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PERFORMANCE OF CHROME-PLATED 105MM M68 GUN TUBES WITH DISCARDING SABOT AMMUNITION

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This report describes testing to determine the feasibility of chrome plating the bore of 105mm M68 Gun Tubes to reduce wear conditions which affect performance of the M392A2 Armor Piercing Discarding Sabot (APDS) Projectile and similar rounds. Two chrome plated tubes were prepared and, with a standard tube for control, fired to monitor relative performance. Based on several factors, it is concluded that special characteristics and sensitivities of M392-type projectiles result in a tendency toward degraded performance in chrome plated tubes. (over)

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Recommendations are made to defer use of chrome plating in the M68 until factors affecting performance are fully identified through an exploratory development program.

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The authors gratefully acknowledge the efforts and cooperation of the many individuals who contributed to the performance evaluation described in this report. Mr. Albert Schumacher and Mr. James Cerqua, Watervliet Arsenal Operations Directorate, assisted in preparing the gun tubes for testing. Mr. V. Peter Greco, Benet Weapons Laboratory Research Directorate, administered the bore plating operation. Mr. J. William Schweiker, Benet Weapons Laboratory Development and Engineering Directorate, assisted in interpreting and reducing the test firing data.

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INTRODUCTION

This report describes the results of recent testing to evaluate the performance of spin stabilized, armor piercing, discarding sabot (APDS) ammunition in chrome-plated 105mm M68 gun tubes. Earlier tests have indicated that, while chrome plating can significantly retard bore wear rates, there is a tendency toward degraded APDS accuracy in plated tubes.

Chrome plating has been considered as a deterrent to the evolution of secondary wear signatures in the M68 tube. Secondary wear is a highly variable erosion condition observed in the first 12 inches of rifled length. Early in tube life, this wear is observed as a diametral expansion at the origin of rifling (O.R.), followed by a contraction and a second expansion before tapering to negligible wear with increasing distance from the O.R. Conditions in the region of this second diametral expansion are called secondary wear. Later in life, the wear expansion starts at the O.R. and increases to a maximum level between 8 and 12 inches forward of the O.R. before tapering out to negligible wear. The point of maximum down-bore expansion is also called secondary wear.

Secondary wear is the result of erosive characteristics of HEAT-type ammunition. The normal consumption of ammunition in field use has been approximately 73% HEAT, 26% HEP and less than 1% APDS. HEP-type ammunition has a very small erosive effect, with a corresponding tube wear life greater than 15,000 rounds. In view of the large proportion of

HEAT-type ammunition consumed, it is apparent why field surveys have shown secondary wear to be prevalent in fielded M68 tubes. APDS ammunition also creates secondary wear, but it is insignificant in comparison to the HEAT-type erosion.[1]

Extensive accuracy firing tests with production tubes have shown that APDS ammunition is sensitive to secondary wear conditions, with drastically degraded performance occurring under certain conditions.[2] Resolution of accuracy considerations is a necessary prerequisite to the use of chrome plating as a solution to secondary wear problems.

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[1]Watervliet Arsenal Report No. WVT-TR-75047, Analysis of Wear Data from 105mm M68 Gun Tubes in Field Service, July 1975.

[2]Aberdeen Proving Ground Report No. FR-P-82476, 22 April 1975.

BACKGROUND

In 1959 and 1960, the United Kingdom tested one 105mm and four 20-pounder chrome-plated gun tubes for firing accuracy. The conclusion from this limited testing was that, while accuracy was not as good in an unplated control tube, it did improve as the unplated tube wore. The accuracy of the plated tubes remained constant.[3,4] In 1962, Watervliet Arsenal chrome plated three 105mm T254 tubes for accuracy testing. Test results indicated that the plated tubes gave poorer accuracy performance than unplated tubes.[5]

Recent testing, in which the 105mm M68 gun tube has been used as a vehicle to evaluate platings, indicates that an M68 tube plated with a 0.010 inch thick layer of chrome will develop negligible origin of rifling wear and minor secondary wear, when firing HEAT-type ammunition. Thus, since chrome plating has demonstrated the potential for reducing secondary wear conditions, the possibility of degraded accuracy performance with APDS ammunition is the determining factor for incorporating chrome plating in the M68 gun tube.

The remainder of this report will describe the special test program, administered by Watervliet Arsenal, to evaluate the accuracy potential of APDS ammunition in chrome-plated M68 gun tubes. This program was designed and implemented as the preliminary phase in the development

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[3]Ordnance Board Proceeding, Q8837, 16 June 1959.
[4]Minutes of Meeting at RARDE, FPA/16/02, November 1960.
[5]USA TECOM Report No. DPS-469, Accuracy and Erosion Studies of Modified T254 Series Gun Tubes for 105mm Gun, M68, APG, 1962.

of wear resistant coatings for the M68 tube. Three possible outcomes of this phase were projected. First, chrome plating could show no adverse effect on accuracy. Given this outcome, a full-scale Product Improvement Project (PIP) for production plating would be initiated. Second, the chrome plate configuration could be found less than optimum, necessitating a major research and development program to prepare an alternate plating. Third, disadvantages or shortcomings of plated tubes could be found to outweigh any advantage they might offer, and the program would be dropped as a solution to APDS erratic performance.

DESCRIPTION OF TEST

Originally, accuracy testing was to consist of comparing a standard production tube, a tube with full bore length chrome plating, and a third tube with full bore length chrome plating over an intermediate cobalt alloy plating. Due to anticipated limitations in the availability of production quantities of cobalt alloy, the intermediate cobalt alloy plated tube was not prepared for testing, being replaced by a tube with a partial length chrome plating. A partial length plated tube offers several advantages in production, including reduced cost and process time. Also, with the possibility of frictional interaction between the bore surface and APDS projectiles strongly influencing dispersion characteristics, the partial length plating presents less chromed bore surface area, while maintaining a wear resistant surface in the region of secondary wear.

Two 105mm M68 gun tubes were prepared under the supervision of the Physical Science Division, Benet Weapons Laboratory. A 0.010 inch thick chrome plating was applied to the full length of the bore of the first tube and chrome plate from the forcing cone to a distance of thirty inches into the rifled region of the bore in the second tube. Final bore diameters of both tubes were that of production tubes. These two tubes, and a standard production tube, were delivered to Aberdeen Proving Ground (APG), Maryland in February 1976.

Accuracy firing was conducted by the Materiel Test Directorate during March and April 1976.[6] Three replications, each consisting of a ten round group from each of the three test tubes, were conducted to measure target dispersion. All ammunition used in the test was Cartridge, 105mm: APDS-T M392A2, from Lot MA 9-4 (MPTS Lot FLP-2-2-71), conditioned to +70°F (+21.11°C). This ammunition lot was chosen as typical of United States production service ammunition. All rounds were fired at a 20-by-20-foot (6.096-by-6.096 meter) vertical target at a range of 1,000 meters. Recorded data included target impacts, muzzle velocity, wind velocity and direction, and smear camera photographs, at 22.5 and 50 feet (6.858 and 15.240 meters) from the muzzle, for each round fired. Prior to initiation of the test, a 10 mph (16 kmh) wind velocity limit was specified.

Replications were performed on 23 March 1976, 29 March 1976, and 6 April 1976. A representative from Watervliet Arsenal was present for the 23 March firing. The firing record and subsequent data analysis are discussed in the following two sections.

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[6] USA TECOM Report No. APG-MT-4802, Product Improvement Test of Gun Tube, 105mm M68 Tube Wear Resistant Plating Accuracy Phase, APG, May 1976, referred to hereafter as USA TECOM Report No. APG-MT-4802.

FIRING RECORD

Firing data is detailed in the report prepared by APG.[7] Table 1 is excerpted from this report and shows horizontal and vertical standard deviations of the impact coordinates for each ten round group. Two-way analysis of variance (ANOVA) and F-tests on variance ratios (pooled over replicates) are unable to detect significant differences among horizontal standard deviations at the 5% level. No significant differences among vertical standard deviations are detected using two-way ANOVA. The F-test detects a just significant difference between the pooled standard deviations for CHR 2 (partial plate) and CHR 3 (unplated). This can be attributed to the 0.76 mil vertical standard deviation for CHR 2 in the first replicate.

Muzzle velocities, and associated standard deviations in velocities, for each tube and replicate are shown in Table 2. Significant differences in velocities, at the 5% level, can be shown to exist among tubes and among replicates. The average velocity of CHR 1 (full length) was significantly higher than that of CHR 3 (unplated) and the average velocity of CHR 1 and CHR 2, taken together, was significantly higher than that of CHR 3. The average velocity for the second replicate was significantly higher than both the first and third replicates, taken together or separately. At the 10% level, ANOVA failed to detect any significant differences among the velocity standard deviations for the three tubes.

[7]USA TECOM Report No. APG-MT-4802.

TABLE 1. HORIZONTAL AND VERTICAL IMPACT DISPERSION

	FIRST REPLICATE		SECOND REPLICATE		THIRD REPLICATE	
TUBE	HOR.* S. D.	VERT. S. D.	HOR. S. D.	VERT. S. D.	HOR. S. D.	VERT. S. D.
CHR 1 (Full Plate)	0.38	0.35	0.18	0.43	0.36	0.48
CHR 2 (Partial Plate)	.45	.76	.19	.33	.45	.27
CHR 3 (Control)	.28	.25	.42	.37	.17	.42

* All values in MILS.

TABLE 2. MUZZLE VELOCITIES

	FIRST REPLICATE		SECOND REPLICATE		THIRD REPLICATE	
	AVERAGE	S. D.	AVERAGE	S. D.	AVERAGE	S. D.
TUBE	fps (mps)	fps (mps)	fps (mps)	fps (mps)	fps (mps)	fps (mps)
CHR 1 (Full Plate)	4888	6.1	4902	6.3	4889	16.4
	(1489.86)	(1.859)	(1494.13)	(1.920)	(1490.17)	(4.999)
CHR 2 (Partial Plate)	4883	17.3	4900	8.6	4887	14.4
	(1488.64)	(5.273)	(1493.52)	(2.621)	(1489.56)	(4.389)
CHR 3 (Control)	4885	10.4	4890	8.9	4882	10.2
	(1488.94)	(3.170)	(1490.47)	(2.713)	(1489.03)	(3.109)

Each of the three gun tubes in the test sustained a total of thirty-seven rounds; one proof round, the three ten round groups, and two warmer rounds prior to each ten round group. Star gauge measurement and borescope inspection were performed after proof firing and after the completion of firing. A summary of these results is in Appendix A. Progressive chipping, flaking, and stripping of chrome in the full plate tube (CHR 1) was noted in the two inspections performed on this tube.

ANALYSIS OF DATA

Upon completion of test firings, additional data analysis was conducted at Watervliet Arsenal to prepare a qualitative assessment of the performance of the three gun tubes involved in the test. In this analysis, emphasis was placed on the relative performance of the three tubes, including segregation of ammunition related performance factors.

Figure 1 shows a cross-sectional view typical of the projectile in the M392/M724/M728 models of discarding sabot ammunition. A variety of parameters have been identified as related to the flight characteristics of this projectile, including frictional interfaces between the rotating and centering bands and the gun tube bore. Proper subprojectile attitude and petal discard, with associated centering band functioning, upon shot ejection have been shown to be determining factors in projectile flight.[8]

It is emphasized that the results of the firings discussed in this report apply only to M392-type APDS projectiles and that it is not correct to interpret these results relative to full bore diameter projectiles (e.g. HEAT, HEP, and HVAP).

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[8] APG Firing Record No. P-82488, Product Improvement Test of Cartridge, 105mm, APDS-T, M392A2 (Mode of Failure), 29 August 1975.

APDS-T PROJECTILE

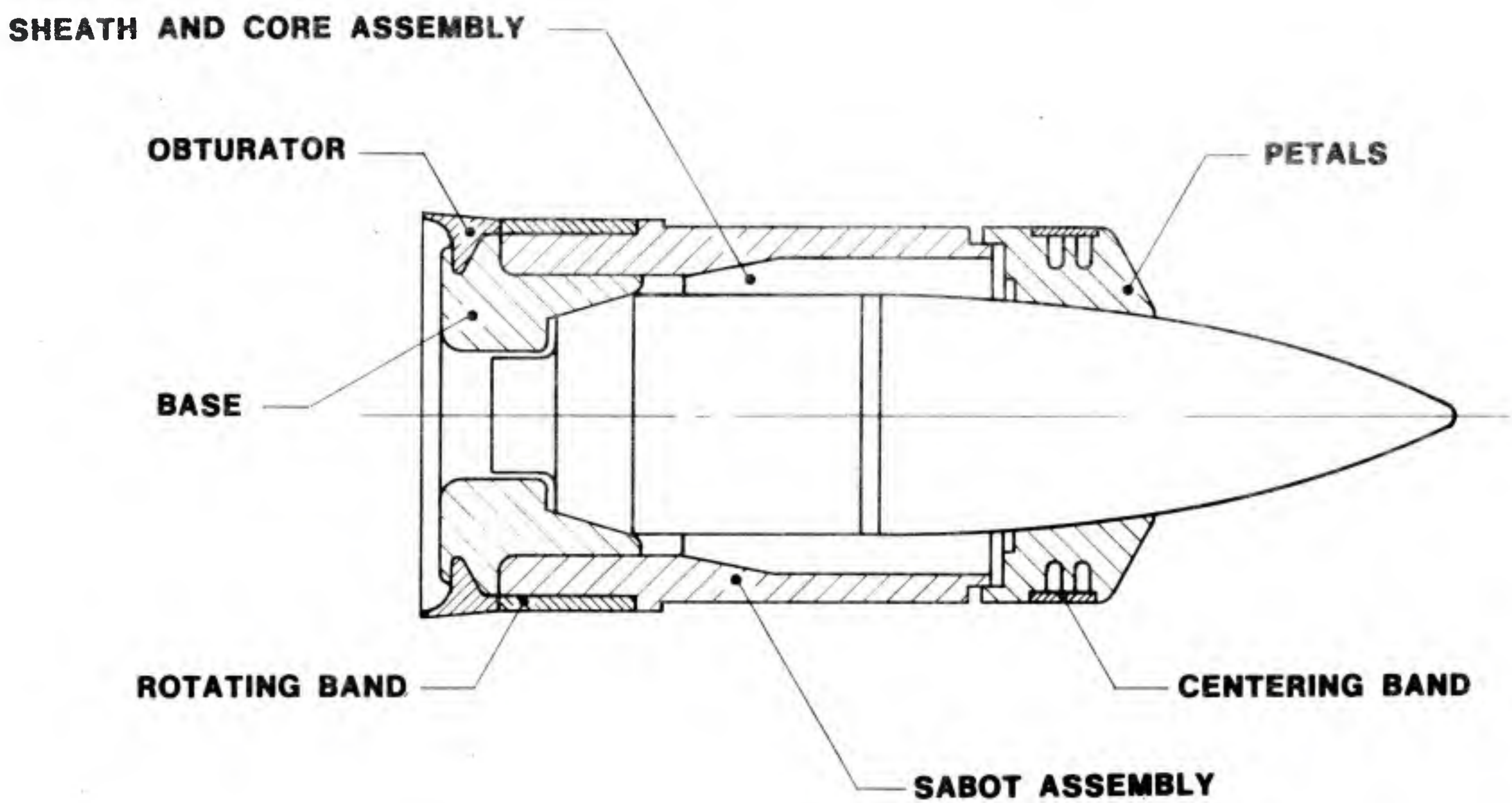

Figure 1. Sectional view of typical APDS-T projectile.

Corrected Impact Data

Vertical target impacts recorded during test firing were corrected for a standard muzzle velocity of 4850 fps (1478.28 mps). Variations in local wind velocity and direction, and in air density, during firing were neglected. Figures 2, 3, and 4 are plots of the impact coordinates for each tube in the three replicates. Since this test addressed only dispersion characteristics, the centers of impact are shown as common for each of the three ten round groups for their respective tubes.

Corrections for standard muzzle velocity had minor effect on vertical impact standard deviations, reducing the value calculated for one tube in the third replicate by 0.01 mil.

For convenience in comparison, the following discussion of impact dispersion has been prepared in terms of circular error (CEP), with values given corresponding to the radius of a circle drawn at the center of impact and having an associated probability of including 50% of the impacts.[9] Table 3 shows circular errors associated with the pooled impact data for each of the three test tubes.

For reference, the desired dispersion for the M60-series tank, specified before type classification of either the M68 gun or the M60 tank, was horizontal and vertical standard deviations of 0.22 mils (corresponding to a circular probable error of 0.26 mils). These values have never been realized with any consistency; horizontal and

[9] This technique is discussed in Statistics Manual (E.L.Crow,F.A.Davies, and M.W. Maxfield, Dover Publications, Inc.,NY, 1960) with necessary approximations described in Chapter 26 of Handbook of Mathematical Functions (M.Abramowitz and I. A. Stegun, National Bureau of Standards, GPO, June 1964).

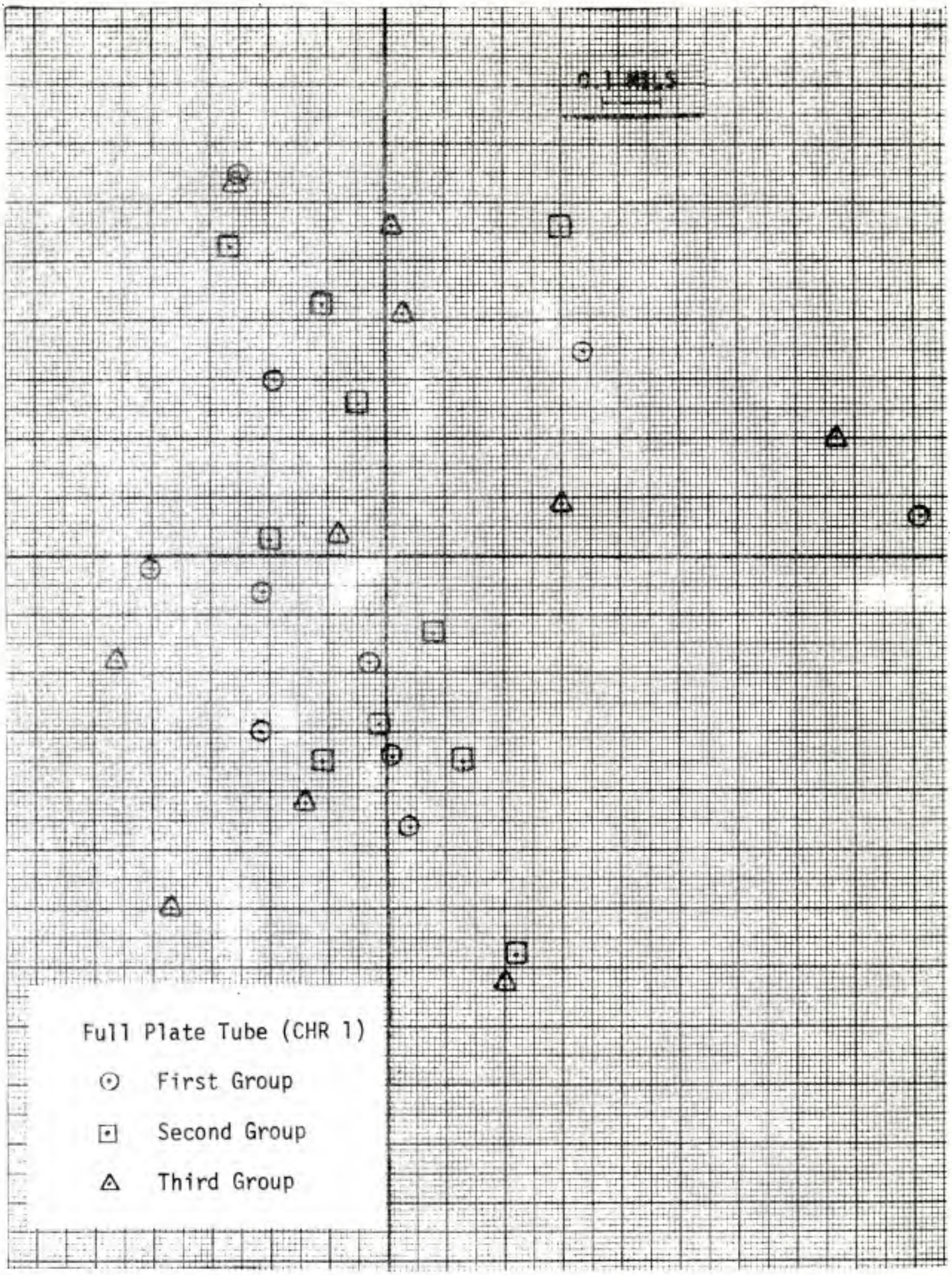

Figure 2. Target impacts--full length plated tube.

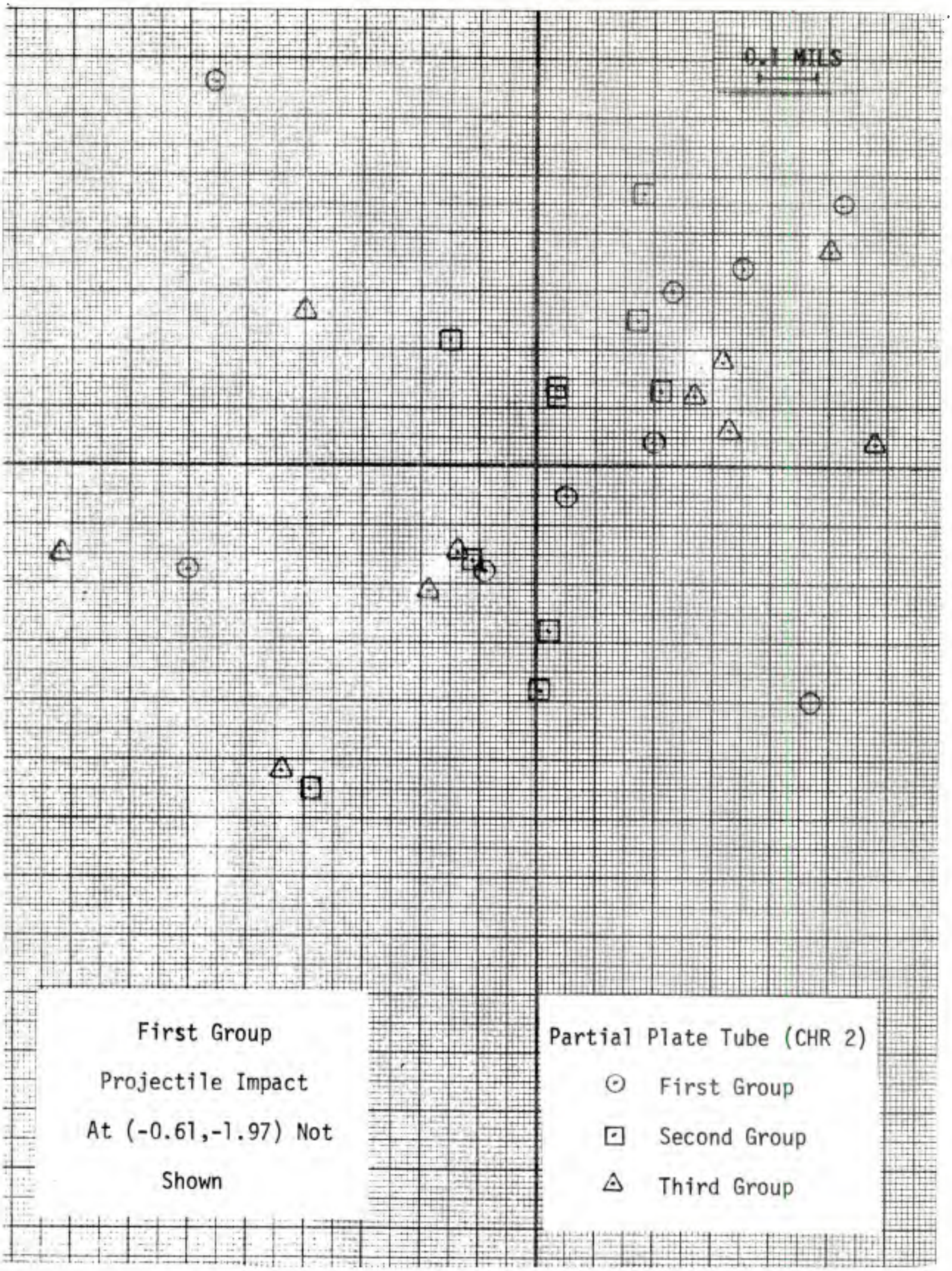

Figure 3. Target impacts--partial length plated tube.

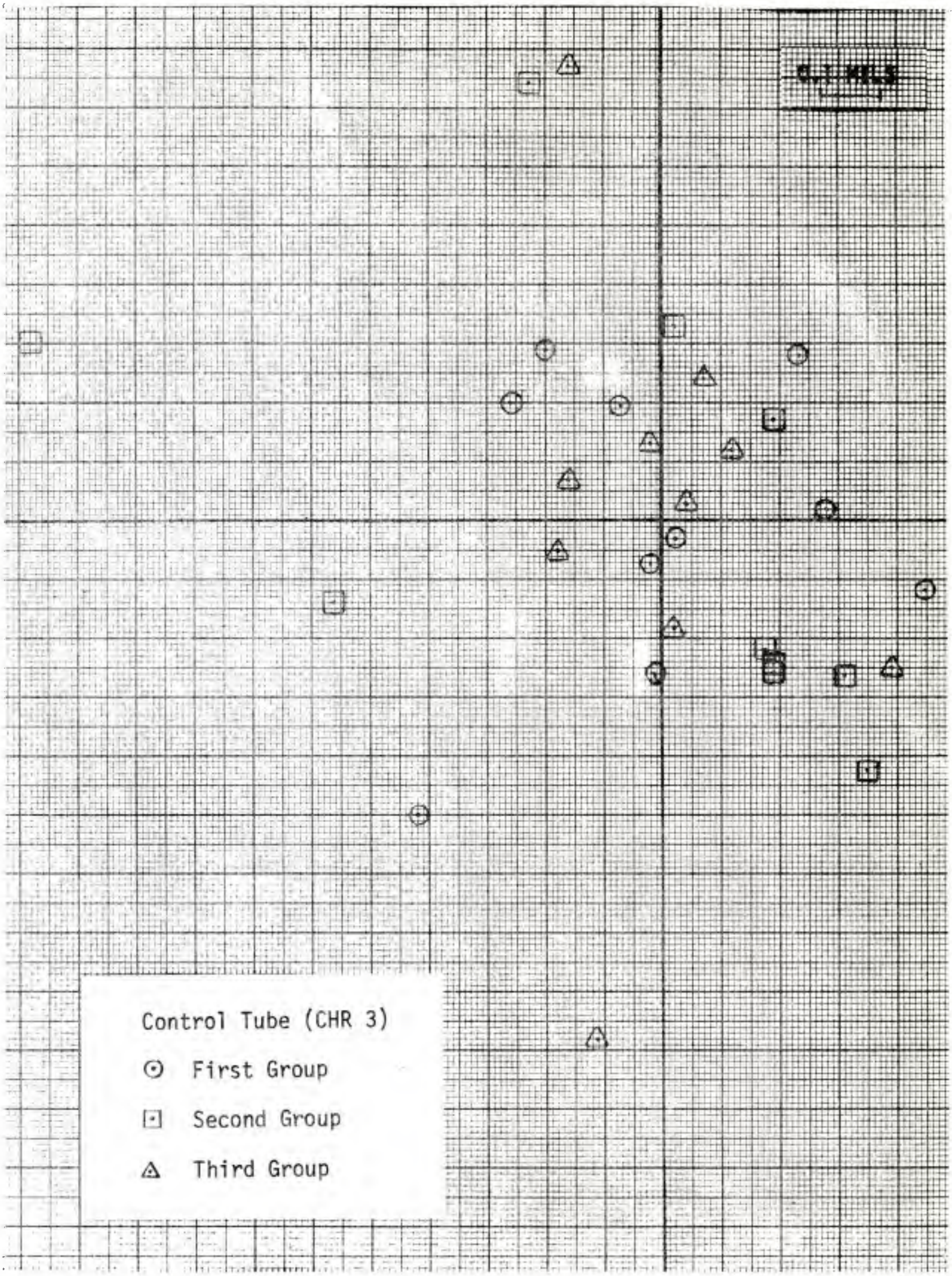

Figure 4. Target impacts--unplated tube.

vertical standard deviations from 563 occasions of M392A2 acceptance tests pool to 0.30 X 0.33 mils, or a CEP of 0.37 mils.[10]

TABLE 3. CIRCULAR IMPACT ERRORS

CHR 1 (Full Plate)	0.42 MILS
CHR 2 (Partial Plate)	.54
CHR 3 (Unplated)	.38
Ammunition Acceptance Tests	.37

Film Data

Two 35mm smear cameras, located at 22.5 and 50 feet (6.858 and 15.240 meters) from the tube muzzle and perpendicular to the line of flight, provided photographs of projectile functioning which were used to analyze the characteristics of each flight. A complete tabulation of the results of this analysis is in Appendix B. Figures 5 through 10 present representative smear camera photographs of several of the abnormal flight conditions noted in the analysis.

To alleviate the influence of variations in ammunition performance, the impact group for each tube was censored by removing the impacts of projectiles which showed various characteristics, and combinations of characteristics, indicating abnormal flight. The results of this censoring is detailed in Table 4. Improved performance was noted in one instance for the full length plated tube, in two instances for the partial length plated tube, and in all instances for the unplated tube.

[10]Data drawn from ammunition acceptance records at Aberdeen Proving Ground.

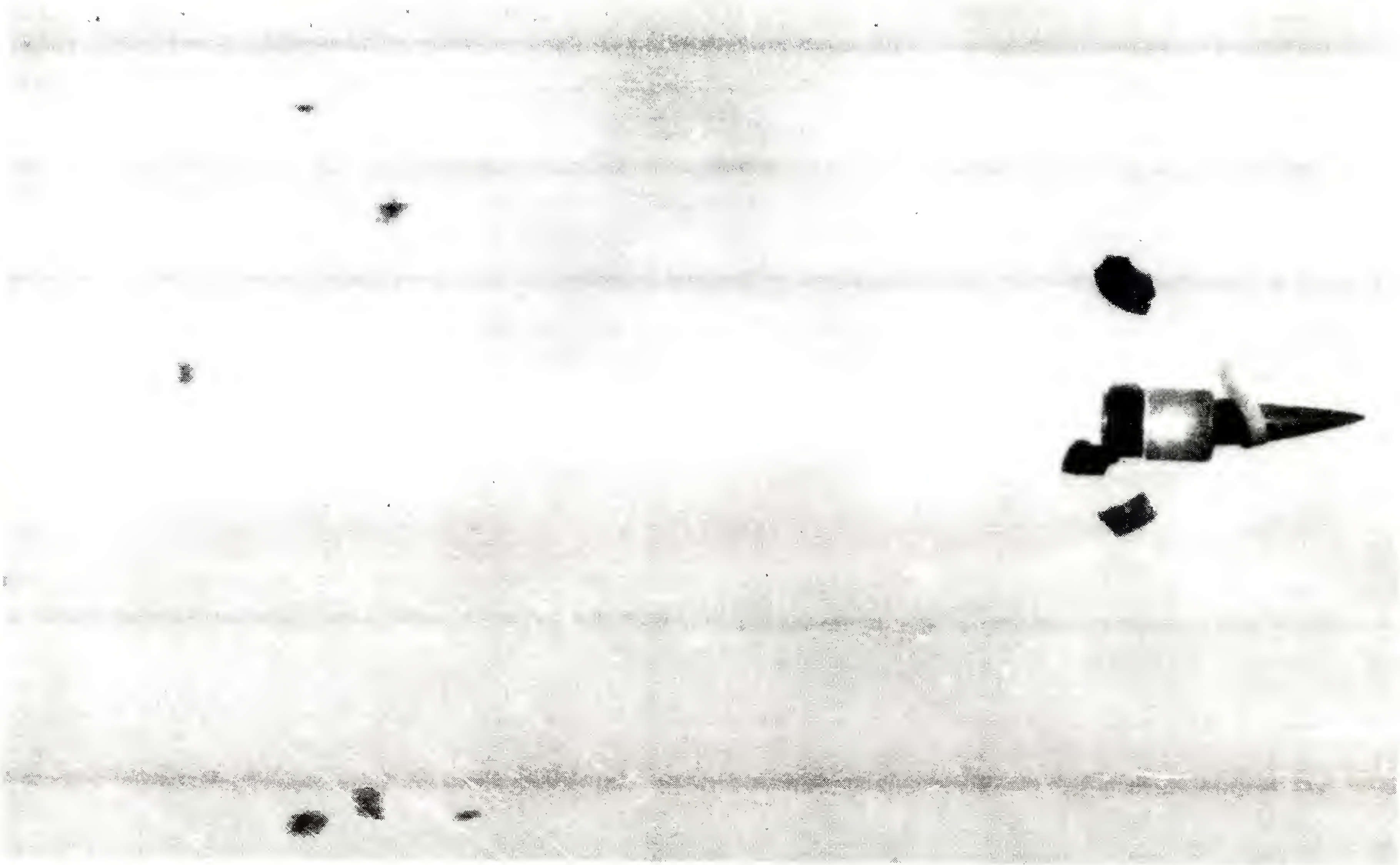

Figure 5. Centering band interference at 22.5 feet (6.858M) - full length plated tube.

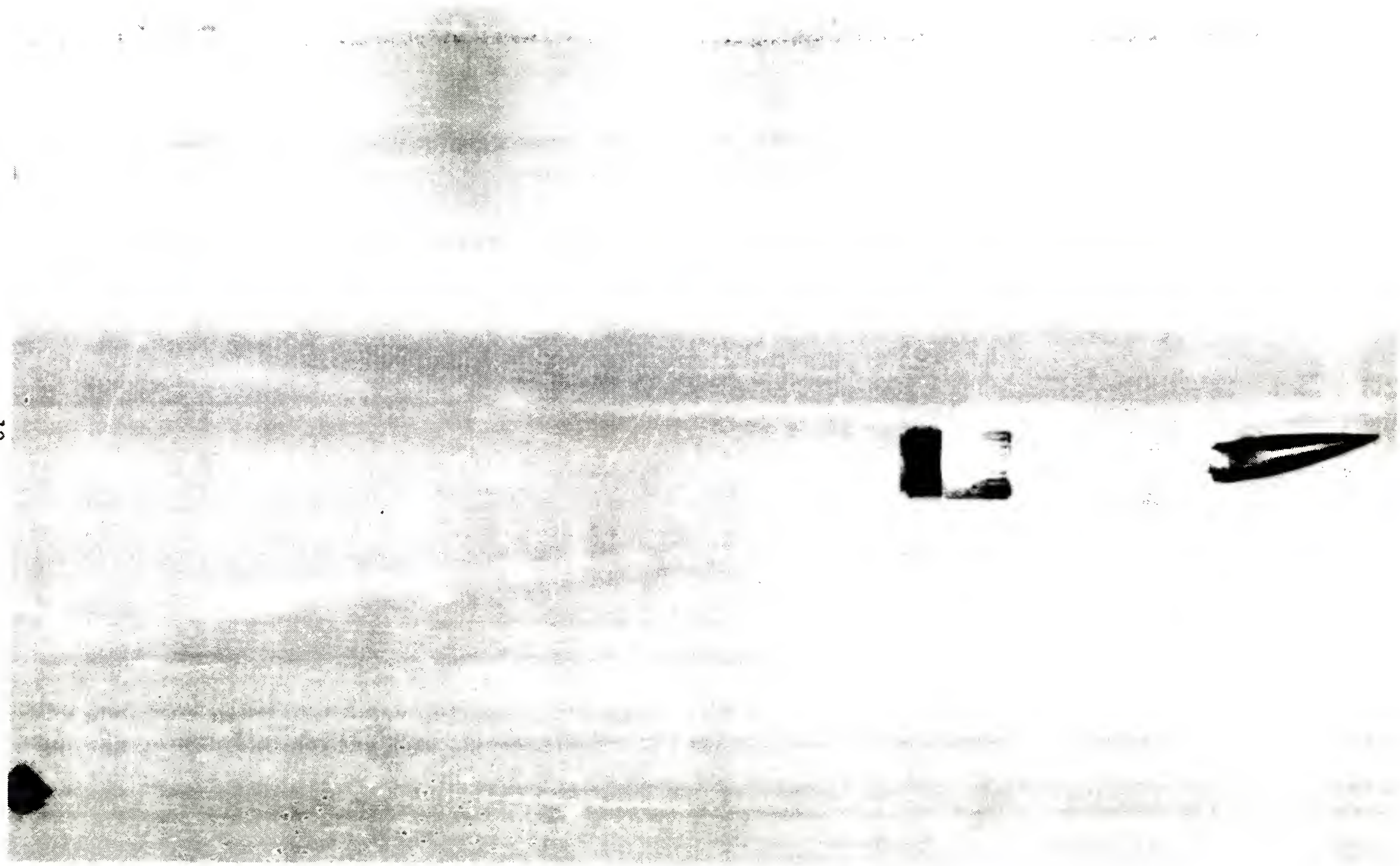

Figure 6. Subprojectile yaw over 8° at 50 feet (15.24M) - full length plated tube.

Figure 7. Centering band interference at 22.5 feet (6.858M) - partial length plated tube.

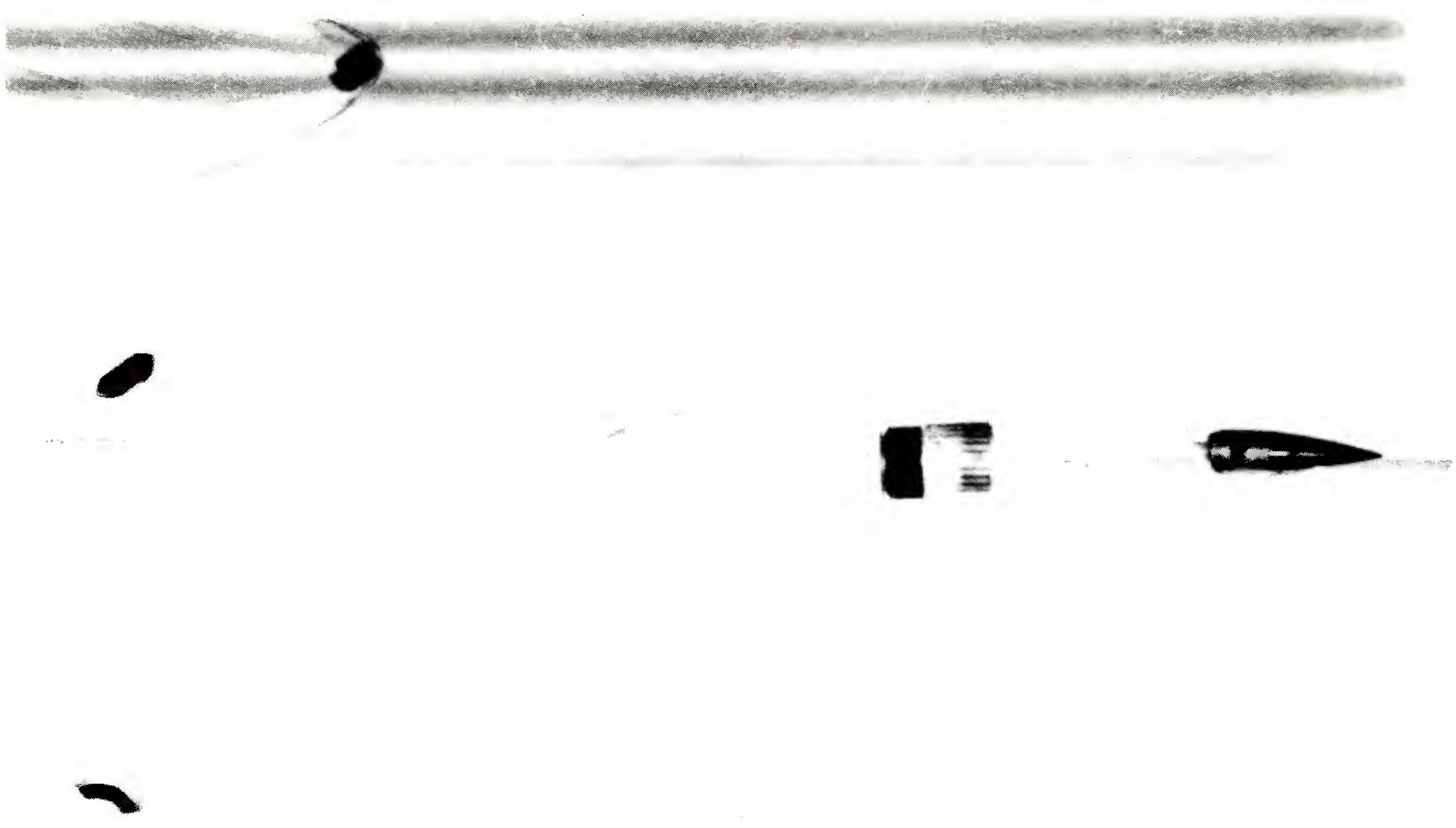

Figure 8. Late petal discard at 50 feet (15.24M) - partial length plated tube.

Figure 9. Centering band interference at 22.5 feet (6.858M) - unplated tube.

Figure 10. Yaw over 8° at 50 feet (15.24M) - unplated tube.

TABLE 4. TARGET IMPACT DISPERSIONS WITH CENSORING OF ABNORMAL PROJECTILE FLIGHT IMPACTS

	NUMBER CENSORED			CIRCULAR ERROR (MILS)		
CHARACTERISTIC[1]	CHR 1	CHR 2	CHR 3	CHR 1	CHR 2	CHR 3
-	-	-	-	0.42	0.54	0.38
F	2	0	2	.42	.54	.32
J	0	4	4	.42	.61	.30
K	4	7	2	.39	.46	.36
F, K	1	0	2	.43	.54	.32
J, K	0	3	4	.42	.49	.30
F, J, K	0	0	2	.42	.54	.32

[1]F - Over 8° subprojectile yaw.

J - Late petal discard.

K - Centering band interference with subprojectile.

CHR 1 - Full length plated tube.

CHR 2 - Partial length plated tube.

CHR 3 - Unplated tube.

CONCLUSIONS

The two chrome-plated tubes show a tendency towards greater dispersion. This tendency is emphasized when projectile flights with characteristics which have been shown to adversely influence impact dispersion are censored from the performance calculations. When this ammunition variable is alleviated, the relative performance of the unplated control tube consistently improves; this consistent improvement does not occur with the plated tubes.

The hypothesis of frictional characteristics of the bore surface affecting performance of APDS ammunition is supported by the evidence of higher muzzle velocities encountered with the plated tubes. The fact that higher muzzle velocities were measured in both tubes tends to indicate that the frictional influence is manifested within the first thirty inches of projectile travel.

Based on the severe chipping, flaking, and stripping encountered in the full length plated tube, its performance is considered unsatisfactory. The plating in the partial length plated tube remained intact and offers advantages in speed and ease of fabrication.

RECOMMENDATIONS

1. The incorporation of wear resistant coatings to control levels of secondary bore wear in the 105mm M68 gun tube should be deferred until the interaction of APDS projectile functioning and bore coatings is fully established.

2. An exploratory development program, addressing the interaction of bore coatings and the APDS projectile, should be established.

3. The advantages of partial length plating over full length plating should be considered in other plating programs.

APPENDIX A

STAR GAUGE AND BORESCOPE INSPECTIONS

The following borescope inspection report is taken from the APG letter report.[11]

105MM M68 TUBE CHR 1 AFTER FIRING 1 ROUND

"BORESCOPED: (Chrome plated between 21.60" from rear face of tube and muzzle.)

Light scratches, stains, and deposits throughout chamber, bore, and rifling. Seventeen lands at various times in the forcing cone 24.60" from rear face of tube have the chrome plating chipped off on the non-driving side. Chrome removed from edges of lands on both driving and non-driving sides at various times and distances throughout bore. Chrome flaked from breech one-third of all bore evacuator holes. Lands in muzzle .25" of tube have chrome chipped from both driving and non-driving edges."

105MM M68 TUBE CHR 1 AFTER FIRING 37 ROUNDS

"BORESCOPED: (Chrome plated between 21.60" from rear face tube and muzzle.)

Light scratches, stains, carbon and other deposits throughout chamber and bore. Lands in forcing cone 24.60" from rear face tube (RFT) have chrome chipped from non-driving side. Chrome chipped,

[11]USA TECOM Report No. APG-MT-4802.

flaked and stripped from lands at various times and distances throughout bore, more pronounced between 9:00 and 3:00 o'clock. Chrome flaked from edges of bore evacuator holes with light erosion in base metal. Lands in muzzle .25" of tube have chrome chipped from both driving and non-driving edges."

Star gauge measurements of the tube bore of each of the gun tubes, taken at the completion of test firings, are shown in Tables A1, A2, and A3.

TABLE A1. STAR GAUGE MEASUREMENTS AT COMPLETION OF TESTING--FULL LENGTH PLATED TUBE

DISTANCE FROM REAR FACE OF TUBE (INCHES)	VERTICAL LAND	VERTICAL GROOVE	DISTANCE FROM REAR FACE OF TUBE (INCHES)	VERTICAL LAND	VERTICAL GROOVE
25.25	0.001	-0.001	59	0.000	0.001
25.5	.000		60	- .001	
26	.000		66.5		
27	- .001		72.5		
28			78.5		
29			84.5		
30			90.5	- .001	.001
31			96.5	.011	.000
32			102.5	- .001	
33			108.5		
34			114.5		
35			120.5		
36			126.5		
37			132.5	- .001	
38			138.5	.008	
39			144.5	.006	
40		- .001	150.5	.001	
41		.000	156.5		
42			162.5		
43			168.5		
44			174.5		.000
45			180.5		.001
46			186.5		
47			192.5		
48			198.5		
49			200.5		
50			202.5		
51			204.5		.001
52			205.5		- .001
53			206.5		.000
54			207.5		.000
55		.000	208.5		.000
56		.001	209.5	.001	.001
57		.001	210	- .001	- .002
58	- .001	.001			

TABLE A2. STAR GAUGE MEASUREMENTS AT COMPLETION OF TESTING--PARTIAL LENGTH PLATED TUBE

DISTANCE FROM REAR FACE OF TUBE (INCHES)	VERTICAL LAND	VERTICAL GROOVE	DISTANCE FROM REAR FACE OF TUBE (INCHES)	VERTICAL LAND	VERTICAL GROOVE
25.25	-0.004	-0.004	59	0.001	0.002
25.5	- .004	- .004	60	.001	
26	- .004	- .004	66.5	.000	
27	- .003	- .004	72.5		
28	- .003	- .003	78.5		
29	- .001	- .002	84.5		
30			90.5	.000	
31			96.5	.001	
32			102.5		
33	- .001		108.5		
34	.000		114.5		
35	.000	- .002	120.5		
36	.000	- .001	126.5		
37	.000	- .001	132.5		
38	.001	- .001	138.5		
39		- .001	144.5		
40		.000	150.5	.001	
41			156.5	.000	
42			162.5	.000	
43			168.5	.000	
44			174.5	.000	
45			180.5	.001	
46			186.5		
47		.000	192.5		
48		.001	198.5		
49	.001		200.5		
50	.000		202.5	.001	
51	.000		204.5	.002	
52	.001		205.5		
53	- .002	.001	206.5		
54	.002	.004	207.5		
55	.006	.005	208.5		
56	.003	.004	209.5		
57	.002	.003	210	.002	0.002
58	.001	.002			

TABLE A3. STAR GAUGE MEASUREMENTS AT COMPLETION OF TESTING--UNPLATED TUBE

DISTANCE FROM REAR FACE OF TUBE (INCHES)	VERTICAL LAND	VERTICAL GROOVE
25.25	0.005	0.002
25.5	.003	.002
26	.002	.001
27	.002	.001
28	.002	.001
29	.001	.000
30		
31		
32		
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
46		
47		
48		
49		
50		
51		
52		
53		
54		
55		
56		
57		
58	.001	.000

DISTANCE FROM REAR FACE OF TUBE (INCHES)	VERTICAL LAND	VERTICAL GROOVE
59	0.001	0.000
60		.000
66.5		.001
72.5		
78.5	.001	
84.5	.002	
90.5		
96.5		
102.5		
108.5		
114.5		
120.5		
126.5		
132.5		
138.5		
144.5		
150.5		
156.5		
162.5		
168.5	.002	
174.5	.001	
180.5		
186.5		
192.5		
198.5		
200.5	.001	
202.5	.002	
204.5		
205.5		
206.5		
207.5	.002	.001
208.5	.001	.002
209.5	.001	.002
210	.001	.000

APPENDIX B

PROJECTILE FLIGHT CHARACTERIZATIONS

Smear camera photographs were analyzed to identify flight characteristics of projectiles fired in the dispersion testing. Tables B1, B2, and B3 describe the results of this analysis.

TABLE B1. PROJECTILE FLIGHT CHARACTERISTICS--FULL LENGTH PLATED TUBE

	CHARACTERISTIC[1]			CHARACTERISTIC	
ROUND	22.5 FT (6.858M)	50 FT (15.24M)	ROUND	22.5 FT (6.858M)	50 FT (15.24M)
3	D, S	E	20	D, S	D, S
4	D, S	D, S	21	D, S	F
5	E	D, S	22	D, S	D, S
6	D, S	D, S	23	E	D, S
7	E	D, S	24	D, S	D, S
8	D, S	D, S	27	K	D, S
9	E	D, S	28	K	E
10	A, D	E	29	D, S	D, S
11	D, S	D, S	30	E	E
12	D, S	D, S	31	K	F
15	D, S	D, S	32	D, S	E
16	E	E	33	D, S	E
17	E	D, S	34	E	E
18	D, S	D, S	35	D, S	D, S
19	E	E	36	K	E

[1]A - Subprojectile not centered in sabot.
C - Rotating band on sabot.
D - 0° to 4° subprojectile yaw.
E - 5° to 8° subprojectile yaw.
F - Over 8° subprojectile yaw.
S - Satisfactory.
J - Late petal discard.
K - Centering band interference with subprojectile.

TABLE B2. PROJECTILE FLIGHT CHARACTERISTICS--PARTIAL LENGTH PLATED TUBE

ROUND	CHARACTERISTIC[1] 22.5 FT (6.858M)	CHARACTERISTIC[1] 50 FT (15.24M)	ROUND	CHARACTERISTIC 22.5 FT (6.858M)	CHARACTERISTIC 50 FT (15.24M)
3	D, S	D, S	20	D, S	D, S
4	K	D, S	21	D, S	D, S
5	A	D, S	22	K	D, S
6	D, S	D, S	23	D, S	D, S
7	D, S	D, S	24	D, S	D, S
8	D, S	D, S	27	K	D, S
9	D, S	D, S	28	D, S	D, S
10	D, S	D, S	29	D, S	D, S
11	J	E, J	30	J, K	D, S
12	D, S	D, S	31	K	D, S
15	D, S	D, S	32	D, S	D, S
16	D, S	D, S	33	D, S	D, S
17	D, S	D, S	34	D, S	D, S
18	D, S	D, S	35	J, K	E
19	D, S	D, S	36	J, K	D, J

[1]A - Subprojectile not centered in sabot.

C - Rotating band on sabot.

D - 0° to 4° subprojectile yaw.

E - 5° to 8° subprojectile yaw.

F - Over 8° subprojectile yaw.

S - Satisfactory.

J - Late petal discard.

K - Centering band interference with subprojectile.

TABLE B3. PROJECTILE FLIGHT CHARACTERISTICS--UNPLATED TUBE

ROUND	CHARACTERISTIC[1] 22.5 FT (6.858M)	50 FT (15.24M)	ROUND	CHARACTERISTIC 22.5 FT (6.858M)	50 FT (15.24M)
3	D, S	D, S	20	D, S	D, S
4	D, S	D, S	21	D, S	D, S
5	D, S	D, S	22	K	E
6	D, S	D, S	23	D, S	D, S
7	D, S	D, S	24	J, K	E
8	D, S	D, S	27	D, S	D, S
9	D, S	D, S	28	K	D, S
10	D, S	D, S	29	J, K	D, S
11	D, S	D, S	30	D, S	D, S
12	J, K	F	31	D, S	D, S
15	J, K	F	32	D, S	D, S
16	D, S	D, S	33	D, S	D, S
17	D, S	D, S	34	D, S	D, S
18	D, S	D, S	35	D, S	D, S
19	D, S	D, S	36	D, S	D, S

[1]A - Subprojectile not centered in sabot.

C - Rotating band on sabot.

D - 0° to 4° subprojectile yaw.

E - 5° to 8° subprojectile yaw.

F - Over 8° subprojectile yaw.

S - Satisfactory.

J - Late petal discard.

K - Centering band interference with subprojectile.

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