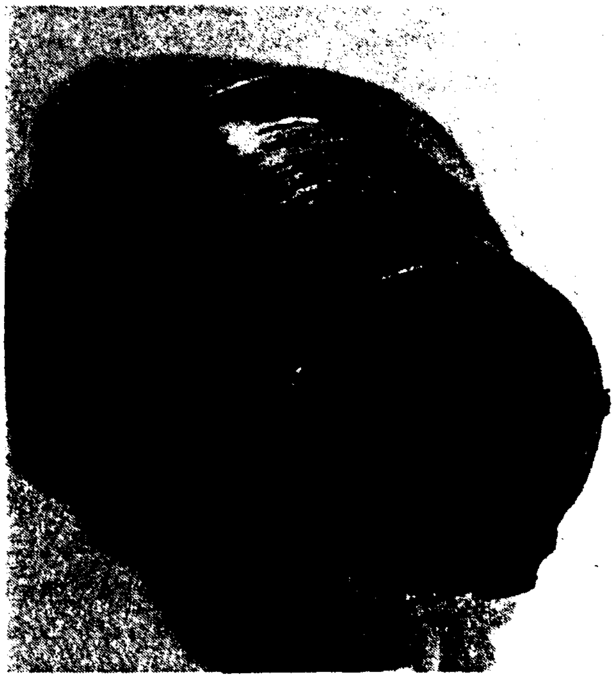


FIGURE 33
TYPICAL BOOSTER & CUP RUPTURE

FIGURE 34
FUZE BODY FAILURE

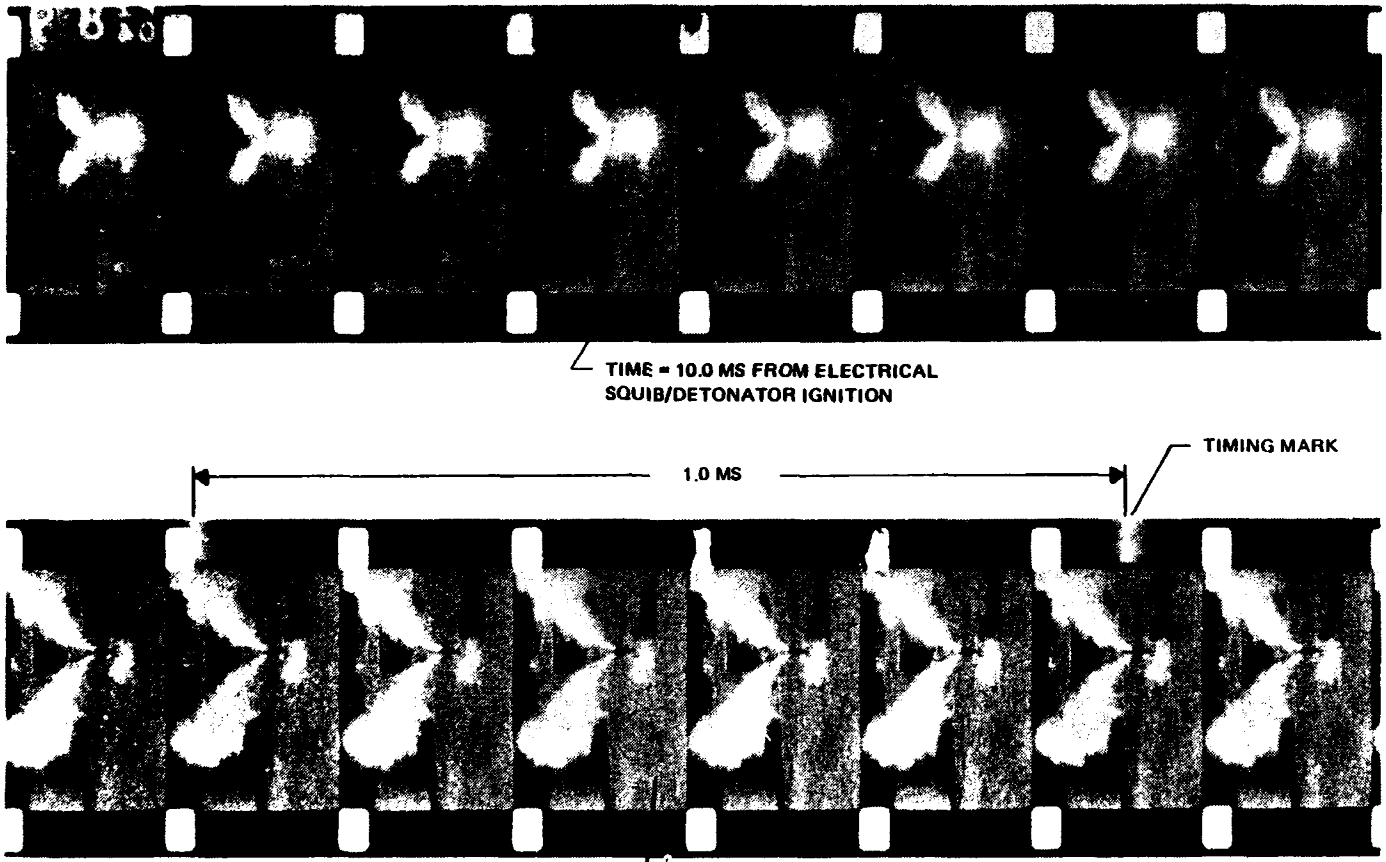


FIGURE 35A
16mm FILM CLIP MOD "E" TEST #51

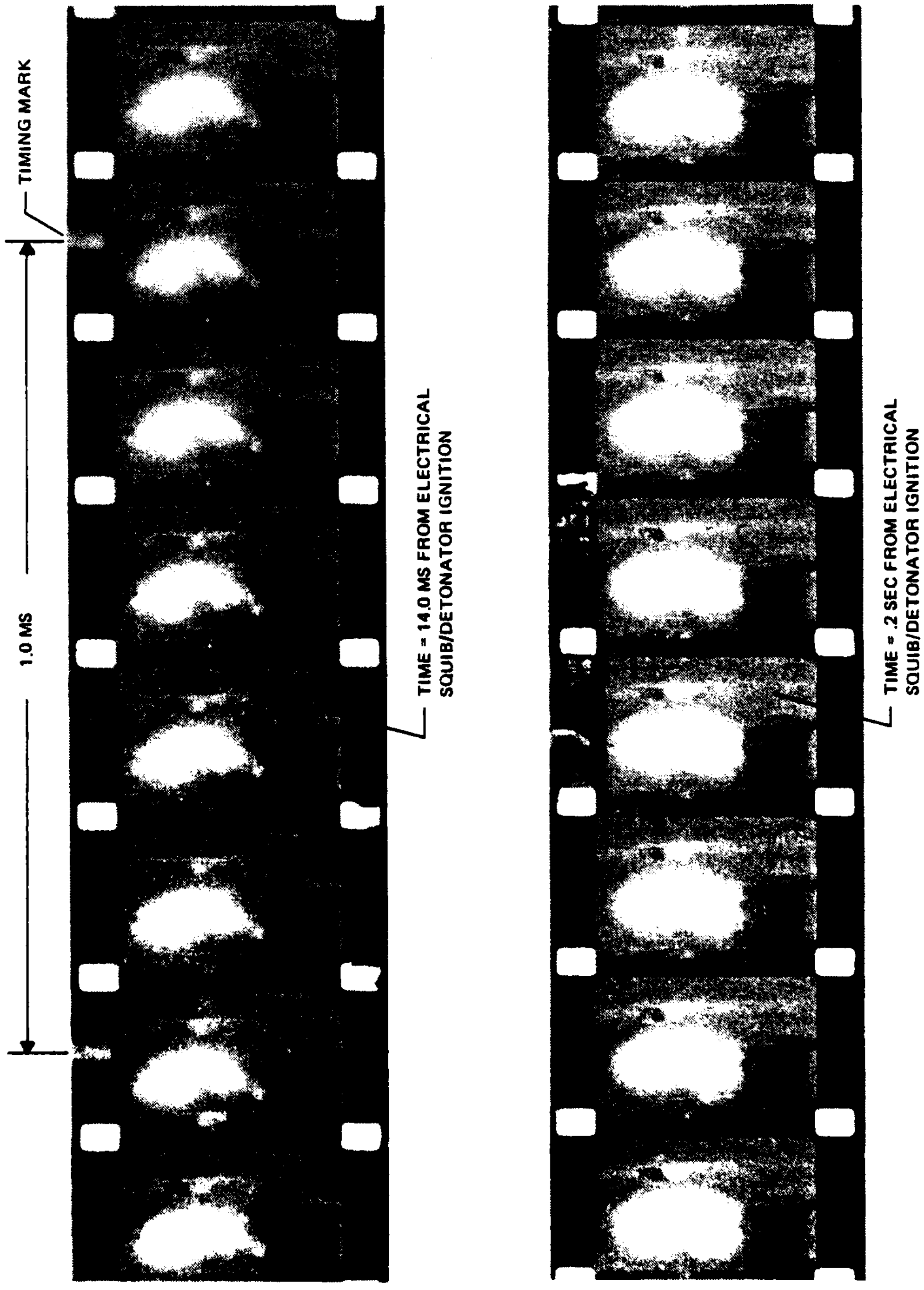
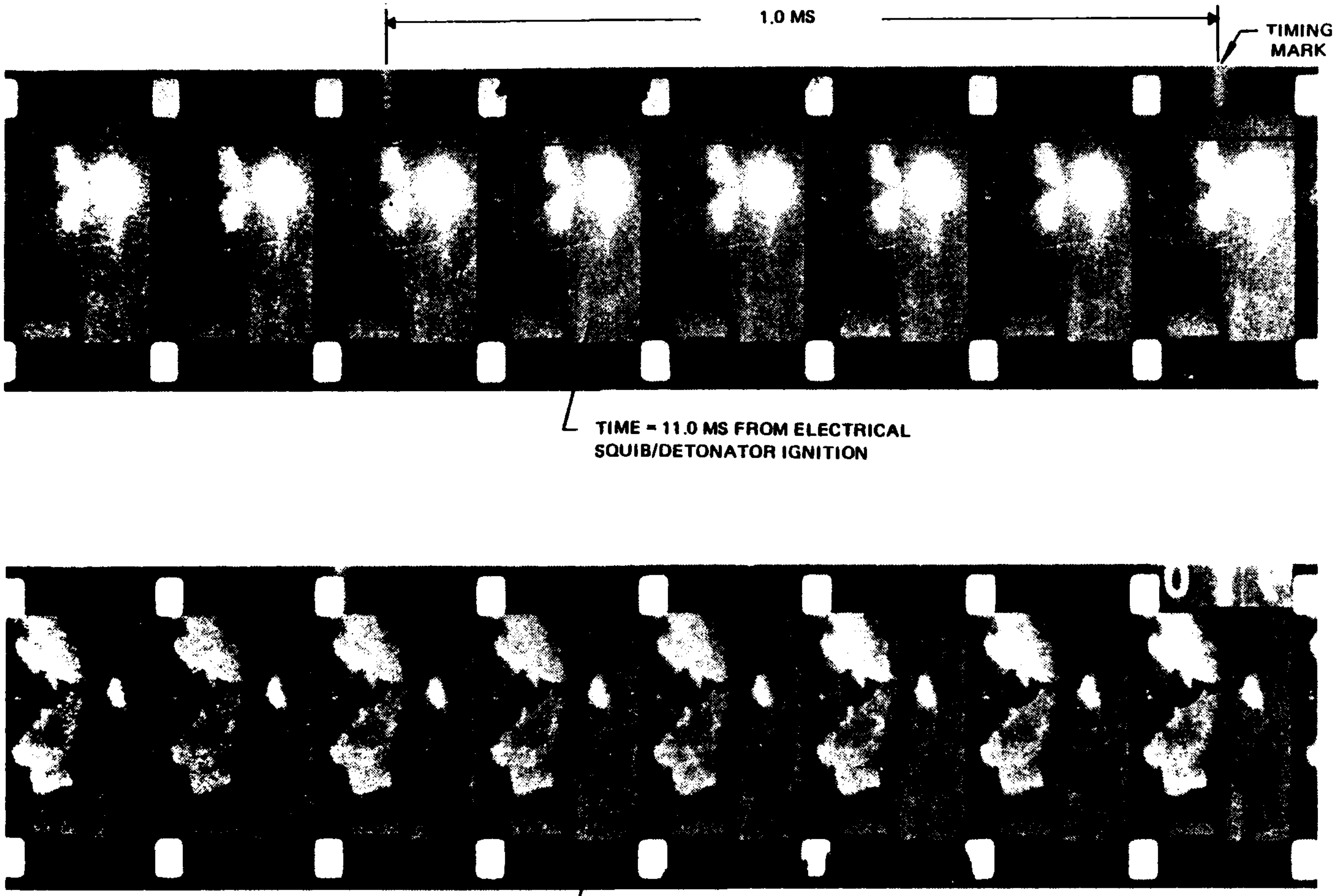


FIGURE 35B
16mm FILM CLIP ORI "C" TEST #48



TIME = 11.0 MS FROM ELECTRICAL SQUIB/DETONATOR IGNITION

TIME = .2 SEC FROM ELECTRICAL SQUIB/DETONATOR IGNITION

FIGURE 35C
16mm FILM CLIP MBA $TiCL_4$ TEST #53

6.3.1 Radiometric Measurements

Radiometric measurements of selected static tests were made in the 1.7-2.8 micron range and the 3-5 micron range. As reviewed above, test equipment included Molectron PR-100 pyroelectric radiometers with correction filters, instrumentation amplifiers with calibration voltage sources, a CEC Model 5-124A recording oscillograph and a Barnes Model 11-200T, 1000°C black body source for calibration. This equipment, shown in Figure 36, together with the measurement procedures, are described in the MBA Radiometric Procedures MB-R-78/32, Rev. 1.

Because of the low total power produced, the radiometers were moved as close as practical to the test fuze. The 7-1/2 degree field of view permitted measurements at 40 feet.

In its simplest form the radiometer equation is:

$$I = CVR^2$$

where

I = source intensity in $w\ sr^{-1}$

C = radiometer calibration in $w\ sr^{-1}\ v^{-1}\ ft^{-2}$

V = radiometer output voltage

R = source to radiometer distance in feet

The I/R^2 dependence of voltage on intensity is a result of the fact that the radiometer has no imaging optics and thus simply measures irradiance (watts per square meter at the detector).

The radiometer response is a function of the wavelength of the incident radiation. This is because the atmosphere between the source and the radiometer; as well as the window, filter and detector, have wavelength dependent responses.

The equation which describes the radiometer voltage output for an irradiance of the radiometer by a monochromatic source

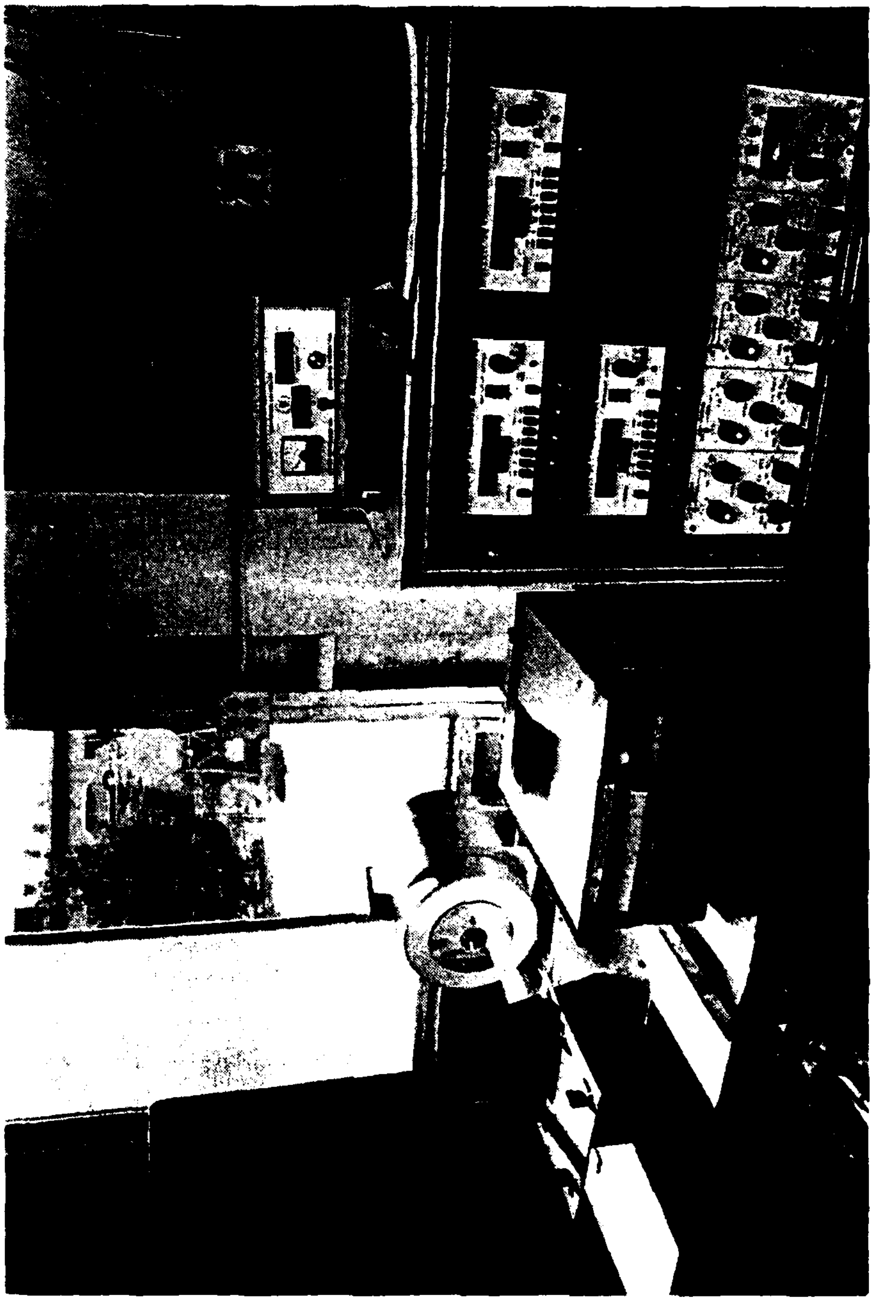


FIGURE 36
RADIOMETER BLACK SOURCE AND CONTROL

of wavelength γ is

$$V(\gamma) = E \cdot sV_d(\gamma) \cdot T_a(\gamma) \cdot T_w(\gamma) \cdot T_f(\gamma)$$

where

E = the irradiance in w m^{-2} in the plane of the detector in the absence of the radiometer or an atmosphere.

$sV_d(\gamma)$ = the spectral detector response in $vm^2\ w^{-1}$ for a given level of irradiance at wavelength γ. The term $V_d(\gamma)$ is a relative response of the system while s is a parameter that reflects the radiometer sensitivity. It may change with time or environment and thus makes periodic calibration necessary.

$T_a(\gamma)$, $T_w(\gamma)$, and $T_f(\gamma)$ = respectively the spectral transmittance of the atmosphere between the source and the radiometer, the radiometer window, and the radiometer filter.

The radiometric measurements were corrected for variations in test conditions by the methods described in the Supplement to MBA Radiometric Procedures, MB-TM-79/02, see Appendix B, dated 27 August 1979. In addition, a correction for attenuation at the 40 foot range was made. The energy in the measurement wavelength band was determined from the area under the curve and by assuming that energy is emitted uniformly from the source in all directions. The total energy of the source was then estimated independently from each wavelength band by dividing the energy in the wavelength band by the fraction of energy expected at that source temperature as determined from the tables given in the referenced procedure.

This assumes black body emission from the sources. The corrected peak intensities, maximum temperature, output energy in each measurement wavelength range, burn duration, burn delay after initiation and the total blackbody energy estimate is given in Table 9. The ratio at the peak intensity in each measurement wavelength range allows an estimate of the maximum temperature (related to grey body temperature and atmospheric conditions). The total energy estimate assumes that the source radiates like a black body in all directions.

The atmospheric corrections and corrections for the source temperature are relatively small and have a minor impact on results. The latter correction was based on extrapolated curves from the previously mentioned procedures on a very sensitive part of the curve. These corrections could have been rerun with the Lowtran computer program for atmospheric attenuation if they had a significant impact on the final result.

The error in the final intensity measurements caused by approximations made in the corrections for atmospheric conditions, source temperature and the different measurement distance (compared to standard procedure) should not exceed 10%. This is the same order of magnitude as the basic measurement error.

6.4 Tests at Fort Lewis, Washington

The ballistic tests were conducted at Ft. Lewis, Washington, on December 18 and 19, 1979.

The objective of the testing was to determine which of the three spotting charge candidates, MOD "E", ORI or MBA, would reliably produce the best visible smoke cloud in a muddy target area.

All spotting charges were loaded into XM747 fuzes (see Figure 37 for the MOD "E" and ORI configurations) and assembled to the four port 155mm, XM804 projectile (see Figure 38).

The testing was conducted in three phases. The first phase was to eliminate either the MOD "E" or ORI spotting charge based on their peformance; the best performance (MOD "E") was carried forward to Phase II testing along with the MBA spotting charge. The Phase II testing yielded

Standard Conditions		Test Conditions
Range	.0229 KM	.0122 KM
Altitude	.1524 KM	.1524 KM
Pressure	1000 MB	~1000 MB
Temperature	21.1°C	~32.2°C
Humidity	40%	~40%
Visibility	100 KM	~100 KM

TABLE 9

SMOKE TESTS RADIOMETRIC MEASUREMENTS CORRECTED FOR RANGE AND ATMOSPHERIC CONDITIONS

TEST	FUZE	INTENSITY 1.7-2.8 m RANGE (Watts/ Steradian)	INTENSITY 3-5 m RANGE (Watts/ Steradian)	TEMP (T) ESTIMATE (°K)	ENERGY 1.7-2.8 m RANGE AT TEMP (T) (Calories)	ENERGY 3-5 m RANGE AT TEMP (T) (Calories)	DURATION OF BURN (Seconds)	DELAY OF BURN AFTER INITIATION (Millisecs.)	TOTAL BLACK BODY ENERGY ESTIMATE (Calories)
#38		636	1599	890	187	494	.225	Not Measured	1332
#39		578	1410	900	98.5	247	.084	17.5	671
#40		1111	2287	950	303	704	.200	11.2	1842
#41		648	1540	905	206	564	.190	15.0	1459
#42		515	1565	850	113	478	.190	18.8	1047
	#048	3418	5754	1020	689	1350	.175	3.0	3529
#11	#030	5830	11855	960	1817	3371	.250	Not Measured	9704
		1806	2705	1080	433	778.5	.200	Not Measured	2078
	#025	2805	4786	1010	881	1587	.225	Not Measured	4364

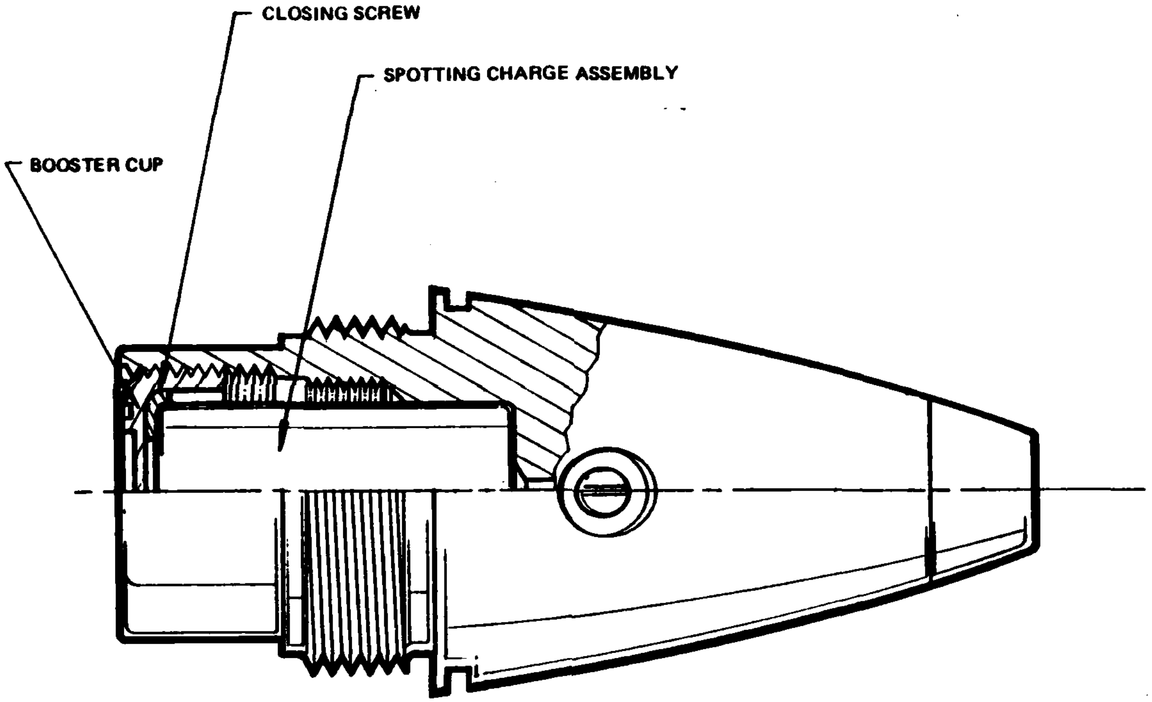


FIGURE 37
MOD "E" AND ORI CONFIGURATION

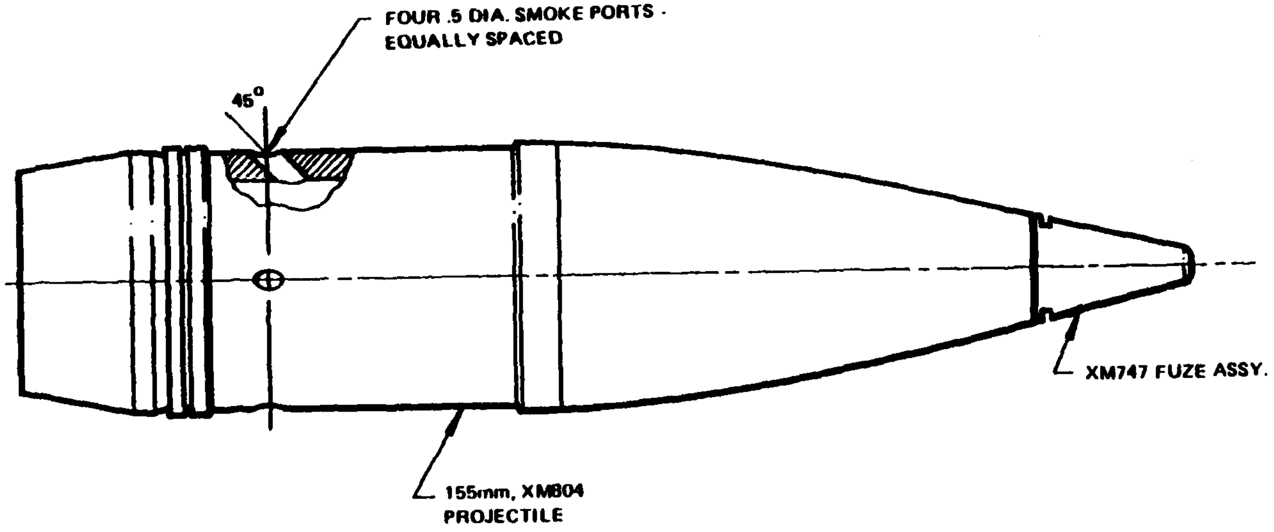


FIGURE 38
PROJECTILE ASSEMBLY

a final candidate for further evaluation in Phase III testing (see Table 10).

To observe and score the spotting charges, observers were stationed at 2000 and 4000 meters for Phase I and 1800 and 2000 meters for Phases II and III testing. The observers were a mix of ARRADCOM, Ft. Sill, Ft. Lewis, Chamberlin, MBA and Yuma Proving Ground personnel (see Appendix C).

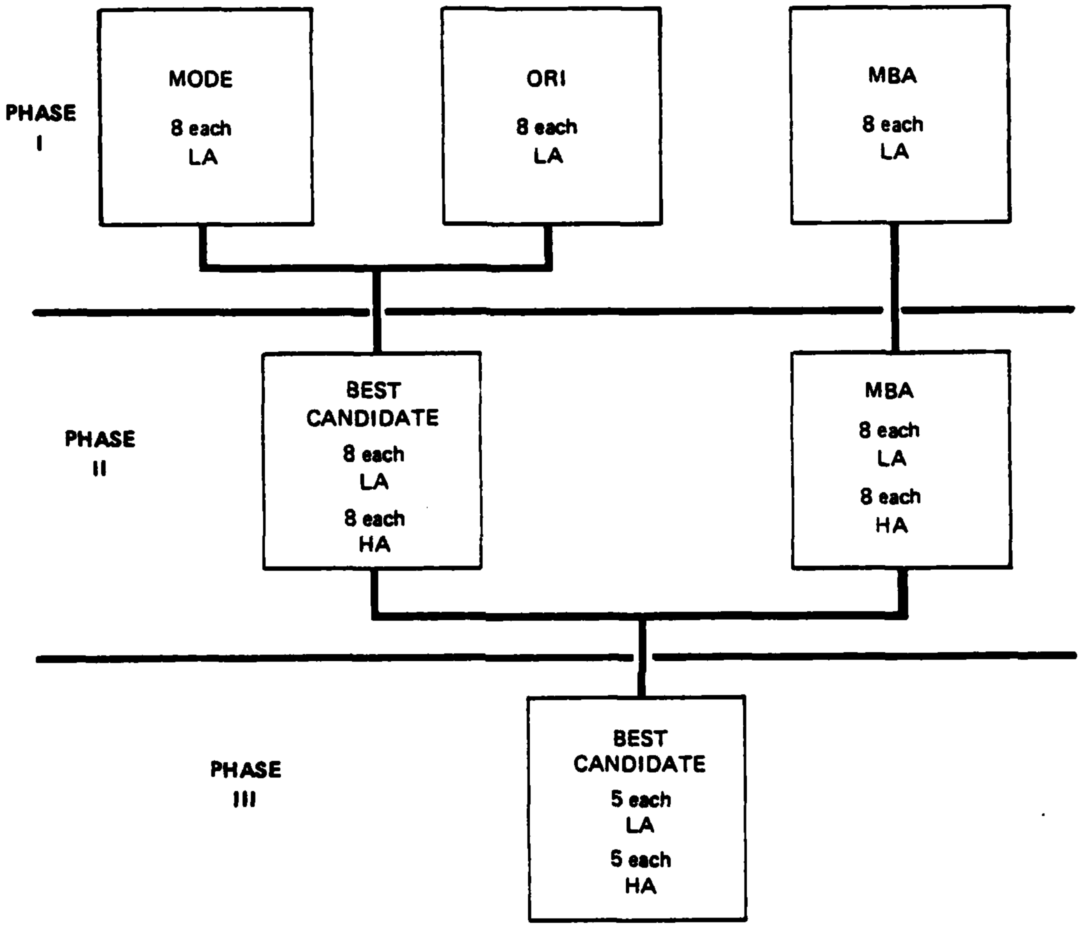
The scoring system for Phase I was complex. Two observers used a number system while the five others used an alphabetical rating system which related as follows: 1 & U = unobserved, 6 & E = excellent. For the balance of the testing, observers used a numbering system 1 through 5 where 1 = unobserved and 5 = excellent. The spotting charges were fired in an alternate order, MOD "E", ORI, MBA.

The tests were recorded on video tape and 16mm camera as follows: Phase 1, 16mm camera and video at 2000 meters and video at 4000 meters. Phases II and III, video at 1800 and 2000 meters and 16mm camera at 1800 meters.

6.4.1 Weather

Rain was intermittent for the two days of testing. The weather conditions listed below were supplied by Ft. Lewis:

Date	Time	Temperature	Humidity	Wind Direction from (True)	Wind Speed
18th.	1100	51°	89%	-	Calm
	1200	52°	89%	-	Calm
	1300	51°	92%	-	Calm
	1400	52°	82%	-	Calm
	1500	51°	86%	120°	4 Knots
19th.	1100	53°	77%	200°	8 Knots
	1200	53°	80%	180°	10 Knots
	1300	53°	83%	200°	10 Knots
	1400	53°	80%	210°	10 Knots
	1500	51°	85%	200°	8 Knots
	1600	50°	89%	190°	4 Knots
	1700	49°	89%	190°	4 Knots



LA – QE: 522 mils

HA – QE: 1054 mils

TABLE 10
TEST MATRIX

The Phase I testing went as planned on December 18, 1979 with eight each of MOD "E", ORI and MBA spotting charges fired at a low QE of 522 mils. There were four observers at 2000 meters and three at 4000 meters.

Based on the scoring of the observers, (MOD "E" 174, MBA 143 and ORI 122, summarized in Appendix C), the ORI spotting charge was dropped from further testing. The smoke clouds for MOD "E" and MBA, when observed, appeared similar in intensity and duration (see Figure 39). The flashes observed were judged poor to none for both configurations.

For the Phase II testing, the observers at 4000 meters were moved to 1800 meters due to poor visibility. There were four observers at 1800 meters, and three observers at 2000 meters. The Phase II and III testing was conducted on December 19th.

In the first part of Phase II testing, eight each MOD "E" and MBA fuzes were fired at a low QE of 522 mils. The MBA spotting charge, with the exception of one round, displayed a smoke cloud which was judged to be good to excellent in both cloud size and persistence. The MOD "E", while also performing better than during Phase I testing, was scored significantly lower than the MBA spotting charge. See Figure 40 for a photographic comparison of the typical cloud size.

In the high QE (1054 mils) portion of Phase II testing, the MOD "E" and MBA spotting charges performed pretty much the same with many unobserved and relatively poor smoke clouds. The poor performance was not totally unexpected. Static testing at MBA in September 1979 showed the function time of the MOD "E" spotting charge to be an average of 2 ms and MBA to be 2.5 ms, from ignition to display of smoke from the projectile smoke ports, while the burial analysis reviewed above suggests that on soft ground at high QE's these times are equivalent to, to slightly longer than, projectile burial time.

Figure 41 presents ARRADCOM's estimate of the worst case, most rapid burial condition for the 155mm projectile in question. This condition exists in deeply saturated light sand soils. The ARRADCOM model predicts coverage of the smoke ports located 19 inches back on the projectile, 1.8 milliseconds after impact.

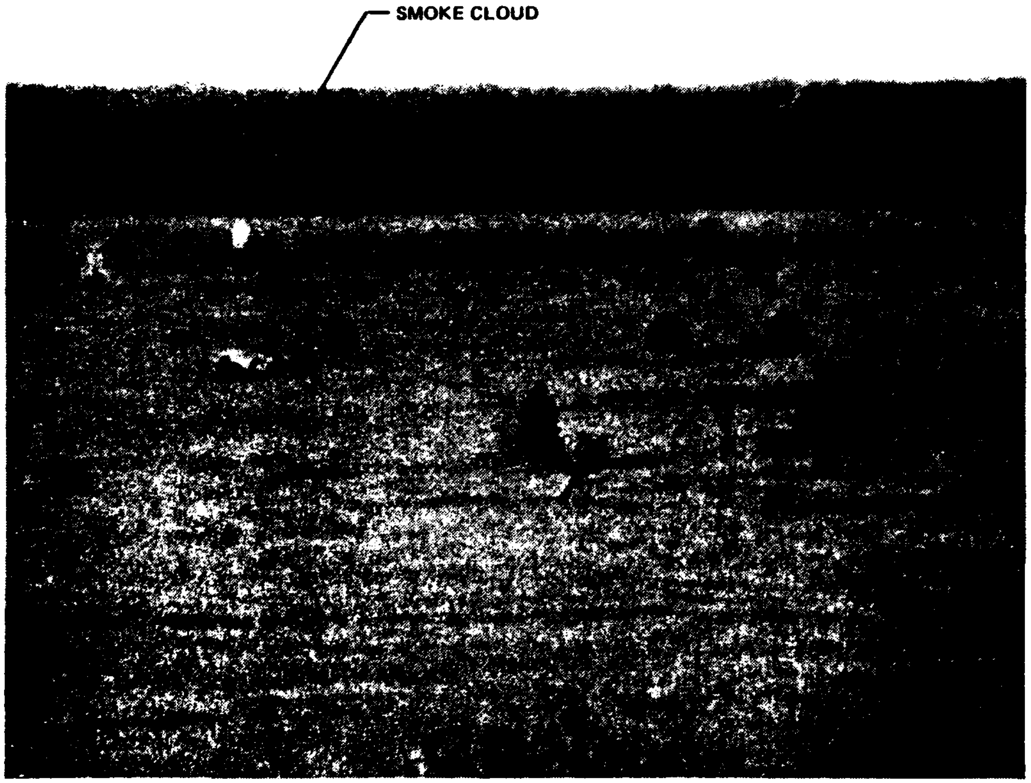
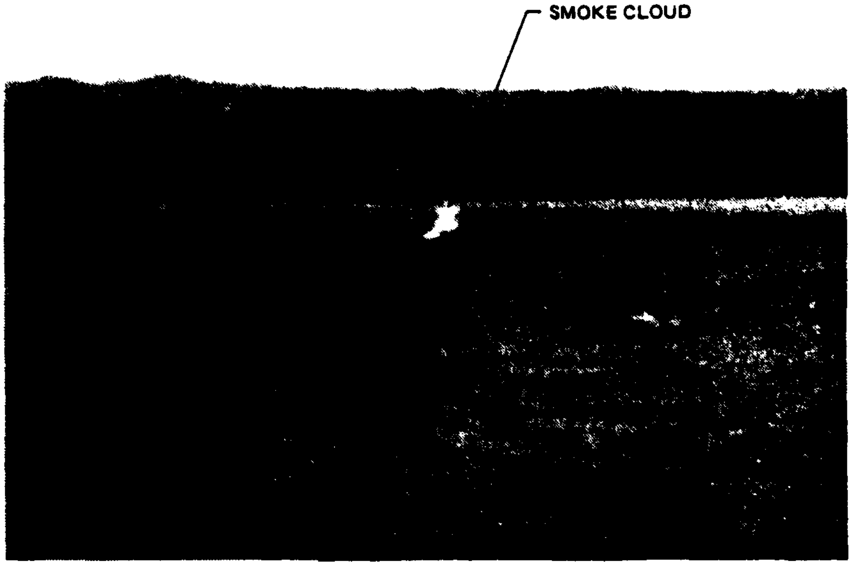
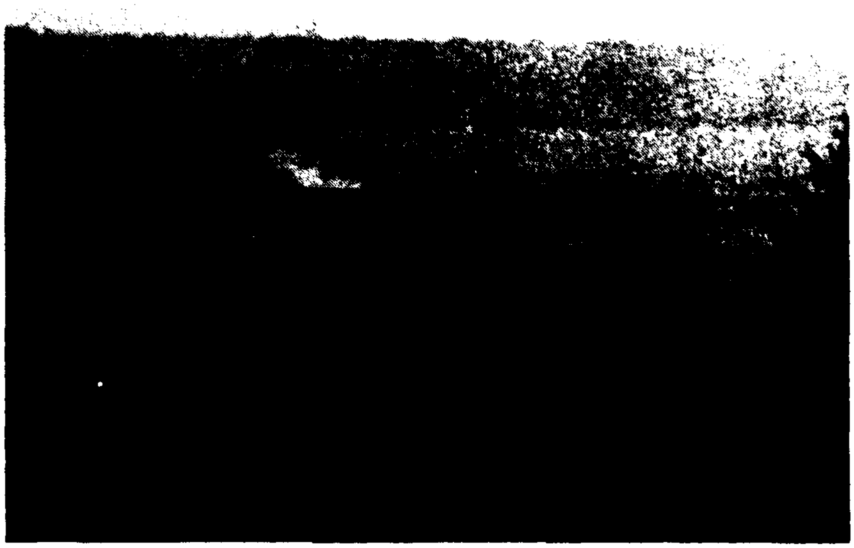


FIGURE 39
PHASE I TESTING
TYPICAL SMOKE CLOUD



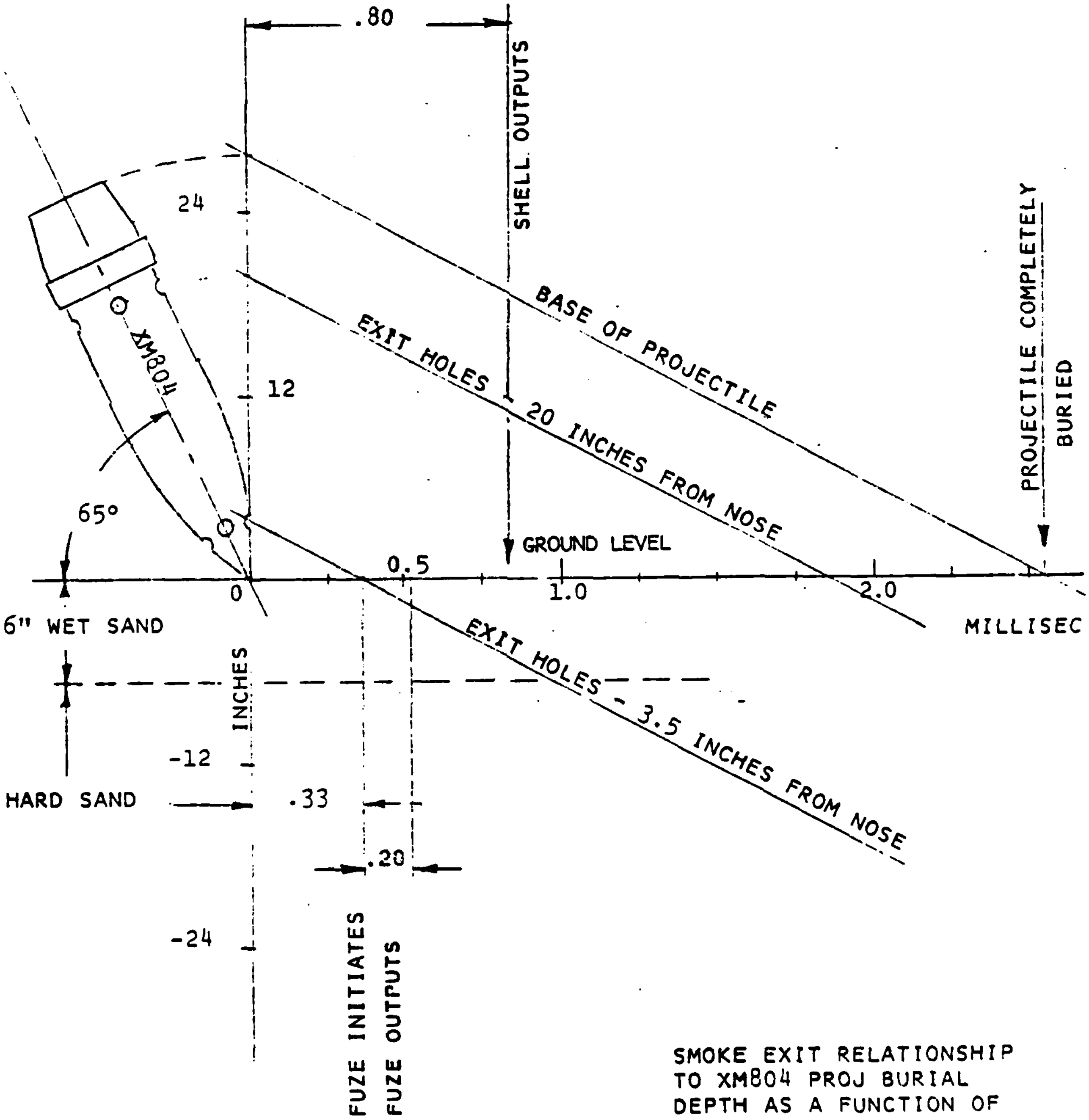
MOD "E"



MBA $TiCl_4$

FIGURE 40
SMOKE CLOUD COMPARISON

MBA
0710-16985



SMOKE EXIT RELATIONSHIP
TO XM804 PROJ BURIAL
DEPTH AS A FUNCTION OF
EXIT HOLE LOCATION

IMP VEL - 900 FT/SEC
IMP ANGLE - 65 DEG
MEDIUM - WET SAND

FIGURE 41

L. POST
NOV. 79

Based on the total scoring of the Phase II testing, the MBA spotting charge was selected for the Phase III testing. Due to the poor performance at the high QE firing, it was decided the Phase III firing would be conducted at a low QE of 522 mils.

The Phase III results were mixed. Three out of the nine firings results in smoke clouds judged good to excellent. The remaining six rounds yielded mixed results reported by the observers, per Appendix B, they ranged from fair to no visible smoke cloud.

It should be noted that rounds 1, 2 & 3 of this test series were assembled to projectiles with 90° ports instead of 45° aft canted ports because of a lack of available hardware in the later configuration.

The smoke clouds produced by the MBA spotting charge, particularly in the low QE Phase II testing, were judged to develop the superior cloud. However, due to the inconsistent performance of both the MOD E and $TiCl_4$ spotting charges, further improvement was needed.

6.4.2 Data Reduction

Figures 45 through 51 show the 90% confidence envelopes for each of the fuze tests with the composite of MOD "E" and $TiCl_4$ fuzes shown in Figures 43 and 44. All data has been normalized by averaging the evaluation with the number of observers, adjusting the evaluating to a common scale, and using zero for a non-visible cloud. The cloud observations are scaled from 0 to 4.

A standard procedure, see Appendix C, was used to determine the statistical quantities for 90% confidence. The curves can be interpreted as follows: The cumulative distributions shows the number of fuzes that will either exceed or be less than a certain value. Using Figure 45 as an example, the intersection of the lower curve with zero, (20), shows the cumulative number of events that would not yield visible results or conversely, 100 less the intersection value which will give visible results. Because the curve is the 90% confidence envelope, this condition is stated

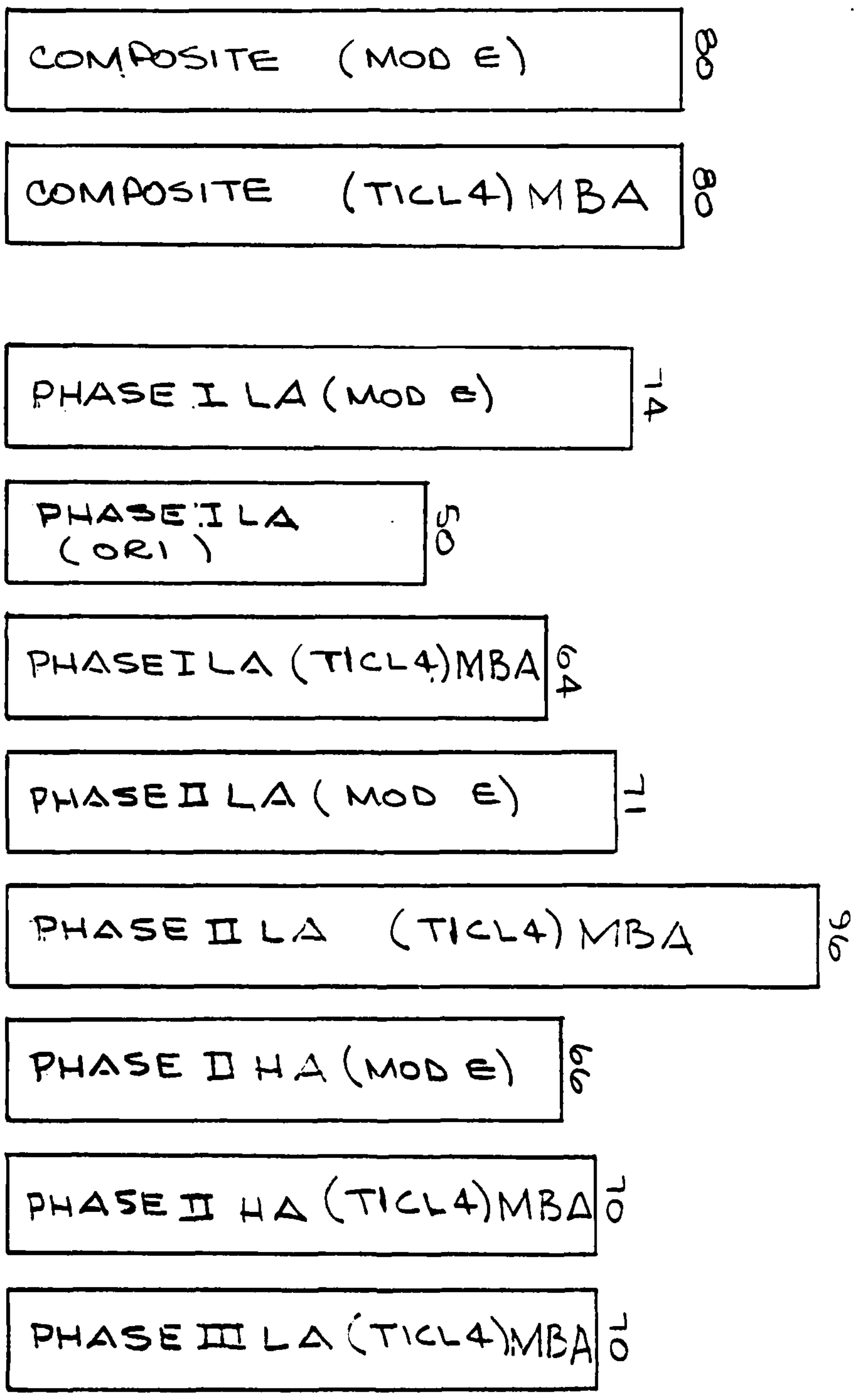


Figure 42 - Comparison of Visible Flares Out of 100 at 90% Confidence

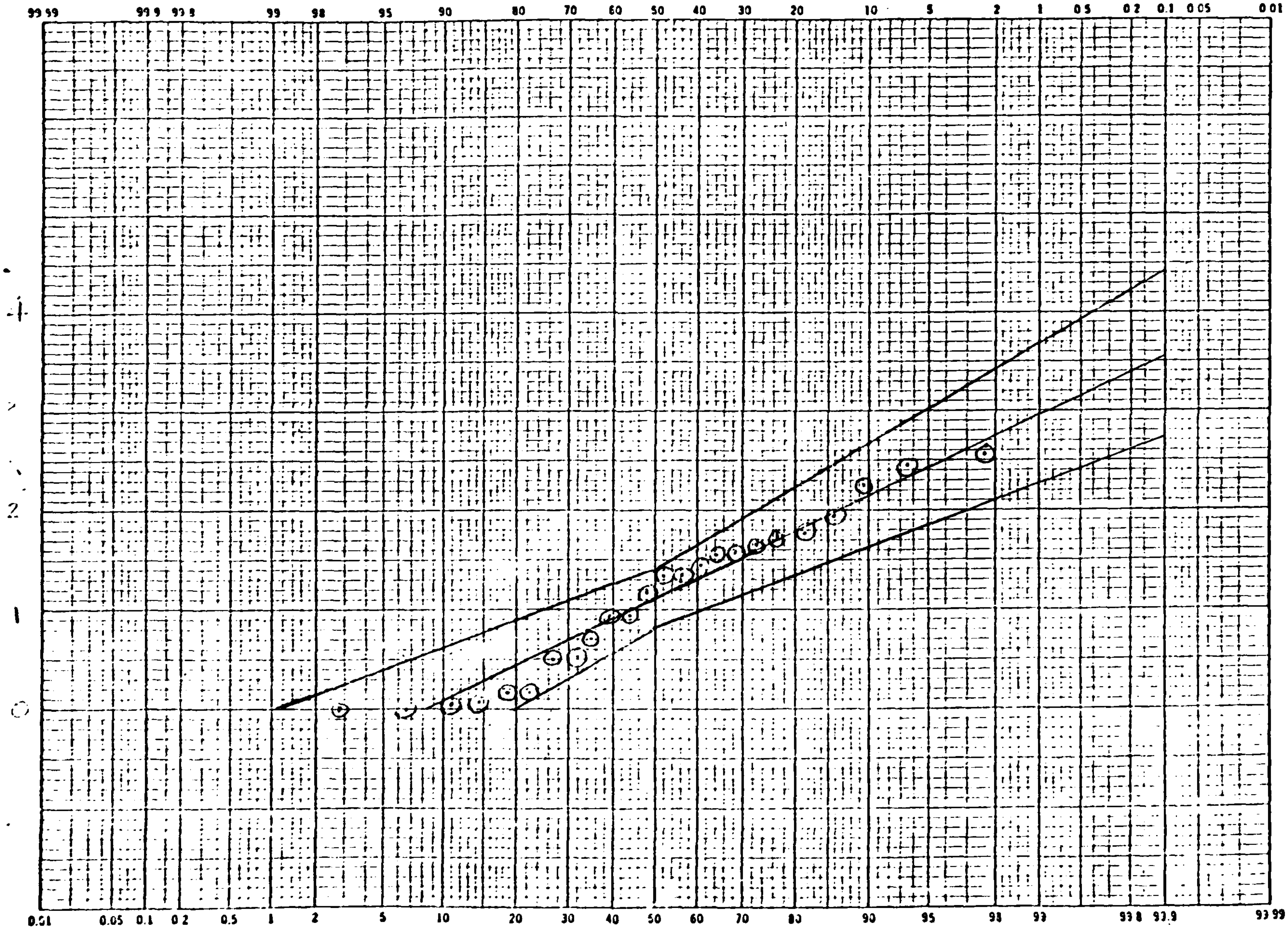


Figure 43 - MOD "E" Composite

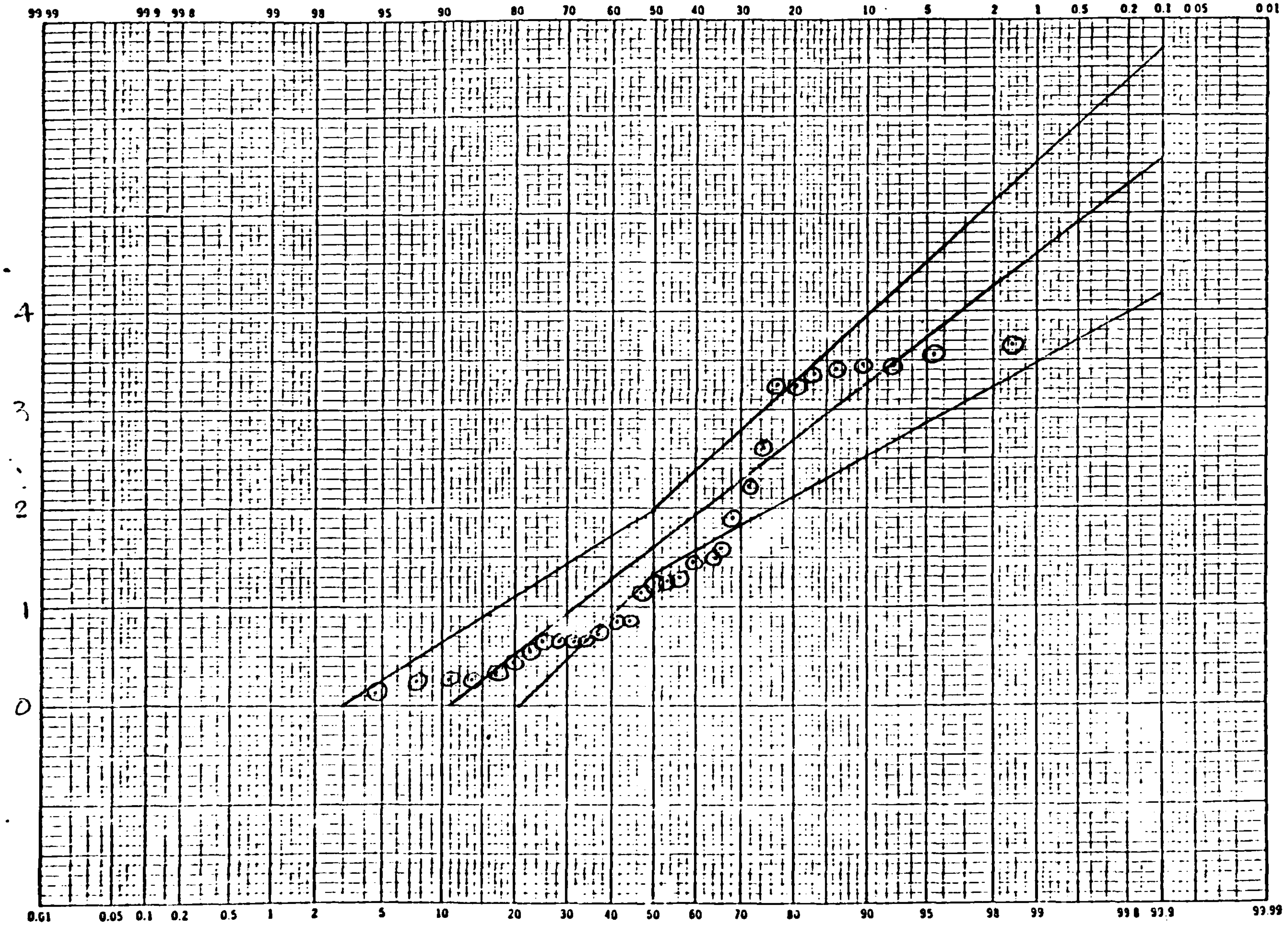


Figure 44- MBA Composite

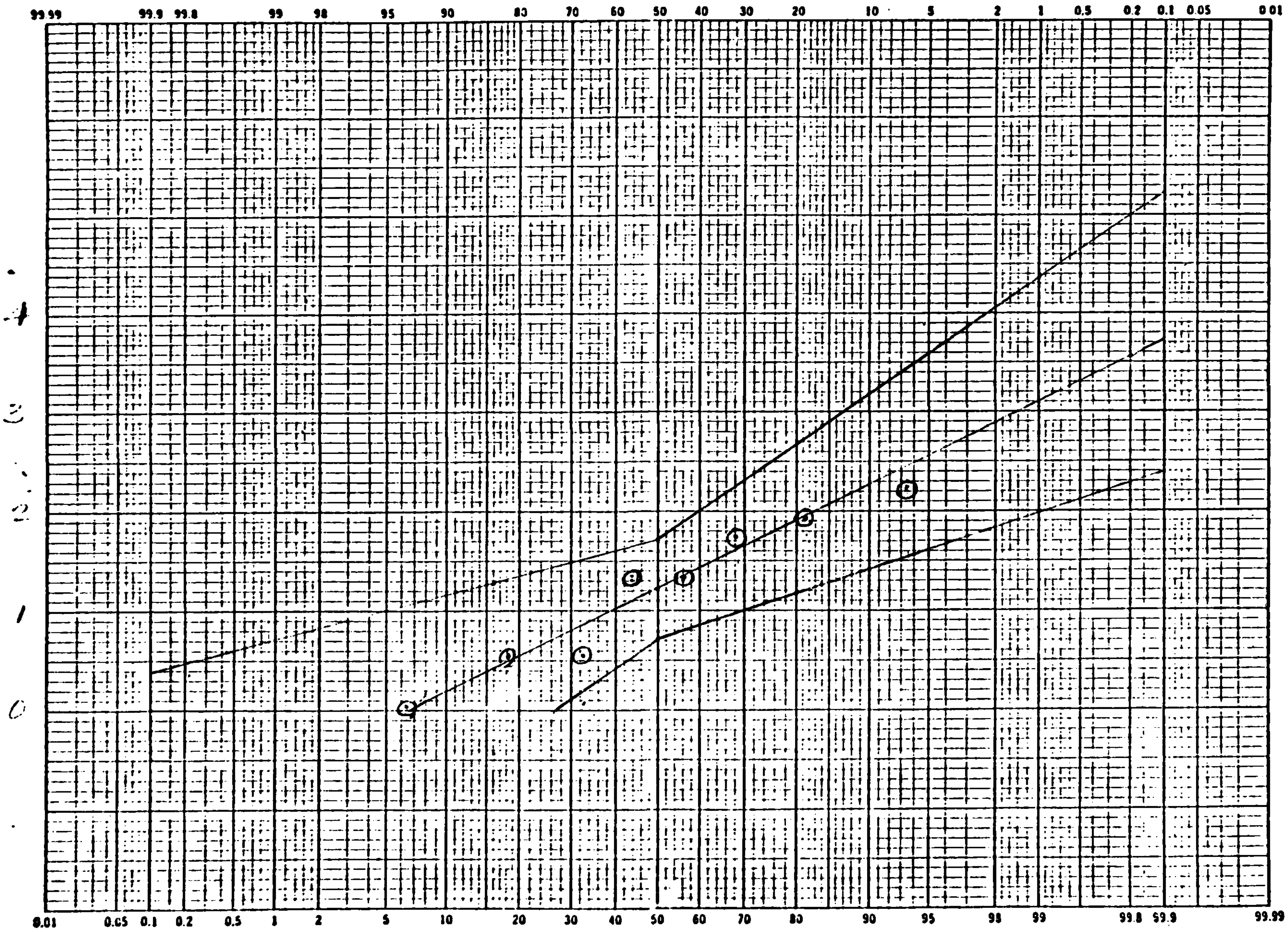


Figure 45 - MOD "E" Phase I Low Angle

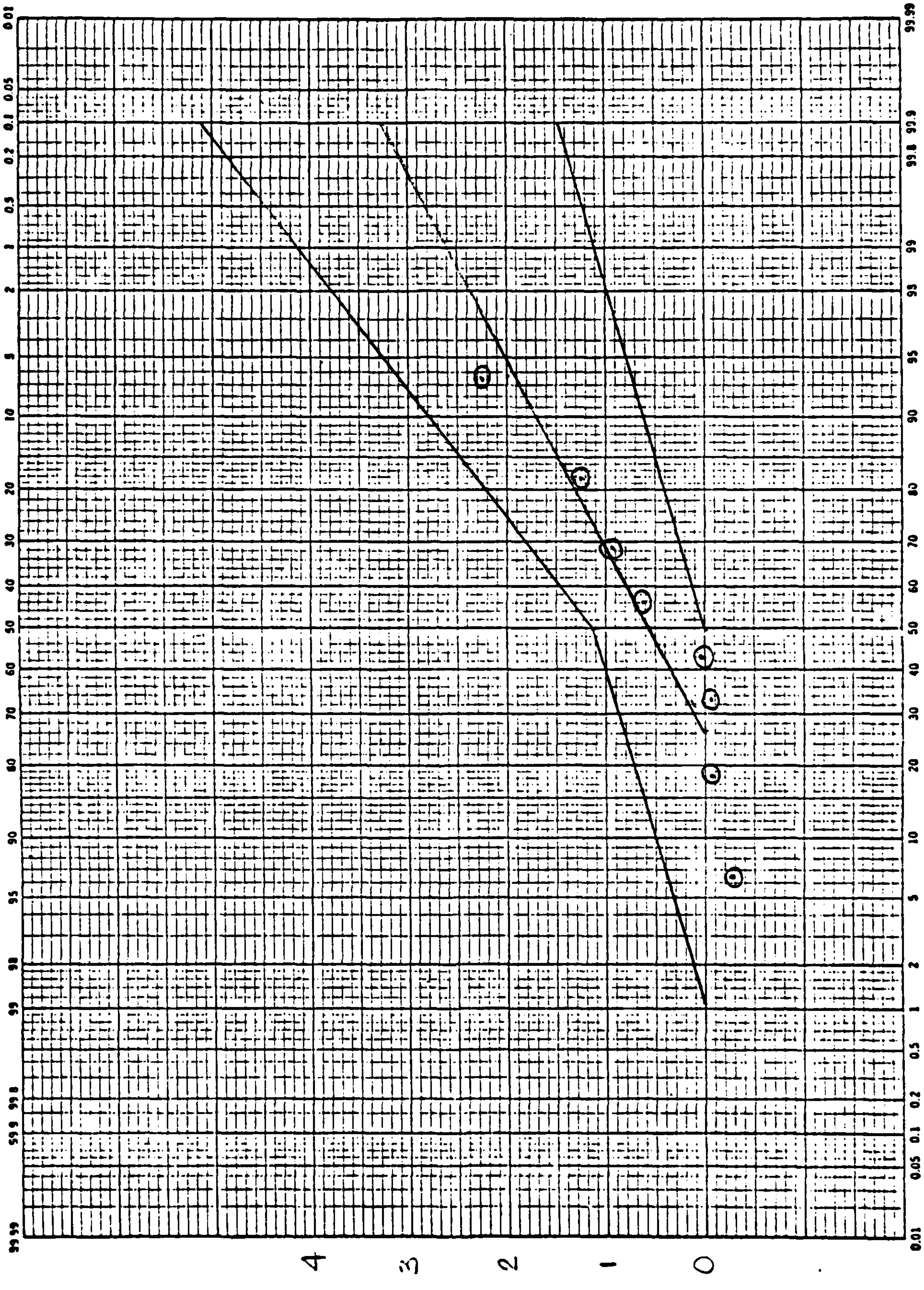


Figure 46 - ORI Phase I Low Angle

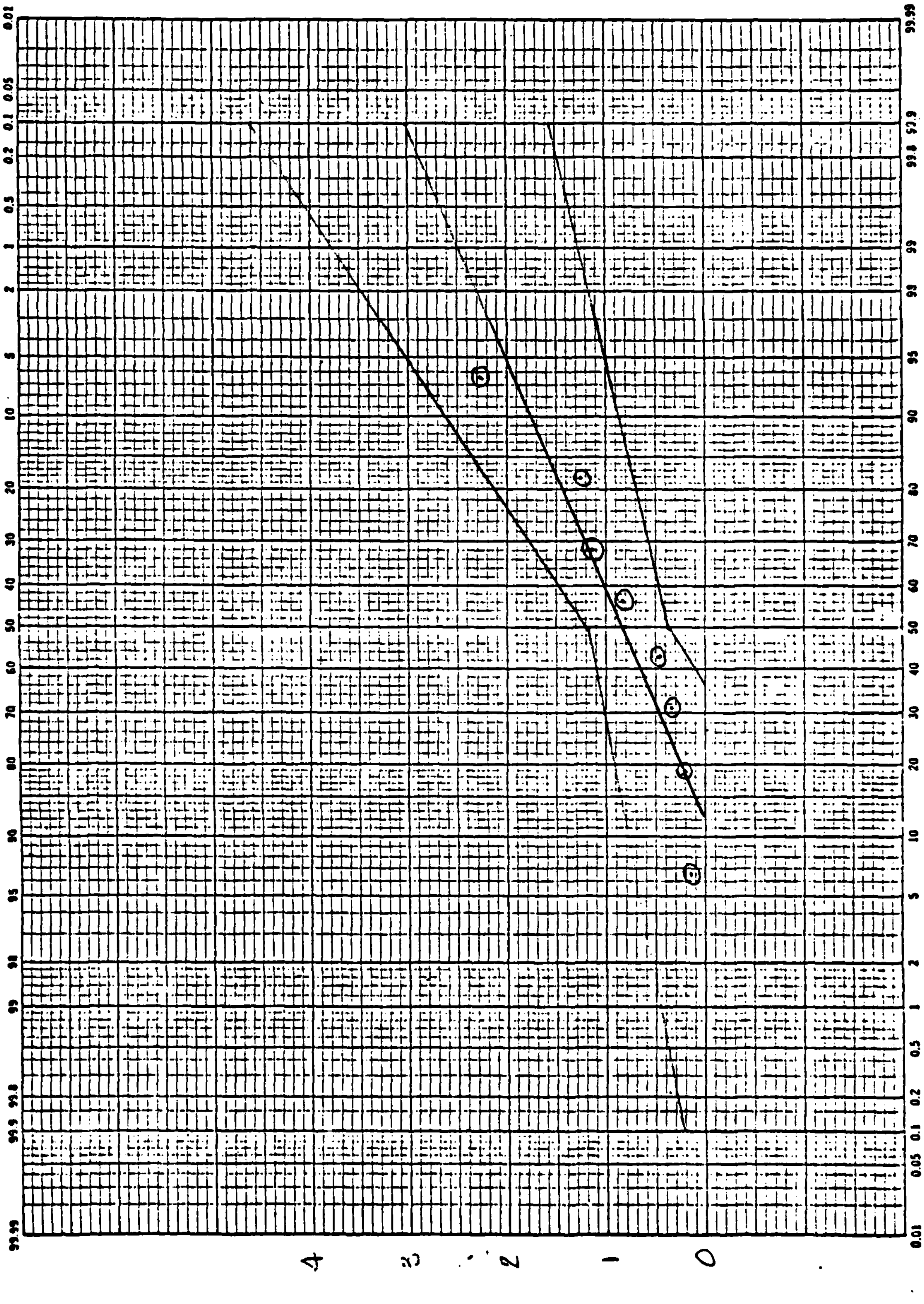


Figure 47 - MBA Phase I Low Angle

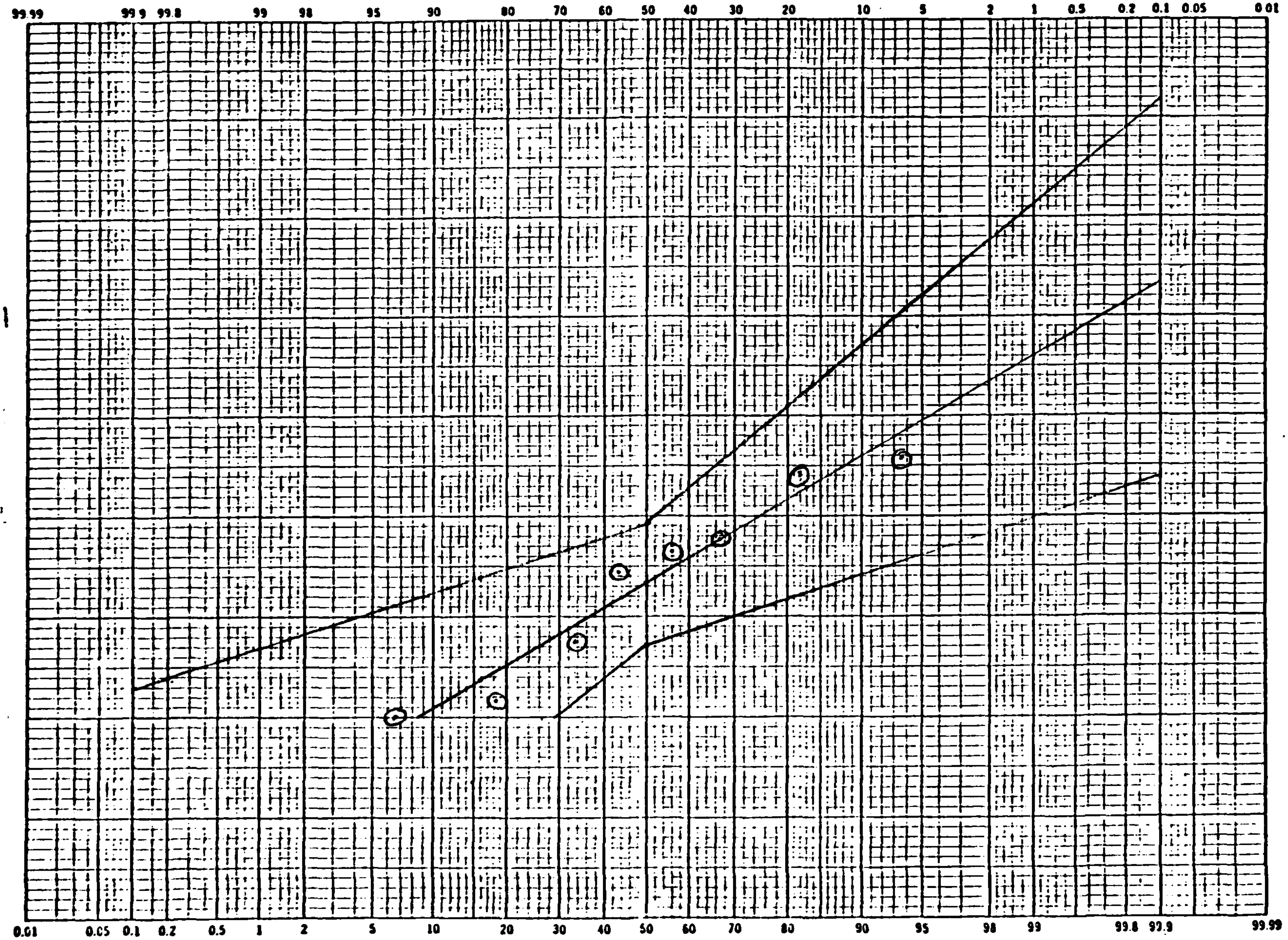


Figure 48 - MOD "E" Phase II Low Angle

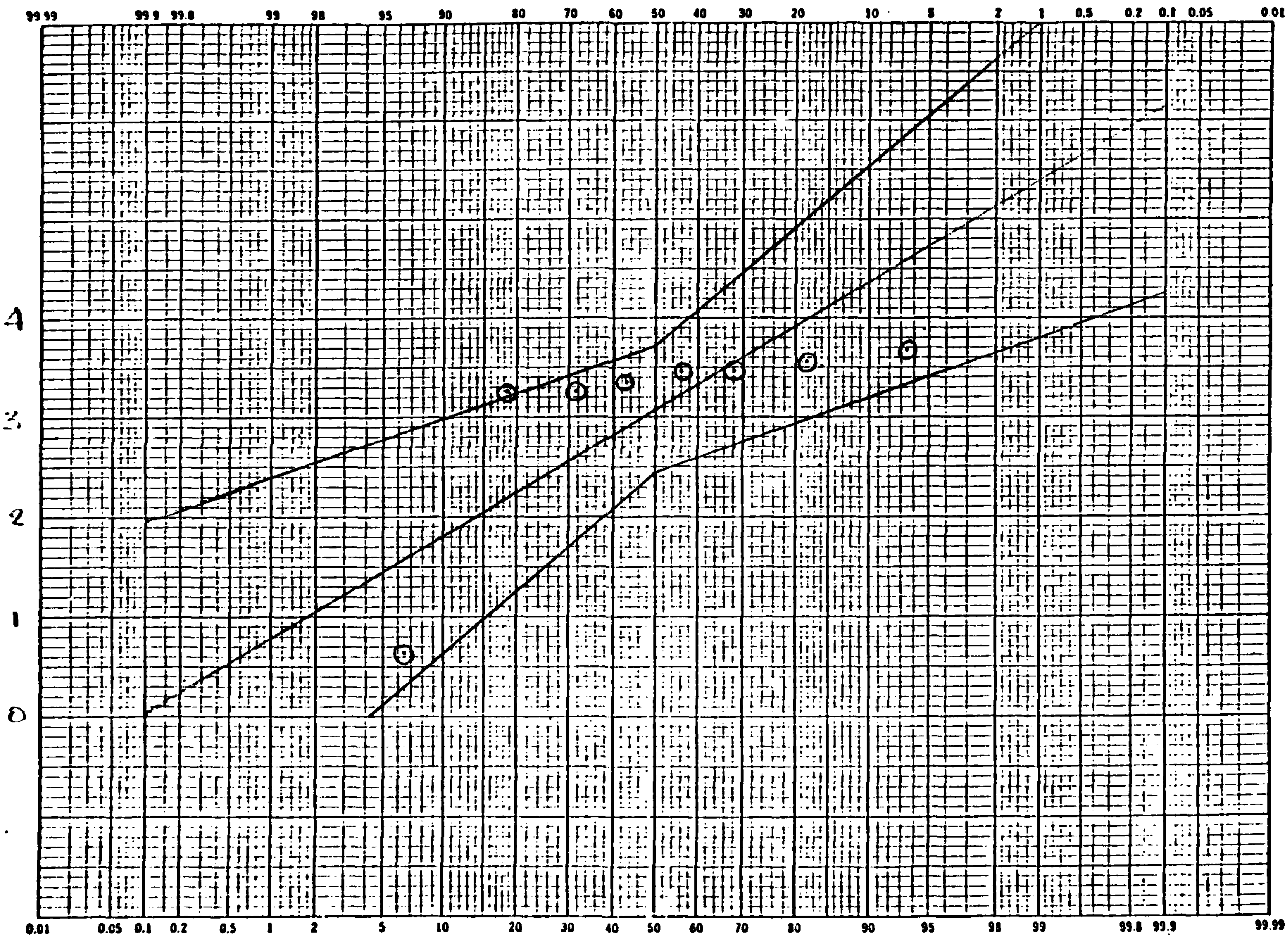


Figure 49 - MBA Phase II Low Angle

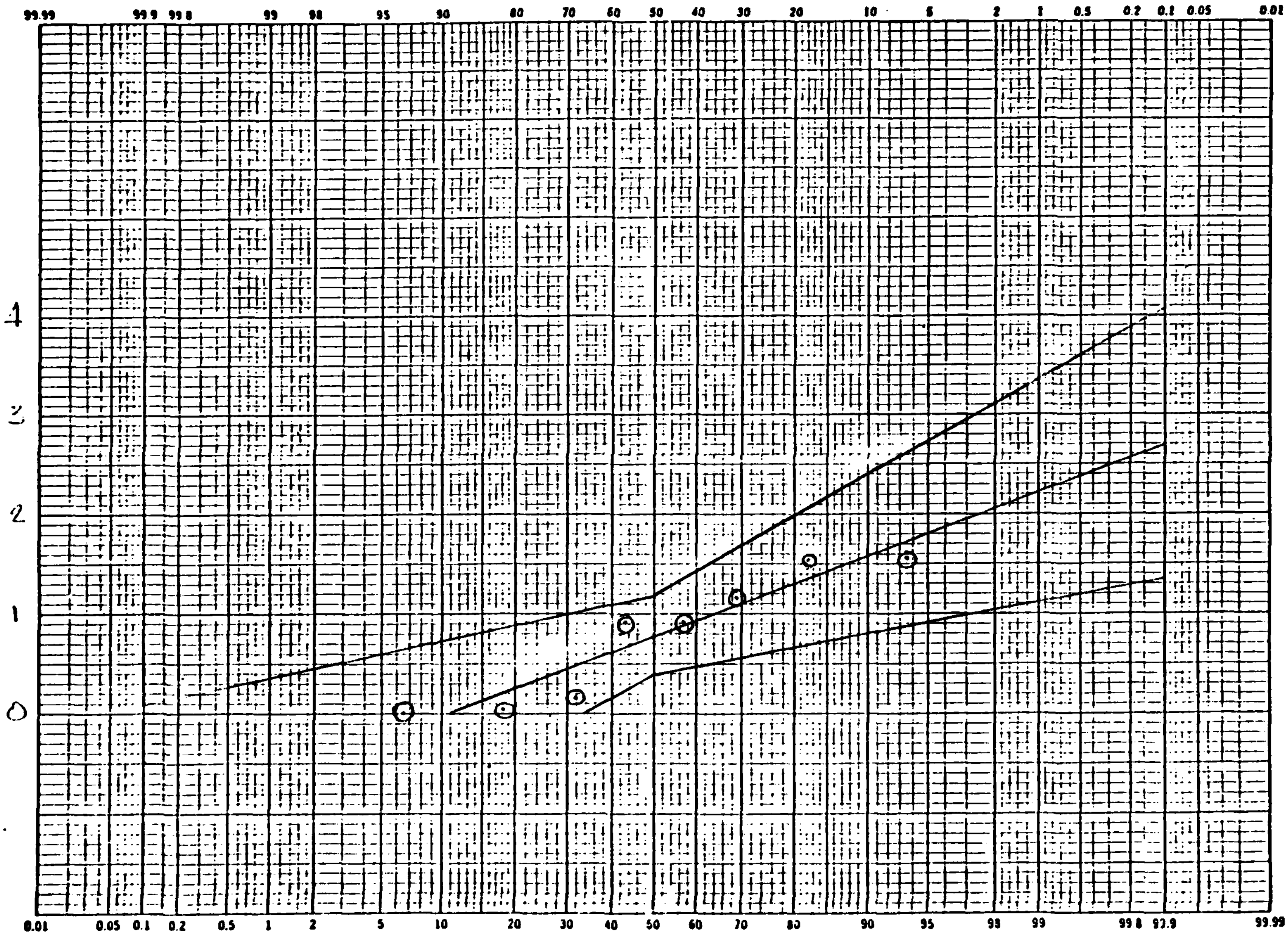


Figure 50 - MOD "E" Phase II Low Angle

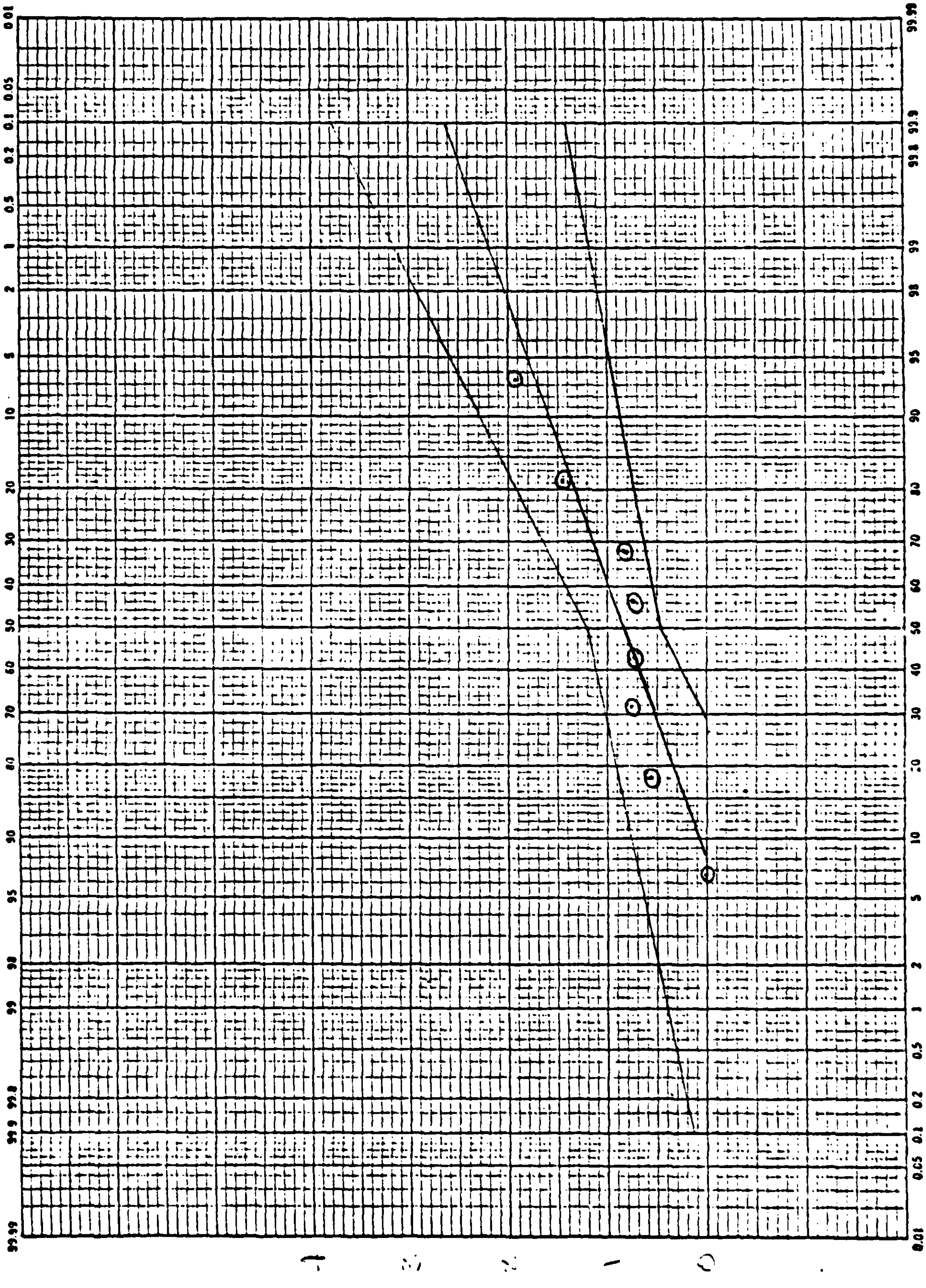


Figure 51 - MBA Phase II Low Angle

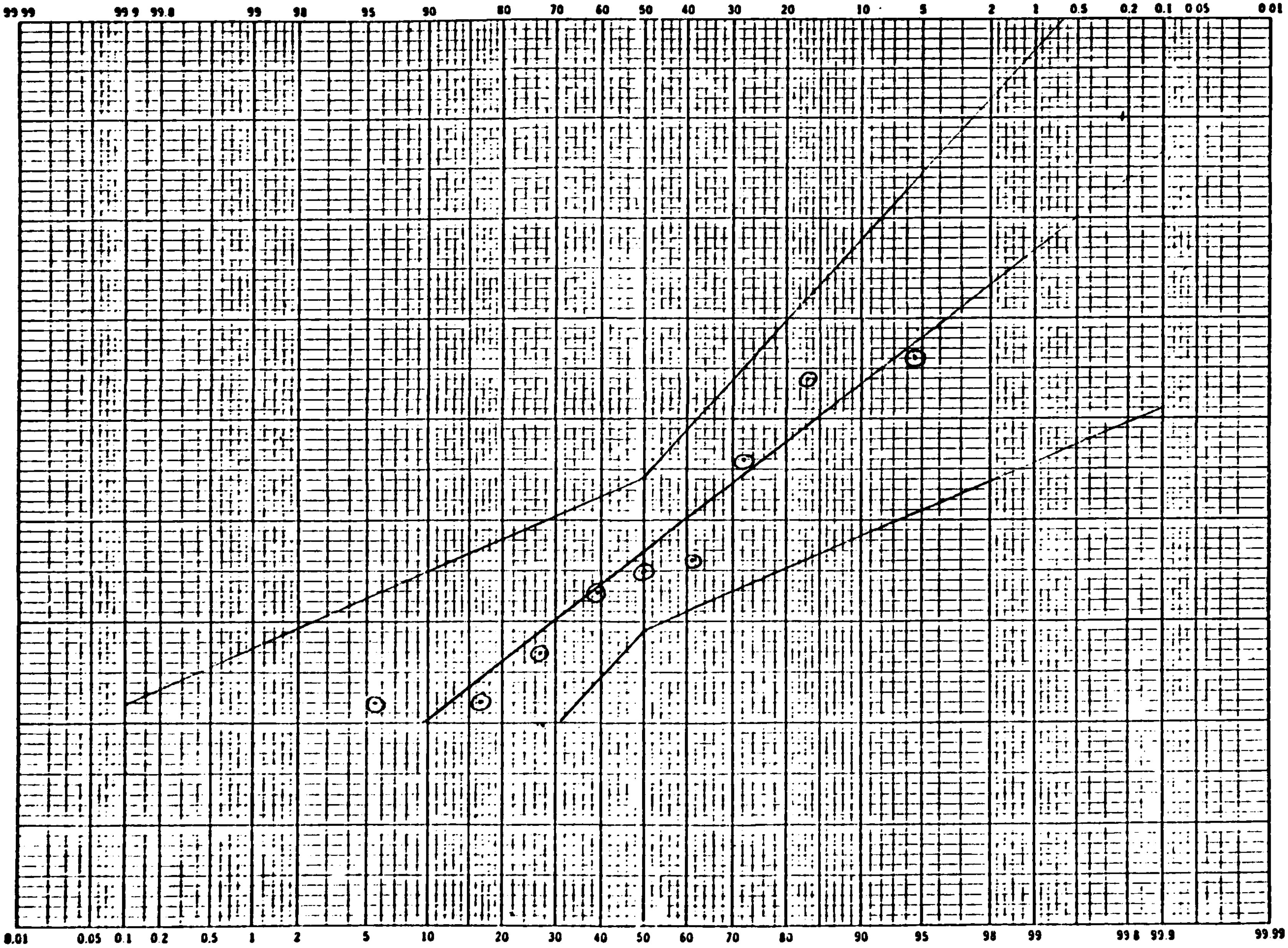


Figure 52 - MBA Phase III Low Angle

as follows:

"You can be 90% confident that 80 times out of 100 the observer will see a cloud."

These results for each individual test and the MOD "E" and $TiCl_4$ composites are shown in the bar chart of figure 42.

The center line between the 90% confidence lines is included on the figures because it represents the average line or 50% confidence curve. The test points are ordered in increasing values and plotted on the figures using the procedures given in the reference. Note that, for the most part, all data points fall within the 90% confidence envelope and that approximately 50% fall on either side of the 50% confidence curve.

The composite 90% confidence performance of the MOD "E" and the $TiCl_4$ configurations are approximately equal. The MOD "E" has a lower average observed intensity, but also a lower dispersion about the average than the $TiCl_4$, which yields good high confidence values. The $TiCl_4$, although some 40% higher than the MOD "E" in average observed intensity, experienced a lower reliability and, therefore, a higher dispersion. It can be expected that with reliability improvements, the $TiCl_4$ configuration will show much better results. For instance, if the $TiCl_4$ reliability is improved to match the MOD "E" configuration, some 92 out of 100 of the $TiCl_4$ clouds would be visible at 90% confidence.

6.5 Contract Add-On

Anticipating additional ballistic and static testing to qualify the Practice Fuze and XM804 Projectile, in November 1979 ARRADCOM requested MBA to submit costing and delivery schedule for 576 XM747E2 P/N 9331823 Practice Fuze Assemblies loaded with SW522 Spotting Charge, P/N 9331826, see Figures 53A and 53B.

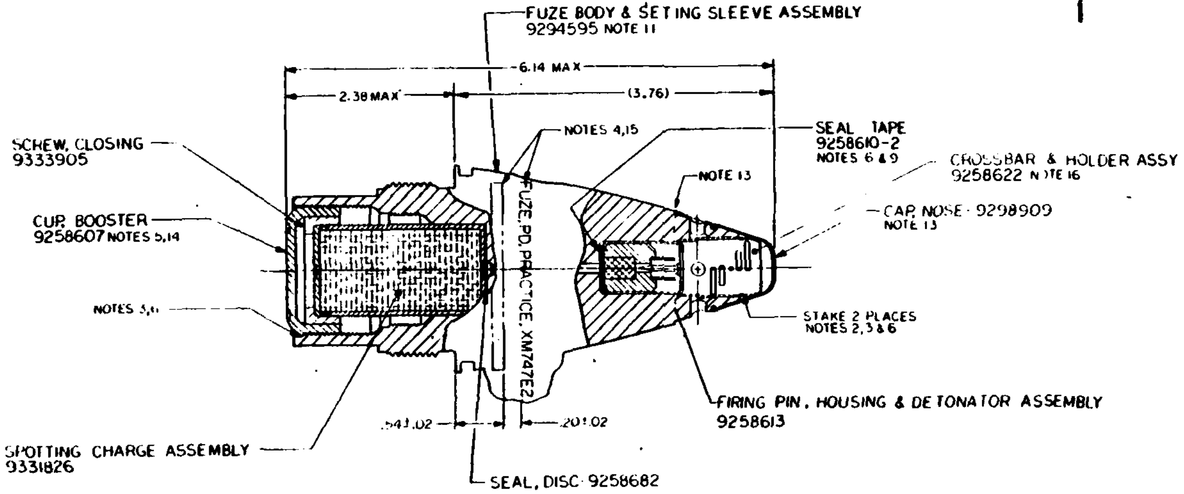
MBA received the contract add-on to fabricate and assemble the 576 Fuze Assemblies in February 1980, of which 330 Fuze Assemblies were delivered to Ft. Sill, Oklahoma for ballistic testing and 246 (less LAT (Lot Acceptance Test) and special test quantities (discussed below)) to ARRADCOM for packing and handling testing.

NOTES:

1- SPEC MIL-A-2550 APPLIES.
2- STAKE 2 PLACES .020 TO .030 WIDE. STAKING TO BE DONE PRIOR TO ASSEMBLY OF CAP, NOSE 9298909.
3- SEAL END 360° IN AREA INDICATED WITH ADHESIVE-SEALANTS, SILICONE, RTV, NON-CORROSIVE, TYPE II, SPEC MIL-A-46146, AND CURE FOR 24 HOURS MIN. (NOTE 6).
4- STAMP AS SHOWN WITH LETTERS AND FIGURES .125±.010 HIGH, .01 MIN DEEP (NOTE 15).
5- TORQUE BOOSTER CUP-9258607 AT TO INCH LBS. REMOVAL TORQUE MUST BE INCH LBS. MIN PRIOR TO CURING OF SEALANT (NOTE 7) WHEN TESTED AS SPECIFIED IN PARAGRAPH OF MIL-F-
6- REQUIREMENTS OF LEAK TEST SPECIFIED IN PARAGRAPH OF MIL-F- MUST BE MET.

7- FUZE BODY ASSY SHALL BE ASSEMBLED AND PACKED IN A HUMIDITY CONTROLLED ROOM MAINTAINED AT 40% MAX RELATIVE HUMIDITY AT 72°F. (OR EQUIVALENT WATER VAPOR GRAINS PER POUND OF DRY AIR). PARTS, ASSEMBLIES AND PACKAGING SHALL REMAIN IN THE HUMIDITY CONTROLLED ATMOSPHERE FOR A PERIOD OF FOUR (4) HOURS MIN PRIOR TO ASSEMBLY.
8- REQUIREMENTS OF ARMING AND PROPAGATION TEST SPECIFIED IN PARAGRAPH OF MIL-F- MUST BE MET. (NOTE 12).
9- TAPE TO BE INSTALLED INTO WELL OF FUZE BODY & SETTING SLEEVE ASSEMBLY 9294595 AS SHOWN.
10- COMPLIANCE WITH TESTS, (PROVING GROUND, BALLISTIC PERFORMANCE AND SHOP) REQUIRED BY THE SPECIFICATIONS AND DRAWINGS ARE MANDATORY. THE CONTRACTOR WILL NOT ASSUME, NOR DOES THE GOVERNMENT GARANTEE THAT ALL POSSIBLE COMBINATIONS PERMITTED BY THE TOLERANCE LIMITS OF THE SPECIFICATIONS AND DRAWINGS WILL CONSISTENTLY SATISFY THE TEST REQUIREMENTS. THEREFORE, THE MANUFACTURER IS OBLIGATED TO CHOOSE THOSE COMBINATIONS OF TOLERANCES AND FITS WITHIN THE LIMITS OF THE SPECIFICATIONS AND DRAWINGS THAT BEST SUIT HIS PROCESS NEEDS AND STILL SATISFY THE TESTING REQUIREMENTS.
11- FUZE BODY & SETTING SLEEVE ASSEMBLY 9294595 MUST NOT EXCEED 300 RPM WHEN ASSEMBLED.
12- FOR THE ARMING AND PROPAGATION TEST, PARAGRAPH OF MIL-F- THE COMPONENTS ARE TO BE ASSEMBLED AS FOLLOWS:— INSERT PLUG, TEST 9294992, AND DISK, TEST 9294993, INTO CUP, BOOSTER; THEN ASSEMBLE CUP, BOOSTER 9258607 TO FUZE BODY ASSEMBLY 9294595 AND TORQUE AT 30 TO 70 IN. LB.
13- CRIMP 360°; CAP, NOSE 9298909 TO BE FLUSH TO .015 ABOVE FLUSH TO THE FUZE BODY 9294595.
14- AFTER TIGHTENING CUP, BOOSTER-9258607 (NOTE 5) APPLY ADHESIVE-SEALANTS, SILICONE, RTV, NON-CORROSIVE, TYPE II, SPEC MIL-A-46146, 360° TO AREA INDICATED, AND LET CURE FOR 24 HOURS MIN. (NOTE 6).
15- LOCATE NOMENCLATURE (FUZE, PD, PRACTICE), LOADERS LOT NUMBER AND DATE AS SHOWN ANYWHERE AROUND PROFILE WITH THE EXCEPTION OF THE SETTING SLEEVE ASSEMBLY AREA. MARK IN ACCORDANCE WITH MIL-STD-1168.
16- ALIGNMENT OF LOWER HOLES IN CROSSBAR AND HOLDER ASSEMBLY-9258622 WITH HOLES IN FUZE BODY AND SETTING SLEEVE ASSEMBLY-9294595 NOT REQUIRED.

KA	REVISED AND REDRAWN	[illegible]	
KB	9294595 WAS 9331824. 9333905 WAS 9258611. DELETED: 9258610-2, [illegible] ADDED: 9258622, 9258682 AND NOTE 16. DIM: 6.14 MAX WAS 5.97 MAX. 2.38 MAX WAS 2.21 MAX. .54±.02 WAS .75±.02.	[illegible]	



SEE SEPARATE PARTS LIST 9331823

PART NO. 9331823

FUZE, PD, PRACTICE, XM747E2

79-04-20

F 19200 T 9331823

FUZE XM747E2

FIGURE 53A

AD-A092 984 MB ASSOCIATES SAN RAMON CALIF F/G 19/1
XM746 PRACTICE FUZE.(U)
JUL 80 DAAK10-79-C-0040
UNCLASSIFIED MB-R-80/12 NL

2 of 2
AD
A092984

END
DATE
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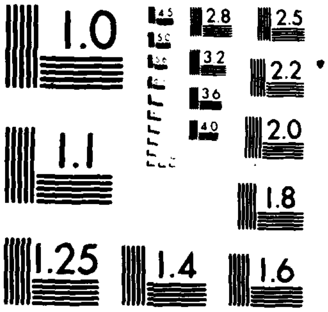


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

DRAWING SIZE C
(ARRADCOMR 70-12)

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
XO			
XA	DIM 2.000 WAS .835. ADDED DIM 1.06, UNIT WT.59GMS, SIDE VIEW & NOTES	79-06-11	MS

NOTES:-

1- SPEC MIL-A-2550 APPLIES.

2- LOAD WITH APPROXIMATELY 52 GRAMS ARRADCOM SMOKE COMPOSITION, SW-522 AS FOLLOWS:

INGREDIENT	% BY WT.	PARTICLE SIZE (MICRONS)	SPEC
ZINC DUST	40 ± 1	7 ± 3	JAN-Z-365
POTASSIUM PERCHLORATE	20 ± 0.5	PER SPEC	MIL-P-217A, GR A, CL 4.
POTASSIUM NITRATE	20 ± 0.5	30 ± 15	MIL-P-156B, CL 2.
ALUMINUM (ATOMIZED)	20 ± 0.5	PER SPEC	MIL-P-14067A, TYPE II

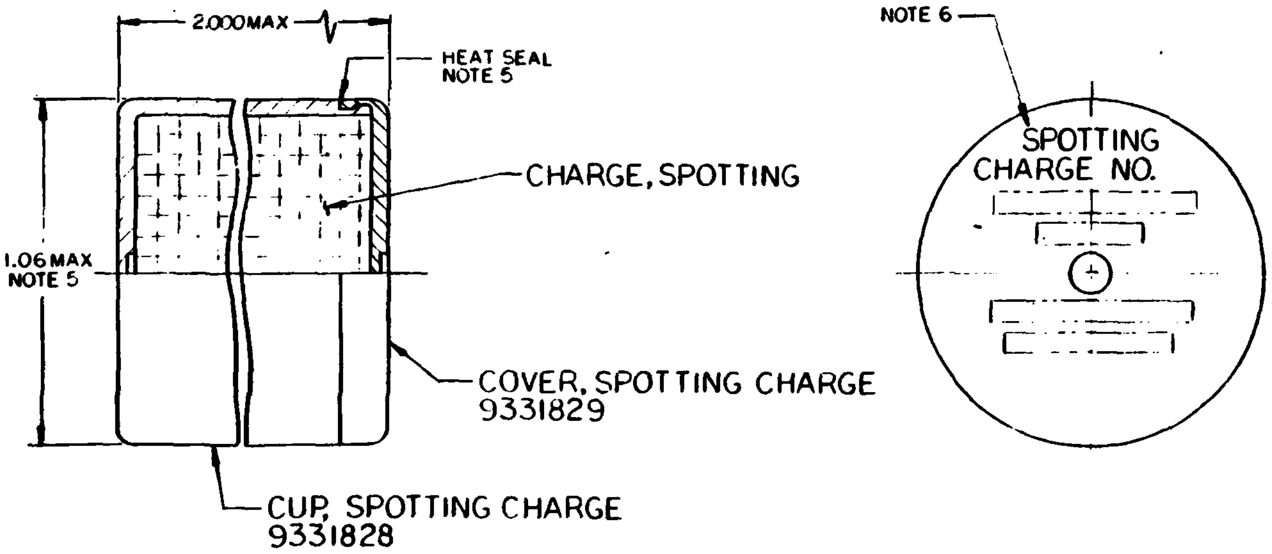
3- ADVISORY: BLEND SMOKE COMPOSITION INGREDIENTS USE GLOBE OR BALL MILL EQUIPMENT.

4- COMPACT CHARGE, SPOTTING BY VIBRATING OR TAPPING IN CUP, SPOTTING CHARGE, 9331828.

5- SECURE COVER TO CUP BY HEAT SEALING 360°. SEAL AREA NOT TO EXCEED DIMENSIONS SHOWN.

6- MARK WITH INK MARKING, STENCIL, OPAQUE, APPROXIMATE COLOR, WHITE NO. 37875, TYPE I OR III PER SPEC TT-I-1795. CHARACTERS TO BE .062 ± .035 HIGH IN APPROXIMATE LOCATION INDICATED. EITHER END MAY BE MARKED. MARK IN ACCORDANCE WITH MIL-STD-1168.

7- CHARGES SHALL BE ASSEMBLED AND PACKAGED IN A HUMIDITY CONTROLLED ROOM MAINTAINED AT 40% MAX RELATIVE HUMIDITY AT 72°F (OR EQUIVALENT WATER VAPOR GRAINS PER LB. OF DRY AIR). PARTS ASSEMBLIES AND PACKAGING SHALL REMAIN IN THE HUMIDITY CONTROLLED ATMOSPHERE FOR A PERIOD OF FOUR (4) HOURS MIN. PRIOR TO ASSEMBLY.



SEE SEPARATE PARTS LIST 9331826

NOV 16 1979

PART NO. 9331826

9331823	FUZE XM747		
NEXT ASSY	USED ON		
APPLICATION			

MECHANICAL PROPERTIES
YP
TS
EL2
RA
BH
BH

DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS ±
FRACTIONS ± ANGLES ±

ORIGINAL DATE OF DRAWING 79-04-26
DRAFTSMAN MS
CHECKER
ENGR
ENGR
ENGR
ENGR

U S ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
DOVER, NEW JERSEY 07801

SPOTTING CHARGE
ASSEMBLY

SIZE	CODE IDENT NO		
C	19200	T	9331826
SCALE 4/1	UNIT WT. 59 GMS	SHEET	

FIGURE 53B

As a result of the Ft. Lewis tests in December, MBA, at the request of ARRADCOM, conducted a series of static tests using Red Phosphorous (RP) in combination with the MOD "E" composition to evaluate the possibility of the RP enhancing the smoke cloud density and duration.

The RP and MOD "E" were loaded into the GFE smoke containers, as shown in Figure 54. A cardboard disk was placed between the RP and MOD "E" composition to maintain the low sensitivity of the MOD "E" composition during handling. Loaded were ten each RP/MOD "E" composition and ten each standard composition MOD "E", see Table 11 for composition proportion.

The tests were recorded on video tape and instrumented with break wires at the fuze detonator and the projectile smoke ports in the same manner as all past testing.

Table 12 lists the test sequence, composition weight and function times.

Reviewing the video tape (5 MBA personnel), it was agreed that the RP did not add to the smoke cloud density. Based on this input, ARRADCOM decided not to pursue this configuration.

Reviewing the function times of the MOD "E" composition revealed considerably longer function times than measured in past testing. An average time of 3.38ms was recorded (see Table 12) in comparison to the September static test where the average time was 2.18ms, see Table 13, lines 1 through 13. As a result of the increased function times, the Lot Acceptance Tests (LAT) for the Ft. Sill shipment included evaluating the composition particle size and blend times. The first nine batches of the MOD "E" composition were screened through 325 micron screen. The zinc dust was analyzed in the Fisher sub-sieve sizer and particle size of the zinc dust averaged 5 microns, well within tolerance 7 ± 3 microns stated on drawing 9331826 (see Figure 53B).

At the conclusion of all testing, reviewing the data showed no real decrease in the function time (see Table 13). A further examination of the data revealed the relative humidity was higher in February 1980 than

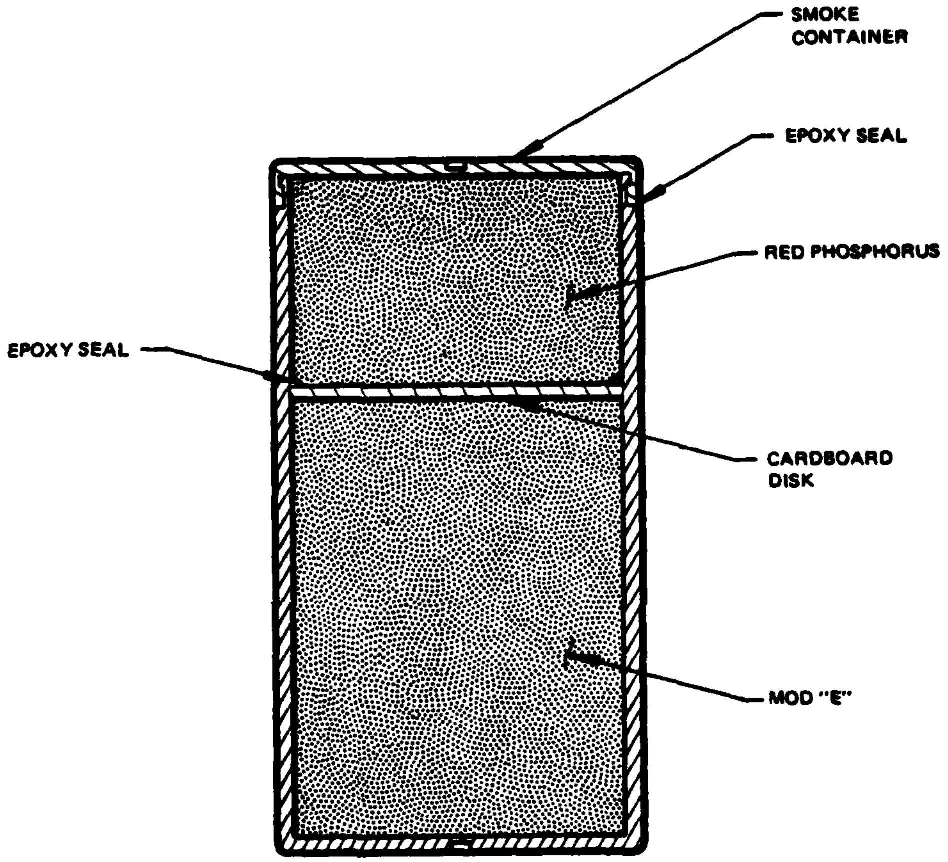


FIGURE 54
MOD "E"/RED PHOSPHORUS CONFIGURATION

TABLE 11

COMPOSITION WT.

FUZE S/N	MOD "E" WT. GRAMS	RED PHOSPHORUS WT. GRAMS
250	33.5	7.5
251	32.9	7.1
252	33.4	7.4
253	32.7	8.0
254	32.8	7.4
255	21.3	15.3
256	20.4	14.3
257	21.2	14.4
258	23.7	14.7
259	20.3	14.7
260	45.7	-
261	45.4	-
262	45.9	-
263	46.5	-
264	46.2	-
265	45.2	-
266	45.1	-
267	45.0	-
268	44.8	-
269	46.3	-

TABLE 12

MOD "E"/RP STATIC TEST

DESCRIPTION		TEMP.	WT. RP	WT. MOD "E"	TIME MS
S/N	TYPE				
260	MOD "E"	AMB.	-	45.7	-
250	MOD "E"/RP	"	7.5	33.5	2.0
255	MOD "E"/RP	"	15.3	21.3	1.36
261	MOD "E"	"	-	45.4	3.19
251	MOD "E"/RP	"	7.1	32.9	3.80
256	MOD "E"/RP	"	14.3	20.4	4.20
262	MOD "E"	"	-	45.9	3.36
252	MOD "E"/RP	"	7.4	33.4	3.34
357	MOD "E"/RP	"	14.4	21.2	4.59
363	MOD "E"	"	-	46.5	3.23
353	MOD "E"/RP	"	8.0	32.7	1.52
358	MOD "E"/RP	"	14.7	23.7	4.47
364	MOD "E"	"	-	46.2	3.77
354	MOD "E"/RP	"	7.4	32.8	3.99
359	MOD "E"/RP	"	14.7	20.3	-
365	MOD "E"	"	-	45.2	-

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TABLE 13
XM747E STATIC TESTING (MBA)

LOT WHEN	S/N	SCREEN	LB MIXED	BLEND TIME	HUMIDITY	COMP WT GM	FUNCT TIME MS	INTER-RUPT IN	FUZE TEMP	
MBA Qual. Testing Sept. 79	034	NO	1 #	2 HR	LO	47.55	1.678	-	AMB	Outside temp. 90+
MBA Qual. Testing Sept. 79	036	NO	1 #	2 HR	LO	46.85	2.160	-	AMB	Outside temp. 90+
MBA Qual. Testing Sept. 79	046	NO	1 #	2 HR	LO	46.60	2,691	-	AMB	Outside temp. 90+
MBA Qual. Testing Sept. 79	047	NO	1 #	2 HR	LO	45.75	2.495	-	-50°F	Outside temp. 90+
MBA Qual. Testing Sept. 79	053	NO	1 #	2 HR	LO	47.05	2.496	-	-30°F	Outside temp. 90+
MBA Qual. Testing Sept. 79	052	NO	1 #	2 HR	LO	46.25	1.620	-	-30°F	Outside temp. 90+
MBA Qual. Testing Sept. 79	051	NO	1 #	2 HR	LO	48.45	2.232	-	-30°F	Outside temp. 90+
MBA Qual. Testing Sept. 79	066	NO	1 #	2 HR	LO	48.75	1.223	-	+140°F	Outside temp. 90+
MBA Qual. Testing Sept. 79	068	NO	1 #	2 HR	LO	45.75	1.892	-	+140°F	Outside temp. 90+
MBA Qual. Testing Sept. 79	067	NO	1 #	2 HR	LO	46.05	2.922	-	40°F	Outside temp. 90+
MBA Qual. Testing Sept. 79	070	NO	1 #	2 HR	LO	49.55	2.180	-	+140°F	Outside temp. 90+
MBA Qual. Testing Sept. 79	069	NO	1 #	2 HR	LO	46.95	2.746	-	+140°F	Outside temp. 90+
Ft. Lewis Dec.79	FUNCTION	TEST ONLY 8 EACH								Outside temp. -60°F Batch Control
Pre Ft.Sill Feb80	261	NO	1 #	1 HR	HI	45.4	3.19	-	AMB	
Pre Ft.Sill Feb80	262	NO	1 #	1 HR	HI	45.9	3.36	-	AMB	" "
Pre Ft.Sill Feb80	263	NO	1 #	1 HR	HI	46.5	3.23	-	AMB	" "
Pre Ft.Sill Feb80	264	NO	1 #	1 HR	HI	46.2	3.77	-	AMB	" "

FEB. 3

Page 2 of 3

TABLE 13
XM747E STATIC TESTING (MBA)

	LOT WHEN	S/N	SCREEN	LB MIXED	BLEND TIME	HUMIDITY	COMP WT GM	FUNCT TIME MS	INTER-RUPT IN	FUZE TEMP	
WK. FEB. 10	Pre Ft.Sill Feb80	310	YES	1 #	1 HR	HI	44.8	3.135	YES	AMB	Outside temp. -60°F BatchCtrl.
	Pre Ft.Sill Feb80	311	YES	1 #	1 HR	HI	46.2	2.460	YES	AMB	" "
	Pre Ft.Sill Feb80	312	YES	1 #	1 HR	HI	45.10	3.442	YES	AMB	" "
	Pre Ft.Sill Feb80	313	YES	1 #	1 HR	HI	45.5	2.98	-	AMB	" "
	Pre Ft.Sill Feb80	314	YES	1 #	1 HR	HI	45.4	3.29	-	AMB	" "
	Pre Ft.Sill Feb80	315	YES	1 #	1 HR	HI	45.2	3.14	-	AMB	" "
	Ft.Sill Lot Feb.80 (96 ea.)	316	YES	1 #	4 HR	HI	46.3	2.33	NP	AMB	" "
	Ft. Sill Lot Feb. 80 (96 ea.)	317	YES	1 #	4 HR	HI	46.3	1.78	YES	AMB	" "
	Ft. Sill Lot Feb. 80 (96 ea.)	318	YES	1 #	4 HR	HI	46.3	1.54	YES	AMB	" "
WK. FEB. 24	Ft. Sill Lot Feb. 80 (96 ea.)	319	NO	2 #	4 HR	HI	45.9	1.301	-	AMB	Belmont 3 case
	Ft. Sill Lot Feb. 80 (96 ea.)	320	NO	2 #	4 HR	HI	45.8	1.710	-	AMB	Belmont 3 case
	Ft. Sill Lot Feb. 80 (96 ea.)	321	NO	2 #	4 HR	HI	46.3	3.204	-	AMB	Belmont 3 case
WK. MAR. 9	Ft. Sill Lot Mar. 80 (96 ea.)	322	YES	2 #	4 HR	HI	45.9	3.12	NO	AMB	Outside Temp. -60°F Random Samp.
	Ft. Sill Lot Mar. 80 (96 ea.)	323	NO	2 #	4 HR	HI	47.4	2.91	YES	AMB	" "
	Ft. Sill Lot Mar. 80 (96 ea.)	324	NO	2 #	4 HR	HI	46.2	3.13	NO	AMB	" "
	Ft. Sill Lot Mar. 80 (96 ea.)	325	NO	2 #	4 HR	HI	46.1	0	NO	AMB	" "
	Ft. Sill Lot Mar. 80 (96 ea.)	326	NO	2 #	4 HR	HI	46.7	3.36	YES	AMB	" "

TABLE 13
XM747E STATIC TESTING (MBA)

WK. MAR. 9

LOT WHEN	S/N	SCREEN	LB MIXED	BLEND TIME	HUMIDITY	COMP WT GM	FUNCT TIME MS	INTER-RUPT IN	FUZE TEMP	
Ft. Sill Lot Mar. 80 (96 ea.)	327	NO	2 #	4 HR	HI	45.8	3.14	YES	AMB	Outside temp. -60°F Random samp.
Ft. Sill Lot Mar. 80 (96 ea.)	328	YES	2 #	4 HR	HI	45.9	3.56	YES	AMB	" "
Ft. Sill Lot Mar. 80 (96 ea.)	329	YES	2 #	4 HR	HI	47.4	2.66	YES	AMB	" "
Ft. Sill Lot Mar. 80 #2	331	NO	2 #	4 HR	HI	46.2	3.12	YES	AMB	

it was in September 1979. The relative humidity in the blending and loading areas was about 10% in September 1979 and between 38 and 40% in February (see note 7 of Figure 53B for humidity spec.

The mean averages for the function times and the standard deviations for both September and February test series were calculated using the following equation:

$$\bar{x} = \frac{\Sigma x_i}{n} \qquad \text{and } s = \left[\frac{\Sigma(x_i - \bar{x})^2}{}\right]^{1/2}$$

For the September test series:

$$\bar{x} = 2.18 \text{ ms}, \; s = .49 \text{ ms} \quad (n = 13)$$

For the February test series:

$$\bar{x} = 2.87 \text{ ms}, \; s = .67 \text{ ms} \quad (n = 24)$$

The above results indicate that humidity could be a factor in causing an increase in the function time of the composition.

Ballistic testing of sixty Practice Fuzes was conducted at Ft. Sill the week of 10 March 1980. The tests had five observers stationed between 1500 through 4000 meters from the impact area. The observers reported slightly better than 50% spotting of the practice fuze smoke cloud with a fair to poor rating (see Table 14). As a result of the poor showing, the balance of the scheduled tests were cancelled.

7.0 RELIABILITY, FAILURE MODES AND CRITICALITY ANALYSIS

7.1 Analysis

A Failure Modes, Effects, and Criticality Analysis has been completed for the XM747E2 Practice Fuze, and is summarized in Table 15. The classification of failures is accomplished in accordance with the following definitions:

Critical - a single event failure resulting in a significantly hazardous environment to personnel.

TABLE 14

XM747E2 BALLISTIC TESTING *

				TOTAL POSSIBLE OBSERVATIONS	NUMBER OBSERVED	RATING
Zone 2	LA	284 to 599 mils	31	155	68	Poor
	HI	991 to 1225 mils	8	40	21	Poor
Zone 3	LA	248 to 384 mils	8	40	36	Fair to Poor
Zone 5	LA	327 to 467 mils	8	40	32	Fair to Poor
	HI	1186	5	25	0	-
			——	——	——	
		TOTAL	60	300	157	

Note: The observed smoke signatures were obscured by dust clouds created on impact.

---

* Ft. Sill week of March 10, 1980.

SUPPLIED BY ARRADCOM

TABLE 15

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

Failure Mode	Time Period	Probability of Event	Failure Classification
1. Failure to arm due to: a) insufficient spin force to overcome interrupter spring b) spring rate out of spec. c) interrupter binds in sleeve due to corrosion or dim. out of tolerance	Launch	less than $1x10^{-6}$	Major (no display)
2. Loss of booster cup at launch due to: a) structural failure of screw threads b) structural failure of cup base	Launch	less than $1x10^{-6}$	Major (no display)
3. Premature arming due to: a) improper assembly b) structural failure of interrupter spring	Launch	less than $1x10^{-6}$	Minor (no effect without a secondary failure
4. Detonator fails to function due to: a) improper assembly - detonator orientation reversed b) assembly dimensions out of tolerance c) detonator charge contaminated - moisture, etc.	Impact	less than $1x10^{-3}$	Major (no display)
5. Spotting charge fails to function due to: a) failure of composition to ignite due to contamination - moisture, etc. b) failure of booster cup to rupture within allotted time	Impact	less than $1x10^{-3}$	Major (no display)

Major - a single event failure resulting in the loss of capability of the item to perform its intended function.

Minor - a single event failure resulting in no effect or degradation of capability of the item to perform its intended function.

The analysis indicates there are no critical failure modes associated with the practice fuze.

8.0 CONCLUSIONS & RECOMMENDATIONS

8.1 Conclusions

None of the compositions in any of the hardware configurations tested were demonstrated to be ready for type classiciation.

Two of the candidate compositions, the ARRADCOM MOD "E" and the MOD "E"/$TiCl_4$, showed promise of being able to meet the training fuze spotting requirements with further development. Both performed well during much of the ballistic testing but were inconsisent with respect to developing a visible smoke cloud, particularly on soft impact media.

The ARRADCOM MOD "E" composition demonstrated the most consistently acceptable performance in the ballistic tests. Also, this composition, during certain of the static tests in the final hardware configuration with four aft canted ports in the shell, demonstrated function times to smoke onset of less than 2 ms (based on independent analysis by both ARRADCOM and MBA, approximately 2 ms is the worst case smoke port burial time on soft media).

Large variability in static function time was measured for MOD "E" lots blended late in the program. The cause of this erratic function time is not known but needs to be understood so that it can be eliminated.

Laboratory testing of the ARRADCOM MOD "E" composition showed it to be a stable, low sensitivity, pyrotechnic material very suitable for blending and loading using normal safety procedures.

The MOD "E"/$TiCl_4$ configuration, where the $TiCl_4$ is a smoke enhancer for the MOD "E" expulsion/smoke charge, produced excellent smoke clouds with respect to size and persistence in almost all the static tests and many of the ballistic tests. However, function times in the static testing were somewhat erratic and probably excessively long where displays were poor to non existent in the ballistic tests.

The long function times (if this is indeed the problem) are believed to be due, in part, to the erratic times of the later blended lots of MOD "E" discussed above. Also, a primary contribution to the functional inconsistency is the more complex failure mode(s) possible with the duel payload compartment configuration of the MOD "E"/$TiCl_4$ design.

The MOD "E"/$TiCl_4$ configuration, while a more complex design, produced the largest, most persistent, clouds using the least pyrotechnic material of any of the other candidates tested.

In summation of these conclusions, both the ARRADCOM MOD "E" and MOD "E"/$TiCl_4$ designs were demonstrated to be capable of producing acceptable smoke clouds but their performance was erratic during ballistic testing. Probably the function time of both designs as presently configured is marginally long for soft media impact but this conclusion may be wrong because of the erratic times recorded statically for the later blended lots of MOD "E" composition.

8.2 Recommendations

Both configurations discussed in the conclusions should be pursued since there is no reason to believe at this time that further development will not yield a cost effective training fuze with either approach.

All aspects of the MOD "E" blending and loading procedure, beginning with raw material control, in process procedures, environmental control, etc., should be reviewed and quantified to identify and establish requirements for minimum mean function times with low dispersions around the mean.

MOD "E" modifications with metal additives should be considered and evaluated with the intent to decrease mean function time without significantly affecting material sensitivity.

The mechanical design of each fuze concept should be reviewed and analyzed in detail to minimize function times. This is particularly true of the MOD "E"/$TiCl_4$ configuration where functional failure mode control can be improved.

The training fuze/shell should be re-evaluated as a system for the possibility of straight aft ejection of the smoke cloud. This evaluation should include a cost effects analysis on the training shell.

All the studies and analyses recommended above should be supported by suitable static testing ultimately leading to ballistic performance verification testing.

ADDENDUM 1 - SPECIAL TESTING

After program completion additional MOD "E" composition testing was performed at ARRADCOM. The purpose was to determine if the high humidity conditions which existed during blending of the later batches, as discussed in the body of this report, was the cause of erratic function times measured with units from these batches.

Twelve MOD "E" spotting charge assemblies were down loaded and MOD "E" composition vacuum dried. Five charge assemblies were fabricated from the vacuum dried material and sent to ARRADCOM for function time testing.

The ARRADCOM results were as follows:

Unit	Time
B/N 031080-1	3.23 ms
-2	2.76 "
-3	1.84 "
B/N 037080-1	1.85 "
-2	1.34 "

The results are inconclusive because the long time measurement of (3.23 ms) is suspect. The mean for the other four measurements is 1.70 ms and the sigma is 0.24 ms. Thus, the three sigma population extends to 2.43 ms which is well below the 3.23 ms measurement. This suggests the measurement itself is suspect; certainly the time is not within the 3 sigma normal distribution of the other four units.

Additional testing of a much longer population size with controlled moisture quantities is believed necessary to understand and resolve this question.

APPENDIX A

REQUIREMENTS:

A. The following requirements apply to a fuze/marker design for artillery applications:

1. The fuze(s) shall arm and function superquick only (regardless of setting) with a reliability not less than 97%. The fuze shall be bore safe as a minimum. The probability of a premature close to the weapon should not exceed 1 in 1,000,000.

2. It is desired that the fuze(s) not contain excessively energetic materials or mechanisms such that if accidentally initiated when assembled to an artillery projectile or ignited in a fire, it would be considered non-hazardous to personnel in the immediate vicinity. Expulsion of fuze or projectile components with lethal velocities is not acceptable.

3. Duds must be non-hazardous and stable enough for collection and transportation to another location for destruction.

4. Duds must remain stable and unactivated when stepped upon by troops engaged in training activities.

5. The fuze(s) functional principle shall be packaged in a standard artillery contour configuration as shown in Figure A1.

6. The fuze(s) shall provide non-functional setting features simulating those of Mechanical Time (MT), and Proximity (PROX) types. This may be accomplished by use of appropriate interchangeable sleeves, alternate body configurations, etc. Typical setting slot contours for MT and PROX fuzing is shown on Figures A2 and A3. The contour, weight and center of gravity of each tactical version shall be matched as close as possible so that ballistic match is preserved.

7. The fuze(s) shall function the spotting charge in the fuze out to max ranges of the specified weapons. The spotting charge contained within the fuze/projectile shall be visible to the naked eye out to the range of 2000 meters (2500 meters desired).

8. The fuze(s) shall be operable between the temperature limits of 0 -110°F and withstand storage in standard level "A" packaging for a period of not less than 10 years.

9. The fuze(s) shall be designed not to contain parts which may be easily omitted or malassembled during assembly operations, particularly any that might make the fuze unsafe.

10. The fuze(s) shall be capable of withstanding all linear, acceleration/deceleration forces, linear-lateral and angular velocity and spin eccentricity encountered at all charges in the 105MM, 155MM, 8 inch and 4.2 inch Weapons as indicated in Table A1.

11. The fuze(s) shall be designed to utilize an absolute minimum of critical materials including copper or copper alloys.

12. The fuze(s) shall be so designed that all materials are compatible.

13. The fuze(s) shall meet the requirements specified in MIL-STD-331A, dated 15 October 1976; "Environmental and Performance Tests for Fuze and Fuze Components" as follows:

a. Test 101.1 Jolt Procedure II: After completion of the Jolt Test, each sample fuze used shall be subjected to Test 102.1 Jumble. The fuze shall be considered acceptable provided the sample fuzes tested comply with paragraph 3.1 of Test 101.1 Jolt.

b. Test 103 - Forty Foot Drop

c. Test 401 - Transportation Vibration

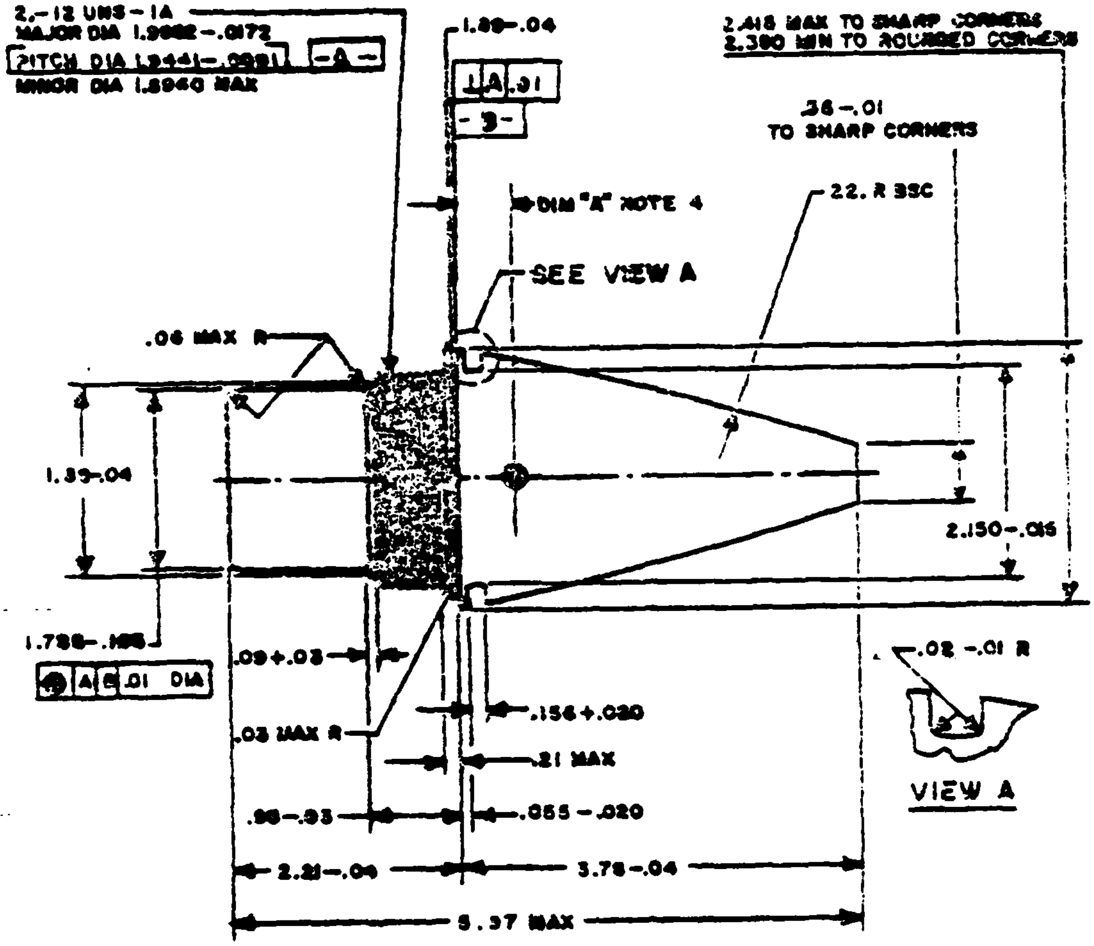
d. Test 108 - Waterproofness

e. Test 111.1 - 1.5 Metre Drop: Criteria A (Paragraph 3.1.1).

f. Test 114 - Rough Handling

14. It is desired that the unit production fuze cost after the third year of mass production should not exceed $5.50 based on 1976 costs and a monthly production rate of 93,000 fuzes.

15. A Safety Statement will be required in accordance with provisions of DIH 1322A.



NOTES:

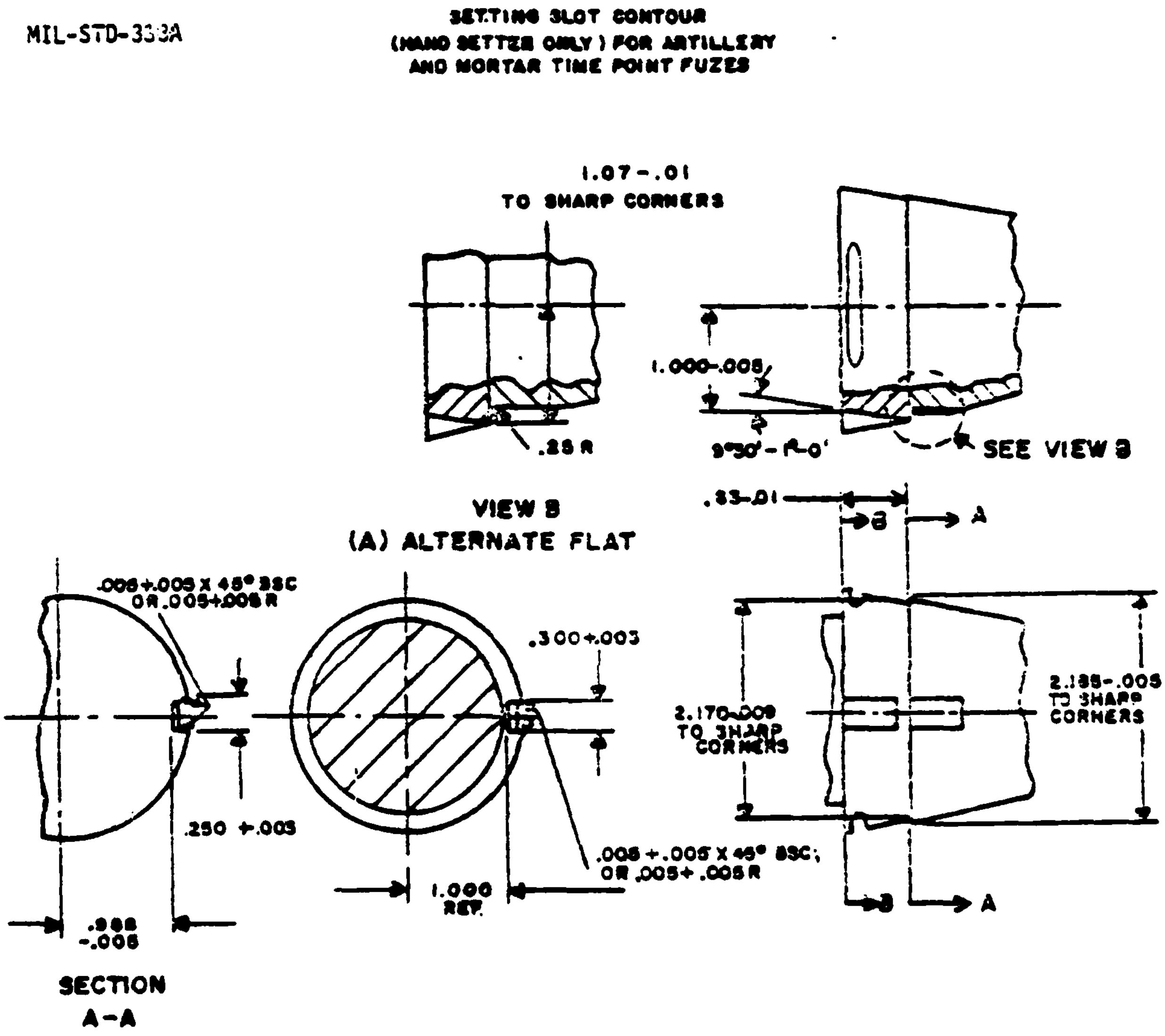
1-Figure A1 is used with Artillery Practice Projectiles 105MM and larger. Simulated PD, MTSQ, ETSQ & PROX types can be provided to this contour.

2-Deviation within the prescribed contour permitted only to the extent that the relative drag coefficient between fuze types shall not exceed 0.5% (0.1% desired) to satisfy ballistic match requirements. Refer to Fig. A1 for typical absolute values of drag coeeficients.

3-Dimension "A" indicates location of center of gravity.

4-For dimensions of slots for hand setters for field artillery and spin stabilized mortar time point fuzes.

FIGURE A1
CONTOUR FOR ARTILLERY POINT PRACTICE FUZE
CALIBER 75MM AND LARGER-UNIT WEIGHT 1.55±.05 LBS.

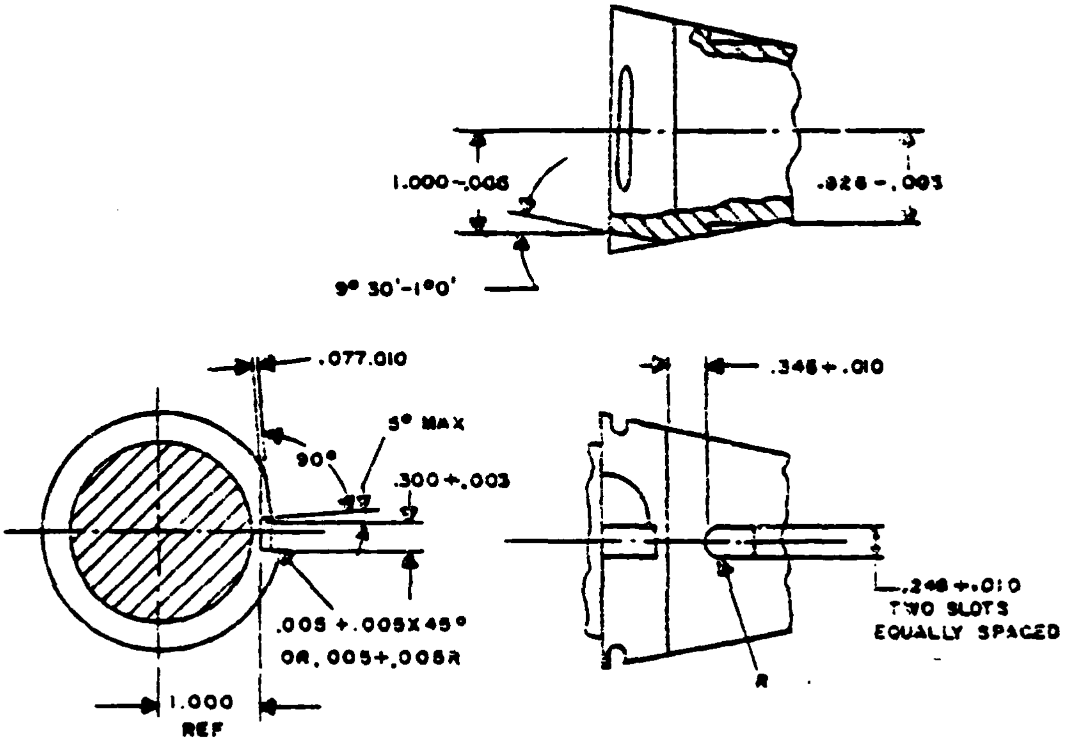


NOTES:

1-Figure A2 and A2A are used for dimensions of slots for hand setters on artiller mortar (81mm and spin stabilized), shallow intrusion time point fuzes and deep intrusion proximity point fuzes.

2-Orientation of fixed slot to moveable slot is for drafting convenience. Normal when the fuze is set "safe" (as received by the troops) the moveable slot is positioned counterclockwise from the fixed slot, for fuzes set clockwise when viewed from the nose of the fuze. Conversely, when the moveable slot is positio clockwise from the fixed slot, the fuze is set counterclockwise when viewed from the nose of the fuze.

FIGURE A2
SETTING SLOT CONTOUR
(HAND SETTER ONLY) FOR ARTILLERY
AND MORTAR TIME POINT FUZES



NOTES:

1-Figure A3 is used for dimensions of slots for hand setter on artillery mortar (81mm and spin stabilized), and shallow intrusion time point fuzes.

2-Orientation of fixed slot to moveable slot is for drafting convenience. Normally when the fuze is set "safe" (as received by the troops) the moveable slots are approximately 45 degrees counterclockwise from the fixed slot when viewed from the nose of the fuze.

3-All other dimensions to be shown on Figure A2.

FIGURE A3
SETTING SLOT CONTOUR
(HAND SETTER ONLY) FOR ARTILLERY AND
MORTAR TIME POINT FUZES

DATE: 27 Aug 76

SHEET 1 of 2

TABLE A1
WEAPON/AMMUNITION DATA
NOMINAL VALUES

WEAPON					AMMO		PROPELLANT		MUZZLE VELOCITY	CHAMBER PRESSURE	ACCEL	SPIN
CAL	TYPE	MOD	CANNON	TWIST	PROJ	WT	ZONE	TYPE	FPS	PSI	G	RPM
105mm	Howitzer	M102	M103, M137, M165	1/35-1/18	HE M1	33	1	M67	673	8100	3330	6510
							7		1615	38000	15700	15626
					HE XM606	28.5	1	M84	420	5300	2496	4063
							8	M85	2200	42600	20061	21287
					RAP HE XM547E1	28.5	1	M84	420	-	-	-
							7	XM176	1600	31700	14929	17417
			M2A2, M49, M4A1	1/20	HE M1	33	1	M67	640	6900	2806	5574
							7		1525	34200	13910	13281
					HE XM606	28.5	1	M84	394	5300	2496	3431
							7		1653	28400	13374	14395
					RAP HE XM547E1	28.5	1	M84	394	5300	2496	3812
							7	XM176	1635	25000	11773	14239
			XM 204	1/35-1/18	HE M1	33	1			9100	3700	-
							8		2170	45000	18302	21060
155mm	Howitzer	M109	M126, M126A1	1/20	HE M107	95	1	M3	699	7000	1960	4124
							7	M4A1	1841	36400	11206	10861
		M109A1	M185, XM181, XM199	1/20	HE M107	95	1	M3	710	5600	1539	4189
							8	M119	2245	30200	9298	13245
		XM198	XM181, XM199	1/20	RAP HE XM549	96	1	XM164	700	6000	1828	4130

TABLE A1

WEAPON/AMMUNITION DATA

NOMINAL VALUES

DATE: 27 Aug 76

SHEET 2 of 2

WEAPON					AMMO		PROPELLANT		MUZZLE VELOCITY	CHAMBER PRESSURE	ACCEL	SPIN
CAL	TYPE	MOD	CANNON	TWIST	PROJ	WT	ZONE	TYPE	FPS	PSI	G	RPM
							8	XM123E2	1800-2250	35500-47500	11000-14500	10600-13500
		M114A1	M1, M1A1, M45	1/25	HE M107	95	1	M3	660	5400	1680	3257
							7	M4A1	1850	36400	11206	8862
8 in.	Howitzer	M110	M2, M2A1,M2A2,M47	1/25	HE M106	200	1	M1	829	9600	2413	2952
							8	XM161	2200	38500	9676	7920
				1/20	RAP HE XM650	200	1	M1	838	8000	2010	3771
							9	XM188	2550	39600	9953	11385
175mm	Gun	M107	M113A1	1/20	HE M437	147.75	1	M86A2	1675	10300	2600	8752
							3		3000	47200	11910	15675
4.2 in.	Mortar		M30	0 TO 1/20	HE M329A1	26.23	5	M36A1	356	3300	2219	3051
							41	M36	983	14300	9617	8425
81mm	Mortar		M29	0	HE M374A2	9.12	0	M9	209	900	490	0
							9	M9	877	8400	7380	0
60mm	Mortar		M2	0	HE M49A4	3.1	0	M9	172	500	700	0
							4	M9	516	3700	5210	0

Reference: 1. Artillery Ammunition Master Calibration Chart - TECOM Rpt #1375 Rev. 15 (Feb 73)

2. Final Report - Study of Setback & Spin - Rpt. #DPS-2611, L. Heppner (Jan 68.)

APPENDIX B

MATERIAL ALLOWABLES

ASTM A-109 TEMPER 5

$F_{ty} = 44 \times 10^3$ PSI

OTHER PROPERTIES CAN BE EXPECTED TO BE

$F_{tu} = 67 \times 10^3$ PSI

$F_{su} = 44 \times 10^3$ PSI

REF ASME HANDBOOK, "METALS PROPERTIES," McGRAW-HILL, 1954

FACTORS OF SAFETY

USE STANDARD AEROSPACE VALUES

FS = 1.15 YIELD STRENGTH

FS = 1.50 ULTIMATE STRENGTH

MARGIN OF SAFETY

DEFINITION: PERCENTAGE THAT MATERIAL ALLOWABLE EXCEEDS THE WORKING STRESS TIMES THE FACTOR OF SAFETY

$$MS = \frac{F_t}{FS \times f_t} - 1$$

$MS > 0$ FOR ADEQUATE STRUCTURE

5.G. 12-75

PRACTICE FUZE STRESS ANALYSIS

LOADING CONDITIONS

SURVIVE - SET-BACK FORCES
11,200 G'S

OPERATE - DETONATION

APPROACH

AARADCOM CONFIG TO BE CHECKED ONLY FOR SET-BACK FOR FAILURE OF THREADS AT CUP/BODY INTERFACE & CUP BASE

MBA CONFIG TO BE SIZED TO SURVIVE SET-BACK & FAIL AT DETONATION.

CUP/BODY INTERFACE

CUP (- TICL4) - EST STRESS CONCENTRATION

EST DESIGN BASED ON SET-BACK

EVALUATE STRENGTH TO DETERMINE FAILURE MODES AT DETONATION.

WGT OF SMOKE CONTAINER 50 GRMS

TANGENTIAL STRESS

$$f_t = \frac{3W}{2\pi m t^2}\left[1 - \frac{r_0^2}{a^2}\right]$$

$$m = 1/\mu = 1/.3$$

$$\therefore \; f_t = .3 f_r = 6600 \text{ PSI}$$

DETERMINE MAXIMUM OCTAHEDRAL STRESS

SEE "ANALYSIS AND DESIGN OF FLIGHT VEHICLE STRUCTURES," EF BRUHN, 1965, CHAPTER C1 PG.17 FOR OCTAHEDRAL SHEAR STRESS THEORY.

$$f_{max} = \sqrt{f_r^2 + f_t^2 - f_r f_t}$$

$$f_{max} = \sqrt{(22)^2 + (6.6)^2 - (22)(6.6)}\; 10^3$$

$$= 19{,}500 \text{ PSI}$$

MARGINS OF SAFETY

$$MS = \frac{F_t}{FS \times f_t} - 1$$

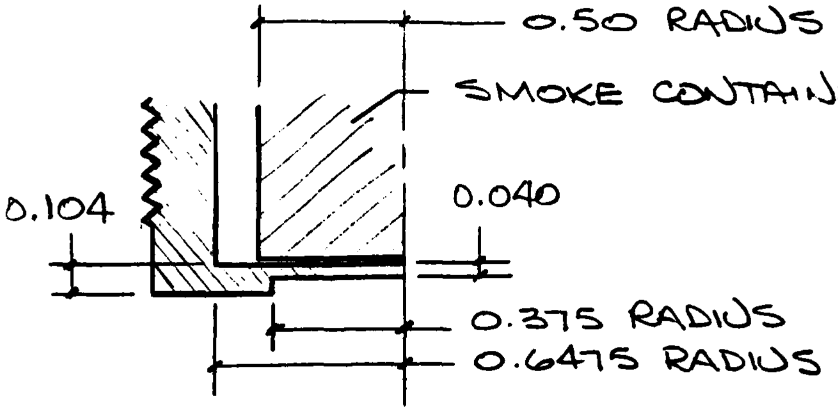
YIELD

$$MS = \frac{44 \times 10^3}{1.15(19.5 \times 10^3)} - 1 = \underline{\underline{0.96}}$$

ULTIMATE

$$MS = \frac{67 \times 10^3}{1.5(19.5 \times 10^3)} - 1 = \underline{\underline{1.29}}$$

AARADCOM CONFIGURATION - BOOSTER CUP BASE



SMOKE CONTAINER (MOD E)

$W = 50/453.8 = 0.110$ LB

$\ddot{X} = 11{,}200$ G'S

$F = (0.110)(11{,}200) = 1234$ LB

SOLVE FOR STRESS AT EDGE USING ROARK 4TH ED p 218 CASE 3 EDGES FIXED UNIFORM LOAD OVER CONCENTRIC CIRCLE r_0

RADIAL STRESS

$$f_r = \frac{3W}{2\pi t^2}\left[1 - \frac{r_0^2}{a^2}\right]$$

$a = 0.6475$

$r_0 = 0.50$

$$f_r = \frac{3(1234)}{2\pi(.104)^2}\left[1 - \left(\frac{.5}{.6475}\right)^2\right]$$

$f_r = 22000$ PSI

$$f_t = -\frac{3W}{2\pi m t^2}\left[(m+1)\log\frac{a}{r_o} + (m+1)\frac{r_o^2}{4a^2} - (m+3)\frac{r^2}{4r_o^2}\right]$$

$$(m+3)\frac{r^2}{4r_o^2} = \left(\frac{1}{.3}+3\right)\left(\frac{.375}{1.0}\right)^2 = 0.390$$

$$f_t = -\frac{3(66)3}{2\pi(.04)^2}\left[.486+.646-.390\right]$$

$$= -14{,}300 \text{ PSI}$$

MAXIMUM STRESS AT $r = 0.375$

$$f_{max} = \sqrt{(24.5)^2 + (14.3)^2 - (24.5)(14.3)} \times 10^3$$

$$= 21{,}300 \text{ PSI}$$

MARGINS OF SAFETY

YIELD

$$MS = \frac{44 \times 10^3}{(1.15)(21.3)10^3} - 1 = \underline{\underline{0.796}}$$

ULTIMATE

$$MS = \frac{67 \times 10^3}{(1.5)(21.3)10^3} - 1 = \underline{\underline{1.097}}$$

THE M8A CONFIGURATION IS IDENTICAL
TO MOD E FOR CUP BASE LOADING
SO THE MOD E STRESS ANALYSIS
APPLIES.

SOLVE FOR STRESS AT R=0.5 (EDGE OF 0.040 THK DISC)

THE CUP BASE IS A REDUNDANT STRUCTURE & THE LOAD WILL DISTRIBUTE ON TO THE TWO BASE THICKNESS SUCH THAT THEIR INTERFACE WILL HAVE THE SAME DEFLECTION. THE DISTRIBUTION WILL BE INVERSELY PROPORTIONAL TO THEIR DEFLECTION. ASSUME THE PLATE STIFFNESS RATIO IS PROPORTIONAL TO t^3 AS FOR A BEAM IN BENDING THEN THE LOAD ON THE CENTER WILL BE

$$W_c = \frac{(0.04)^3}{(.104)^3+(.04)^3} W$$

$$= 66 \text{ LB} \qquad .654$$

AGAIN FROM ROARK CASE 8 AT r=0.5

$$f_r = \frac{3W}{2\pi m t^2}\left[(m+1)\log\frac{a}{r_o} + (m+1)\frac{r_o^2}{4a^2} - (3m+1)\frac{r^2}{4r_o^2}\right]$$

$$(m+1)\log\frac{a}{r_o} = \left(1+\frac{1}{.3}\right)\log\frac{.6475}{.5} = 0.486 \ ?$$

$$(m+1)\frac{r_o^2}{4a^2} = \left(1+\frac{1}{.3}\right)\left(\frac{.5}{1.295}\right)^2 = 0.646$$

$$(3m+1)\frac{r^2}{4r_o^2} = \left(1+\frac{3}{.3}\right)\left(\frac{.375}{1.0}\right)^2 = 1.547$$

$$f_r = \frac{3(66)3}{2\pi(.04)^2}\left[.486+.646-1.547\right]$$

$$= -24500 \text{ PSI}$$

(- SIGN DENOTES TENSION ON TOP SURFACE)

$$f_s = \frac{P}{A} = \frac{8800}{2.5} = 3520 \text{ PSI}$$

MS = HIGH

CHECK BODY TENSION

$$A = \pi D_M t$$
$$= \pi(1.6)(.105) = 0.528 \text{ IN}^2$$

$$f_t = \frac{P}{A} = \frac{8800}{.528} = 16{,}700 \text{ PSI}$$

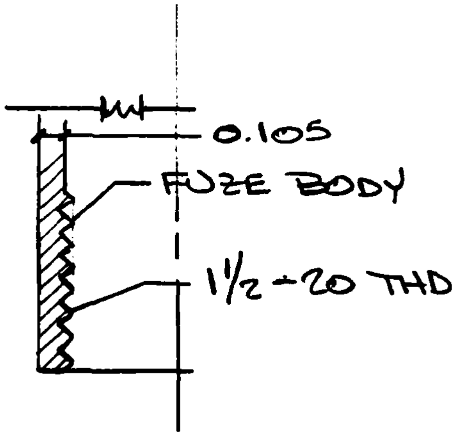
YIELD..

$$MS = \frac{42\times10^3}{1.15(16.7)10^3} - 1 = \underline{\underline{1.18}}$$

ULTIMATE

$$MS = \frac{62\times10^3}{1.5(16.7)10^3} - 1 = \underline{\underline{1.47}}$$

MBA CONFIGURATION - THREAD SHEAR



MATERIAL PROPERTIES

2024-T4 AL ALLOY

$F_{tu} = 62 \times 10^3$ PSI

$F_{ty} = 42 \times 10^3$ PSI

$F_{su} = 37 \times 10^{-3}$ PSI

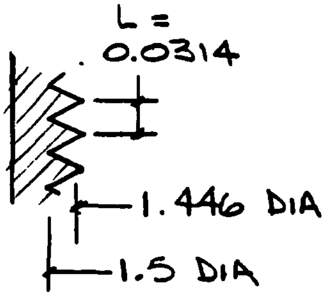
THE ALUMINUM BODY WILL BE CRITICAL BECAUSE THE ALUMINUM ALLOWABLES ARE SLIGHTLY LOWER THE THE A-109 STEEL VALUES

THE LOAD ON THE MBA CONFIGURATION IS ≃ 3 TIMES THAT ON THE MOD E FUZE ∴ ONLY THE MBA CONFIGURATION WILL BE ANALYZED

$$WGT(TICL4) = 0.565 \text{ LB}$$

$$WGT(WP + SMOKE) = 0.220 \text{ LB}$$

$$F = (.565 + .220)\,11{,}200 = 8800 \text{ LB}$$



AREA IN SHEAR

$$A = \pi D L N$$

$$= \pi(1.446)(0.0314)(17.5)$$

$$= 2.5 \text{ IN}^2$$

AREA OF PRESSURE ACTION

$$A = \frac{\pi}{4}(.375)^2 = 0.1104 \text{ IN}^2$$

$$\text{PRESSURE} = 206.3/.11$$

$$= 1870 \text{ PSI}$$

THIS PRESSURE APPEARS TO BE ON THE LOW SIDE A BETTER APPROACH MAY BE TO USE ROARK CASE 6, EDGES FIXED, UNIFORM LOAD OVER ENTIRE SURFACE.

$$f_r = \frac{3W}{4\pi t^2} \qquad f_t = \frac{3W}{4\pi m t^2}$$

$$\therefore \frac{f_t}{f_r} = .3 =$$

$$f_m = \sqrt{(.3)^2 + 1 - .3}\, f_t = 0.90 f_t$$

$$f_t = \frac{67 \times 10^3}{0.9} = 75\,400 \text{ PSI}$$

$$75\,400 = \frac{3W3}{4\pi(.105)^2} = 65W$$

$$W = 1160$$

$$\text{PRESSURE} = \frac{1160}{.1104} = 10{,}507 \text{ PSI}$$

WHICH APPEARS TO BE A MORE MEANINGFUL VALUE.

EVALUATION OF RUPTURE PRESSURE

THE PRESSURE REQUIRED TO RUPTURE THE CUP BASE CAN BE ESTIMATED BY DETERMINING THE FORCE REQUIRED TO FAIL THE BASE & THE TRANSLATING THIS FORCE INTO A PRESSURE

THE MINIMUM MARGINS OF SAFETY OCCUR AT THE CHANGE IN BASE THICKNESS, WHERE

$$f_r = \frac{3W}{2\pi m t^2}\left[(m+1)\log\frac{a}{r_0} + (m+1)\frac{r_0^2}{4a^2} - (3m+1)\frac{r^2}{4r_0^2}\right]$$

$$f_t = \frac{3W}{2\pi m t^2}\left[(m+1)\log\frac{a}{r_0} + (m+1)\frac{r_0^2}{4a^2} - (m+3)\frac{r^2}{4r_0^2}\right]$$

BECAUSE ONLY W IS A VARIABLE THE RATIO f_r/f_t WILL BE A CONSTANT

EQUATION f_{max} TO THE ULTIMATE ALLOWABLE

$$F_u = f_{max} = \sqrt{f_r^2 + f_t^2 - f_r f_t}$$

$$f_r/f_t = \frac{24.5}{14.3} = 1.713$$

$$F_u = \sqrt{(1.713)^2 + 1 - 1.713}\ f_t$$

$$= 1.5 f_t \qquad f_t = \frac{67\times10^3}{1.5} = 44{,}700 \text{ PSI}$$

$$44{,}700 = \frac{3W3}{2\pi(.04)^2}\left[.486 + .646 - .390\right]$$

$$W = 206.3 \text{ LB}$$

APPENDIX C

SUMMARY - FT LEWIS TEST RESULTS

FUZE, PRACT XM747E-, PROJ 155MM, XM804
(155MM HOW M114A1 - CHG M4A2/5)

DATE DEC 79	QUAN	MOD FUZE/SMOKE	PROJ MOD	QE	RNG OF OBSER (KM)	RESULTS
				PHASE I		
	8	E2/E	4-Hole	LA	1.8	FAIR TO GOOD SMOKE & FLASH
18	8	E2/ORI	"	LA	TO	POOR SMOKE & FLASH (ELIMINATE IN PH II)
	8	E2/MBA	"	LA		FAIR SMOKE, NEGLIGIBLE FLASH
	5	M739	M107/T2	LA	4.0	CONTROLS
				PHASE II(1)		
	8	E2/E	4-Hole	LA	1.8	POOR TO FAIR SMOKE
19	8	E2/MBA	"	HA	TO	GOOD TO EXCELLENT SMOKE (SELECT FOR PHASE III)
(AM)	8	E2/E	"	LA		POOR SMOKE
	8	E2/MBA		HA		POOR SMOKE
	3	M739	M107/T2	2 LA, 1 HA	2.0	CONTROLS
				PHASE III		
	9(2)	E2/MBA	4-Hole	LA	1.8	POOR TO FAIR SMOKE & FLASH
19	1	E2/E	"	LA		POOR TO FAIR SMOKE & FLASH
(PM)	10	M739	T2	LA	TO	FLASH/SMOKE SMALL - NOT PERSISTENT
	10	M739	H6	LA		BETTER THAN T2 TYPE
	3	E1/E	NONE	LA		VERY POOR
	1	M739	M107/T2	LA	2.0	CONTROLS
TOT	98					

(1) INADVERTENTLY SEVEN XM804 PROJECTILES W/90° HOLES WERE FIRED AMONG PROJECTILES W/45° HOLES WITHOUT ASSOCIATION TO FUZE/ROUND COMBINATION.

(2) FIRST THREE ROUNDS WERE PROJECTILES WITH 90° HOLES. ALL OTHERS HAD 45° HOLES.

DATA & SUMMARY SUPPLIED BY ARRADCOM

PHASE I - OBSERVER ANALYSIS
155MM×M804 TRAINING PROJECTILE
WITH 4 EACH 1/2" DIA SMOKE PORTS

TEST DATE: DEC. 18, 1979

OBSERVERS
1. GI-FO 4000M
2. GI FO 4000M
3. MBAssociates 4000M
4. ARRADCOM 2000M
5. Y.P.G. 2000M
6. ARRADCOM 1800M
7. FT. CILL 2000M

TYPE	TEST	SMOKE							FLASH							RATING
FUSE	SERIES	1	2	3	4	5	6	7	1	2	3	4	5	6	7	SUMMATION
MOD "E"	1	4	4	F	G	?	G	G						X		23
	2	4	3	P	F	G	G	F						X		23
	3	?	?	U	F	G	G	F								15
	4	1	1	U	U	G	U	U								10
	5	2	2	U	P	G	F	U								15
	6	6	6	U	G	P	G	G						?		27
	7	5	6	G	G	VG	G	G	X			X				32
	8	5	6	G	F	G	G	G	X	X		X		X		29
	TOTAL															174
ORI	1	1	1	U	U	P	U	U								8
	2	3	2	P	G	G	F	G								22
	3	1	1	U	U	U	P	U								8
	4	1	1	U	U	G	U	U								10
	5	4	3	U	U	G	P	U					X			16
	6	4	4	F	F	U	P	P	X	X	X	X		X	X	19
	7	1	1	U	U	U	U	U								7
	8	4	5	G	Ex	G	G	VG	X	X	X	X		X	X	32
	TOTAL															122
MBA	1	1	2	U	P	P	F	P								13
	2	3	3	U	G	G	F	G								22
	3	1	1	U	G	P	F	P								14
	4	3	4	U	F	P	F	P								18
	5	1	2	U	U	P	P	P								11
	6	2	2	U	P	P	P	U								12
	7	5	6	G	G	G	G	VG	X	X						32
	8	4	4	F	U	G	F	P								21
	TOTAL															143

LEGEND

1 - U = UNOBSERVED
2 - P = POOR
3 - F = FAIR
4 - G = GOOD
5 - VG = VERY GOOD
6 - EX = EXCELLENT

PHASE II - OBSERVER ANALYSIS
155MMXM804 TRAINING PROJECTILE
WITH 4 EACH 1/2" DIA PORTS
LOW ANGLE - QE 522 MILS

TEST DATE: DEC. 19, 1979 (A.M.)

OBSERVERS
MBASSOCIATES 1800M
GI-FO 1800M
GI-FO 1800M
ARRADCOM 1800M
GI-FO 2000M
GI-FO 2000M
ARRADCOM 2000M
Y.P.G 2000M
CHAMBERLAIN 2000M
ARRADCOM 2000M
FT. CILL 2000M

TYPE	TEST	SMOKE											FLASH											RATING
FUSE	SERIES	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	10	11	SUMMATION
MOD"E"	1	1	1	1	1	1	2	1	2	1	1	1												13
	2	3	4	4	3	2	2	1	2	1	3	2												27
	3	1	1	1	1	1	1	1	1	1	1	1												11
	4	4	5	5	4	4	3	2	4	1	3	4												39
	5	3	2	2	3	1	1	1	1	3	1	1												19
	6	3	4	3	3	3	2	2	3	1	3	2												29
	7	3	5	5	4	3	3	3	4	1	4	3												38
	8	4	3	4	3	3	2	1	2	4	2	2												30
	TOTAL																							205
MBA	1	2	2	3	2	2	2	1	1	1	1	1			X									18
	2	5	5	5	4	4	3	4	4	4	4	5		X										47
	3	5	5	5	4	4	4	3	5	4	4	5												48
	4	5	5	5	4	4	4	4	5	4	4	5												49
	5	5	5	5	4	4	4	4	5	4	5	5												50
	6	4	5	5	4	4	4	3	5	4	4	5												47
	7	4	5	5	4	4	4	4	5	4	5	5												49
	8	4	5	5	5	4	4	5	5	4	5	5												51
	TOTAL																							358

NOTE:
INADVENTENTLY SEVEN XM804 PROJECTILES WITH 90° HOLES WERE FIRED AMONG PROJECTILES WITH 45° HOLES IN PHASE II WITHOUT ASSOCIATION TO TYPE OF FUSE/ROUND COMBINATION.

LEGEND
1. = UNOBSERVED
2 = POOR
3 = FAIR
4 = GOOD
5 = EXCELLENT

PHASE II - OBSERVER ANALYSIS
155 MM XM 804 TRAINING PROJECTILE
WITH 4 EACH 1/2" DIA PORTS
HIGH ANGLE-QE 1054 MILS

TEST DATE: DEC. 19, 1979 (AM)

		OBSERVERS																						
		MBASSOCIATE 1800M	GI-FO 1800M	GI-FO 1800M	ARRADCOM 1800M	GI-FO 2000M	GI-FO 2000M	ARRADCOM 2000M	Y.P.G 2000M	CHAMBERLAIN 2000M	ARRADCOM 2000M	FT. CILL 2000M												
TYPE	TEST	SMOKE											FLASH										RATING
FUSE	SERIES	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	10	11	SUMMATION
MOD'E'	1	3	2	3	3	2	2	2	3	2	3	3												28
	2	2	1	1	1	1	1	1	1	1	1	1												12
	3	1	1	1	1	1	1	1	1	1	1	1												11
	4	3	3	2	3	2	2	1	2	1	1	1												21
	5	1	3	3	3	1	3	3	4	3	2	2												28
	6	3	1	1	1	1	1	1	1	1	1	1												13
	7	2	3	3	3	1	1	1	4	1	2	3												24
	8	2	2	2	3	1	2	2	2	1	2	2												21
	TOTAL																							158
MBA	1	2	2	3	2	2	2	1	1	1	1	1												18
	2	3	3	3	2	2	2	2	4	2	2	2												27
	3	1	1	1	1	1	1	1	1	1	1	1												11
	4	2	3	2	1	1	1	1	3	1	1	2												18
	5	2	2	2	1	2	2	2	2	1	1	1												18
	6	1	3	3	3	2	2	1	2	1	1	1												20
	7	1	2	2	1	2	1	2	2	1	2	1												17
	8	1	4	4	2	2	3	4	3	2	3	3												30
	TOTAL																							161

NOTE:

INADVENTENTLY SEVEN XM804 PROJECTILES WITH 90° HOLES WERE FIRED AMONG PROJECTILES WITH 45° HOLES IN PHASE II WITHOUT ASSOCIATION TO TYPE OF FUSE/ROUND COMBINATION.

LEGEND

1 - UNOBSERVED
2 - POOR
3 - FAIR
4 - GOOD
5 - EXCELLENT

PHASE III- OBSERVER ANALYSIS
155 MMXM 804 TRAINING PROJECTILE
WITH 4 EACH 1/2" DIA PORTS
LOW ANGLE - QE 522 MILS

TEST DATE: DEC. 19, 1979 (P. M.)

OBSERVERS
MBASSOCIATES 1800M
ARKADCOM 1800M
ARRADCOM 2000M
ARRADCOM 2000M
CHAMBERLAIN 2000M
FT. CILL 2000M
G1-FO 2000M
G1-FO 2000M
G1-FO 1800M
G1-FO 2000M

TYPE	RD	SMOKE										FLASH										RATING
FUSE	NO	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	SUMMATION
MBA	1	3	3	?	?	?	?	?	3	?	3		X		X		?	?		?		12
MBA	2	4	3	4	3	4	3	3	4	3	5		X	X	X	X	X	X		X		36
MBA	3	2	2	3	2	2	2	3	2	3	4		X				X	X		X		25
MBA	4	2	3	2	1	2	2	3	2	3	3		X									23
MBA	5	1	1	1	1	1	1	2	1	2	1		X					X	X	X		12
E	6	3	3	2	1	2	2	3	2	3	3		X		X			X	X			—
MBA	7	3	3	1	2	3	2	3	3	3	3		X		X		X			X		26
MBA	8	5	4	5	4	4	5	5	5	4	5		X		X			X		X		46
MBA	9	?	?	1	1	1	2	3	3	1	3		X				X					17
MBA	10	5	3	5	3	4	5	5	5	4	5		X		X		X	X		X		44
	TOTAL																					241

NOTE:
FIRST THREE (3) MBA ROUNDS WERE XM 804 PROJECTILES WITH 90° HOLES ALL OTHERS HAD 45° HOLES

LEGEND
1 · UNOBSERVED
2 - POOR
3 - FAIR
4 - GOOD
5 - EXCELLENT

How to Use Probability Paper to Solve Materials Problems

It can help you

1. *Set specification limits*
2. *Check material or process performance over a period of time*
3. *Check a supplier's claims*

by Donald Peckner, *Associate Editor, Materials in Design Engineering*

Application of statistical quality control principles is simplified when arithmetic probability paper is used. This type of paper has as its abscissa a probability scale, and as its ordinate a linear arithmetic scale on which the variable is plotted.

On a probability plot, a large amount of data, which may extend over a wide range, is condensed to only two numbers: the arithmetic mean $\bar{X}$, and the estimate of the standard deviation, s. For most engineering purposes, the arithmetic mean and the estimate of standard deviation, together, furnish the information necessary so that a material can be used.

Since 50% of the total number of observations will be above, and 50% below, the arithmetic mean, the intercept of the ordinate and the 50% abscissa can be read to obtain the mean directly.

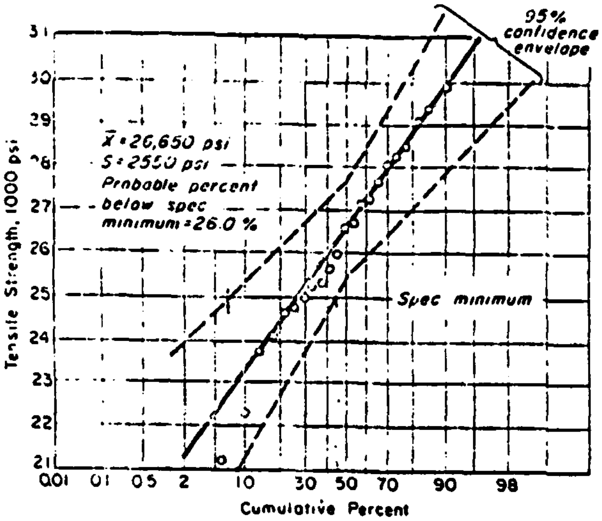
To obtain the value of s, another well-known property of the normal distribution is used. On probability paper the area under the curve between the 16% and 84% abscissas is equivalent to the value of $\bar{X} \pm s$. Therefore, determining the intercept of the curve with the 84% abscissa and subtracting $\bar{X}$ will give the value of s directly.

How to plot the data

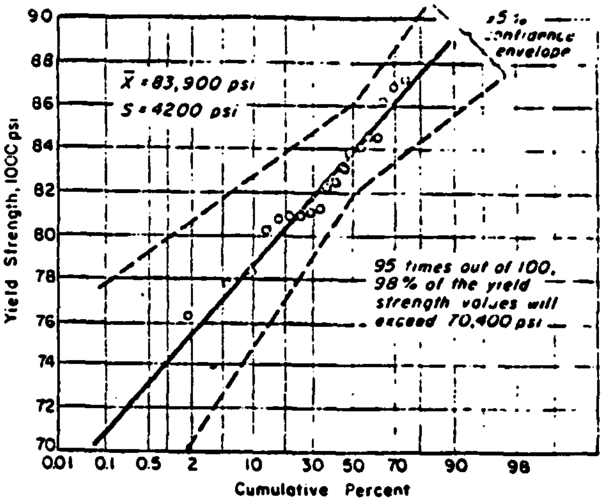
The next few paragraphs describe how to plot data on prob-

TABLE 1—CUMULATIVE PERCENTS CORRESPONDING TO VARIOUS SAMPLE SIZES

Observation Number	10	11	12	13	14	15	16	17	18	19	20	21	22	23	✓ 24	25	26	27	28	29	30
1	5	4.5	4.2	3.8	3.6	3.3	3.1	2.9	2.8	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.9	1.8	1.7	[illegible]
2	15	13.6	12.5	11.5	10.7	10.0	9.4	8.8	8.3	7.9	7.5	7.1	6.8	6.5	6.25	6.0	5.8	5.6	5.4	5.2	[illegible]
3	25	22.7	20.8	19.2	17.8	16.7	15.6	14.7	13.9	13.2	12.5	11.9	11.4	10.9	10.4	10.0	9.6	9.3	8.9	8.6	8.3
4	35	31.8	29.2	26.9	25.0	23.3	21.9	20.6	19.4	18.4	17.5	16.7	15.9	15.2	14.6	14.0	13.5	13.0	12.5	12.1	[illegible]
5	45	40.9	37.5	34.6	32.1	30.0	28.1	26.4	25.0	23.7	22.5	21.4	20.4	19.6	18.75	18.0	17.3	16.7	16.1	15.5	[illegible]
6	55	50.0	45.8	42.3	39.2	36.7	34.4	32.3	30.6	29.0	27.5	26.2	25.0	23.9	22.9	22.0	21.2	20.4	19.6	19.0	[illegible]
7	65	59.1	54.2	50.0	46.4	43.3	40.6	38.2	36.1	34.2	32.5	30.9	29.6	28.3	27.1	26.0	25.0	24.1	23.2	22.4	21.7
8	75	68.2	62.5	57.7	53.5	50.5	46.9	44.1	41.7	39.5	37.5	35.7	34.1	32.6	31.25	30.0	28.9	27.8	26.8	25.9	25.0
9	85	77.3	70.8	65.4	60.7	56.7	53.1	50.0	47.2	44.8	42.5	40.5	38.7	37.0	35.4	34.0	32.7	31.5	30.4	29.3	28.3
10	95	86.4	79.2	73.1	67.8	63.3	59.4	55.9	52.8	50.0	47.5	45.2	43.2	41.3	39.6	38.0	36.6	35.2	33.9	32.8	31.7
11		95.5	87.5	80.8	75.0	70.0	65.6	61.8	58.4	55.3	52.5	50.0	47.7	45.7	43.75	42.0	40.4	38.9	37.5	36.2	35.0
12			95.8	88.5	82.1	76.7	71.9	67.7	63.9	60.6	57.5	54.7	52.2	50.0	47.9	46.0	44.2	42.6	41.1	39.7	38.3
13				96.2	89.2	83.3	78.1	73.6	69.4	65.8	62.5	59.5	56.8	54.4	52.1	50.0	48.1	46.3	44.6	43.1	41.7
14					96.4	90.0	84.4	79.5	75.0	71.1	67.5	64.4	61.4	58.7	56.25	54.0	51.9	50.0	48.2	46.6	45.0
15						96.7	90.6	85.4	80.6	76.4	72.5	69.1	66.0	63.1	60.4	58.0	55.8	53.7	51.8	50.0	48.3
16							96.9	91.2	86.1	81.6	77.5	73.8	70.5	67.4	64.6	62.0	59.6	57.4	55.4	53.7	51.7
17								97.1	91.7	86.9	82.5	78.6	75.0	71.8	68.75	66.0	63.5	61.1	58.9	56.9	55.0
18									97.2	92.2	87.5	83.4	79.6	76.1	72.9	70.0	67.3	64.8	62.5	60.4	58.3
19										97.4	92.5	88.1	84.1	80.5	77.1	74.0	71.2	68.5	66.1	63.8	61.7
20											97.5	93.0	88.6	84.8	81.25	78.0	75.0	72.2	69.6	67.3	65.0
21												97.7	93.2	89.2	85.4	82.0	73.8	75.9	73.2	70.7	68.3
22													97.7	93.5	89.6	86.0	82.7	79.6	76.8	74.2	71.7
23														97.9	93.75	90.0	86.5	83.3	80.4	77.6	75.0
24															97.9	94.0	90.4	87.0	83.9	81.1	78.3
25																98.0	94.2	90.7	87.5	84.5	81.7
26																	98.1	94.4	91.1	88.0	85.0
27																		98.1	94.6	91.4	88.3
28																			98.2	94.9	91.7
29																				98.3	95.0
30																					98.3



1—*Distribution of tensile strength on arithmetic probability paper is accurate check on material performance.*



2—*Distribution of yield strength forecasts minimum expected values for use in setting specification limits.*

ability paper in two situations: 1) when the number of data is small, and 2) when the data are available in large quantities that cannot be conveniently handled without grouping.

After arranging the data so that cumulative percentages can be obtained and plotted, the next step is to determine the scatter of data that might be encountered. This can be done by making use of the confidence envelope which is described in detail in an accompanying box.

When the number of data is small (30 or less)—Arithmetic probability paper, in this case, is used as follows:

1. Arrange the data in order of increasing magnitude and assign each datum point a cumulative percentage value from Table 1.

2. Choose an appropriate scale on the abscissa and plot the data against the appropriate cumulative percentage value on the ordinate.

Table 2 is an example of random numbers rearranged and assigned a cumulative percentage from Table 1.

When the number of data is large—When more than 30 observations must be plotted, the method just described becomes both lengthy and tedious. The procedure is varied as follows:

1. Tabulate the number of observations that lie in equal-sized intervals. The interval should be at least 10 times the last significant figure to which the values are measured.

2. Calculate the percentage of observations in each interval and determine the cumulative percentage in and below the interval.

3. Plot the cumulative percent on the probability scale against the *top* of each interval on the abscissa.

A typical arrangement of data is shown in Table 3.

How probability paper can be used

To check material performance—Fig 1 demonstrates the use of arithmetic probability paper to check performance of a material. The data represent a permanent mold cast aluminum alloy with a specified minimum tensile strength of 25,000 psi. Data were obtained over a three month period. As seen in Fig 1:

1. Average tensile strength to be expected is 26,650 psi.

2. By inspection, the intercept of the specification minimum and the curve indicates that 26% of

TABLE 2—ARRANGING DATA FOR USE WITH TABLE 1

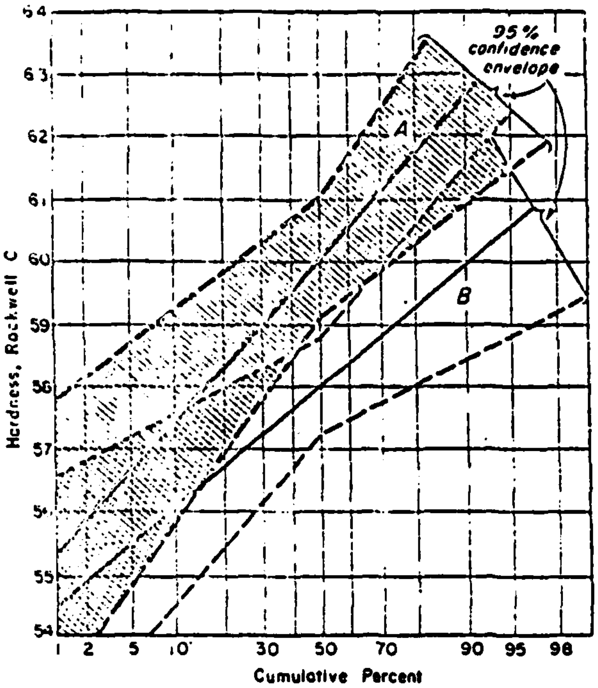
Observation	Rearranged, Magnitude Increasing	Cumulative Percent*
477	370	4.2
370	440	12.5
491	463	20.8
463	471	29.2
440	477	37.5
495	478	45.8
506	486	54.2
509	491	62.5
471	493	70.8
486	495	79.2
478	506	87.5
493	509	95.8

*Taken from Table 1.

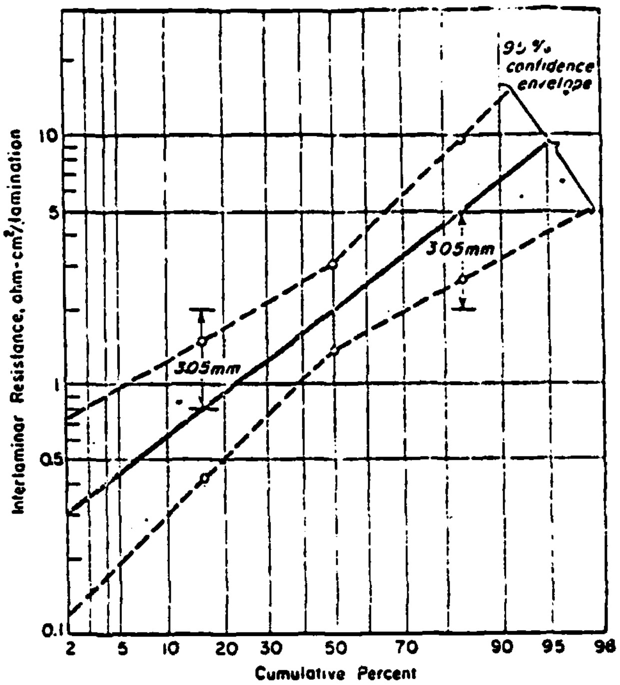
TABLE 3—ARRANGING LARGE NUMBERS OF OBSERVATIONS

Interval, arbitrary units	Number of Observations In Each Interval	Observations In Each Interval, %	Cumulative Percent
6.01-6.10	1	0.5	0.5
6.11-6.20	9	4.5	5.0
6.21-6.30	36	18.0	23.0
6.31-6.40	68	34.0	57.0
6.41-6.50	57	28.5	85.5
6.51-6.60	24	12.0	97.5
6.61-6.70	4	2.0	99.5
6.71-6.80	1	0.5	100.0*

*This number cannot be plotted since, theoretically, it is at infinity on this scale.



3—*Two groups of hardness data are compared. Since confidence envelopes do not overlap at the 50% ordinate, the groups are different and Process A will produce better results than Process B 95% of the time.*



4—*Confidence envelope for logarithmic probability paper. Estimate of standard deviation (s) is made equivalent to distance between 50% ordinate and either 16% or 84% ordinate.*

the material will probably be below the specification minimum.

3. The confidence envelope indicates that 95 times out of 100, as little as 7.5% and as much as 45% of the material can be expected to exhibit a tensile strength below the specification minimum.

Probability paper, then, shows the engineer how well a material is performing and suggests a course of action to follow. In this case, there are two possible courses: either revise the specification properties in accordance with the facts of actual performance, or choose a new alloy for the application.

To set up specification limits—Take a case where a literature survey turned up a promising casting alloy but, as usual, only average mechanical properties were quoted. Since an arithmetic average gives no indication of values at the extremes of a distribution, a more precise estimate of mechanical properties was needed for specification purposes.

By pouring tensile bars from several experimental heats, it is possible to forecast the minimum expected values of yield strength, tensile strength, elongation, etc., and incorporate them into a specification. In this use the probability plot in Fig 2 indicates that 95% of the time a specified yield strength of 70,000 psi will be obtained 98 times out of 100.

To compare sets of data—An additional useful application of arithmetic probability paper is the comparison of several sets of data to determine whether they were picked from the same or from different distributions. This is a general engineering problem since many situations occur where a design or process is changed and a decision must be made as to whether a real improvement has been obtained, i.e., an improvement that matches the economic factors involved.

Two heat treating methods gave the hardness results plotted in Fig 3. Although the variation in hardness produced by process A is no less than that produced by process B, a comparison of the arithmetic means ($\bar{X}$) shows that process A will consistently produce higher average hardness values. Since the confidence envelopes do not overlap at the 50% ordinate, it can be stated with 95% confidence that the two heat treating processes are significantly different.

When data are not normally distributed

One major shortcoming of probability paper should be noted here. If the data do not fall on an approximately straight line when plotted on arithmetic probability paper, this method of analysis cannot be used. Radical deviation from a straight line indicates a skewed distribution (some types of data, such as measurements of interlaminar resistance or stress rupture, seem to be inherently skewed), whereas the scale of the abscissa has been based on a normal distribution. The case with which the arithmetic mean ($\bar{X}$) and the estimate of standard deviation (s) can be obtained sometimes leads to an artificial "fit" of a straight line to the data with the consequence that invalid data are obtained. If the data are skewed, then $\bar{X}$ and s must be calculated mathematically or the distribution of logarithms of the observations must be considered.

If logarithms are used, two approaches are possible. In the first, the logarithms of the observations are plotted on arithmetic probability paper. This is often more convenient than using logarithmic probability paper because the scale of the abscissa can be chosen to fit each set of data, while the logarithmic probability paper has a fixed number of cycles. If logarithmic probability paper has a fixed number of standard deviation, *s*, is obtained by subtracting the log of the 50% value from the log of the value at 84% and expressing *s* as the difference in logs or in fractions of log cycles.

The confidence envelope—If the logarithms of a set of observations are plotted on arithmetic probability paper, the mechanics of determining the confidence envelope are the same as those noted in the box. If logarithmic probability paper is used, the method for calculating the limits of the confidence envelope is varied slightly. Rather than estimating *s* on the basis of log differences, measure the distance between the 50% ordinate and 16% or 84% ordinate as shown in Fig 4. This distance is representative of the value of *s* and may be substituted for *s* in the equation used to determine the limits of the confidence envelope (see box).

Consult a statistician in planning experiments

The graphical methods just described are excellent tools for evaluating properties of materials and processes after data have been obtained. If possible, the services of a statistician should be obtained *before* a program is run in order to obtain maximum benefits from a minimum of data.

The statistically designed experimental program, as opposed to the normal engineering "one at a time" approach, will vary several parameters at one time. A statistical design may evaluate the existence of interactions between several variables, usually one of the pitfalls of the "one at a

FACTOR k FOR MULTIPLYING THE ESTIMATED STANDARD DEVIATIONS OF $\bar{X}$ AND s TO OBTAIN CONFIDENCE ENVELOPES

Probability Level, %	Sample Size			
	10-15	16-20	21-30	Very Large
90	1.78	1.73	1.71	1.65
95	2.17	2.10	2.06	1.96
99	3.03	2.68	2.79	2.58

The Confidence Envelope

Its significance

In Fig 1-4 note that an "envelope" has been drawn around the curve representing test observations. The confidence level chosen and the confidence envelope associated with it are used to answer the question, "How reliable are the statements that have been made?"

Note also that two sets of similar observations on the same material, plotted on probability paper, will give rise to slightly different distributions. The use of a confidence envelope, which takes into account errors in the mean ($\bar{X}$) and estimate of the standard deviation (s), becomes a necessity if the interval within which a distribution lies is to be determined.

The "confidence level" desired must be determined. For most engineering purposes, the 95% confidence level is generally chosen. The degree of certainty associated with this confidence level will satisfy almost all engineering requirements.

One danger of using too high a confidence level (such as the 99% level) arises from the fact that in many engineering investigations a great many observations cannot be made. Fig 5 on the next page indicates that the degree of reliability increases with the number of observations. It also increases when the confidence level is decreased. In other words, as the width of the confidence envelope decreases, the amount of scatter to be expected in data also decreases. By sacrificing some degree of certainty it is possible to actually increase the practical utility of a statement of material properties.

How to construct it

Drawing the confidence envelope is done on the basis of the following facts:

1. The true arithmetic mean lies within the interval
$$\bar{X} \pm ks/\sqrt{n}$$

50%

2. The true standard deviation lies within the interval
$$s \pm ks/\sqrt{2n}$$

@ 16 & 84

The constant, *k*, depends on the number of observations and desired confidence level, while *n* represents the number of observations. The accompanying table lists approximate values of *k* for different confidence levels and sample sizes.

Using the values of $\bar{X}$ and *s* derived from Fig 1, the confidence envelope for these observations was derived as follows:

The arithmetic mean lies within the range $\pm ks/\sqrt{n}$. From Fig 1, we note that ~~$\bar{X}$~~ s = 2550 psi. From the accompanying table, on the basis of a 95% confidence level and 22 observations, $k = 2.06$. Therefore, $ks/\sqrt{n} = \pm (2.06)(2550)/\sqrt{22} = \pm 1120$ psi.

The range of the estimate of the standard deviation is $\pm ks/\sqrt{2n}$. Since *k* and *s* remain the same, the interval is $\pm (2.06)(2550)/\sqrt{44} = \pm 790$ psi.

To construct the confidence envelope, at 50 cumulative percent plot two points: one 1120 psi above and one 1120 psi below the curve. At 16 and 84 cumulative percent, plot points 1910 psi (1120 psi + 790 psi) above and below the curve. Connecting the points produces the confidence envelope.

@ 50% plot $\bar{x} \pm ks/\sqrt{n}$
@ 16 plot $(\bar{x} - s) \pm (ks/\sqrt{n} + ks/\sqrt{2n})$
@ 84 " " $(\bar{x} + s) \pm (ks/\sqrt{n} + ks/\sqrt{2n}$

time" approach.

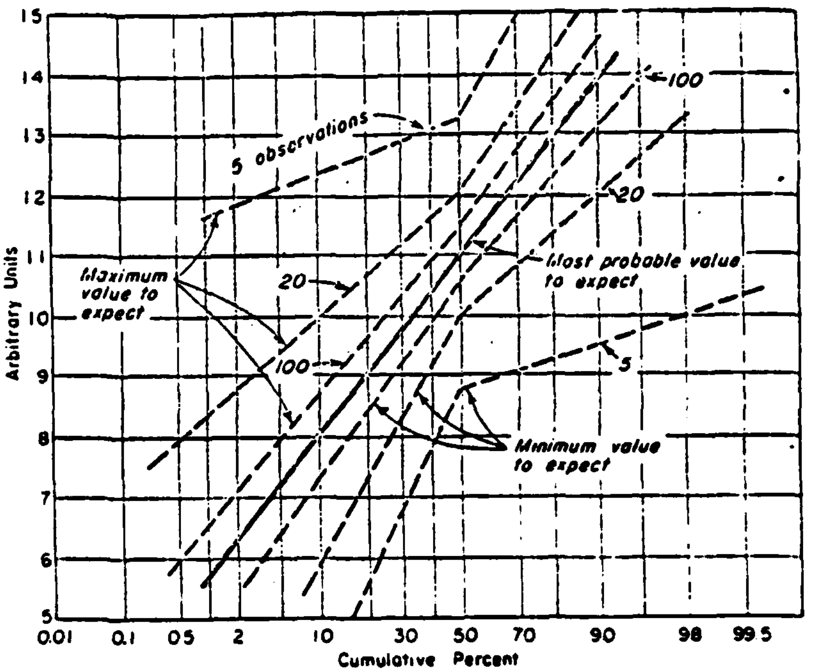
Statistical techniques permit the engineer to decide the minimum number of observations necessary to make a reliable decision. Since the cost of making each observation is usually fixed, such knowledge can save the engineer both time and money.

The importance of statistics as a tool for all engineers cannot be overemphasized. It is a particularly valuable tool for those who are required to predict results or formulate additional, and possibly expensive, programs on the basis of a few test results. Large evaluation errors may be made when only a few samples can be taken. Consider, for example, these two diametrically opposed extremes of evaluation errors:

1. A positive result is obtained on the first trial when the probability of obtaining such a result is relatively low. This is an unfortunate situation since a large effort may be expended in an attempt to obtain the original result.

2. The reverse may occur and a negative result is obtained when the probability of obtaining a positive result is relatively high. This places the predictor in the position of, perhaps, discontinuing a potentially successful project. The unfortunate corrollary is that a large and wasteful effort may be made to develop another method when the first would have been the most satisfactory one.

(more E&D on p 171)



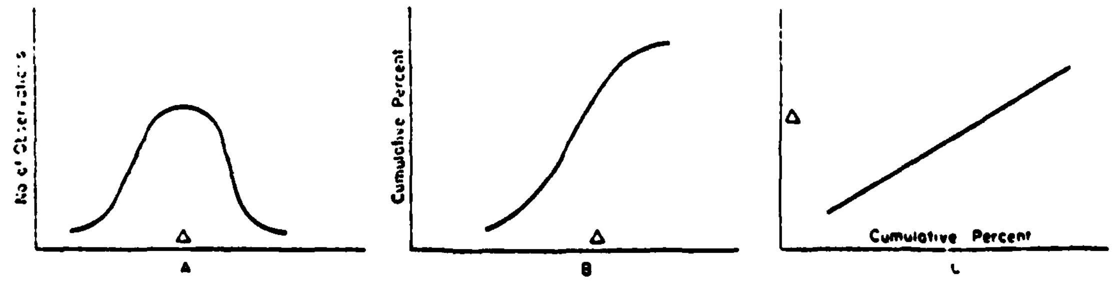
5—*Reliability increases as the number of observations increase. A similar effect results when the confidence level is decreased.*

What Is Probability Paper?

The development of arithmetic probability paper can be visualized as follows: Assume that *A* represents the standard normal distribution curve of a set of data, the familiar "bell-shaped" curve defined by $\phi(t) = (1/\sqrt{2\pi})e^{-t^2/2}$. Integrating $\phi(t)$ results in a curve similar to *B* on which is plotted the cumulative percent of observations at or below a given value, against that value. If the abscissa of *B* is now stretched symmetrically, but nonlinearly, about the 50% value, the curve becomes a straight line (C) and the scale of the abscissa becomes a probability scale. Cumulative percent is plotted on the probability scale since the probability curve represents the integral of the area under the normal probability curve. Cumulative percentages for varying numbers of observations are given in Table 1.

Getting the paper

Two sources for probability paper are: Codex Book Co., Norwood, Mass. (arithmetic—No. 3127, logarithmic—No. 3128), and Keuffel & Esser Co., New York City (arithmetic—No. 359-23, logarithmic—No. 359-22G).



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