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AUTHORITY

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U. S. ARMY
ABERDEEN PROVING GROUND
Aberdeen Proving Ground
Maryland 21005

475761

In Reply Refer To
STEAP-DS-T/

2 AUG 1965

SUBJECT: First Interim Report of Military Potential Test of 20MM and 40MM Interim Air Defense Weapons Systems, RDT&E Project No. Not Available, USATECOM Project No. 3-5-9240-06/08/10/12/14 (U)

TO: Commanding General
U. S. Army Test and Evaluation Command
ATTN: AMSTE-BA
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(FOUO) SECTION I - GENERAL (U)

1.1 (U) REFERENCES

1.1.1 Letter, AMSTE-BA, dated 18 Dec 64, subject: Test Directive, USATECOM Project No. 3-5-9240, Military Potential Test of Four IAD Weapons Systems (U).

1.1.2 Letter, AMSTE-BA, dated 4 Dec 64, subject: Coordinated Test Program for USATECOM Project No. 3-5-9240, Evaluation of Four IAD Weapons Systems (U), w/1st Ind, AMCPM-IADS, 4 Dec 64 and 2nd Ind, AMSTE-BA, 7 Dec 64.

1.1.3 Letter, AMSTE-BA, dated 30 Dec 64, subject: Change 1 to Coordinated Test Program for USATECOM Project No. 3-5-9240, Evaluation of Four IAD Weapons Systems (U).

1.1.4 Letter, STEAP-DS-TA, dated 12 Mar 65, subject: Status Report of Military Potential Test of Four IAD Weapons Systems, USATECOM Project No. 3-5-9240 (U), w/1st Ind, AMSTE-BA, dated 22 Mar 65.

1.1.5 Plan of Test, Military Potential Test of 20MM and 40MM Interim Air Defense Weapons Systems (U), dated January 1965.

1.1.6 Letter, AMCRD-SR, dated 25 January 1965, subject: Proposed Qualitative Materiel Requirement (QMR) for a Division Air Defense Weapon System (U), w/1st Ind, STEAP-DS-T, dated 24 February 1965.

1.2 (FOUO) OBJECTIVE (U)

Under the direction of USATECOM, a Military Potential Test of four interim forward area defense weapon system candidates was conducted to

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determine a gun solution winner for early field issue in limited quantities.

1.3 (U) RESPONSIBILITIES

The D&PS responsibilities were to investigate certain engineering characteristics of each candidate system and to support applicable data acquisition requirements of the Weapons System Laboratory of BRL for their evaluation.

1.4 (U) DESCRIPTION OF MATERIEL

The weapons systems tested are described below:

1.4.1 Self-Propelled, Twin 40MM Gun, M42 (DUSTER) Antiaircraft Weapon. This mounts two 40mm guns, M2A1 in parallel firing un-synchronized at a nominal rate of 120 rounds per minute from each tube. The fire control consist of the M24C reflex with the M38 lead computer sight. For details see TM 9-7218.

1.4.2 Self-Propelled, Twin 40MM M42 (DUSTER) Modified. This is the standard M42 described above, modified by the installation of a gun synchronizer device, improved hydraulic powered gun control servos, vehicle suspension lock-out and a MK 20 reflex computer sight. The modified M42 is considered to be the only 40mm contender. The standard model was tested only for comparison and to evaluate the performance improvements effected by the modifications.

1.4.3 20MM MG, M61/M113A1 which incorporates the M61 vulcan machine gun and power turret mounted on the M113 Armored Personnel Carrier and equipped with the MK 20 lead computing sight.

1.4.4 20MM MG, M61A1/M113A1. An improved linkless feed mechanism coupled with a new protective "tub" turret and a modified MK 20 sight comprise the principle differences between this and the M61/M113 described above. Both versions are mounted on the diesel powered M113A1 vehicle.

1.4.5 20MM Triple MG, HS 820/665/M113A1. The final candidate is the Hispano-Suiza 20mm machine gun HS/820, triple mounted in an improved M665 carriage and incorporating a new model of Gallileo lead computing optical sight. This system is also mounted on the M113A1 vehicle.

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1.5 (FOUO) BACKGROUND (U)

The primary objective of this program was to provide HQ, USATECOM with certain engineering data on weapon system performance for their evaluation and recommendation of a gun winner. These data were to include basic performance characteristics of both the fire control systems and the weapon. In addition, recommendations for system improvement and safety considerations are to be included where applicable. No automotive tests were required for any of the systems. This interim report is intended to expediously provide the essential data required by USATECOM to meet the AMC time commitment for their gun winner recommendation. A final report will be submitted at a later date which will contain follow-on test results that may be required prior to start of the planned Engineering-Service Test of the selected system. Test dates covered in this report are 6 Jan 65 through 2 Aug 65.

1.6 (FOUO) FINDINGS (U)

For the sake of brevity only general findings and a sampling of significant data will be included in the body of this report. Complete and detailed supporting data and test procedures can be found in the inclosures.

1.6.1 Evaluation of the M42 Modified vs Standard M42.

1.6.1.1 In general, all four modifications resulted in improved performance characteristics ranging from significant to marginal. The most significant improvements were in the gun synchronizer, the modified power controls and the fire control. Although the suspension lock-out improved vehicle stability slightly, the unmodified system was not found to be objectionably unstable during firing.

1.6.1.2 Gun Synchronizer

a. The gun synchronizer performed satisfactorily throughout the firing. One minor failure was noted during inspection prior to firing. The tapered retaining pin (No. MS 24692-156) was sheared on the right actuator lever (No. RDI-C7309) and would have prevented that gun from firing. Bending of these pins occurred during firing of both guns. However, this can be readily corrected by installation of a stronger pin or a woodruff key.

b. The rate of fire for synchronized firing was controlled by the rate of the slowest gun. However, it was found that the rate

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change varied inversely with the quandrant elevation, i.e., 133 rounds per minute per gun at 0° elevation vs 120 rounds per minute per gun at 65° elevation. The unmodified M42 exhibited similar characteristics, i.e., 112 RPM vs 102 RPM. The lower average rate of unmodified is not considered significant since it is possible to adjust all properly assembled guns to give the minimum nominal rate of 120 RPM.

c. Vertical target dispersion in automatic fire was substantially less in synchronized firing at all conditions tested than that recorded without. There was less difference noted when firing single round salvo from both guns. Typical combined standard deviation figures are given in Table I below. See detailed results, Inclosure 1-1.

TABLE I

Type of Fire	No. of Rds	Weapon Model	Elev mils	Distance to Tgt mils	Combined Std Dev, mils X	Y
Auto	32	M42	5	200	3.65	1.49
Auto	32	M42 Mod	5	200	2.79	1.44
Auto	32	M42	600	42.6	3.64	1.68
Auto	32	M42 Mod	600	42.6	2.88	1.87
Single	16	M42	5	200	1.47	.90
Single	16	M42 Mod	5	200	1.83	1.29

Note: All above groups fired forward at 0° traverse.

d. Firing moment errors were substantially reduced with the modified M42 compared to the standard model. However, it is difficult to attribute this directly to the synchronizer since the new gun power controls were markedly more stable than the "oil gear" servos of the M42. When using the latter system, the gunner tended to "over correct" on even small excursions induced by assymetrical firing moments when firing at fixed targets. It is quite possible that the modified controls are capable of damping out or eliminating such errors without the benefit of synchronized firing. The measured firing moment errors during automatic fire with the unmodified M42 were ± 3.5 mils laterally and a total of 2.5 mils vertically. During this test the turret was in oil gear operation, but with the hand control mechanically locked in a fixed position to eliminate the known human error. Under the same relative conditions with the modified M42 the firing moments were negligible. See Inclosure 2-1.

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1.6.1.3 Gun Power Control Servos

a. As stated above the modified gun control servos proved more effective in stabilizing the weapons during static firing. In tracking smoothness they were moderately superior to the original oil gears at high angular velocity and significantly better at low angular velocities.

b. Tracking capabilities of the modified system were definitely superior to those at the unmodified version. Table II below shows the test results in this area. Also see Inclosure 2-1.

TABLE II

Weapon System	Max Traverse Vel	Max Elev Vel	Max Accel Traverse	Max Accel Elev
M42	40°/sec	26°/sec	100°/sec^2	95°/sec^2
M42 Mod	72°/sec	51°/sec	115°/sec^2	288°/sec^2

c. A potential safety hazard was noted during tracking tests that must be corrected in the event the weapon is adopted. It was found that when the gun is elevated beyond 60° the clearance between the top edge of the turret armor and the rear face of the MK 20 sight is insufficient to allow the gunner to maintain his normal position in relation to the sight and a serious head injury could result. Corrective modifications are readily apparent and could be easily incorporated.

1.6.1.4 MK 20 Lead Computer Sight.

a. The scope of local tests did not permit a meaningful or comprehensive evaluation of the MK 20 sight vs the M24C-M38 fire control system. Tracking tests with both systems were inconclusive since a direct accuracy comparison could not be made. Accuracy evaluation data are expected to be developed from the USAADBD service test phase.

b. One obvious advantage of the MK 20 sight is the elimination of estimated target speed inputs by the gunner. This improves settling time and should theoretically improve hit probability if the lead angle computer is functioning properly. In addition, the overall system weight is reduced by approximately 200 pounds. See Inclosure 2-1.

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1.6.1.5 Vehicle Suspension Lock-Out.

a. Total vehicle motion, as recorded by hop cards during the stability and accuracy firings, was insignificantly reduced by use of the suspension lock-out feature. However, the magnitude of this motion was quite small in both freely sprung and locked positions. The magnitude and direction of the individual motion of the vehicle corners also varied normally with changes in gun orientation in respect to the vehicular axis. Table III shows some typical hop measurements taken in automatic fire. Also see Inclosure 1-2.

TABLE III

Vehicle Suspension	No. of Rds	Gun Elev	Traverse Orient f/Veh Axis	Vehicle Motion, inches							
				Right Front		Right Rear		Left Front		Left Rear	
				X	Y	X	Y	X	Y	X	Y
Locked-out	16	0°	0°	1.1	.5	.73	.60	-	-	-	-
Free	16	0°	0°	.75	1.0	.50	1.20	-	-	-	-
Locked-out	16	32°	0°	1.1	.5	1.05	.75	-	-	-	-
Free	16	32°	0°	.75	.73	.50	.90	-	-	-	-
Locked-out	16	0°	90° Left	.63	.25	.32	.23	.52	.25	.25	.25
Free	16	0°	90° Left	.50	.25	.37	.32	.75	.37	.60	.37
Locked-out	16	32°	90° Left	.48	.32	.25	.13	.37	.13	.19	.13
Free	16	32°	90° Left	.37	.32	.37	.40	.37	.25	.50	.18

b. The hydraulic accumulator system pressures were found to vary considerably with changes in ambient temperatures. Before each firing with the suspension lock-out engaged the pressure was stabilized at 200 psi. Periodic checks during each days firing showed that the pressure could build up to as high as 300 psi in less than two hours. Otherwise, no difficulties or malfunctions of the system were experienced.

1.6.1.6 Special malfunction and parts failure investigation of the M42 weapon systems.

a. At the request of Project Manager, AMCPM-IADS, D&PS conducted an additional test to determine if possible the cause or causes of repeated malfunctions reported during the USAADBD Service Test of the Unmodified M42 (Vehicle No. 12H298). Upon receipt of the vehicle a complete tear-down inspection of the weapons systems was performed.

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The most significant findings were that many of the component parts such as cocking levers, breech cranks and extractors were cracked, deformed or contained crack pattern indications. Many of the springs such as rammer and rammer lever springs exhibited compressive strengths below specification requirements. Similar inspections of the two D&PS test weapons, (Vehicle Nos. 12H297 and 12H273) were performed, but neither had the same high incidence of defects as No. 12H298. See Inclosure 2-2 for detailed inspection reports.

b. Following inspections No. 12H298 and 12H273 (Mod M42) were reassembled with replacement parts and fired 1500 rounds per gun for reliability. Only one stoppage was experienced with No. 12H273 but with 12H298 repeated failures of the left gun to feed occurred early in the test. Investigation then disclosed that the left loader was either improperly manufactured or damaged in a manner not readily detectable. The chute opening appeared to be approximately .054 inch too narrow to permit reliable feeding of the cartridges through the pawls during automatic firing. In the opinion of this office this condition existed at the time the weapon was issued for test. After replacing the entire loader assembly the loader functioned satisfactorily. However, stoppages continued to occur with the left gun. Experimental adjustments of the buffer eventually eliminated the failure and the last 400 rounds were fired without malfunction.

1.6.1.7 Ballistic Test of Cartridge, 40MM, TP-T, M91.

A ballistic check test was carried out with samples from the test lots of the 40mm, M91 cartridges to determine their suitability for use in the M42 comparison test. All lots tested performed satisfactorily and there was no significant difference in the velocity levels between lots. Detailed results are contained in Inclosure 1-1 and Table IV below gives the velocity data summary.

TABLE IV

Lot No.	Avg Muzzle Vel., fps	Vel Std Dev., fps
UE-4	2803	8.8
UE-5	2822	8.9
UE-9	2812	7.1
UE-11	2810	10.0
UE-41	2856	8.7

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1.6.2 Military Potential Comparison Test of Four IAD Weapons Systems.

1.6.2.1 The primary objective of this program was to compare the engineering and fire control characteristics of the four candidate systems to provide data for the USATECOM evaluation and recommendation of gun winner. This was done concurrently with the comparison test of the 40mm M42 and M42 modified weapons. The tests of the three 20mm systems were conducted separately. In addition, data for a comparative evaluation was gathered to meet the requirements of the Weapons Systems Laboratory of the BRL.

1.6.2.2 During July 1965, USATECOM furnished an evaluation interim guide, based partially upon provisions of a proposed QMR, Ref. 1.1.6. Table V contains excerpts of these criteria applicable to the D&PS test responsibilities.

TABLE V

Evaluation Criteria	40MM M42 Mod	20MM M61/M113A1	20MM M61A1/M113A1	20MM HS 820/M113A1
Measured Avg Rates of Fire	255 Rds/min 0^{o}-65^{o} Elev	2666 Rds/min	3202 Rds/min	2503 Rds/min
Assessed Muzzle Velocity	2870 fps	3250 fps	3250 fps	3434 fps
Ballistic Coefficient	.845 on B_5	.350 on T_1	.350 on T_1	.442 on $C_{5.1}$
Ground Tgt Accuracy Disp	Std Dev, ϕ 1.65 vert x 2.83 horiz	Not Obtained	Not Obtained	Std Dev, ϕ 45 Rd Bursts 2.45 vert x 2.30 horiz
Effective Ground Range-Estimated	1500 meters	800 meters	800 meters	1000 meters
Barrel Life	12,000 Rds	6000-8000 Rds Est	6000-8000 Rds Est	8000-10,000 Rds

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TABLE V - (continued)

Evaluation Criteria	40MM M42 Mod	20MM M61/M113A1	20MM M61A1/M113A1	20MM HS 820/M113A1
Equivalent Wt of Proj per minute	501.88 lbs	570.52 lbs	685.23 lbs	659.79 lbs
Failure Rates of Weapons Systems	0.3/1000 Rds 3000 Rd Test	Not Tested	.2/1000 Rds 19,867 Rd Test	0.9/1000 Rds w/1.6mm gas port. 3300 Rd Test 1.5/1000 Rds w/1.5mm gas port. 12,300 Rd Test
Warm Up Time Fire Control	10 sec	10 sec	10 sec	None
Power Modes and Operational Reqmnts				
1. Gun	Not Req'd (Manual)	Elect 450 Amps	Elect 475 Amps	Not req'd (Manual)
2. Fire Control	Elect 27 Amps	Elect 9 Amps	Elect 8 Amps	Hydro-mechanical
3. Turret	Electro-hydraulic	Elect	Elect	Hydro-mechanical
a. Max Slew	250 Amps	65 Amps	60 Amps	N/A
b. Tracking	27-250 Amps	9-65 Amps	8-60 Amps	N/A

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TABLE V - (continued)

Evaluation Criteria	40MM M42 Mod	20MM M61/M113A1	20MM M61A1/M113A1	20MM HS 820/M113A1
Manual Back Up Operation				
1. Gun	None req'd	None	None	None req'd
2. Fire Control	None	None	None	Manual
3. Turret				
a. Slew	Limited Manual	None	None	Manual
b. Track	Ground tgts only	None	None	Aerial and Ground Tgts
APU Required	Yes	No	No	Yes
Settling Time	4.5 sec	5 sec	5 sec	6 sec
Slewing Rates	72°/sec-Traverse	76°/sec-Traverse	78°/sec-Elev	94°/sec-Traverse
Maximum Angular Velocity	51°/sec-Elevation	46°/sec-Elevation	48°/sec-Elevation	58°/sec-Elevation
Slewing Rate Accelerations	109°/sec^2-Traverse	110°/sec^2-Traverse	300°/sec-^{2} Traverse	452°/sec^2-Traverse
Maximum Angular in °/sec^2	288°/sec^2-Elevation	350°/sec^2-Elevation	340°/sec-^{2} Elevation	744°/sec^2-Elevation
Firing Moment Errors	Negligible	40 # CCW-Trav 22 # Down	40 # CCW-Trav 20 # Down	Negligible

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TABLE V - (continued)

Evaluation Criteria	40MM M42 Mod	20MM M61/M113A1	20MM M61A1/M113A1	20MM HS 820/M113A1
Tracking Accuracy Angular Vel Limits Rad/sec	.33 Horiz .4 Vert	.43 Horiz- .4 Vert	.43 Horiz- .4 Vert	.6 Horiz- .6 Vert
System Weight, Empty, as Tested	43,725 lbs	21,250 lbs	22,100 lbs	21,900 lbs
Safety				
1. Azimuth and Elev Cut-Out	None	None	None	None
2. Suitability of Ammo for fld handling	Satisfactory	Satisfactory	Satisfactory	Not Tested
3. Hazards	inadequate clnc between sight and turret armor at elevations over 60°	No cut-out device to prevent gun from striking hatch covers	Potential interference by the turret magazine with driver, crew and equipment in crew compartment. No cut-out device to prevent gun from striking open commander and driver hatch covers	None observed

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1.6.3 General

1.6.3.1 20MM M61/M113A1

a. The poor condition of ~~this gun and~~ drive mechanism of the weapon received for test precluded adequate test firing for gun data. The weapon had been fired approximately 90,000 rounds previously and it was found that firing moment forces were too great to permit a meaningful test. Inspection showed that the main drive gears were badly chipped and worn. A replacement gun with a serviceable ring gear was subsequently installed and limited test firing was accomplished.

b. Examination of the fire control system disclosed that the elevation and azimuth tachometers and power inverter were defective. These were replaced by contractor personnel prior to commencement of tracking accuracy testing.

1.6.3.2 20MM M61A1/M113A1

a. An endurance test of 19,867 rounds, in 100 round bursts, was conducted with this system to determine a malfunction rate. This proved to be 0.2 rounds per 1000 rounds. See Inclosure 1-3.

b. The overall performance of this weapon was significantly better than that of the towed version tested by D&PS Jul-Aug 1964 (see Report DPS-1155). The principle area of improvement lay in the new linkless feed mechanism which virtually eliminated stoppages caused by belt separation, ammo box jams and belt end damage to feed mechanism. The basic ammunition load has been increased from 300 to 1200 rounds which is considered to be significant improvement.

1.6.3.3 20MM HS 820/M113A1

a. This system was also subjected to an extended endurance test in which 5200 rounds, in 50 round bursts, were fired from each of the 3 guns for a total of 15,600 rounds. Two sizes of gas port, 1.5mm diameter and 1.6mm diameter, were tried to determine the optimum size for functioning reliability. As a result, two system malfunction rates were determined as shown in Table VI. Also see Inclosure 1-3.

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TABLE VI

System Malfunctions	Gas Port dia, mm	Number of Rounds	System Malf/1000 Rds
18	1.5	12,300	1.5
3	1.6	3,300	.9

b. Parts breakage history was also obtained and the findings are shown in Table VII below.

TABLE VII

Component	Round History	Gun No.
Cracked inertia bars	2526	58118
Broken extractor	3783	58113
Broken extractor	4166	58165
Broken pushrod	4726	58165
Driving spring (perm set)	4422	58113
Cracked inertia bars	4922	58113
Cracked inertia bars	4966	58165
Cracked extractor	4976	58118
Inertia bar spring (broken coil)	4922	58113

c. Vertical target accuracy dispersion at 200 meters range and vehicle stability tests were conducted. Typical dispersion data is reported in Table V above, and detailed results are given in Inclosure 1-3 along with vehicle stability data. Vehicle motion was negligible, averaging less than 0.5 inches at all three azimuth orientations of the guns (0°, 90° left and 180°). See Inclosure 1-3.

Tested

d. Overall performance of the HS 820 gun system was found to be greatly improved over that of the towed version tested by D&PS during Jul-Aug 64 (see Report DPS-1155). Stoppage rates, parts breakage and magazine malfunctions were notably less with the new system.

e. Preliminary results received from the USAADBD service tests reported that it was necessary to lubricate the cartridge cases with light oil prior to loading in order to prevent weapon stoppages. Various combinations of gas port size and case oiling frequency were

tried, but the most satisfactory combination proved to be the 1.6mm dia. gas port and 100% oiling of the cartridge cases. However, during the D&PS endurance test no cases whatever were oiled and the stoppage rates observed were comparable to the USAADBD experience. The reason for this difference in performance could not be properly characterized by these limited tests.

1.6.3.4 MK 20 Sight - M61 and M42 Mod Systems

a. In the process of acquiring data to satisfy the WSL-BRL requirements, many laboratory and field tests were performed and most of the operating parameters and characteristics were obtained (see Inclosure 2-1). However, the scope of testing was limited by time and facilities available and sufficient system accuracy error data could not be obtained.

b. Informal data from the USAADBD service tests, monitored by D&PS, indicated that significant errors may exist in the MK 20 lead angle generator system. This was most pronounced in aircraft target engagements by the two 20mm M61 weapons on crossover targets. The modified 40mm, M42 had more success on these targets, using the a similar sight system. This may be accounted for by the presence of the second operator who has the capability of adjusting range inputs during the relatively longer firing engagements typical of the 40mm weapons.

c. A limited assessment of firing shock effects upon the MK 20 sight was made after the M61A1 stoppage rate endurance test. A deficiency was found in the synchro resolver component of the automatic range generator which was caused by loosening of the retainer screws. This allowed the item to rotate out of position. Since the synchro resolver produces an input to the lead angle through horizontal and vertical angular velocity inputs, the sight could not be operated in automatic mode. Also, it was found that the range generator was supplying an incorrect range current to the MK 20 sight in the automatic mode. The cause has not been found and the manufacturer has recommended return to the factory for rebuild and calibration.

1.6.3.5 Gallileo Sight - 20MM HS 820

a. Laboratory and field tests, similar to those of the MK 20 sight were also performed with the Gallileo sight of the 20mm HS 820 system (see Inclosure 2-1). Preliminary USAADBD data were also monitored for informational purposes.

b. No direct evaluation of the system accuracy errors was made. However, information furnished by Frankford Arsenal demonstrated the technical accuracy of the computer. In view of the known positive nature of the computer drive it is reasonable to assume that lag in predicted lead angle does not exist in the system.

c. After the firing of approximately 3500 rounds of the stoppage rate endurance test the sight was examined for defects. This inspection revealed that a significant failure had occurred in the computer drive which resulted in displacement of the sight reticle approximately 180° out of phase. Sight checks performed prior to the start of this test showed normal operation. Therefore, it is concluded that the damage was caused by firing shock. Repairs could not be made locally, so the firing was resumed and no further checks made. Subsequent examination by contractor personnel, with D&PS participation, found that the adhesive bonded Delta line reticle lens had dislodged and rotated out of position. This would preclude use of the sight in antiaircraft mode.

1.6.4 Discussion of Results

1.6.4.1 40MM, M42 DUSTER, Modified

a. The modified M42 DUSTER is a distinct improvement over the standard model and has many desirable characteristics to recommend it as an interim weapon, compared to the 20mm candidates. The larger caliber projectile should prove more lethal, given a hit, than either 20mm shell. The system is in the inventory and presumably available for modification. Cost of these modifications should compare favorably with that of either 20mm system procurement. Performance characteristics tested and reported herein also compare favorably with those of the 20mm systems.

b. The firing doctrine in effect for the 40mm M42 systems prescribe long firing engagements, since the gunners are instructed to fire as soon as possible after target identification. This, coupled with the relatively low rate of fire, affords the range input operator an opportunity to adjust for lead angle errors or lag. Thus, the system would not be as severely penalized as the M61 systems, should the MK 20 sight be found to have such inherent errors.

c. Factors that can be considered against the selection of the weapon are the overall system weight as it affects transportability and obsolescence of the basic vehicle. Condition of the weapons

currently available for modification is not known. However, two out of the three weapons systems examined by this agency required extensive replacements of springs and component parts.

1.6.4.2 20MM HS 820/M113A1

a. The principle advantageous features of the 20mm HS 820, compared to the other candidate systems, are unusually high tracking rate capabilities, the positive and accurate hydro-mechanical sight computer and gun drive, its immunity to electrical failure and the excellent manual mode operational back-up. In addition, the exterior ballistic profile and time of flight for the HS 20mm cartridge compares favorably with the 40mm HE-T MK 2 and is superior to the 20mm, HE, M55.

b. The disadvantages of the system, compared to the other candidates, are the somewhat higher frequency of gun stoppages, the demonstrated fragility of the sight reticle, the relatively limited availability of ammunition imposed by the drum magazine feed and the awkwardly high system silhouette. In addition, the combined rate of fire as measured did not equal the prescribed 3000 rounds per minute.

c. Settling time during tracking tests of the Gallileo sight proved to be high since the operators found it more difficult to acquire the target initially than with the MK 20. In some instances, the target could not be acquired at all. Once on target, tracking accuracy remained good throughout. Training operators to become proficient in use of the sight will require more time than with the MK 20.

1.6.4.3 20MM M61A1/M113A1 (Improved)

a. The recommending features of the improved M61 include the low frequency rate of gun failures, increased ammunition capacity and a rate of fire greater than prescribed. The turret affords limited protection of the gunner and the weapon system transient response characteristics are acceptable, better than the M42 Mod, but not as good as the HS 820.

b. The magnitude of the firing moment errors in both traverse and elevation are considered unsatisfactory and the accuracy of the MK 20 sight system has not been established.

1.6.4.4 20MM M61/M113A1

There were not sufficient D&PS firing tests conducted with this weapon to permit a meaningful discussion of the results. Those aspects

of the fire control characteristics evaluated did not adequately consider the mode differences between the two versions of the MK 20 sight on the M61 systems.

1.6.4.5 Weapon System Operational Availability - All Candidates

a. An analysis of the operational power requirements of the four candidate systems and the results are given in Table V. The 20mm HS 820/M113A1 is the only system that can operate effectively in both aerial and ground targets without power. The manual controls drive the same hydro-mechanical servos driven by the integral gasoline power unit. The 40mm M42 Modified has limited operational capability in the event of auxilliary power failure since it would then depend entirely upon the condition and remaining life of the batteries. Manual back-up is provided for the hydraulic turret and gun drive servos and power tracking could be maintained. Power loss has no effect upon the fire power of the weapons. However, complete loss of electrical power renders the MK 20 sight useless. Both 20mm M61 systems depend entirely upon electric power for sighting, tracking and firing. Ampere hour life of the batteries used in these systems is not known.

b. Although none of the systems tested would meet the slew and elevation rate requirements of the proposed QMR (130°/sec desired, 110°/sec required in traverse and 75°/sec desired, 60°/sec required in elevation), all are considered acceptable for the interim gun solution.

1.7 (FOUO) CONCLUSIONS (U)

1.7.1 It is concluded that:

1.7.1.1 For the 40MM, M42 Modified,

a. The gun synchronizer will substantially reduce firing moment errors and accuracy dispersion with no adverse effect upon rates of fire or functioning reliability. However, the lever retaining pins, Part No. MS 24692-156, should be strengthened. Para 1.6.1.2.

b. The modified gun control servo system of the modified M42 is superior to the oil gears of the standard model and will permit more positive control in all modes of firing, smoother tracking and improved tracking velocities. However, the system will not meet the requirements of the proposed QMR. Para 1.6.1.3 and Table V.

c. The location of the MK 20 sight in relation to the modified M42 turret armor, at high angles of elevation, is a potential safety hazard. Para 1.6.1.3.

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d. The vehicle suspension lock out will not provide any significant improvement in modified M42 vehicle stability and the system is subject to objectionable and rapid changes in pressure under normal temperate climatic conditions. Para 1.6.1.5

e. The .3 per 1000 rounds failure rate of the Modified M42 is satisfactory and will meet the proposed QMR for Air Defense Systems. Para 1.6.2.2, Table V

f. The range input operator for the MK 20 sight on the Modified M42 has the capability to correct for observed lead angle errors. Para 1.6.4.2

g. In the event of auxilliary power failure the system will have limited operational availability, dependent upon the condition and remaining life of the batteries supplying electrical power to the MK20 sight. Para 1.6.4.5 and Table V

h. Slewing rates, angular accelerations and velocity limits will not meet the requirements of the proposed QMR. Para 1.6.2.2, Table V

i. Tracking accuracy and settling times are satisfactory. Para 1.6.2.2, Table V

1.7.1.2 For the 20MM HS 820/M113A1,

a. The measured rate of fire will not meet the requirements of the proposed QMR. Para 1.6.2.2, Table V

b. Under the normal temperate climate conditions the 1.6mm diameter gas port will permit acceptable operational reliability while the 1.5mm diameter gas port will not. Para 1.6.2.2, Table V

c. Under the same conditions as b above lubrication of the cartridge cases will not be required to achieve satisfactory performance. Para 1.6.3.3

d. Slewing rates, angular accelerations and tracking angular velocity limits will not meet the requirements of the proposed QMR. However, it is the best of all systems tested and is only marginally unsatisfactory. Para 1.6.2.2, Table V

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e. Firing moment errors will not adversely effect the operator. Para 1.6.2.2, Table V

f. In the event of auxilliary power failure the system will not loose the capability of engaging aerial targets. Para 1.6.4.5 and Table V

g. Proper use of the Gallileo sight will require more extensive personnel training than the other systems tested. Para 1.6.4.3 and Table V.

h. The sight reticle lenses will not withstand prolonged firing shock. Para 1.6.3.5

1.7.1.3 For the 20MM M61/M113A1

a. Slewing rates, angular accelerations and angular velocity limits of this system will not meet the requirements of the proposed QMR. Para 1.6.2.2, Table V

b. Firing moment errors are excessive. Para 1.6.2.2, Table V

c. The all-electric powered system is more likely to suffer complete loss of operational capabilities than the other systems examined. Para 1.6.4.5 and Table V

1.7.1.4 For the 20MM M61A1/M113A1

a. Same as paragraphs 1.7.1.3 a, b and c above.

b. The M61A1 gun will function more reliably, with fewer stoppages than the other candidates and meets the proposed QMR requirements. Para 1.6.2.2, Table V

c. The gun rate of fire exceeds all other candidates and meets the requirements of the proposed QMR. Para 1.6.2.2, Table V

d. Tracking accuracy and settling times are satisfactory. Para 1.6.2.2, Table V

e. The automatic mode feature of the MK 20 sight on the improved M61A1 will not withstand prolonged firing shock. Para 1.6.3.4

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f. The temporary provisions for eliminating the observed safety hazards will not meet operational requirements in their present form. Para 1.6.2.2, Table V.

g. Although it could not be defined within the scope of this test, there is some reason to believe the lead angle error exists in the MK 20 sight when engaging crossover targets. Para 1.6.3.4.

1.8 (FOUO) RECOMMENDATIONS (U)

1.8.1 In consideration of the results of this test, the 20mm HS820 is recommended as having the most of the characteristics desired for the interim weapon system. If availability of the weapon and overall costs are also considered, it is then recommended that the 40mm M42 Modified be adopted for the interim weapon and a new weapon system be developed for the final gun solution. Both the 20mm HS820 and the 20mm M61A1 are recommended for continued development as potential candidates for the final weapon.

1.8.2 It is further recommended that:

1.8.2.1 If the 40MM, M42 DUSTER, Modified is selected,

a. The gun synchronizer be adopted, but redesigned for increased parts life and reliability.

b. The hydraulic power control servo system be adopted in its present configuration, but that an effort be made to provide increased, slewing rates.

c. The MK 20 sight be adopted.

d. The vehicle suspension lock-outs be abandoned.

e. The turret armor and MK 20 sight location be modified to eliminate the potential safety hazard.

1.8.2.2 If the 20MM HS 820/M113A1 is selected,

a. The reticle lenses be redesigned to insure positive retention and shock resistance.

b. Continue design efforts to reduce parts breakage and improve stoppage rates.

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c. An effort be made to improve slewing rates.

1.8.2.3 If the 20MM M61A1/M113A1 is selected,

a. Vehicle hatch cover safety interlocks and an interior protective screen for the turret be provided.

b. Redesign the angular velocity power input components for improved reliability in automatic operation of the MK 20 sight.

c. Efforts be made to improve slewing rates.

d. Efforts be made to minimize firing moment errors.

e. A more comprehensive test be conducted with the MK 20 sight to characterize all system accuracy errors. A dynamic tracking facility is recommended to accomplish this program.

1.8.2.4 If the M61/M113A1 is selected the recommendations are the same as listed in para 1.8.2.3 above except for the turret protection requirement.

FOR THE COMMANDER:

SUBMITTED:

DONALD K. TAG
Chief, Artillery Weapons Br

J. A. TOLEN
Acting Deputy Director
For Engineering Testing
Development and Proof Services

2 Incl
1. SECTION II - Details of Test
2. SECTION III - Laboratory Reports

STEAP-DS-TA
SUBJECT: First Interim Report of Military Potential Test of 20MM and 40MM Interim Air Defense Weapons Systems, RDT&E Project No. Not Available, USATECOM Project No. 3-5-9240-06/08/10/12/14 (U)

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SECTION II -- Details of Test

Contents:

1-1 Firing Record No's P-71594, M-83331, M-83332, M-83333

1-2 Hop Card Records

1-3 Engineering Data - Guns

ABERDEEN PROVING GROUND
ABERDEEN PROVING GROUND, MARYLAND 21005
FIRING RECORD

USATECOM Project No. 3-5-9240-12,
Ballistic Evaluation of Cartridge,
40-MM, Mk 2

Firing Record No.: P-71594
Dates of Test: 3 March, 12 April, and 18 June 1965
Authority: Ltr, USATECOM, 30 September 1965

Related Firing Records: M-83331, M-83332, and M-83333

W. O. No. 324-016-50 aec

ITEMS UNDER TEST

Ammunition:

Cartridge, 40-mm (standard calibration).

Propellant, MP, M1, 0.0198-inch web, 10.48 ounces, lot ROW-9356-S.

Projectile, M81A1, AP-T, lot No. FML-10-1944.

Primer, M38, mod 1, lot LS-8-67.

Case, M25, lot 302.

Cartridge, 40-mm, inert-loaded, HE, Mk 2, BL&T, with tracer, lots No. UE-4-McA-55, UE-5-McA-55, UE-9-McA-52, UE-11-McA-55, and UE-41-McA-52.

FACILITIES

Gun, 40-mm, M2A1, serial Nos. 2984 and 1336.

Tube, 40-mm, M2A1, serial No. 141144.

Mount, 40-mm, M4E1, serial Nos. 3012 and 2984.

Vehicle, self-propelled, twin 40-mm, M42, USA Registration Nos. 12H297 and 12H273.

Gage, copper, Mk I, copper lot 1-54.

Gage, copper, T20, copper, lot 1-63.

Velocity chronograph.

ROUND-BY-ROUND DATA

Round-by-round data are contained in Inclosure I.

RESULTS

			Velocity, fps				Press., psi/100			
Date, 1965	Lot	No.	Avg[a]	Cal Avg	Std Dev	No.	Avg[a]	Std Dev		Gage Type
3 March	Cal	10	2870		12.2	10	415	24.9	Copper	Mark I
	UE-5	10	2822	2822	8.9		No Gages			
	UE-11	10	2810	2810	10.0		No Gages			
	UE-41	10	2856	2856	8.7		No Gages			
12 April	Cal	9	2891		10.0	9	519	11.0	PEP	T20
	UE-9	10	2833	2812	7.1		No Gages			
	UE-4	9	2824	2803	8.8		No Gages			
18 June	Cal	10	2860		9.5		No Gages			
	Cal	10	2873		10.8	10	408	22.8	Copper	Mark I
	Cal	10	2866		13.5	10	505	18.2	PEP	T20

[a] Velocities and pressures corrected for presence of gages when used.

Notes: Calibration Rounds: Propellant, 9356, MP, M1, 0.0198-inch web, charge weight, 10.48 ounces; projectile, M81A1, AP-T, lot FML-10-1944.
All rounds fired from tube No. 141144.
Calibration Values of Propellant: 2870 fps; 40,000 psi, copper; 47,200 psi, PEP.
Weapon RMP: 40,000 psi, copper; 48,000 psi, PEP.

SUBMITTED:

P. R. GREPPS
Test Director

REVIEWED:

D. K. TAG
Chief, Artillery Weapons
Branch

FOR THE COMMANDER:

H. A. BECHTOL
Chief, Artillery Division
Development and Proof Services

1 Incl
Round-by-Round Data

ROUND-BY-ROUND DATA

Tube Rd No.	Time Fired	Test Rd No.	Ammo Lot No.	Average Chamber Pressure[a], psi/100	MV, fps
Date Fired:	3 March 1965.				
855	1322	1	9356-S	423	2859
856	1332	2	UE-5		2828
857	1333	3	UE-11		2824
858	1335	4	UE-41		2858
859	1337	5	9356-S	452	2898
860	1341	6	UE-5		2828
861	1342	7	UE-11		2800
862	1343	8	UE-41		2859
863	1344	9	9356-S	455	2876
864	1346	10	UE-5		2830
865	1347	11	UE-11		2822
866	1348	12	UE-41		2858
867	1349	13	9356-S	409	2876
868	1353	14	UE-5		2816
869	1354	15	UE-11		2808
870	1355	16	UE-41		2851
871	1356	17	9356-S	408	2888
872	1357	18	UE-5		2809
873	1358	19	UE-11		2801
874	1359	20	UE-41		2835
875	1400	21	9356-S	405	2869
876	1401	22	UE-5		2812
877	1402	23	UE-11		2804
878	1403	24	UE-41		2866
879	1404	25	9356-S	443	2884
880	1405	26	UE-5		2824
881	1406	27	UE-11		2816
882	1407	28	UE-41		2858
883	1408	29	9356-S	382	2881
884	1409	30	UE-5		2816
885	1410	31	UE-11		2819
886	1411	32	UE-41		2850
887	1412	33	9356-S	430	2876
888	1413	34	UE-5		2837
889	1414	35	UE-11		2811
890	1415	36	UE-41		2863

[a]Tube rounds 855 through 894 used Mk I gage; tube rounds 1408 through 1437 used T20 gage.

Tube Rd No.	Time Fired	Test Rd No.	Ammo Lot No.	Average Chamber Pressure[a], psi/100	MV, fps
891	1416	37	9356-S	390	2859
892	1417	38	UE-5		2825
893	1418	39	UE-11		2795
894	1419	40	UE-41		2858

Note: Tube life remaining before firing test, 95%.

Date Fired: 12 April 1965.

1408	1039	1	9356-S	516	2896
1409	1047	2	UE-9		2836
1410	1048	3	UE-4		2836
1411	1049	4	9356-S	526	2905
1412	1053	5	UE-9		2829
1413	1054	6	UE-4		2822
1414	1055	7	9356-S	521	2902
1415	1057	8	UE-9		2839
1416	1058	9	UE-4		2829
1417	1059	10	9356-S	535	2911
1418	1102	11	UE-9		2825
1419	1103	12	UE-4		2810
1420	1104	13	9356-S	544	2920
1421	1106	14	UE-9		2830
1422	1107	15	UE-4		2830
1423	1108	16	9356-S	521	2898
1424	1111	17	UE-9		2829
1425	1112	18	UE-4		2825
1426	1113	19	9356-S	Lost	2901
1427	1115	20	UE-9		2825
1428	1116	21	UE-4		2810
1429	1117	22	9356-S	539	2914
1430	1119	23	UE-9		2843
1431	1120	24	UE-4		Lost
1432	1121	25	9356-S	535	Lost
1433	1136	26	UE-9		2828
1434	1137	27	UE-4		2823
1435	1138	28	9356-S	547	2925
1436	1141	29	UE-9		2844
1437	1142	30	UE-4		2828

[a]Tube rounds 855 through 894 used Mk I gage; tube rounds 1408 through 1437 used T20 gage.

Note: Tube life remaining after firing test was 85%.

Firing Record No. P-71594

Tube Rd No.	Time Fired	Test Rd No.	Cu Gage Model No.	Average Chamber Pressure, psi/100	MV, fps
Date Fired:	18 June 1965.				
1462	0916	1	-		2848
1463	0917	2	Mk I	444	2890
1464	0919	3	T20	508	2877
1465	0921	4	-		2870
1466	0922	5	Mk I	436	2879
1467	0924	6	T20	554	2911
1468	0925	7	-		2847
1469	0926	8	Mk I	394	2884
1470	0927	9	T20	503	2877
1471	0928	10	-		2870
1472	0929	11	Mk I	442	2883
1473	0930	12	T20	505	2874
1474	0931	13	-		2859
1475	0932	14	Mk I	421	2890
1476	0933	15	T20	518	2876
1477	0934	16	-		2864
1478	0935	17	Mk I	407	2867
1479	0937	18	T20	525	2891
1480	0938	19	-		2862
1481	0939	20	Mk I	393	2871
1482	0940	21	T20	545	2899
1483	0941	22	-		2857
1484	0942	23	Mk I	375	2863
1485	0943	24	T20	498	2870
1486	0944	25	-		2848
1487	0945	26	Mk I	399	2874
1488	0946	27	T20	510	2877
1489	0947	28	-		2871
1490	0948	29	Mk I	415	2896
1491	0949	30	T20	508	2871

Note: Tube life remaining before firing test was 80%.

ABERDEEN PROVING GROUND
ABERDEEN PROVING GROUND, MARYLAND 21005
FIRING RECORD

USATECOM Project No. 3-5-9240-14,
Military Potential Test of Gun,
Dual, 40-MM, M42 (Duster),
Modified

Related Firing Records: P-71594,
M-83332, and M-83333

Firing Record No.: M-83331
Dates of Test: 10 June to
7 July 1965
Authority: Ltr, USATECOM,
30 September 1964

W. O. No. 377-010-14 ag

ITEMS UNDER TEST

Vehicle, self-propelled, twin 40-mm, M42 (modified), USA Registration No. 12H273.
Gun, 40-mm, M2A1, serial No. 1336.
Mount, gun, 40-mm, M4E1, serial No. 2988.
Modified fire control system for M42 duster.
Lock-out shock absorbers.
Mechanical gun synchronization device.

SUPPORTING FACILITIES AND MATERIALS

Ammunition:

Cartridge, 40-mm, inert-loaded, HE, Mk 2, BL&T, with tracer, lot UE-41-McA-52.

Facilities:

Tubes, 40-mm, M2A1, serial Nos. 129746(L) and 141144(R).

Instrumentation:

Hop-board stands.
Cameras, Benson-Lehner motion-picture cameras to record vehicle, gun, and turret displacement, rate-of-fire, and target impact data.

ROUND-BY-ROUND DATA

Round-by-round data are contained in Inclosure 1.

SUMMARY OF RESULTS

Target Dispersion Data for 40-MM Duster, Modified

Series No.	Elev, mils	Type of Fire: Auto	Type of Fire: Single	Dist to Target, meters	No. Rds Cons: L	R	T	Target Data (Standard Deviation), mils: Left Tube X	Left Tube Y	Right Tube X	Right Tube Y	Over-All X	Over-All Y
Date Fired: 28 June 1965.													
1	- 5.2		S	200.00	8	8	16	0.54	1.09	0.80	1.09	1.83	1.29
2	+543.0		S	42.67	8	8	16	0.73	0.73	1.04	1.36	3.20	1.26
5	+597.0	A		42.67	16	12	28	0.93	0.76	1.00	1.19	3.26	1.33
7	- 5.2		S	200.00	8	9	17	1.43	0.87	1.05	0.92	2.69	1.06
8	+539.0		S	42.67	8	8	16	1.57	2.72	1.15	2.30	4.21	2.53
10	+ 6.6	A		200.00	16	16	32	-	-	-	-	2.76	0.98
11	+597.0	A		42.67	16	16	32	2.32	0.67	1.81	1.05	4.14	1.15
Date Fired: 29 June 1965.													
13	- 5.2		S	200.00	8	8	16	1.25	0.60	0.71	0.78	2.19	0.90
14	+537.4		S	42.67	8	8	16	1.15	0.63	1.57	1.15	3.79	1.10
16	+ 6.6	A		200.00	16	16	32	0.58	-	0.92	-	1.76	1.50
17	+592.4	A		42.67	16	16	32	1.10	1.68	1.01	1.10	3.45	1.44
19	- 5.2		S	200.00	8	8	16	0.64	0.71	1.74	1.43	2.23	1.38
20	+535.8		S	42.67	8	8	16	1.25	1.04	0.84	0.73	3.96	1.26
22	+ 6.6	A		200.00	16	16	32	1.62	0.95	1.73	0.58	2.58	1.32
23	+587.6	A		42.67	16	16	32	1.43	1.10	0.84	0.67	3.60	1.44
Date Fired: 30 June 1965.													
25	- 5.2		S	200.00	8	8	16	1.23	1.20	1.40	0.69	2.59	1.40
26	+600.6		S	42.67	8	8	16	0.63	1.15	1.04	1.04	3.28	1.52

Series No.	Elev, mils	Type of Fire Auto	Type of Fire Single	Dist to Target, meters	No. Rds Cons L	R	T	Target Data (Standard Deviation), mils Left Tube X	Y	Right Tube X	Y	Over-All X	Y
28	+ 6.6	A		200.00	16	16	32	0.70	1.19	0.63	0.79	1.87	1.26
29	+546.6	A		42.67	17	16	33	1.00	1.16	0.51	1.26	3.00	1.86
Date Fired: 30 June 1965.													
44	+ 28	A		38.40	16	16	32	1.50	1.22	0.84	1.03	3.04	1.44
45	+ 28	A		38.40	16	16	32	1.22	0.84	0.94	1.22	3.36	1.20
46	+ 36	A		37.40	16	16	32	0.86	1.54	0.67	2.21	3.28	1.89
Date Fired: 2 July 1965.													
47	- 5.8	A		200.00	16	16	32	1.29	1.33	1.69	1.26	2.79	1.44
48	+ 6.6	A		200.00	16	16	32	0.72	1.17	0.79	1.04	1.90	1.47
49	+549.8	A		42.67	16	16	32	0.84	1.52	0.59	1.60	2.88	1.87
50	+600.4	A		42.67	16	16	32	1.01	1.34	0.76	0.76	2.88	1.87

Note: Standard deviations are unbiased estimates.

OBSERVATIONS AND REMARKS

When the rate of fire for the left gun was 120 rd/min and the right gun 121 rd/min at 65° gun elevation, the synchronized guns fired at the rate of the slowest gun (120 rd/min). With the guns at 0° elevation the left gun fired 134 rd/min, the right gun 136 rd/min, and both guns synchronized fired 134 rd/min.

When firing the durability phase (series 51 and 52) of 1500 plus rounds in each gun, there were no malfunctions of the weapon; however, on numerous occasions the ammunition handler failed to have the next clip of rounds loaded in time and one gun would stop firing while the other gun continued. At no time did either gun fail to continue to fire when the other gun stopped.

This firing record is made part of the final report on USATECOM Project No. 3-5-9240-12-49.

SUBMITTED:

P. R. GREPPS
Test Director

REVIEWED:

D. K. TAG
Chief, Artillery
Weapons Branch

FOR THE COMMANDER:

H. A. BECHTOL
Chief, Artillery Division
Development and Proof Services

1 Incl
Round-by-Round Data

ROUND-BY-ROUND DATA

Date Fired: 10 June 1965.

Group No.	Test Rd No. L	Test Rd No. R	Elev, mils	Recoil Length, in.	Rate of Fire, rd/min	Remarks
1		1 to 8	0	7.8	Lost	At 0945, lock-out pressure was 200 psi. No data on brush recorder.
2		9	0		Lost	Recorder check.
3		10	0		Lost	Recorder check.
4		11 to 18	0		137	
5	1		0	7.5	Lost	Recorder check.
6	2 to 8		0	7.85	140	Failed to feed last round. Round was not in clip.
7	9 to 16	19 to 26	0		Lost	Recorder failed to pick up rounds.
8		27 to 34	1155	8.05	123	
9	17 to 24		1155	8.05	127	
10	25 to 32	35 to 42	1155		120	Left gun, 120, right gun, 121 rd/min.
11	33 to 40	43 to 50	0		134	Left gun, 134, right gun, 136 rd/min.
12		51 to 58	0		136	
13	59 to 67		0		132	
14	68 to 71		0		Lost	
15	72		0		-	Rounds expended. Lock-out jacks at 1145 hours, 185 psi; raised to 200 psi.

Note: These rounds were fired to determine the rate of fire of each gun singly and both guns with the synchronizer operating.

ABERDEEN PROVING GROUND
ABERDEEN PROVING GROUND, MARYLAND 21005
FIRING RECORD

USATECOM Project No. 3-5-9240-12,
Military Potential Test of Gun,
Dual, 40-MM, M42 (Duster),
Unmodified

Related Firing Records: P-71594,
M-83331, and M-83333

Firing Record No.: M-83332
Dates of Test: 17 March to
12 April 1965
Authority: Ltr, USATECOM, 30
September 1964

W. O. No. 324-016-50 es

ITEMS UNDER TEST

Vehicle, self-propelled, twin 40-mm, M42, USA Registration No. 12H297 (unmodified).
Gun, 40-mm, M2A1, serial No. 2984.
Mount, gun, 40-mm, M4E1, serial No. 3012.

SUPPORTING FACILITIES AND MATERIALS

Ammunition:

Cartridge, 40-mm, inert-loaded, HE, Mk 2, BL&T, with tracer, lot VE-41-McA-52.

Facilities:

Tubes, 40-mm, M2A1, serial Nos. 129746 (L) and 141144 (R).

Instrumentation:

Hop-board stands.
Cameras, Mitchell and Benson-Lehner motion-picture cameras to record vehicle, gun, and turret displacement, rate-of-fire, and target impact data.

ROUND-BY-ROUND DATA

Round-by-round data are contained in Inclosure 1.

SUMMARY OF RESULTS

Target Dispersion Data for 40-MM Duster, Unmodified

Series No.	Elev, mils	Type of Fire: Auto	Type of Fire: Single	Dist to Target, meters	No. Rds Cons: L	R	T	Target Data (Standard Deviation), mils: Left Tube X	Left Tube Y	Right Tube X	Right Tube Y	Over-all X	Over-all Y
Date Fired: 17 March 1965.													
1	- 5.2		S	200	8	7	15	0.11	0.22	0.19	0.19	0.57	0.22
2	558		S	42.67	8	8	16	1.22	4.76	5.38	5.27	5.09	4.58
4	5.5	A		200	16	16	32	0.27	0.22	0.47	0.43	2.61	1.06
5	607	A		42.67	16	6	22					3.38	1.82
Date Fired: 18 March 1965.													
1	7		S	200	8	8	16	1.12	0.49	1.32	0.87	1.47	0.90
2	605		S	42.67	8	8	16	0.71	0.51	0.51	1.02	2.29	0.98
4	- 4.6	A		200	16	16	32					3.65	1.49
5	556	A		42.67	16	16	32					3.64	1.68
Date Fired: 22 March 1965.													
7	8.4		S	200	8	8	16					1.95	1.47
8	603.4		S	42.67	8	8	16	1.22	0.81	0.61	0.81	3.11	1.06
10	- 2.5	A		200	16	16	32					5.63	1.54
11	555.2	A		42.67	16	16	32					3.36	2.03

Note: Standard deviations are unbiased estimates.

Series No.	Elev, mils	Type of Fire Auto	Type of Fire Single	Dist to Target, meters	No. Rds Cons L	R	T	Target Data (Standard Deviation), mils Left Tube X	Left Tube Y	Right Tube X	Right Tube Y	Over-all X	Over-all Y
Date Fired: 5 April 1965.													
13	5.8		S	200	8	8	16	0.31	0.76	0.94	1.07	1.47	0.83
16	- 4.2	A		42.67	16	16	32	17.27	8.84	14.19	7.17	14.68	9.41
14	591.8		S	200	8	8	16	0.22	0.27	0.16	0.22	0.65	0.27
17	544.0	A		200	16	16	32					0.69	0.55
17A	544.0	A		200	16	16	32					0.65	0.51
Date Fired: 7 April 1965.													
18A	38.10	A		38.10	16	16	32					4.02	1.85
Date Fired: 9 April 1965.													
19	- 6.0		S	200	16	16	32	0.65	0.58	0.58	0.47	1.54	0.74
22	- 4.6	A		200	16	16	32					2.58	1.89
20	593		S	42.67	8	8	16	2.54	0.71	1.32	0.71	3.44	1.06
23	545.6	A		42.67	16	16	32					2.66	1.68
25	6.0		S	200	8	8	16	0.29	0.60	0.49	0.67	1.42	0.90
28	- 3.4	A		200	16	16	32					2.07	1.63
26	553.4		S	42.67	8	8	16	1.22	1.12	1.52	0.81	3.28	1.31
29	541.6	A		42.67	16	16	32					2.80	1.68

Note: Standard deviations are unbiased estimates.

OBSERVATIONS AND REMARKS

This firing record is made part of the final report on USATECOM Project No. 3-5-9240-12-49.

SUBMITTED:

P. R. GREPPS
Test Director

REVIEWED:

D. K. TAG
Chief, Artillery
Weapons Branch

FOR THE COMMANDER:

H. A. BECHTOL
Chief, Artillery Division
Development and Proof Services

1 Incl
Round-by-Round Data

ROUND-BY-ROUND DATA

Series No.	Test Rd No.		Elev, mils	Type of Fire	Target Data (Dispersion) in.						Distance, Muzzle to Target, meters	Remarks
	L	R		Auto Sing	Left X	Left Y	Right X	Right Y	Over-all X	Over-all Y		
Date Fired: 17 March 1965. Guns pointed forward 0° traverse.												
1	1 to 8	1 to 7	- 5.2	S								Left gun fired round 6, right gun did not fire. Reason unknown.
2	9 to 16	8 to 15	558	S	Data in this series not reliable							
3	17 to 24	16 to 23	1155	S								
4	25 to 40	24 to 39	+ 5.5	A								Left gun fired 16 rounds. Right gun failed to feed after six rounds. Rounds jammed in pawls. All rounds removed and reloaded.
5	41 to 56	40 to 45	607	A								Right gun fired remaining rounds satisfactorily.
5		46 to 55	607	A								Target data not recorded due to only one gun firing at a time.
6	57 to 67	56 to 63	1155	A								Right gun failed to feed after eight rounds. Gun recocked and rounds pushed down.
6	68 to 72	64 to 66	1155	A								Right gun failed to feed after three rounds. Gun recocked and round pushed down.
6		67 to 72	1155	A								Remaining rounds fired satisfactorily.
Date Fired: 18 March 1965. Guns pointed forward 0° traverse.												
*1	73 to 80	73 to 80	+ 7	S	25	11	29-1/2	19-1/2	41	25	200	*Series 1 through 6 repeated due to poor auto. fire data caused by malfunctioning weapon.
2	81 to 88	81 to 88	605	S	3-1/2	2-1/2	2-1/2	5	14	6	42.67	
3	89 to 96	89 to 96	1155	S								Right gun firing slower than left.
4	97 to 112	97 to 112	- 4.6	A					119	48-1/2	200	
5	113 to 128	113 to 128	556	A					26	12	42.67	
6	129 to 141	129 to 136	1155	A								Right feed pawls jammed after eight rounds. Rounds removed and pawls released themselves.
6	142 to 144	137 to 141	1155	A								Right gun fired five rounds when cover (No. 7225118) blew open. Catch (No. 7165191) struck the body and damaged the rear edge of the cover opening.

Series No.	Test Rd No. L	Test Rd No. R	Elev, mils	Type of Fire Auto	Type of Fire Sing	Target Data (Dispersion) in. Left X	Left Y	Right X	Right Y	Over-all X	Over-all Y	Distance, Muzzle to Target, meters	Remarks
Date Fired: 22 March 1965													
Guns 45° left traverse.													
7	145 to 152	142 to 149	8.4		S					55	41-1/2	200	Left gun fired only two rounds on first single-fires. Reason can not be determined.
8	153 to 160	150 to 157	603.4		S	6	4	3	4	19	6-1/2	42.67	Right gun still slower returning to battery than left.
9	161 to 168	158 to 165	1155		S								
10	169 to 179	166 to 178	- 2.5	A									Left gun failed to feed after 11 rounds; gun recocked and rounds pushed down.
10	180 to 184	179 to 181	- 2.5	A						180	50	200	
11	185 to 199	182 to 189	555.2	A									Right gun jammed (pawls); pawls released and gun reloaded.
11	200	190 to 197	555.2	A						24	14-1/2	42.67	
12	201 to 216	198 to 210	1155	A									Right gun failed to feed; recocked gun and pushed rounds down.
12		211 to 213	1155	A									
Date Fired: 5 April 1965.													
Guns 90° left traverse.													
13	217 to 224	214 to 221	+ 5.8		S	7	17	21	24	41	23	200	
16	225 to 240	222 to 237	- 4.2	A		103	53	85	43	103	66	200	Ammunition loader loading left gun was slow on inserting last clip; last four rounds fired solo.
14	241 to 248	238 to 245	591.8		S	5	6	3-1/2	5	18	7-1/2	42.67	
17	249 to 264	246 to 261	544.0	A						22-1/2	18	42.67	All rounds fired satisfactorily. The cameras jammed and series had to be refired (17A)
17A	265 to 280	262 to 270	544.0	A									Fired for camera data. Right gun failed to feed last seven rounds; gun recocked and loaded.
17A		271 to 2-7	544.0	A						21	16-1/2	42.67	Seven rounds fired satisfactorily.
15	281 to 284	278 to 281	1155.0		S								
15	285		1155.0		S								One round fired in left gun for camera data.
15		282	1155.0		S								One round fired in right gun for camera data.
15	286 to 288	283 to 285	1155.0		S								
18	289 to 303	286 to 289	1155.0	A									Right gun failed to feed last three rounds; gun recocked and loaded.
18	304	299 to 301	1155.0										

Series No.	Test Rd No. L	Test Rd No. R			Type of Fire Auto	Type of Fire Sing	Left X	Left Y	Right X	Right Y	Over-all X	Over-all Y	Distance, Muzzle to Target, meters	Remarks
Date Fired: 7 April 1965														
Guns 90° left traverse.														
18A	305 to 316	302 to 310		.?	A									Right buffer opened 1/8 turn before firing. Fired for camera data on turret and gun motion.
18A	317 to 320	311 to 313		17	A									Right gun failed to feed after nine rounds. Gun recocked and loaded.
18A		314 to 317		17	A						24-1/2	11-1/2	38.10	Right gun failed to feed; recocked and loaded. Buffer on right gun closed 1/4 turn.
18A	321			17		S								
18A		318		17		S								
Date Fired: 9 April 1965														
Guns 135° left traverse.														
19	322 to 337	319 to 334	+	6.0		S	18	16	16	13	50	24	200	
22	338 to 345	335 to 339	-	4.6	A									Right gun failed to feed after five rounds; gun recocked and rounds pressed down.
22	346 to 353	340 to 350	-	4.6	A						84	61-1/2	200	
20	354 to 361	351 to 358		593		S	12-1/2	3-1/2	6-1/2	3-1/2	21	6-1/2	42.67	
23	362 to 373	359 to 362		545.6	A									Right gun failed to feed after four rounds. When gun was recocked, the rounds dropped down about 1 inch. The rounds were pressed down into a tray.
23	374 to 377	363 to 371		545.6	A									Right gun failed to feed after nine additional rounds. The gun was recocked and the rounds pressed down.
23		372 to 374		545.6	A						19	12	42.67	
21	378 to 385	375 to 382		1155		S								
24	386 to 401	383 to 398		1155	A									After firing, right buffer replaced.
Guns 180° left traverse.														
25	402 to 404	399 to 401	+	6.0		S								After firing, right buffer adjustment turned out 1/8 turn (3 rounds).
25	405	402	+	6.0		S								After firing, right buffer adjustment turned in 1/16 turn.
25	406	403	+	6.0		S								After firing, right buffer adjustment turned out 1/16 turn. Right gun still slower than left.
25	407 to 409	404 to 406	+	6.0		S	6-1/2	13-1/2	11	15	39-1/2	25	200	After firing, right buffer setting back to original (in. 1/8 turn).

Series No.	Test Rd No. L	Test Rd No. R	Elev, mils	Type of Fire Auto	Type of Fire Sing	Target Data (Dispersion) in. Left X	Left Y	Right X	Right Y	Over-all X	Over-all Y	Distance, Muzzle to Target, meters	Remarks
28	418 to 425	407 to 422	- 3.4	A						67-1/2	53	200	
26	426	423	583.4		S								Omit from test due to improper elevation.
26	427 to 430	424 to 427	553.4]		S								After firing, left buffer adjustment turned in 1/8 turn.
26	431 to 434	428 to 431	553.4		S	6	5-1/2	7-1/2	4	20	8	42.67	Left gun failed to fire in rounds 430 and 432 of group. These rounds did fire on second attempt
29	435 to 450	432 to 447	541.6	A	S					20	12	42.67	Left gun stopped after twelve rounds due to gunner loading ammo clip wrong.
27	451 to 458	447 to 455	1155		S								
30	459 to 464	456 to 460	1155	A									Left gun failed to feed after six rounds. Gun recocked and rounds pressed down.
30	465 to 474	461 to 471	1155	A									Before firing, left buffer setting returned to original (1/8 turn out). All rounds fired satisfactorily.
Date Fired: 12 April 1965. Guns 180° left traverse.													
30A	475 to 478	472 to 475	17	A									Groups 30A and 30B fired for fire control data on movement of elevation and azimuth manual cranks. when oil gears are engaged and drive control handles locked in one position.
30B	479 to 482	476 to 479	17	A									
18B	483 to 498	480 to 495	17	A									Fired for camera data on turret vs vehicle vs tube motion. Manual control.
18C	499		17		S								Same as 18B except only one round from left tube.
18D		496	17		S								Same as 18B except right tube fired.
18E	500 to 515	497 to 512	18.4	A									Same as 18B except with oil gears engaged.
18F	516		18.4		S								Same as 18C except with oil gears engaged.
18G		513	18.4		S								Same as 18F except right tube.

Notes: Gun traverse was measured in relation to the longitudinal axis of the vehicle. In 0° traverse, the guns were directly over the centerline of the front of the vehicle at all times; the guns were aimed downrange and the vehicle was traversed right.
Rounds 18B thru 18G were fired for camera data.
Rounds 30A and 30B were fired for Fire Control Division data.

ABERDEEN PROVING GROUND
ABERDEEN PROVING GROUND, MARYLAND 21005
FIRING RECORD

USATECOM Project No. 3-5-9240-10,
Evaluation of Gun, Dual, 40-MM,
M42 (Duster), Unmodified

Related Firing Records: P-71594,
M-83331, and M-83332

Firing Record No.: M-83333
Dates of Test: 9 to 12 July 1965
Authority: Ltr, USATECOM,
30 September 1964

W. O. No. 377-010-12 ag

ITEMS UNDER TEST

Gun, 40-mm, M2A1, serial No. 2977.
Mount, gun, 40-mm, M4E1, serial No. 3006.

SUPPORTING FACILITIES AND MATERIALS

Ammunition:

Cartridge, 40-mm, inert-loaded, HE, Mk 2, BL&T, with tracer, lot UE-41-McA-52.

Facilities:

Tubes, 40-mm, M2A1, serial Nos. 129746(L) and 141144(R).
Vehicle, self-propelled, twin 40-mm, M42, USA Registration No. 12H298 (unmodified).

ROUND-BY-ROUND DATA

Round-by-round data are contained in Inclosure 1.

SUMMARY OF RESULTS

Group No.	Malfunction
Date Fired: 9 July 1965.	
2 and 3	Left gun failed to feed.
5 through 17	Left gun, rounds hung up in automatic loader.

47

Group No.	Malfunction
20	Left loader receiver replaced to eliminate hang-up of rounds.
21	Left gun failed to feed two times.
29	Left gun failed to feed.
31	Left gun failed to retain round in tray; round fell out on ground underneath vehicle.
33	Left gun failed to retain round in tray; round fell out on ground underneath vehicle.
36	Two failures. Left gun failed to fire; round laying loose in tray. Left gun failed to retain round in tray; round fell out on ground underneath vehicle.

Date Fired: 12 July 1965.

39 and 40	Left gun failed to retain round in tray; round fell out on ground underneath vehicle.
41	Two failures. Left gun failed to feed. Left gun failed to fire; round laying loose in the tray.
42	Left gun failed to feed two times.
44	Left gun failed to retain round in tray; round dropped out underneath vehicle.
46	Left and right flash suppressors broke. Replaced with components from vehicle No. 12H297.
48	Left gun failed to fire; round loose in tray.
50	Left gun failed to fire; round loose in tray.
56	Left gun failed to feed two times and failed to fire one time with round loose in tray.
57	Left gun failed to fire; round laying loose in tray. Rammer tray assembly replaced.
61	Left gun failed to feed two times.
62	Left gun failed to retain round in tray; round fell to ground underneath vehicle.
63	Left gun failed to feed.
66	Left gun failed to feed.

OBSERVATIONS AND REMARKS

When investigating the reason for the rounds hanging up approximately 3 to 4 inches from the top of the automatic loader, it was noted that the clearance in the guide was approximately 1/16 inch less than that of the right loader. These rounds could be made to feed by the ammunition

handler applying a slight downward pressure on the rounds while firing. The loader receiver was replaced with one from vehicle No. 12H297. This corrected the difficulty with the rounds binding.

When first firing the weapon, the rate of fire was extremely high. It was noted that the buffer adjustment screws were open 1-1/2 turns. The two screws were set to 1/2 turn open thereby reducing the rate of fire to approximately 120 rd/min with the right gun slightly slower than the left. The right buffer screw was opened 1/8 turn and the two guns fired at approximately the same rate.

It appeared that after the buffers were closed down, the left gun failed to recock and feed a round onto the rammer tray on numerous occasions. Several times the round was on the tray and the gun failed to fire. It was noted that the round was laying loose in the tray with the base of the case behind the catches. When this occurred, and the gun was elevated, the round would fall out of the tray and drop on the ground underneath the vehicle. In an attempt to correct this condition, the rammer-tray assembly was replaced with one from vehicle No. 12H297. This change did not correct the malfunction.

The left buffer adjustment screw was then progressively opened 1/8 turn at a time until the gun appeared to function satisfactorily. At this point the adjustment screw was 1-1/8 turns open. The right buffer adjustment screw was opened in the same manner until the guns were synchronized as well as possible without the installation of a synchronizing device. At this point the right setscrew was 7/8 turn open.

After these adjustments were made, 200 rounds per weapon were fired without a malfunction of any kind.

The rod around the circumference of the three prongs of the flash suppressor broke on both the left and right tube. The suppressors were replaced with two removed from vehicle No. 12H297.

At no time throughout the test did the right gun fail to function satisfactorily.

This firing record is made part of the final report on USATECOM Project No. 3-5-9240-12-49.

SUBMITTED:

P. R. Grepps
P. R. GREPPS
Test Director

REVIEWED:

D K Tag
D. K. TAG
Chief, Artillery
Weapons Branch

FOR THE COMMANDER:

H. A. BECHTOL
Chief, Artillery Division
Development and Proof Services

2 Incls
Round-by-Round Data
Summary Results of Parts Inspection

ROUND-BY-ROUND DATA

Gun Elev, deg	Group No.	Round No. L	Round No. R	Remarks
Date Fired: 9 July 1965.				
1 to 45	1	1 to 20	1 to 20	Rate of fire of both guns very fast.
1 to 45	2	21 to 40	21 to 40	Rounds failed to feed after five rounds (left gun). None in tray.
1 to 45	3	41 to 60	41 to 60	Rounds failed to feed after five rounds (left gun). None in tray.
1 to 45	4	61 to 80	61 to 80	
1 to 45	5	81 to 100	81 to 100	Rounds hung up in automatic loader about 1/2 way down after four rounds.
1 to 45	6	101 to 120	101 to 120	Rounds hung up in automatic loader about 1/2 way down after four rounds.
1 to 45	7	121 to 140	121 to 140	Rounds hung up in automatic loader about 1/2 way down after four rounds.
1 to 45	8	141 to 160	141 to 160	Rounds hung up in automatic loader about 1/2 way down after four rounds.
1 to 45	9	161 to 180	161 to 180	Rounds hung up in automatic loader about 1/2 way down after four rounds.
1 to 45	10	181 to 200	181 to 200	Rounds hung up in automatic loader about 1/2 way down after four rounds. Both guns still firing very fast. Left buffer closed 1 turn and right buffer closed 1-1/4 turn. Both are now 1/2 turn open. It was noted that the rounds were hanging (binding) in the guides of the left automatic loader.
1 to 45	11	201 to 220	201 to 220	Rate of fire now about 120 rpm. Right buffer opened 1/8 turn.

Gun Elev, deg	Group No.	Round No. L	Round No. R	Remarks
1 to 45	12	221 to 240	221 to 240	Both guns firing close together. Rounds still hung up unless ammunition handler kept pressure on them.
1 to 45	13	241 to 260	241 to 260	Left loader fed with pressure on rounds.
1 to 45	14	261 to 280	261 to 280	Left loader fed with pressure on rounds.
1 to 45	15	281 to 300	281 to 300	Left loader fed with pressure on rounds.
1 to 45	16	301 to 320	301 to 320	Left failed to feed round into tray. Recocked gun and pressed round down into tray.
1 to 45	17	321 to 340	321 to 340	Left loader pawls tight. Raised cocking lever and pawls released.
1 to 45	18	341 to 360	341 to 360	All rounds fired satisfactorily.
1 to 45	19	361 to 380	361 to 380	All rounds fired satisfactorily.
1 to 45	20	381 to 400	381 to 400	All rounds fired satisfactorily. Removed left loader-receiver and replaced with one from vehicle No. 1211297.
1 to 45	21	401 to 420	401 to 420	Left gun failed to load. Recocked gun and pressed round in tray.
1 to 45	22	421 to 440	421 to 440	All rounds fired satisfactorily.
1 to 45	23	441 to 460	441 to 460	
1 to 45	24	461 to 480	461 to 480	
1 to 45	25	481 to 500	481 to 500	
1 to 45	26	501 to 520	501 to 520	
1 to 45	27	521 to 540	521 to 540	
1 to 45	28	541 to 560	541 to 560	
1 to 45	29	561 to 580	561 to 580	Left gun failed to load twice. Recocked and pressed round down.
1 to 45	30	581 to 600	581 to 600	

Gun Elev, deg	Group No.	Round No. L	Round No. R	Remarks
1 to 45	31	601 to 620	601 to 620	Left gun failed to load; round on ground under vehicle. Recocked and pressed round down.
1 to 45	32	621 to 640	621 to 640	
1 to 45	33	641 to 660	641 to 660	Left gun failed to load; round on ground under vehicle. Recocked and pressed round down.
1 to 45	34	661 to 680	661 to 680	
1 to 45	35	681 to 700	681 to 700	
1 to 45	36	701 to 720	701 to 720	Left gun, round loose in tray. Round removed, gun cocked, and round pressed down. After three rounds, the left gun failed to keep round in tray and round fell to the ground under vehicle. Gun recocked and rounds pressed down.
1 to 45	37	721 to 740	721 to 740	
1 to 45	38	741 to 750	741 to 750	
Date Fired: 12 July 1965.				
0 to 45	39	751 to 770	751 to 770	Round dropped out of left loading tray on ground. Left buffer opened 1/8 turn (5/8 total).
0 to 45	40	771 to 790	771 to 790	Round dropped out of left loading tray on ground.
0 to 45	41	791 to 810	791 to 810	Left gun failed to load; gun recocked and round pressed onto tray. Opened left buffer 1/8 turn (3/4 total). After three additional rounds, left gun failed to fire; round laying loose in tray. Removed round and recocked gun; remaining rounds fired satisfactorily.

Gun Elev, deg	Group No.	Round No. L	Round No. R	Remarks
4	42	811 to 830	811 to 830	Left gun failed to load; tray empty after three rounds. Recocked gun and pressed round onto tray. After firing four more rounds, the left gun failed to load again. Recocked and pressed round onto tray. Remaining round fired satisfactorily. Left buffer opened 1/8 turn (7/8 turn).
4	43	831 to 850	831 to 850	
4	44	851 to 870	851 to 870	Left gun failed to fire; round fell out of tray and onto ground under vehicle. Recocked gun and pressed round onto tray.
13	45	871 to 890	871 to 890	
13	46	891 to 910	891 to 910	Left and right flash suppressors broken; replaced both.
4	47	911 to 930	911 to 930	
4	48	931 to 950	931 to 950	Left gun failed to fire fourth round; round loose in tray. Round removed, gun recocked, and rounds pressed down.
4	49	951 to 970	951 to 970	
0	50	971 to 990	971 to 990	Left gun failed to fire fourth round. Round in tray; rammer lever failed to catch round. Round removed, gun recocked, and rounds pressed down.
0	51	991 to 1010	991 to 1010	
0	52	1011 to 1030	1011 to 1030	
15	53	1031 to 1050	1031 to 1050	
15	54	1051 to 1070	1051 to 1070	
4	55	1071 to 1090	1071 to 1090	
0	56	1091 to 1110	1091 to 1110	Left gun, rounds 4 and 8 failed to fire. Rounds failed to drop in tray. Gun recocked and rounds

Gun Elev, deg	Group No.	Round No. L	Round No. R	Remarks
				pressed down. Round 12 failed to fire, with round loose in tray. Round removed, gun cocked, and rounds pressed down.
0	57	1111 to 1130	1111 to 1130	Left gun, round 4 failed to fire with round in tray, loose. Round removed, gun cocked, and rounds pressed down. The rammer-tray assembly was replaced with one from vehicle No. 12H297.
0	58	1131 to 1150	1131 to 1150	Left gun, rounds 4 and 10 failed to fire; round was laying loose in tray. Rounds removed, gun cocked, and rounds pressed down.
15	59	1151 to 1170	1151 to 1170	
30	60	1171 to 1190	1171 to 1190	
45	61	1191 to 1210	1191 to 1210	Left gun, rounds 4 and 8 failed to fire; rounds failed to feed onto tray. Gun cocked and rounds pressed down. After firing, left buffer opened 1/8 turn (1 turn total).
45	62	1211 to 1230	1211 to 1230	Left gun, failed to fire round 12; round fell out of tray, laying under vehicle. Gun recocked, and rounds pressed down. Left buffer opened 1/8 turn (1-1/8 total).
45	63	1231 to 1250	1231 to 1250	Left gun failed to fire round 4; no round in tray. Gun cocked, rounds pressed down.
45	64	1251 to 1270	1251 to 1270	After firing, right buffer opened 1/8 turn (1 turn total).
45	65	1271 to 1290	1271 to 1290	After firing, right buffer closed 1/4 turn (3/4 turn total).

Gun Elev, deg	Group No.	Round No. L	Round No. R	Remarks
45	66	1291 to 1310	1291 to 1310	Left gun failed to fire round 4; no round in tray. Gun cocked and rounds pressed down. Right buffer opened 1/8 turn (7/8 turn total).
45	67	1311 to 1330	1311 to 1330	
45	68	1331 to 1350	1331 to 1350	
0	69	1351 to 1370	1351 to 1370	
0	70	1371 to 1390	1371 to 1390	
5	71	1391 to 1410	1391 to 1410	
5	72	1411 to 1430	1411 to 1430	
10	73	1431 to 1450	1431 to 1450	
15	74	1451 to 1470	1451 to 1470	
20	75	1471 to 1490	1471 to 1490	
25	76	1491 to 1502	1491 to 1502	

Note: There was no malfunction of the weapon when firing groups 67 through 76.

Time, hrs	Series No.	Test Rd No. L	Test Rd No. R	Elev, mils	Type of Fire Salvo Auto	Type of Fire Salvo Single	Target Data (Dispersion), in. Left Tube X	Left Tube Y	Right Tube X	Right Tube Y	Both Tubes, Over-All X	Both Tubes, Over-All Y	Distance, Muzzle to Target, meters	Lock-Out Suspension Press., psi	Remarks
Date Fired: 28 June 1965.															
Guns 0° traverse.															
Without power controls.															
0900	BF													200	
1100	1	1 to 8	1 to 8	- 5.2		S	12	24-1/2	18	24-1/2	51	36	200	300	Pressure lowered to 200 psi.
	2	21 to 28	25 to 32	+ 543		S	3-1/2	3-1/2	5	6-1/2	19	7-1/2	42.67		
1300	3	45 to 52	45 to 52	+1155		S								300	Pressure lowered to 200 psi.
	4	9 to 20	9 to 24	+ 6.2	A						76	40	200		
	5	29 to 44	33 to 44	+ 597	A		5-1/2	4-1/2	5-1/2	6-1/2	22	9	42.67		
1445	6	53 to 68	53 to 68	+1155	A									210	
Guns 45° left traverse.															
	7	69 to 76	69 to 77	- 5.2		S	32	19-1/2	24-1/2	21-1/2	76	30	200		
	8	93 to 100	94 to 101	+ 539		S	7-1/2	13	5-1/2	11	25	15	42.67		
1515	9	117 to 124	118 to 125	+1155		S								300	Pressure lowered to 200 psi.
	10	77 to 92	78 to 93	+ 6.6	A						90	32	200		
	11	101 to 116	102 to 117	+ 597	A		13-3/4	4	10-3/4	6-1/4	28-3/4	8	42.67		
	12	125 to 136	126 to 141	+1155	A										
1600	12	137 to 152	142 to 157	+1155	A									210	Pressure released for day.
Date Fired: 29 June 1965.															
Guns 90° left traverse.															
0845	BF													200	Pressure at 0935 hours, 300 psi. Lowered pressures to 200; at 1000 hours, pressure 280 psi; at 1030 hours, pressure 300 psi. Pressure released completely (0 psi) and built back up to 260 psi.
1040	13	153 to 160	158 to 165	- 5.2		S	28	13	16	17-1/2	61	25	200	200	
	14	177 to 184	182 to 189	+ 537.4		S	5-1/2	3	7-1/2	5-1/2	22-1/2	6-1/2	42.67		

Time, hrs	Series No.	Test Rd No. L	Test Rd No. R	Elev, mils	Type of Fire Salvo Auto	Type of Fire Salvo Single	Target Data (Dispersion), in. Left Tube X	Left Tube Y	Right Tube X	Right Tube Y	Both Tubes, Over-All X	Both Tubes, Over-All Y	Distance, Muzzle to Target, meters	Lock-Out Suspension Press., psi	Remarks
	15	201 to 208	206 to 113	+1155		S									
	16	161 to 176	166 to 181	+ 6.6	A		16		25-1/2		57-1/2	49	200		
	17	185 to 200	190 to 205	+ 592.4	A		6-1/2	10	6	6-1/2	24	10	42.67		
1245	18	209 to 224	214 to 229	+1155	A									200	
Guns 135° left traverse.															
	19	225 to 232	230 to 237	- 5.2		S	14-1/4	16	39	32	62	38-1/2	200		
	20	249 to 256	254 to 261	+ 535.8		S	6	5	4	3-1/2	23-1/2	7-1/2	42.67		
	21	273 to 280	278 to 285	+1155		S									
	22	233 to 248	238 to 253	+ 6.6	A		45	26-1/2	48	16	84	43	200		
	23	257 to 272	263 to 278	+ 587.6	A		8-1/2	6-1/2	5	4	25	10	42.67		
1600	24	281 to 296	286 to 301	+1155	A									220	Pressure released for day.
Date Fired: 30 June 1965. Guns 180° left traverse.															
0845	BF													200	
1015	25	297 to 304	302 to 309	- 5.2		S	27-1/2	27	31-1/2	15-1/2	72	39	200	100	Pressure increased to 200 psi.
	26	321 to 328	326 to 333	+ 600.6		S	3	5-1/2	5	5	19-1/2	9	42.67	200	
1100	27	345 to 352	351 to 357	+1155		S								120	Pressure raised to 200 psi.
	28	305 to 320	310 to 325	+ 6.6	A		19-1/2	33	17-1/2	22	61	41	200	200	
	29	329 to 345	334 to 349	+ 546.6	A		6	7	3	7-1/2	21	13	42.67		
1130	30	353 to 368	358 to 373	+1155	A									120	Pressure released.
With power controls.															
	31	369 to 372	324 to 377	+ 27	A										Hands off power controls (elevation and azimuth).
	32	373 to 376		+ 27	A										Hands off power controls (elevation and azimuth).
	33		378 to 381	+ 27	A										Hands off power controls (elevation and azimuth).

Firing Record No. M-83333

Time, hrs	Series No.	Test Rd No. L	Test Rd No. R	Elev, mils	Type of Fire Salvo Auto	Type of Fire Salvo Single	Target Data (Dispersion), in. Left Tube X	Left Tube Y	Right Tube X	Right Tube Y	Both Tubes, Over-All X	Both Tubes, Over-All Y	Distance, Muzzle to Target, meters	Lock-Out Suspension Press., psi	Remarks
Without power controls.															
	34	377 to 380		◆ 27	A										Gun fired only two rounds for no apparent reason.
	35	381 to 384		◆ 27	A										Camera failed to operate (repeat).
	36	385 to 388		◆ 27	A										Camera failed to operate (repeat).
	37	389 to 392		◆ 27	A										
	38		382 to 385	◆ 27	A										
With power controls.															
	39	393 to 394		◆ 27		S									Gun set on SF and fired automatic fire. Hands off power controls.
	40	395 to 396		◆ 27		S									Hands off power controls.
	41		386 to 387	◆ 27		S									Hands off power controls.
Without power controls.															
	42	397 to 398		◆ 27		S									
	43		388 to 389	◆ 27		S									
	44	399 to 414	390 to 405	◆ 28	A		8	6-1/2	4-1/2	5-1/2	19	9	38.40		
With power controls.															
	45	415 to 430	406 to 421	◆ 28	A		6-1/2	4-1/2	5	6-1/2	21	7-1/2	38.40		Hands off power controls.
	46	431 to 446	422 to 437	◆ 36	A		4-1/2	8	3-1/2	11-1/2	20	11-1/2	38.40		Hands on power controls.
		447	438	◆ 27	A										Rounds expended.

Firing Record No. M-83333

Time, hrs	Series No.	Test Rd No. L	Test Rd No. R	Elev, mils	Type of Fire Salvo Auto	Type of Fire Single	Target Data (Dispersion), in. Left Tube X	Left Tube Y	Right Tube X	Right Tube Y	Both Tubes, Over-All X	Both Tubes, Over-All Y	Distance, Muzzle to Target, meters	Lock-Out Suspension Press., psi	Remarks
Date Fired: 2 July 1965.															
Guns 0° traverse.															
Without power controls.															
	47	448 to 463	439 to 454	- 5.8	A		36	37	47	35	91	47	200	200	Fired for camera and vehicle hop data.
	48	496 to 511	487 to 502	+ 6.6	A		20	32-1/2	22	29	62	48	200	0	Fired for camera and vehicle hop data.
	49	464 to 479	455 to 470	+ 549.8	A		5	9	3-1/2	9-1/2	20	13	42.67	200	Fired for camera and vehicle hop data.
	50	480 to 495	471 to 486	+ 600.4	A		6	8	4-1/2	4-1/2	20	13	42.67	0	Fired for camera and vehicle hop data.
With power controls.															
1050 to 1410	51	512 to 948	502 to 939	+ 17 to 800	A									[a] -	Expenditure rounds for weapon performance. Guns constantly being elevated and depressed during firing while azimuth is locked at 0°. No weapon malfunctions were noted.
Date Fired: 7 July 1965.															
	52	949 to 1548	939 to 1539	+ 17 to 800	A									[b] -	Repeat of group 51. No weapon malfunctions were noted.

[a] The suspension lock-out system was pumped up to 200 psi at the start of firing at 1050 hours and 55 minutes later (1145 hours), the pressure was holding at 200 psi. The weapon stood idle from 1145 to 1330 hours (1 hour 45 minutes), and the pressure built up to 300 psi. At this time, the pressure was bled off to 200 psi and remained this way during the remainder of the firing (1410 hours). The pressure was then released for the day.

[b] At 0845 hours, the suspension lock-out system was pumped up to 200 psi and allowed to stand idle for 1 hour 45 minutes (1030 hours). At this time the pressure had dropped to 100 psi. The pressure was increased to 200 psi for firing, and after 26 minutes (1056 hours), the pressure had dropped to 160 psi. The pressure was again raised to 200 psi and after 19 minutes (1115 hours) it had dropped to 180 psi. The pressure was not raised, and at 1142 hours it was still 180 psi. The vehicle was left standing idle for 1 hour 20 minutes (1302 hours); the pressure had risen to 210 psi. The pressure was allowed to remain at 210 psi. When firing resumed at 1302 hours, and 25 minutes later (1327 hours), the pressure had risen to 300 psi. The pressure was then released for the day.

Gun, 40-MM, M2A1, on SP, M42, No. 12H298,
Summary Results of Parts Inspection

Item	Ord Part No.	Before Fire APG					After Firing 1502 Rds APG		
		Gun	Cracked	Worn	Re-placed	Quant	Gun	Cracked	Re-placed
Arm, breech ring control	5222434	L R	X		Yes	2			
Arm, extractor, left	7165194	L	X		No	1	L	X	No
Arm, extractor, right	6197107	R	X		No	1	R	X	No
Breechblock assembly, composed of:	62609141	L R	X	X	Yes	2			
Breechblock	6550027	L R		X					
Cover, firing pin spring	5222588	L R	X(R)	X(L)			L R	X	No
Lever, breechblock outer cocking	6197147	L R	X				L R	X	No
Lever, breechblock inner cocking	5222586	L R	X(L)	X(R)			L	X	No
Pin, firing	7238625	L R		X					
Plunger, breechblock inner cocking sear	6197148	L R	X				L R	X	No
Spring, firing pin	5222592	L		X(L)					
Spring, breechblock inner cocking lever sear plunger	5222593	L R	Below Spec				R	Below Spec	No
Bolt, loader tray connecting	5222427	R	[a]Missing			2	L R	[a]Missing	No
Case, breech closing spring assembly, left, composed of:	6197141	L	X		Yes	1			

[a]Parts missing or unserviceable when weapon received at APG. Replacement parts were not available and parts were removed from vehicle No. 12H297 to conduct test.

L = Left.
R = Right

Item	Ord Part No.	Before Fire APG					After Firing 1502 Rds APG		
		Gun	Cracked	Worn	Re-placed	Quant	Gun	Cracked	Re placed
Case, breech closing spring, left	6197102	L	X						
Cover, breech closing spring, left	6197103	L	X						
Spring, breech closing, left	6197113	L	Serviceable						
Case, breech closing spring assembly, right, composed of:	7165195	R	X		Yes	1			
Case, breech closing spring, right	7165196	R	X						
Cover, breech closing spring, right	7165197	R	X						
Spring, breech closing, right	7165198	R	Serviceable						
Crank, breech ring outer, left assembly, composed of:	6197142	L	X	X	Yes	1			
Crank, breech ring outer, left	6197105	L		X					
Pin, taper	BFCX1	L		X					
Roller, breech ring outer crank	5222439	L		X					

L = Left.
R = Right.

Item	Ord Part No.	Before Fire APG					After Firing 1502 Rds APG		
		Gun	Cracked	Worn	Replaced	Quant	Gun	Cracked	Replaced
Screw, machine	BCLX1.9	L		X					
Shaft, breech ring crank	6197104	L	X						
Washer, breech ring outer crank roller	5222440	L		X					
Crank, breech ring inner, left	5595003	L R	X		Yes	2	L	X	No
Crank, breech ring inner, right	5595004	L R	X		Yes	2	L R	X	No
Extractor, cartridge case, left	6197146	L R	X(L)	X(R)	Yes	2			
Extractor, cartridge case, right	6197126	L R	X(L)	X(R)	Yes	2			
Guide, loader, rear, left	6550009	L	X		No	1	L	X	No
Guide, loader, rear, right	7225129	R	X		No	1	R	X	No
Loader, automatic, assembly	7305371	L	[a]Unserviceable			1	L	[a]Unserv-iceable	No
Roller, feed rod	5222461	R	[a]Missing		No	4	L R	[a]Missing	No
Tray, automatic loader, assembly, composed of:	7308571	L R	X	X	Yes	2			
Lever, rammer, left	5222411	L		X					
Lever, rammer, right	5222412	R		X					
Nut, slotted, light, hex	BBHX3	L R		X					

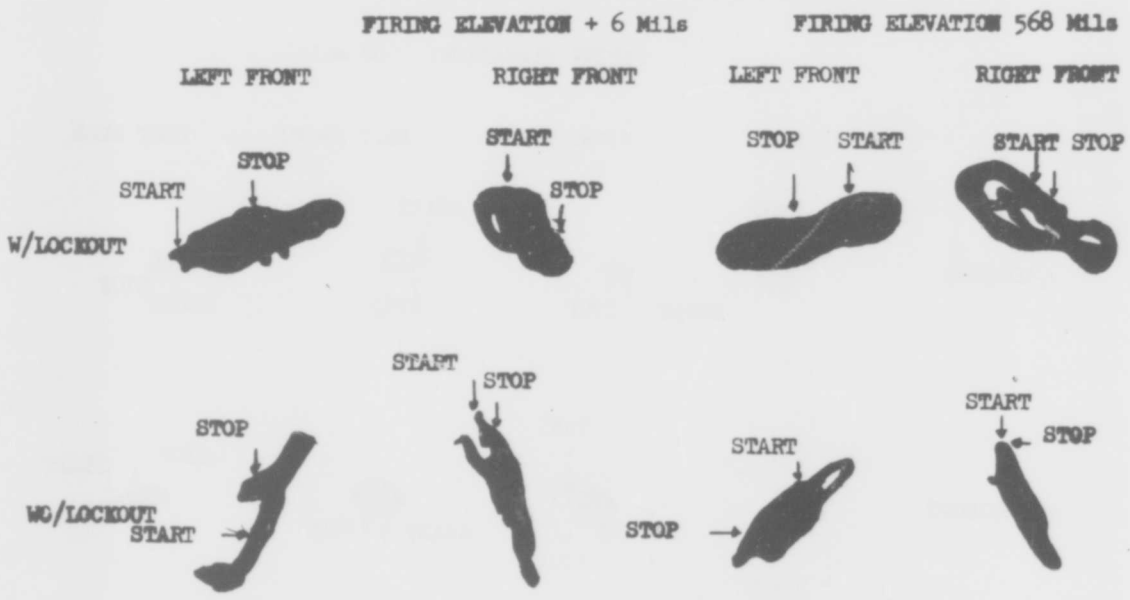
[a]Parts missing or unservicable when weapon received at APG. Replacement parts were not available and parts were removed from vehicle No. 12H297 to conduct test.

L = Left.
R = Right.

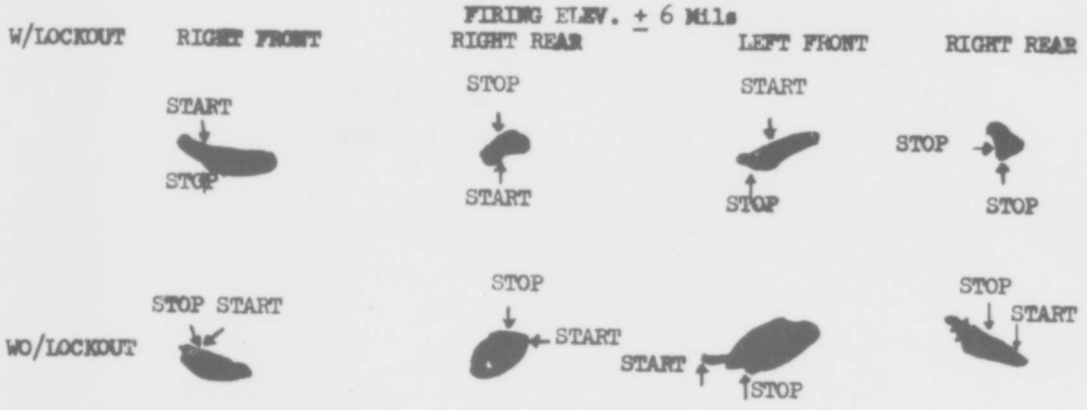
Item	Ord Part No.	Before Fire APG Gun	Cracked	Worn	Replaced	Quant	After Firing 1502 Rds APG Gun	Cracked	Replaced
Nut, rammer rod	7308570	L R		X					
Pad, rammer buffer assembly (riveted)	5222487	L R		X					
Pawl, tray assembly, left	5226443	L		X					
Pawl, tray assembly, right	5226442	R		X					
Pin, cotter, split	BAFAX3	L R		X					
Plunger, tray pawl	5222568	L R		X					
Rammer, cartridge, assembly	6197143	L R		X					
Screw, rammer spring rear seat	5222475	L R		X					
Shoe, rammer, assembly	5226441	L R	X(L)	X(R)					
Spring, rammer lever plunger	5222407	L R	Below spec						
Spring, tray pawl plunger	5222463	L R	Serviceable						
Tray, automatic loader	7305585	L R		X					
Spindle, extractor, left	7165193	L	X		Yes	1			
Spindle, extractor, right	6197106	R	X		Yes	1			
Spring, rammer inner	6260936	R	Below spec		Yes	1			
Spring, rammer outer	6260937	L R	Below spec		Yes	2	L	Below spec	No
Spring, recuperator	7238632	R	Below spec		Yes	1			

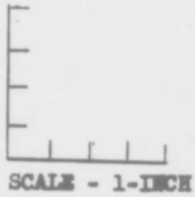
L = Left.
R = Right.

HOP RECORDS
40-MM GSP, M42 DUSTER (MODIFIED)
WITH AND WITHOUT LOCK-OUT SHOCK ABSORBERS
VEHICLE FIRING POSITION: OVER FRONT 0° TRAVERSE



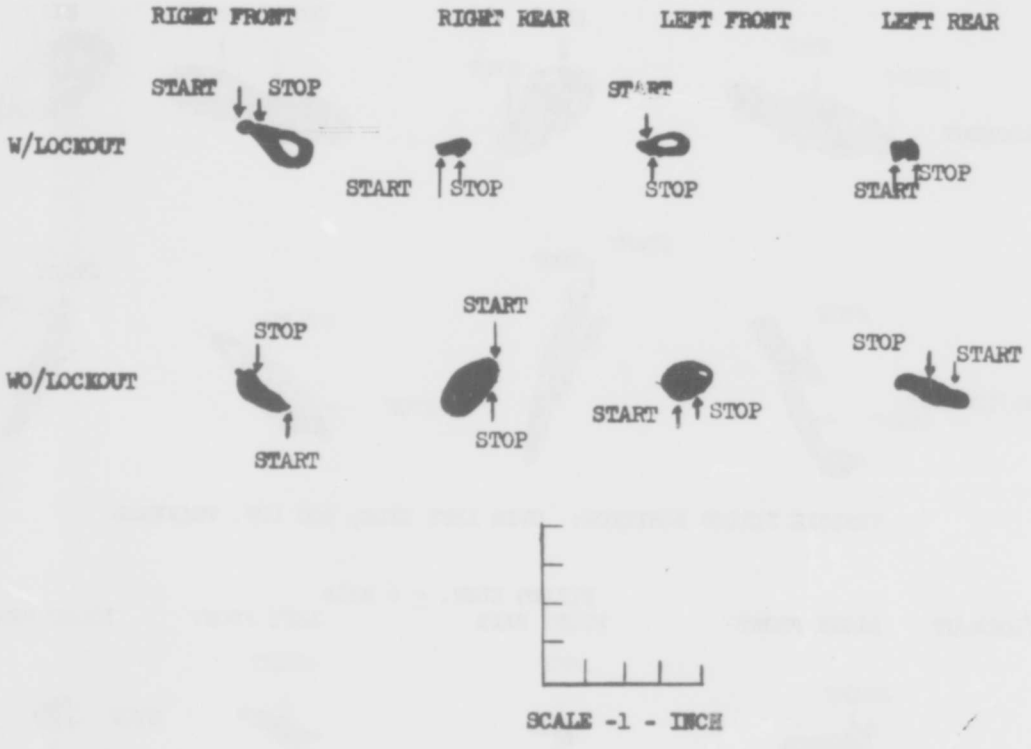
VEHICLE FIRING POSITION: OVER LEFT SIDE, 900 LEF. TRAVERSE





HOP RECORDS
40-MM GSP, M42 DUSTER (MODIFIED)
WITH AND WITHOUT LOCK-OUT SHOCK ABSORBERS
VEHICLE FIRING POSITION: OVER LEFT SIDE, 900 LEFT TRAVERSE

FIRING ELEVATION: 568 Mils



ENGINEERING DATA - GUNS

Incl 1-3
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MALFUNCTION DATA HS 820/M113

Legend:

FF - Failure to feed, cause unknown.
FF-BUR - Failure to feed, bolt under round.
FBR- Failure of bolt to remain at rear after last round.
FF-CB - Failure to feed, case bounce
FF-SROB - Failure to feed, stub round on face of barrel
FF-MJ - Failure to feed, ammunition jam in magazine.
FBC - Failure of bolt to close
FX - Failure to extract
FF-SR - Failure to feed, short recoil
FJ - Failure to eject
FBC-BPR - Failure of bolt to close, broken push rod.

HS 820/M113 - SUMMARY OF MALFUNCTIONS

Malfunction				Gun Elevation	Barrel Gas Port	System	Rounds
Type	System	Other	Total	Degrees	Dia. (mm)	Malf./1000 Rds	Fired
FBR	1		1	6	1.5		3600
FF-BUR	1		1				
FF-CB	2		2				
FF-SROB	1		1				
FF-MJ		1	1				
FF	1		1				
TOTAL	6	1	7			1.7	
FF	2		2	6	1.6		3000
FF-BUR	1		1				
TOTAL	3		3			1.0	
FBR		1	1	20	1.5		3000
FBC	2	4	6				
FX	1		1				
FF-SR		1	1				
FJ		1	1				
FF-BUR	1		1				
TOTAL	4	7	11			1.3	
FBC		4	4	40	1.5		2700
FX	3		3				
FBC-BPR	1		1				
TOTAL	4	4	8			1.5	
FBC		2	2	40	1.6		300
TOTAL		2	2			0.0	
FBR	2	3	5	60	1.5		3000
FF-SR	1	2	3				
FJ	1		1				
TOTAL	4	5	9			1.3	

Malfunction			Gun Elevation	Barrel Gas Port	System	Rounds
Type	System	Other	Total	Degrees	Dia.(mm)	Malf./1000 Rds	Fired
	21				1.5/1.6	1.3	15600
Summation							
	18				1.5	1.5	12300
	3				1.6	0.9	3300

Note: System malfunction is defined as failure of the weapon and related components. Other malfunction is defined as those caused by personnel or supporting facilities.

M61/M113 TABLE OF MALFUNCTIONS

Type	System	Other	Total	Gun Elevation Degrees	System Malf/ 1000 Rounds	Rounds Fired
*FFR	2		2	6	0.2	10961
Total	2		2			
				20		2850
Total	0		0		0.0	
FFR	1		1	40		2846
Total	1		1		0.4	
FFR		1	1	60		3210
Total		1	1		0.0	
Summation	3				0.2	19867

*FFR - Failure to fire

H.S. HEPT CARTRIDGE DATA

Velocity Data

Source	BBL. No.	Ammo Temp	Midpoint of Screens	Velocity, fps				
				Max.	Min.	Avg	Ext. Var.	Std Dev.
DPS 1155	7	70°F	50.8'	-	-	3411	-	9.70
DPS 1155	4	70°F	50.8'	-	-	3401	-	10.88
DPS 1155	6	70°F	50.8'	-	-	3416	-	9.13
Current	7	80.6°F	53.0'	3436	3406	3423	30	9.0

CARTRIDGE COMPONENT WEIGHTS - gms

	Projectile	Propellant	Ctg. Case
DPS 1155	120	50.0	142.4
Current	121.7	50.7	146.5

Accuracy Data HS 820/M113 - 200 Meter Range

Target No.	Rds in Burst	C.I. From A.P. V	C.I. From A.P. H	EV	MVD	SVD	EH	MHD	SHD	ES	MR
						(reading in inches)					
						Firing over front of vehicle					
1	45	2.5	0.6	59.7	11.7	14.6	75.1	11.2	16.0	78.4	20.2
2	45	12.2	5.6	90.0	14.5	19.3	60.2	12.3	15.9	107.5	21.5
3	45	7.4	10.6	74.0	11.9	15.4	71.0	15.4	16.1	83.2	21.4
Avg		7.4	5.6	74.6	12.7	16.4	68.8	13.0	16.7	89.7	21.0
4	30	13.0	8.3	64.4	12.7	16.1	60.1	10.6	14.7	72.6	18.2
5	30	9.8	5.3	68.5	12.8	17.0	47.0	12.0	14.2	69.3	18.8
6	30	5.5	7.7	60.5	13.4	16.1	55.0	9.6	12.2	71.5	17.8
Avg		9.4	7.1	64.5	13.0	16.4	54.0	10.7	13.7	71.1	18.3
7	10	-5.0	12.1	28.0	7.3	9.9	14.6	3.8	4.9	29.1	8.6
8	10	-0.8	13.0	34.8	9.9	11.8	17.2	4.8	5.6	35.0	11.3
9	10	-1.2	7.3	24.9	5.6	7.8	34.1	8.9	9.4	34.3	11.8
Avg		-2.3	10.8	30.7	7.6	9.8	22.0	5.6	6.6	32.8	10.6
						Firing over left side of vehicle					
10	10	20.2	7.3	54.6	16.4	19.4	26.8	8.5	9.8	54.7	19.6
11	10	-2.0	8.8	43.5	10.8	13.6	37.2	9.0	11.1	46.0	14.0
12	10	1.0	2.2	41.4	8.7	11.6	40.2	11.3	13.6	47.5	15.5
Avg		6.4	6.1	46.5	12.0	14.9	34.7	9.6	11.5	49.4	16.4
13	30	6.0	6.5	60.9	8.7	11.8	53.2	10.9	13.6	61.8	15.5
14	30	4.6	6.4	73.1	12.0	15.7	58.1	10.8	13.8	73.1	17.3
15	30	10.4	6.5	51.9	11.4	13.7	62.7	11.4	14.8	62.7	17.3
Avg		7.0	6.5	62.0	10.7	13.7	58.0	11.0	14.1	65.9	16.7

Target No.	Rds in Burst	C.I. From A.P. V	C.I. From A.P. H	EV	MVD	SVD	EH	MHD	SHD	ES	MR	
						(reading in inches)						
16	45	0.4	20.0	72.3	12.6	16.4	82.1	16.7	20.1	96.5	23.6	
17	45	2.9	14.2	70.3	14.0	17.1	71.3	13.3	16.6	81.3	21.3	
18	45	3.5	16.2	78.3	11.7	15.8	70.6	13.2	16.4	82.4	20.0	
Avg		2.3	16.8	73.6	12.8	16.4	74.7	14.4	17.7	86.7	21.6	
					Firing over rear of vehicle							
21	10	-4.0	0.7	46.9	9.4	12.9	28.8	7.2	9.1	47.0	13.5	
22	10	-3.8	-5.7	40.3	7.7	11.5	39.0	9.0	11.9	43.0	14.7	
23	10	-2.1	-4.2	47.4	9.7	13.8	31.7	8.5	10.2	48.5	14.8	
Average		-3.3	-3.1	44.9	8.9	12.7	33.2	8.2	10.4	46.2	14.3	
24	45	----------	Lost	----------								
25	45	21.2	-1.1	92.2	20.2	25.0	64.3	12.8	16.0	96.3	27.0	
26	45	17.5	5.9	101.5	18.9	25.2	84.4	16.0	19.9	105.6	26.7	
Avg		19.4	2.4	96.9	19.6	25.1	74.4	14.4	18.0	101.0	26.9	
					Fired over left side of vehicle for turret movement							
19	15	6.1	10.1	62.2	14.7	18.5	34.3	8.8	10.5	65.5	18.2	(Horizontal movement)
20	15	1.8	14.4	52.2	10.3	13.9	35.9	8.6	10.8	53.0	14.1	(Vertical movement)
Avg		3.9	12.3	57.2	12.5	16.2	35.1	8.7	10.7	59.3	16.2	

HS 820/M113 - HOP CARD DATA*

Target No.	Direction of Fire	Location of Card	x Axis (readings in inches)	y Axis (readings in inches)
2	Over front	Right side (front)	+0.22	+0.32
3			+0.25	+0.18
Average			+0.235	+0.25
2		Right side (rear)	+0.32	-0.29
3			+0.33	-0.23
Average			+0.325	-0.26
16	Over left side	Right side (front)	+0.19	-0.18
18			+0.12	-0.18
Average			+0.155	-0.18
16		Right side (rear)	-0.15	-0.10
18			-0.12	-0.16
Average			-0.135	-0.13
27	Over rear	Right side (front)	-0.38	-0.33
29			-0.34	-0.39
Average			-0.36	-0.36
27		Right side (rear)	-0.44	+0.34
29			-0.45	+0.35
Average			-0.445	+0.345

*Measurements describe the direction of movement of the vehicle during the firing of 45 round bursts and are based on coordinates having the origin at the starting point of the stylus trace with the x axis parallel to the ground. The portion of the stylus trace produced by the vehicle returning to the static position was not measured.

MAGAZINE TORQUE DATA - HS 820/M113

Magazine Number	Torque (kg at 500 mm) Before	After
19367*	5.4	5.8
19357	5.3	5.1
19354	5.7	5.5
19353	5.4	5.4
19356	5.4	5.3
19352	5.5	5.4

*Magazine torque dropped to 4.9 kg after firing 1000 rounds retorqued to 5.8 kg.

PARTS BREAKAGE HS 820/M113

Component	Round	Gun No.
Cracked inertia bars	2526	58118
Broken extractor	3783	58113
Broken extractor	4166	58165
Broken pushrod	4726	58165
Driving spring (perm. set)	4422	58113
Carcked inertia bars	4922	58113
Cracked inertia bars	4966	58165
Cracked extractor	4976	58118
Inertia bar spring (broken coil)	4922	58113

SECTION III -- Laboratory Reports

Contents:

2-1 Electronic Control and Guidance Division Report

2-2 Physical Test Laboratory Reports

LABORATORY REPORT

ELECTRONIC CONTROL AND GUIDANCE DIVISION

DEVELOPMENT AND PROOF SERVICES

ABERDEEN PROVING GROUND, MARYLAND

DATE:

USATECOM PROJECT NO. 3-5-9240

PROJECT ENGINEER: Walter Myers

REPORT NO.: STEAP-DS-TF

FIRE CONTROL TEST

OF

FIVE FORWARD AREA AIR DEFENSE WEAPON SYSTEMS

DATES OF TEST: 29 October 1964 to 23 July 1965

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1. INTRODUCTION

The Fire Control and Guidance Branch of the Electronic Control and Guidance Division, Development and Proof Services, conducted a limited number of tests on the fire control components of five forward Area Air defense systems. The tests were conducted in conjunction with the Artillery Division, Development and Proof Services to determine the military potential of the subject systems and to establish data for use by BRL in comparing system effectiveness.

The systems tested were the:

a. Standard M-42 Duster.

b. Modified M-42 Duster.

c. M-61 20-mm Automatic Weapon System.

d. Modified M-61 20-mm.

e. Hispano Suiza 20-mm Automatic Weapon System.

2. DESCRIPTION OF MATERIEL

2.1 Standard M-42 Duster 40-mm Automatic Weapon System

This system consists of the twin 40-mm gun mount M4E1 mounted on a modified T41E1 light tank chassis. The major components of the gun mount are:

a. Local control system M16A1E1.

b. M-38 Computing Light (T154).

c. Twin 40-mm gun, M2A1.

The local control system consists of the drive controller, wiring harness and azimuth and elevation oil gear assemblies. This system enables one man to position the gun during power operation.

The computing sight is of the course and speed type and is equipped with the reflex sight M24C. The sight setter estimates the target course (attack angle and climb or dive angle) and speed. From this information, a lead angle is computed which physically displaces the reflex sight away from the gun. Assuming the computed lead angle is correct and the operator is smoothly tracking the target, the gun is aimed at the future position of the target. Corrections to bring the fire onto the target are accomplished by the sight setter observing the tracers and changing the value of his estimated inputs to the computer.

Handcranks provide a manual operating capability as a backup to power operation. An additional operator is required in this mode.

Reference 1 contains a thorough description of this system.

2.2 Modified M-42 Duster 40-mm Automatic Weapon System

Four modifications transform the standard M-42 Duster AWS into the modified M-42 Duster AWS. These are:

a. The addition of a suspension lock-out system which assists in providing a stable firing platform.

b. A mechanical synchronizer which forces the guns to fire together.

c. A Mark 20 Mod 7 lead computing sight in place of the M-38 course and speed type computing sight.

d. An electro-hydraulic power control mechanism in place of the azimuth and elevation oil gear assemblies.

Additional information on this system is contained in reference 2.

2.3 Standard M-61 20-mm Automatic Weapon System

This system consists of an M-61 six barrel gun, a Mark 20, Mod 6 gyro lead computing sight with its associated circuitry and a servo controlled turret mounted on an M-113 vehicle. With this system, the operator must estimate the target velocity and choose between one of four modes of inserting range information into the system. These modes and a brief description of each follows:

a. Manual Mode - The operator must estimate the range at which he expects to engage or fire on the target before he begins tracking it. This range estimate dictates the amount of magnet current in the Mark 20 sight and therefore, the magnitude of the lead angle.

b. Remote Mode - This mode is a duplicate of the manual mode except that a second operator, located away from the system, can estimate and set in ranges throughout an engagement.

c. Automatic Mode - An estimated target velocity and range are inserted by the operator. When the operator feels the target is at the inserted range he depresses a switch located on the right handcontrol. This activates the range generator unit which continuously computes the future position range up to crossover.

d. Crossover Mode - An estimated target velocity is inserted by the operator. Utilizing this data and the turret velocity data, as taken from tachometers driven by the turret positioning servo systems, the range generator provides the Mark 20 sight with a current proportional to the future range of the target. In this mode, firing can be conducted from approximately 30° before crossover to crossover.

Refer to reference 3 for a more complete description of this system.

2.4 Modified M-61

The fire control system on the modified M-61 possesses one significant change from that of the standard M-61. This change is within the automatic mode of operation of the range generator. The operator is only required to estimate the target velocity. Using this and turret velocity and acceleration data, the range generator provides the Mark 20 sight with a current proportional to future range throughout each engagement. Also added is a foot switch for shifting from incoming to outgoing targets. This changes the calibration of the range generator and theoretically increases the system accuracy on outgoing targets.

See reference 4 for a complete description of this system.

2.5 Hispano Suiza 20-mm Automatic Weapon System

The fire control system of this item is composed of:

a. An air-cooled gasoline engine which supplies all of the power required to operate the weapon system.

b. A hydraulic power transmission system consisting of an A-end pump, B-end motor and associated hydraulic servo systems for controlling motion of the turret.

c. A two degree of freedom, viscously damped joystick which provides simultaneous control of the weapon in both azimuth and elevation.

d. A mechanical computer for solving the fire control problem.

e. An optical sighting system.

The system requires that target velocity and the slant range at crossover be inserted as estimated inputs. The computer, using these quantities and the operator's control of the joystick, solves the fire-control problem for any rectilinear, constant velocity target flight course.

See references 5 and 6 for a more complete description of this system.

2.6 Mark 20 Gyro Lead Computing Sight

Since three of the five systems tested employ the Mark 20 sight, a brief description of it is offered as a separate entity.

The Mark 20 gun sight functions to offset the line of sight from the axis of the gun bore by an angle which is approximately equal to the product of the time-of-flight of the projectile to the advance position and the angular speed of the target about the gun position. To do this, an electrically driven gyroscope and an electromagnet are employed as the principle elements within the sight. A copper disk is attached to the axis of the gyro. The physical location of these elements is depicted in Figure 1.

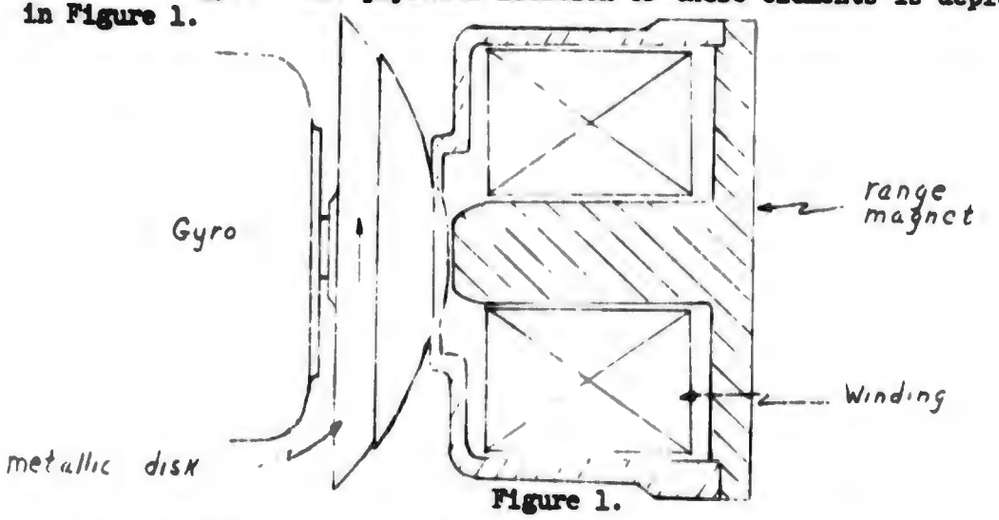

Figure 1.

The electromagnet is attached to the case of the sight which maintains a constant relative position with the gun axis. The optical elements of the sight are moved by the gimbaling of the gyro and therefore, maintain a constant position relative to the gyro axis. As a result, the lead angle between the sight and the gun is also the angle existing between the gyro spin axis and the electromagnet.

One property of a gyro is to maintain a fixed position until acted upon by an external force, at which time it will precess or move it's spin axis at right angles to the direction of the force. The rate it precesses is proportional to the magnitude of the force.

In the Mark 20 sight, this force, and therefore the precession rate, increases as the strength of the magnet increases and as the distance between the magnet and the gyro spin axis increases. If the magnet is carrying a uniform current and moving at a constant speed, it must move through a definite angle from the center of the copper disk before the precessing force is large enough to move the gyro at the same speed. At that time, the gyro follows the magnet with a definite angle of lag until the magnet current or speed is altered.

The magnet current is proportional to the time-of-flight of the projectile to the future position of the target and therefore, the range to the target. This creates the basic precessing force. Since the operator is tracking and thereby imparting an angular motion to the sight case, the magnet moves away from the copper disk which creates the second component of the precessing force, thereby moving the gyro and optical section away from the gun to create the basic lead angle. Additional factors change the basic lead angle to compensate for superelevation, etc.

For a complete description of the Mark 20 sight see reference 7.

3. DETAILS OF TEST

The primary objective of the following tests was to provide BRL with some of the basic data required in evaluating the effectiveness of the systems tested. They were not intended to be the basis for an independent evaluation by this division; to satisfy the requirements of an ET; nor to allow an analysis in light of the QMR.

Where appropriate, the significance and completeness of the data is discussed. The data was accumulated under a variety of conditions. These included laboratory set-ups, the tracking of simulated and actual aircraft in the field and the firing of each weapon under static conditions.

3.1 System Velocity and Acceleration

3.1.1 Purpose:

To determine the response characteristics of the gun positioning servo mechanisms.

3.1.2 Method:

A step function was inserted into each of the servo mechanisms via the control mechanisms. The system velocity and/or position, taken from transducers geared to the system, were recorded with an oscillograph. These records were analyzed to provide the required data.

3.1.3 Results:

The results for each system are summarized in Table I and are shown in Figures 1 through 10 of Appendix I.

Table I - Response Characteristics

System			Maximum Accelerations	Maximum Velocity	Average Acceleration to Attain Maximum Velocity
Standard M-42 Duster	El.	Up	95°/sec²	26°/sec	18° per sec²
		Down	97°/sec²	26°/sec	23° per sec²
	Az.	CW	100°/sec²	43°/sec	30° per sec²
		CCW	100°/sec²	44°/sec	31° per sec²
Modified M-42 Duster	El.	UP	288°/sec²	51°/sec	173° per sec²
		Down	369°/sec²	62°/sec	209° per sec²
	Az.	CW	109°/sec²	72°/sec	68° per sec²
		CCW	129°/sec²	75°/sec	69° per sec²
M-61 20-mm AWS	El.	Up	350°/sec²	46°/sec	92° per sec²
		Down	225°/sec²	66°/sec	59° per sec²
	Az.	CW	110°/sec²	76°/sec	46° per sec²
		CCW	169°/sec²	78°/sec	50° per sec²
Modified M-61 20-mm AWS	El.	Up	340°/sec²	48°/sec	176° per sec²
		Down	200°/sec²	66°/sec	76° per sec²
	Az.	CW	300°/sec²	78°/sec	114° per sec²
		CCW	310°/sec²	78°/sec	116° per sec²
Hispano Suiza 20-mm AWS	El.	Up	744°/sec²	57.8°/sec	633° per sec²
		Down	822°/sec²	57.8°/sec	533° per sec²
	Az.	CW	470°/sec²	102°/sec	237° per sec²
		CCW	452°/sec²	94°/sec	228° per sec²

3.1.4 Analysis:

These results show a significant improvement in the response characteristics of the improved M-42 and M-61 systems over their standard counterparts. The results obtained with the Hispano Suiza are considered excellent.

Figures 11 through 14 of Appendix I show the effective engagement area possible with each system if a fire control system were used which allowed the potential of the positioning servo mechanisms to be used.

Figure 15 of Incl I is a composite curve of Figures 11 through 14. It should be noted that a curve is not included for the improved M-61. The system was not available at D&PG in time to include this test. Its curve would almost duplicate that of the standard M-61 as the limitations result from velocity limits rather than from acceleration limits.

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3.2 Rates of Fire

3.2.1 Purpose:

To determine the average rate of fire and the variation of the rate of fire throughout a firing burst.

3.2.2 Method:

Electrical pulses, generated by blast gages located near the muzzle of each gun, were recorded on an oscillograph. These records were analyzed to provide the data required. Where possible, the rates were obtained at three firing elevation angles. Firing sector limits precluded doing this for all systems.

3.2.3 Results:

The average firing rate for each of the weapons is shown in Table 2.

The firing rate of each of these weapons can be varied approximately 15%; the Hispano Suiza via changing the gas ports (a 1.5-mm gas port was installed when these rates were taken), the M-61 via the electrical components (ie: a different motor on an additional battery in parallel) and the M-42 via an adjustment of the recoil mechanism.

Table II - Average Rates of Fire (rds/min)

Elevation	0 mils			600 mils			1100 mils		
	Gun			Gun			Gun		
System	Left		Right	Left		Right	Left		Right
M-42 Duster Standard	106		118	103		104	98		105
	Total: 224			Total: 207			Total: 203		
M-42 Duster Modified	134		137	Not obtained			122		123
	Synchronized 266						Synchronized 243		
M-61 20-mm AWS Standard	2571			2700			2727		
M-61 20-mm AWS Modified	3178			3225			3204		
	Gun			Gun			Gun		
Hispano Suiza 20-mm	Left	Center	Right	Left	Center	Right	Left	Center	Right
	803	876	824	808	868	818	810	882	826
	Total: 2503			Total: 2494			Total: 2518		

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3.3 Slant Plane Cut-off Boundry

3.3.1 Purpose:

To define the effective engagement domain of each of the weapon systems tested, the parameter responsible for the limitation, and the physical element within the system which is responsible for the limiting parameter.

3.3.2 Method:

3.3.2.1 Outer Boundry

A systems effective engagement domain is defined by both an inner and outer limit. The outer boundry is dependent on:

a. The maximum lead angle that can be generated by the weapon system.

b. The ballistic characteristics of the gun-ammunition combination.

c. The maximum effective range of the weapon-ammunition combination.

d. The velocity of the target.

The maximum lead angles quoted in the system descriptions and available ballistic data were used for this test. These data were analyzed to determine the crossover range as a function of target velocity at which the maximum lead angle is exceeded.

3.3.2.1 Inner Boundry

The inner boundry is defined by the maximum effective angular tracking limit of the system and the target flight course as defined by target velocity, horizontal crossover range and altitude.

Computer programs were written which, when values are assigned to $\dot{\theta}$ and $\ddot{\theta}$ and a target velocity is specified, solves for points lying in the slant plane where $\dot{\theta}$ and/or $\ddot{\theta}$ are exceeded for various altitudes and crossover ranges. A target velocity of 450 knots was used for all systems. The values used for $\dot{\theta}$ and $\ddot{\theta}$ were the effective limits established in Test No. 3.8.

3.3.3 Results:

3.3.3.1 Outer Boundry

Figures 17-I, 18-I and 19-I of Incl. 1 show the crossover range as a function of target velocity at which the lead angles of the Hispano Suiza, Modified M-42 and both M-61's will be exceeded. Also shown are areas of engagement encompassed within specific tracking rates. When available, the firing accuracy data being analyzed by BRL should be compared with these data to assist in defining the effective engagement area.

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3.3.3.2 Inner Boundry

Figures 20-I, 21-I and 22-I of Incl I are contour plots showing the region existing around each of the systems where it's effectiveness is limited due to inaccurate tracking created by high target angular velocities. Additional data and analysis are required to establish the effect of angular acceleration on this boundry.

3.3.4 Analysis:

In consonance with the engagement speed requirements stated in the SMR, the outer boundry of each system is defined only by the maximum effective range of the gun-ammunition combination. The systems inner boundry, having been computed from angular limits generated during the tracking accuracy test, does not necessarily reflect the systems dead zone. The angular limits at which future position accuracy becomes intolerable should be used in generating the elevation plane inner boundry.

3.4 Power Requirements

3.4.1 Purpose:

To determine the amount of electrical power (DC) required by each system under various operating conditions.

3.4.2 Method:

The total current drawn from the battery and the voltage across the battery were recorded during various operating conditions. Since this is a DC circuit, the consumed power is the product of the voltage and current readings.

3.4.3 Results:

The results are shown in Table III. It is pointed out that the Hispano Suiza system is not included. This system has its own primary power source and is purely a mechanical hydraulic system.

Table III - Electrical Power Requirements

System	Mode of Operation		
	Standby	Slewing	Firing
Standard M-42 40-mm AWS	Not obtained	Not obtained	n/a
Modified M-42 40-mm AWS	27 amps (640 watts)	250 amps (6000 watts)	n/a
Standard M-61 20-mm AWS	9 amps (207 watts)	65 amps (1430 watts)	450 amps (6750 watts)
Modified M-61 20-mm AWS	8 amps (185 watts)	60 amps (1130 watts)	475 amps (950 watts)

3.4.4 Analysis:

Not applicable.

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3.5 Firing Moment Error

3.5.1 Purpose:

To determine the amount of total system error which can be attributed to inadequate torque in gun positioning servo mechanisms as a result of the moments created by the firing forces.

3.5.2 Method:

The system control mechanisms (joystick on the Hispano Suiza and handcontrols on the other weapons) were locked at a null position with special fixtures. Electrical transducers were attached to the systems which provided an electrical signal proportional to the mechanical displacement between the gun and carriage. This signal was recorded and analyzed to determine the displacement when firing the weapon with the servo systems active. The burst lengths used in this test are shown in Table IV.

Table IV - Burst Lengths for Test No. 2.5

Standard	Burst Length
Standard M-42 Duster 40-mm AWS	16 rds/gun
Modified M-42 Duster 40-mm AWS	16 rds/gun
Standard M-61 Vulcan 20-mm AWS	100 rds
Modified M-61 Vulcan 20-mm AWS	100 rds
Hispano Suiza	30 rds/gun

3.5.3 Results:

The direction and maximum displacement recorded for each system is shown in Table V.

Table V - Firing Moment Errors

System	Azimuth Displacement	Elevation Displacement
Standard M-42 Duster	+3.5 mils	Up & down total 2.5
Modified M-42 Duster	Negligible	Negligible
M-61 20-mm AWS	CCW 40 mils	Down 22 mils
Modified M-61 20-mm AWS	CCW 40 mils	Down 20 mils
Hispano Suiza 20-mm AWS	Negligible	Negligible

3.5.4 Analysis:

The results show that:

a. The synchronization of the guns on the M-42 Duster minimizes the system motion during firing. This is undoubtably more important than the recorded 7 mils of motion indicates as the operator is not jostled about, thereby being able to maintain better control of the weapon.

b. A severe moment exists on the M-61 Vulcan. This moment and it's effect on the dynamic distribution of the projectiles will have to be determined before it's effect on firing accuracy can be assessed.

3.6 Azimuth Control Sensitivity

3.6.1 Purpose:

To determine the relationship between the system control mechanisms displacement (joystock and hand controls) and system velocity in azimuth.

3.6.2 Method:

The control mechanisms were offset from their null position in 2.5 degree increments, throughout their range of operation. The system velocity was measured at each of the positions and plots made of the azimuth velocity vs the position of the control mechanism.

3.6.3 Results:

The results are shown in Figures 23 through 27 of Incl. 1.

3.6.4 Analysis:

The interpretation of these results is difficult as it is not known how precisely an operator can position the different types of control mechanisms under firing conditions. An investigation and analysis of this should be made when all of the data (including that from USARADBD & BRL) from this program becomes available.

Preliminary results of the firing tests conducted at Ft. Bliss and under evaluation at BRL show the firing error of the M-61 system = $130\ (w)^2$ where w = angular velocity of the slant plane in radians/second and the error is milliradians.

Figure 28 of Appendix II is a plot of this curve. It's form is similar to that of the azimuth control sensitivity curves for the M-61 showing a correlation to exist. It is not understood why the slope of the firing error curve fails to change as rapidly as that of the azimuth control sensitivity curve beyond about .4 radians/second. This and the relationship of the firing errors and control sensitivity on each system should be pursued to determine the optimum scaling or transfer function.

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3.7 System Weights

3.7.1 Purpose:

To determine the weight of each of the systems tested.

3.7.2 Method:

Each system, less the OVM equipment, ammunition load and operating personnel was weighed.

3.7.3 Results:

The results are shown in Table VI.

Table VI- System Weights

System	Weight
Standard M-42 Duster 40-mm AWS	44,200
Modified M-42 Duster 40-mm AWS	43,725
Standard M-61 20-mm AWS	21,250
Modified M-61 20-mm AWS	22,100
Hispano Suiza 20-mm AWS	21,900

3.7.4 Analysis:

Not applicable.

3.8 Tracking Accuracy

3.8.1 Purpose: To determine the accuracy to which experienced operators can track a moving target under various flight conditions.

3.8.2 Method:

A simulated target was used for this test, thereby insuring controlled and repetitive test conditions. The target consisted of a sphere approximately 5 inches in diameter moving between two poles located 60 yards apart. All target flight course parameters (ie: target altitude, crossover range, and velocity) were scaled 50:1. The 60 yards of target travel represented 3,000 yards of tracking range and the angular rates imposed on the system were identical to those of an actual target as was the total engagement time.

Eight different target flight courses were used for this test. These courses are outlined in Table VII.

Table VII - Target Flight Courses

Course No.	Target Velocity	Minimum Ground Range	Altitude	
			Feet	Meters
1	400 knots	0	1250	362
2	400 knots	290 meters	1000	290
3	400 knots	608 meters	0	0
4	400 knots	869 meters	1000	290
1a	270 knots	0	1250	362
2a	270 knots	290 meters	1000	290
3a	270 knots	608 meters	0	0
4a	270 knots	869 meters	1000	290

Through sight cameras were used to record the position of the line of sight relative to the target throughout the tracking engagements. Two experienced operators were used and each tracked the courses described twice with each of the systems tested. In addition, limited tracking tests were conducted using a T-33 jet aircraft to assess the realism offered by the simulated target. From this, it was concluded that the only difference noted was when tracking with the Hispano Suiza. The sight picture on this system is illustrated in Figure 2.

Figure 2
Hispano Suiza Sight Picture

The correct tracking point is with the intersection of the spiral and radial lines superimposed over the target with the radial line, which can be rotated by joystick notion, superimposed over the path of flight of the aircraft. It is convenient to use the longitudinal axis or fuselage of the aircraft as a reference when rotating the radial line to this position.

The film data from courses 1, 2, 3 and 4 were reduced for all but the modified M-61 system. Since there were 4 different systems, a like number of courses, and two operators, each tracking the courses twice, a total of 64 runs were recorded and reduced.

In addition to the courses listed in Table VII, seven additional courses were used for the Hispano Suiza. These are shown in Table VIII

Table VIII - Additional Hispano Suiza Courses

Target Velocity, (mph)	Minimum Ground Range (meters)	Altitude (ft)
100	730	1000
150	730	1000
200	730	1000
250	730	1000
300	730	1000
350	730	1000
400	730	1000

These courses were added to the Hispano Suiza test as it was established in the previous courses that the tracking accuracy has a definite relationship to target velocity and system motion.

Also, curves have been prepared from which the angular velocities in the three planes can be found at any time throughout the courses and from which the acceleration within the slant plane can be found.

The film data was reduced to provide the azimuth and elevation tracking errors as a function of course time. Also, composite curves were prepared which show the standard deviation of the tracking error for each system on courses 1, 2, 3, and 4.

3.8.3 Results:

The results are shown in Appendix I. Table IX shows the figures within Appendix I which apply to each system. One group presents the tracking error for each individual course. The second group presents composite curves showing the mean tracking error for each course.

Table IX - Location of Tracking Accuracy Results

System	Individual Results	Composite Results
Standard M-42 40-mm AWS	Figures 29-I thru 44-I	Figures 45-I thru 48-I
Modified M-42 40-mm AWS	Figures 49-I thru 64-I	Figures 65-I thru 68-I
Standard M-61 20-mm AWS	Figures 69-I thru 84-I	Figures 85-I thru 88-I
Hispano Suiza 20-mm	Figures 89-I thru 104-I	Figures 105-I thru 108-I

The results from those courses ran exclusively with the Hispano Suiza and described in Table VIII are shown in Figures 109-I thru 122-I.

Figures 123-I presents the target angle from crossover as a function of course time for courses 1, 2, 3 and 4.

Figures 124-I thru 135-I show the target angular velocity as a function of the target angle from crossover for each of the courses.

Figures 136-I thru 139-I show the target angular acceleration in the slant plane as a function of the target angle from crossover for courses 1, 2, 3 and 4.

3.8.4 Analysis:

A direct comparison cannot be made of the tracking accuracy data. The data on the Hispano Suiza more closely represents future position accuracy than present position accuracy. Referring to Figure 2, the circle shown at the end of the radial line represents the future position of the aircraft. The distance between the intersection of the spiral and radial lines and the circle is the lead angle. Therefore, any error between the aircraft position and the intersection of the two lines approximates a future position error.

The above does not hold true for those systems employing the Mk. 20 sight. Any tracking error observed by the operator can be rapidly corrected by an increase (either momentary or continuous) in the systems angular rate. In accelerating however, the gyro assumes a new lag angle which is not necessarily correct, thereby allowing accurate present position tracking with an error in future position. Too little is known about this acceleration lag error to characterize it but it undoubtably is one of the factors limiting the system effectiveness on crossing courses.

In much of the data on the Hispano Suiza, it would appear an excessive error developed or that the operator stopped tracking during the course although the tracking errors were small. This loss of data is due to the optical system and camera used in the test. The contractor was to have provided a through sight camera capability but did not and the adaption used had a limited field of view. As the lead angle approached 10° it would leave the field of view and the data remaining on the course was lost. This precludes selecting an angular tracking limit for the system.

The data shown in Figures 110-I thru 123-I indicate the system can track accurately at high angular velocities once a smooth track is established. The problem is to establish this smooth track. Several courses have been tracked at angular velocities of greater than .6 radians/sec. and therefore, this value is assigned as a limit. This and the limits selected from the data for the other systems are shown in Table X.

Table X - Tracking Accuracy Limits

System	Angular Velocity Limits(rad/sec) Horizontal	Vertical
Standard M-42 Duster 40-mm AWS	.3	.4
Modified M-42 Duster 40-mm AWS	.33	.4
Standard M-61 Vulcan 20-mm AWS	.43	.4
Modified M-61 Vulcan 20-mm AWS	.43	.4
Hispano Suiza 20-mm AWS	.6	.6

Although data was not obtained on the modified M-61 system, it is reasonable to assume it's limits will approximate those of the standard M-61.

3.9 Settling Time

3.9.1 Purpose:

To determine the length of time required for the operator and computing elements of the systems to establish a smooth track on the target and it's future position.

3.9.2 Method:

The methods used to determine this time varied and are discussed separately.

3.9.2.1 Standard M-42 Duster 40-mm AWS - Since the M-38 computing sight is purely mechanical, the reflex sight is offset from the gun by the computed amount as soon as the sight setter inserts the estimated data. This can be done as the operator is slewing to the target. Therefore, the system settling time is the time required by the operator to initiate a smooth track on the target. This time was read directly from the tracking accuracy curves of paragraph 3.8.

3.9.2.2 Hispano Suiza 20-mm AWS - This system is completely settled when the target is being tracked as described in paragraph 3.8.2., again allowing the settling time data to be read directly from the results of test No. 3.8. In addition, a separate test was conducted on this system as it was obvious that the settling time has a functional relationship to target velocity and therefore, the angular rates and accelerations during the initial part of

the tracking engagement. This test consisted of keeping the system in a fixed position and varying the targets simulated velocity in 50 knot increments. A through sight camera was used to record the data. The data was reduced to show the tracking accuracy and settling time as a function of course time and the kinematics of the system.

3.9.2.3 Standard M-61 20-mm AWS, Modified M-61 20-mm AWS and Modified M-42 40-mm AWS - Since these systems all employ the Mark 20 lead computing sight, the method of obtaining settling time was identical. The average time required for the operator to establish a smooth track of the target was taken from the tracking accuracy curves presented in test No. 3.8. To this was added the average time required for the gyro of the Mark 20 sight to settle in tests conducted within the laboratory. These tests consisted of inserting the range and target velocity inputs used in the tracking accuracy tests, depressing the slewing switches provided with each system (this limits the lead angle when slewing), establishing a system angular velocity comparable to that incurred when first engaging the target on the courses described in Table III (the angular velocity was then held constant), releasing the slew button and recording the time required for the gyro to assume a constant lag angle.

3.9.3 Results:

The average settling time required for each system is shown in Table XI.

Table XI - Average Settling Time

System	Time(sec)
Standard M-42 Duster 40-mm AWS	2.3
Modified M-42 Duster 40-mm AWS	4.5
Standard M-61 Vulcan 20-mm AWS	5
Modified M-61 Vulcan 20-mm AWS	5
Hispano Suiza 20-mm AWS	6*

*Based only on the courses where settling was accomplished.

3.9.4 Analysis:

The above results are based on limited data and should be supported by additional tests and analysis.

Also, additional tests and analysis of the settling time, the Air Defense Boards system reaction time data, the time required to resettle after firing a burst, and the effective tracking limitations should be performed to determine the number of effective bursts which can be fired per engagement as a function of detection range and target velocity.

3.10 Superelevation vs lead change

3.10.1 Purpose:

To depict the relationship between the change in the distance a target is led and the change in firing elevation angle for a change in the estimated range input.

3.10.2 Method:

An assumption was made that any change in the range input was correctly mechanized by the computer, thereby allowing a theoretical analysis to be made. From the ballistic data, a family of curves were constructed showing the superelevation angle as a function of slant range and target angular altitude. Also, the lead distance required, based on a 450 knot target and the ballistics of the systems HE round was computed and plotted as a function of range. This was done for each of the guns being tested.

3.10.3 Results:

The results are shown in Figures 140-I thru 145-I.

3.10.4 Analysis:

To use the resultant curves, one needs to select a set of firing conditions (ie range, target location, direction of flight and a firing elevation error in mils). From the superelevation curve one can read the range change required to bring the firing elevation on target. Using this same range change within the same range interval on the lead distance curve, one can find the change in lead distance.

As an example, assume the elevation error on the Modified M-42 Duster is 2.5 mils high when firing at a 450 knot target at 1700 meters range, near crossover, and at an elevation angle of 400 mils. From the superelevation curve it is found that a range change of 200 meters (from 1700 to 1500 meters) is required to bring the elevation down to the targets altitude. Referring to the lead distance curve, it can be seen that the change in lead distance between a range of 1700 and 1500 meters is about 80 meters. Since the target is near crossover, this appears as a change in the horizontal lead of about 3^{o} as sine of $3^{o} \simeq \frac{80}{1500} \simeq .05$.

From this it can be seen that the boresight of the system and the current to the Mk. 20 sight are critical. If a system enploying the Mk. 20 sight is selected, additional tests and analysis should be performed to determined the best blend of concepts and components.

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4. Conclusions

It is concluded that:

a. The data that D&PS was required to supply BRL for use in their effectiveness study has been provided.

b. The limited number of tests conducted on the fire control systems pre-cludes an independent evaluation by this division.

c. Additional tests and analyses should be conducted on the MK 20 sight in an effort to characterize its errors. This is considered mandatory if either of the M-61 systems are selected.

d. The electro-hydraulic control system on the modified M-42 Duster provides a slew rate of approximately twice that of the oil gears.

e. A severe firing moment exists on the M-61 systems. It's effect on the dynamic distribution of the projectiles should be determined and exploited if possible, should the M-61 be selected as the interim weapon.

f. The relationship between the line and lead changes as a function of range data exemplifies the need for accurate boresighting of the systems. Additional reduction of available data should be done to establish the optimum boresight for the selected system. Also, a comparison test of the different concepts and components providing range data within the M-61 systems should be conducted and the best blend of these used in any production models if this item is selected.

g. The scaling on the hand control unit of the M-61 system is penalizing the systems effectiveness.

h. The synchronized guns on the modified M-42 prevents a firing moment error.

i. None of the systems tested met the required or desired slew rates specified in Para 7(c)1 of reference 8.

j. It is difficult to acquire and establish a smooth track of the target with the Hispano Suiza system. A modification should be made to the computer to limit the magnitude of the lead angle when slewing the weapon.

k. A requirement exists for a study effort which would outline the optimum test and evaluation program for integrated weapon systems undergoing developmental tests.

/cc

5. Recommendations:

It is recommended that:

a. Additional tests and analysis be performed on the system selected as the interim forward area air defense weapon system.

b. Some agency within USATECOM be appointed the task of preparing (with inputs from other agencies) an outline of an optimum test and evaluation program for integrated weapon systems.

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APPROVED BY:

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Chief, Electronic Control
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REVIEWED BY:

WILLIAM M. ROBERTS
Chief, Fire Control and
Guidance Branch

References

1. TM9-7218, Twin 40-mm Full Tracked Self-Propelled Gun M-42 (T141), May 1957.

2. Preliminary description of mechanical synchronization device, lock-out shock absorbers and gun sight modifications for twin 40-mm M-42, undated.

3. General Electric document, No. GEI 74186, Preliminary Operating and Maintenance Manual M-61 20-mm Automatic Weapon System, dated 15 June 1964.

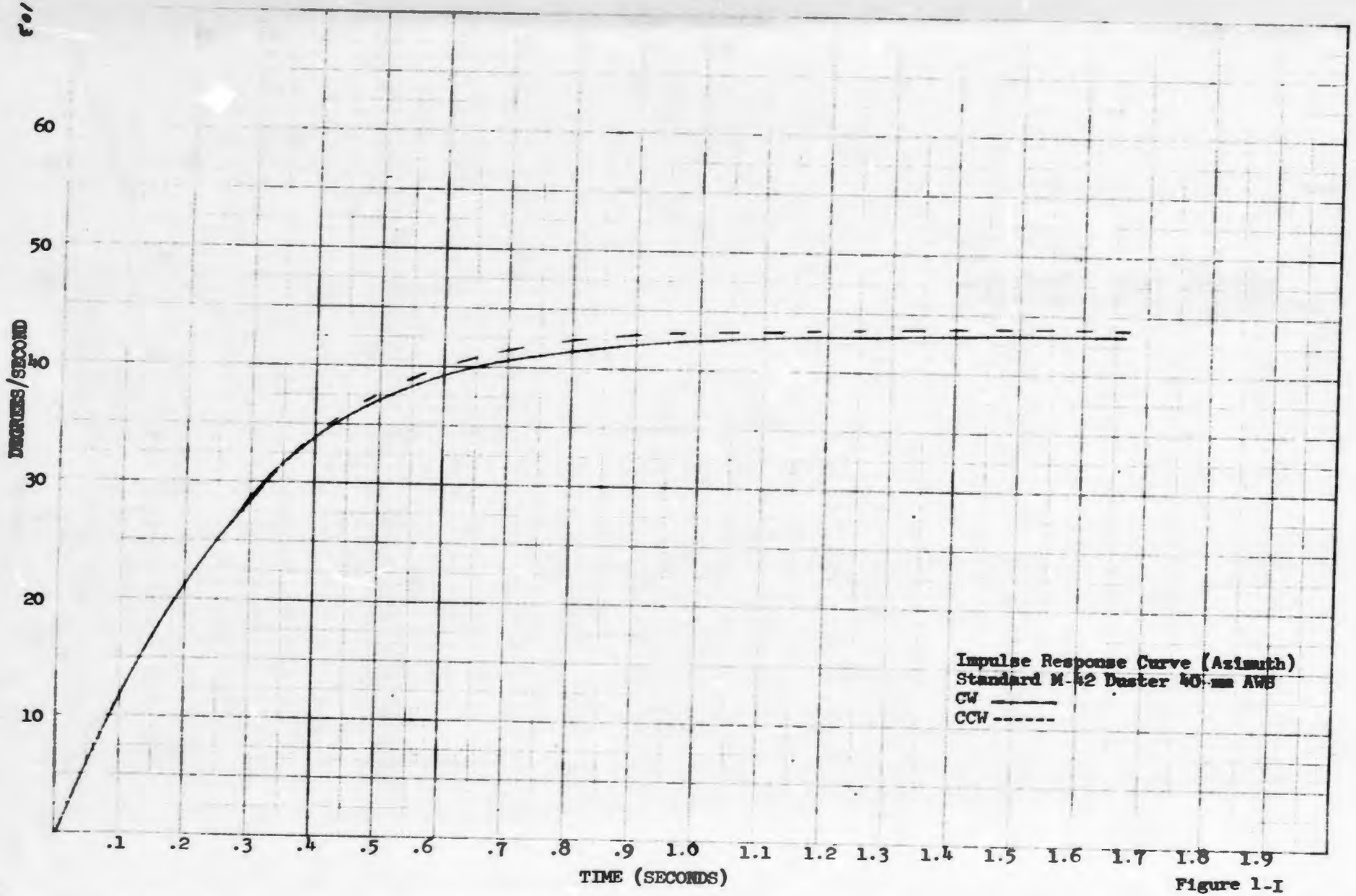
4. General Electric document, No. GEI 74194, Preliminary Operating and Maintenance Manual M-61/M113 Automatic Weapon System, dated 1 May 1965.

5. Weapon Manual, Hispano Suiza Type 8206/85, 20-mm Automatic Gun, undated.

6. Manual, Gun Fire Control System P. 36, P.T. 0116/02-I, undated.

7. OP 1870 A, Gun Light Mark 20, Mods 6 and 7 Maintenance Manual, dated 24 December 1952.

8. Proposal Qualitative Materiel Requirement (QMR) for a Division Air Defense System, dated 11 December 1964.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DEGREES/SECOND
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TIME (SECONDS)
Impulse Response Curve (Azimuth)
Standard M-42 Duster 40 mm AWS
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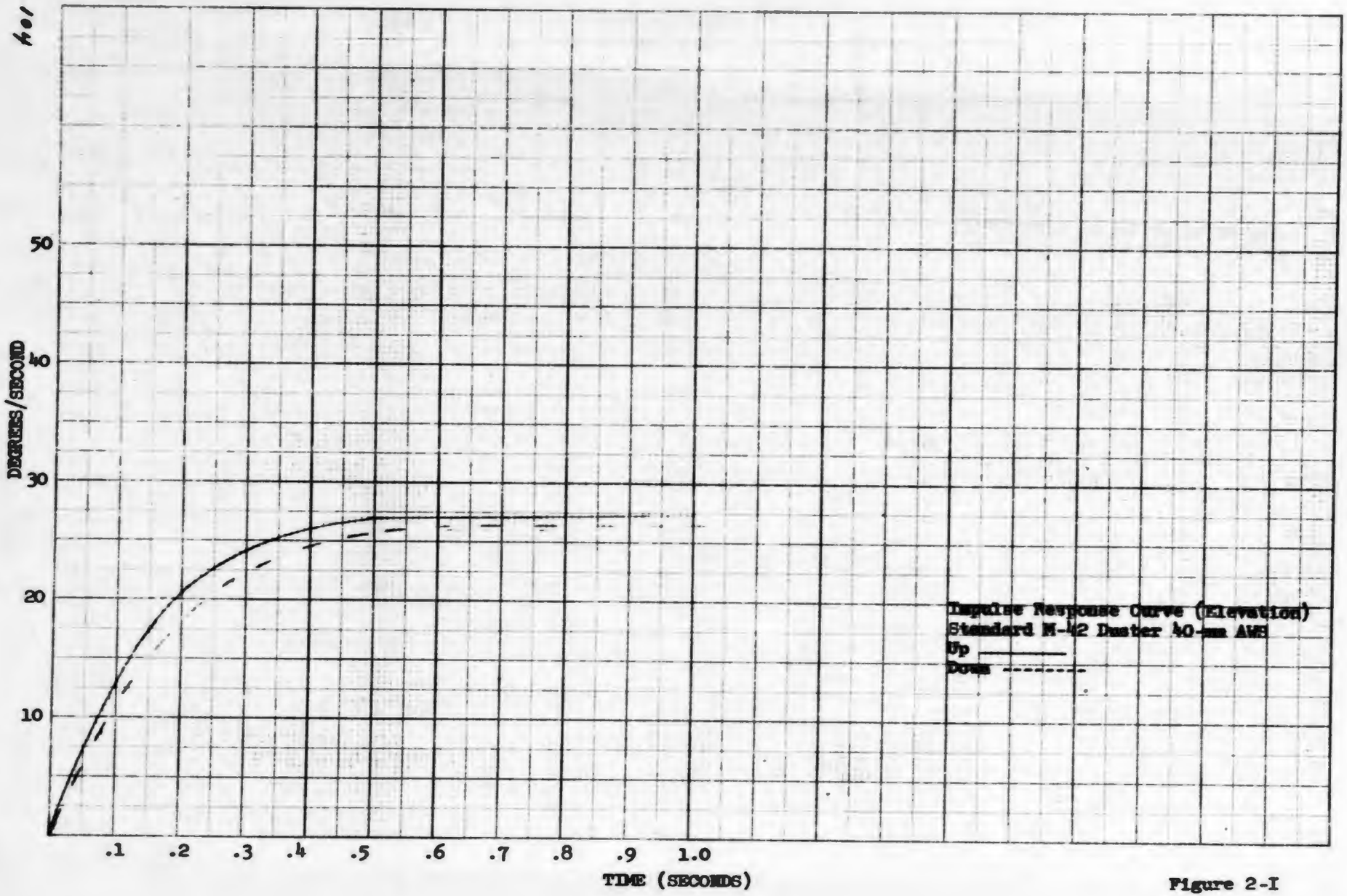
CCW - - - - - -

Figure 1-I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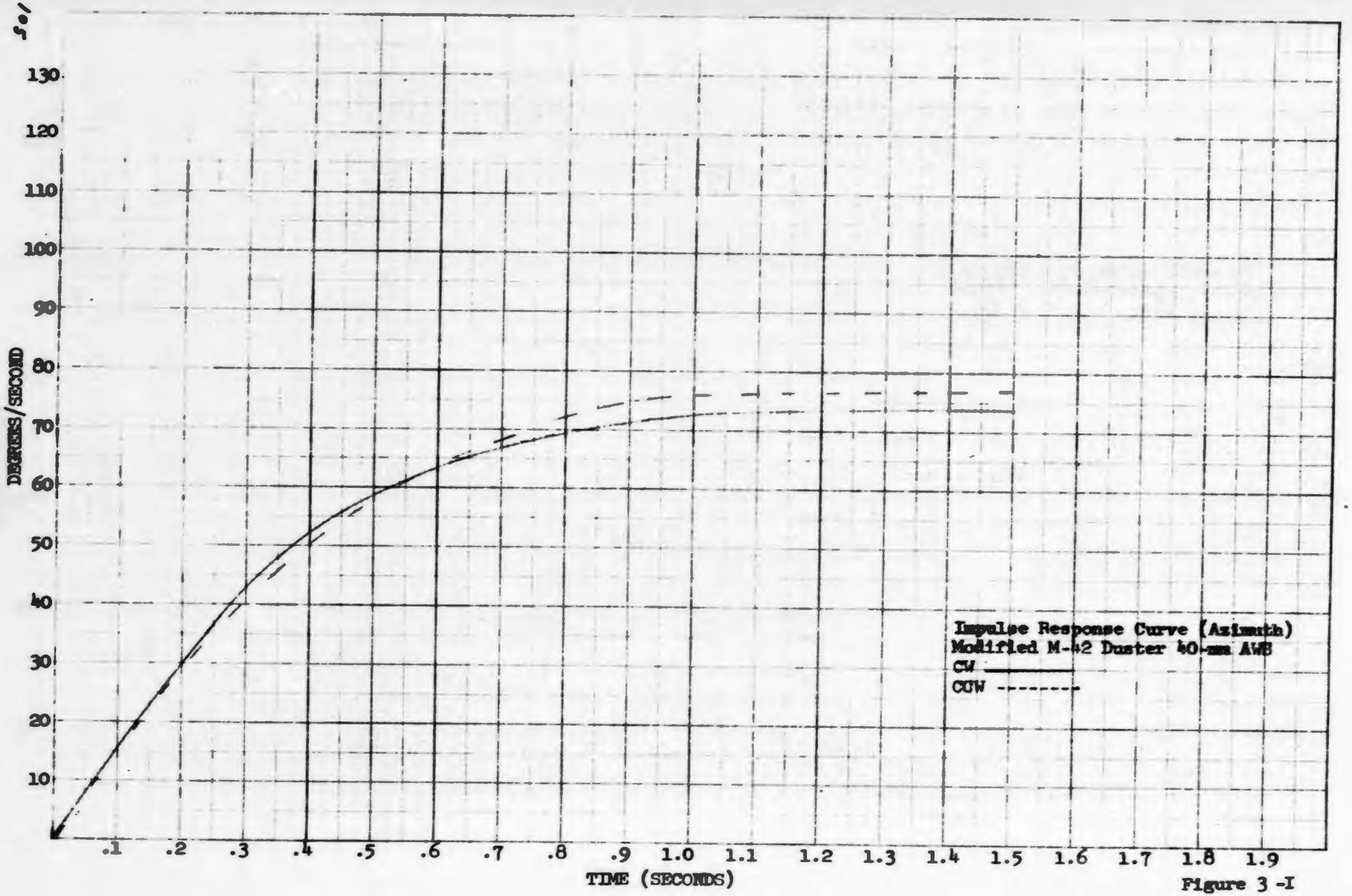
TIME (SECONDS)
Impulse Response Curve (Elevation)
Standard M-42 Duster 40-mm AWH
Up
Down

Figure 2-I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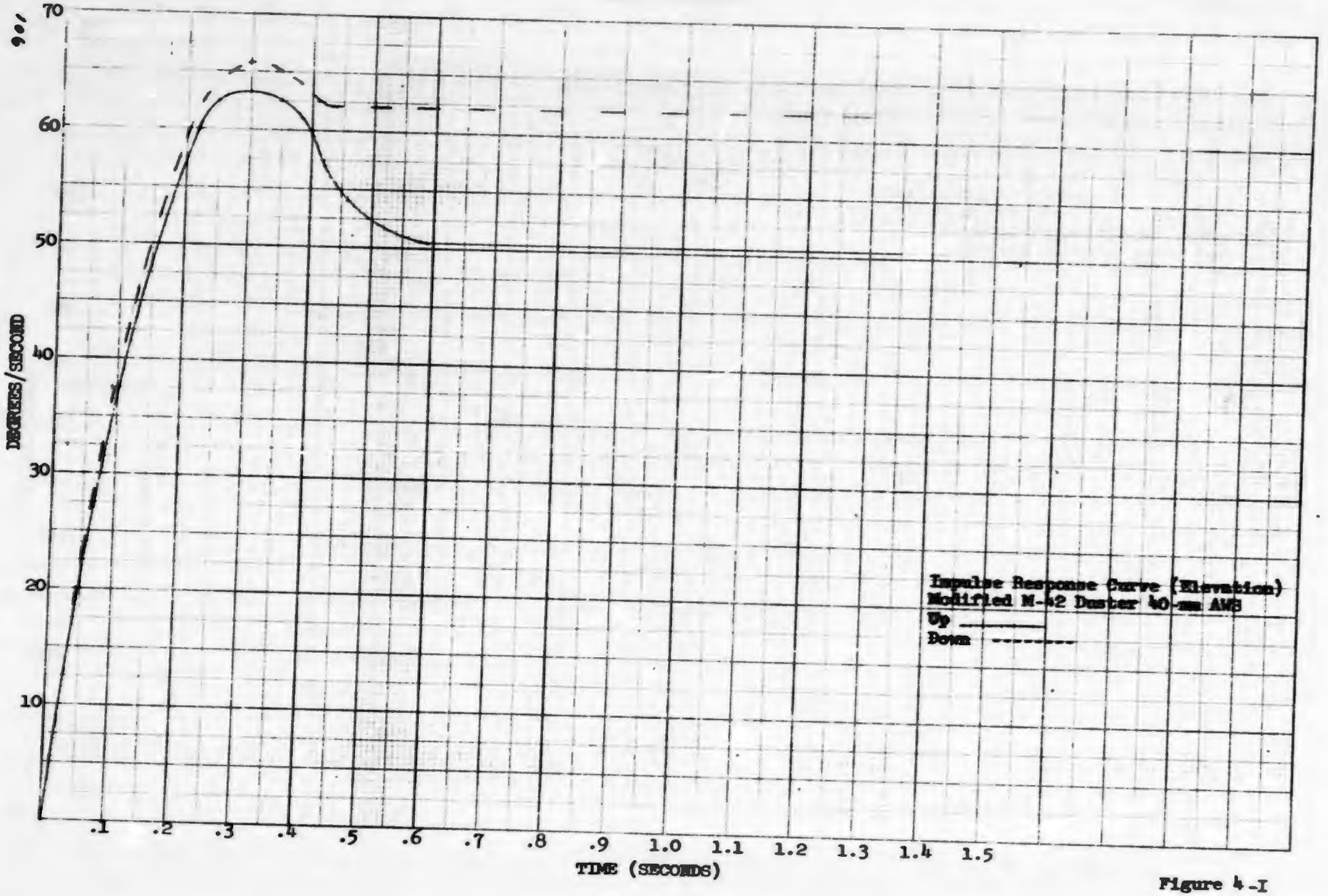
TIME (SECONDS)
Impulse Response Curve (Azimuth)
Modified M-42 Duster 40-mm AWS
CW
CCW

Figure 3 -I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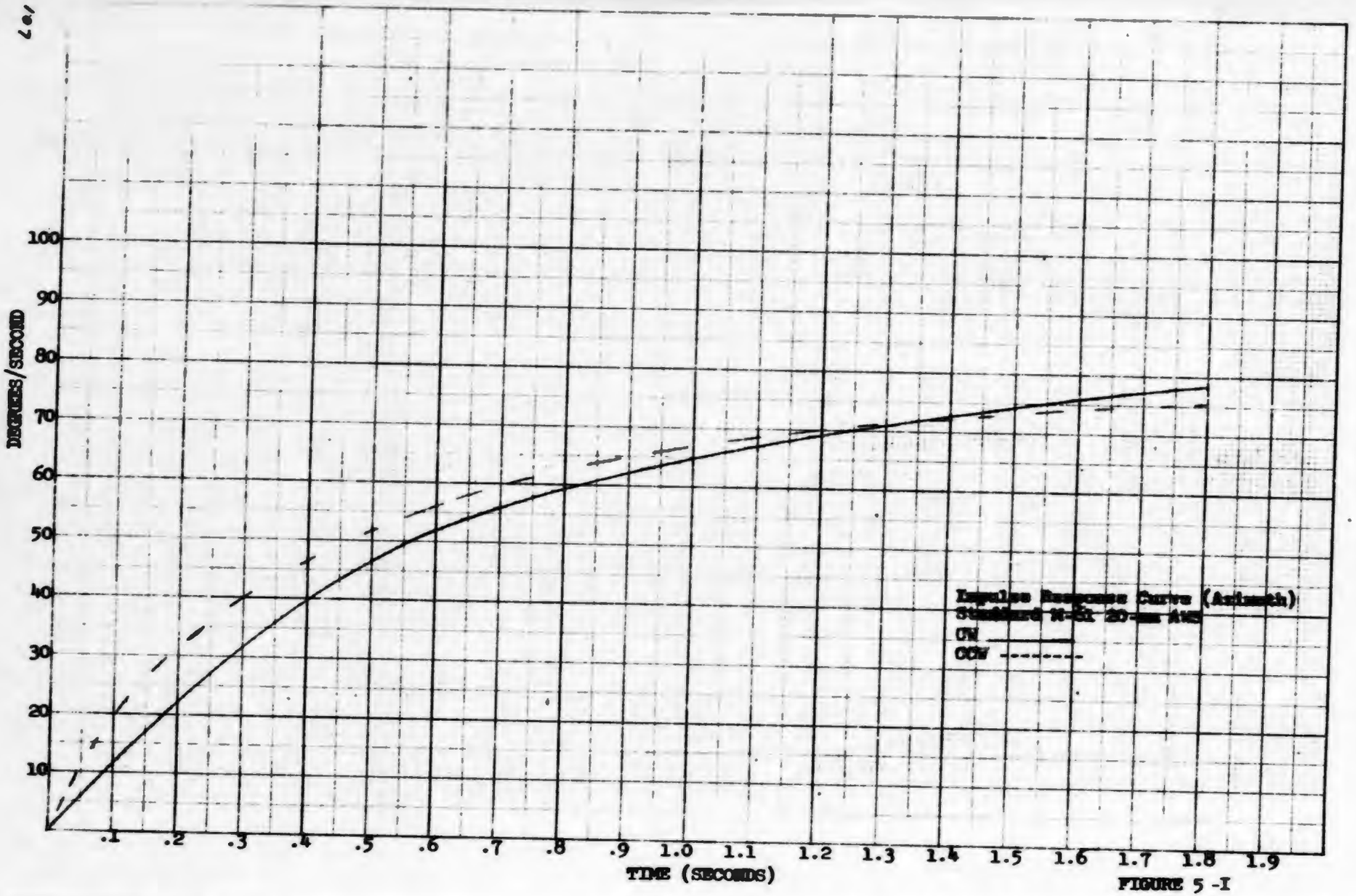
TIME (SECONDS)
Impulse Response Curve (Elevation)
Modified M-42 Duster 40-mm AWS
Up
Down

Figure 4-I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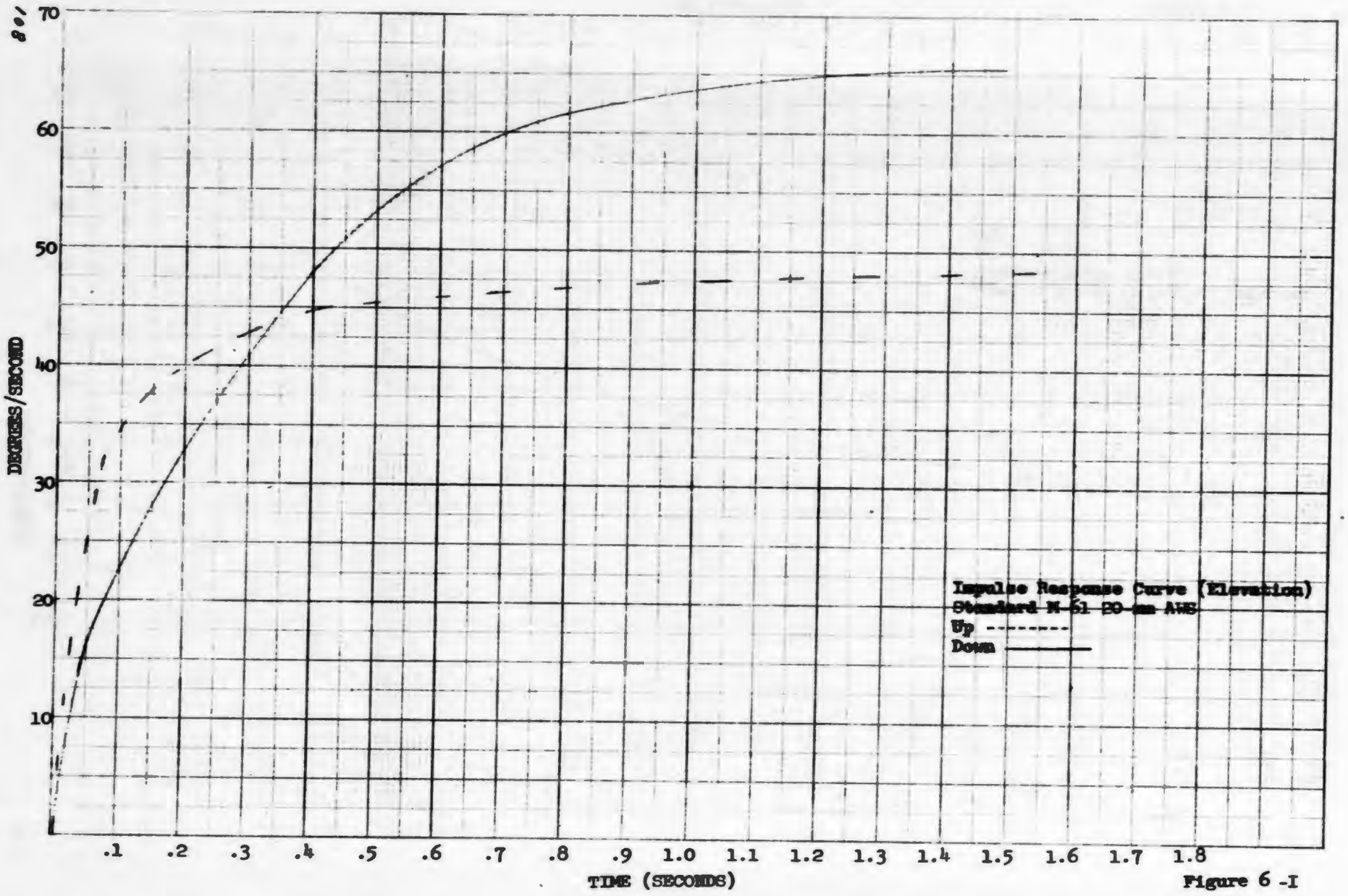
TIME (SECONDS)
Impulse Response Curve (Anitsmith)
CW
CCW

FIGURE 5 -I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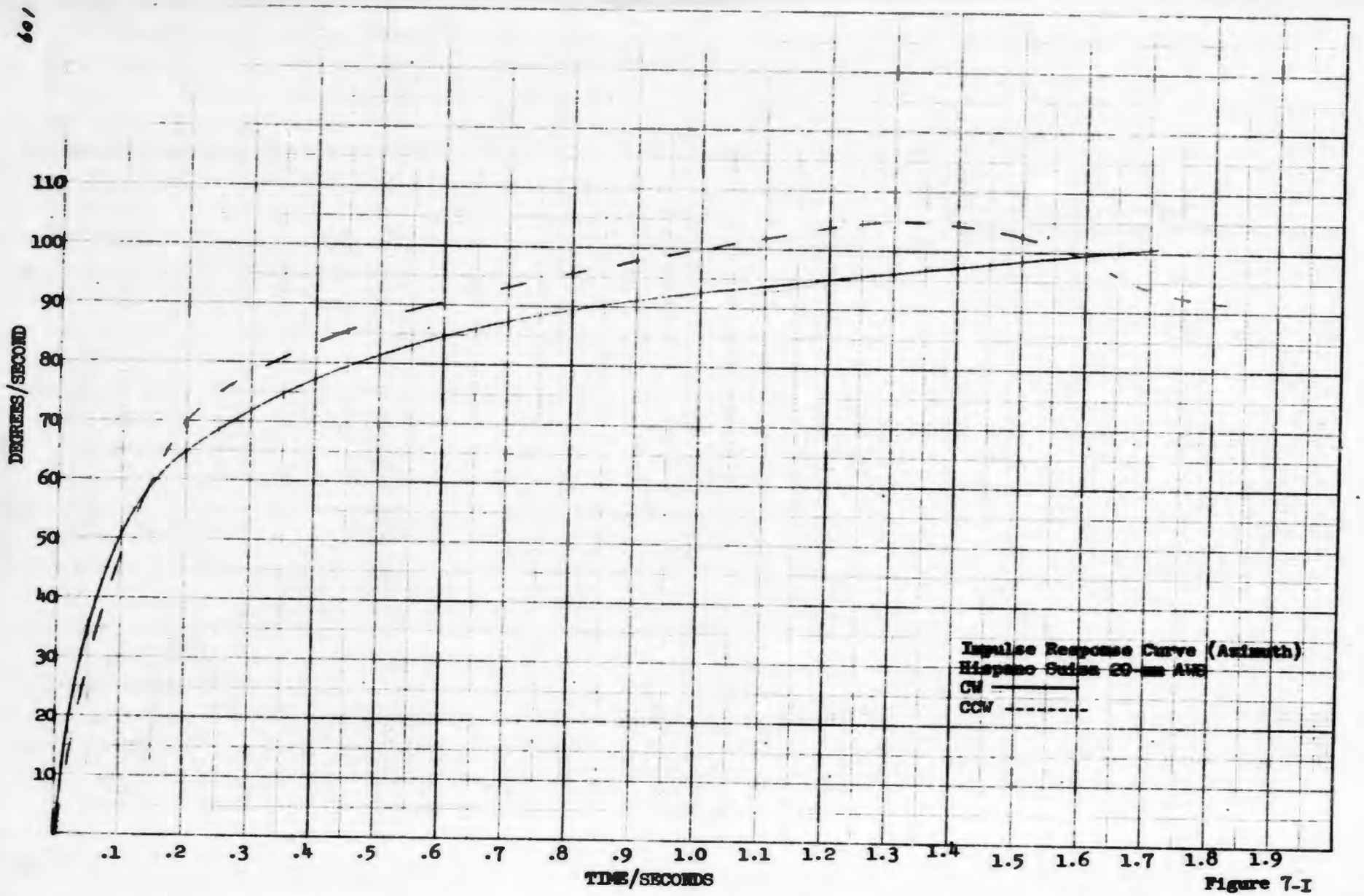
TIME (SECONDS)
Impulse Response Curve (Elevation)
Standard M-61 20-mm AWS
Up
Down

Figure 6 -I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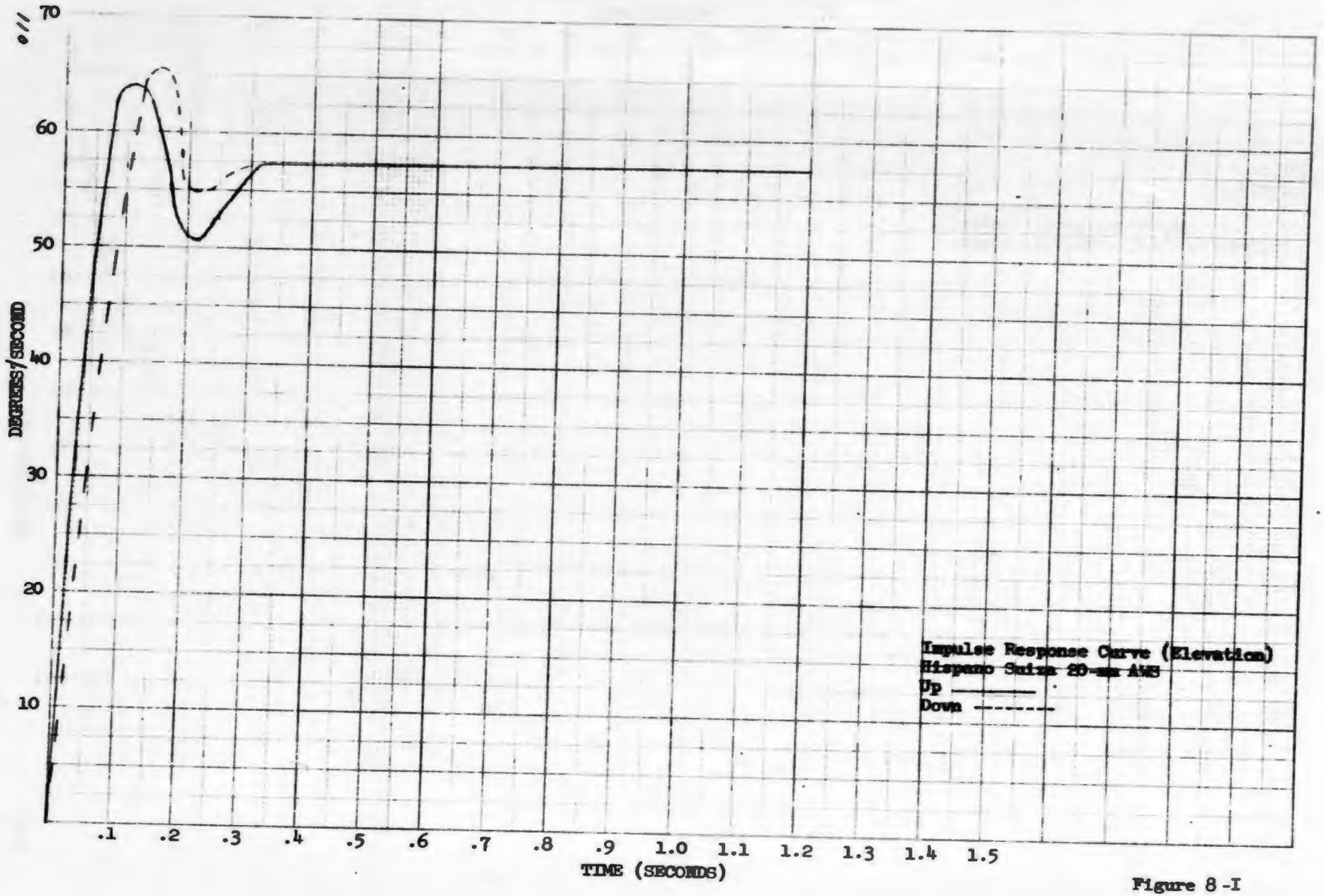
TIME/SECONDS
Impulse Response Curve (Azimuth)
CW
CCW

Figure 7-I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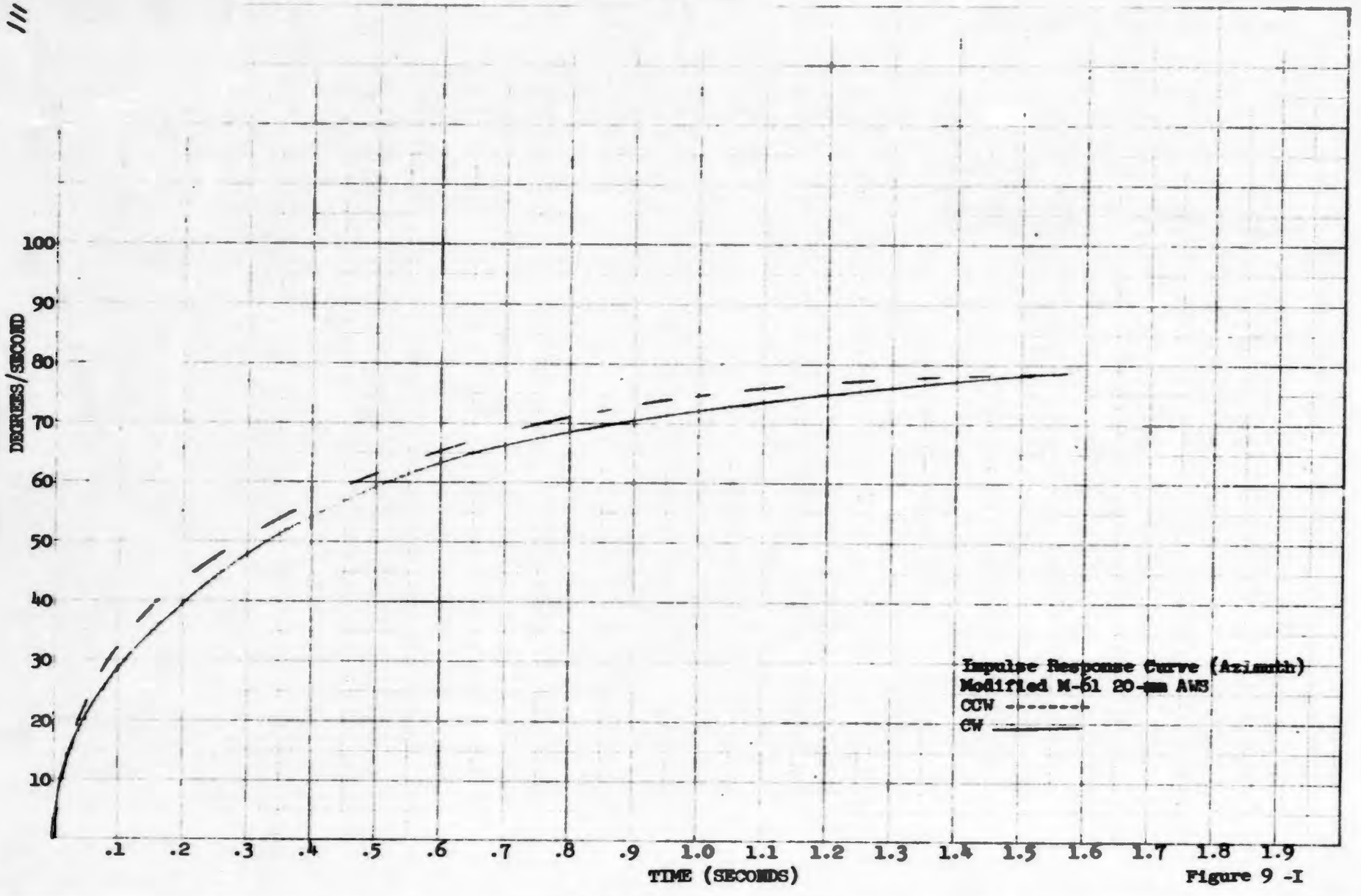
TIME (SECONDS)
Impulse Response Curve (Elevation)
Hispano Suiza 20-mm AMS
Up
Down

Figure 8-I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1.1
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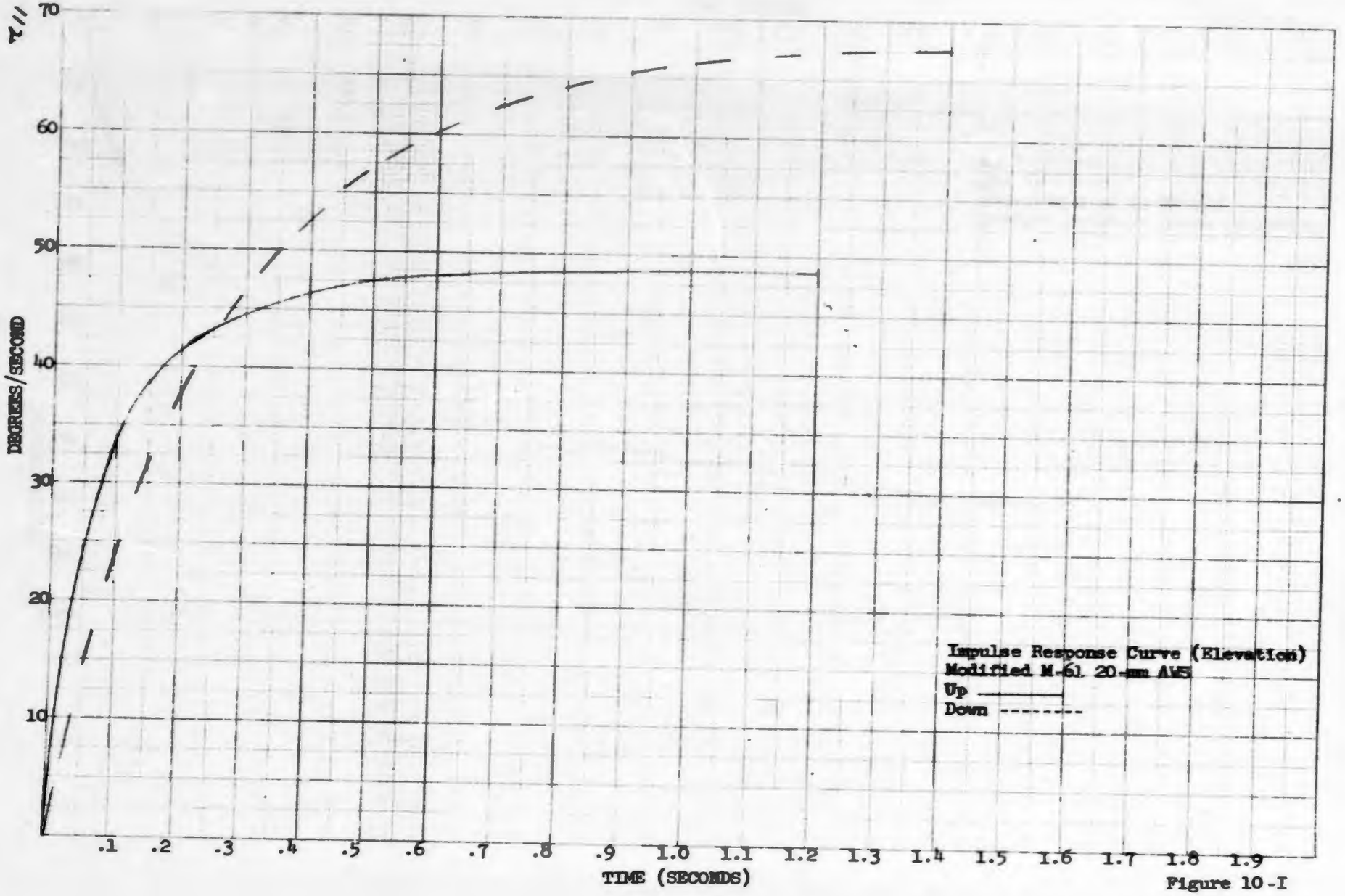
TIME (SECONDS)
Impulse Response Curve (Azimuth)
Modified M-61 20-mm AWS
CCW
CW

Figure 9 -I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TIME (SECONDS)
Impulse Response Curve (Elevation)
Modified M-61 20-mm AN5
Up
Down

Figure 10-I

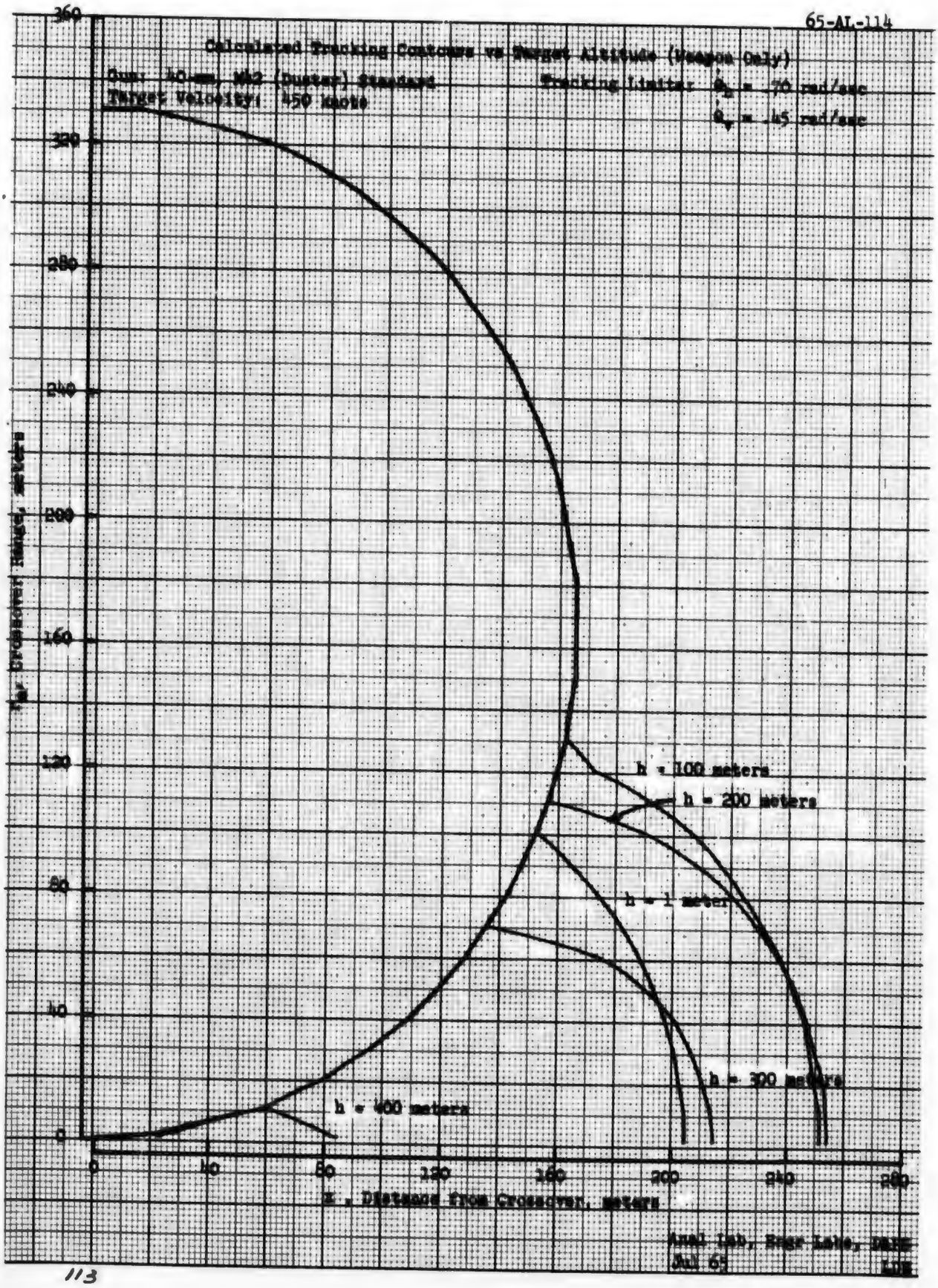

Calculated Tracking Contours vs Target Altitude (Weapon Only)
Gun: 40-mm, M42 (Duster) Standard
Target Velocity: 450 knots
Tracking Limits: $\dot{\theta}_h$ = .70 rad/sec
$\dot{\theta}_v$ = .45 rad/sec
Slant Range, meters
h = 100 meters
h = 200 meters
h = 1 meter
h = 300 meters
h = 400 meters
x - Distance from Crossover, meters
Aval Lab, Edgr Lake, Dade
Jul 65

Figure 11.7

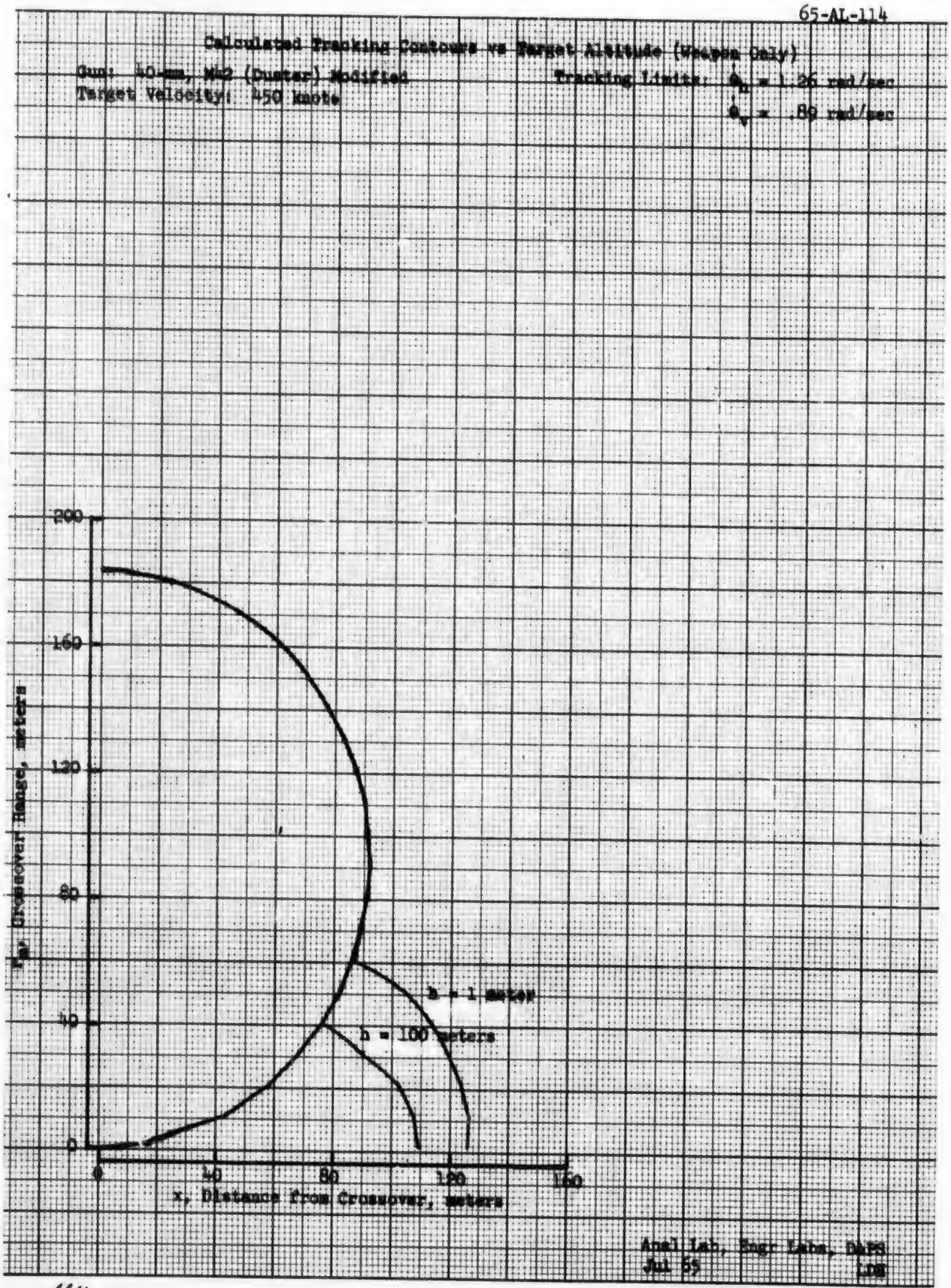
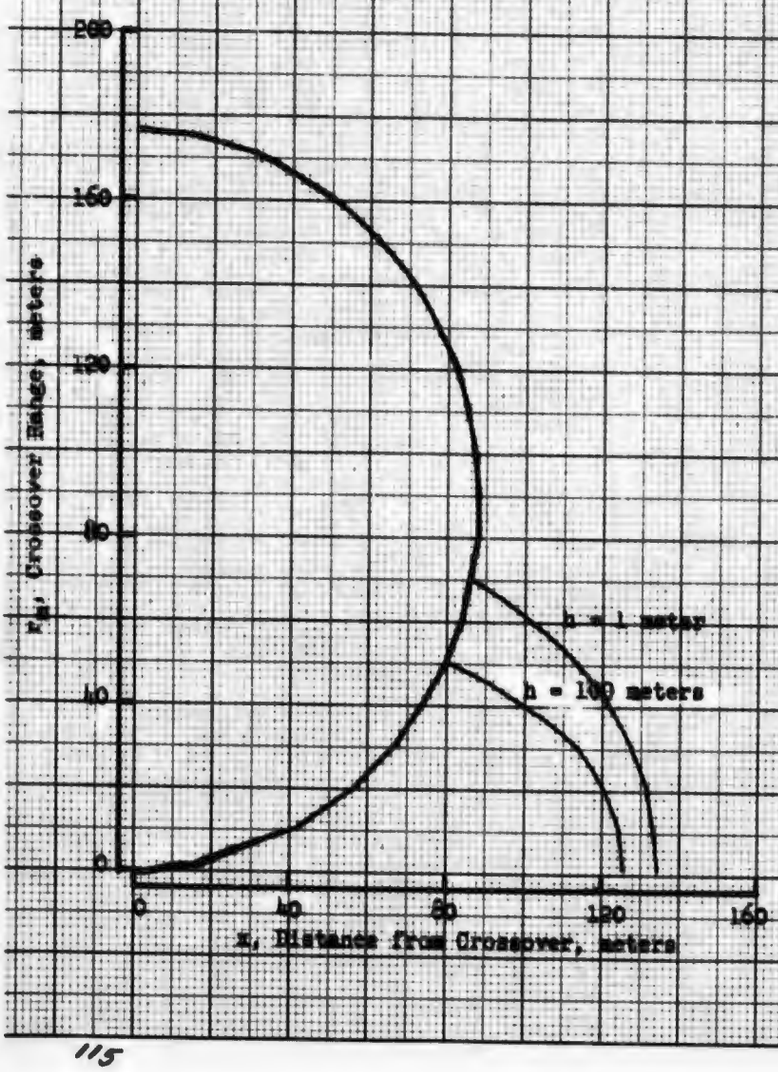

Calculated Tracking Contours vs Target Altitude (Weapon Only)
Gun: 40-mm, M2 (Duster) Modified
Target Velocity: 450 knots
Tracking Limits: $\dot{\theta}_H$ = 1.26 rad/sec
$\dot{\theta}_V$ = .89 rad/sec
200
160
120
80
40
0
h, Crossover Range, meters
h = 1 meter
h = 100 meters
0
40
80
120
160
x, Distance from Crossover, meters
Anal Lab, Engr Labs, DARCOM
Jul 65

Figure 12 I

Calculated Tracking Contours vs Target Altitude (Weapon Only)

Gun: 20-mm, M61 Standard
Target Velocity: 450 knots

Tracking Limits: $\dot{\theta}_H$ = 1.31 rad/sec
$\dot{\theta}_V$ = .83 rad/sec



Anal Lab, Engr Labs, DARC
Jul 65

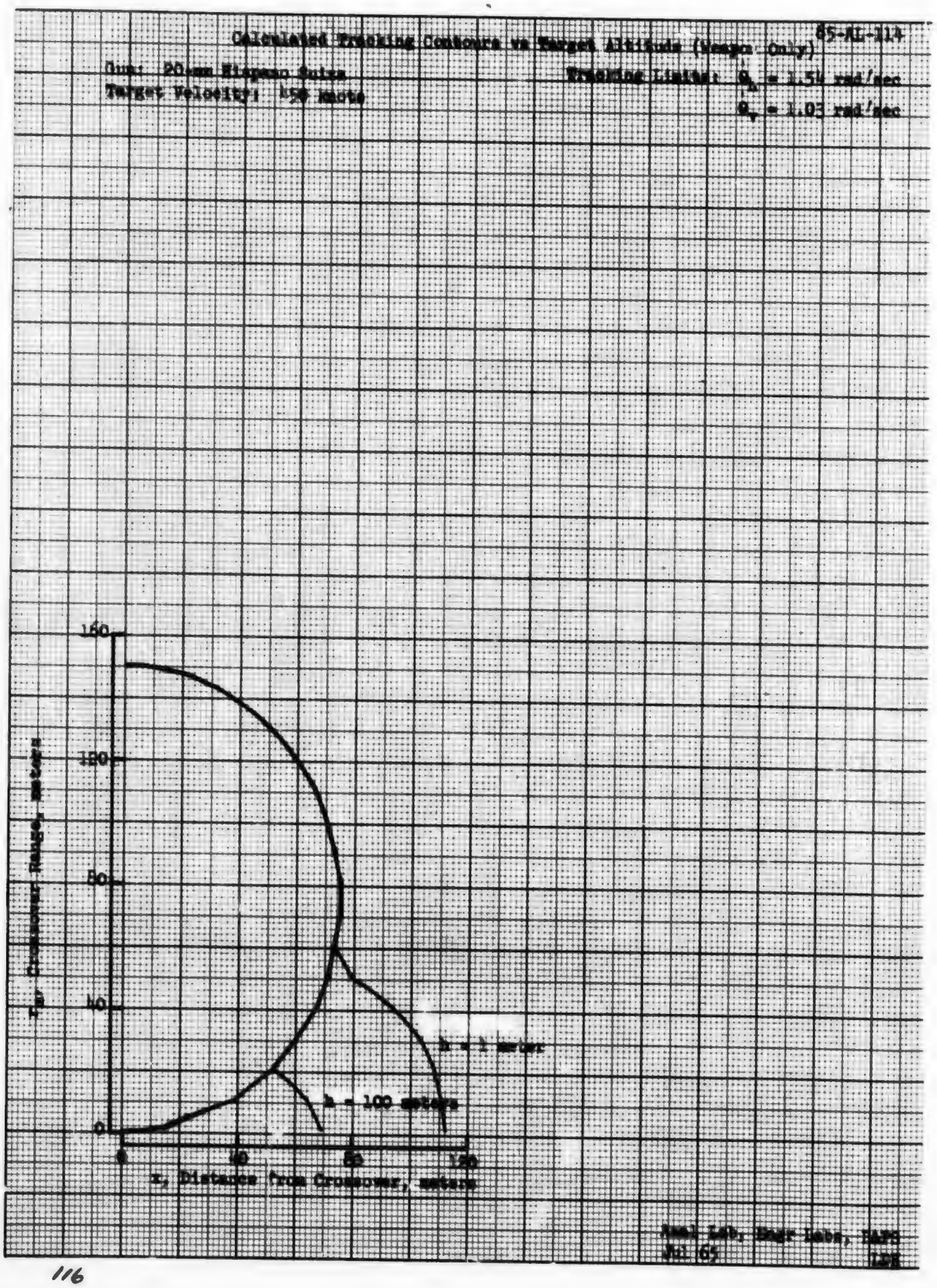


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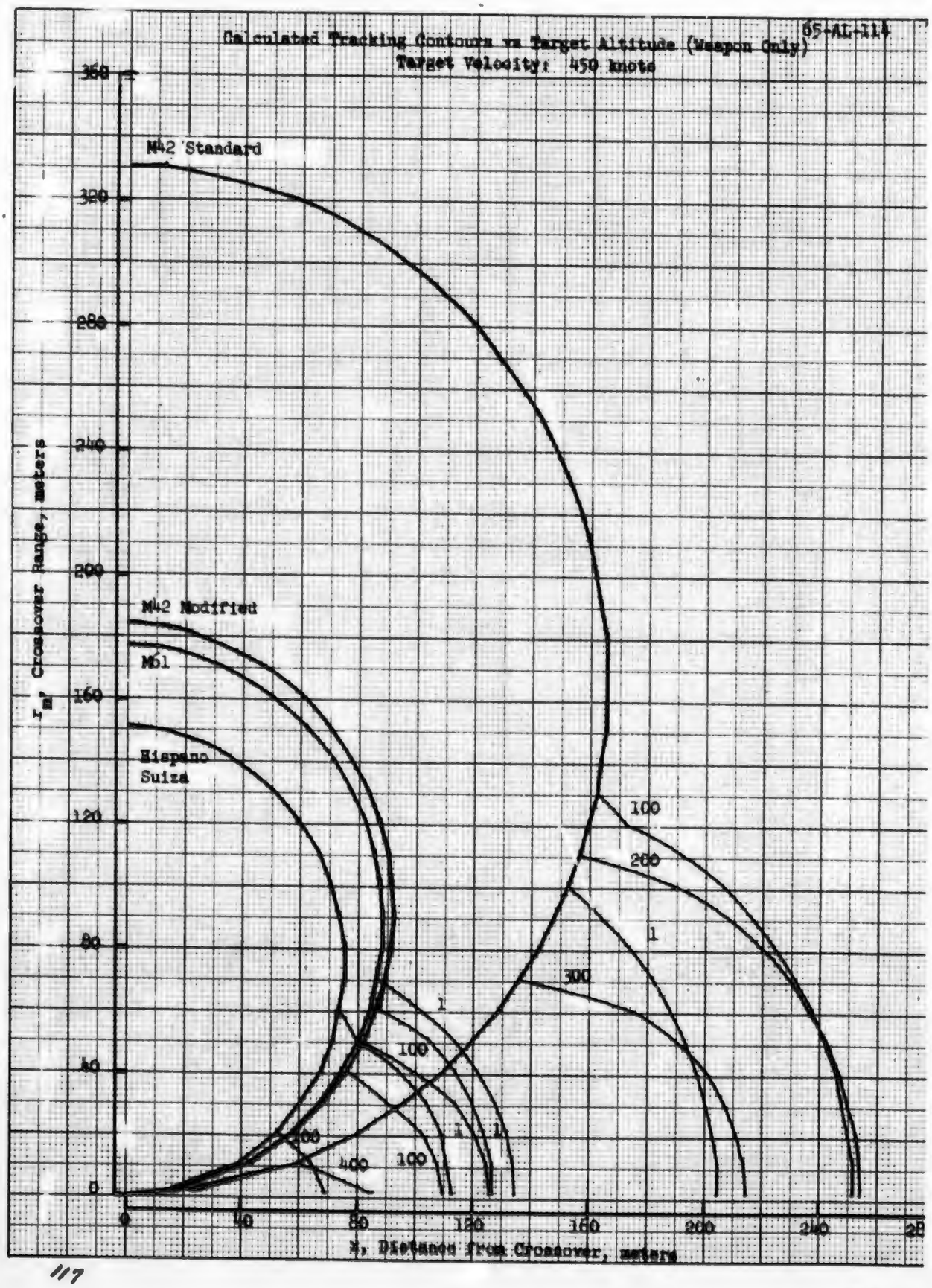
Figure 14


Calculated Tracking Contours vs Target Altitude (Weapon Only)
Target Velocity: 450 knots
M42 Standard
M42 Modified
M61
Hispano Suiza
100
200
1
300
400
h_m, Crossover Range, meters
X, Distance from Crossover, meters

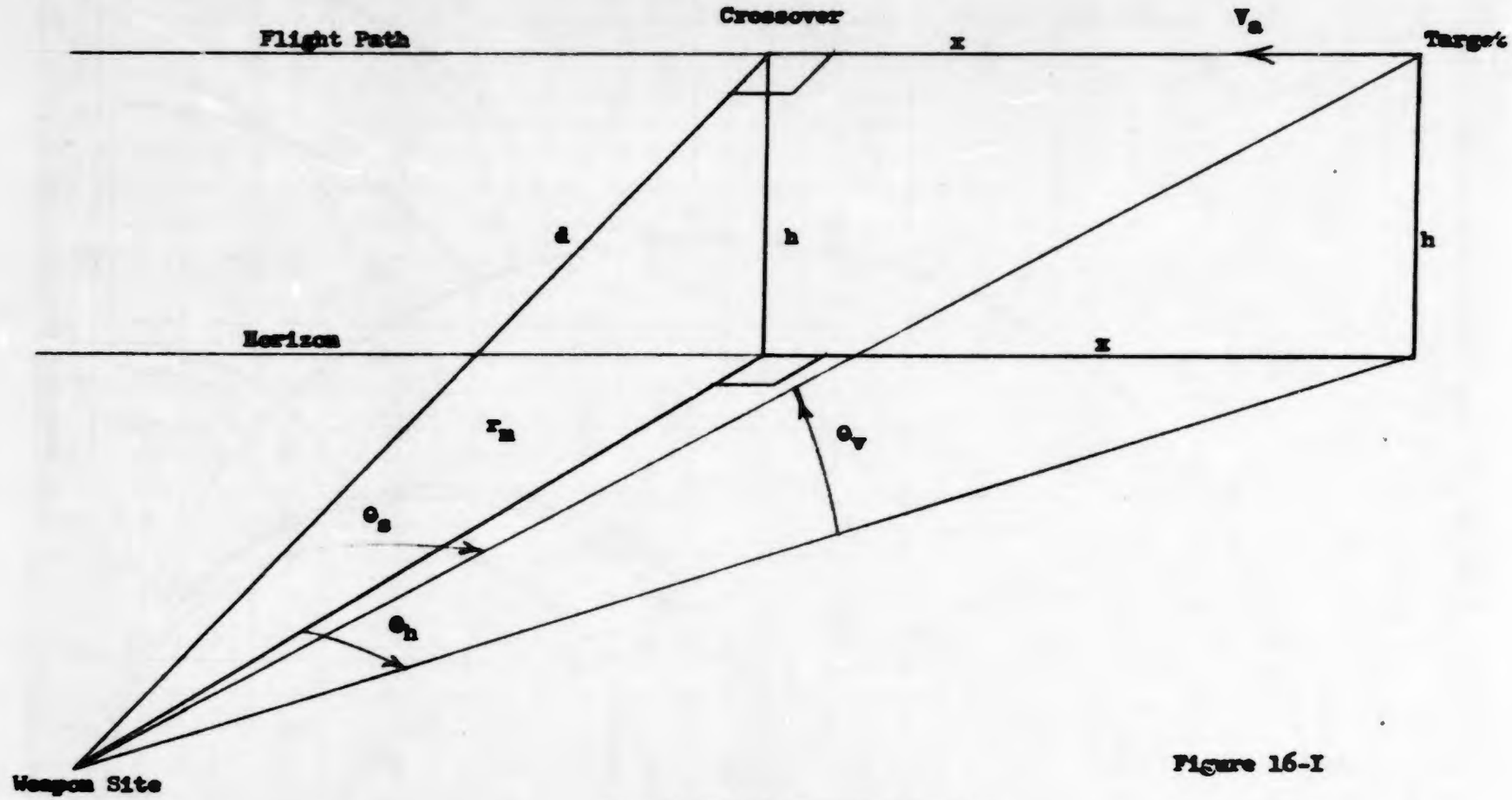
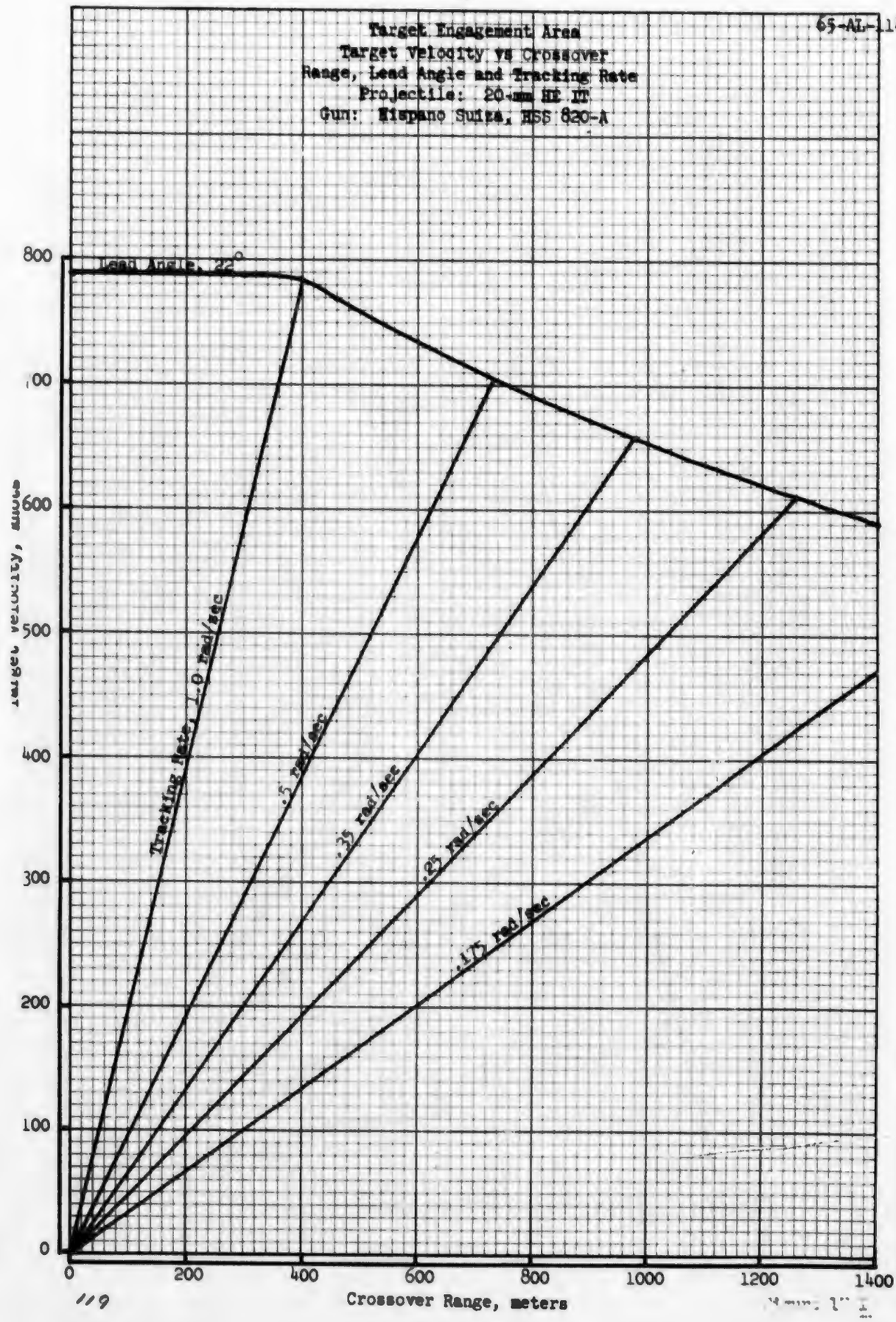


Figure 16-I

Target Flight Course Geometry


Target Engagement Area
Target Velocity vs Crossover
Range, Lead Angle and Tracking Rate
Projectile: 20-mm HE IT
Gun: Hispano Suiza, HS5 820-A
Lead Angle, 22°
Tracking Rate, 1.0 rad/sec
.5 rad/sec
.35 rad/sec
.25 rad/sec
.175 rad/sec
Target Velocity, knots
0
100
200
300
400
500
600
700
800
0
200
400
600
800
1000
1200
1400
Crossover Range, meters

65-AL-114

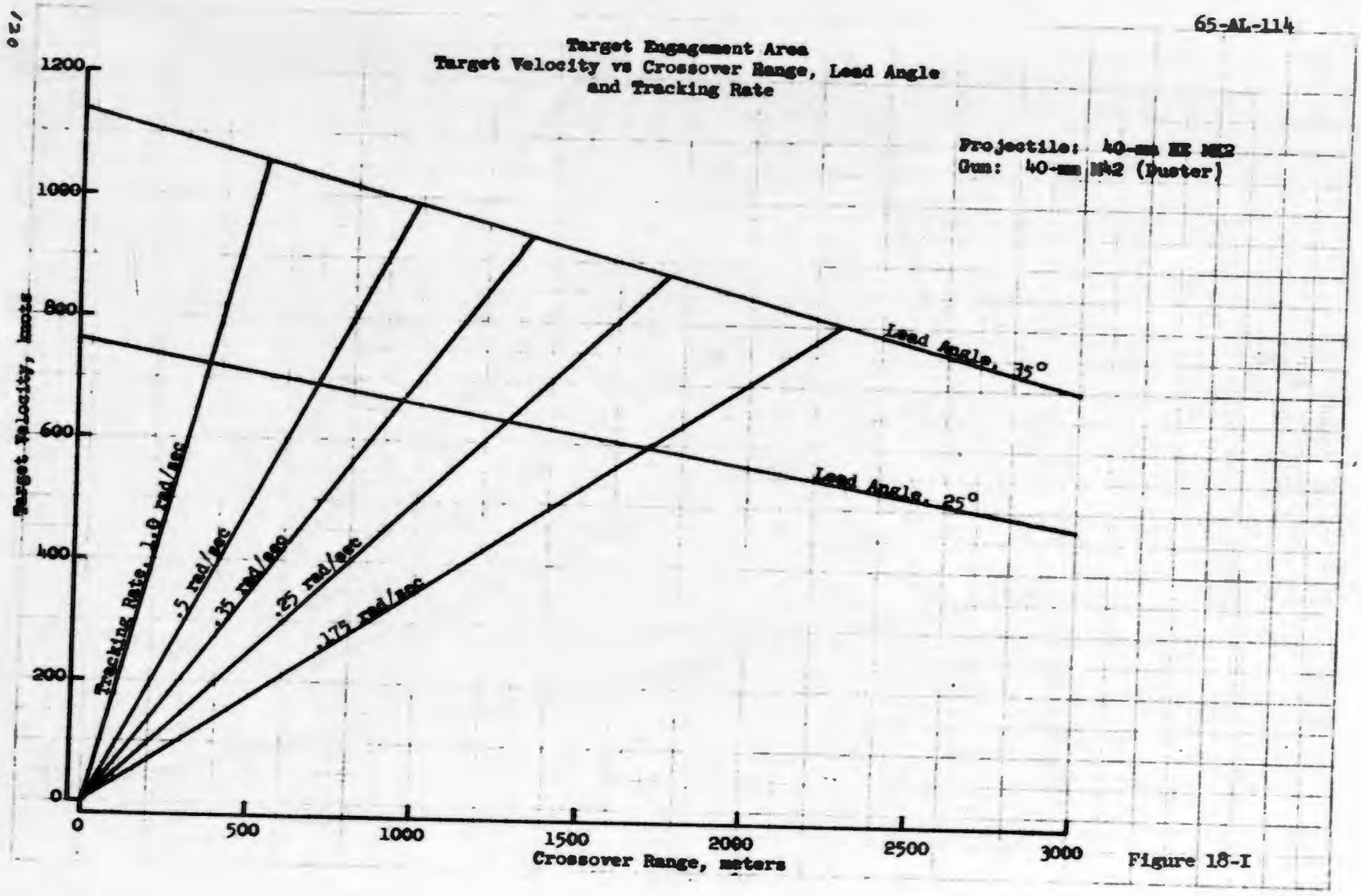
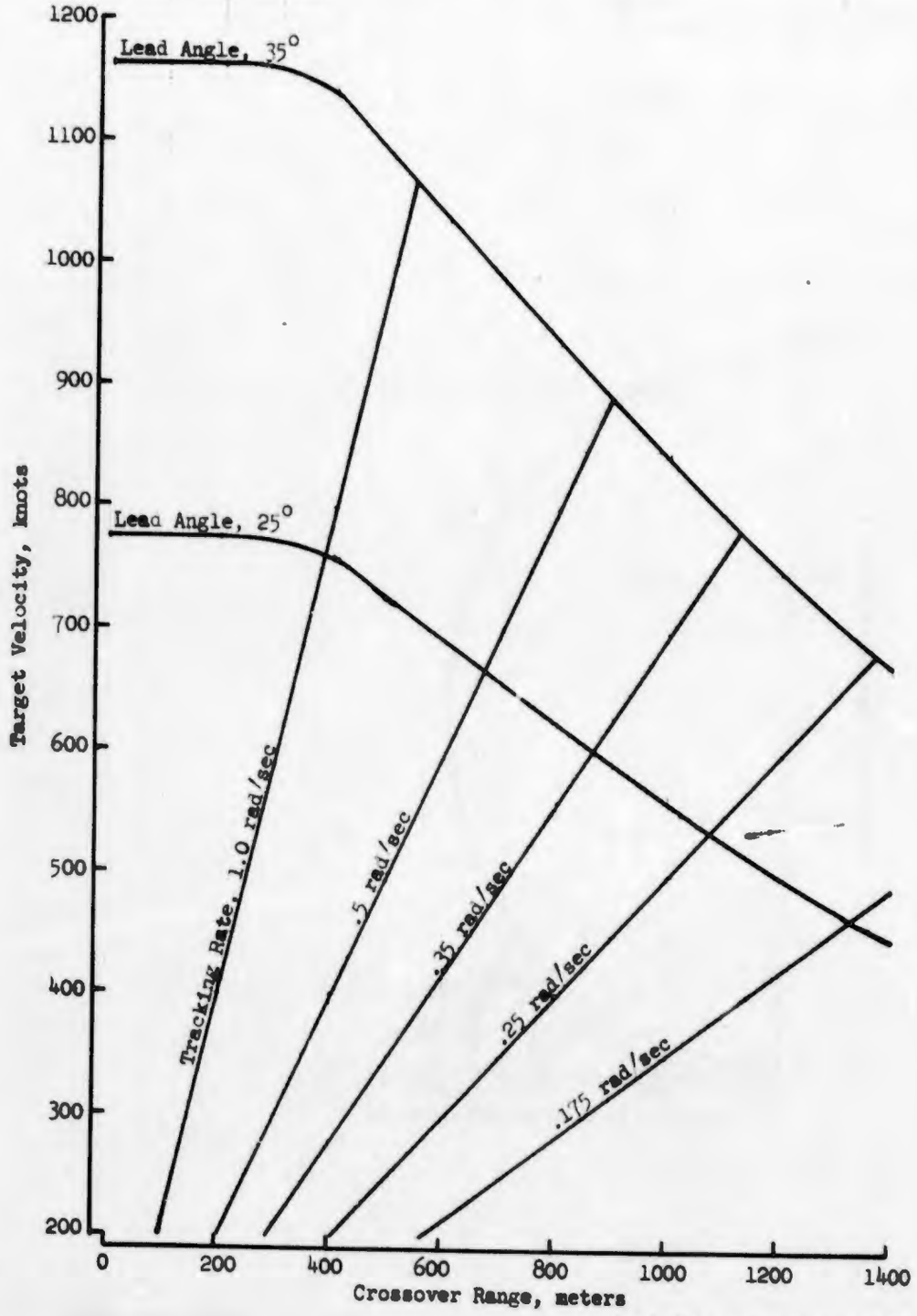


Figure 18-I

Target Engagement Area

Target Velocity vs Crossover Range, Lead Angle and Tracking Rate
Projectile: 20-mm M56 HEI
Gun: M61 Valcan



Anal Lab, Engr Labs, D&PS
Jun 65
LDH

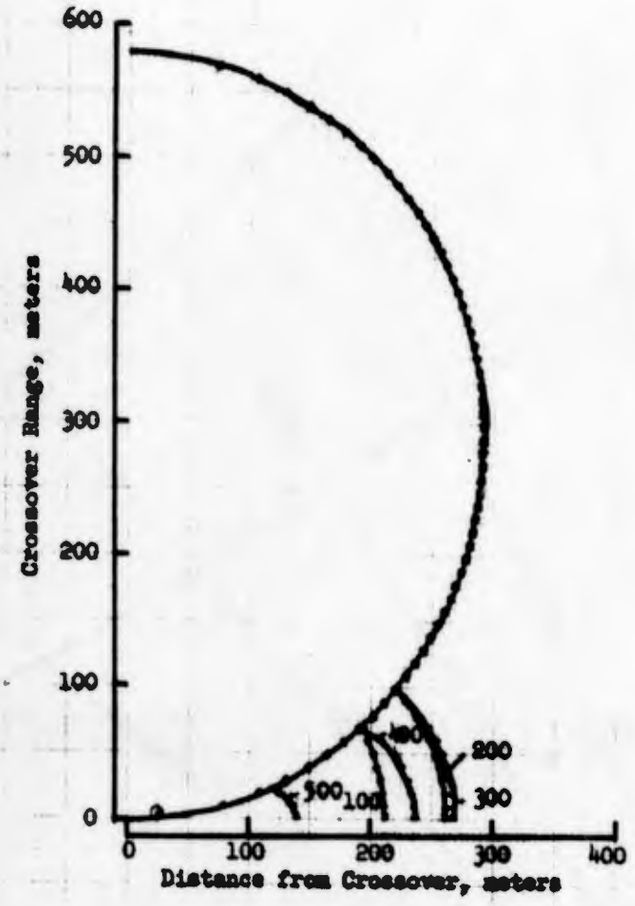
Figure 19-I

65-AL-114

Calculated Tracking Contour vs Target Altitude (Weapon and Man)

Gun: 20-mm, M61
Target Velocity: 450 knots

Tracking Limits: $\dot{\theta}_h$ = .40 rad/sec
$\dot{\theta}_v$ = .43 rad/sec



Anal Lab, Engr Labs, D&PS
Jul 65 LDH

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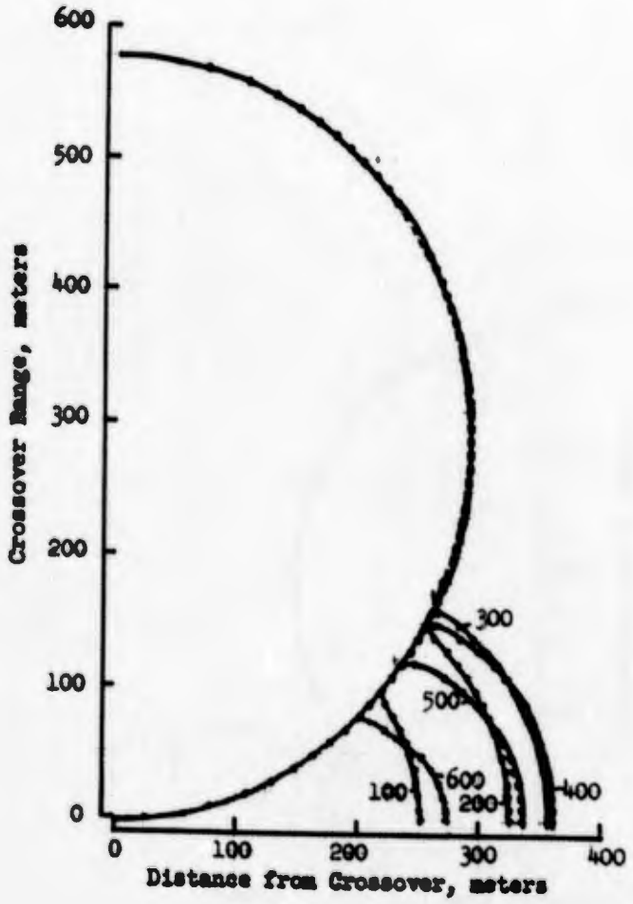
Figure 20-I

Calculated Tracking Contour vs Target Altitude (Weapon and Man) 65-AL-114

Gun: 40-mm, M42
Target Velocity: 450 knots

Tracking Limits: $\dot{\theta}_h$ = .40 rad/sec
$\dot{\theta}_v$ = .32 rad/sec



Anal Lab, Engr Labs, D&PS
Jul 65 LDH

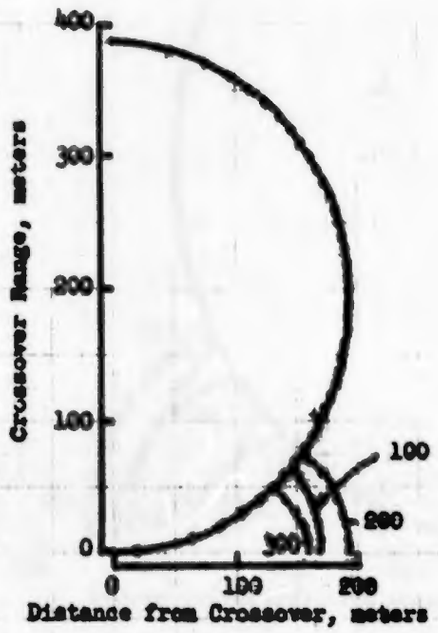
Figure 21-I

65-AL-114

Calculated Tracking Contour vs Target Altitude (Weapon and Man)

Gun: 20-mm, Hispano Suiza
Target Velocity: 450 knots

Tracking Limits: $\dot{\theta}_h$ = .60 rad/sec
$\dot{\theta}_v$ = .60 rad/sec



Anal Lab, Engr Labs, DAPG
Jul 65

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Figure 22-I

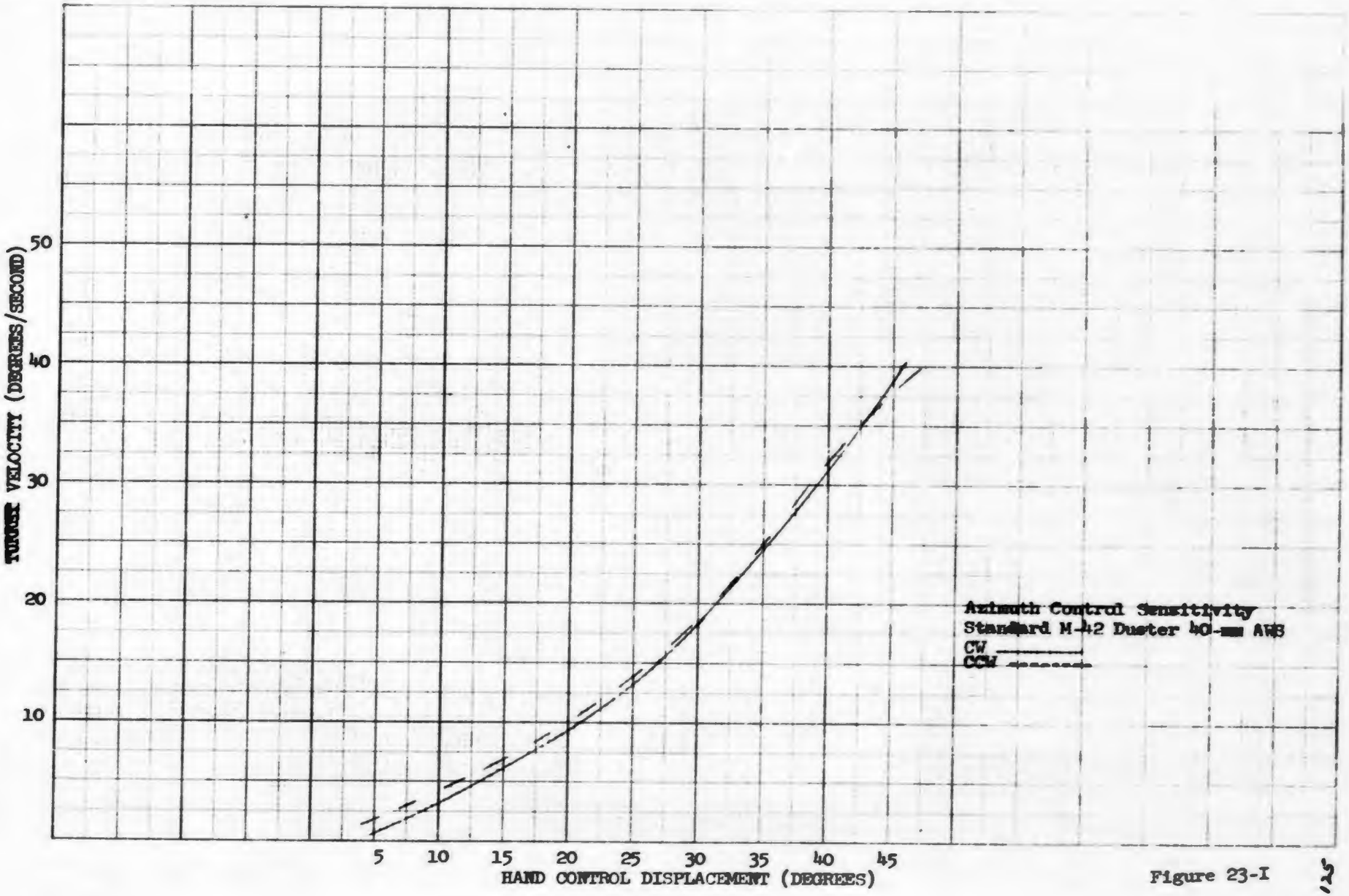

TURRET VELOCITY (DEGREES/SECOND)
50
40
30
20
10
5
10
15
20
25
30
35
40
45
HAND CONTROL DISPLACEMENT (DEGREES)
Azimuth Control Sensitivity
Standard M-42 Duster 40-mm AWB
CW
CCW

Figure 23-I

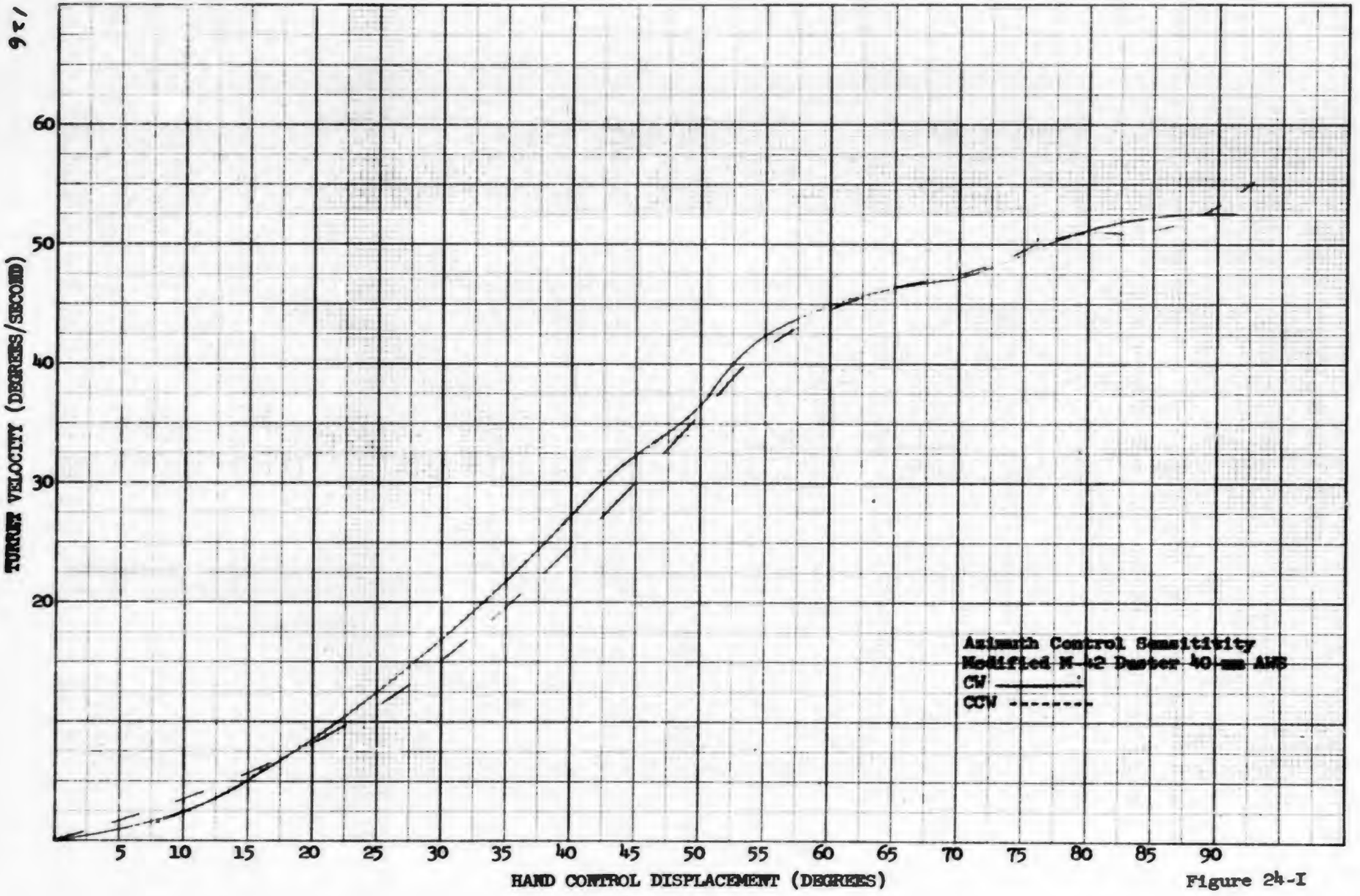

TURRET VELOCITY (DEGREES/SECOND)
60
50
40
30
20
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
HAND CONTROL DISPLACEMENT (DEGREES)
Azimuth Control Sensitivity
Modified M-42 Duster 40 mm AWS
CW
CCW

Figure 24-I

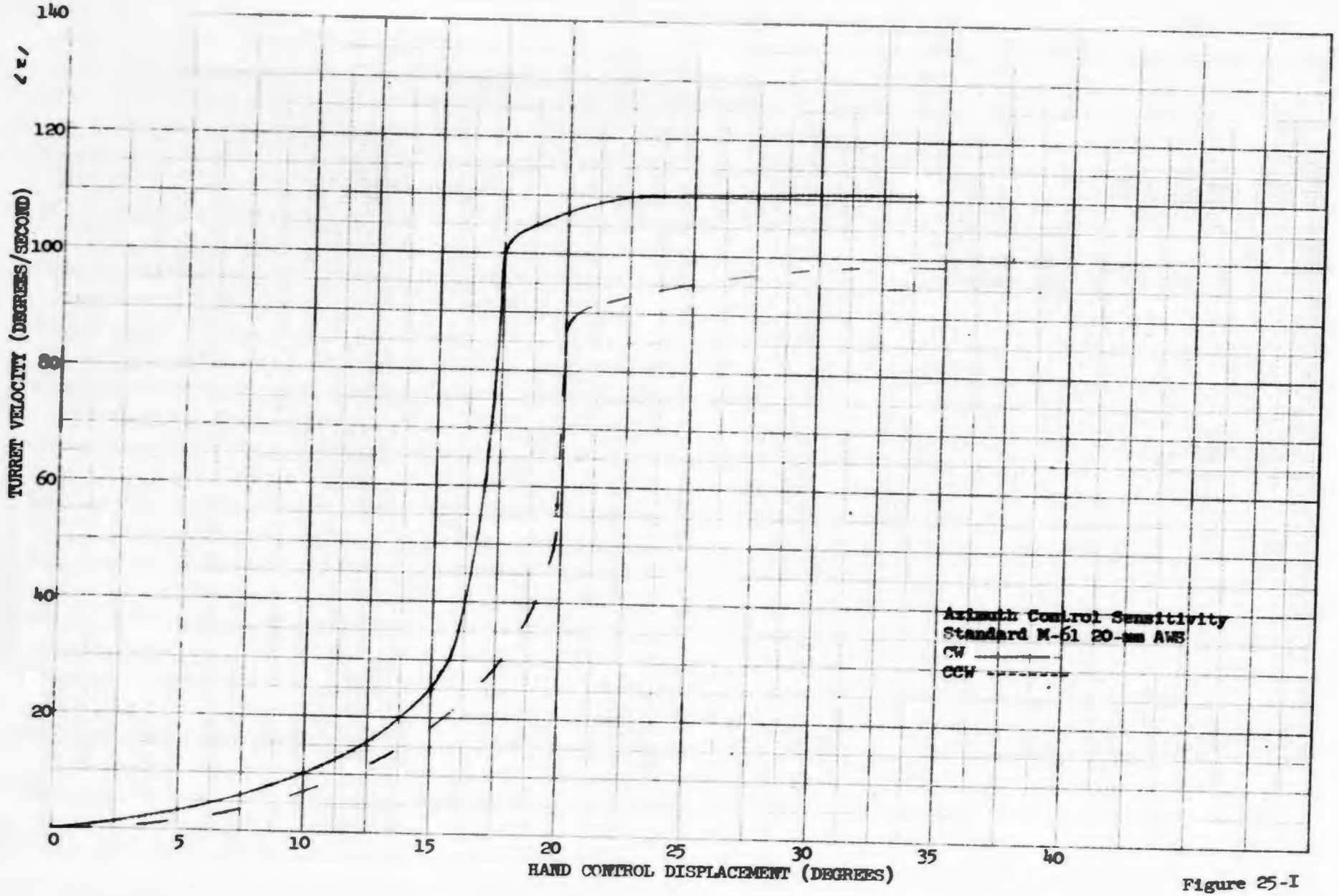

TURRET VELOCITY (DEGREES/SECOND)
140
120
100
80
60
40
20
0
5
10
15
20
25
30
35
40
HAND CONTROL DISPLACEMENT (DEGREES)
Azimuth Control Sensitivity
Standard M-61 20-mm AWS
CW
CCW

Figure 25-I

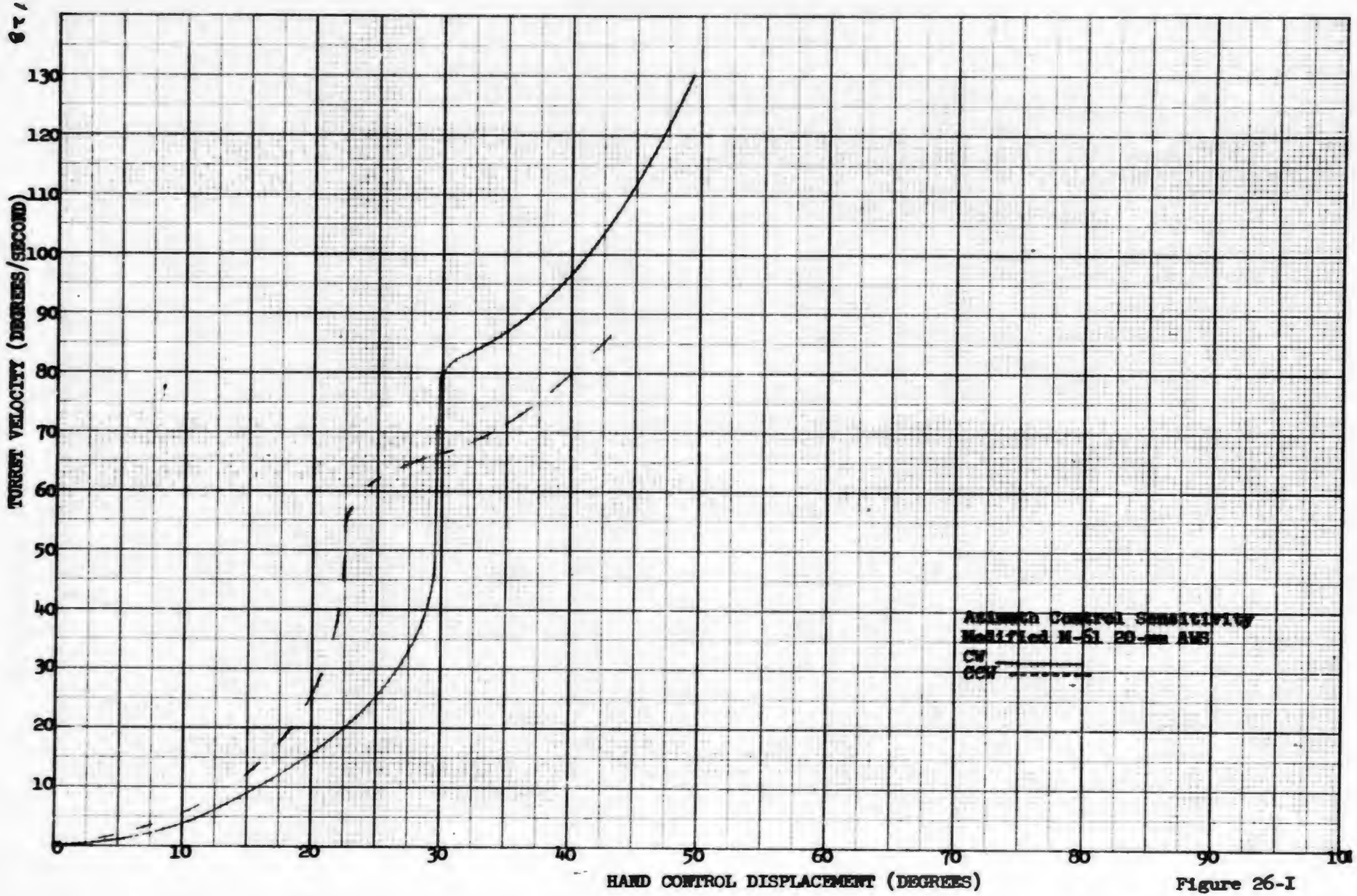

TURRET VELOCITY (DEGREES/SECOND)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
HAND CONTROL DISPLACEMENT (DEGREES)
Azimuth Control Sensitivity
Modified M-51 20-mm AWS
CW
CCW

Figure 26-I

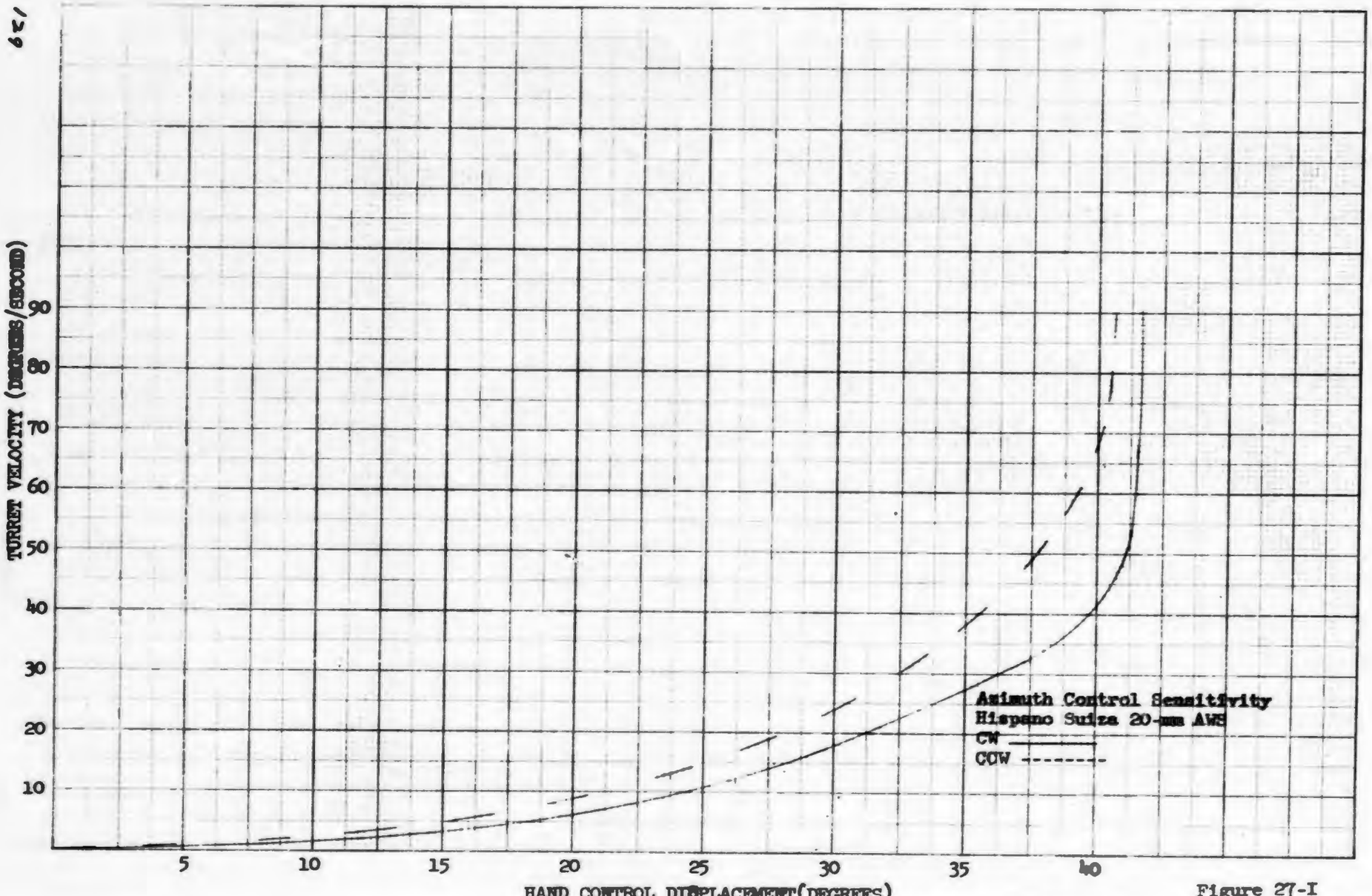

TURRET VELOCITY (DEGREES/SECOND)
10
20
30
40
50
60
70
80
90
5
10
15
20
25
30
35
40
HAND CONTROL DISPLACEMENT (DEGREES)
Azimuth Control Sensitivity
Hispano Suiza 20-mm AWS
CW
CCW

Figure 27-I

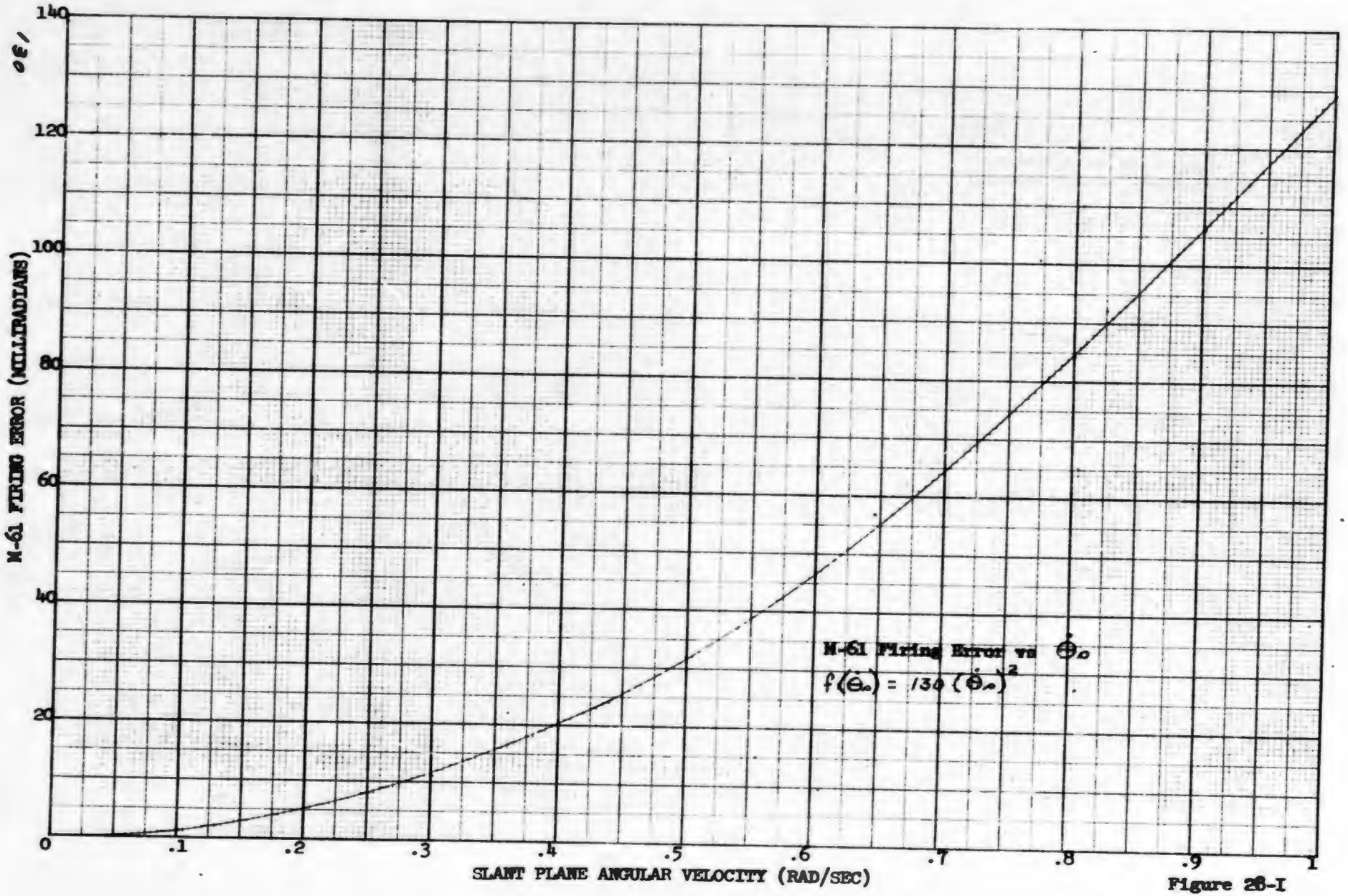

140
120
100
80
60
40
20
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
M-61 FIRING ERROR (MILLIRADIANS)
SLANT PLANE ANGULAR VELOCITY (RAD/SEC)
M-61 Firing Error vs $\dot{\theta}_o$
$f(\dot{\theta}_o) = 130\,(\dot{\theta}_o)^2$

Figure 28-I

Tracking Error
M62 (Standard)
Position 1
Run 1
+2°
0
-2°
Elevation, mils
+2°
0
-2°
Azimuth, mils
0
2
4
6
8
10
12
Time, seconds

Figure 79-I

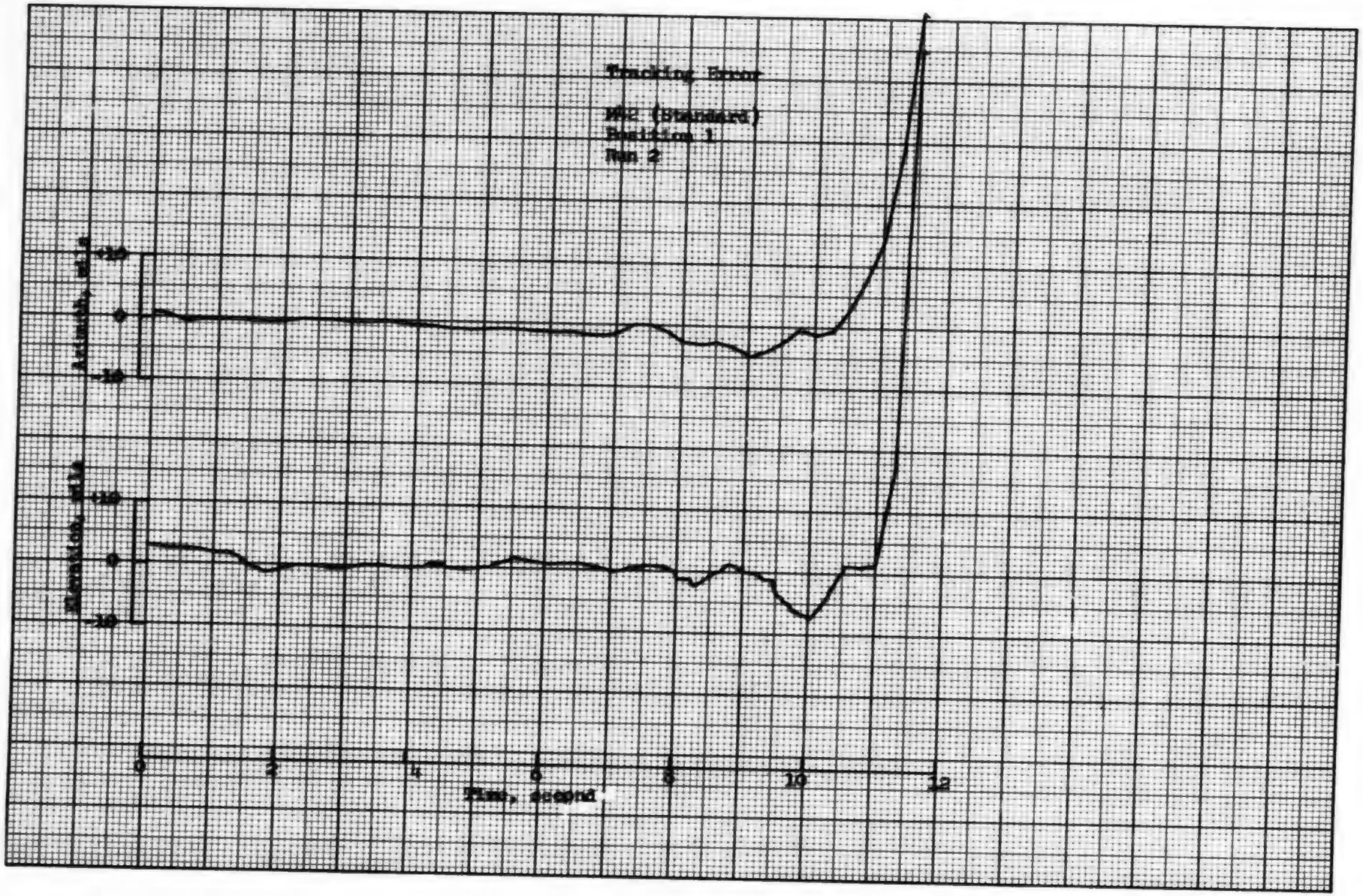

Tracking Error
MH2 (Standard)
Position 1
Run 2
Elevation, mils
+10
0
-10
Azimuth, mils
+10
0
-10
0
2
4
6
8
10
12
Time, second

Figure 30-I

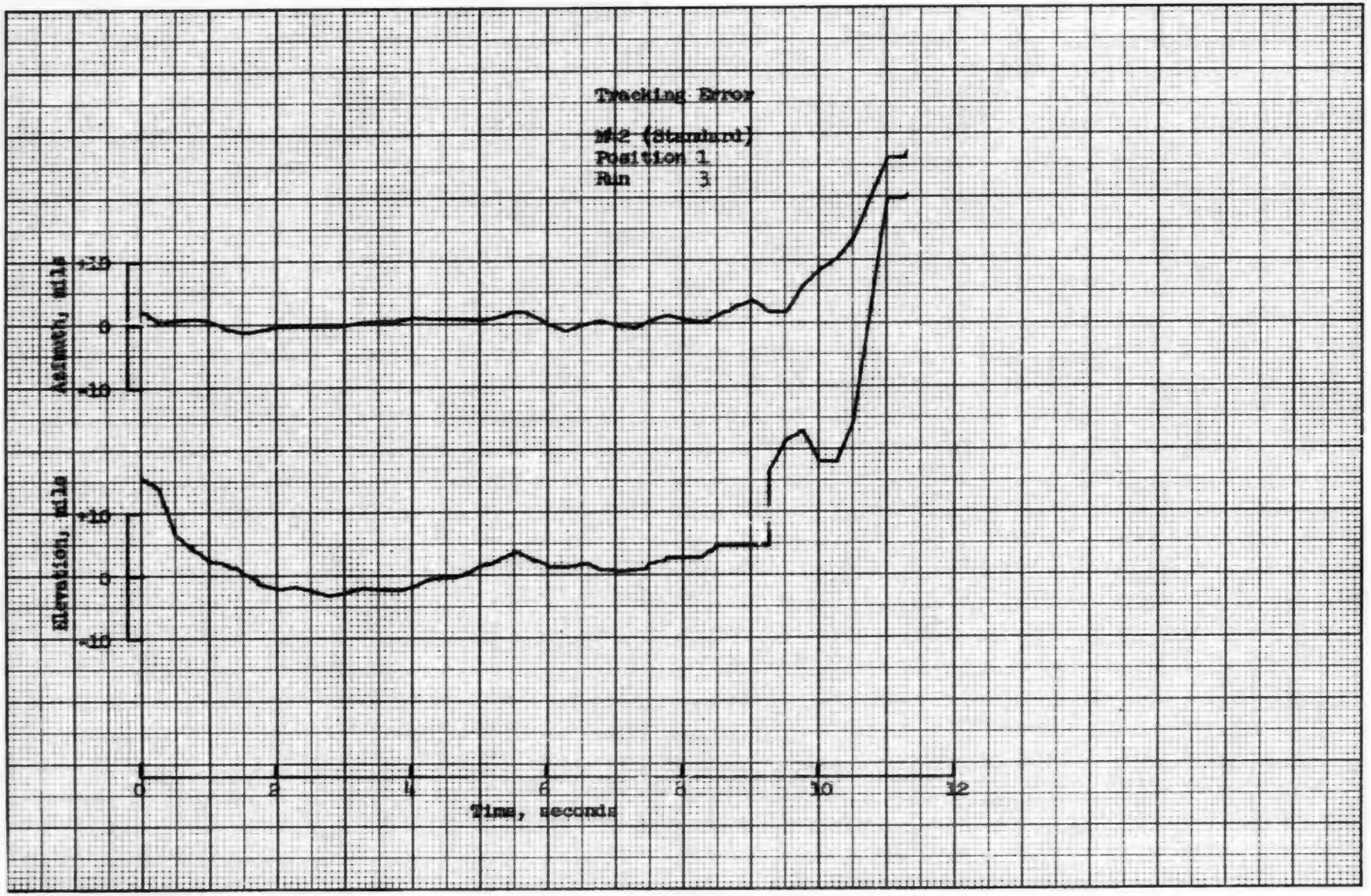

Tracking Error
M-2 (Standard)
Position 1
Run 3
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 31-I

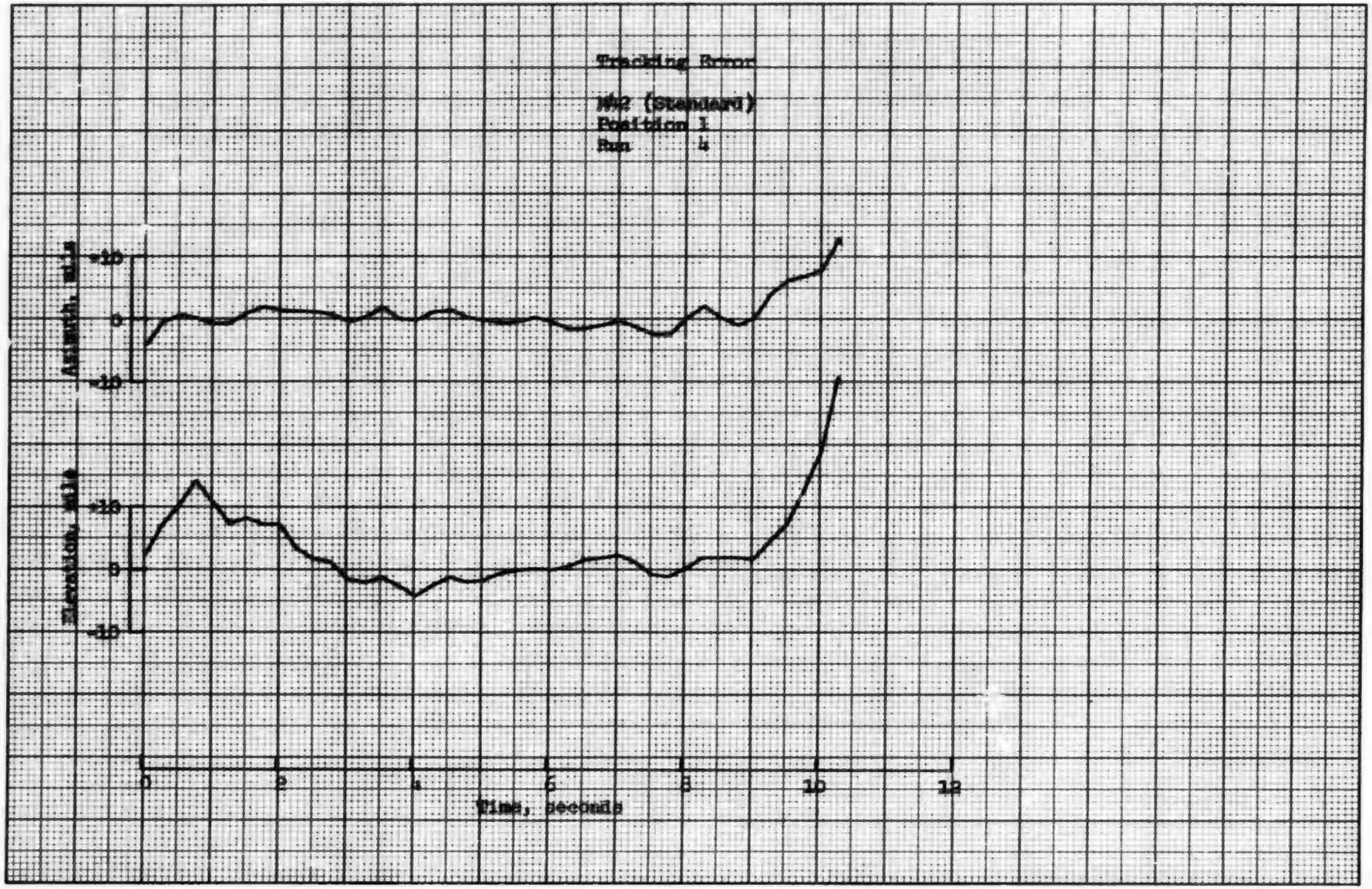
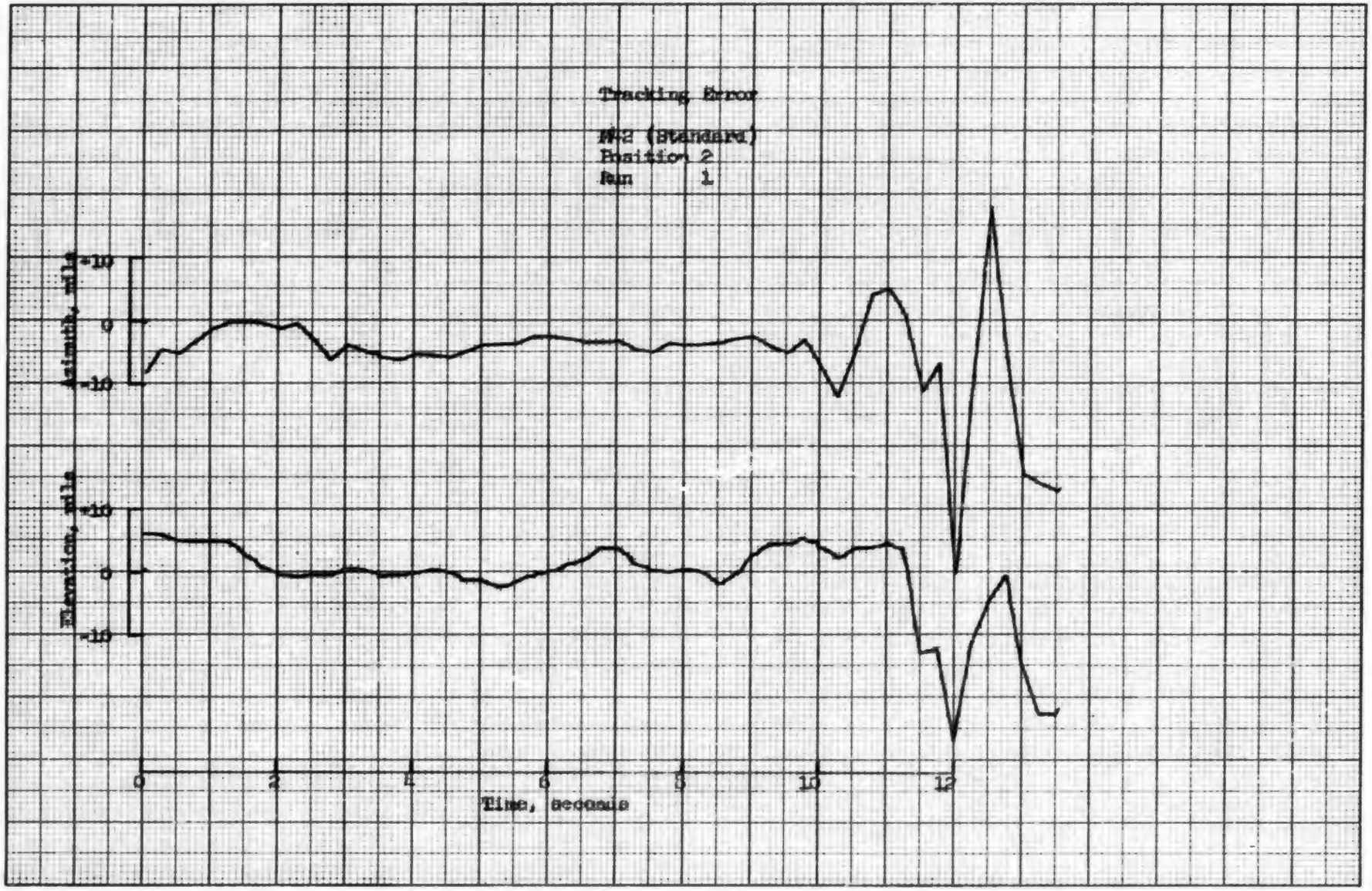

Tracking Error
#2 (Standard)
Position 1
Run 4
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 32-I


Tracking Error
#2 (Standard)
Position 2
Run 1
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

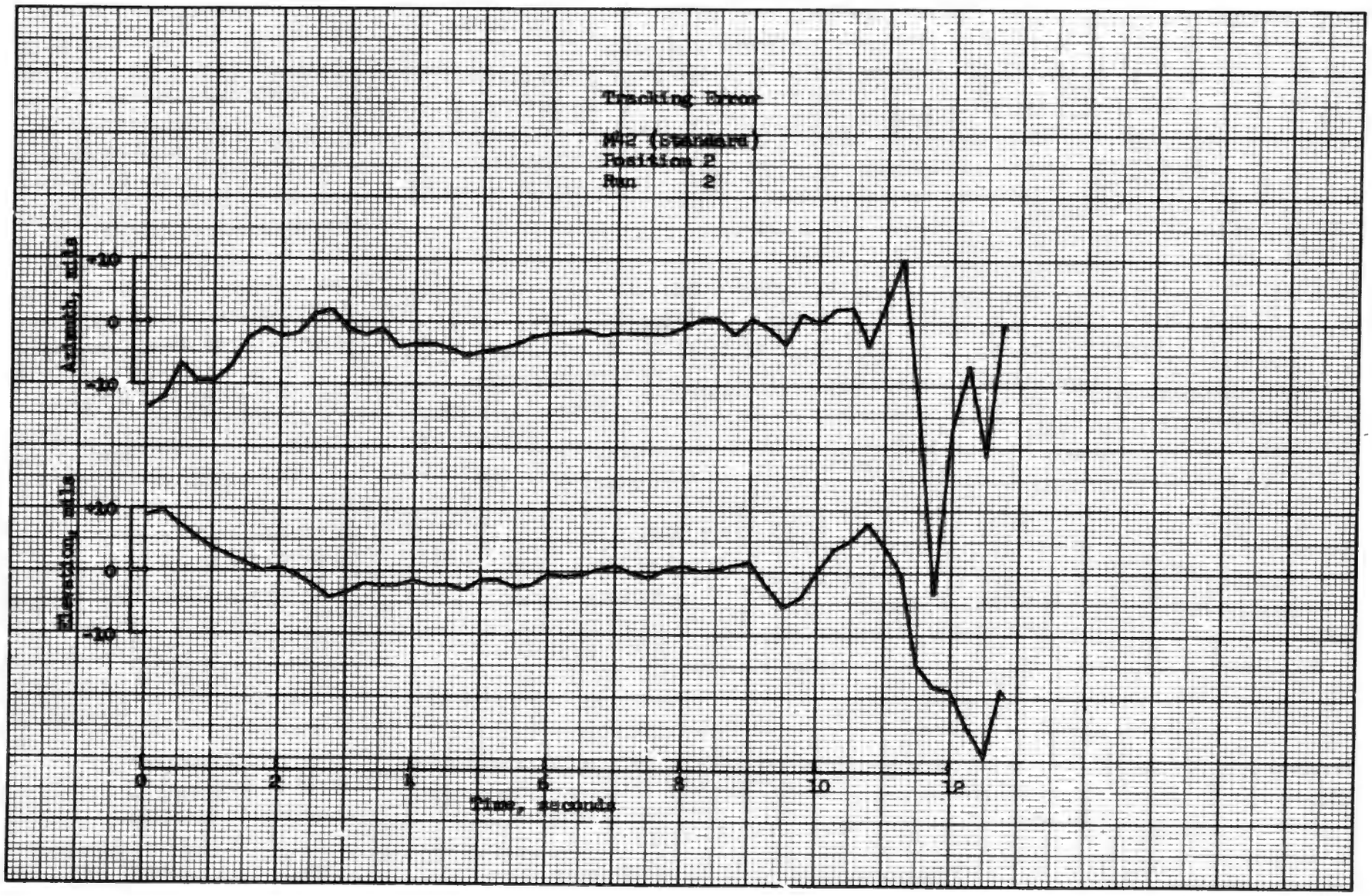

Tracking Error
M2 (Standard)
Position 2
Run 2
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 34-I

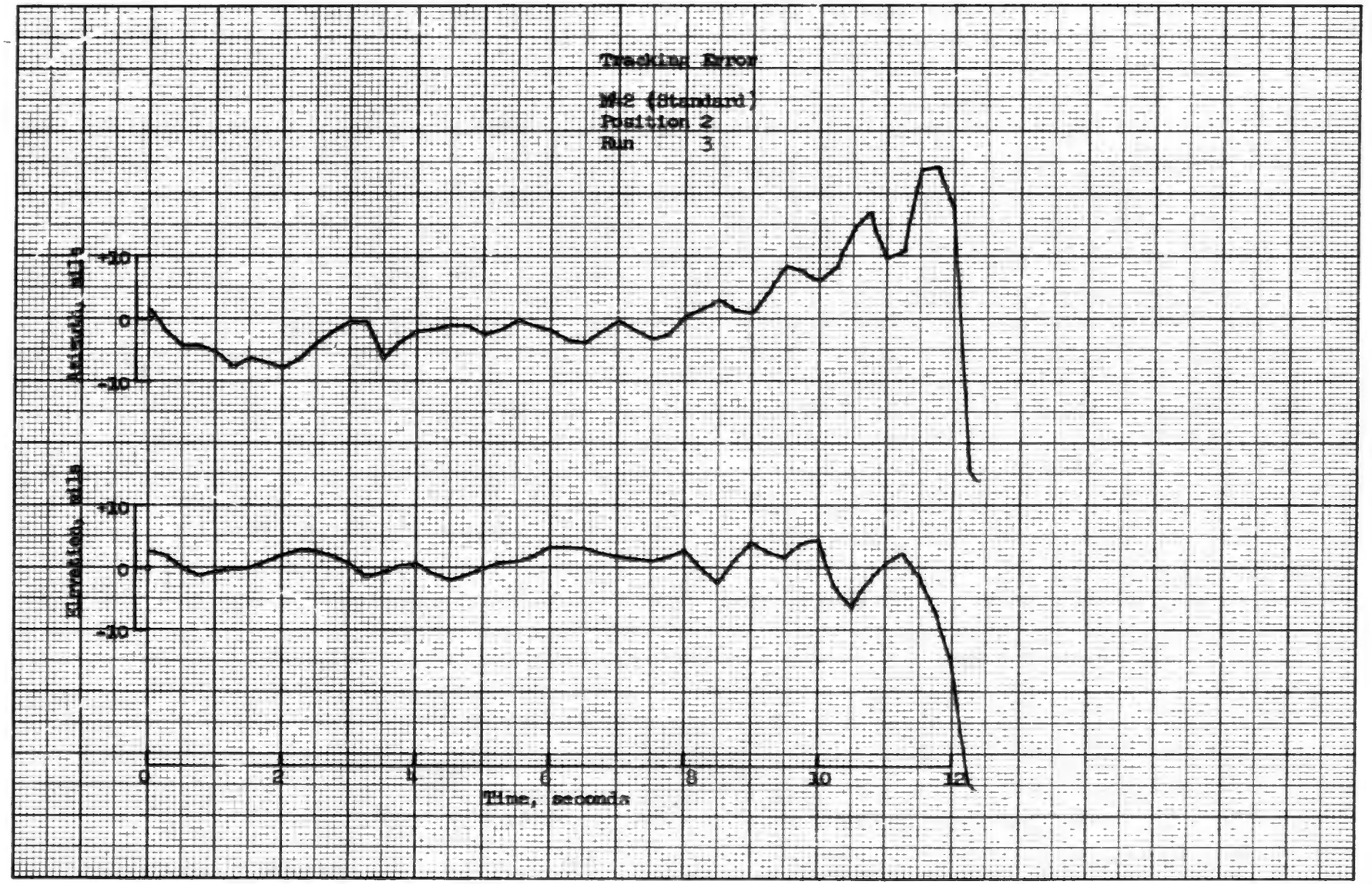

Tracking Error
M42 (Standard)
Position 2
Run 3
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 35-I

Figure 36-I

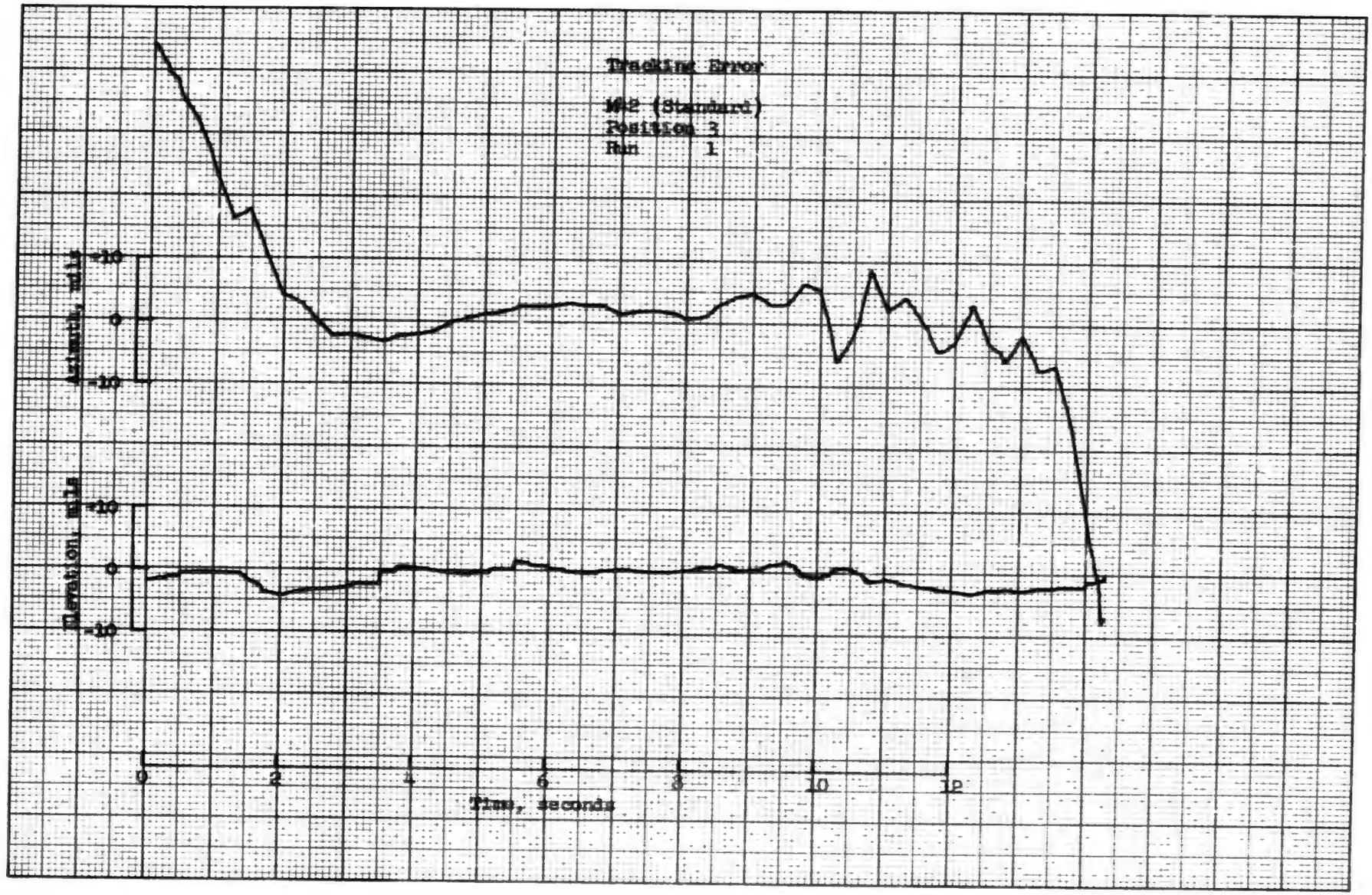

Tracking Error
M42 (Standard)
Position 3
Run 1
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 37-I

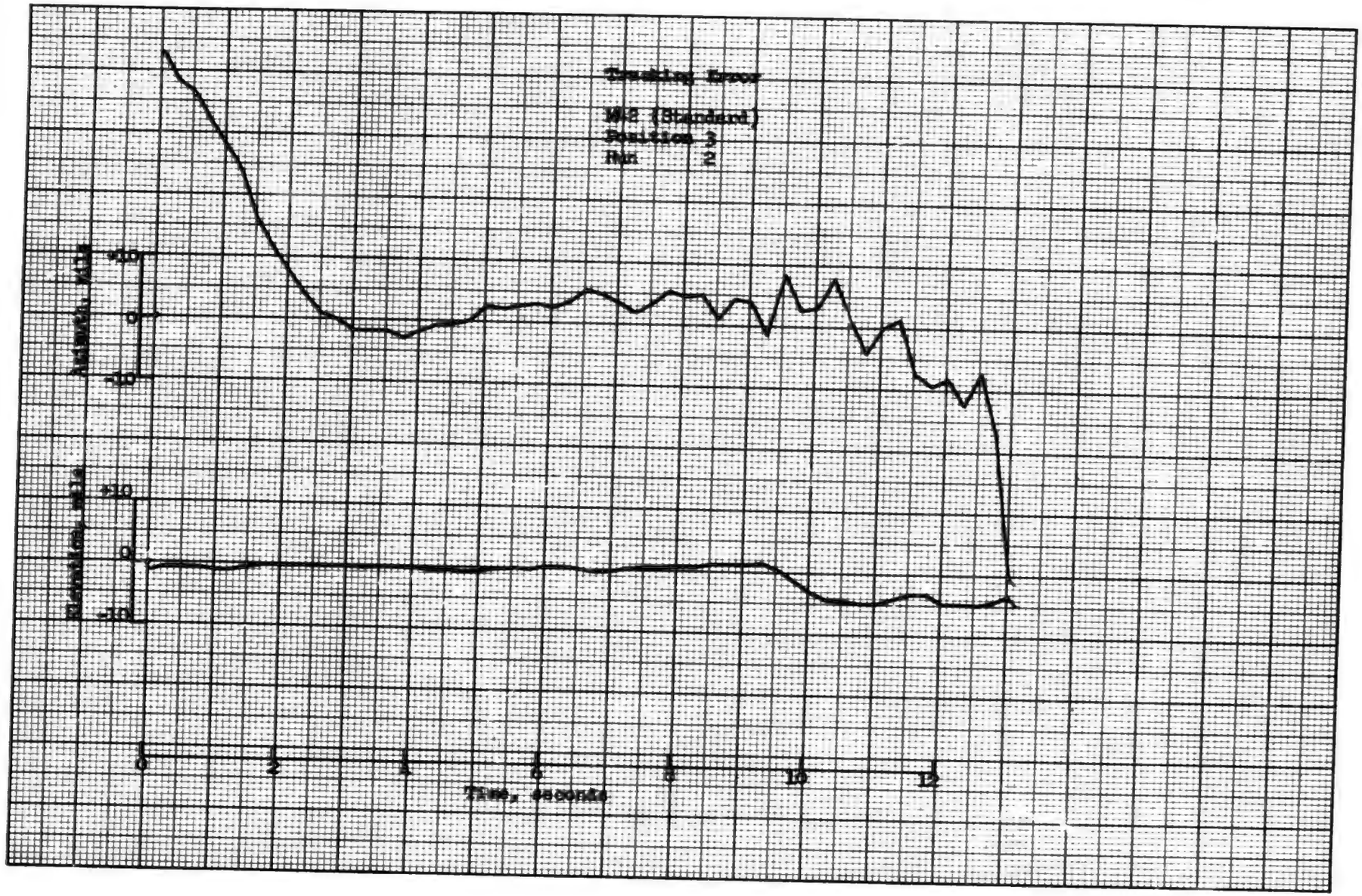
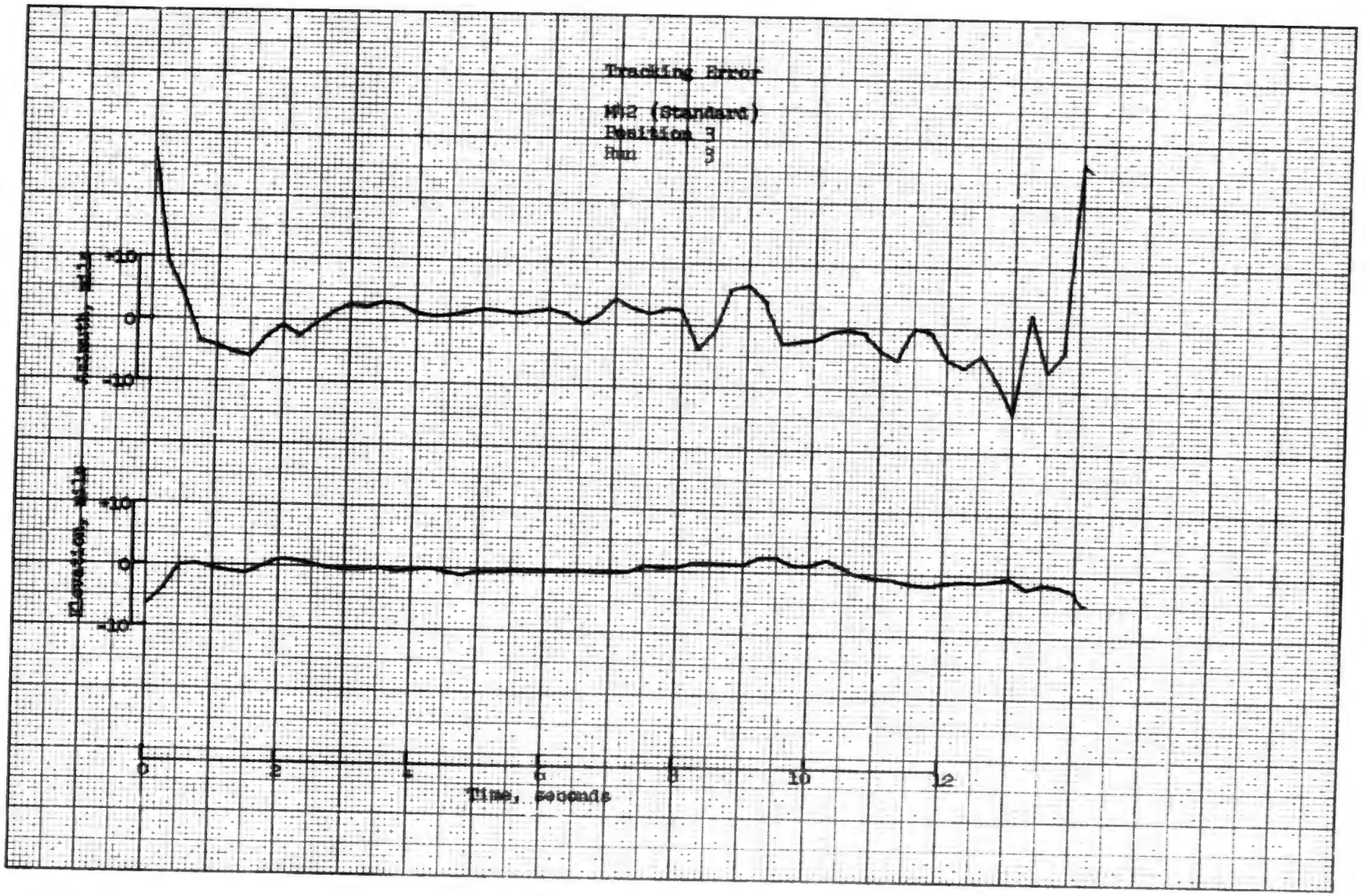

Tracking Error
M2 (Standard)
Position 3
Run 2
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
½
1
1½
2
Time, seconds

Figure 38-I


Tracking Error
M2 (Standard)
Position 3
Run 3
Elevation, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

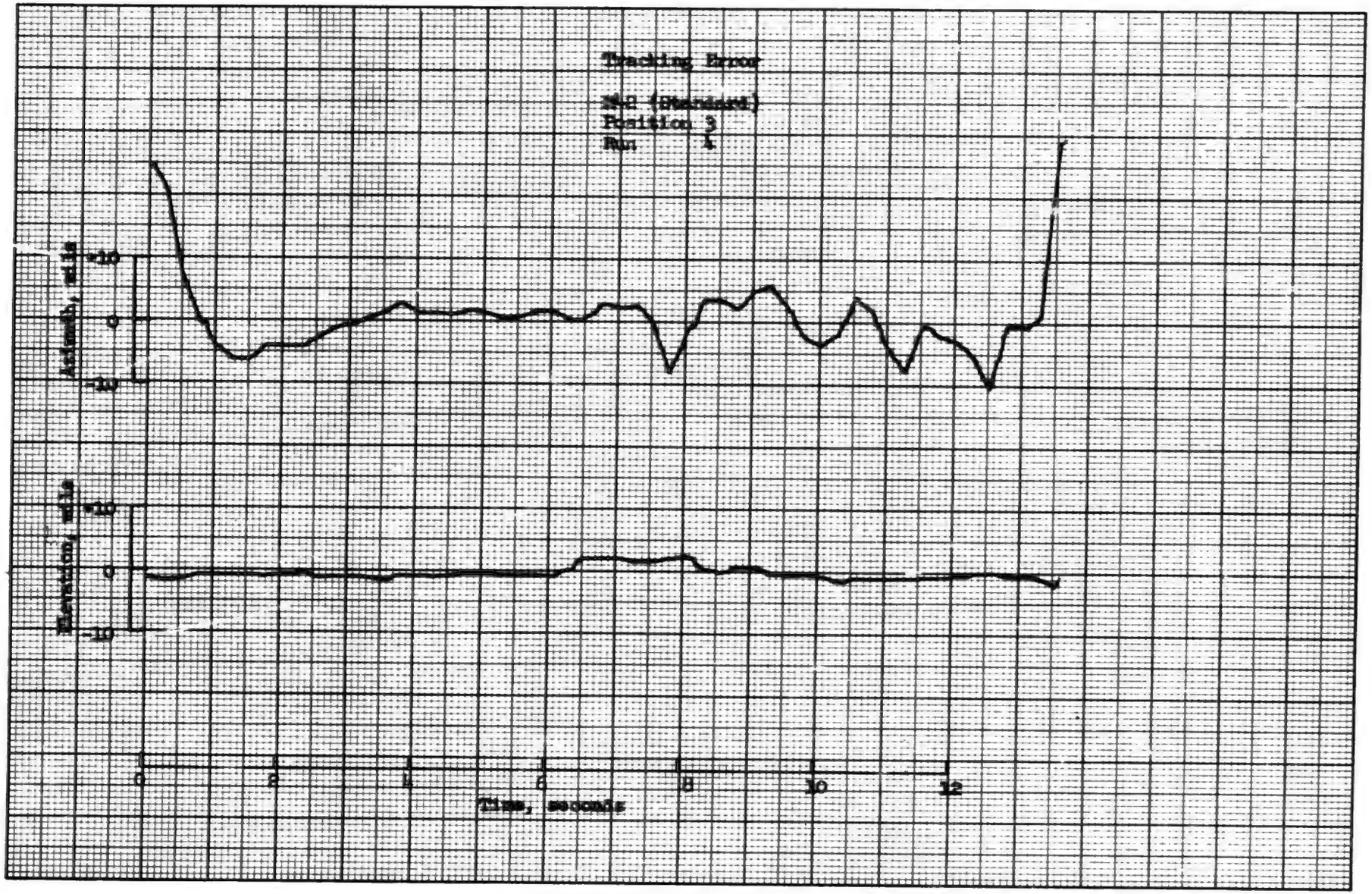
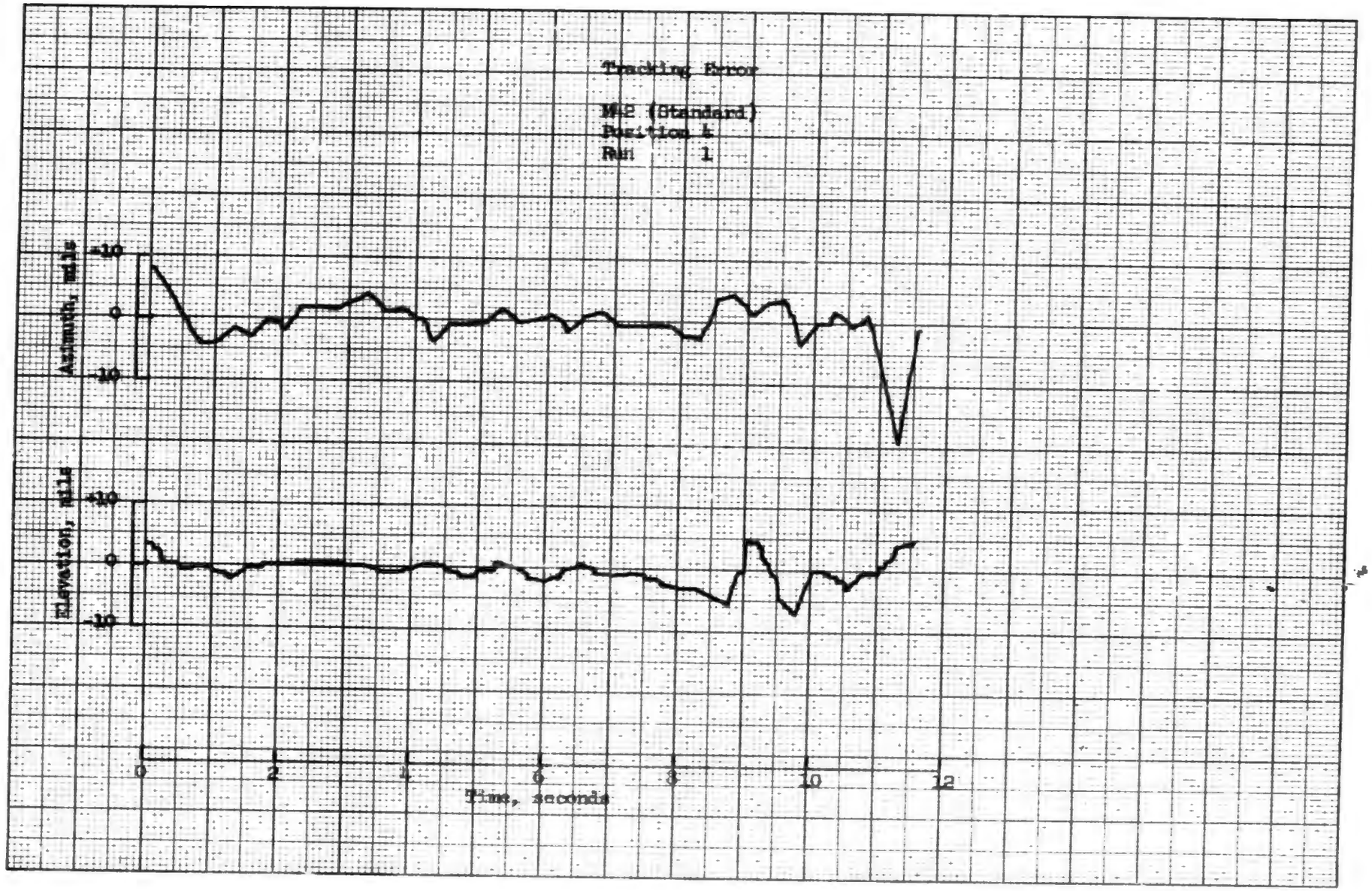

Tracking Error
Position 3
Run 1
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 40-I


Tracking Error
M-2 (Standard)
Position 4
Run 1
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

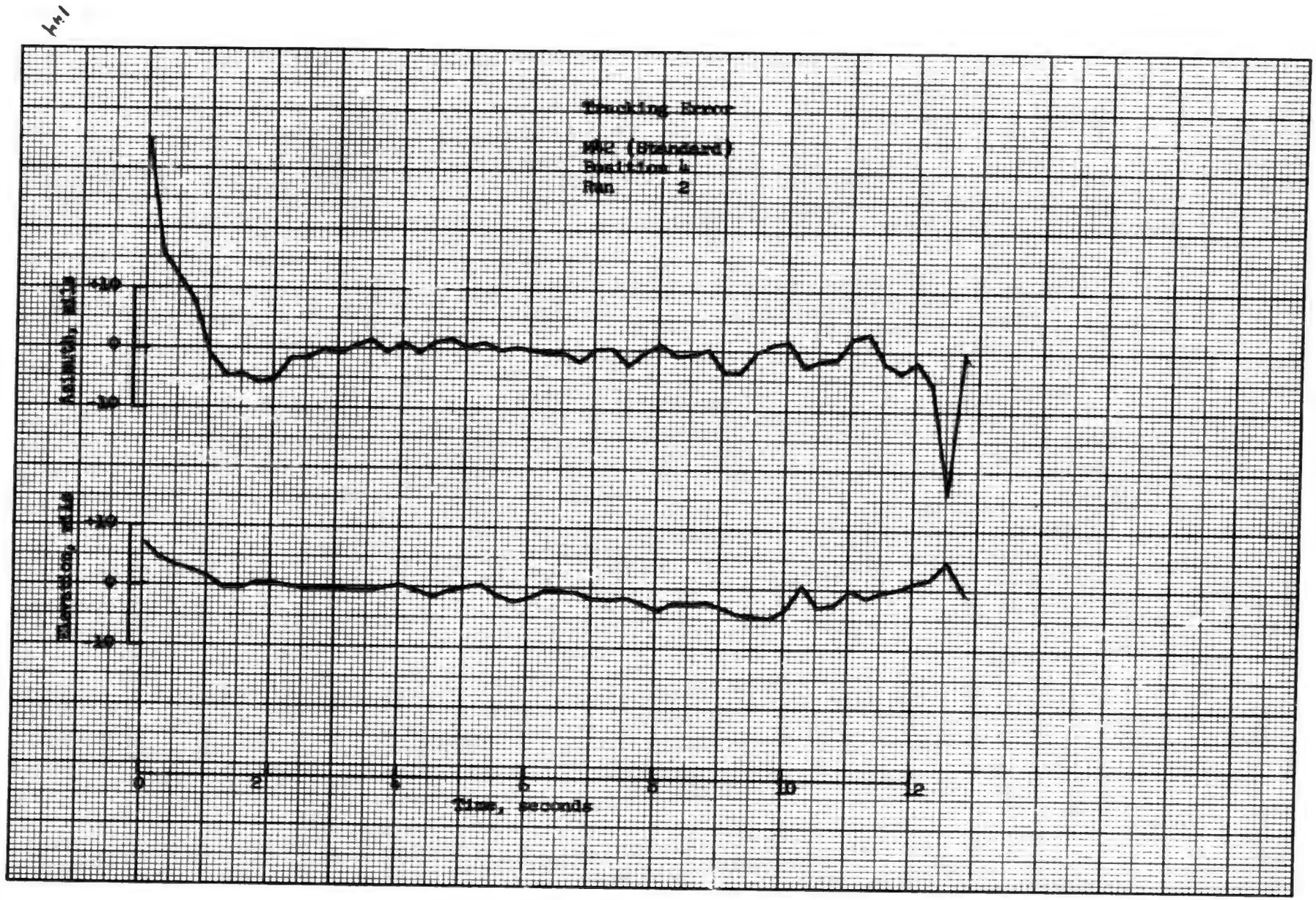

Tracking Error
MK2 (Standard)
Position 4
Run 2
Aileron, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure AC-I

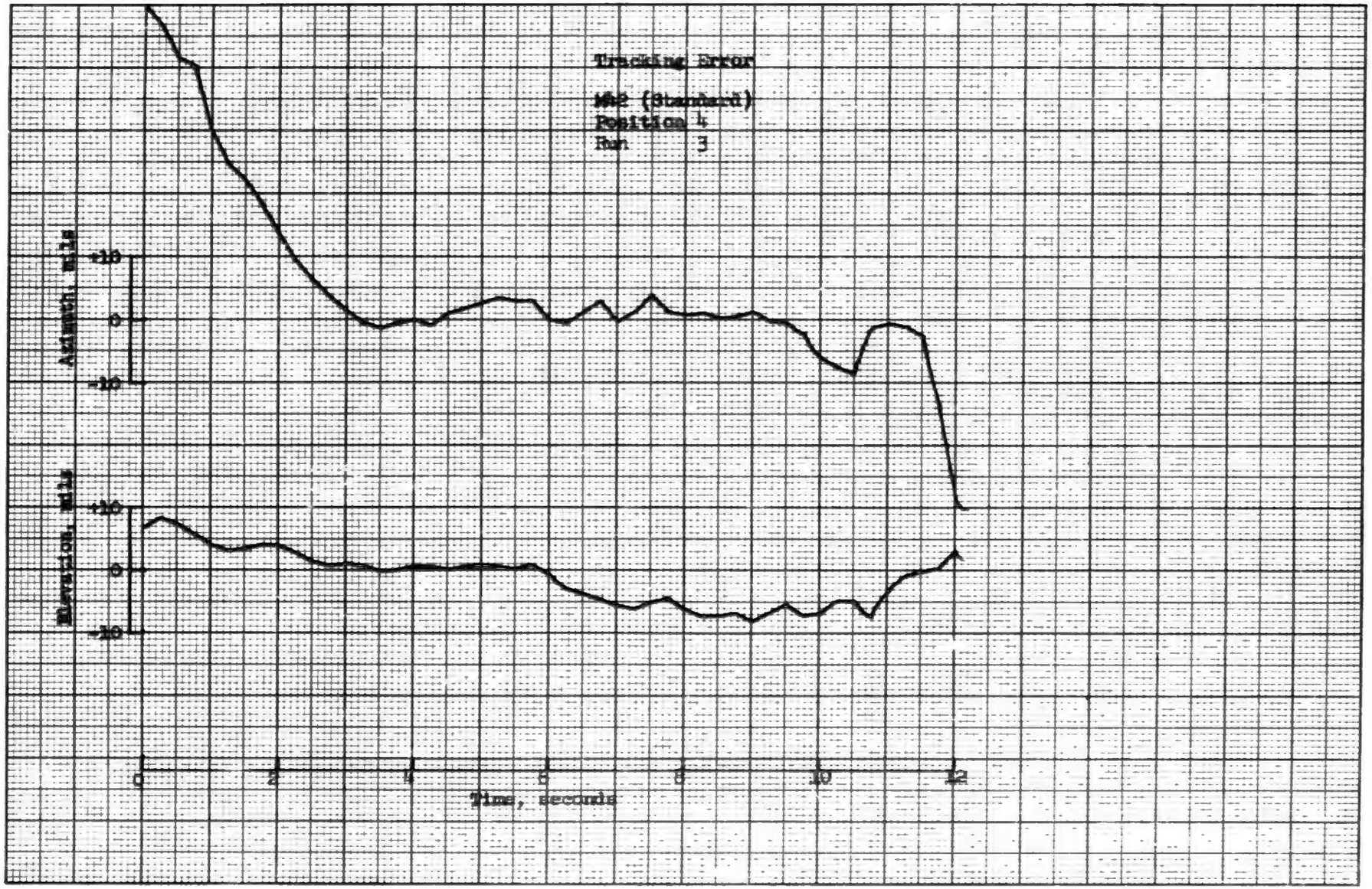

Tracking Error
M62 (Standard)
Position 4
Run 3
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 13-I

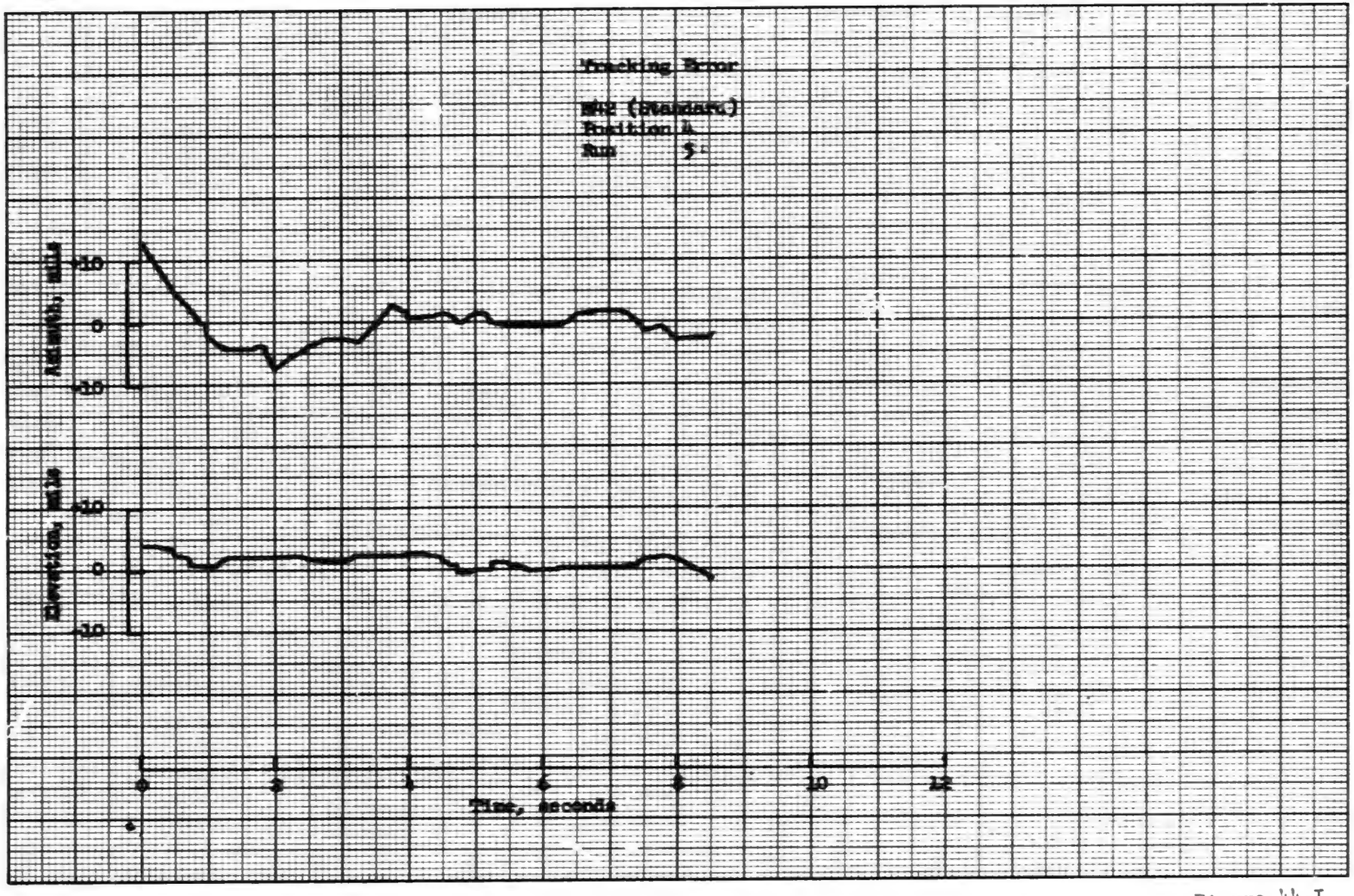
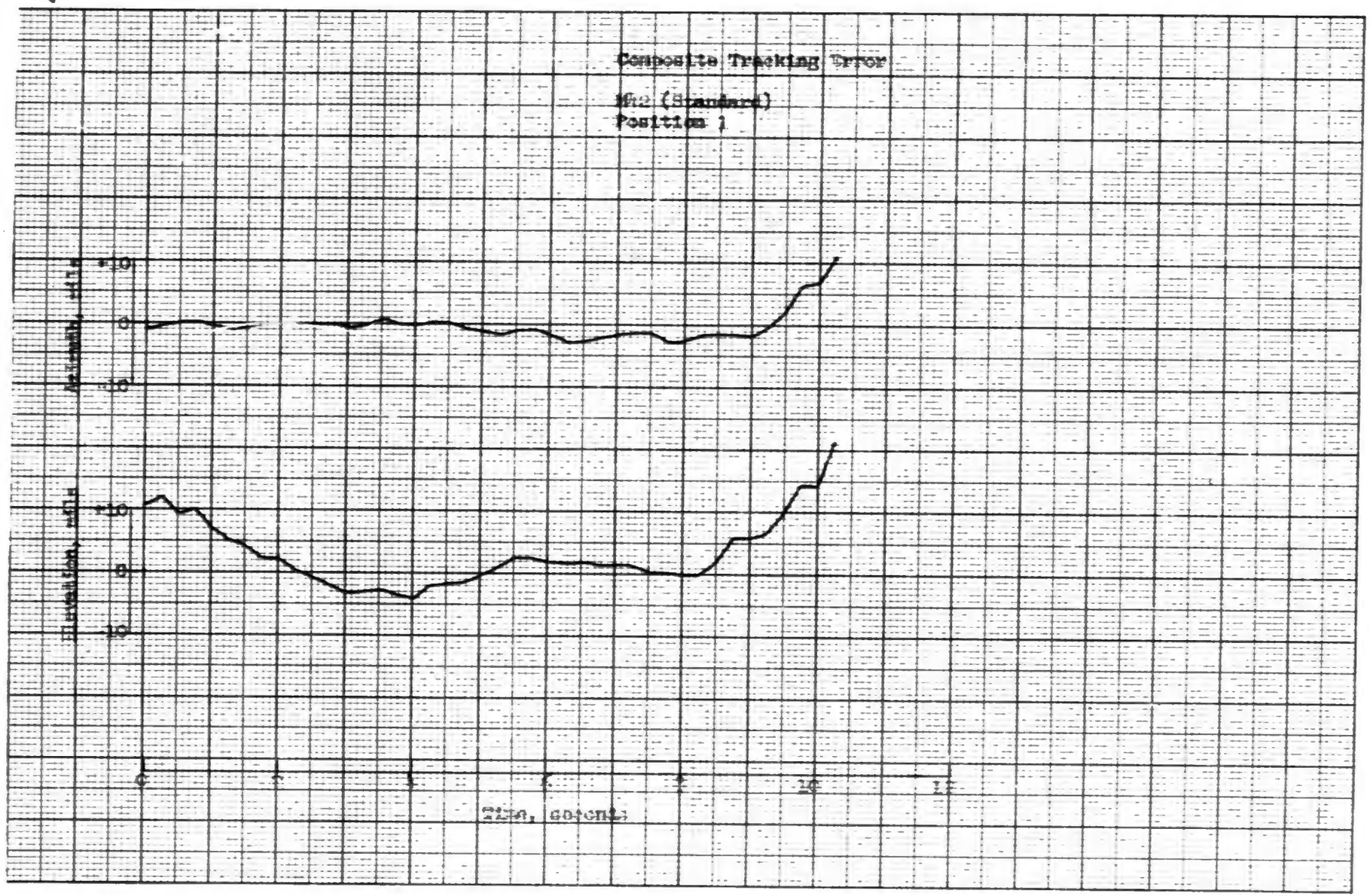

Tracking Error
MH2 (standard)
Position 4
Run 5
Azimuth, mils
10
0
-10
Elevation, mils
10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 44-I


Composite Tracking Error
Position 1
+10
0
-10
+10
0
-10
Time, seconds

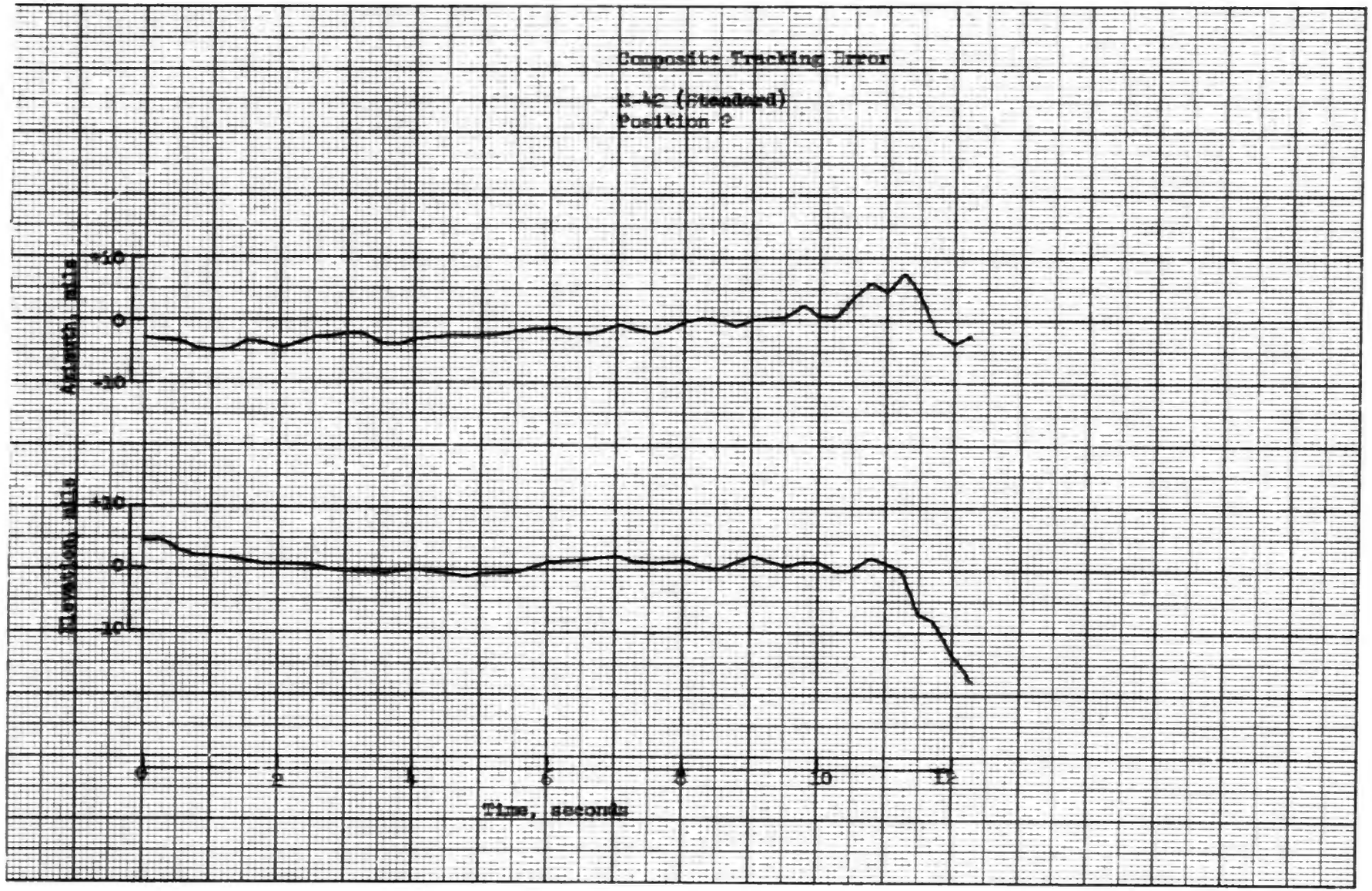
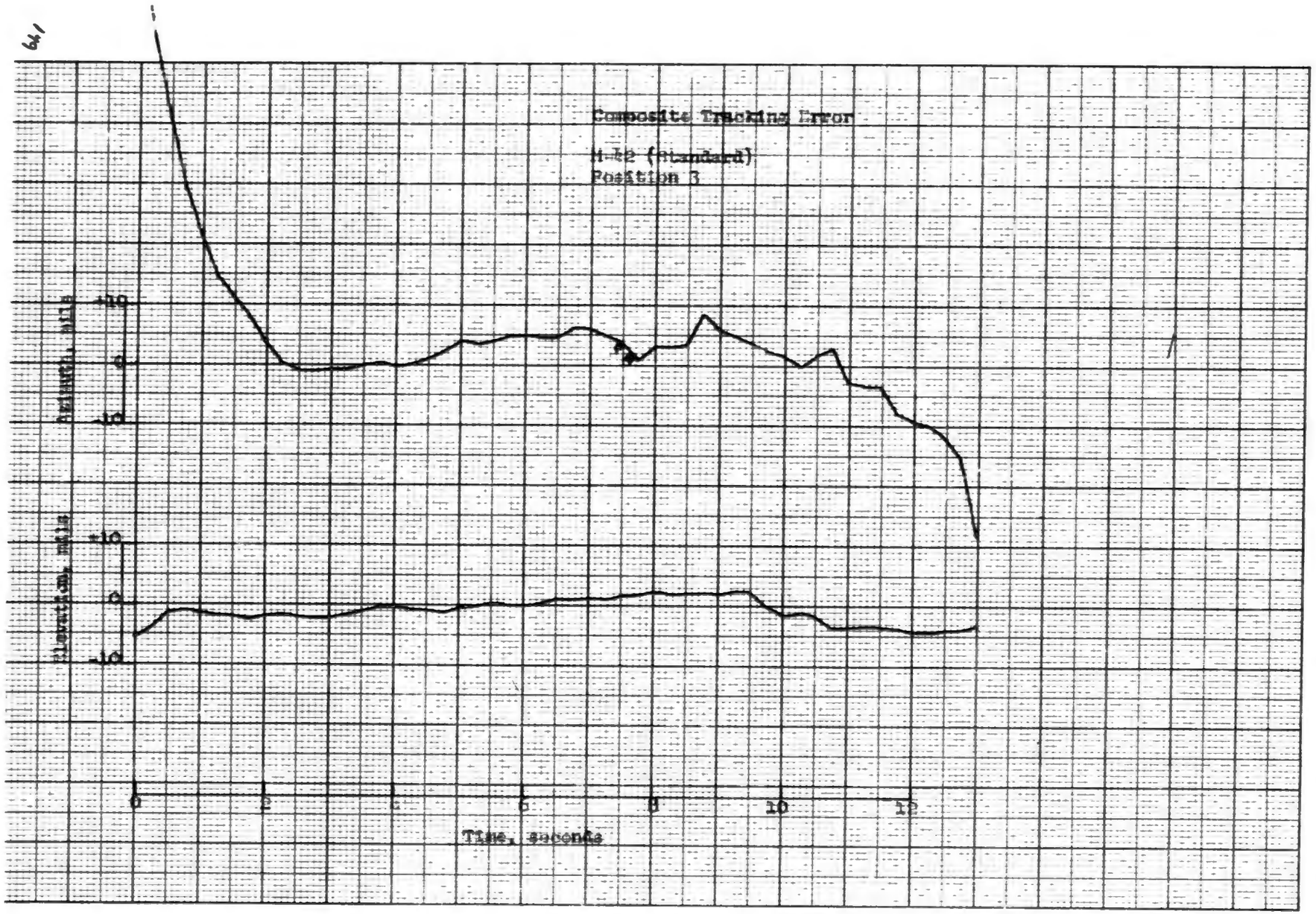

Composite Tracking Error
X-AC (Standard)
Position 2
+10
0
-10
Azimuth, mils
+10
0
-10
Elevation, mils
0
2
4
6
8
10
12
Time, seconds

Figure 46-I


Composite Tracking Error
H-42 (standard)
Position 3
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

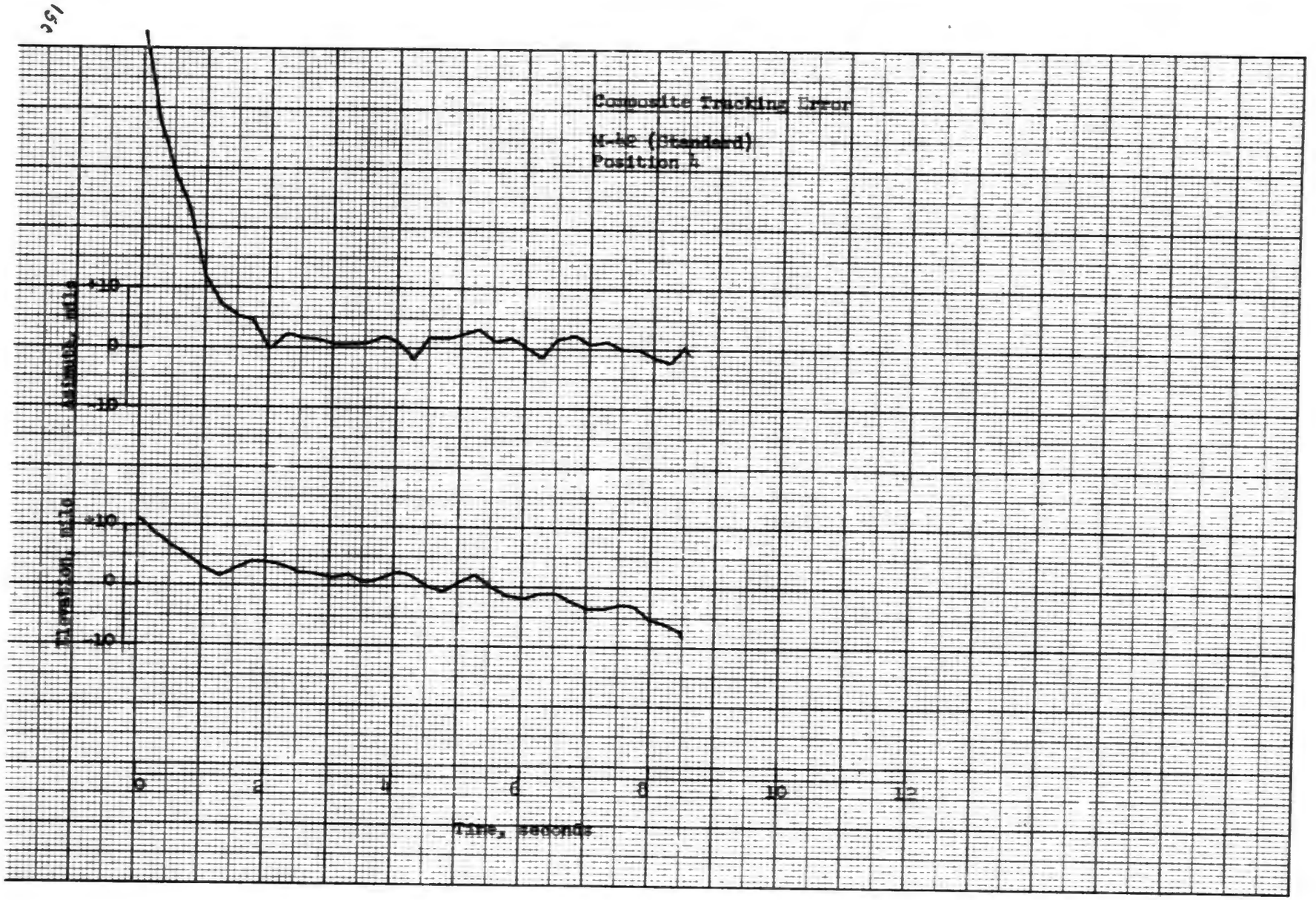
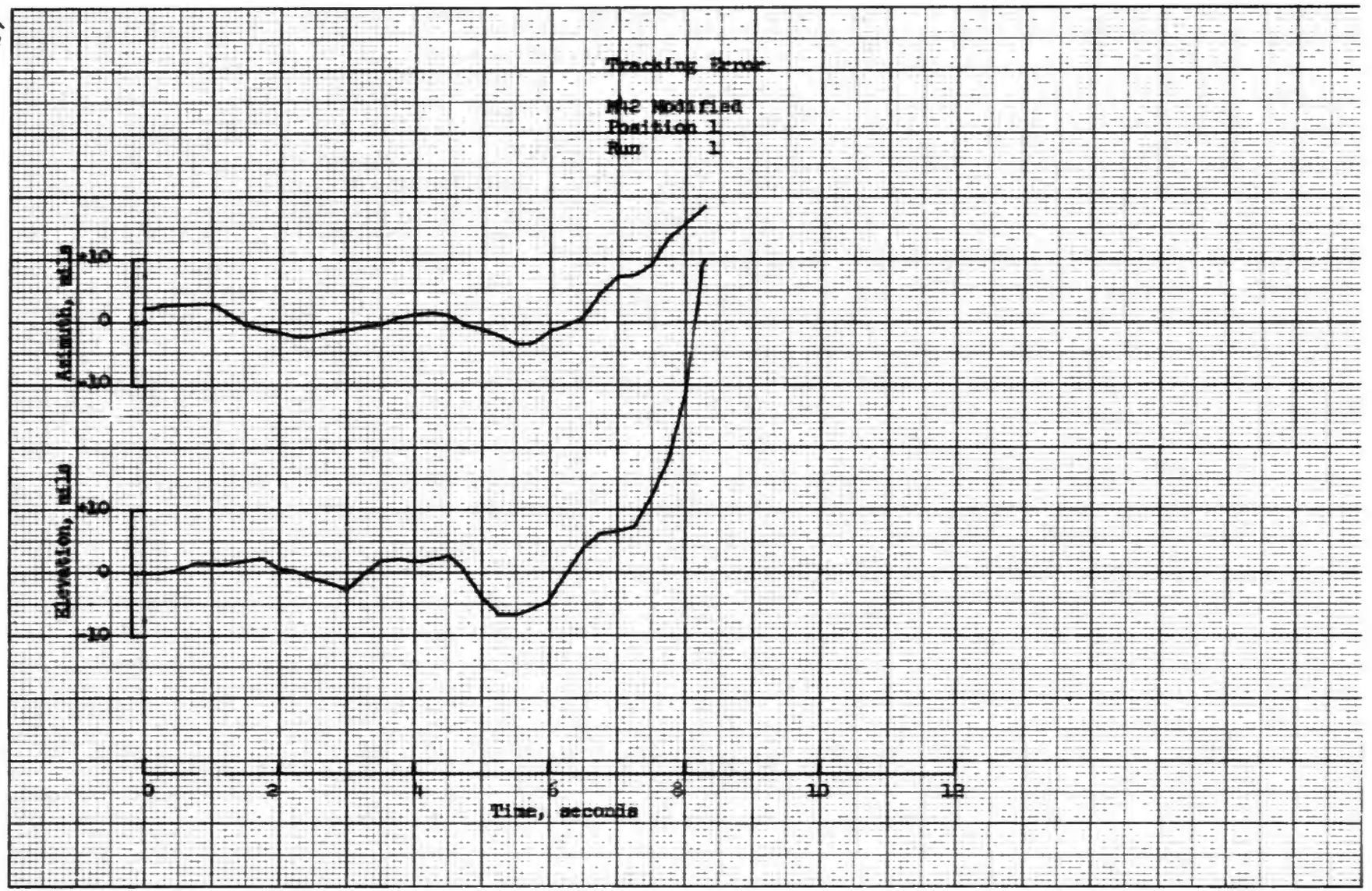
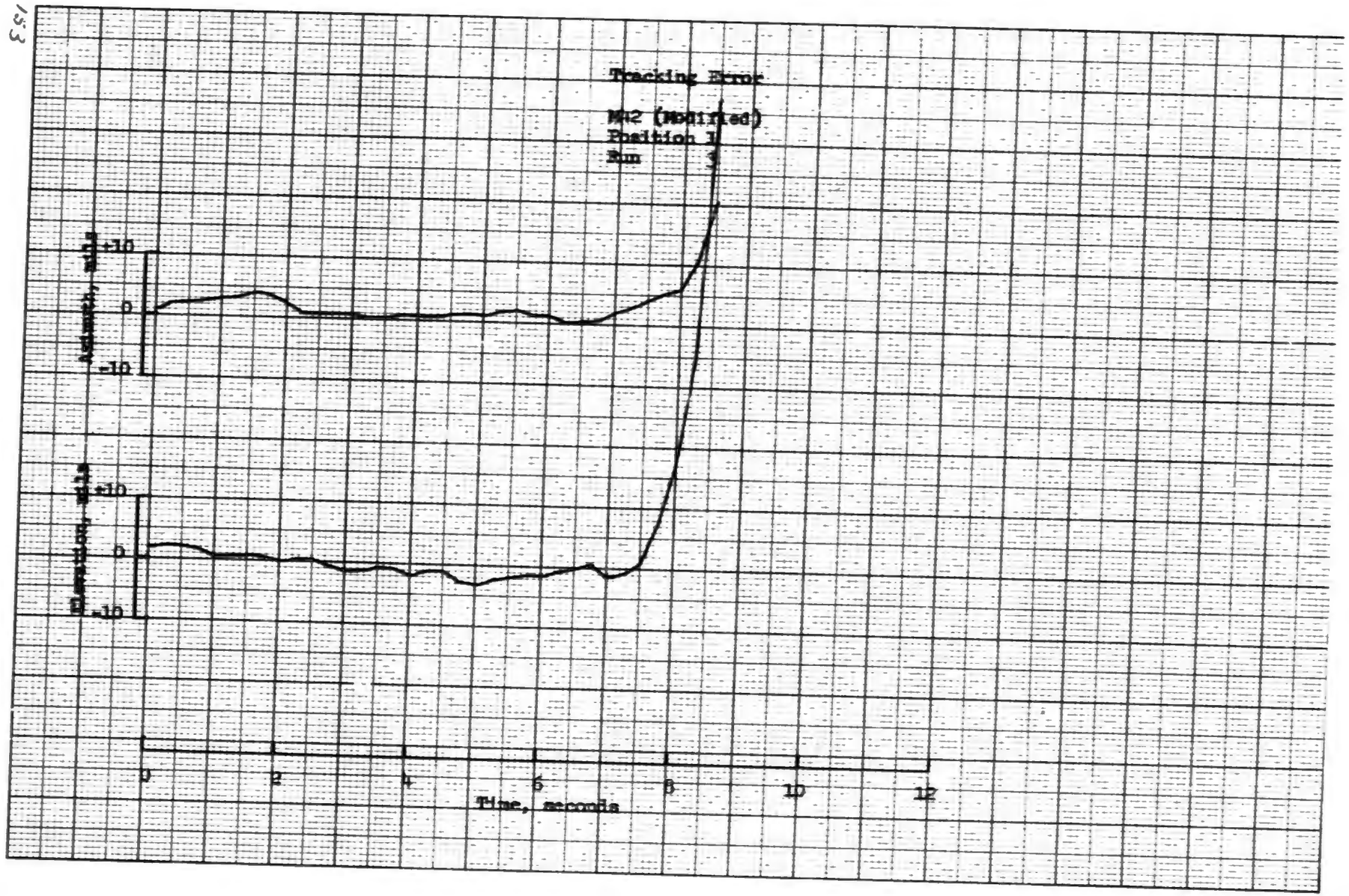

Composite Tracking Error
M-1C (Standard)
Position 4
+10
0
-10
Elevation, mils
+10
0
-10
Elevation, mils
0
2
4
6
8
10
12
Time, seconds

Figure 18-I


Tracking Error
M42 Modified
Position 1
Run 1
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Time, seconds
0
2
4
6
8
10
12
Elevation, meters
Azimuth, meters
Reading Error
Run 2

Figure C-1


Tracking Error
M42 (Modified)
Position 1
Run 3
+10
0
-10
Azimuth, mils
+10
0
-10
Elevation, mils
0
2
4
6
8
10
12
Time, seconds

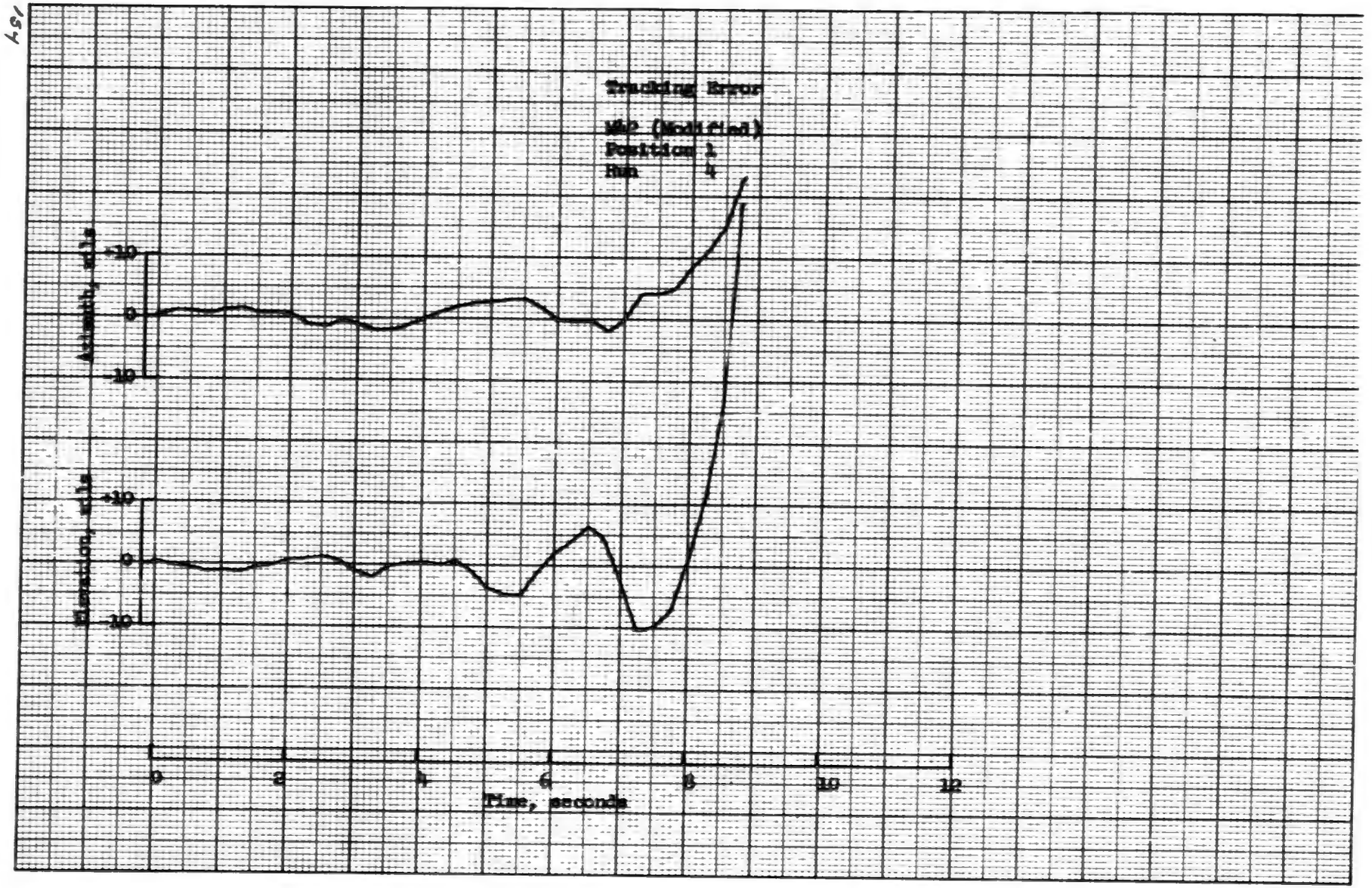
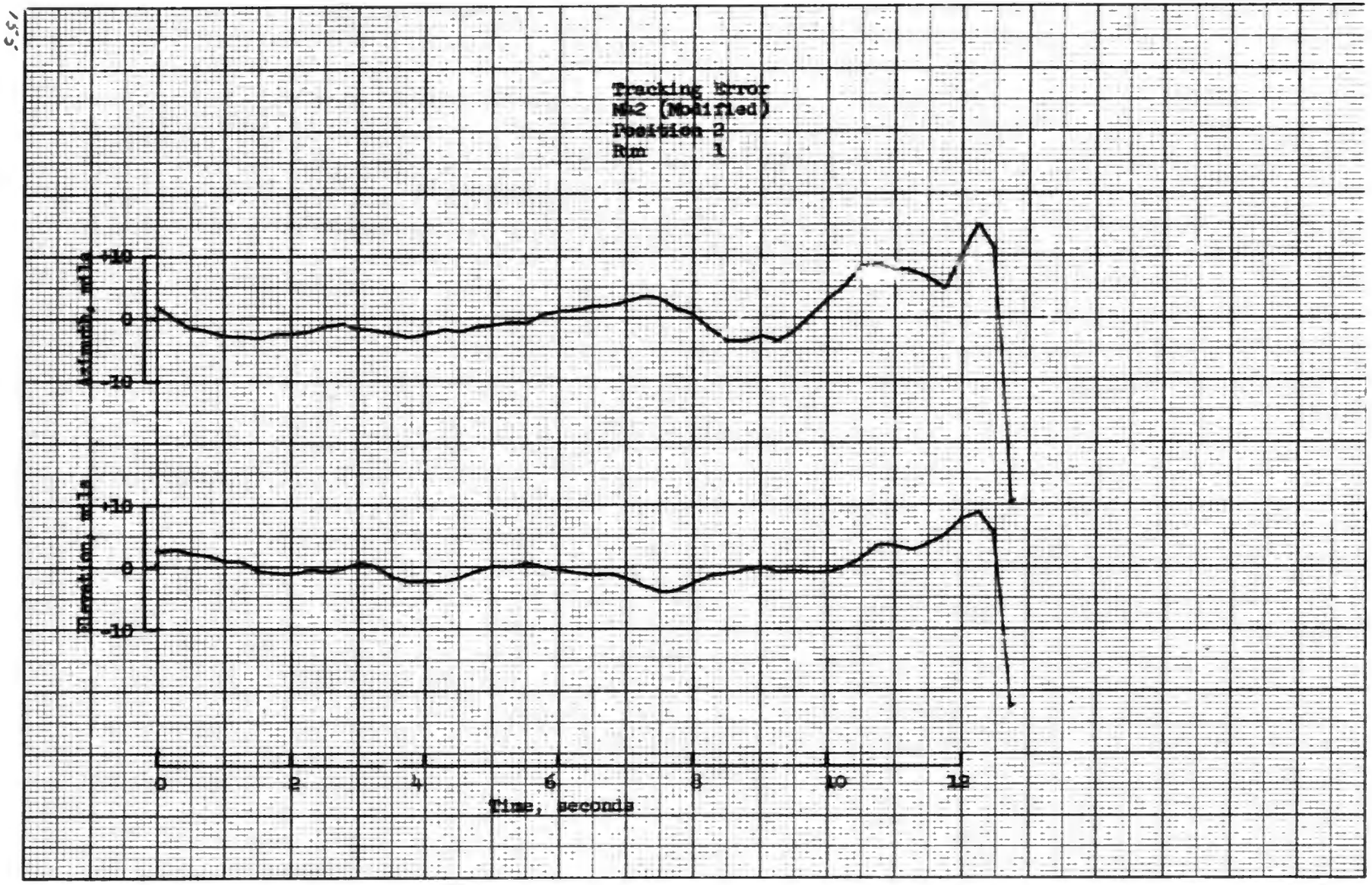

Tracking Error
MK2 (Modified)
Position 1,
Run 4
Elevation, mils
+10
0
-10
Azimuth, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 58-I


Tracking Error
M-2 (Modified)
Position 2
Run 1
Elevation, mils
+10
0
-10
Deflection, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

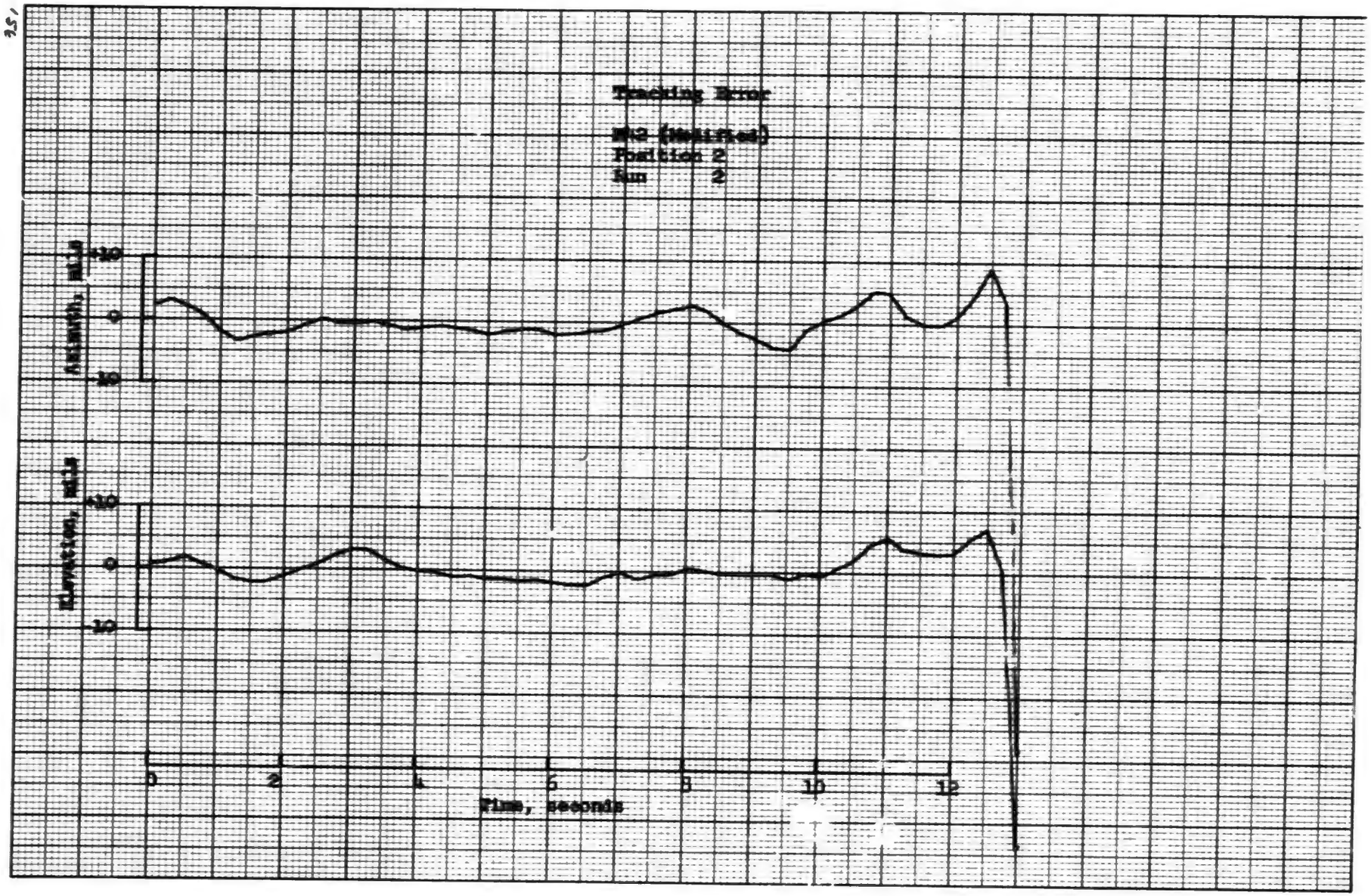
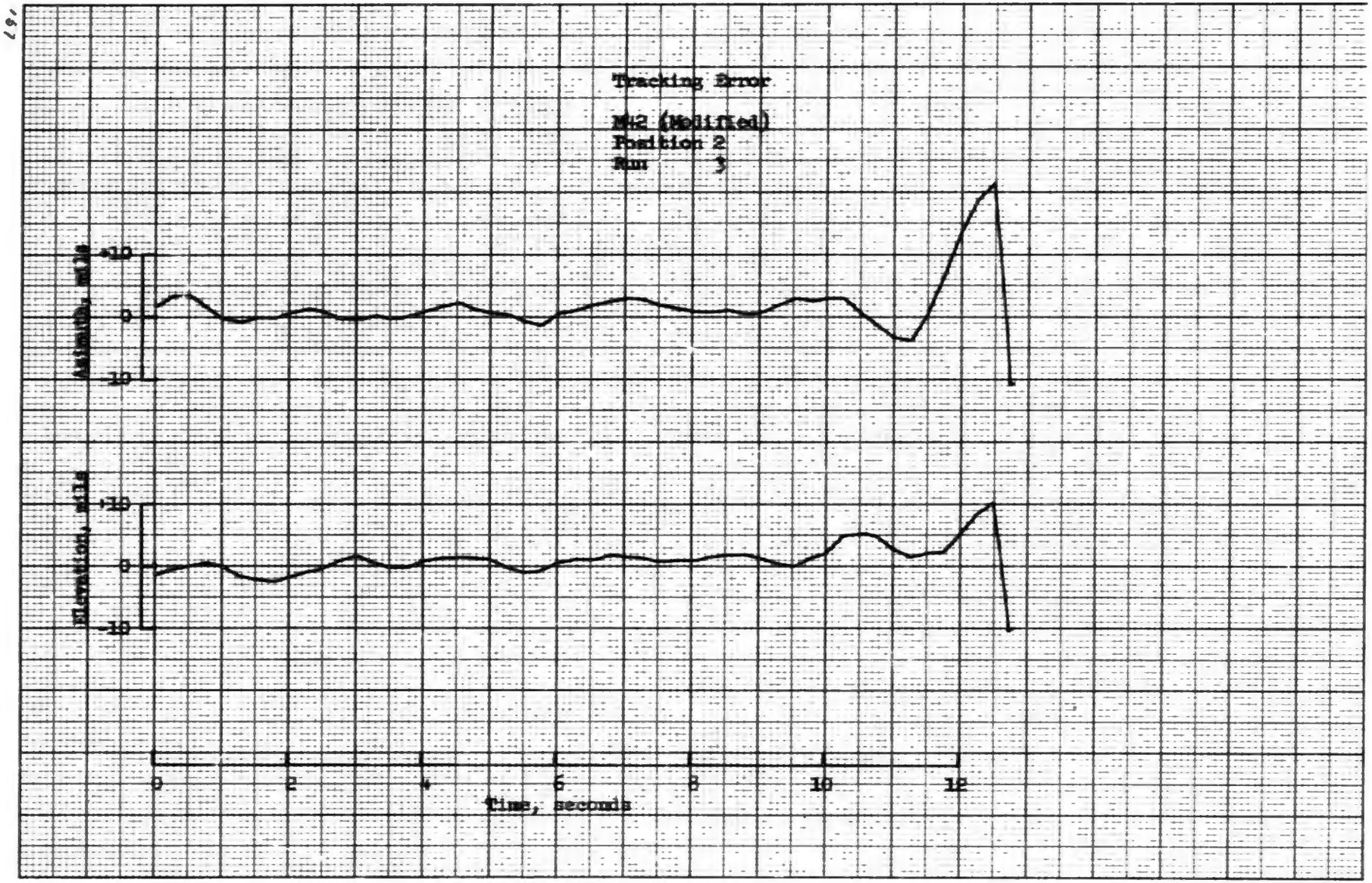

Tracking Error
Position 2
Run 2
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 54-I


Tracking Error
M42 (Modified)
Position 2
Run 3
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

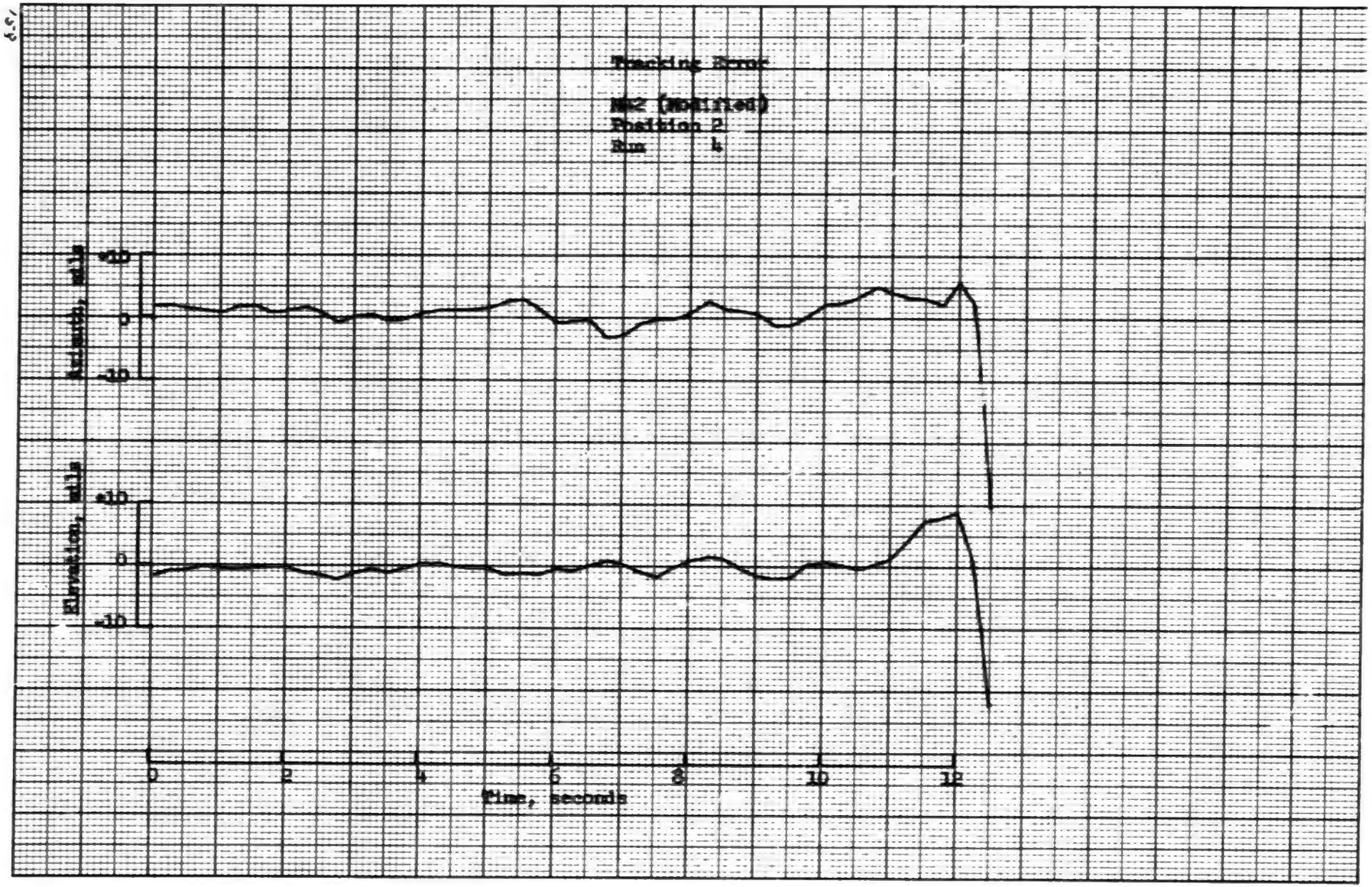
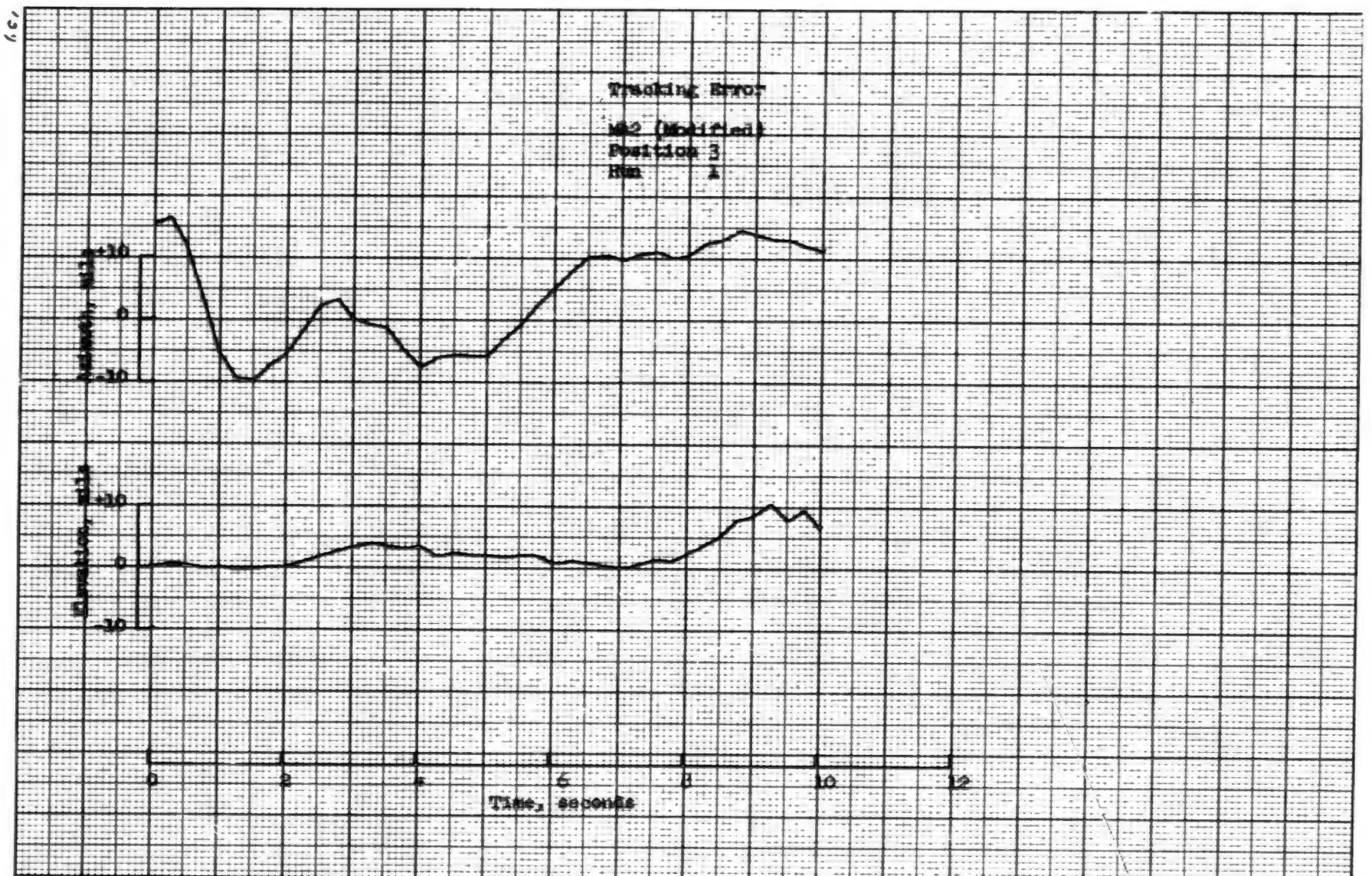
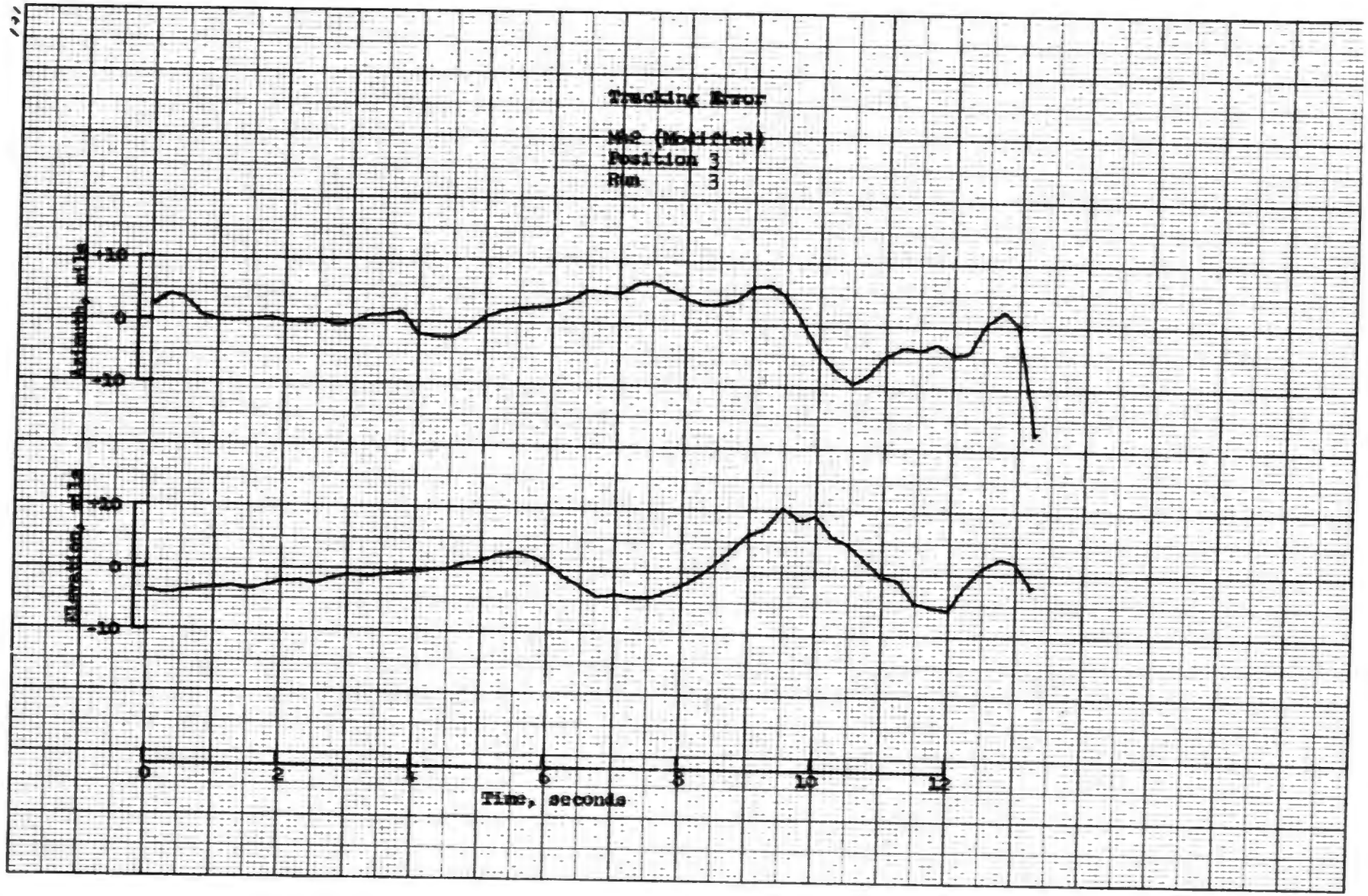

Tracking Error
M=2 (Modified)
Position 2
Run 4
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 56.3


Tracking Error
M2 (Modified)
Position 3
Run A
Elevation, mils
+30
0
-30
Elevation, mils
+30
0
-30
0
2
4
6
8
10
12
Time, seconds

Tracking Error
M=2 (Required)
Position 3
Run 2
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 5-I


Tracking Error
Mk2 (Modified)
Position 3
Run 3
Elevation, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

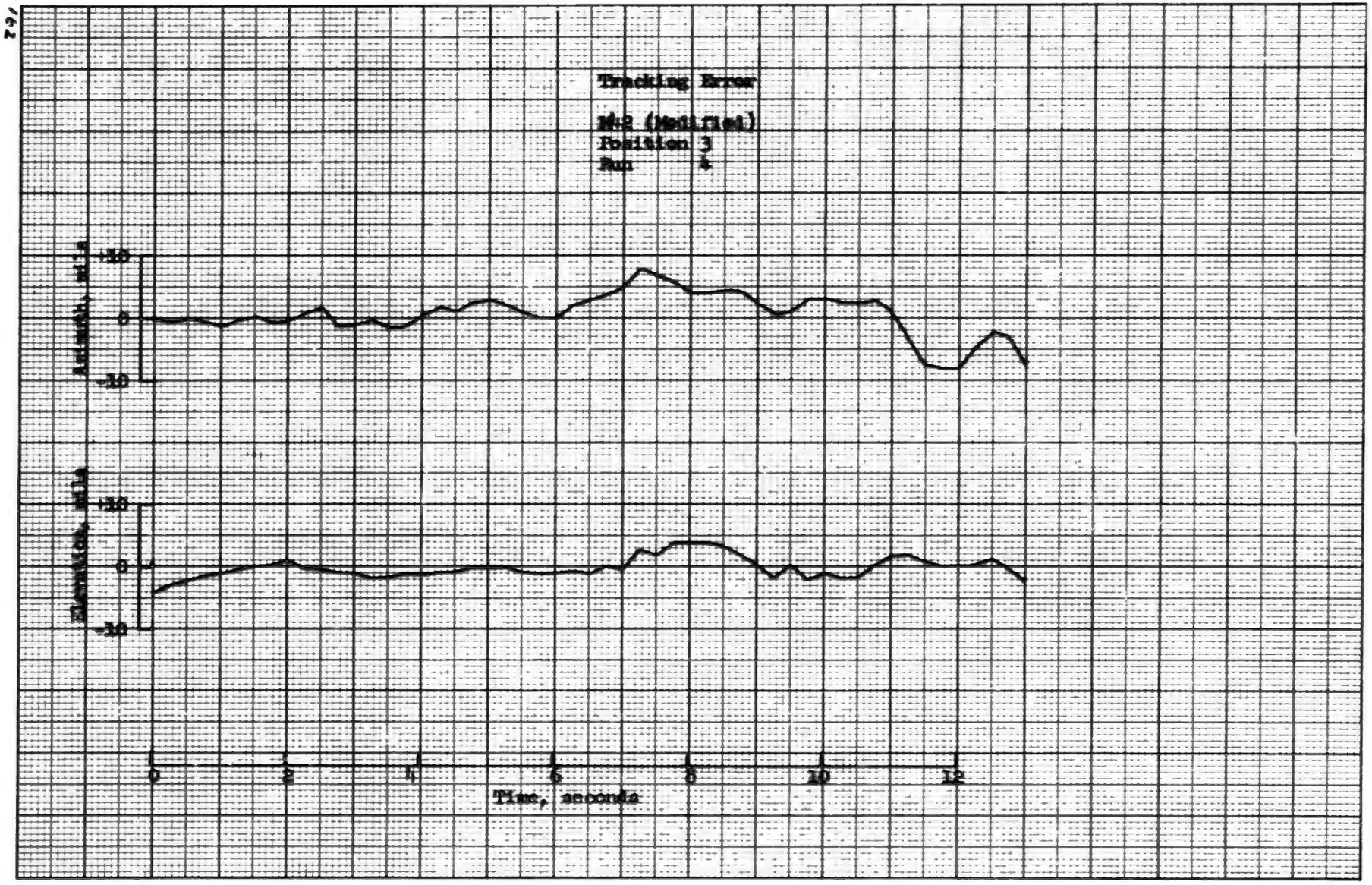
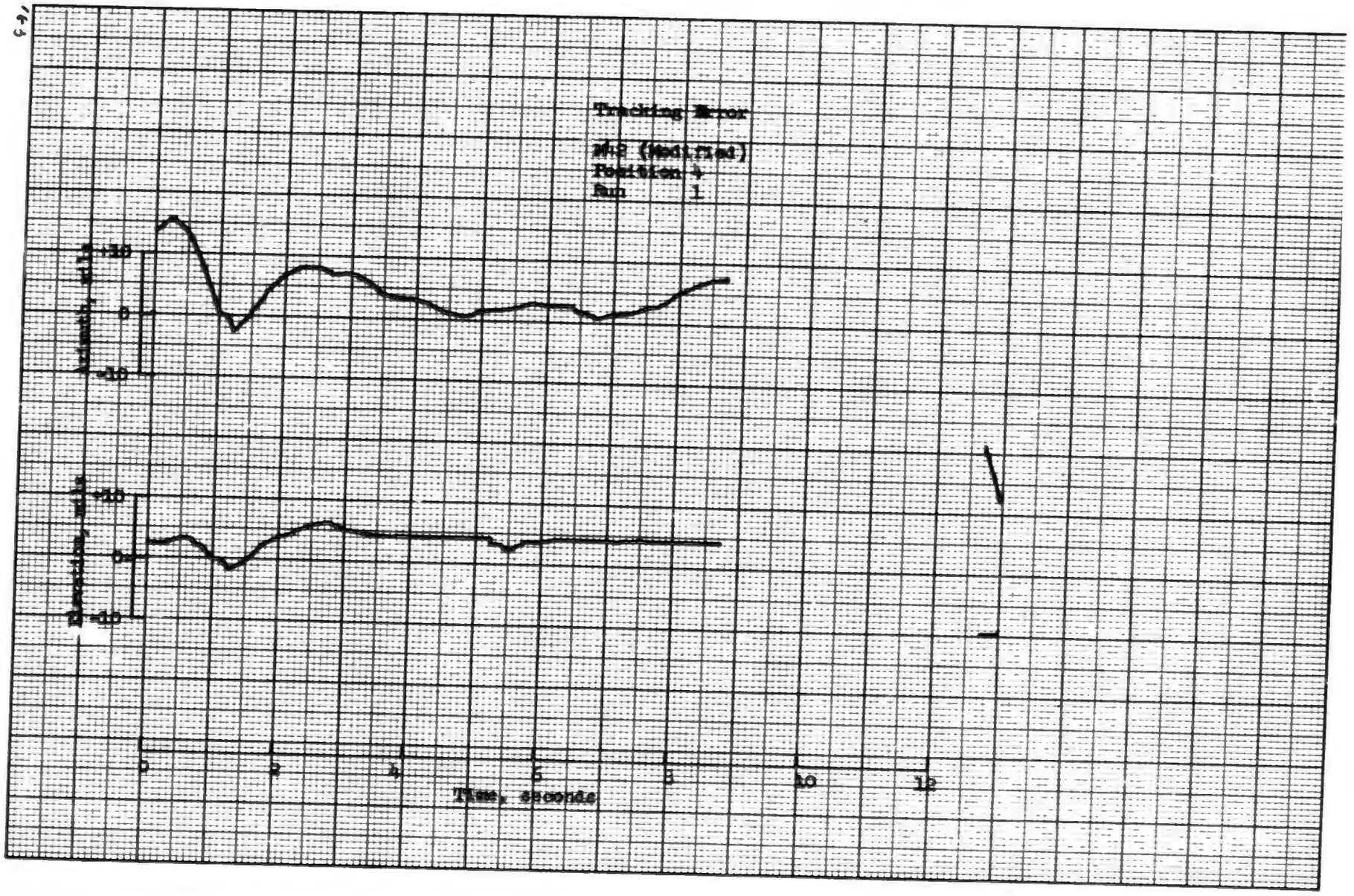

Tracking Error
M:2 (Modified)
Position 3
Run 4
Elevation, mils
+20
0
-20
Elevation, mils
+20
0
-20
0
2
4
6
8
10
12
Time, seconds

Figure 60 I


Tracking Error
Run 1
+10
0
-10
+10
0
-10
5
2
4
6
8
10
12
Time, seconds

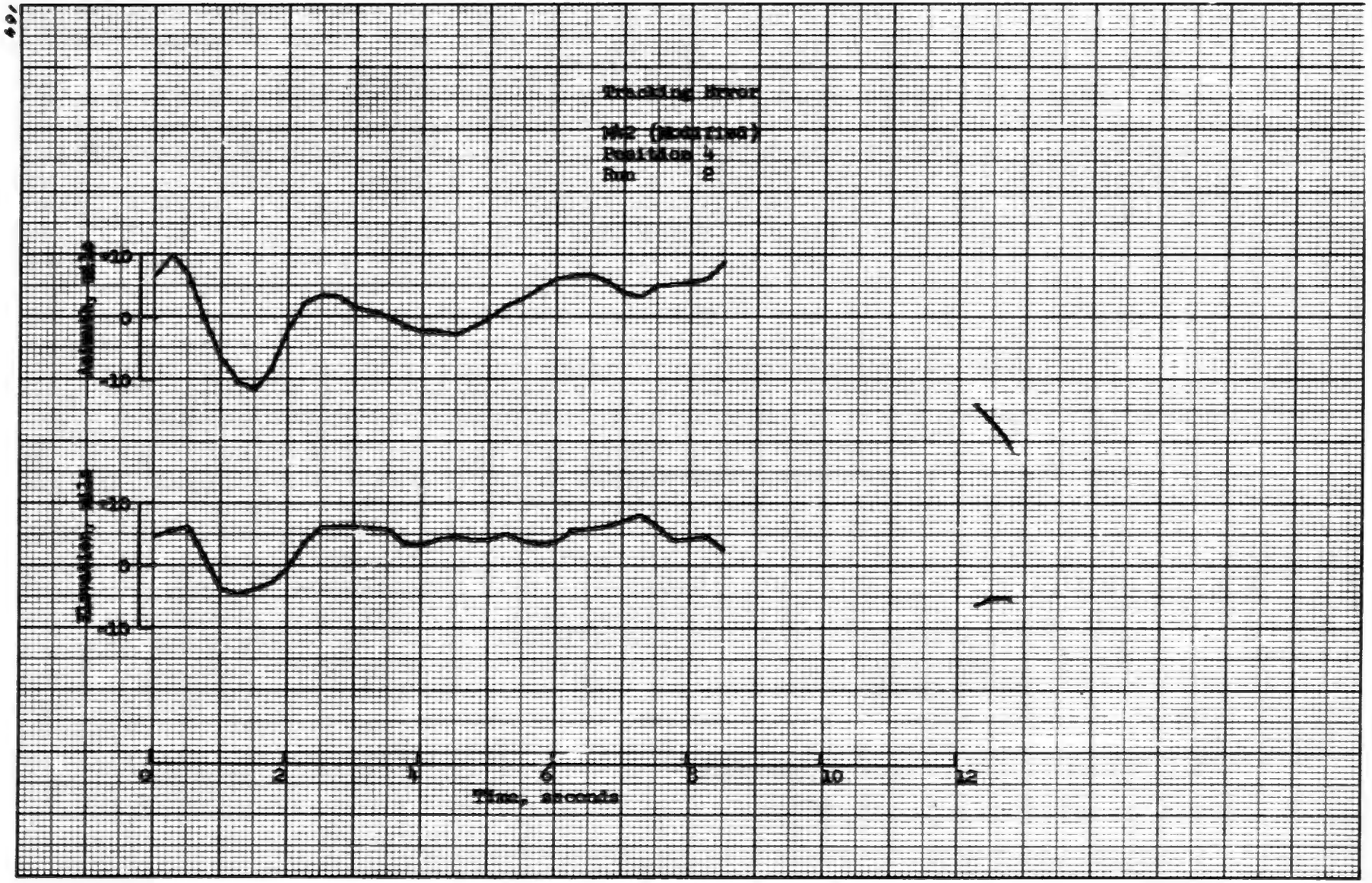

Tracking Error
Position 4
Run 2
+20
0
-10
+20
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 62-I

Recording Error
MSC (Recalibrated)
Position 4
Run 3
+40
0
-40
Time, seconds
0
5
10
15
20

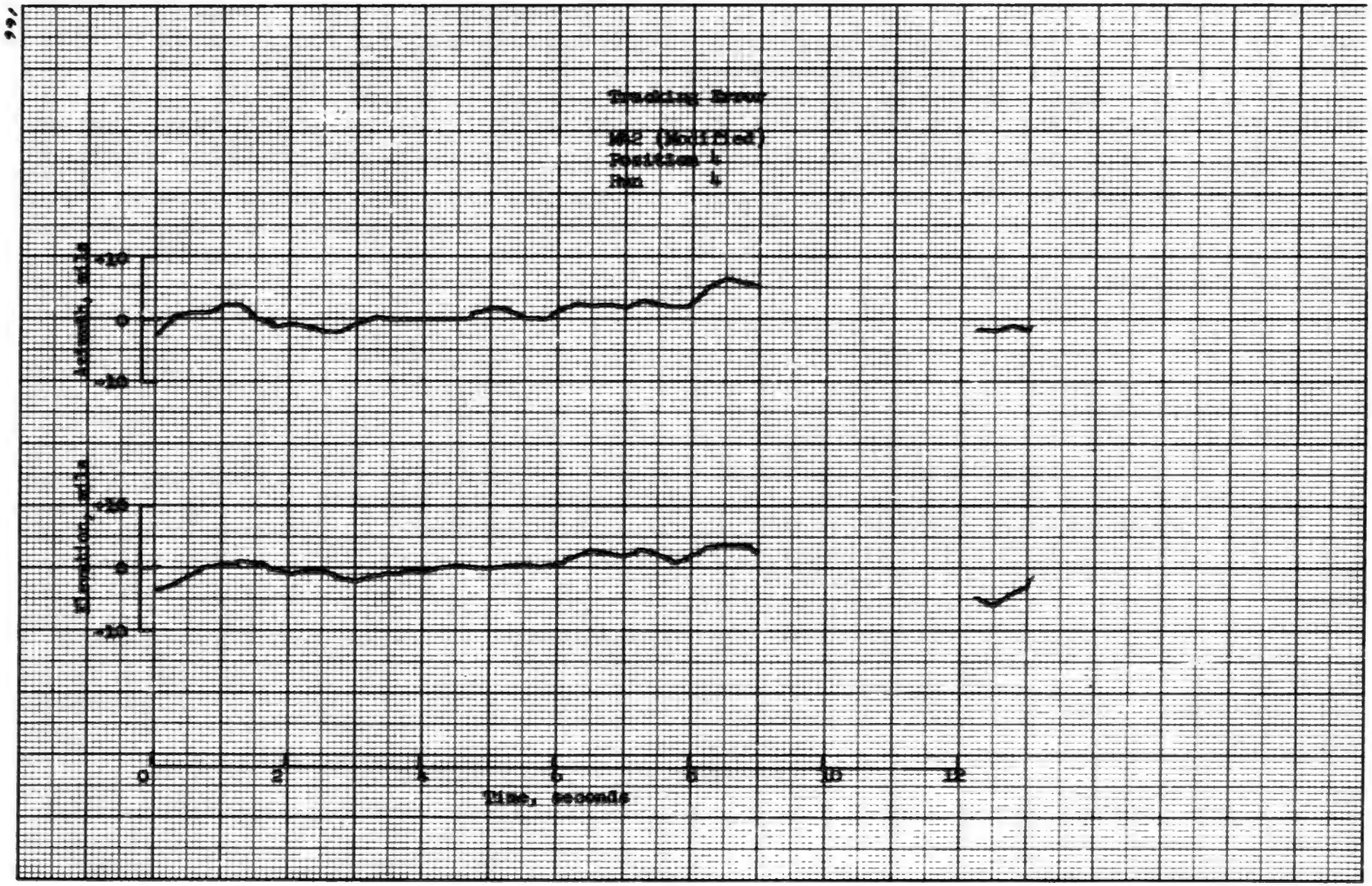
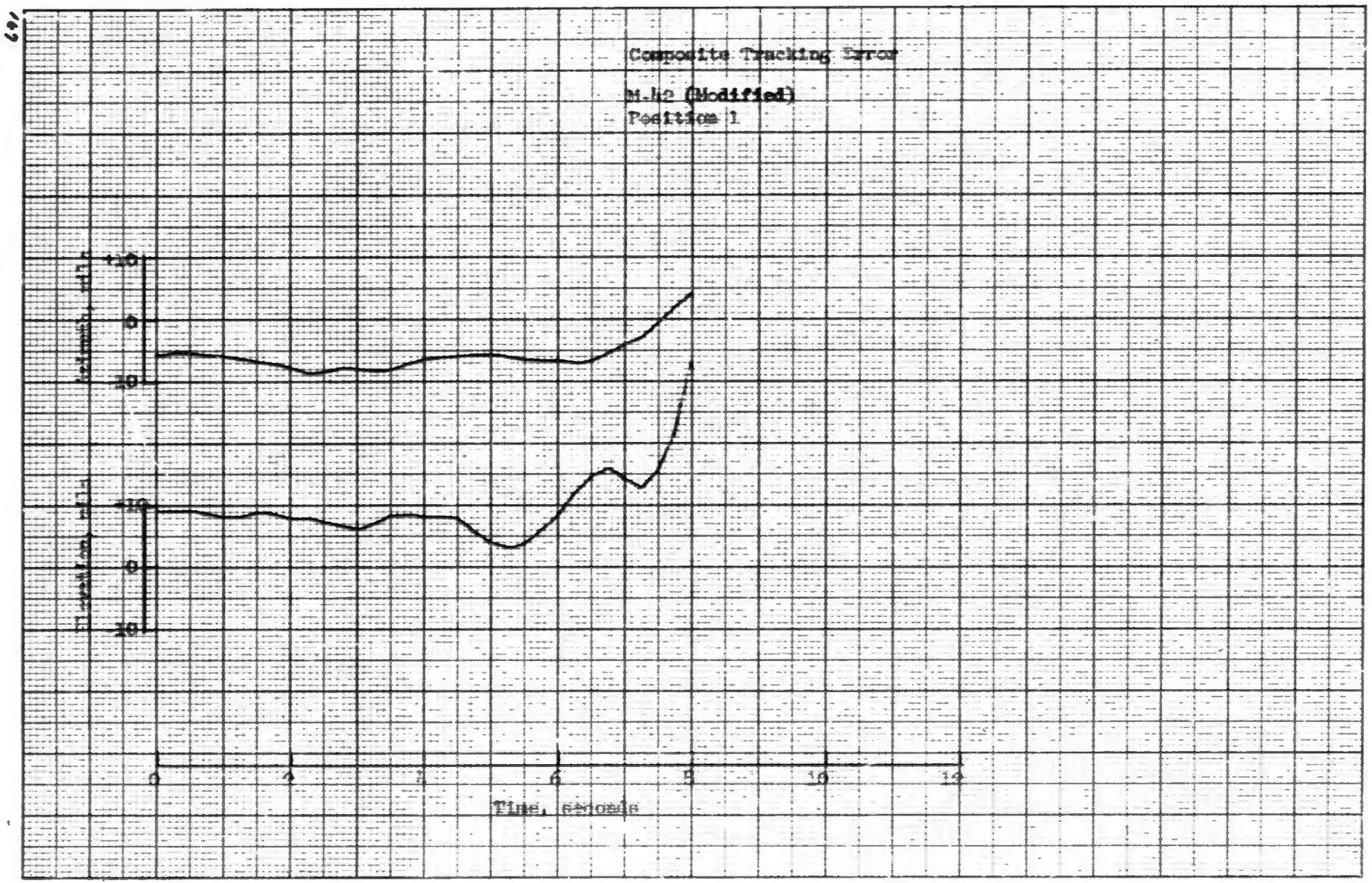


Figure 54-I


Composite Tracking Error
M.42 (Modified)
Position 1
+10
0
-10
+10
0
-10
0
4
8
6
12
14
Time, seconds

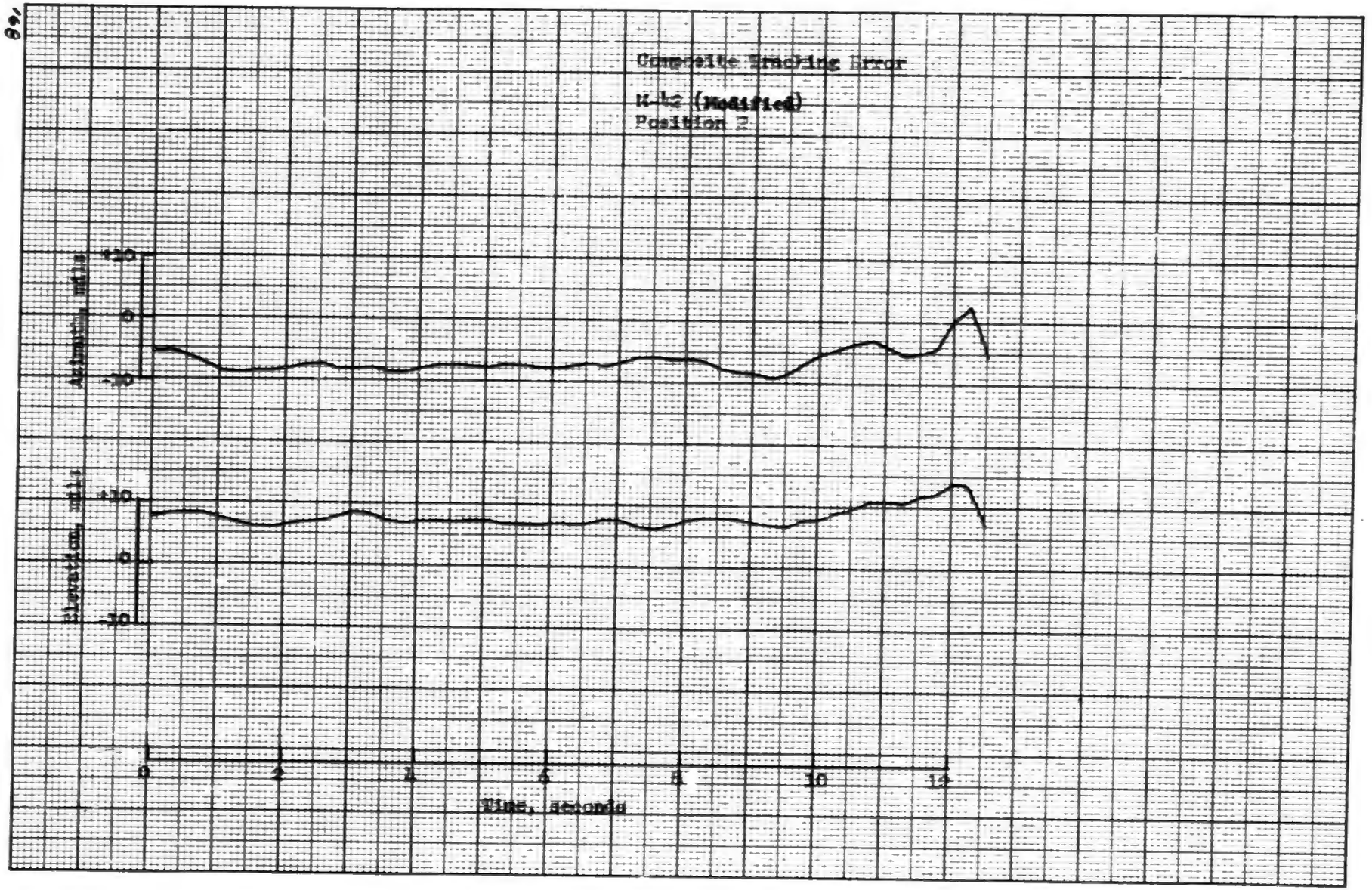

Composite Tracking Error
K-12 (Modified)
Position 2
Elevation, Mils
+20
0
-20
Azimuth, Mils
+20
0
-20
0
2
4
6
8
10
12
Time, Seconds

Figure 16-I

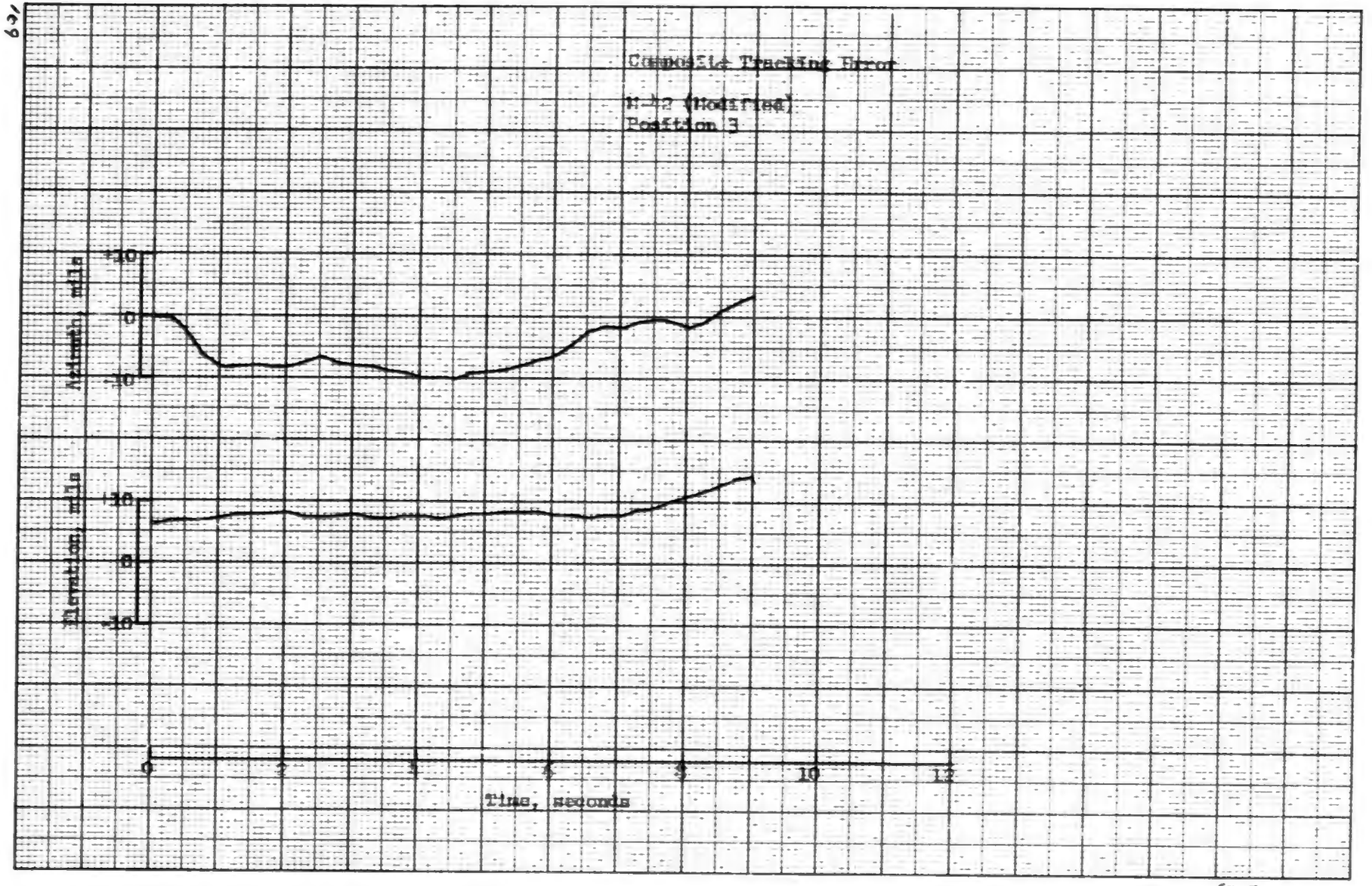
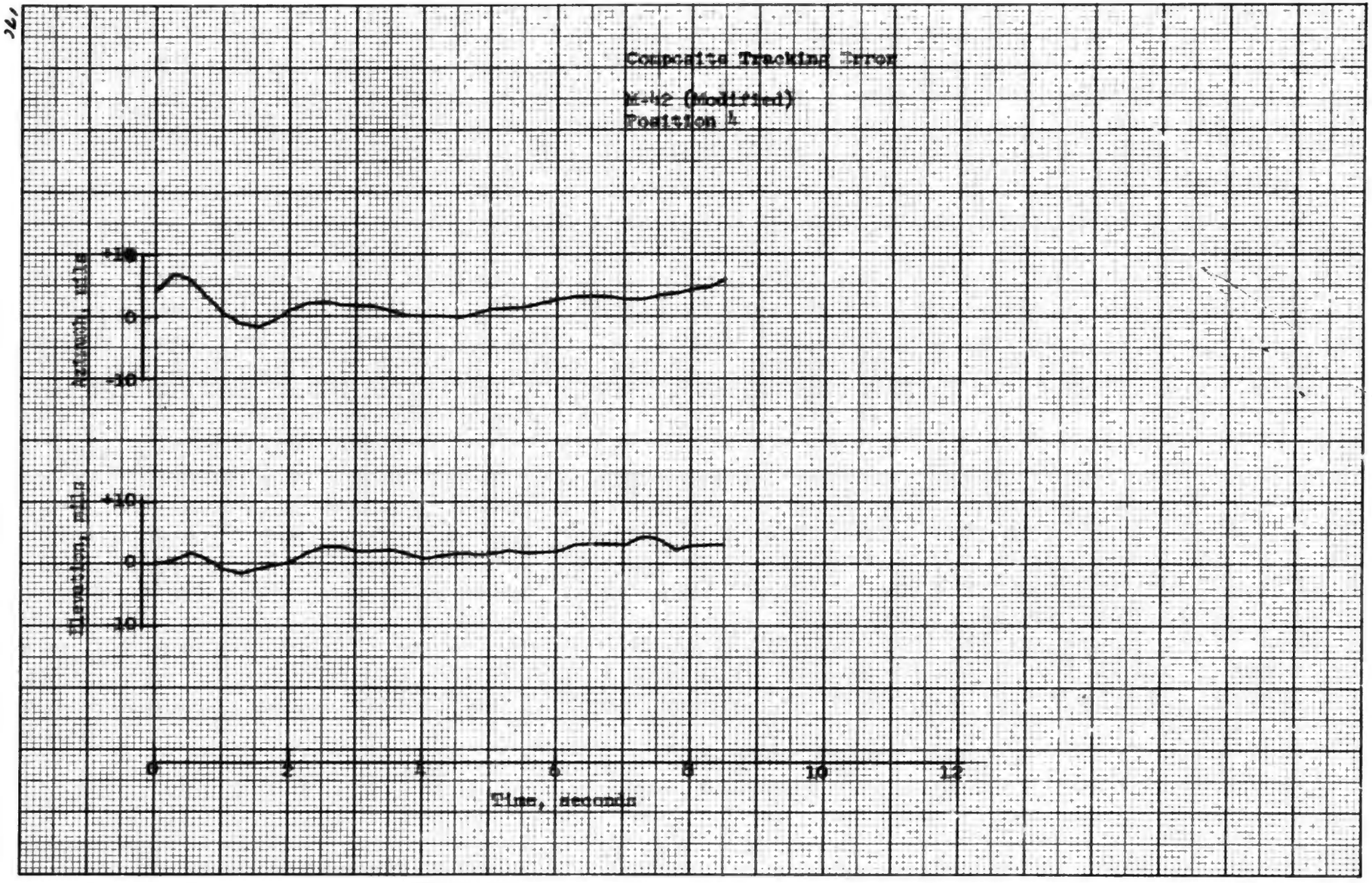

Composite Tracking Error
M-h2 (Modified)
Position 3
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure C-1


Composite Tracking Error
K-42 (Modified)
Position 4
Azimuth, mils
+20
0
-20
Elevation, mils
+20
0
-20
0
2
4
6
8
10
12
Time, seconds

Time 69 I

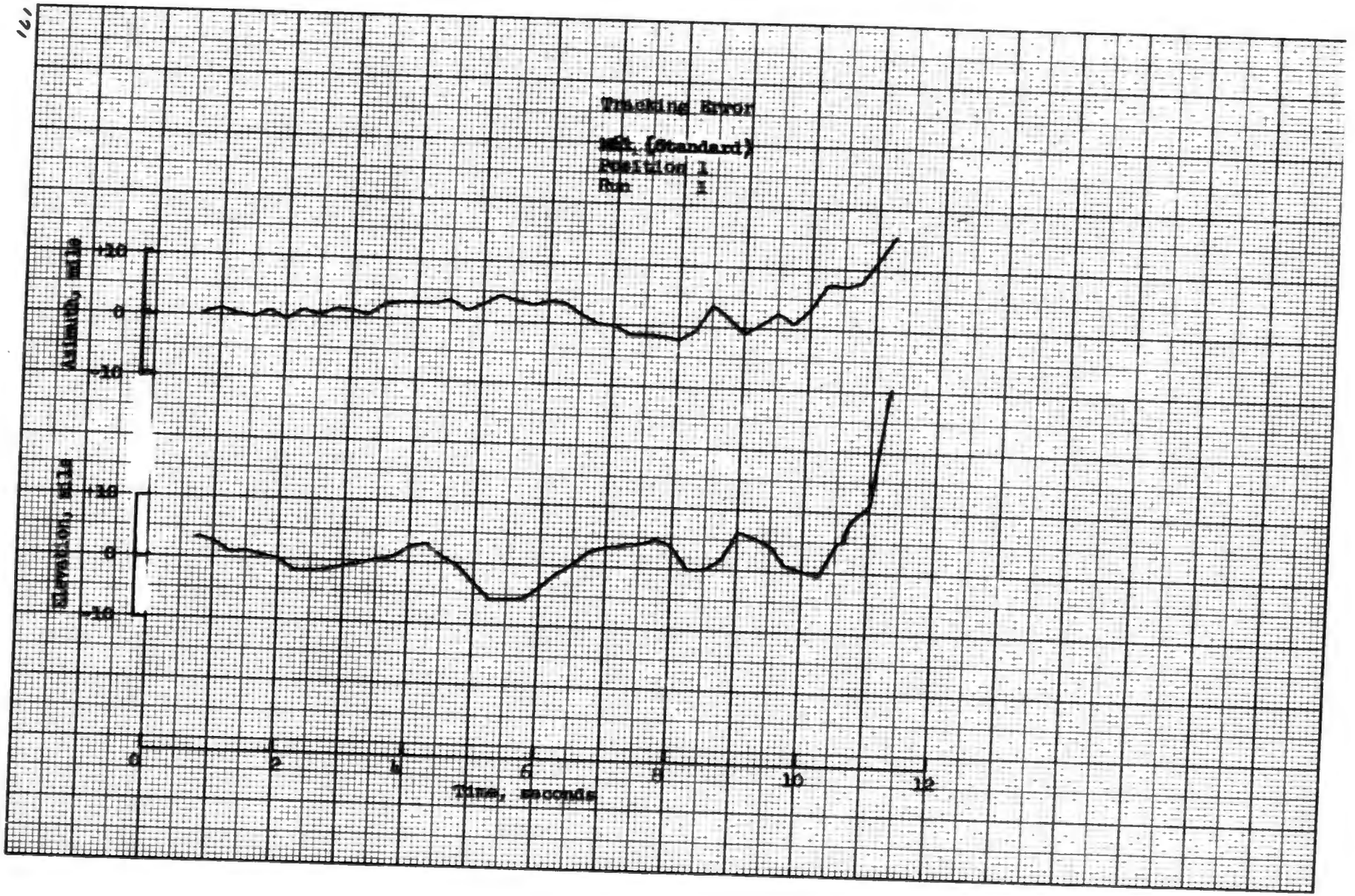

Tracking Error
Left (Standard)
Position 1
Run 1
Elevation, mils
+10
0
-10
Azimuth, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 69.1

Tracking Error
Roll (Stabilized)
Position
Run 2
+10
0
-10
Roll, degrees
+10
0
-10
Pitch, degrees
0
2
4
6
8
10
12
Time, seconds

Figure 70-I

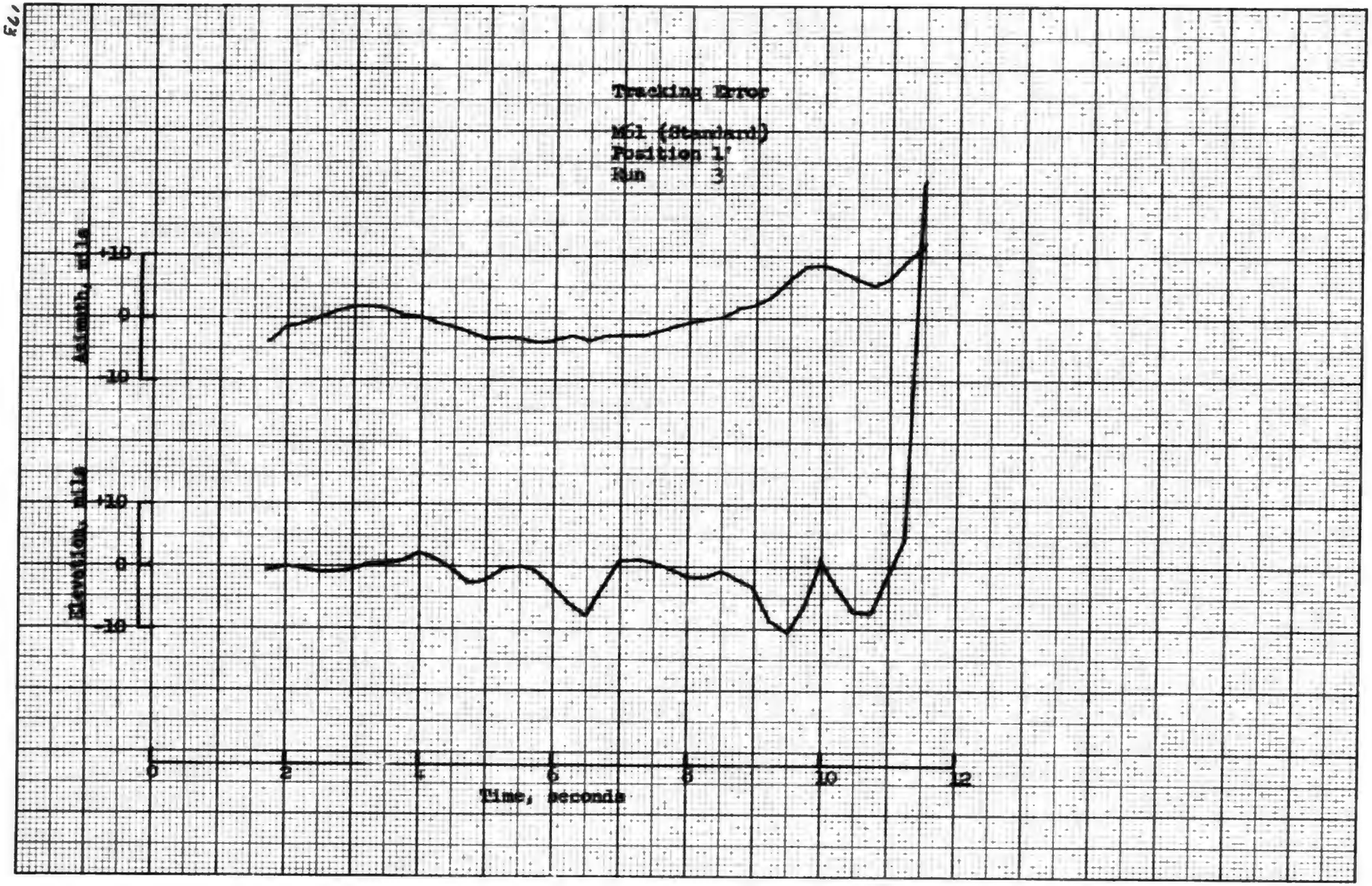

Tracking Error
M61 (Stemland)
Position 1'
Run 3
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 71-I

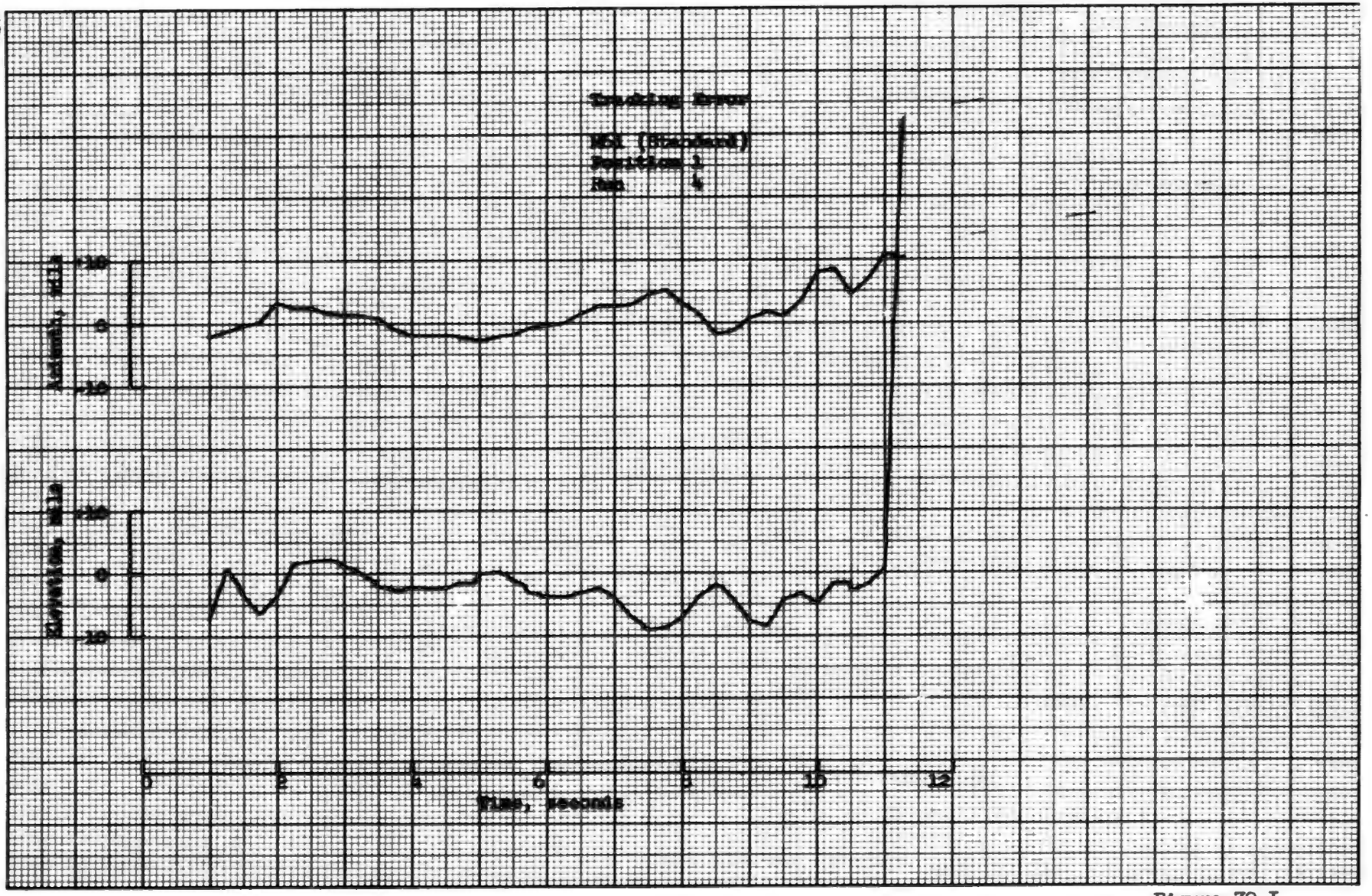

Tracking Error
MSL (Standard)
Position 1
Run 4
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 72-I

Time, seconds
0
4
8
12
16
Flywheel, mils
-40
0
+40
Absolute, mils
-40
0
+40
Bearing Pedestal Strain
Bearing Pedestal Strain

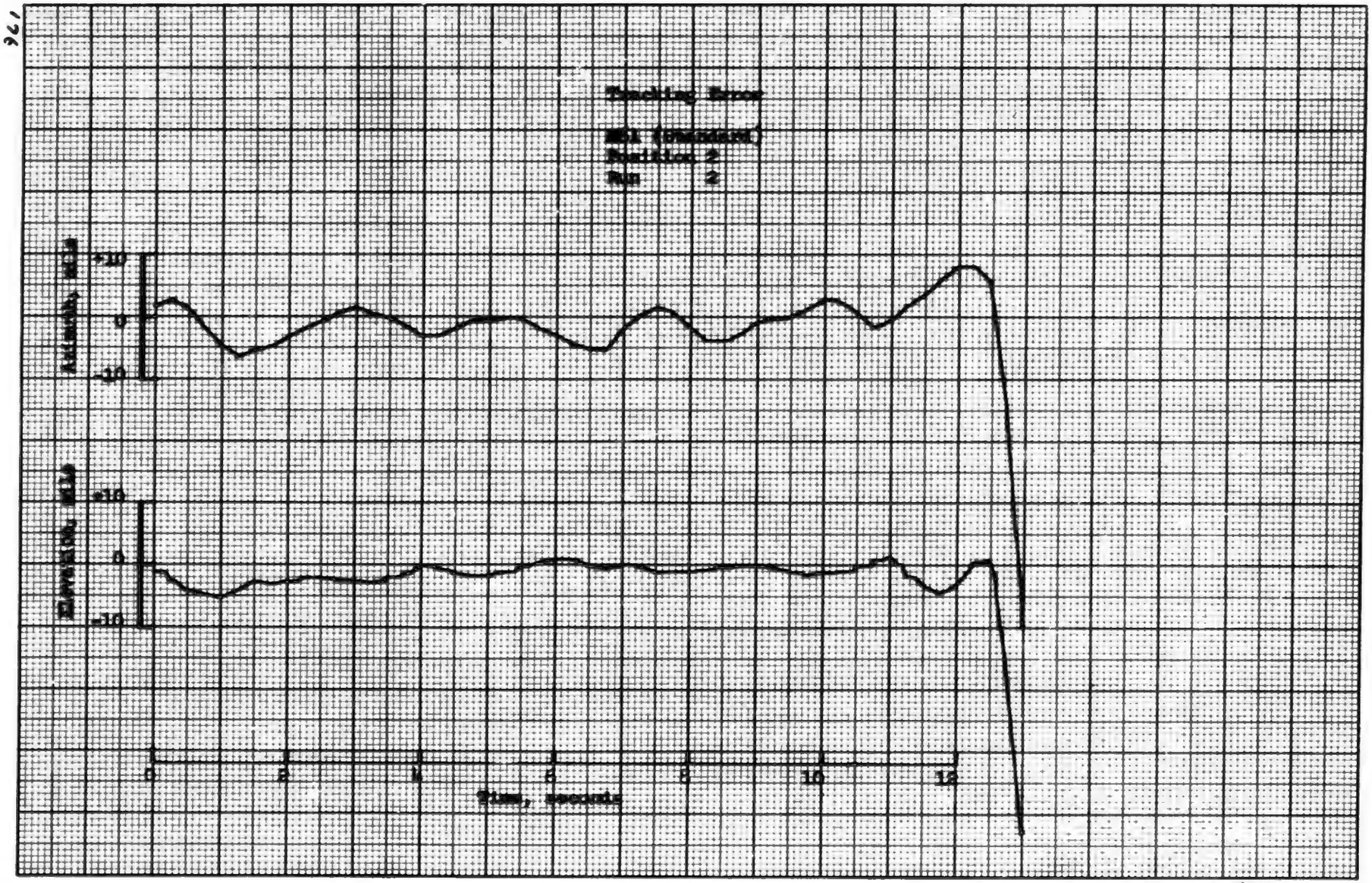
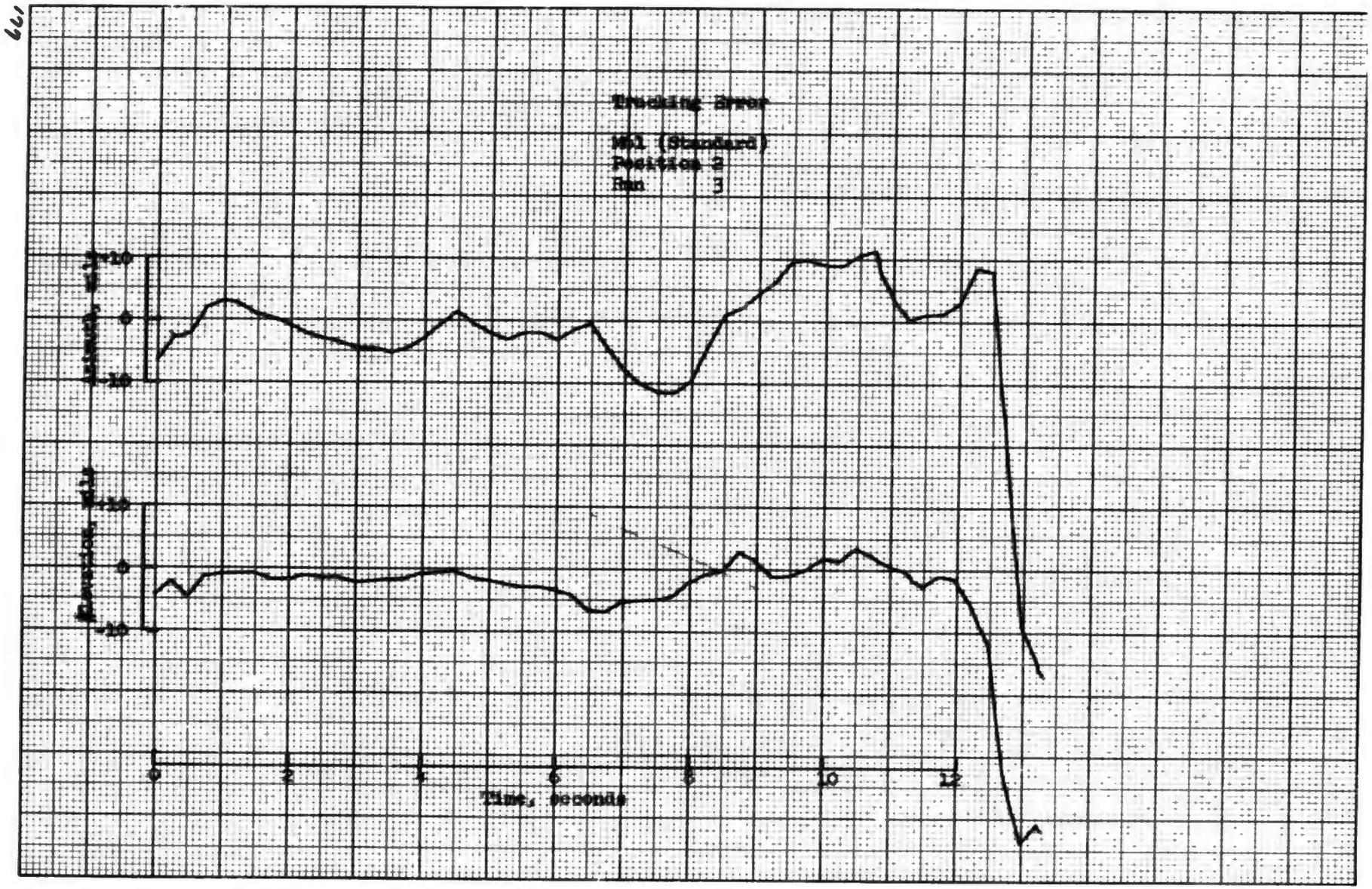

Tracking Error
Aileron, deg
+10
0
-10
Elevator, deg
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 74-I


Tracking error
M51 (Standard)
Position 2
Run 3
+10
0
-10
Time, seconds
0
2
4
6
8
10
12

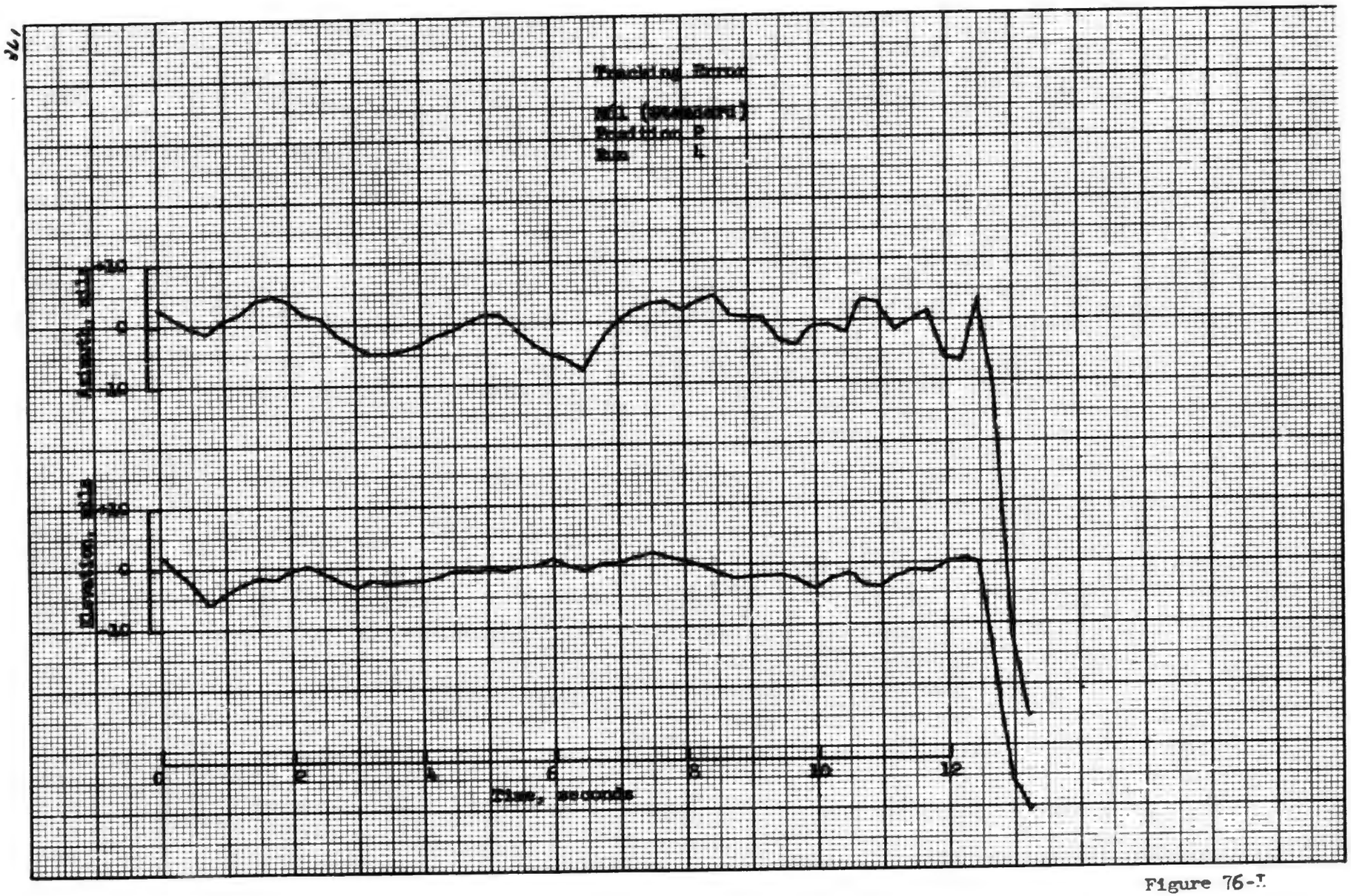


Figure 76-1

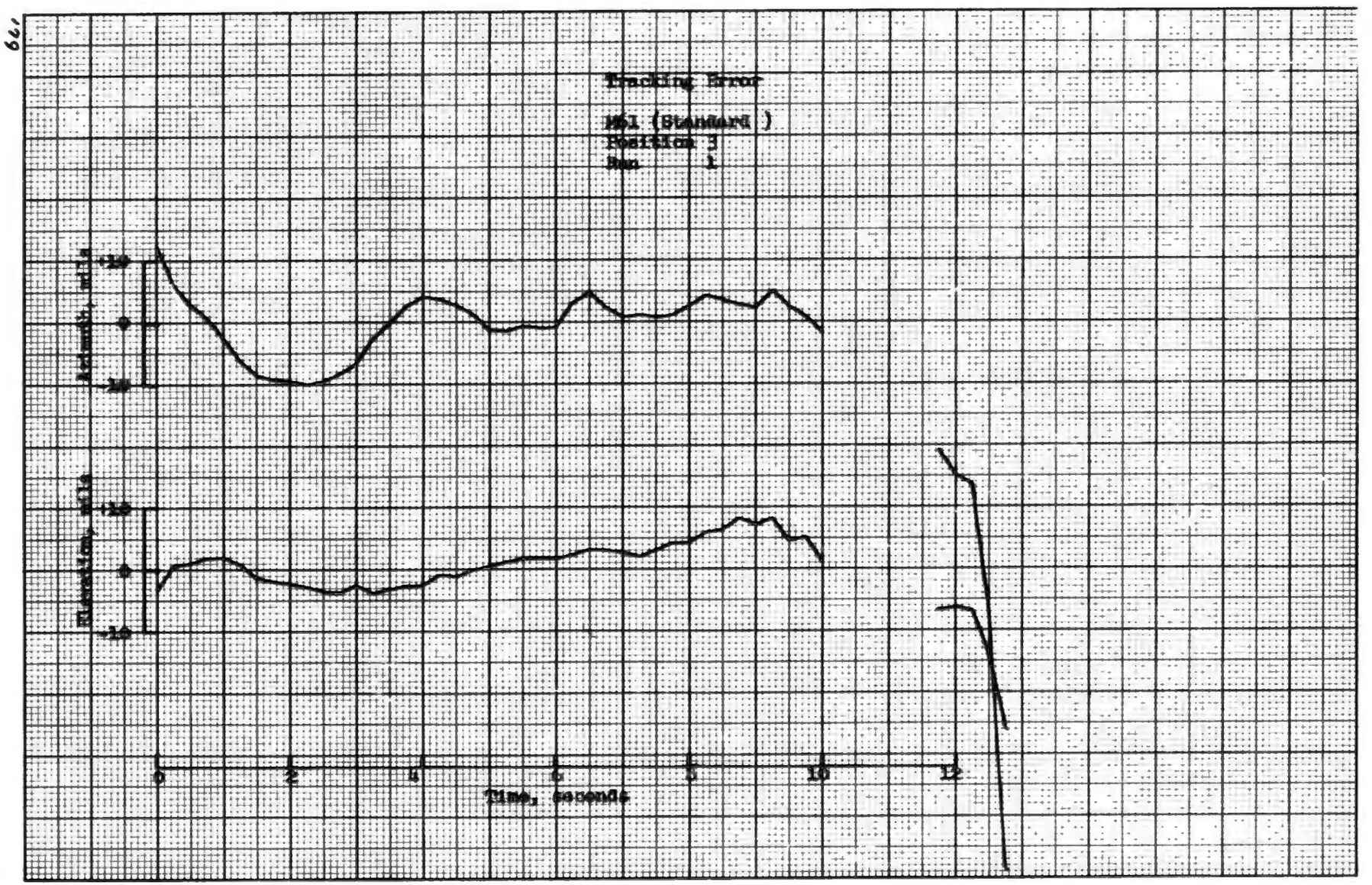

Tracking Error
M51 (Standard)
Position 3
Run 1
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 77-I

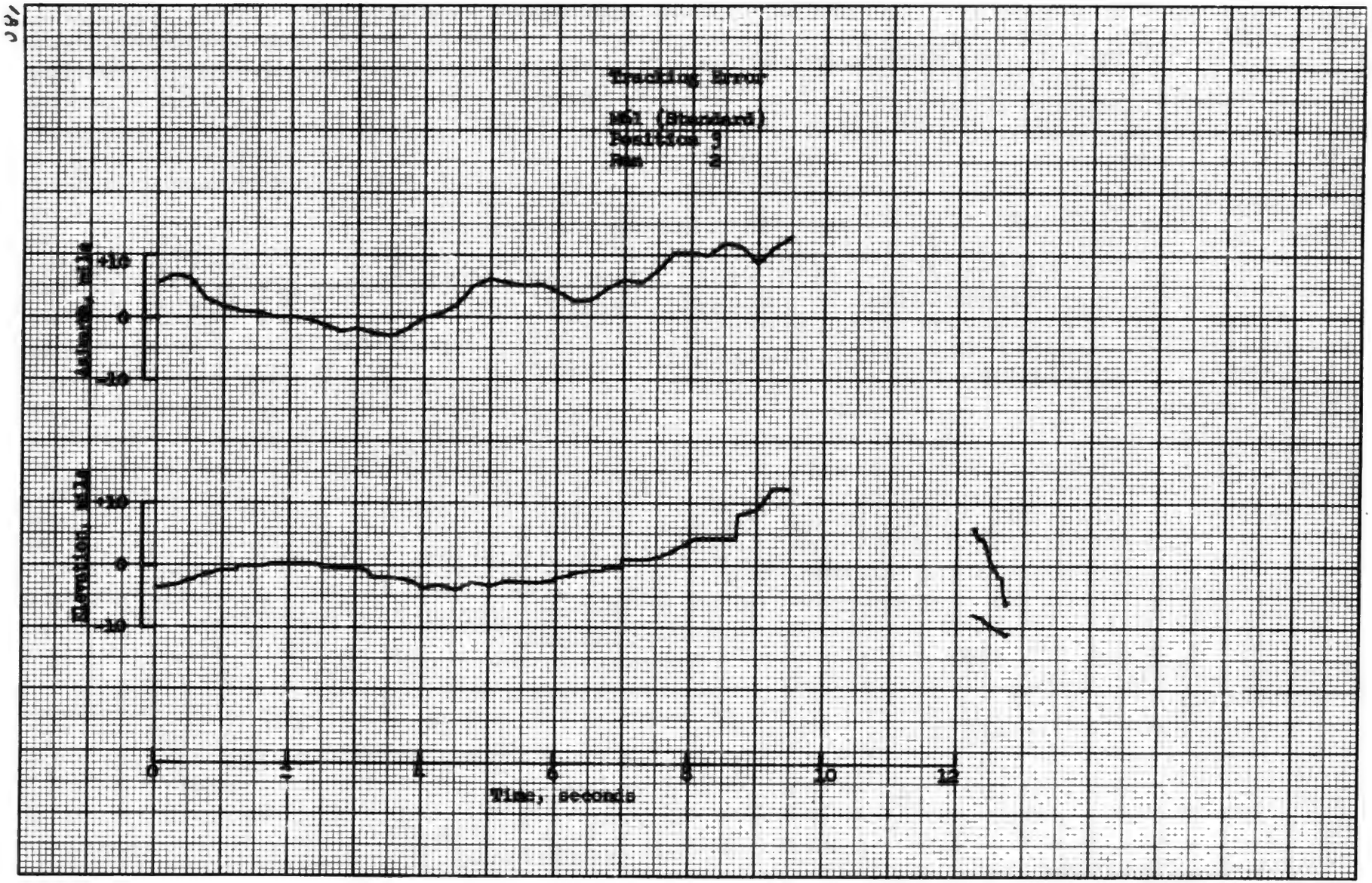


Figure 78-I

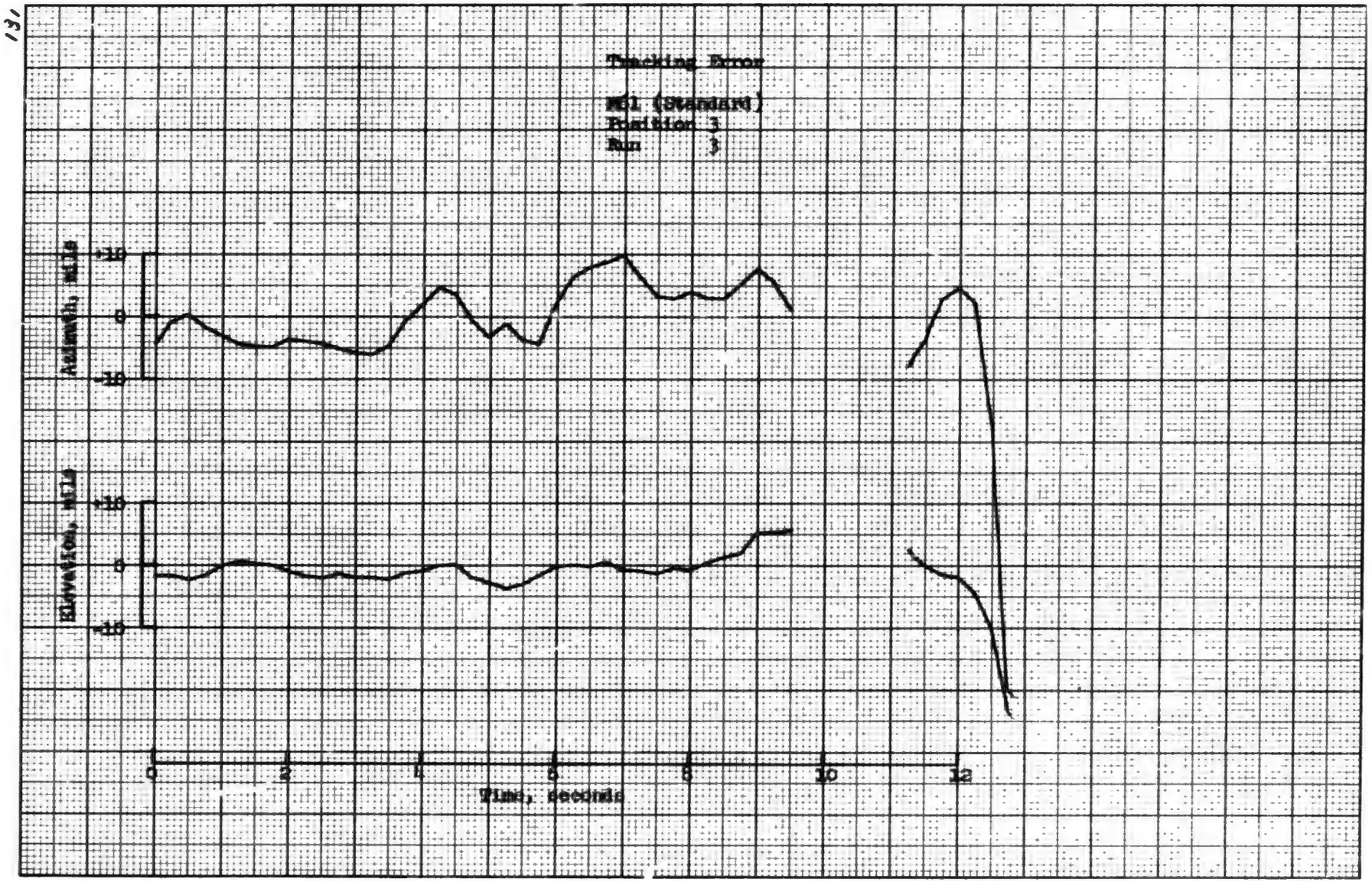

Tracking Error
#21 (Standard)
Position 3
Run 3
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 79-I

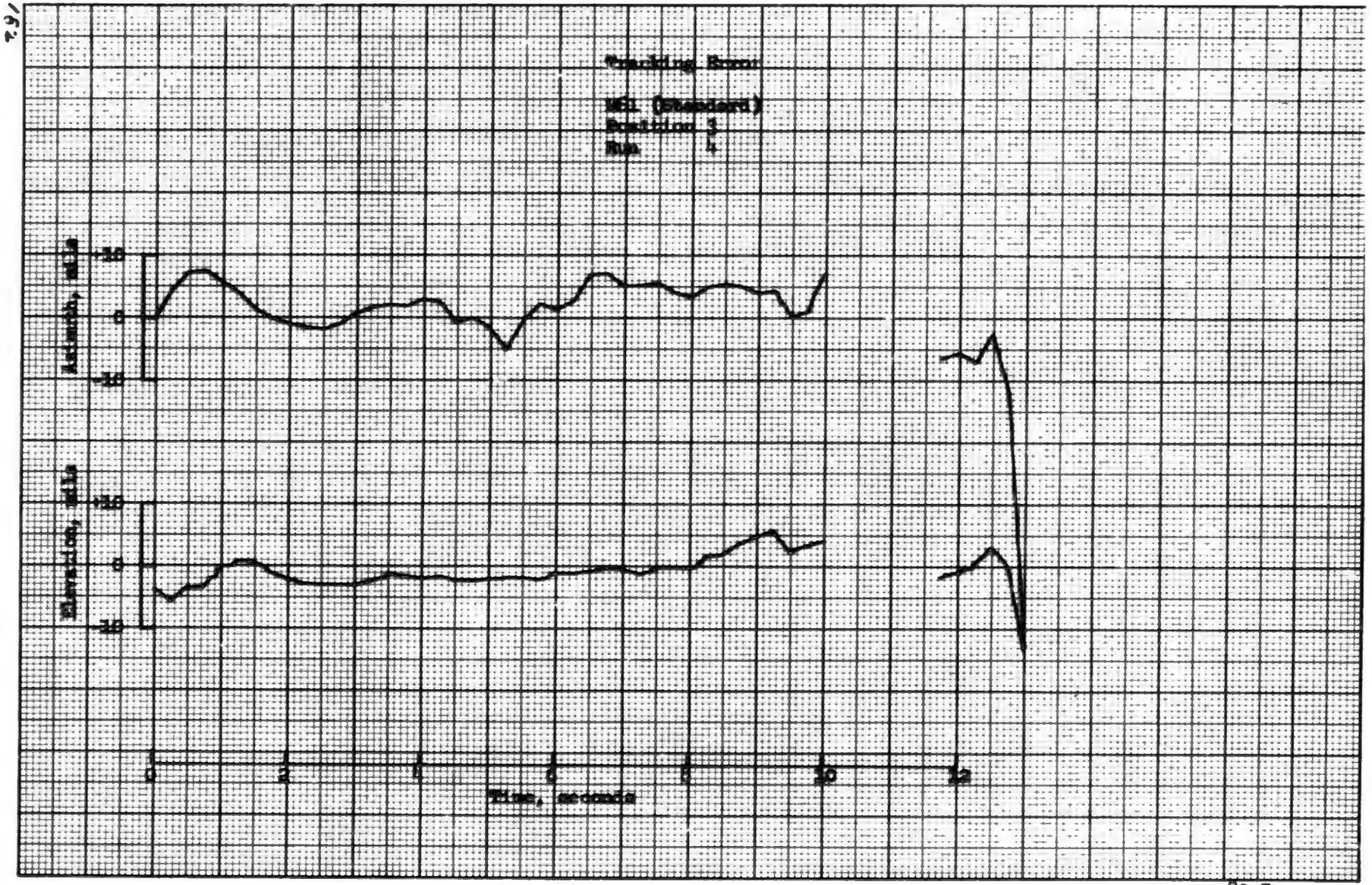

Tracking Error
MIL (Standard)
Position 3
Run 4
Lateral, mils
+10
0
-10
Elevator, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 80-I

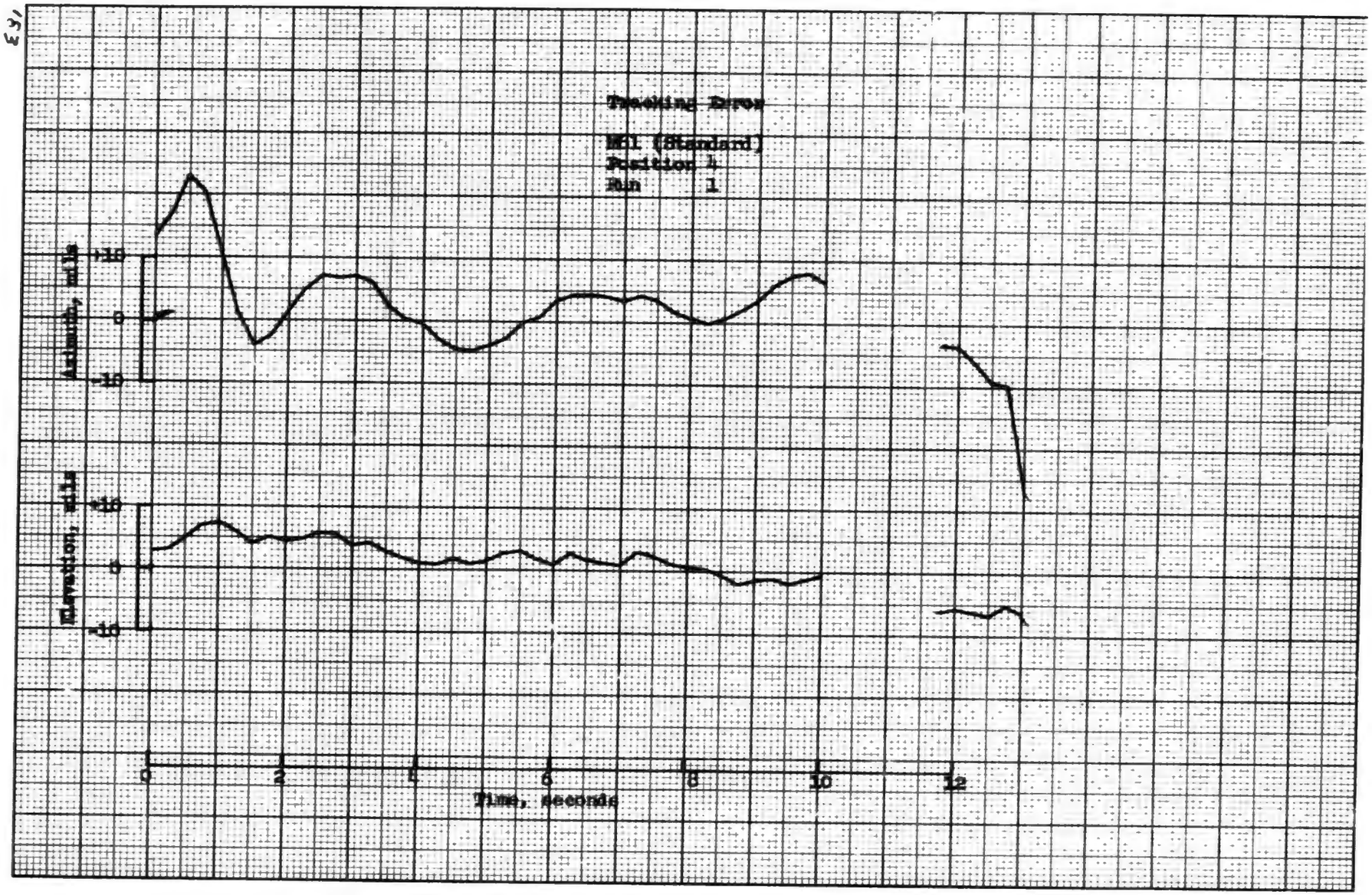

Tracking Error
Mil (Standard)
Position 4
Run 1
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 81-I

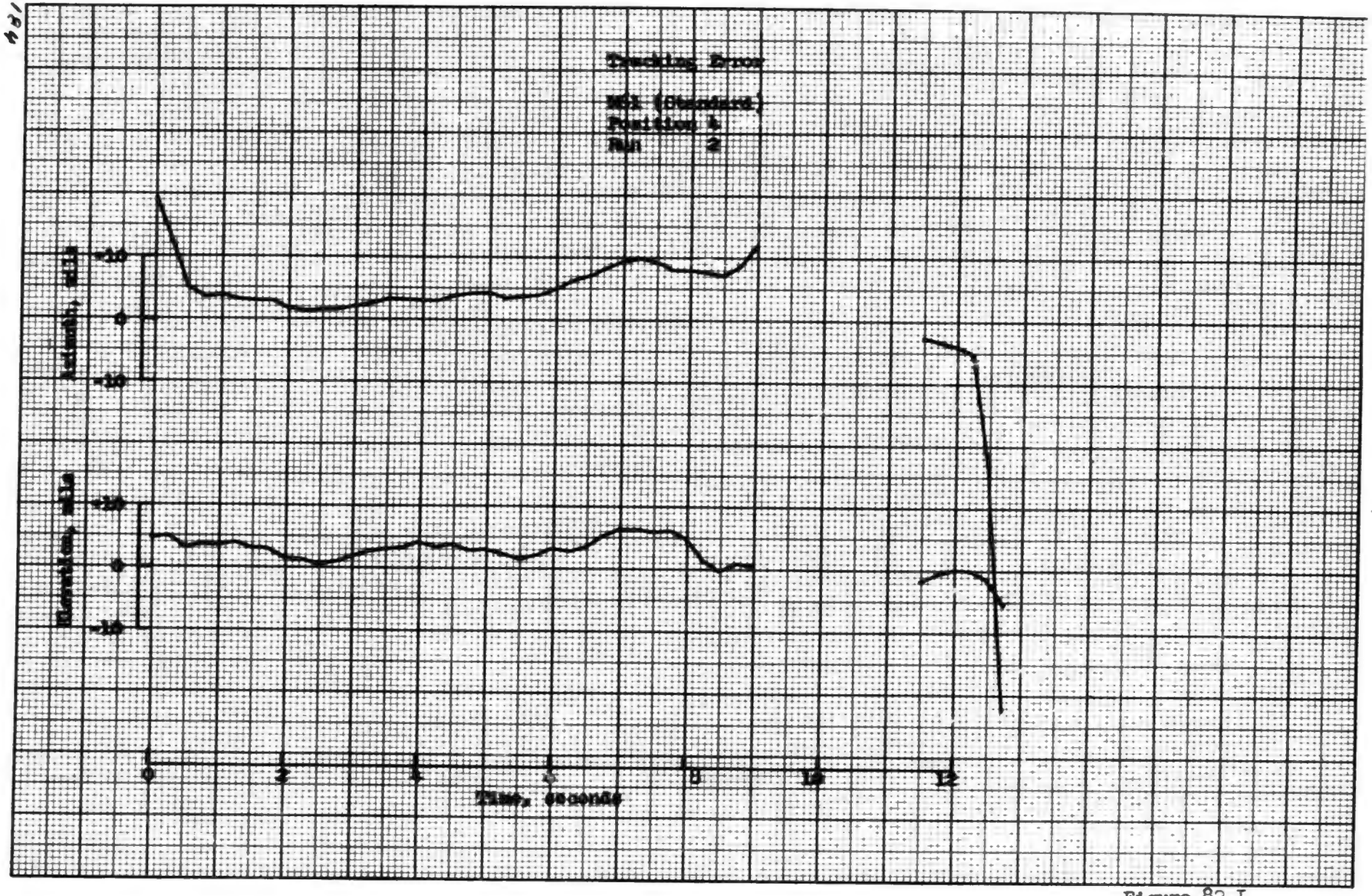


Figure 82-I

Tracking Error
M61 (Standard)
Run 3
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 93-I

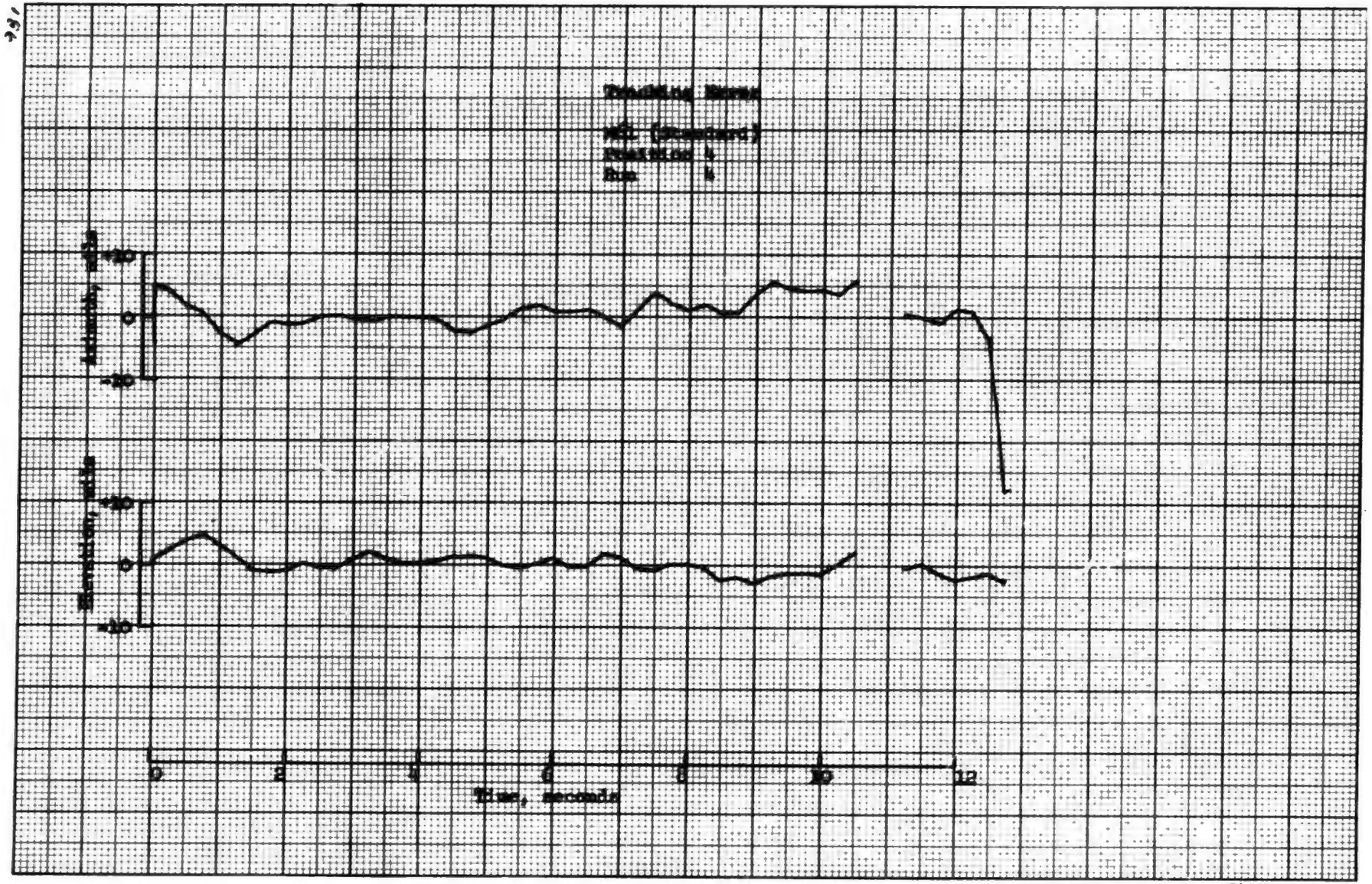


Figure 84-I

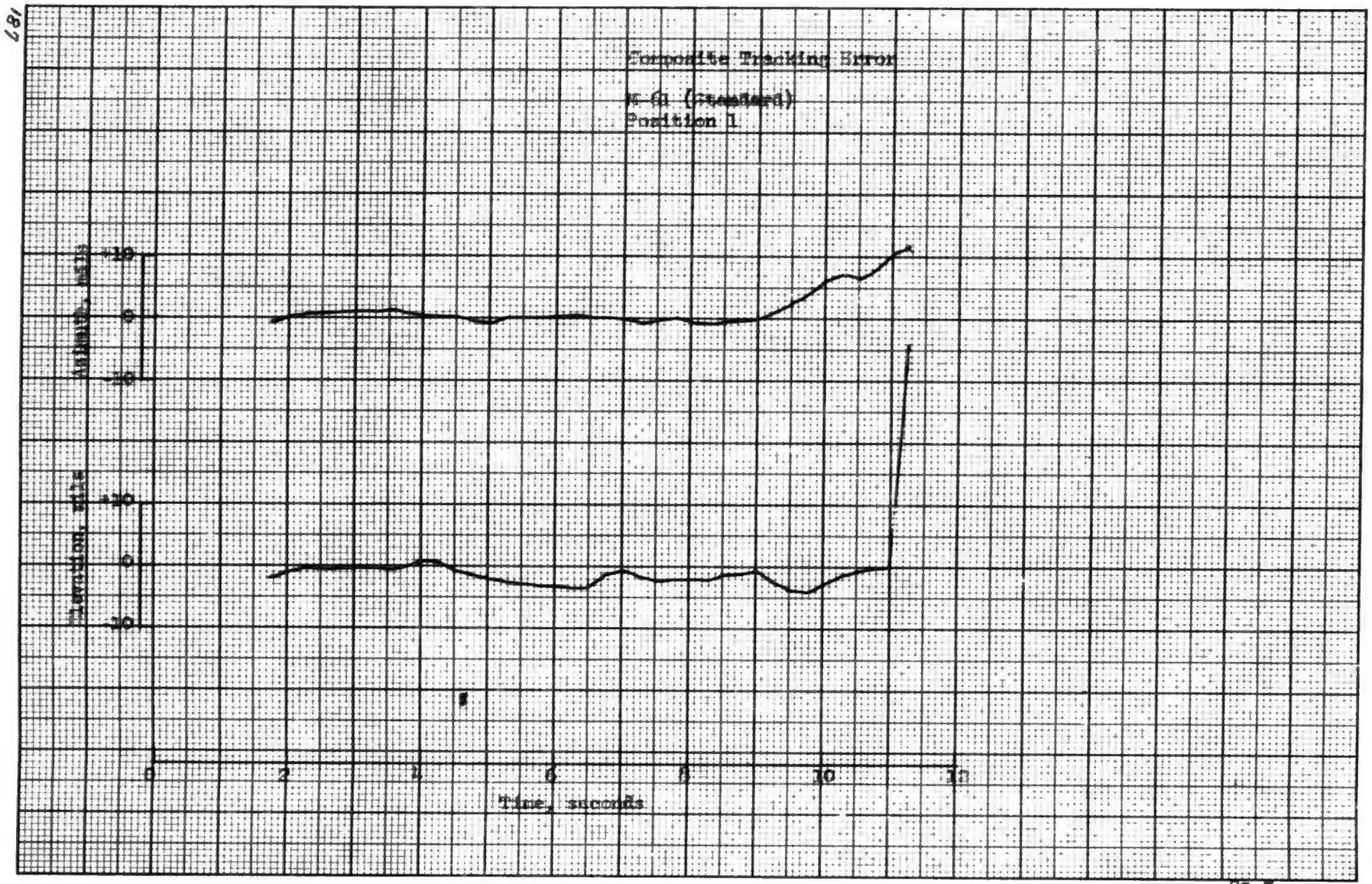

Composite Tracking Error
K-G1 (Constant)
Position 1
+10
0
-10
+10
0
-10
Time, seconds

Figure 35-I

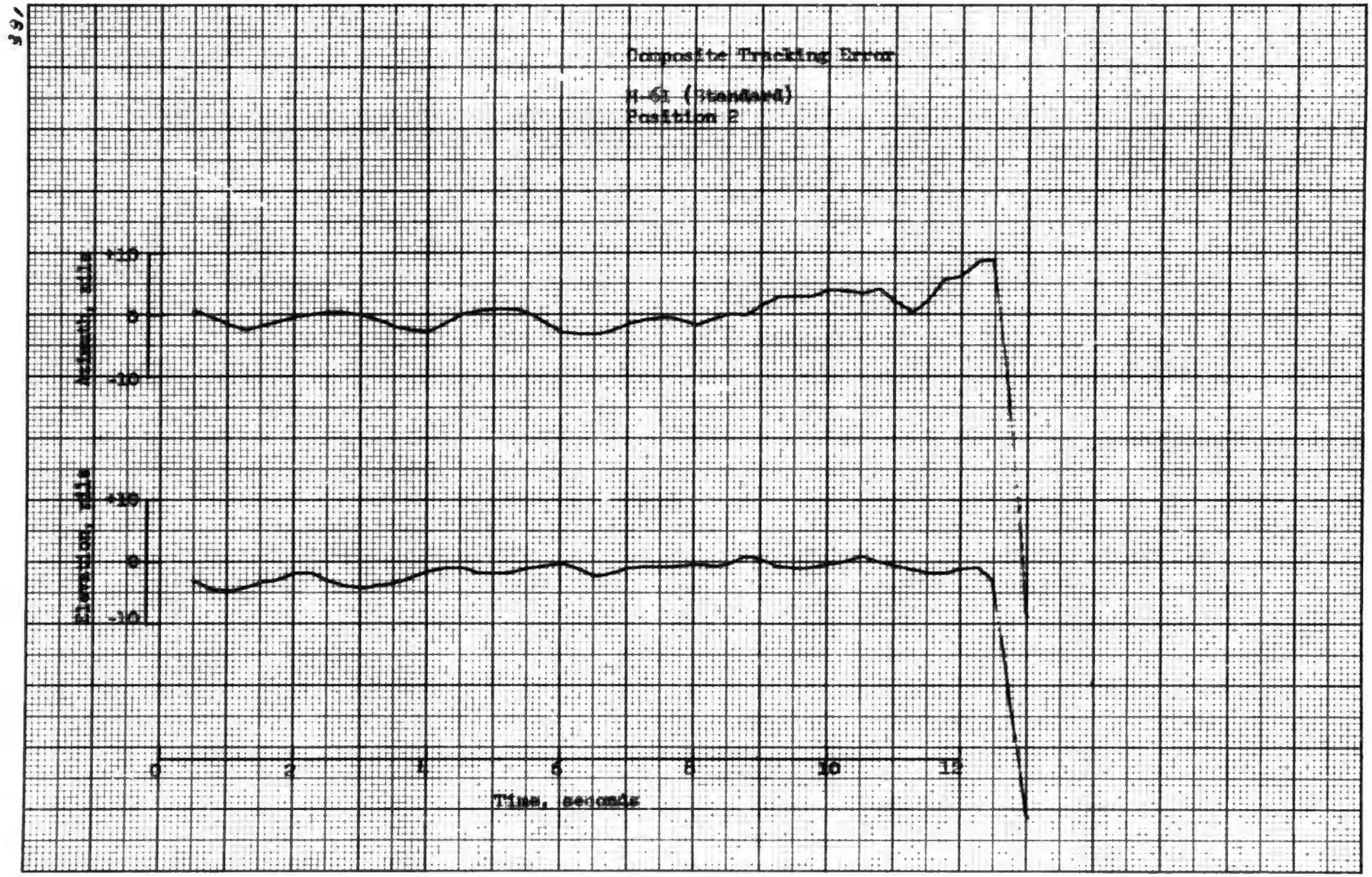

Composite Tracking Error
M-63 (Standard)
Position 2
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 86-I

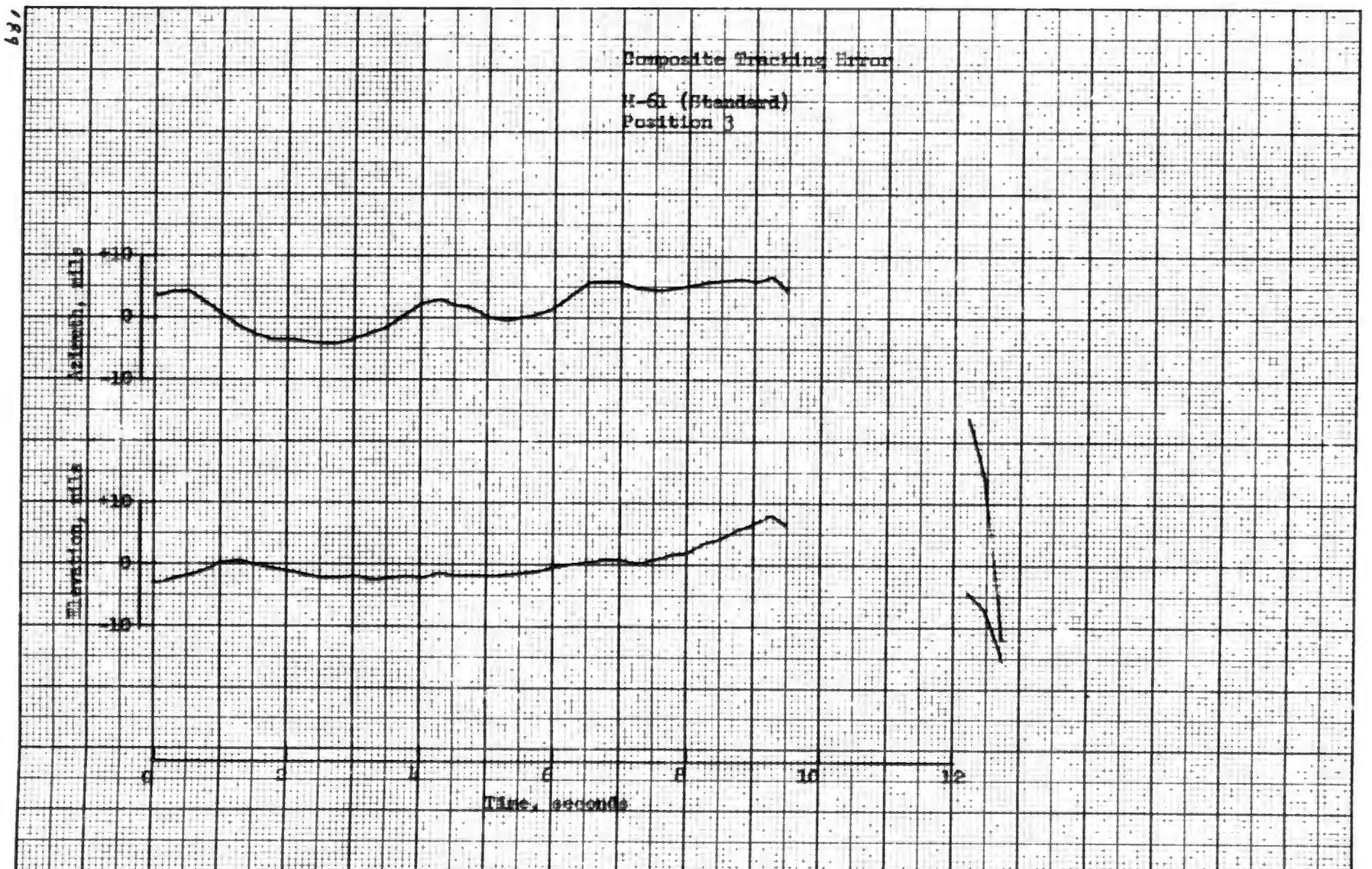

Composite Tracking Error
K-6A (Standard)
Position 3
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 87-I

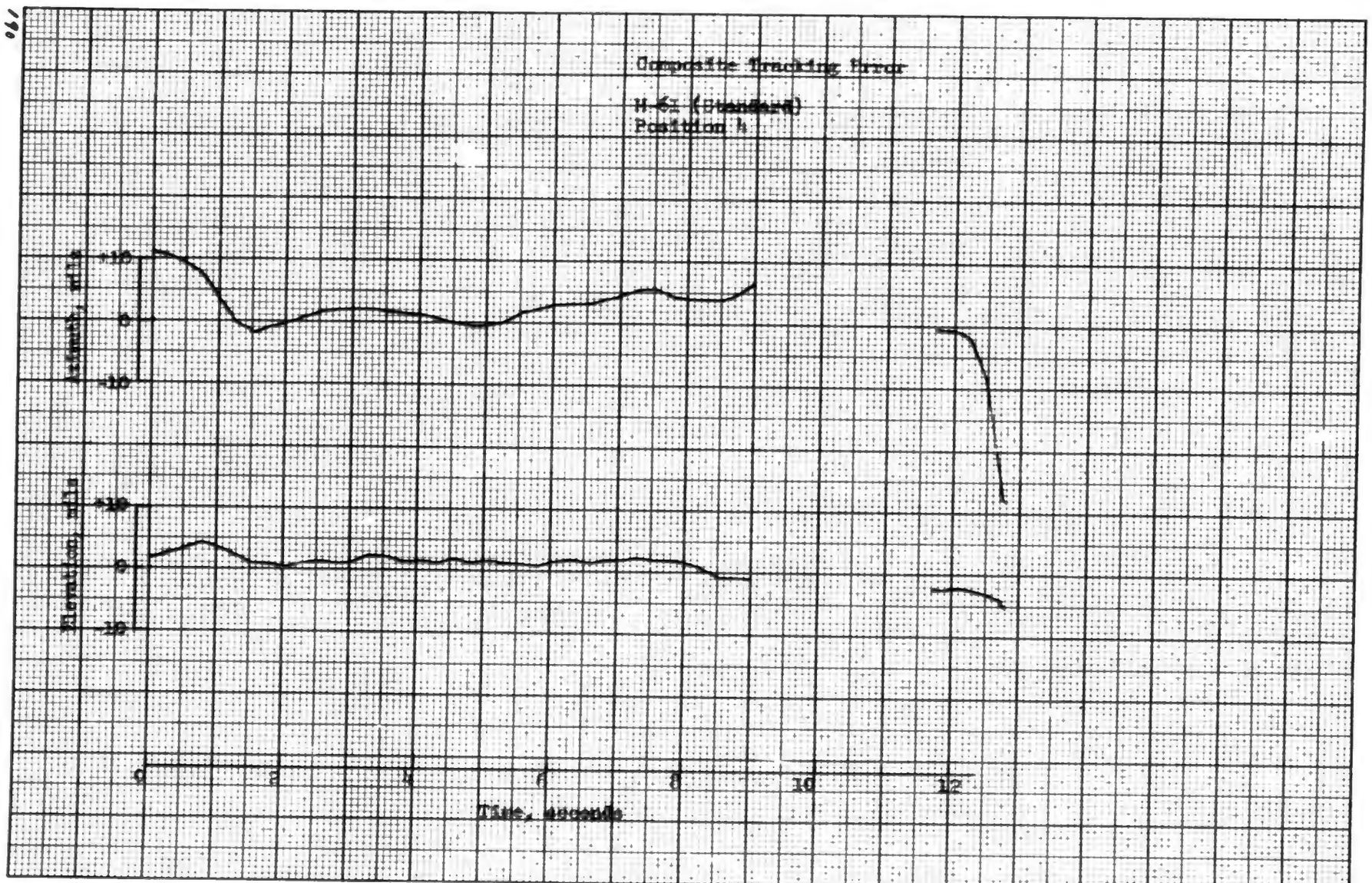

Composite tracking error
Position h
+10
0
-10
Elevation, mils
Time, seconds
0
2
4
6
8
10
12

Figure 88-I

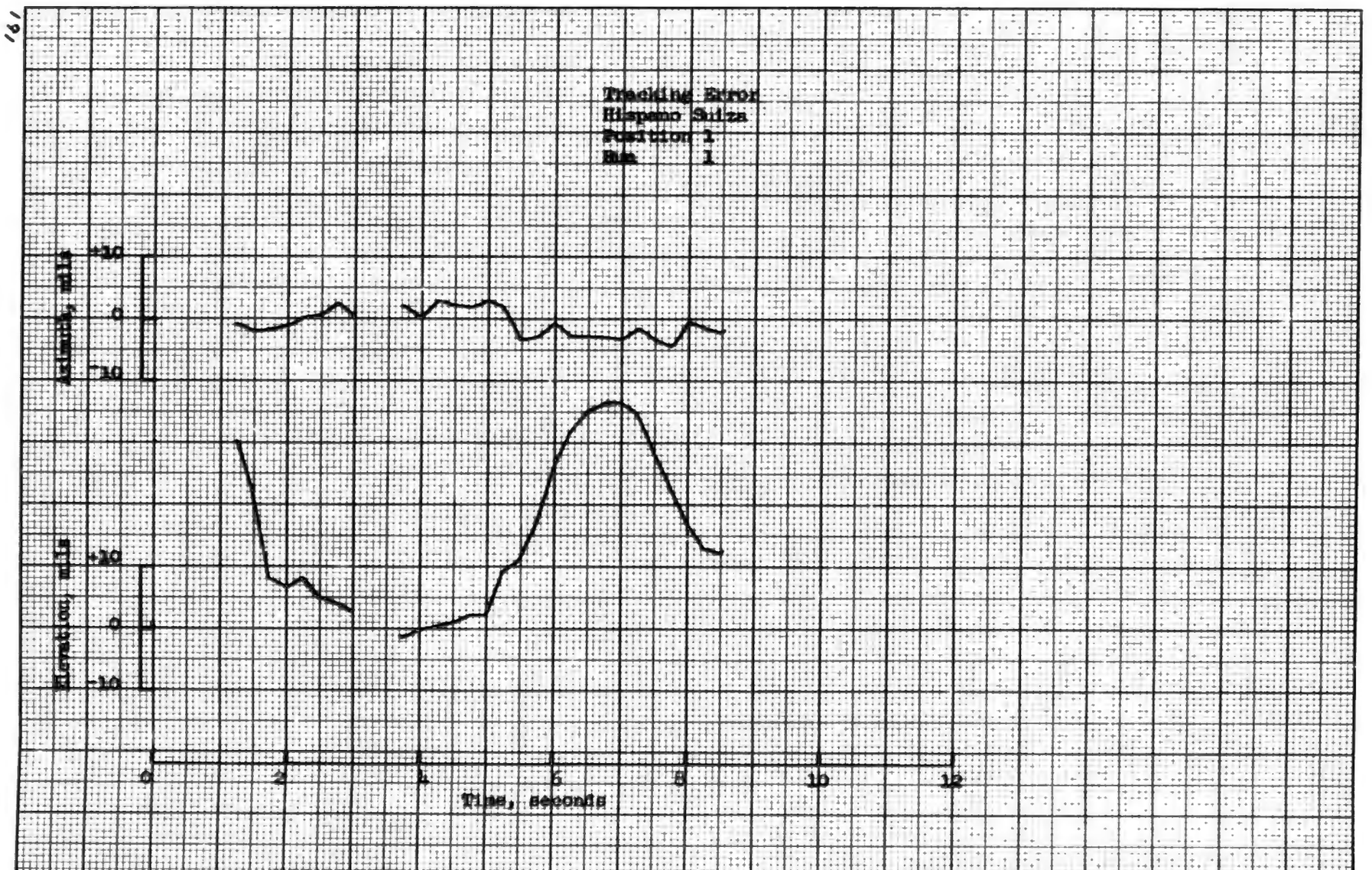

Tracking Error
Hispano Suiza
Position 1
Run 1
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 39-I

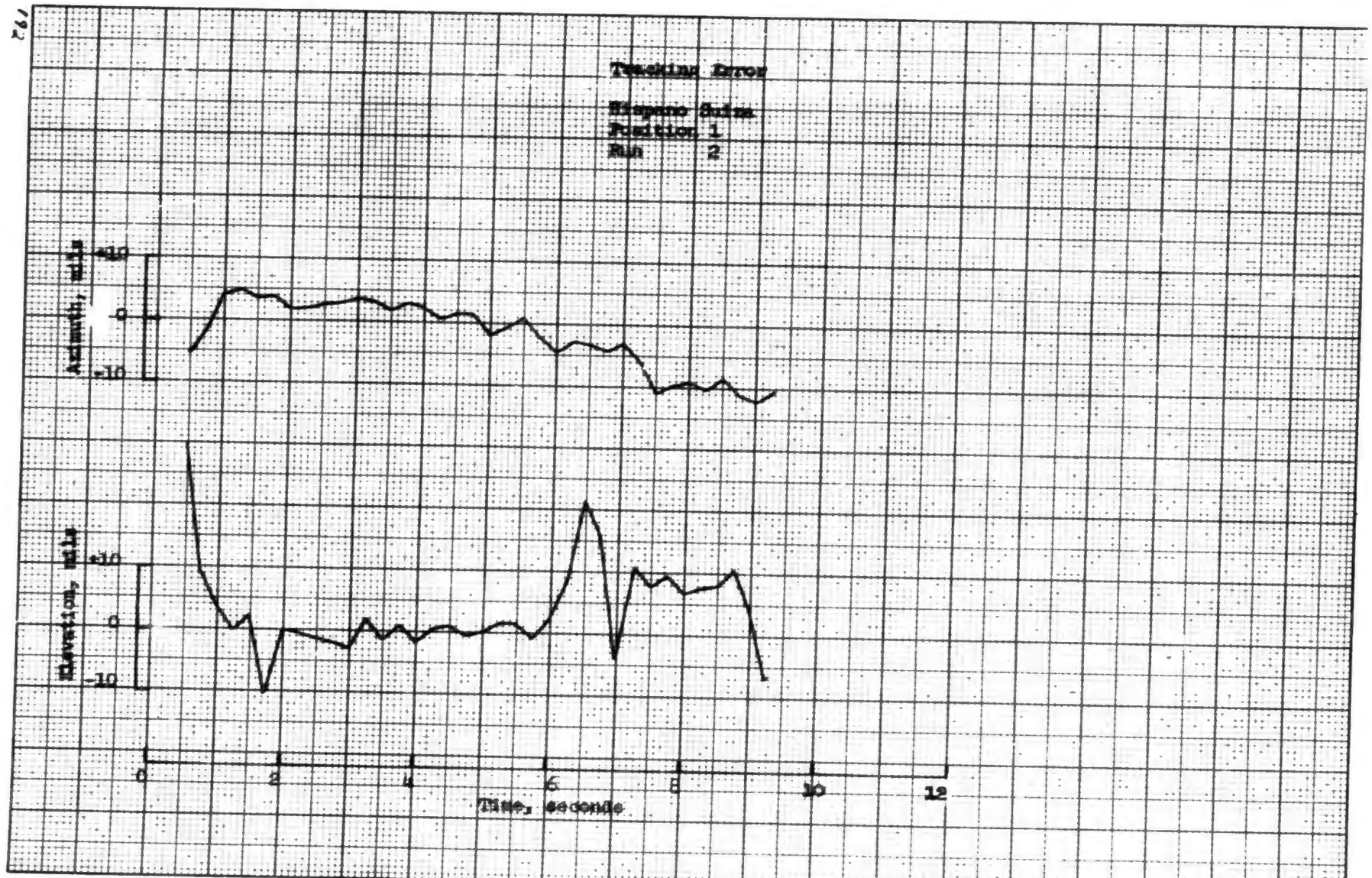
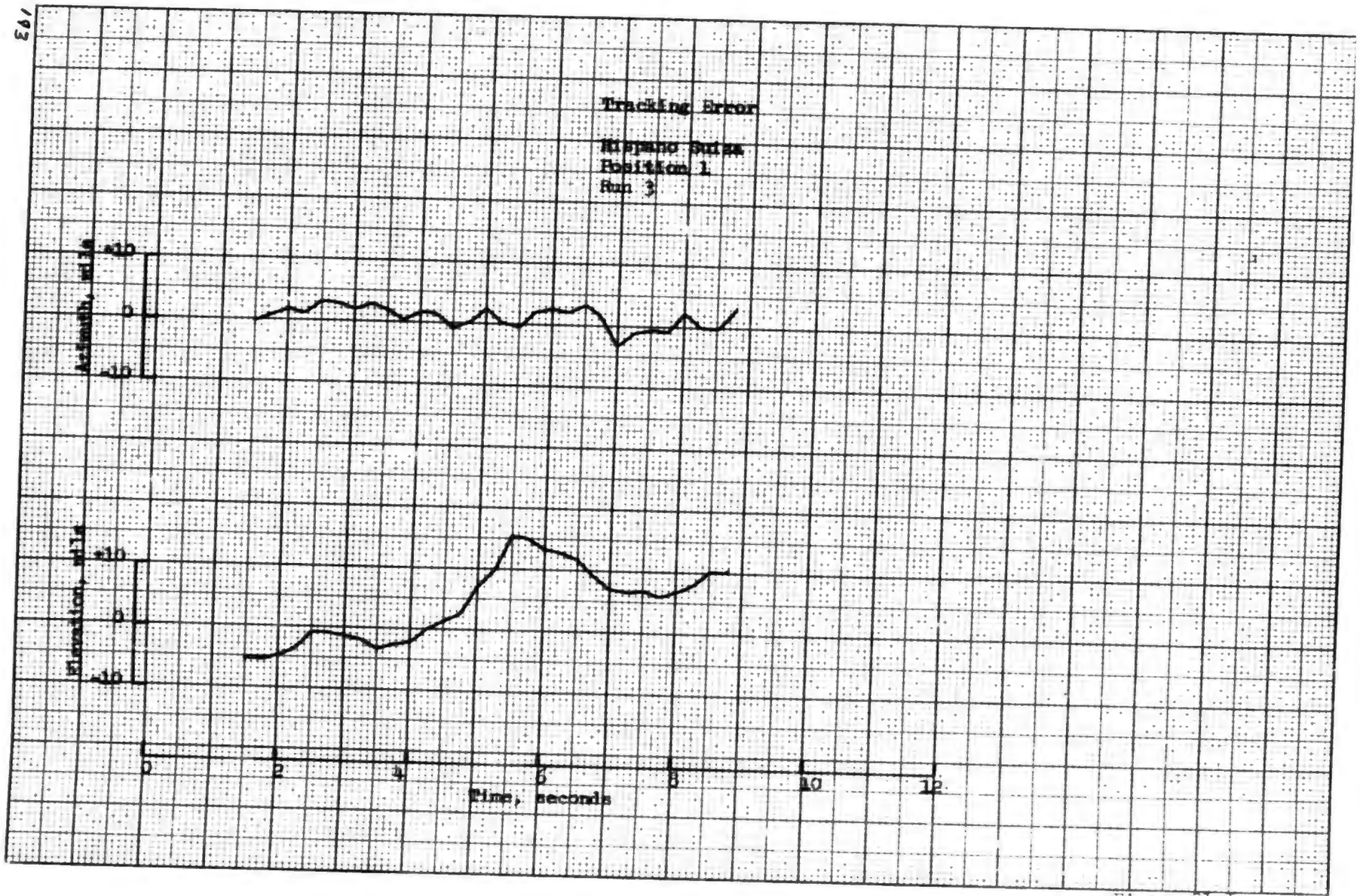

Tracking Error
Hispano Suiza
Position 1
Run 2
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 90-I


Tracking Error
Hispano Suiza
Position 1
Run 3
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

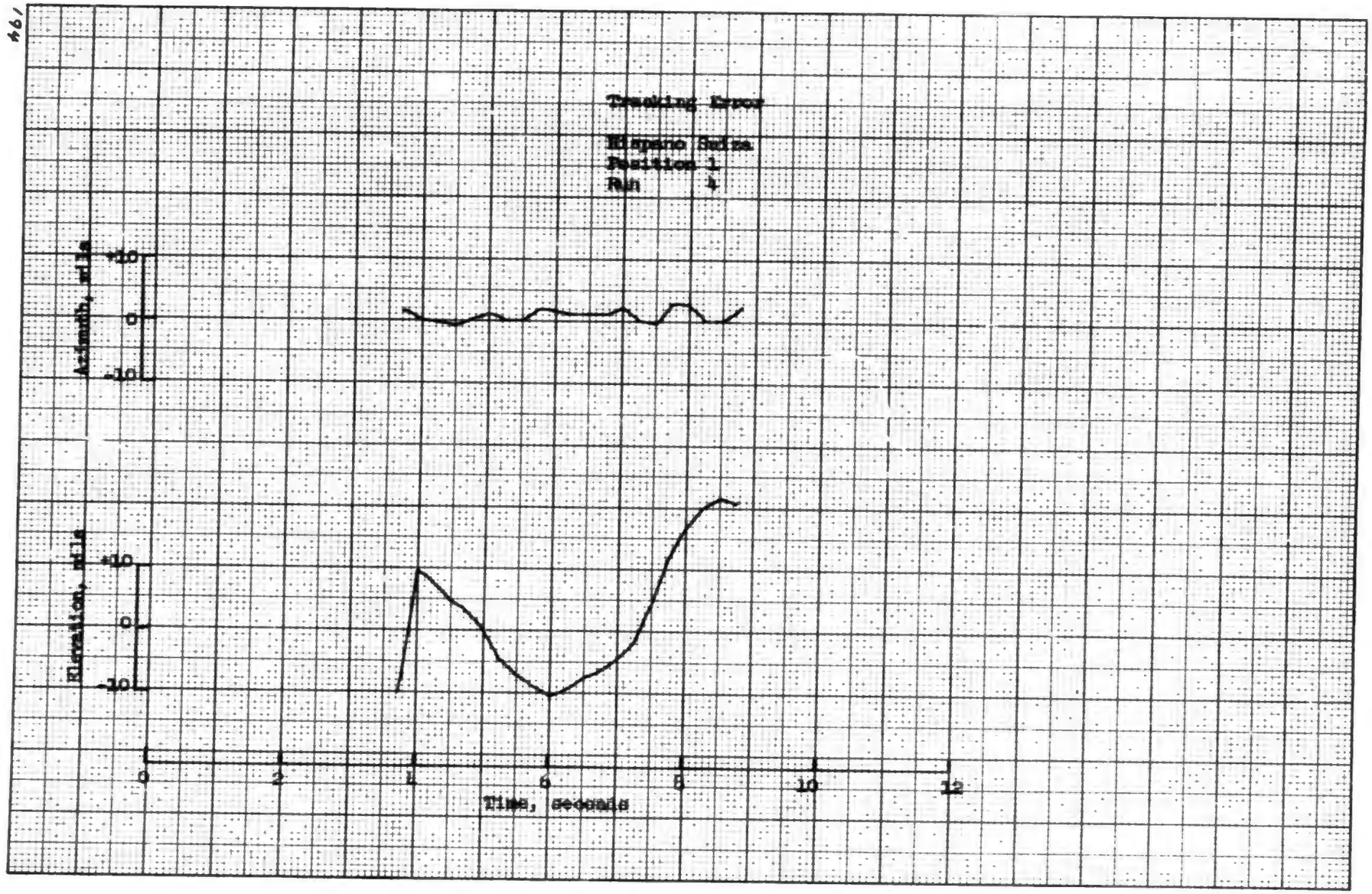

Tracking Error
Hispano Suiza
Position 1
Run 4
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 92-I

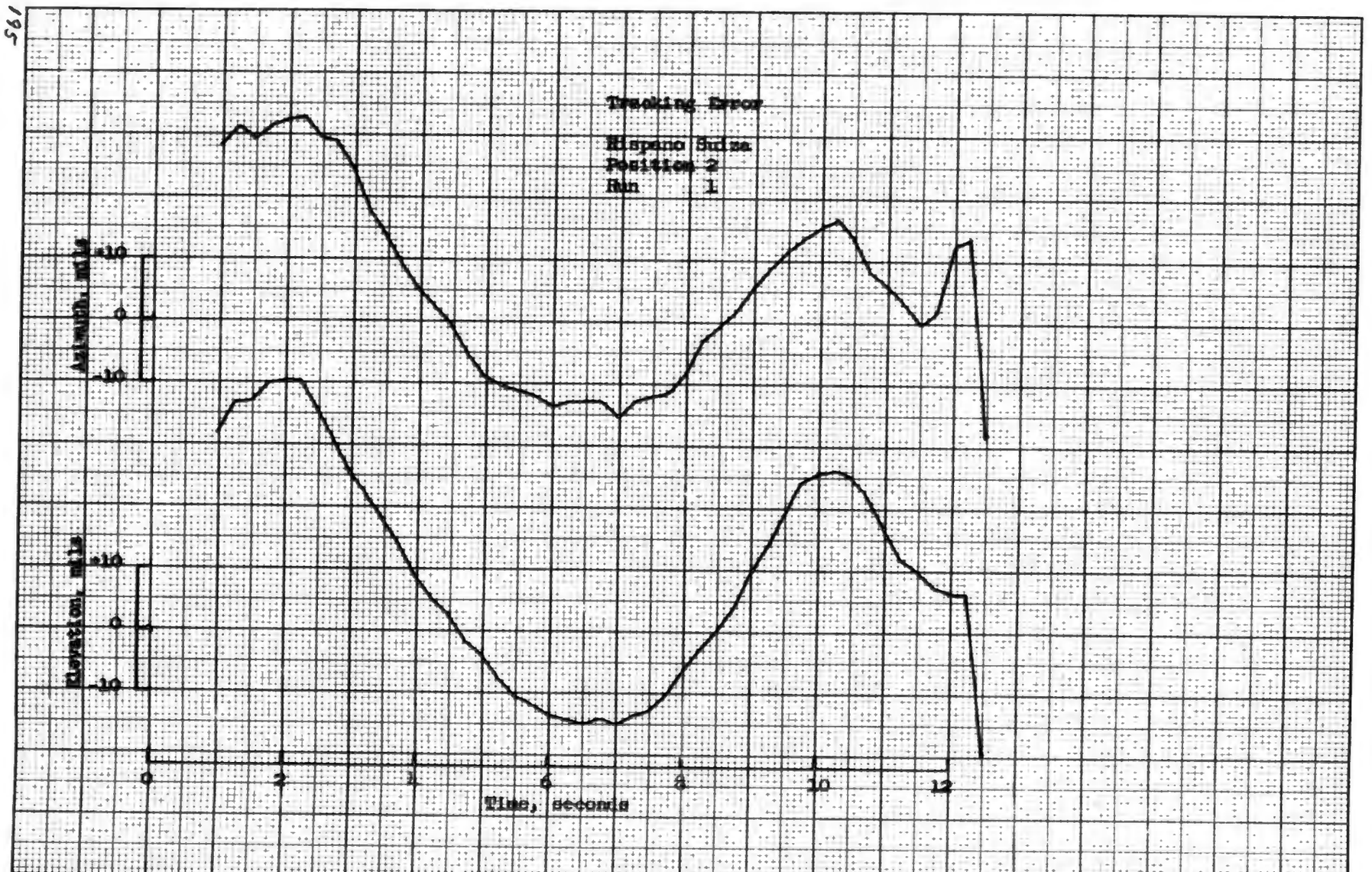

Tracking Error
Hispano Suiza
Position 2
Run 1
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 23-I

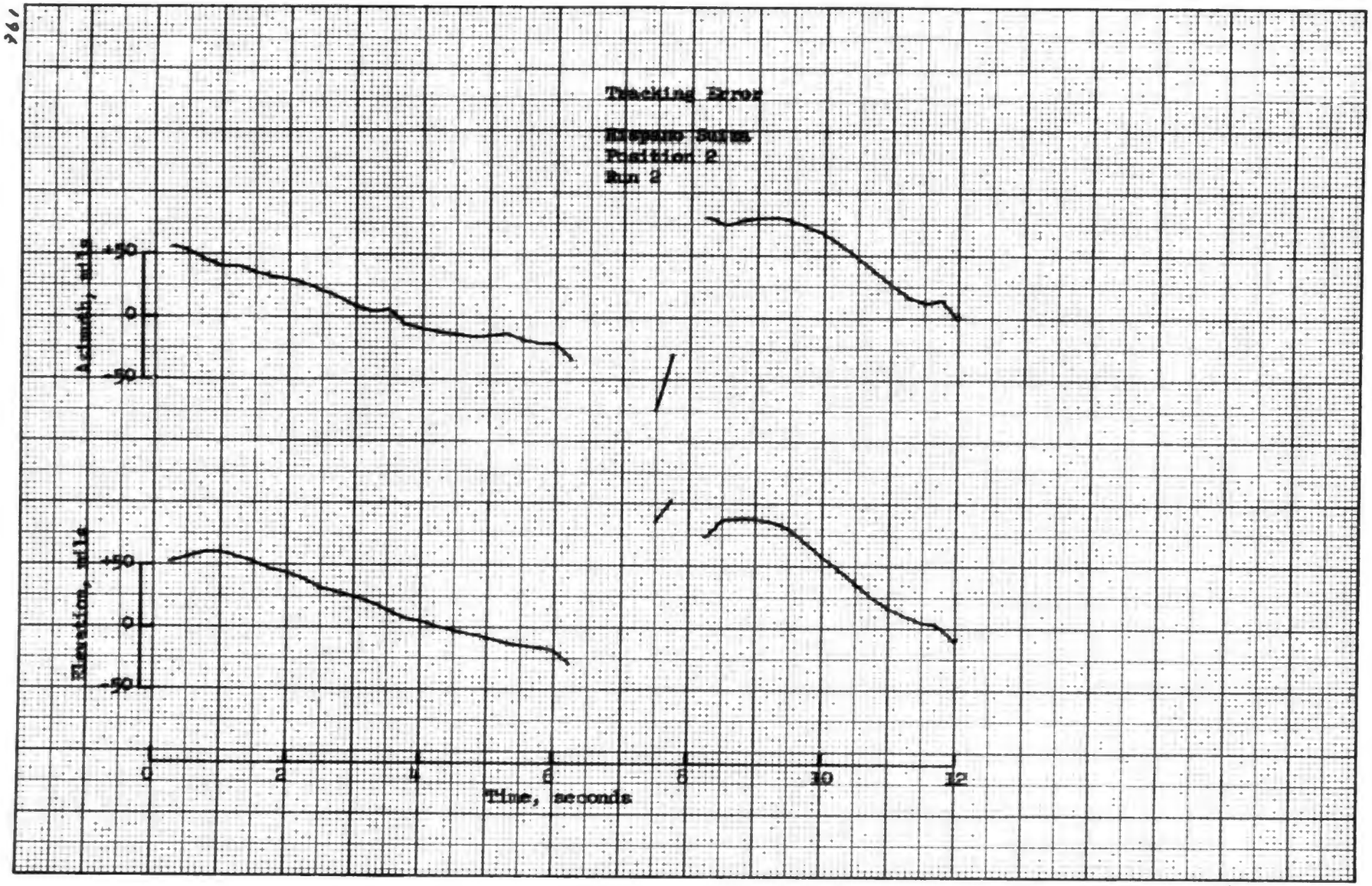
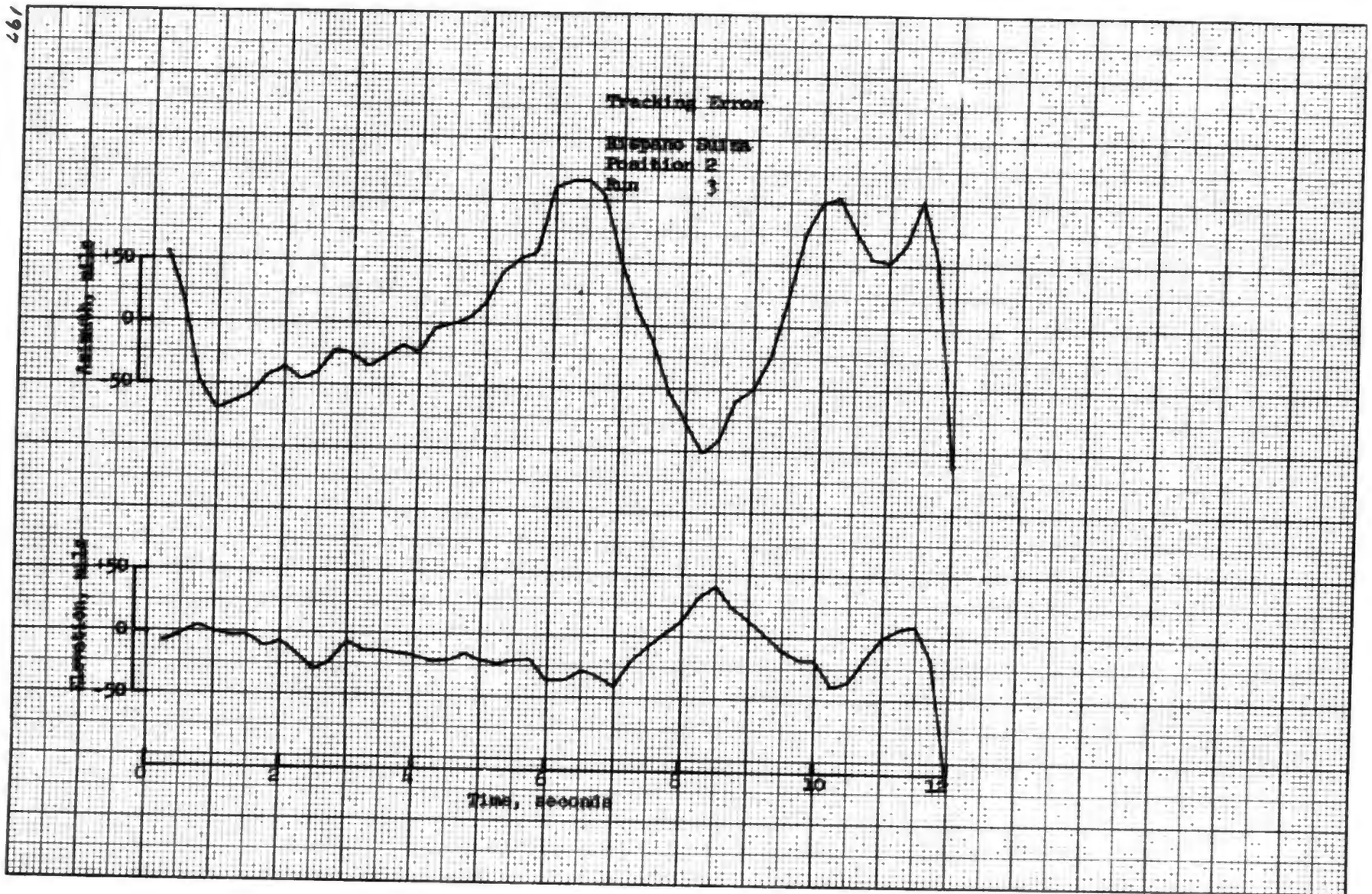

Tracking Error
Response Curve
Position 2
Run 2
Azimuth, mils
+50
0
-50
Elevation, mils
+50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure 94-I


Tracking Error
Airplane Data
Position 2
Run 3
+50
0
-50
Elevation, mils
+50
0
-50
Aileron, mils
0
2
4
6
8
10
12
Time, seconds

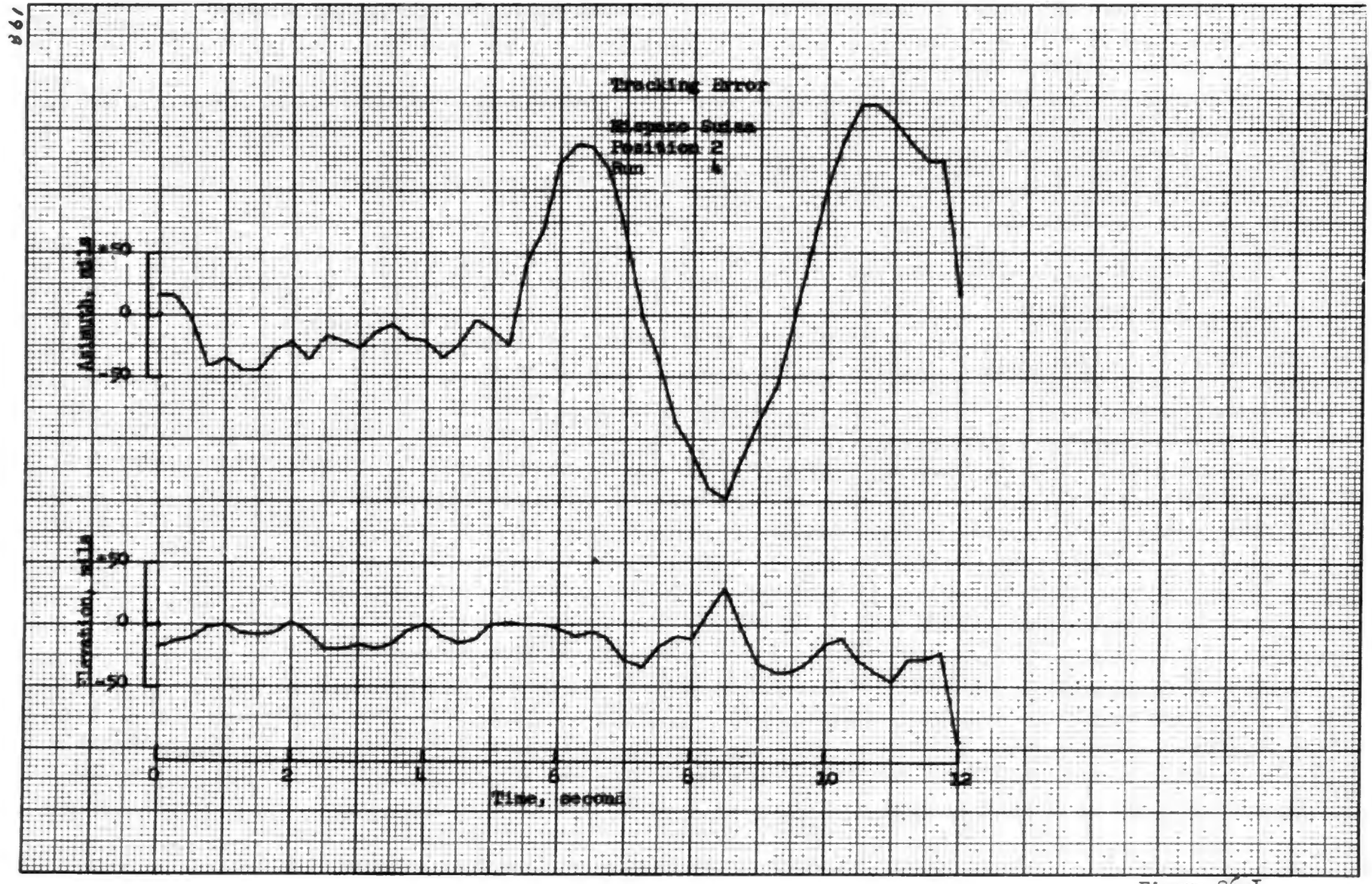

Tracking Error
Elegance Sudan
Position 2
Run 4
Azimuth, mils
+50
0
-50
Elevation, mils
+50
0
-50
0
2
4
6
8
10
12
Time, second

Figure 26-I

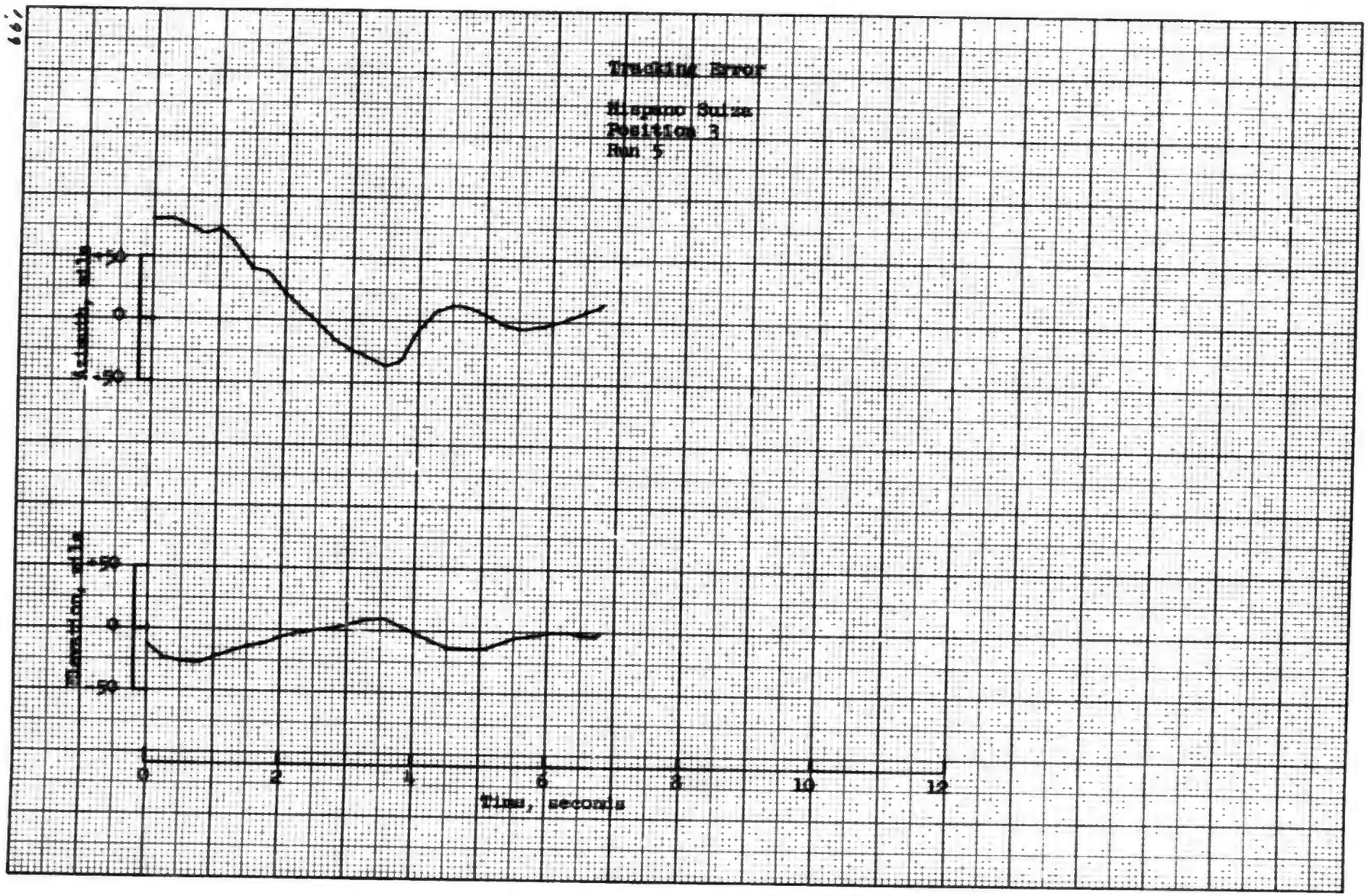

Tracking Error
Hispano Suiza
Position 3
Run 5
Elevation, mils
+50
0
-50
Azimuth, mils
+50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure 27-I

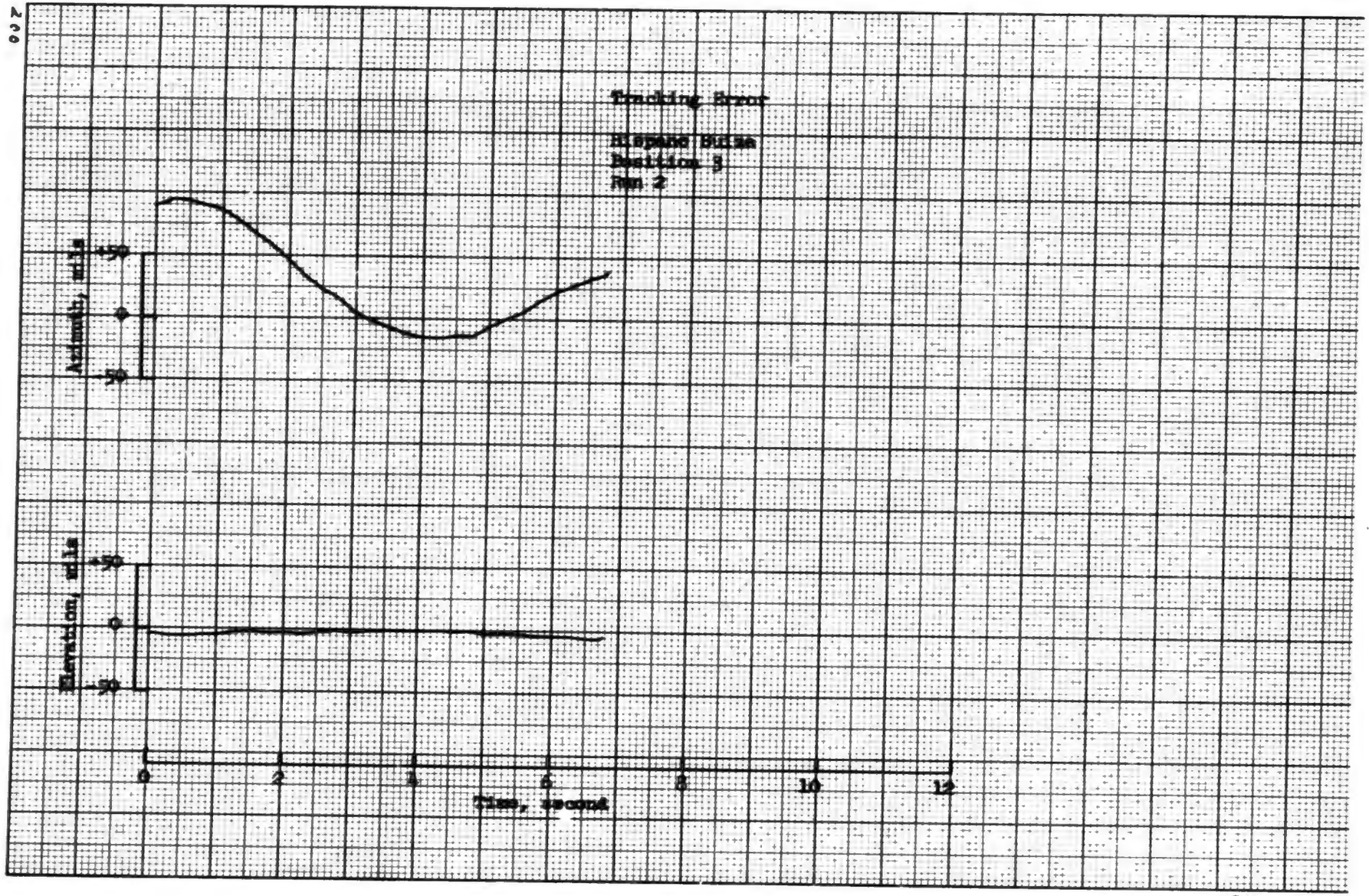

Tracking Error
Response Button
Position 3
Run 2
Azimuth, mils
+50
0
-50
Elevation, mils
+50
0
-50
0
2
4
6
8
10
12
Time, second

Figure 98-I

Reaching Error
Hispano Suiza
Rotation 1-3
Run
Azimuth, mils
Elevation, mils
Time, seconds
0
2
4
6
8
10
12

Figure 9-I

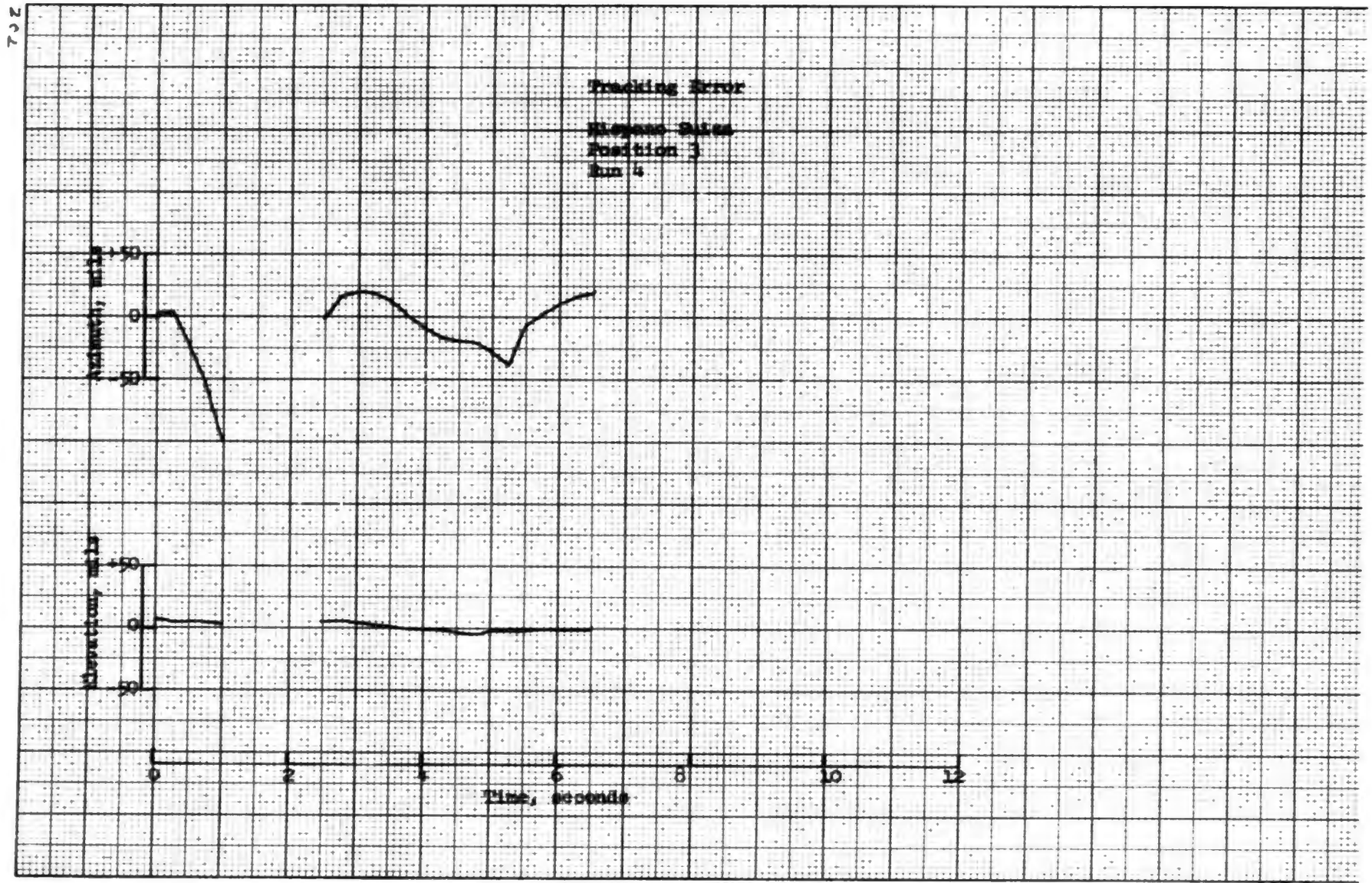

Tracking Error
Elegance Sites
Position 3
Run 4
Azimuth, mils
+50
0
-50
Elevation, mils
+50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure 100-1

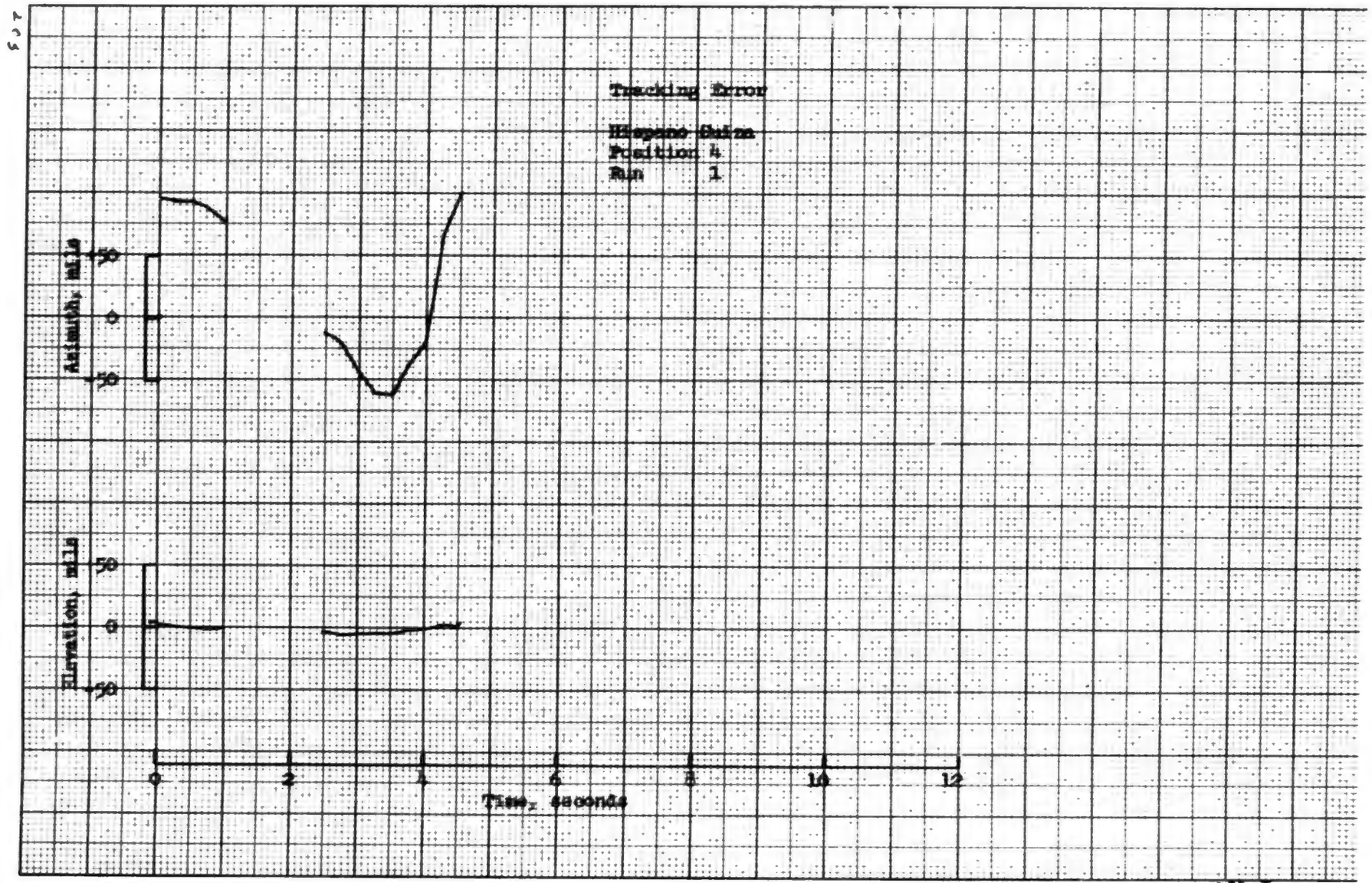

Tracking Error
Hispano Suiza
Position 4
Run 1
Azimuth, mils
50
0
-50
Elevation, mils
50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure 101-1

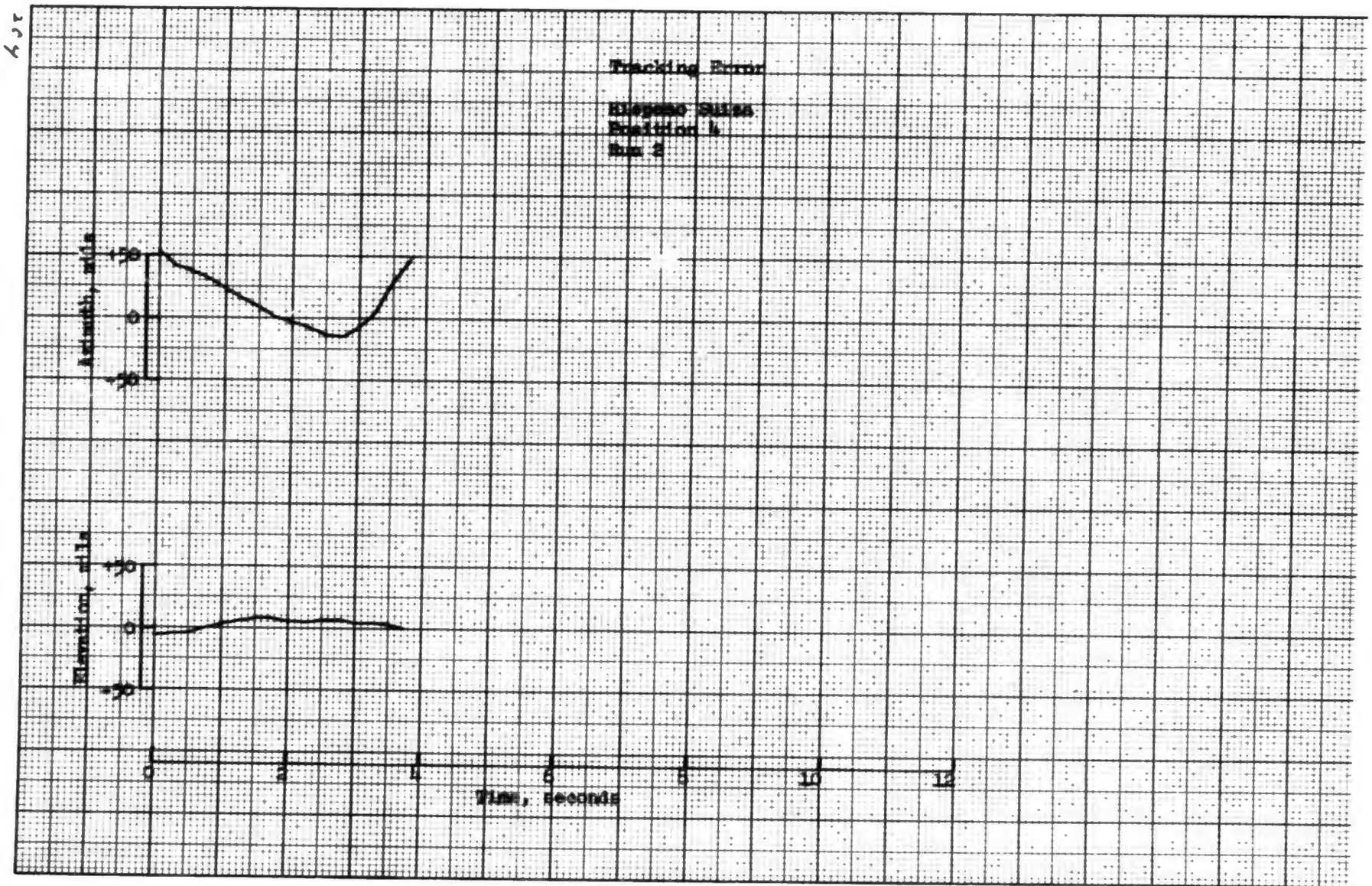

Tracking Error
Elegante Curve
Position 4
Run 2
Azimuth, mils
+30
0
-30
Elevation, mils
+30
0
-30
0
2
4
6
8
10
12
Time, Seconds

Figure 102-I

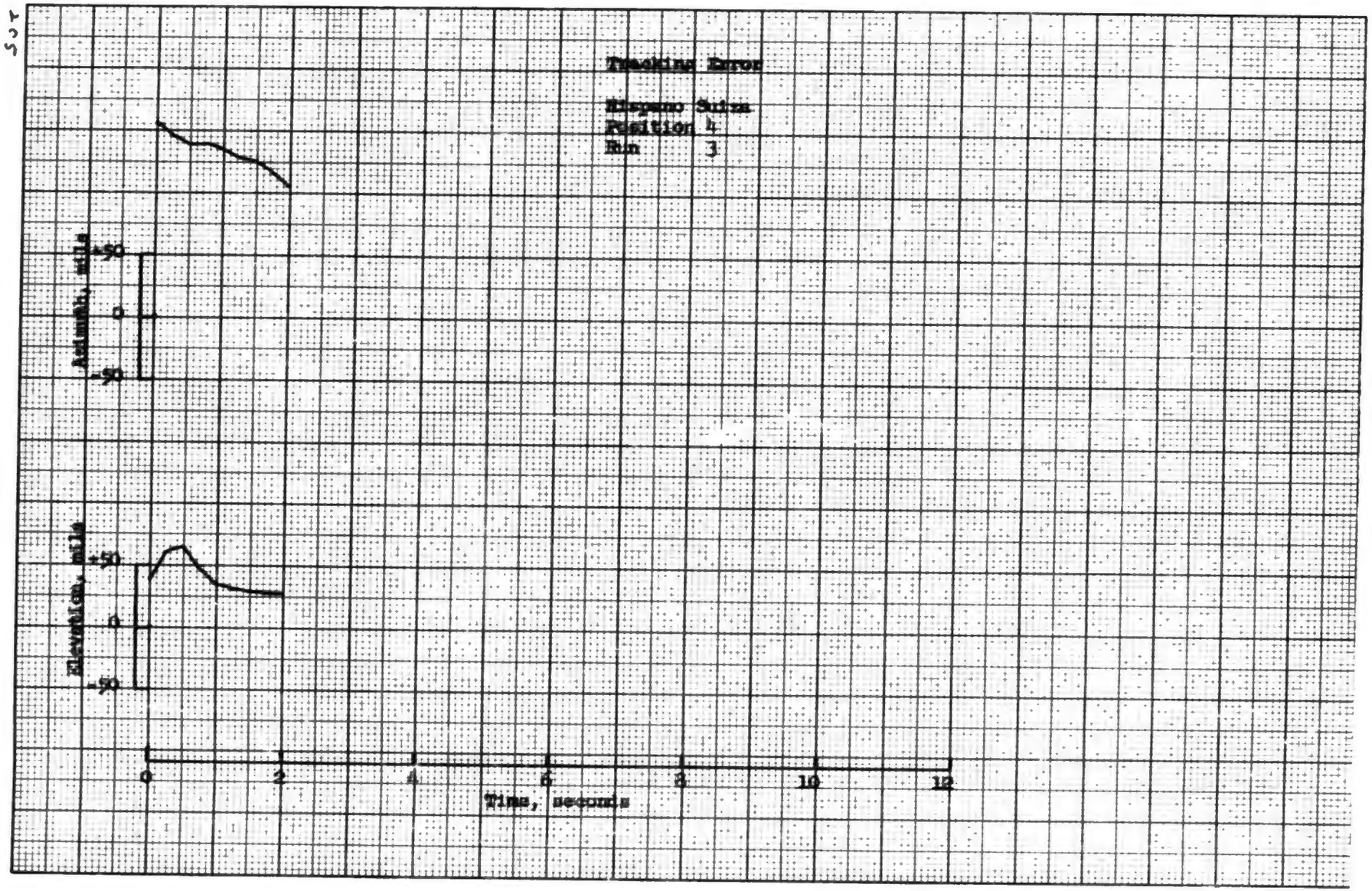

Tracking Error
Ringmo Sutra
Position 4
Run 3
Azimuth, mils
+50
0
-50
Elevation, mils
+50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure 103-I

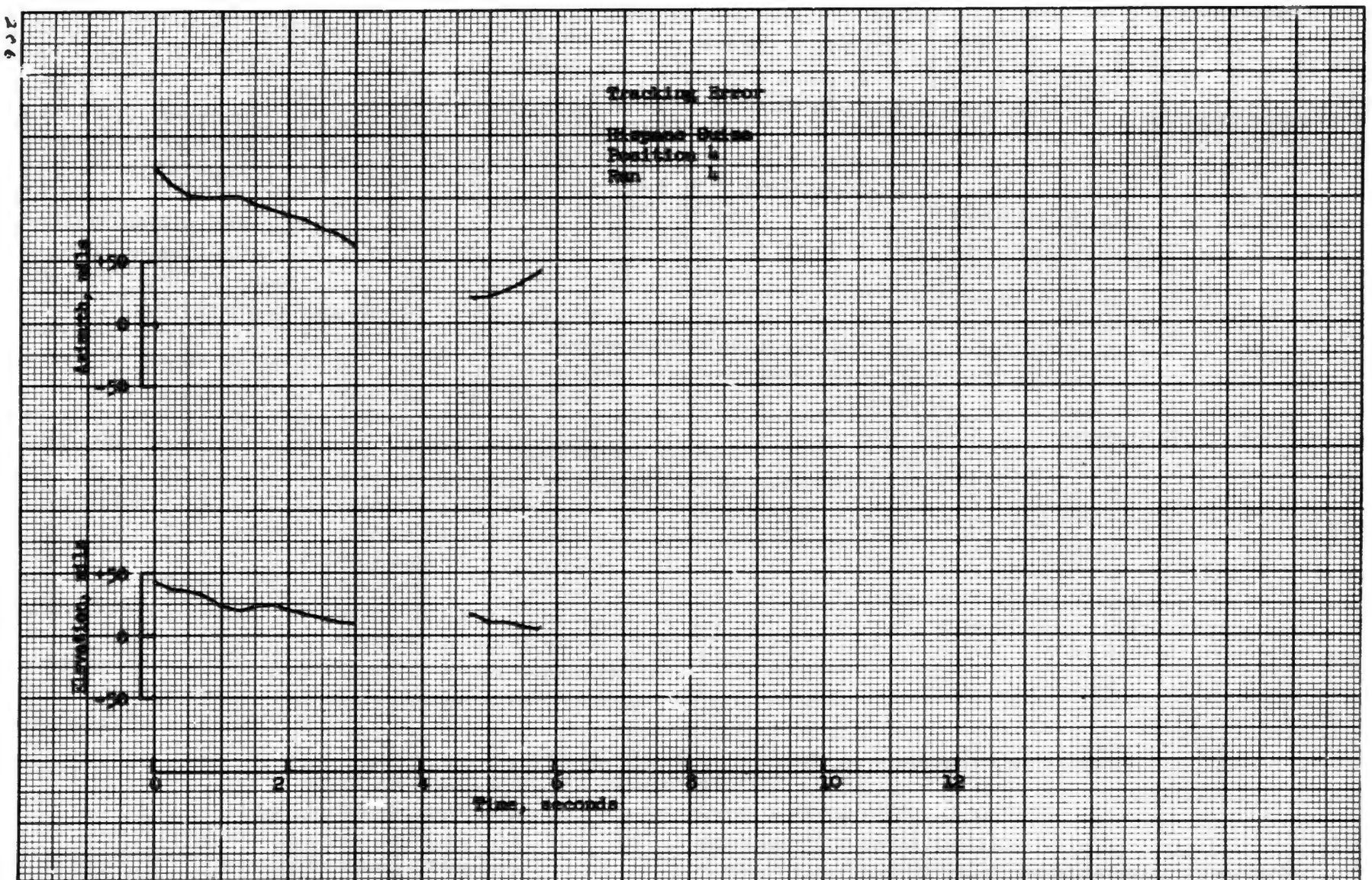

Tracking Error
Elevation, mils
+50
0
-50
Azimuth, mils
+50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure 104-I

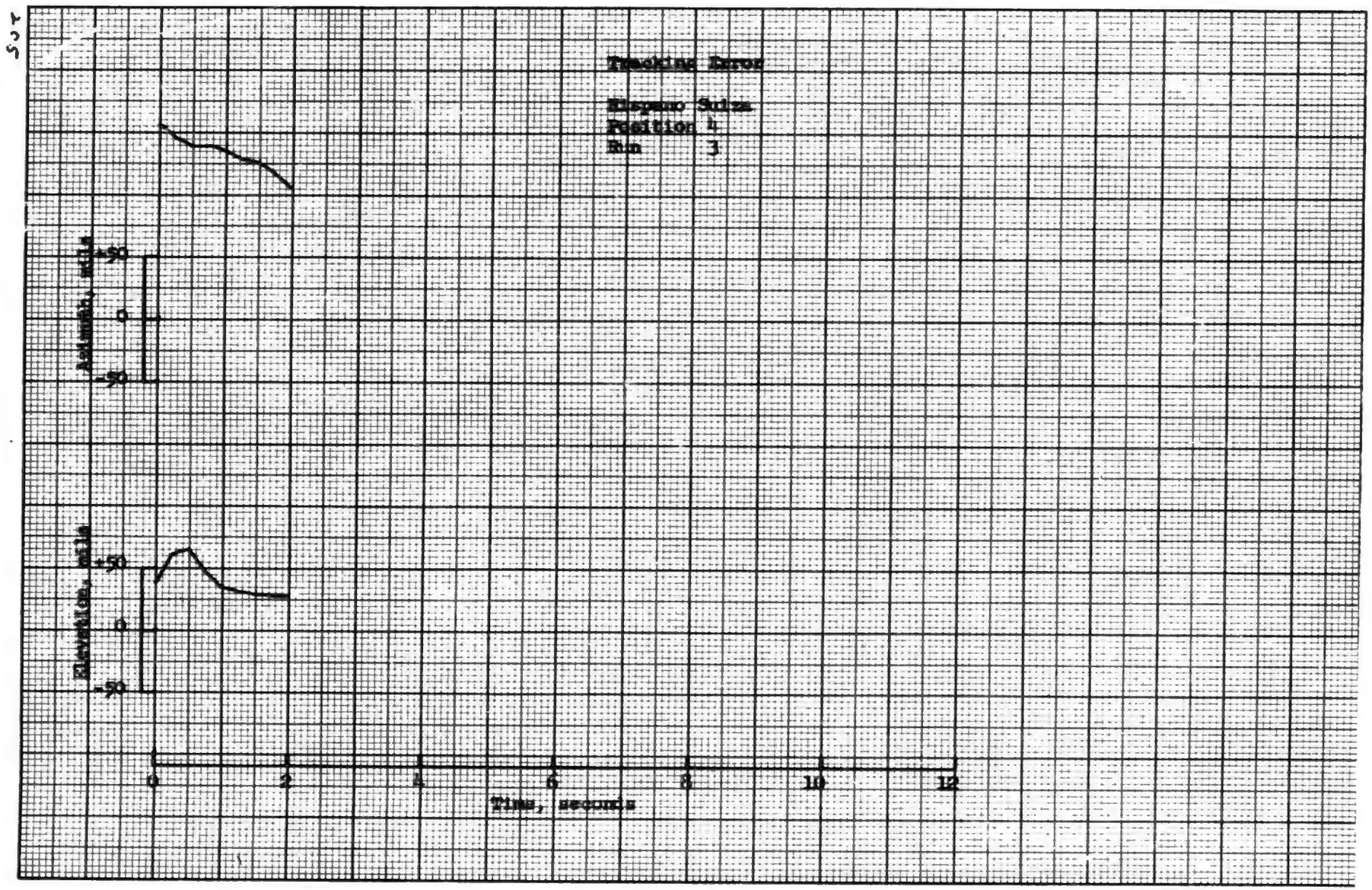

Tracking Error
Diagramo Suiza
Position 4
Run 3
Azimuth, mils
+50
0
-50
Elevation, mils
+50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure 103-I

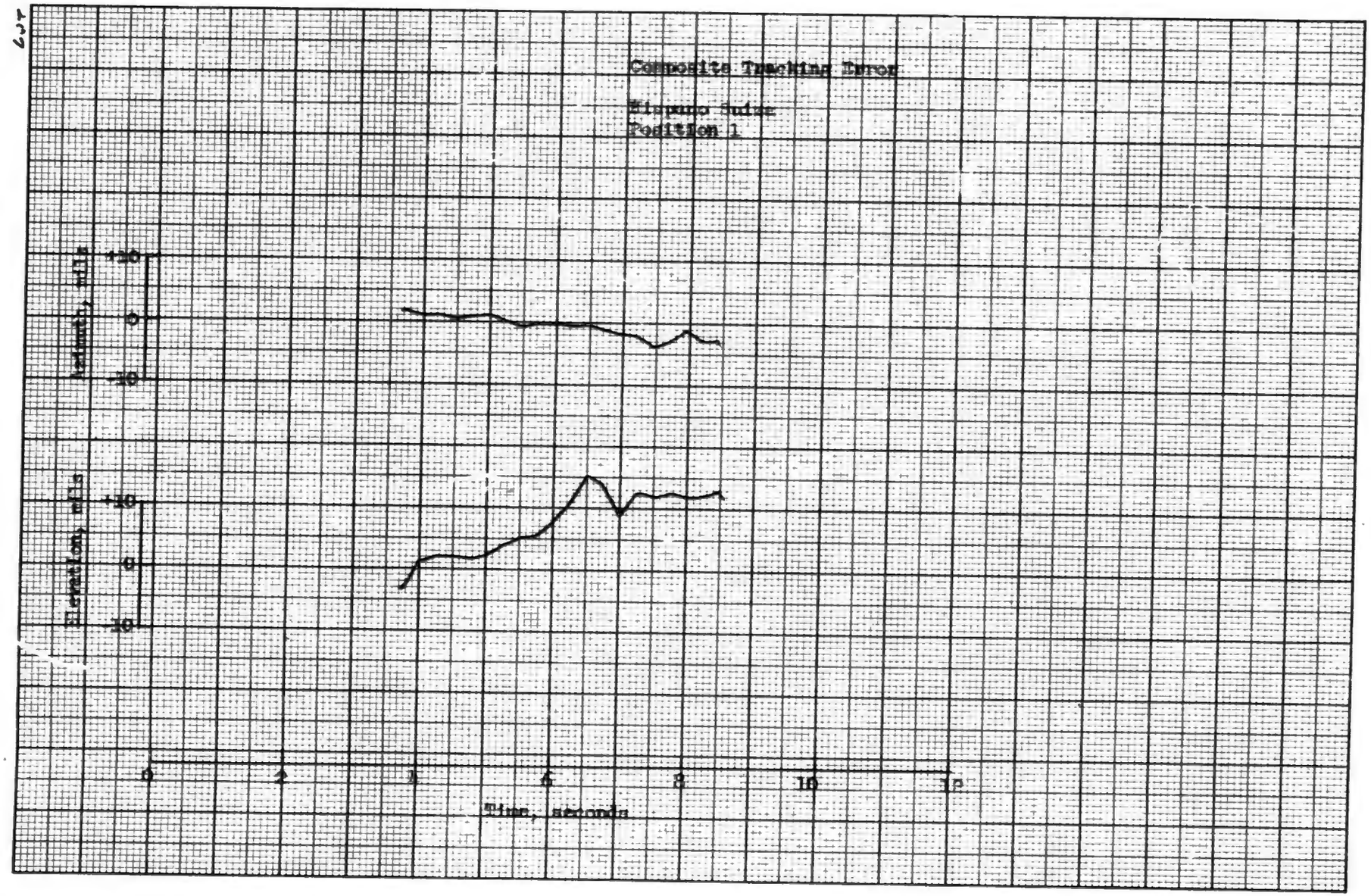

Composite Tracking Error
Simpson Subject
Position 1
Azimuth, mils
+20
0
-20
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 105-I

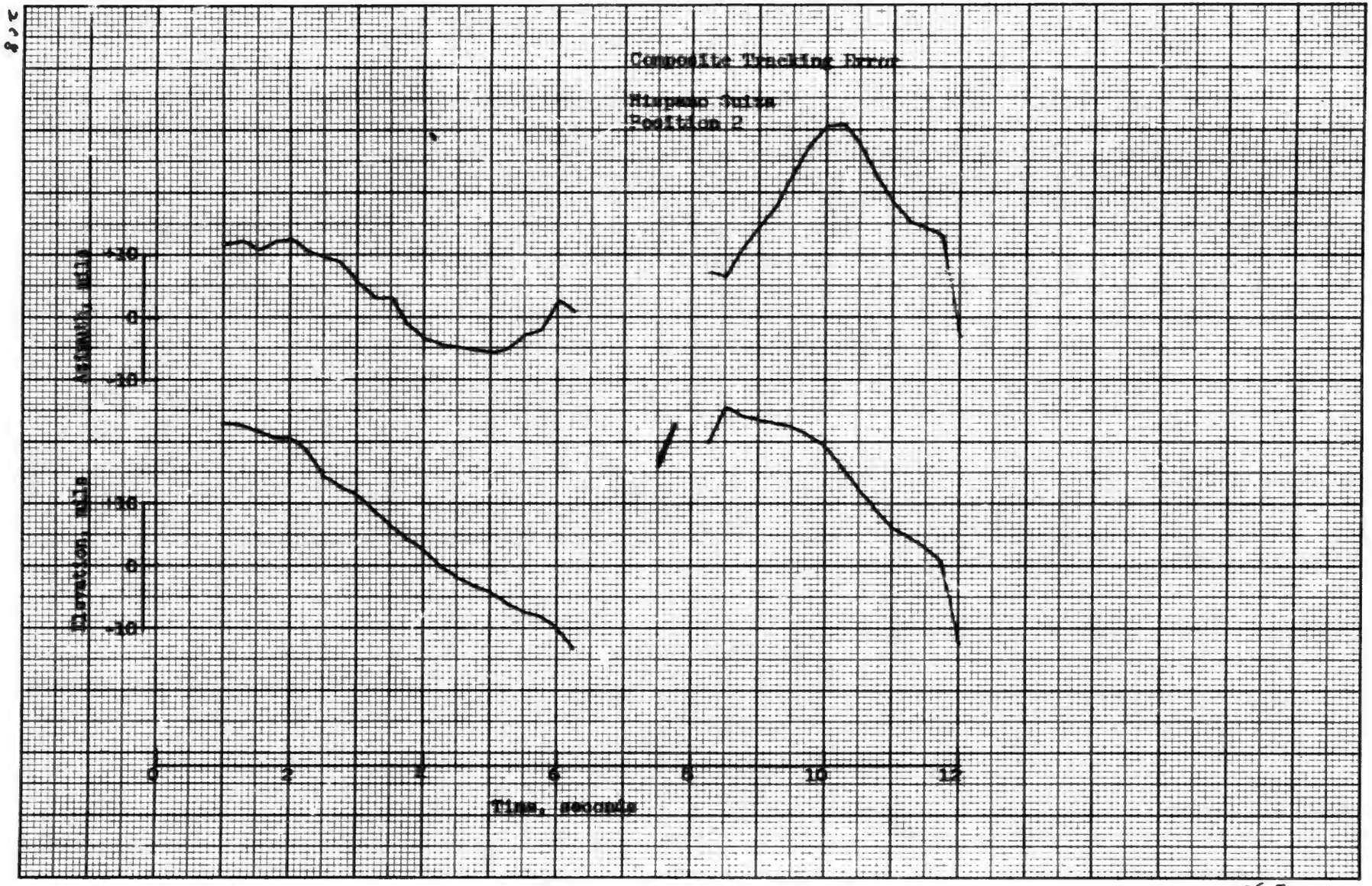

Composite Tracking Error
Hispano Suiza
Position 2
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 106-I

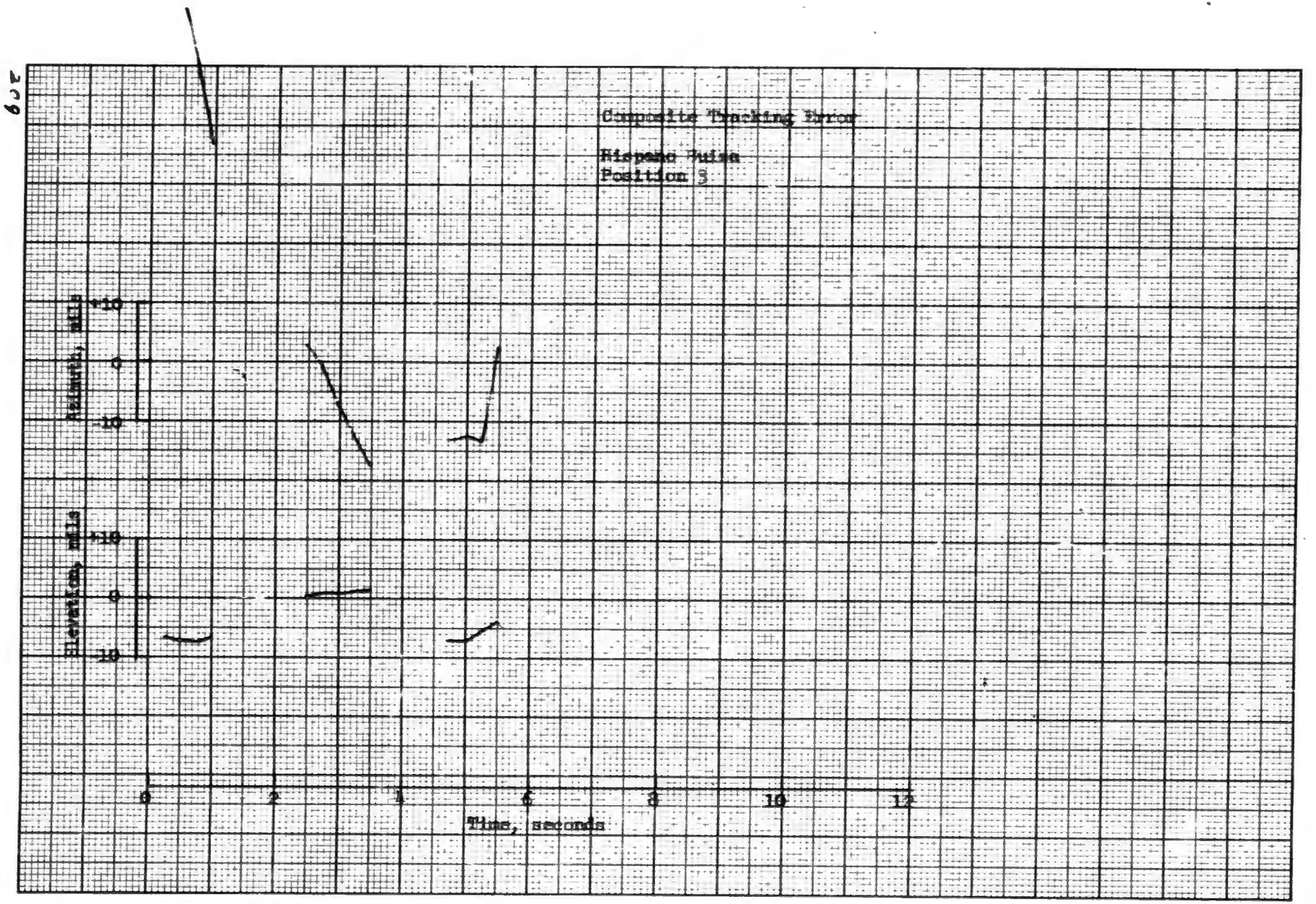

Composite Tracking Error
Response Pulse
Position 3
Azimuth, mils
+10
0
-10
Elevation, mils
+10
0
-10
0
2
4
6
8
10
12
Time, seconds

Figure 107-I

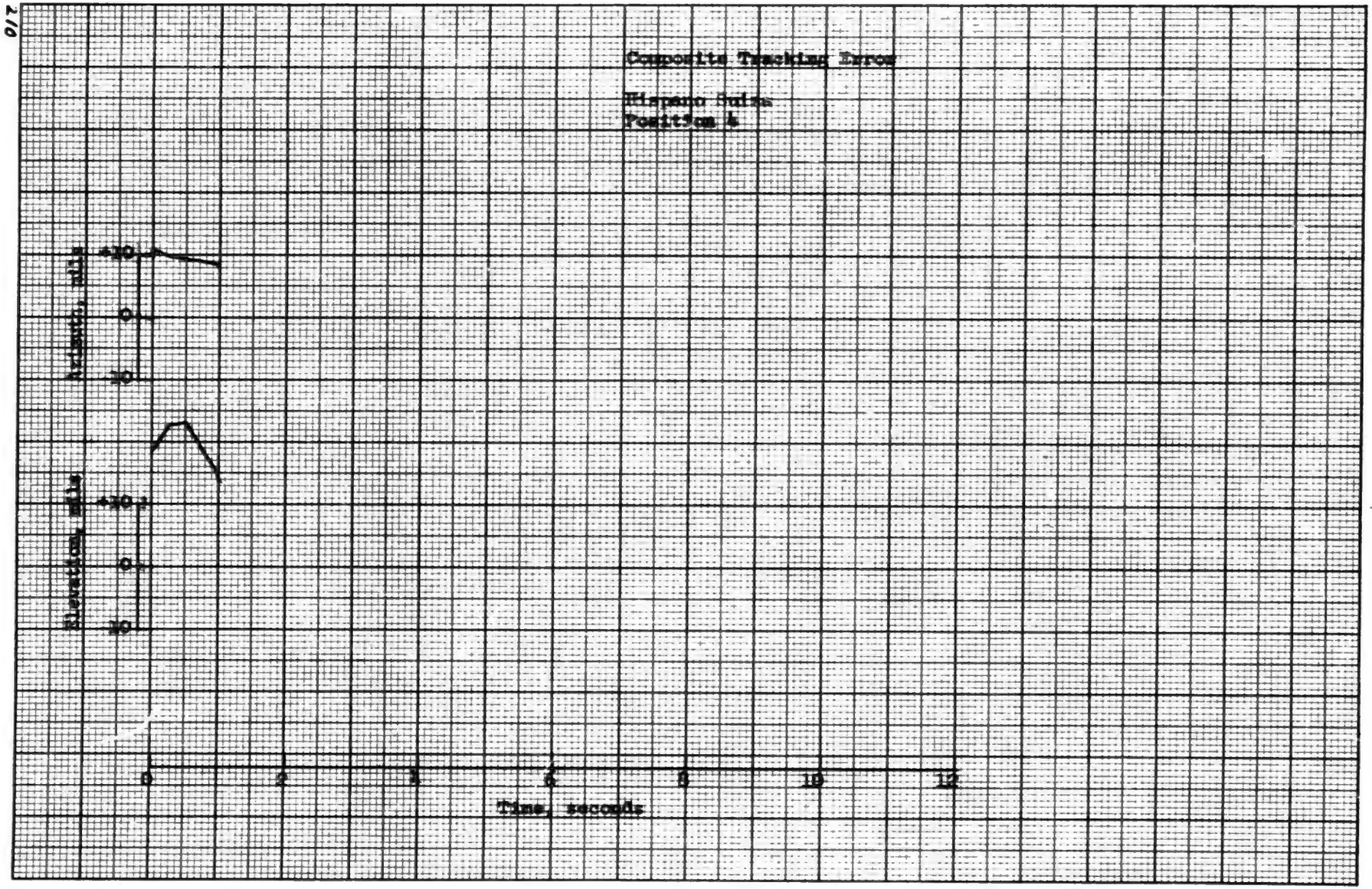

Composite Tracking Error
Mirapaso Suits
Position 5
Elevation, mils
+30
0
-30
Elevation, mils
+30
0
-30
0
2
4
6
8
10
12
Time, seconds

Figure 108-I

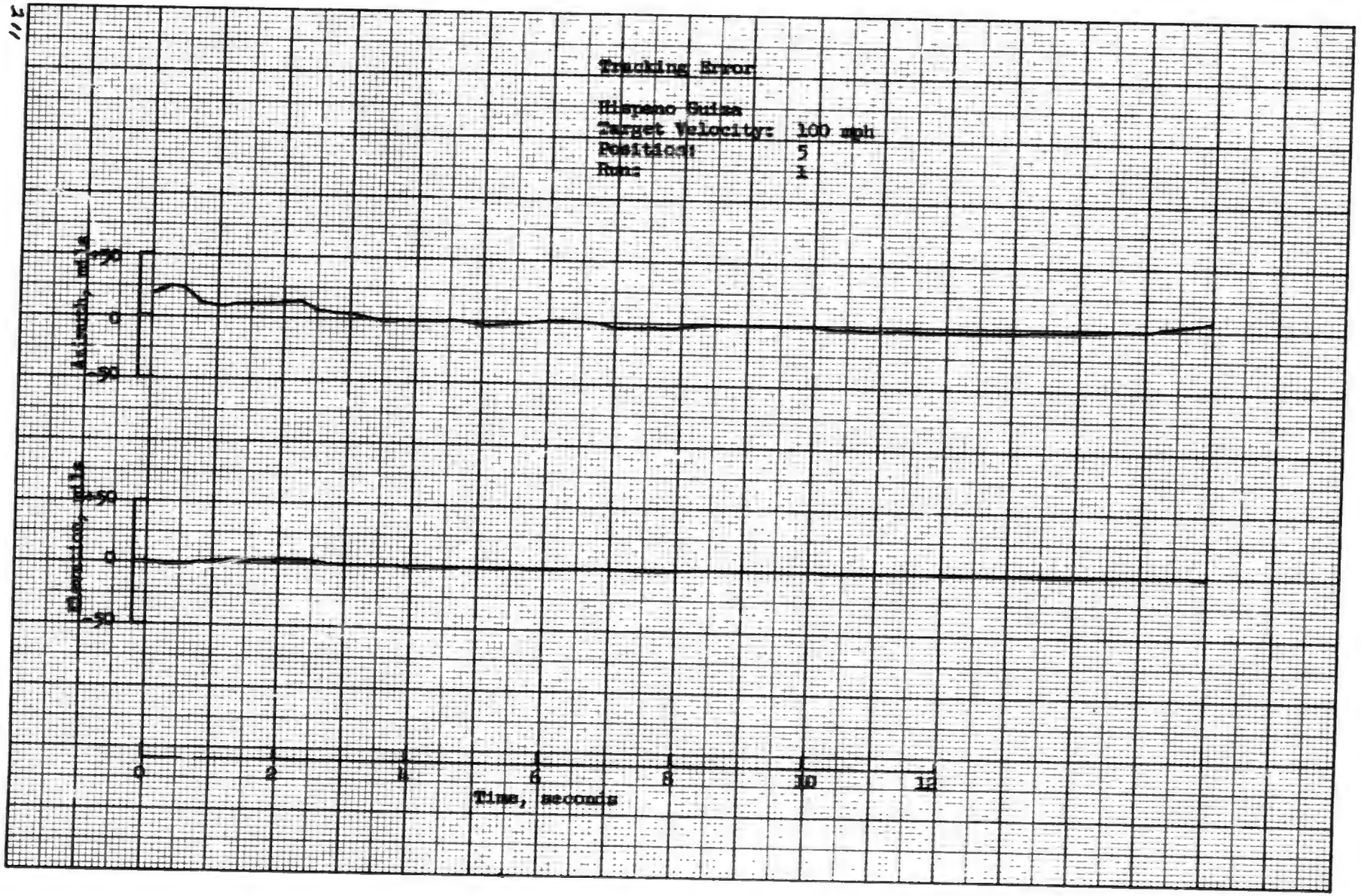

Tracking Error
Hispano Suiza
Target Velocity: 100 mph
Position: 5
Run: 1
+90
0
-90
+90
0
-90
0
2
4
6
8
10
12
Time, seconds

Figure 109-I

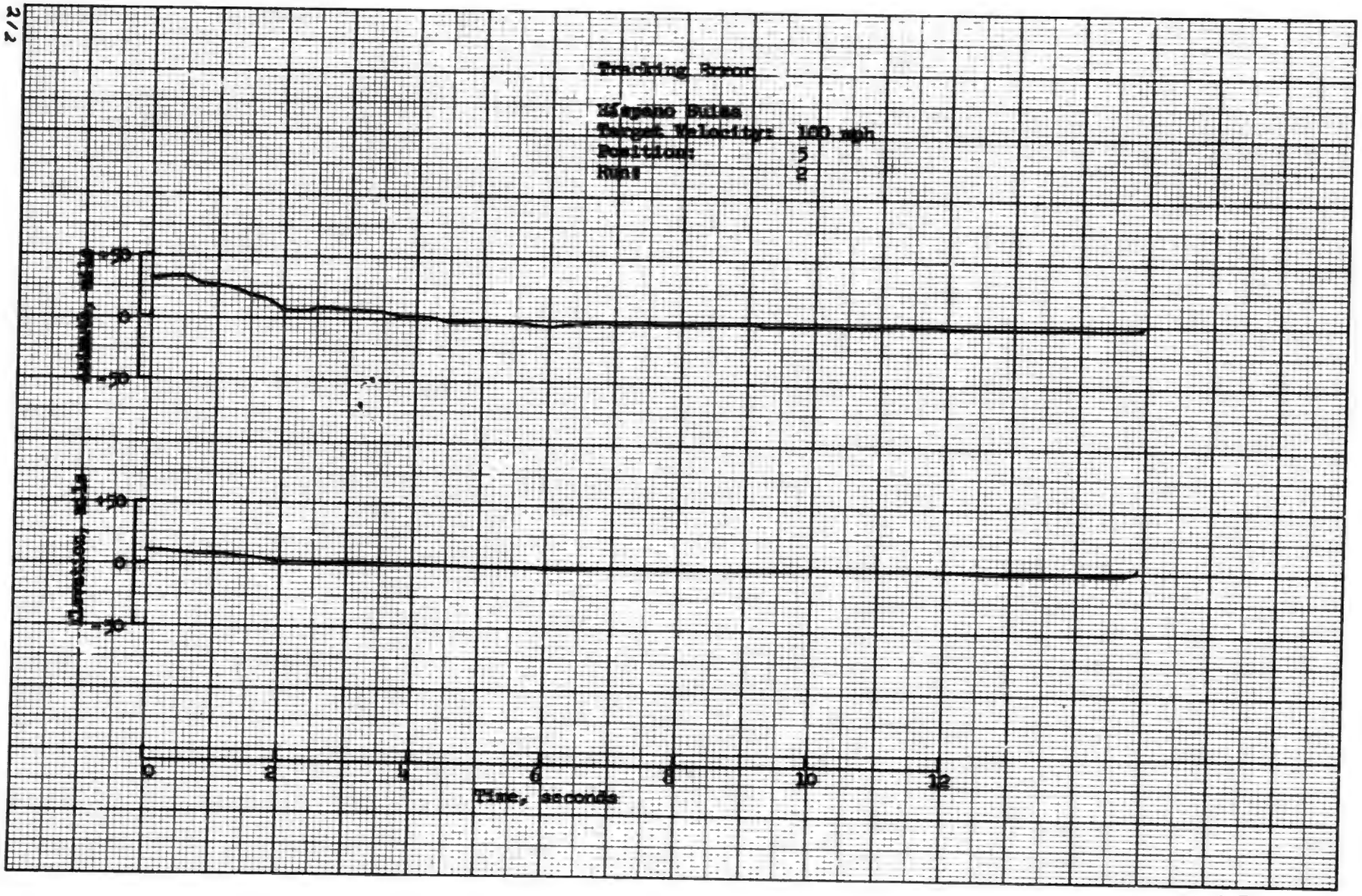

Tracking Error
35 ogive Rates
Target Velocity: 100 mph
Position: 5
Run: 2
+30
0
-30
+30
0
-30
0
2
4
6
8
10
12
Time, seconds

Figure 110-I

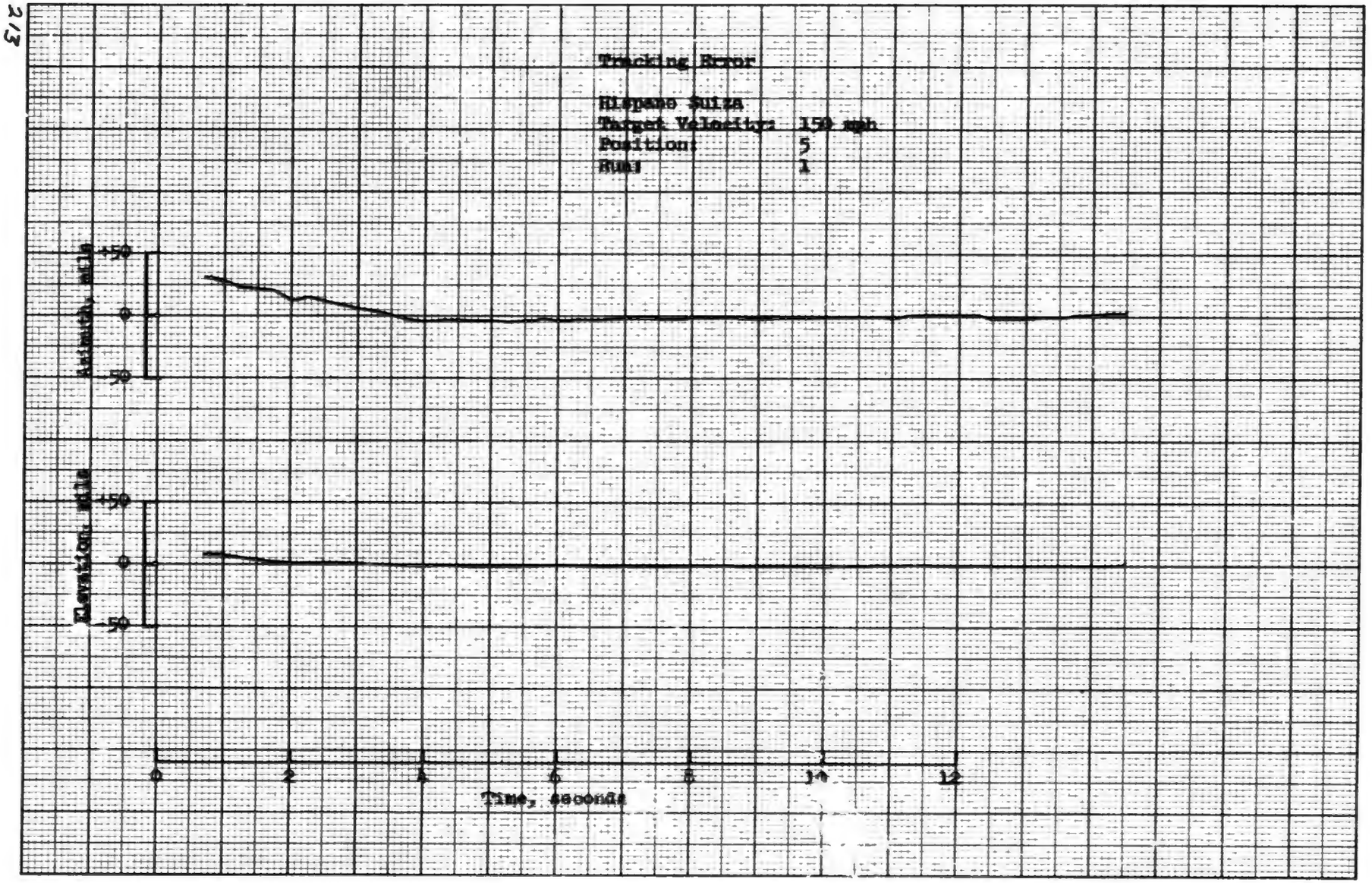

Tracking Error
Hispano Suiza
Target Velocity: 150 mph
Position: 5
Run: 1
Azimuth, mils
+50
0
-50
Elevation, mils
+50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure III-I

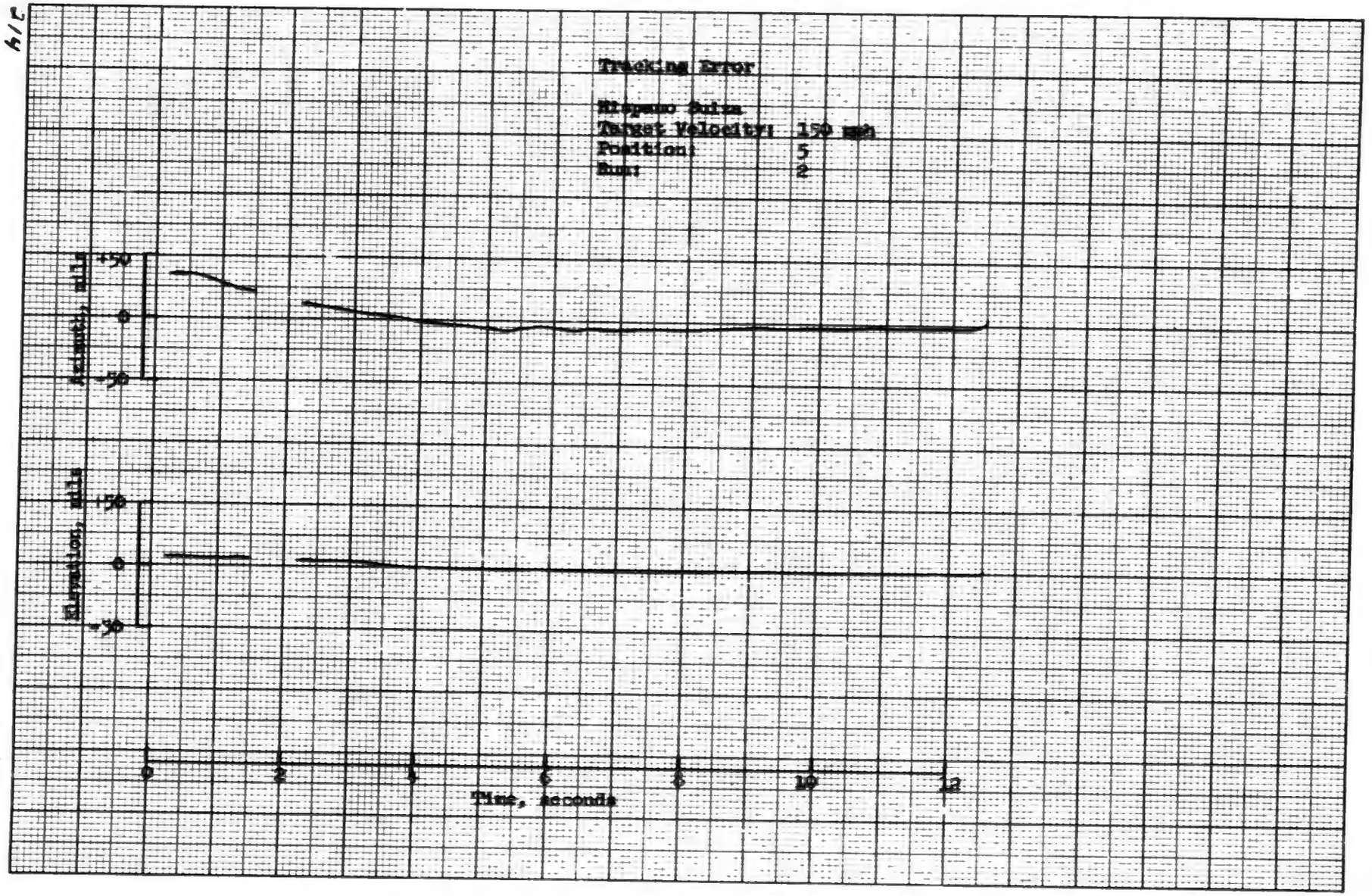

Tracking Error
Response Curve
Target Velocity: 150 mph
Position: 5
Run: 2
+50
0
-50
Elevation, inches
+50
0
-50
Azimuth, inches
0
2
4
6
8
10
12
Time, seconds

Figure 112-I

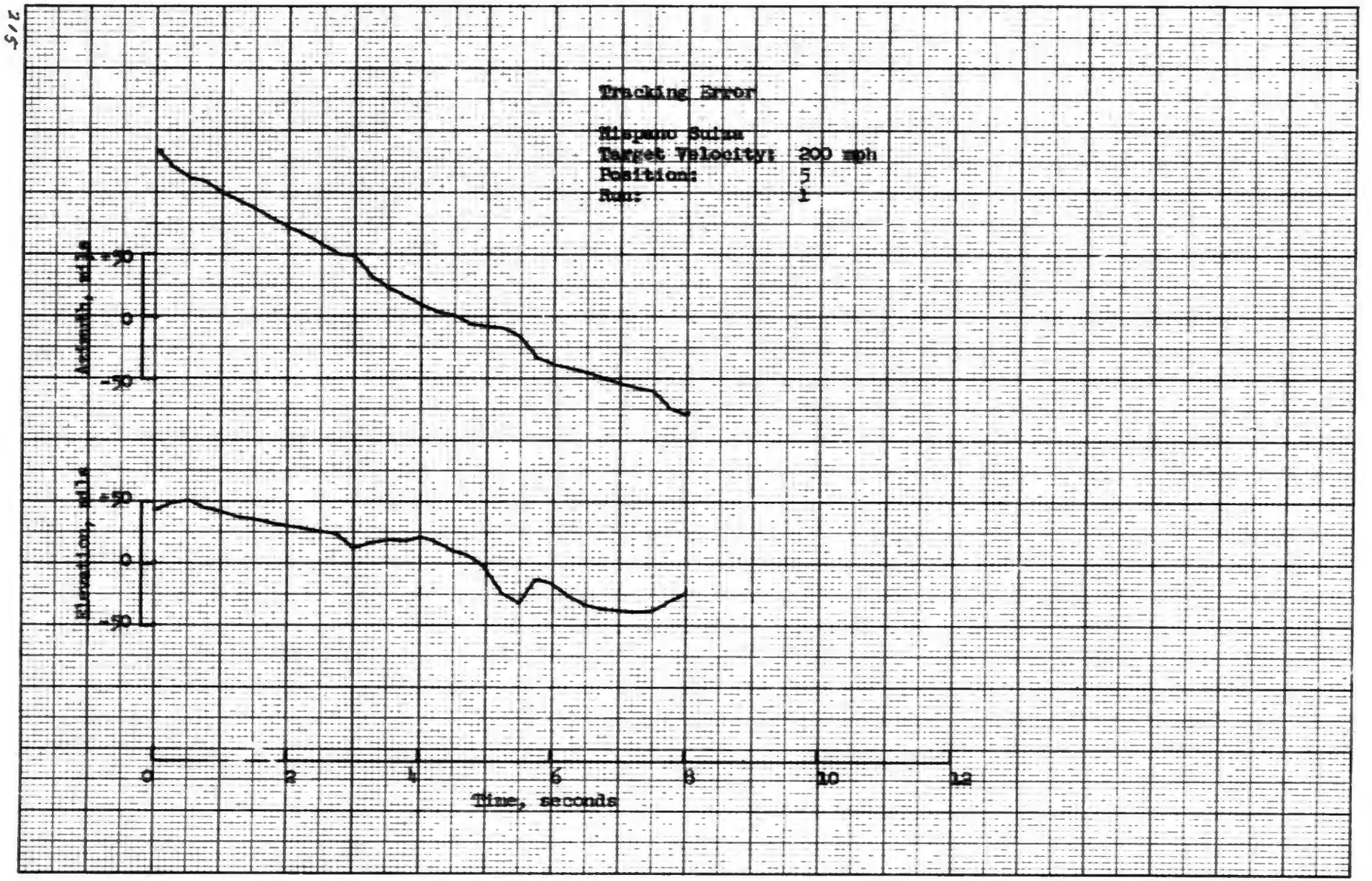

Tracking Error
Hispano Suiza
Target Velocity: 200 mph
Position: 5
Run: 1
Azimuth, mils
+50
0
-50
Elevation, mils
+50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure 113-I

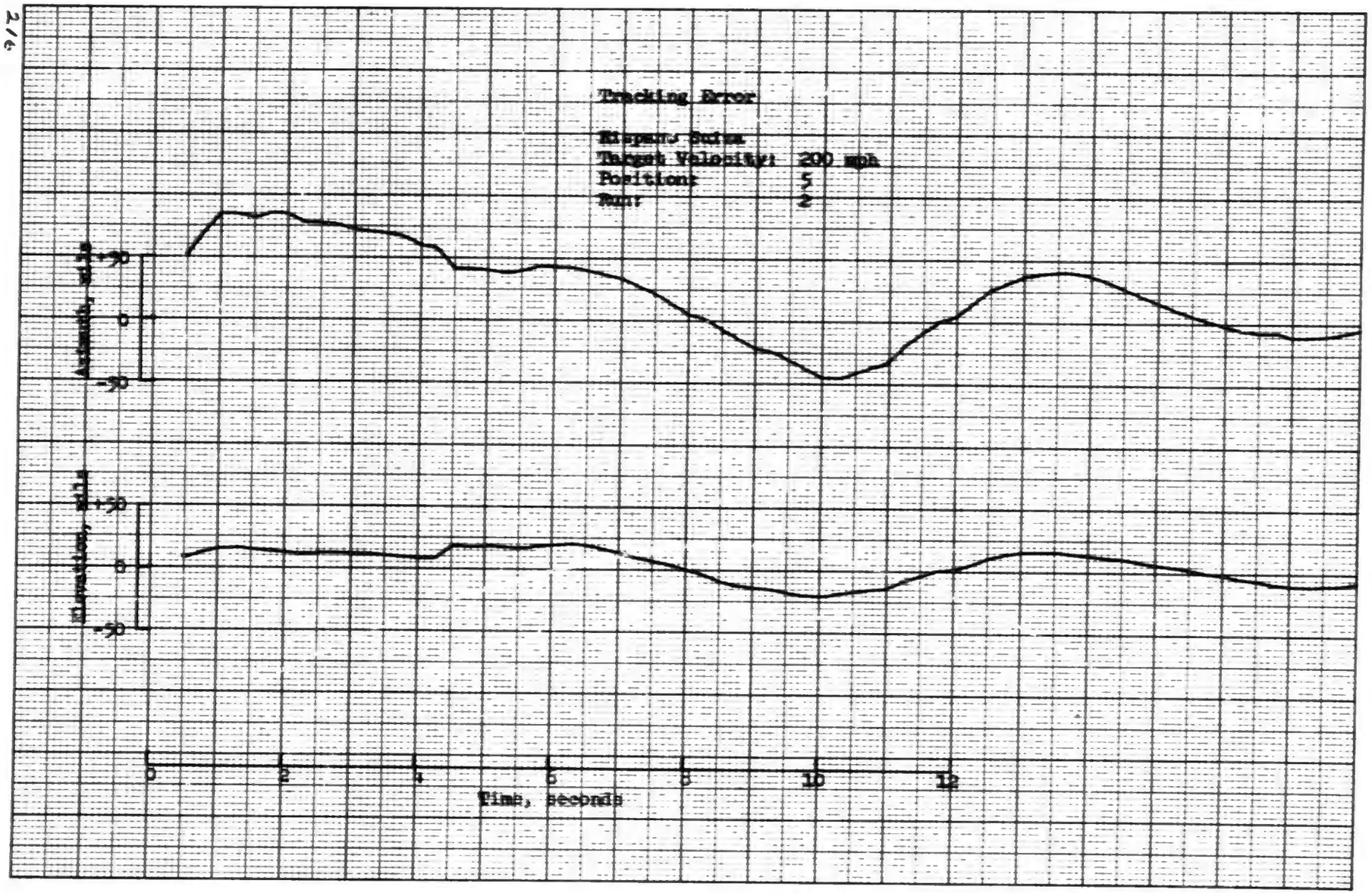

Tracking Error
Response Setup
Target Velocity: 200 mph
Position: 5
Run: 2
+30
0
-30
+30
0
-30
0
2
4
6
8
10
12
Time, Seconds

Figure 114-I

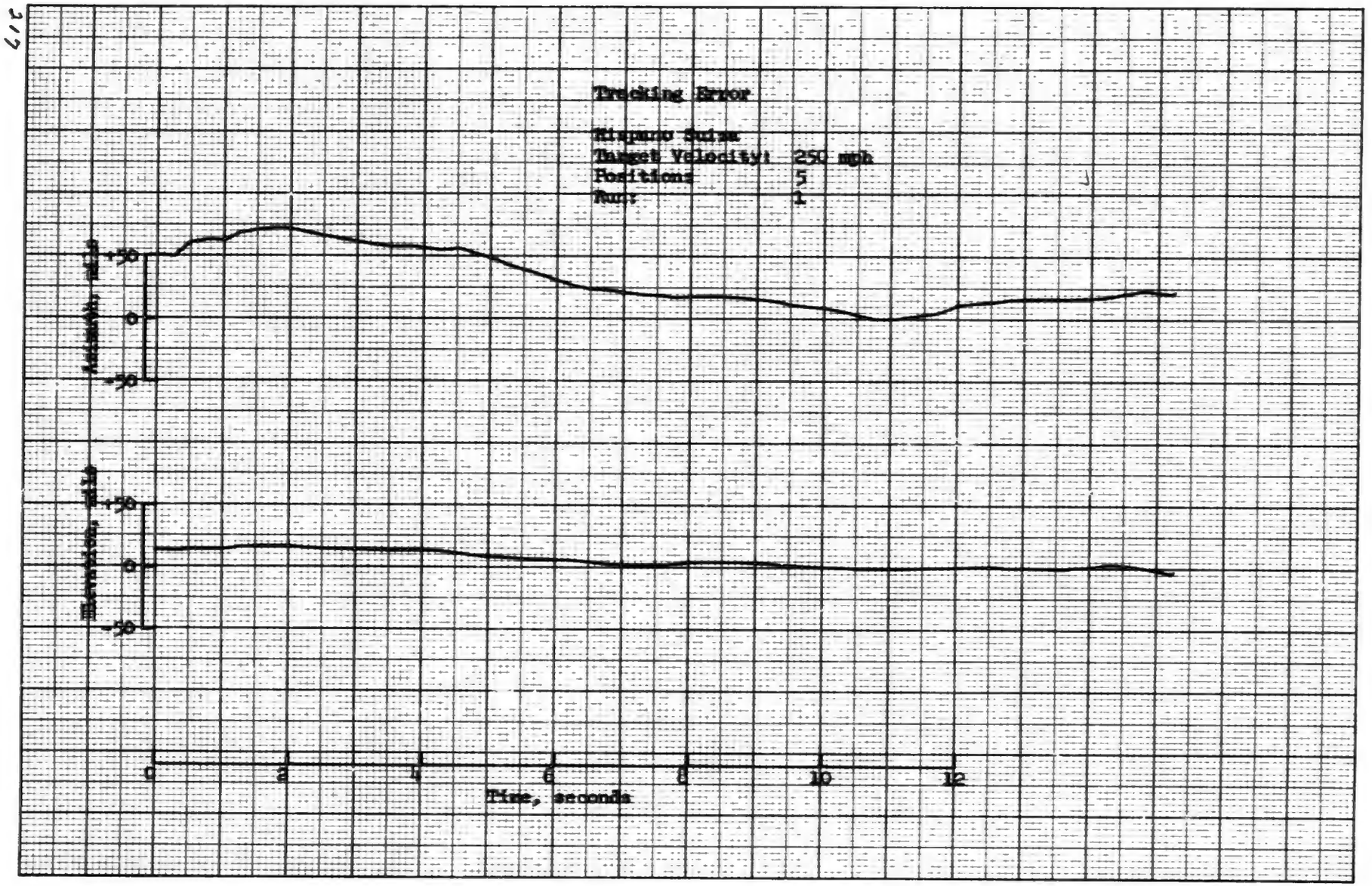

Tracking Error
Higgins Guns
Target Velocity: 250 mph
Position: 5
Run: 1
+50
0
-50
+50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure 115-I

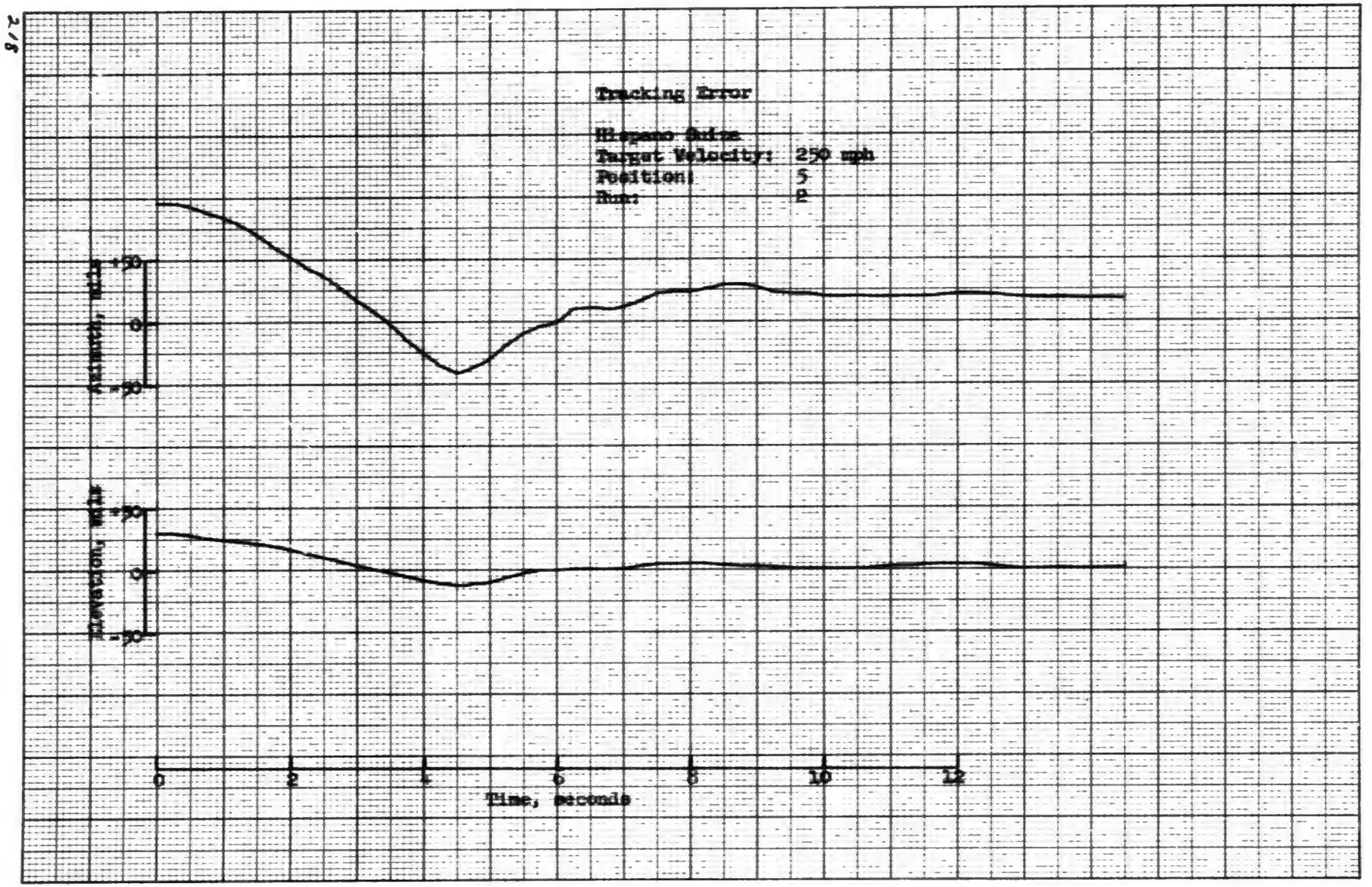

Tracking Error
Hispano Suiza
Target Velocity: 250 mph
Position: 5
Run: 2
+30
0
-30
Time, seconds
0
2
4
6
8
10
12

Figure 116-I

Tracking Error
Ringmo Sight
Target Velocity: 300 mph
Positions:
Run
Elevation, mils
Deflection, mils
Time, seconds
0
4
8
12
16
+50
0
-50

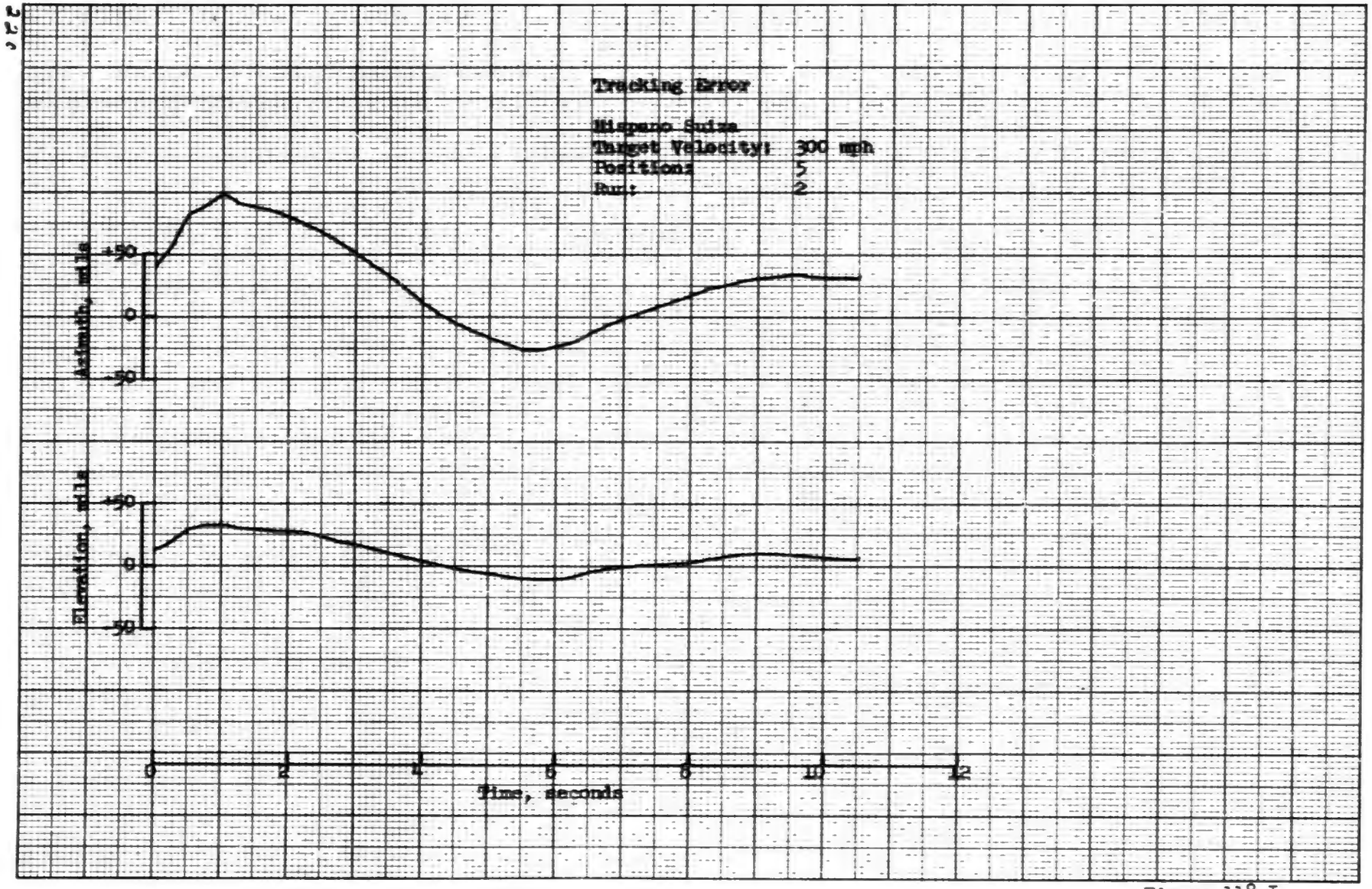

Tracking Error
Hispano Suiza
Target Velocity: 300 mph
Position: 5
Run: 2
Azimuth, mils
+50
0
-50
Elevation, mils
+50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure 118-I

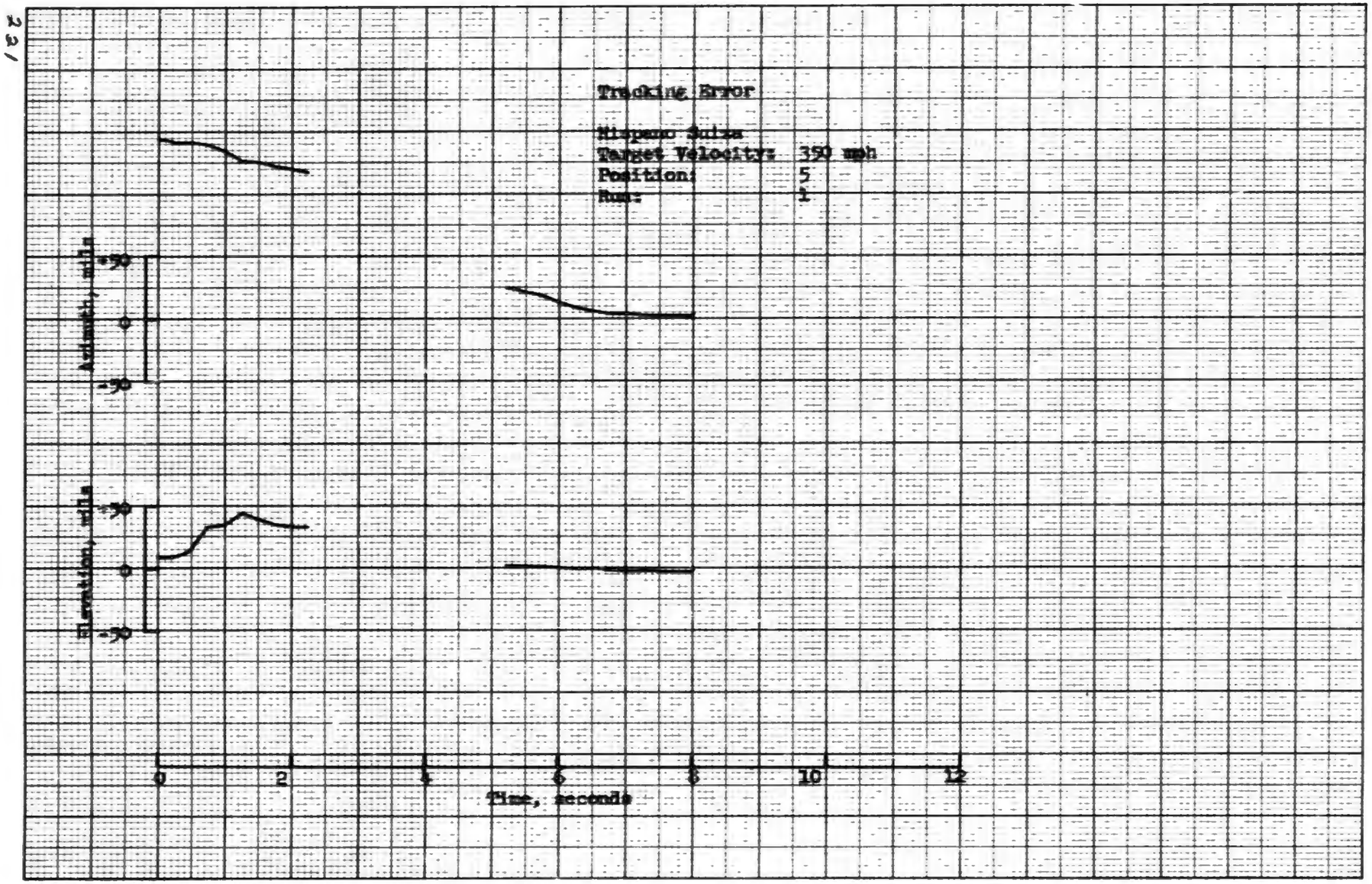

Tracking Error
Missouo Sulpa
Target Velocity: 350 mph
Position: 5
Run: 1
Azimuth, mils
+50
0
-50
Elevation, mils
+50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure 119 I

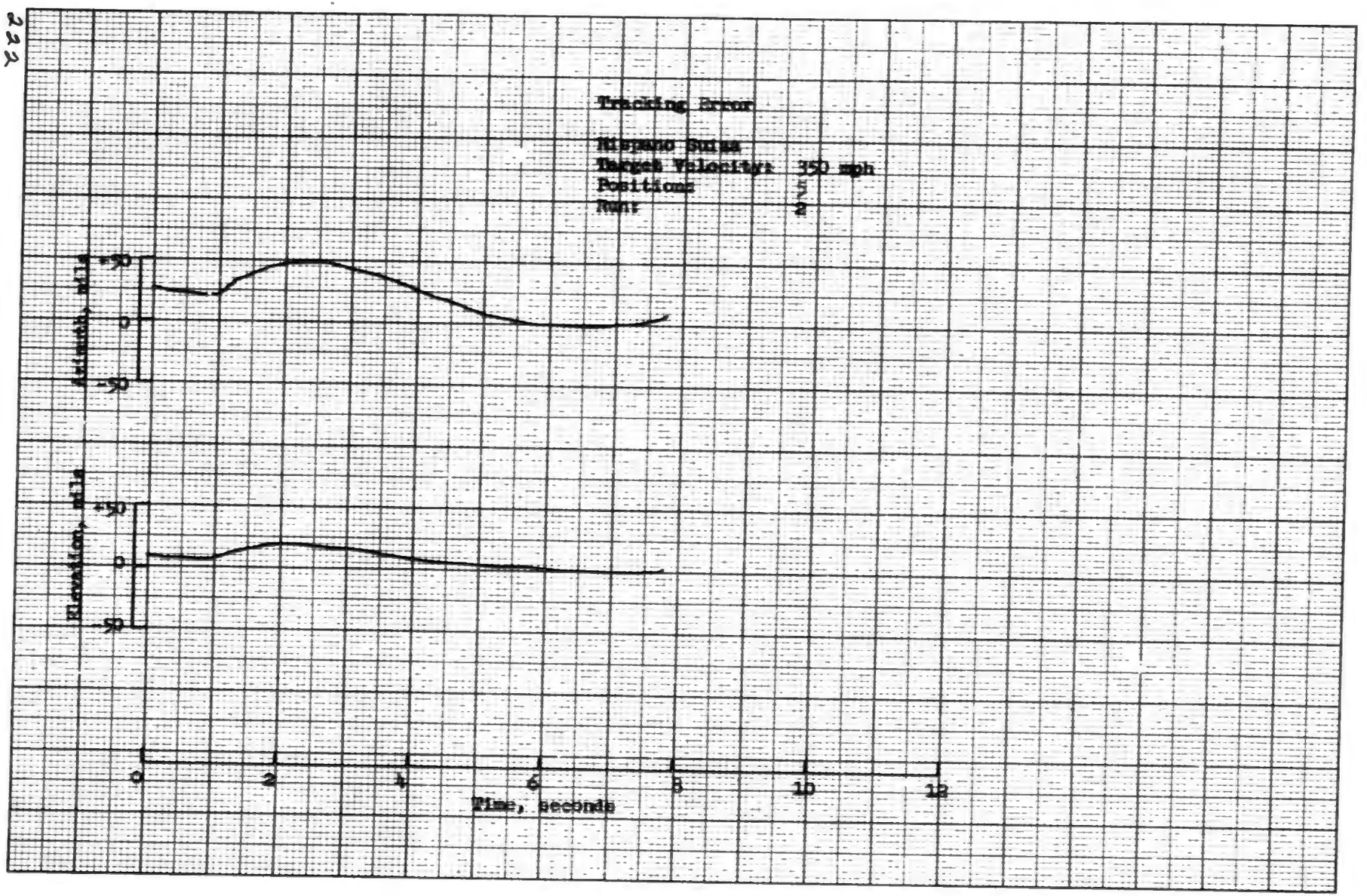

Tracking Error
Hispano Suiza
Target Velocity: 350 mph
Position: 5
Run: 2
Azimuth, mils
+50
0
-50
Elevation, mils
+50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure 120-I

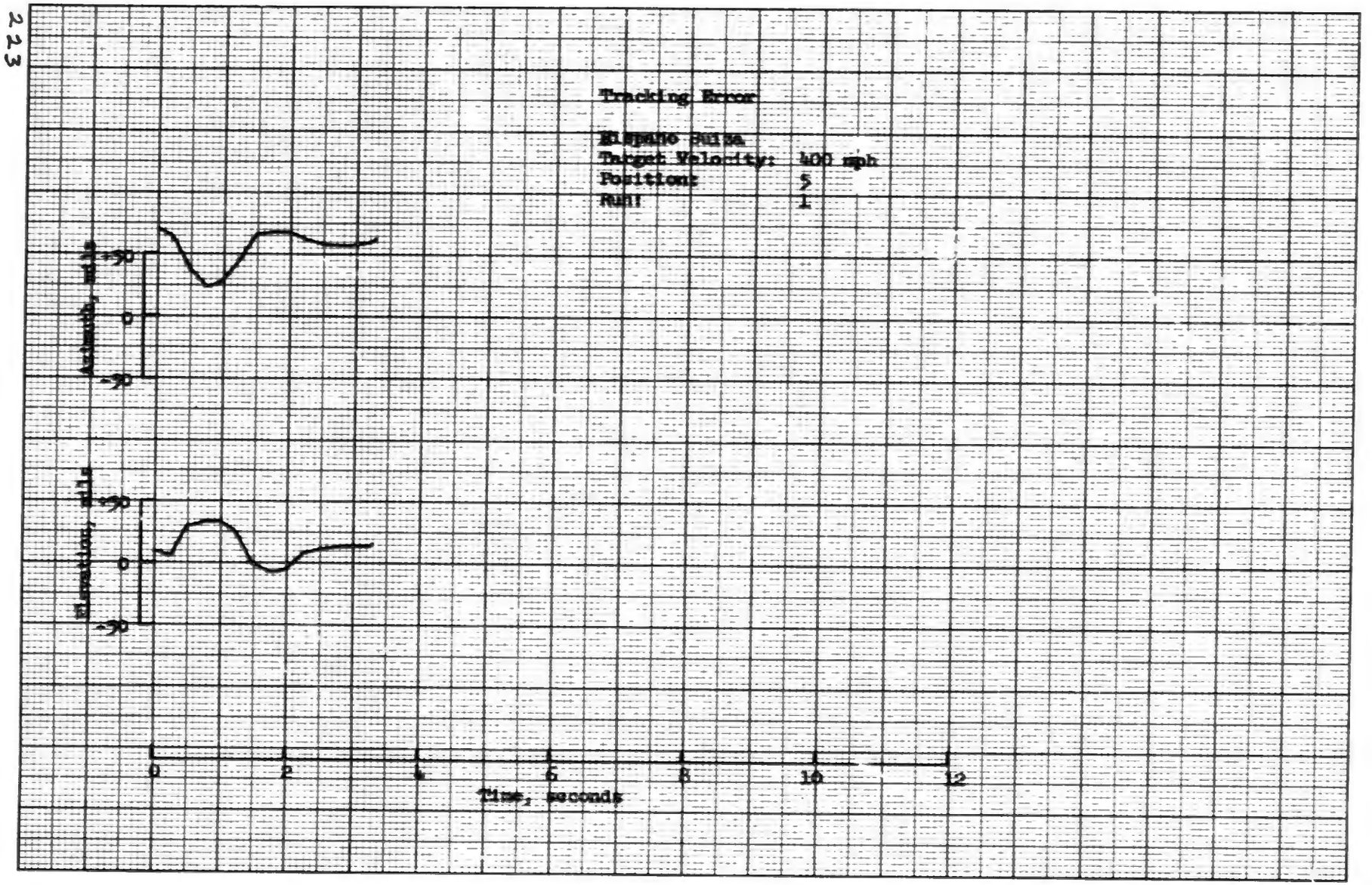

Tracking Error
Target Velocity: 400 mph
Position: 5
Run: 1
+30
0
-30
Elevation, mils
+30
0
-30
Azimuth, mils
0
2
4
6
8
10
12
Time, seconds

Figure 121 I

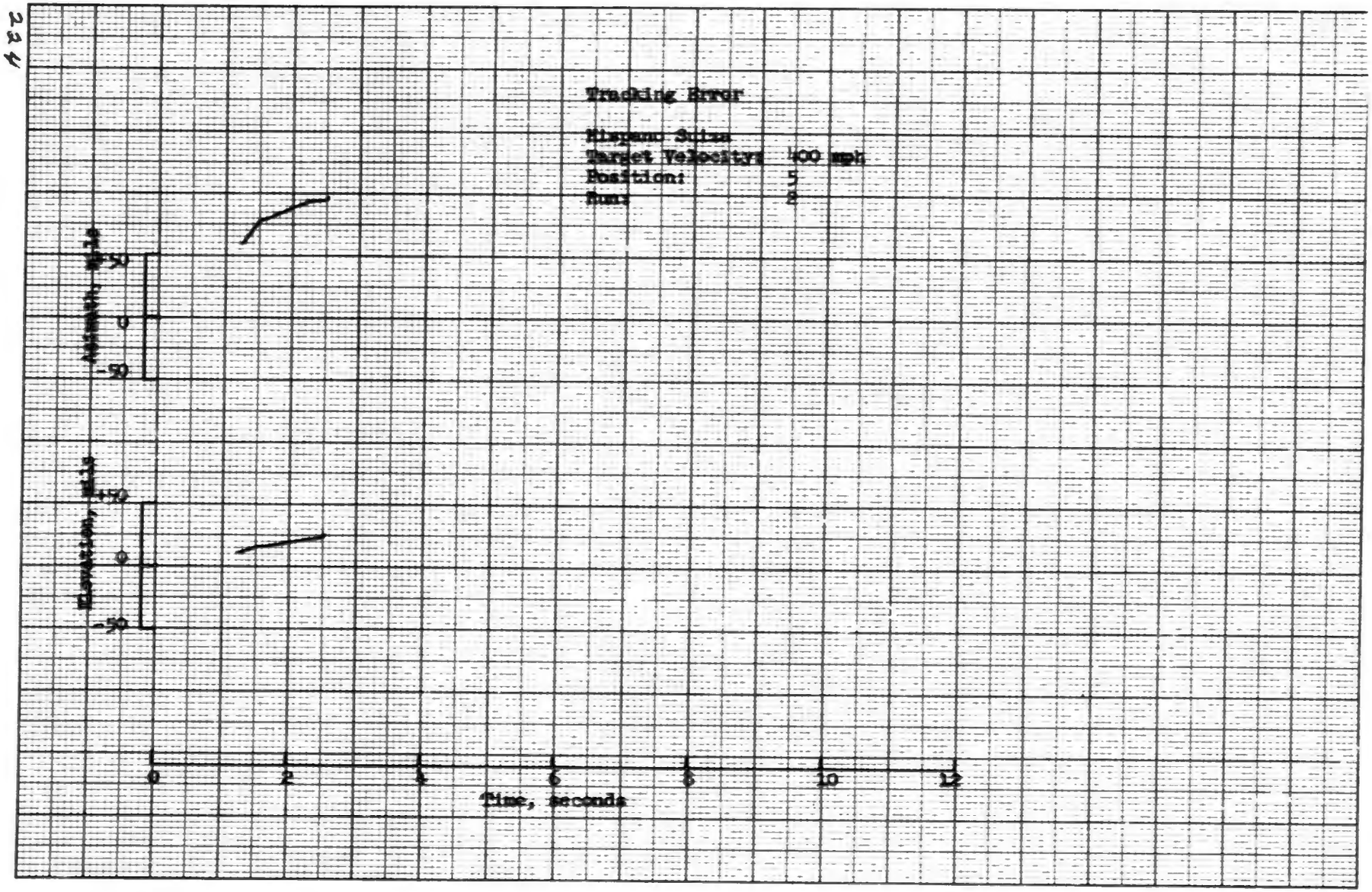

Tracking Error
Diagram Sulzu
Target Velocity: 400 mph
Position: 5
Run: 8
+50
0
-50
+50
0
-50
0
2
4
6
8
10
12
Time, seconds

Figure 122-I

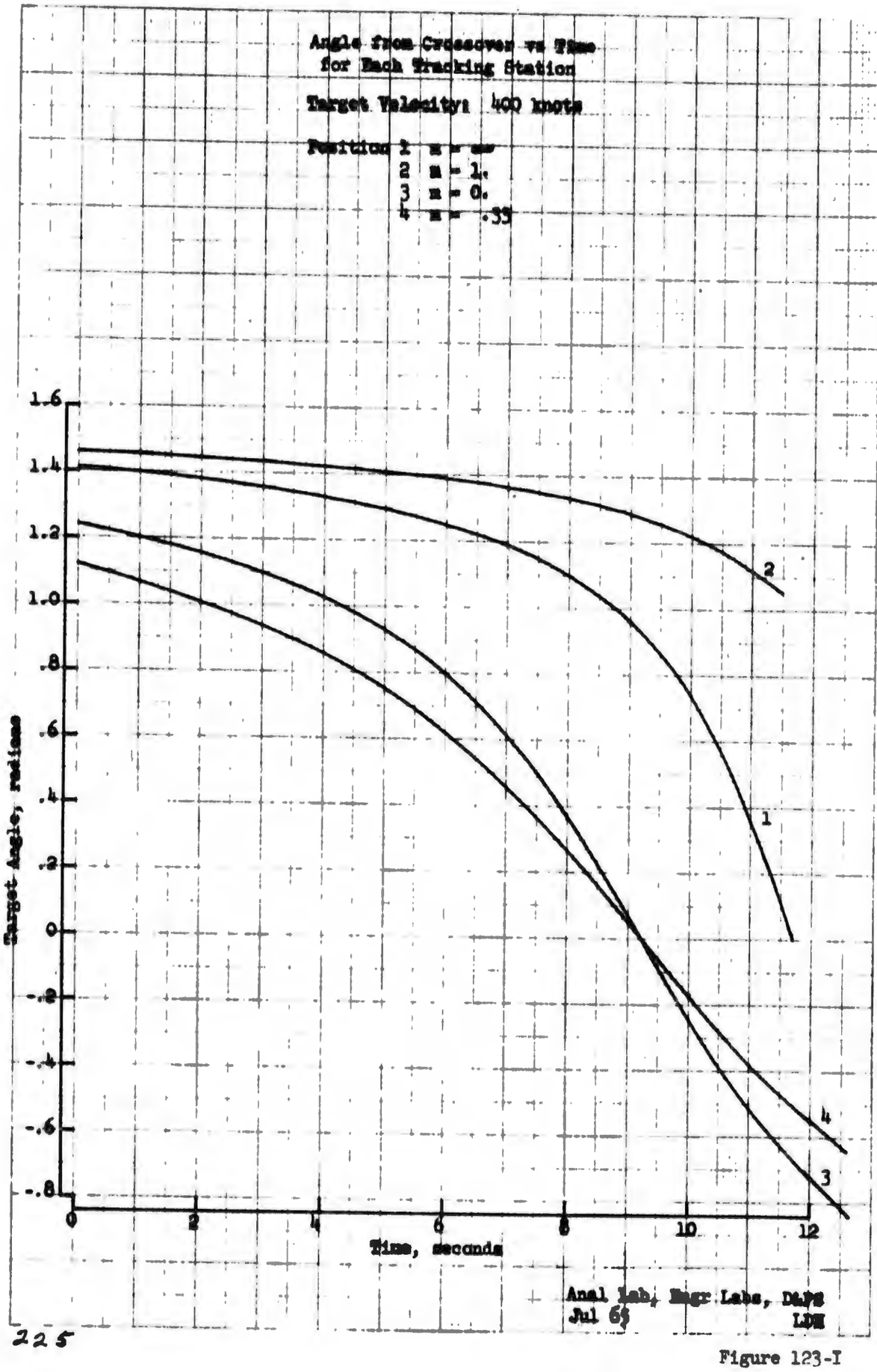

Angle from Crossover vs Time
for Each Tracking Station
Target Velocity: 400 knots
Position 1 m = ∞
2 m = 1.
3 m = 0.
4 m = -.55
Target Angle, radians
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
-.2
-.4
-.6
-.8
0
2
4
6
8
10
12
Time, seconds
1
2
3
4
Anal Lab, Engr Labs, D&PS
Jul 65
LDM

Figure 123-I

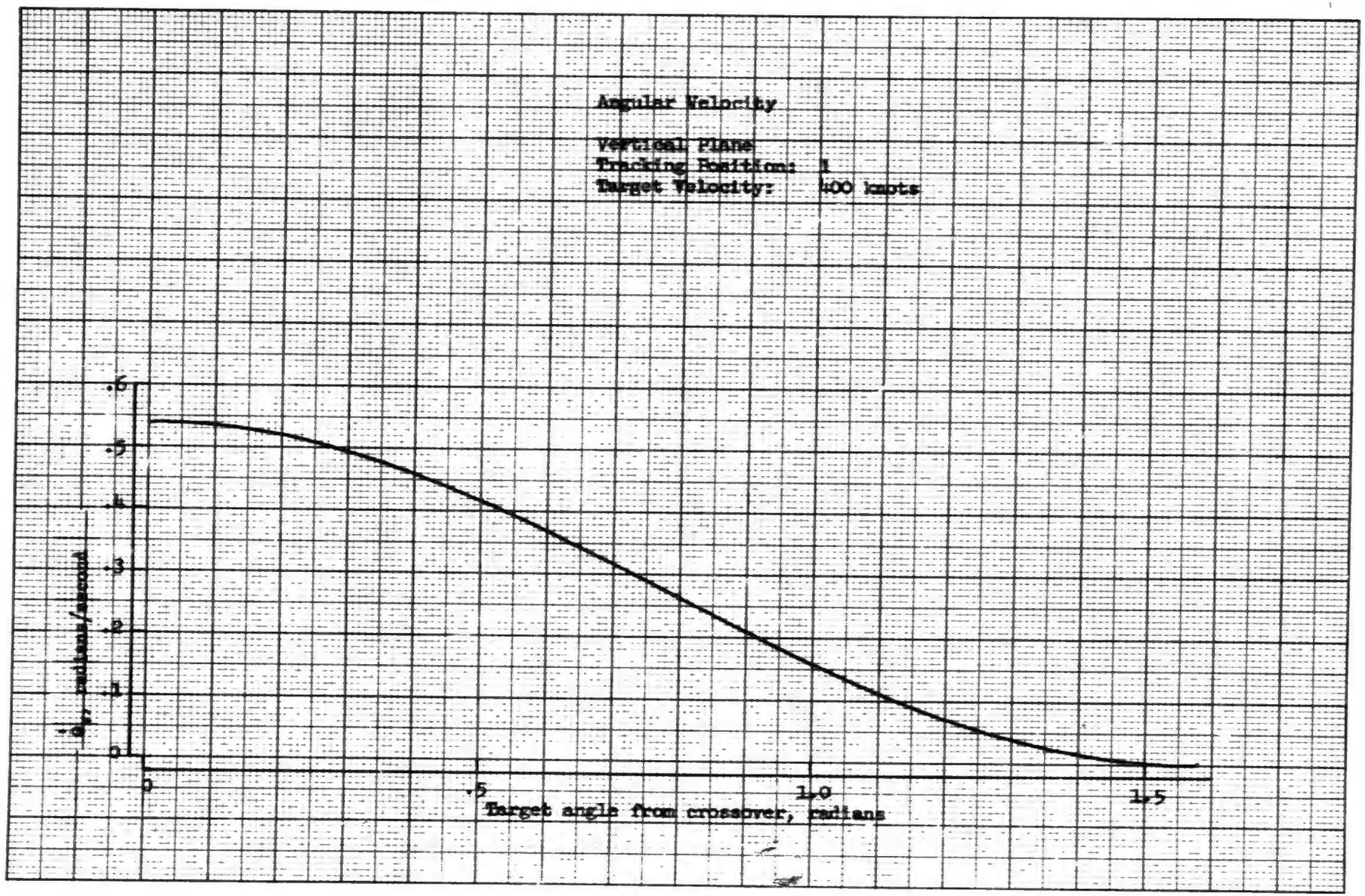

Angular Velocity
Vertical Plane
Tracking Position: 1
Target Velocity: 400 knots
.6
.5
.4
.3
.2
.1
0
Radians/second
0
.5
1.0
1.5
Target angle from crossover, radians

Figure 124-I

Angular Velocity
Horizontal Plane
Tangential Position: 1
Target Velocity 400 knots
0
.5
1.0
1.5
Target angle from crossover, radians

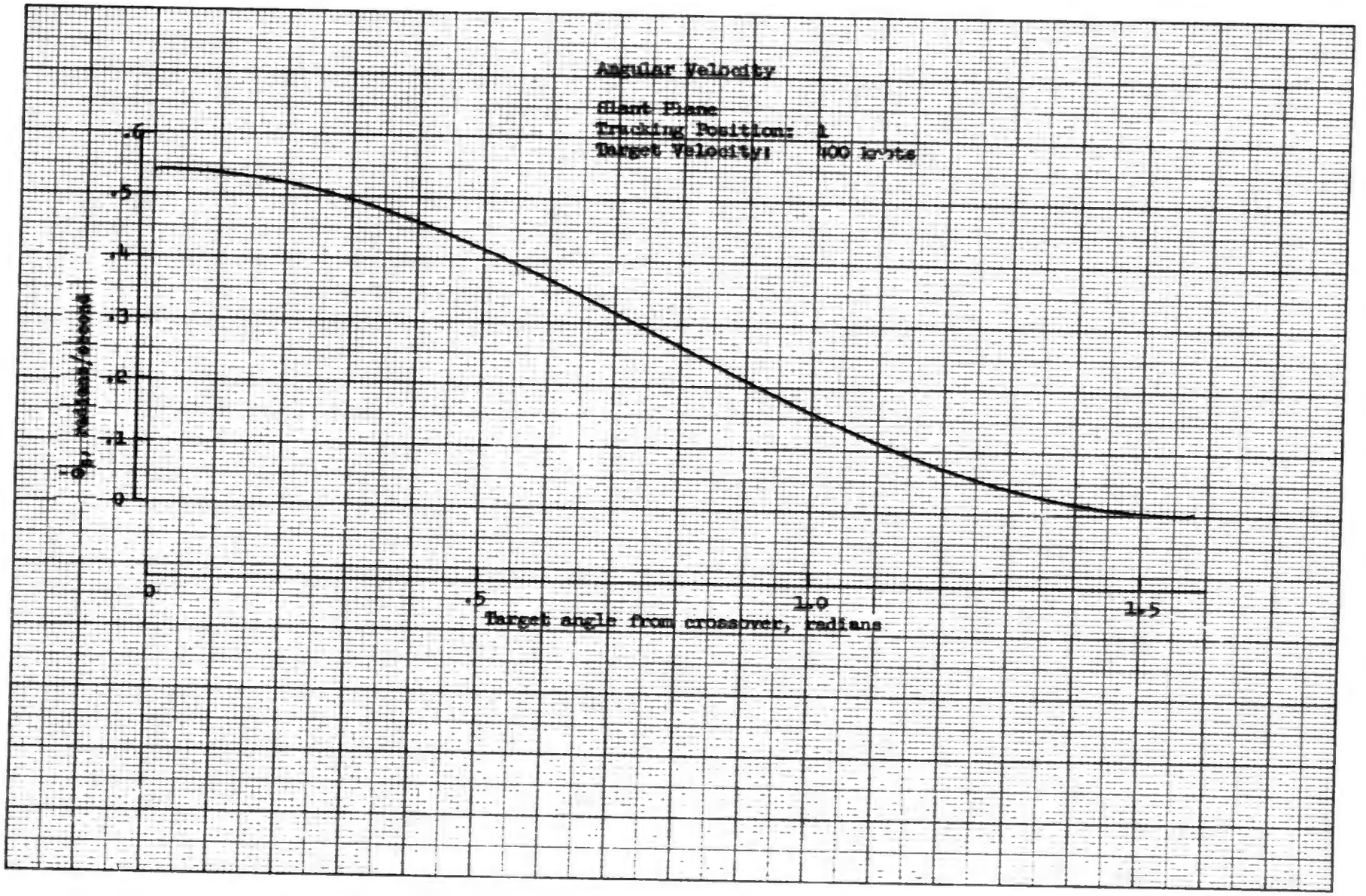
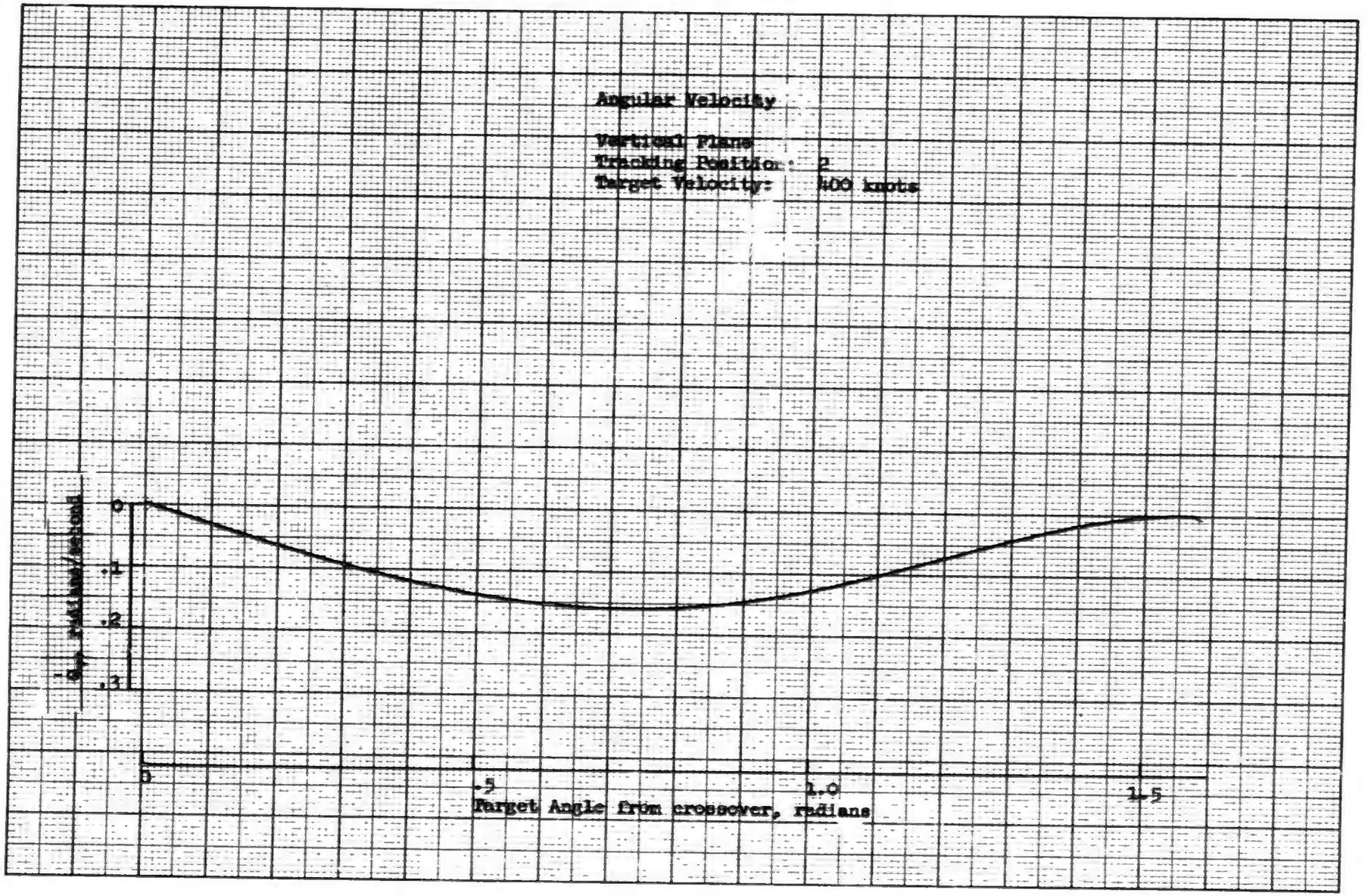

Angular Velocity
Chart Plane
Tracking Position: A
Target Velocity: 400 knots
.6
.5
.4
.3
.2
.1
0
0
.5
1.0
1.5
Target angle from crossover, radians

Figure 126-I


Angular Velocity
Vertical Plane
Tracking Position: 2
Target Velocity: 400 knots
0
.1
.2
.3
-0
0
.5
1.0
1.5
Target Angle from crossover, radians

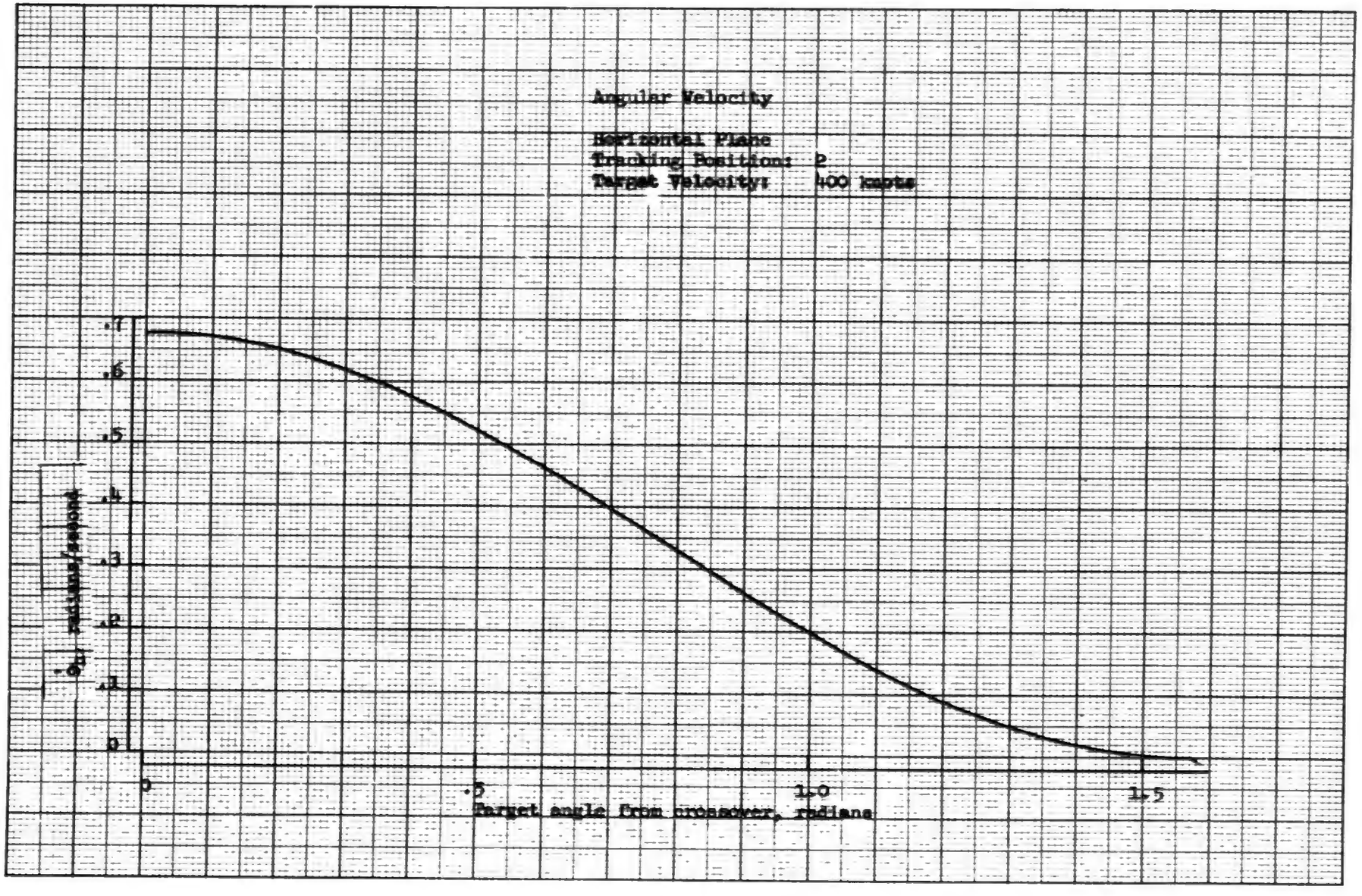
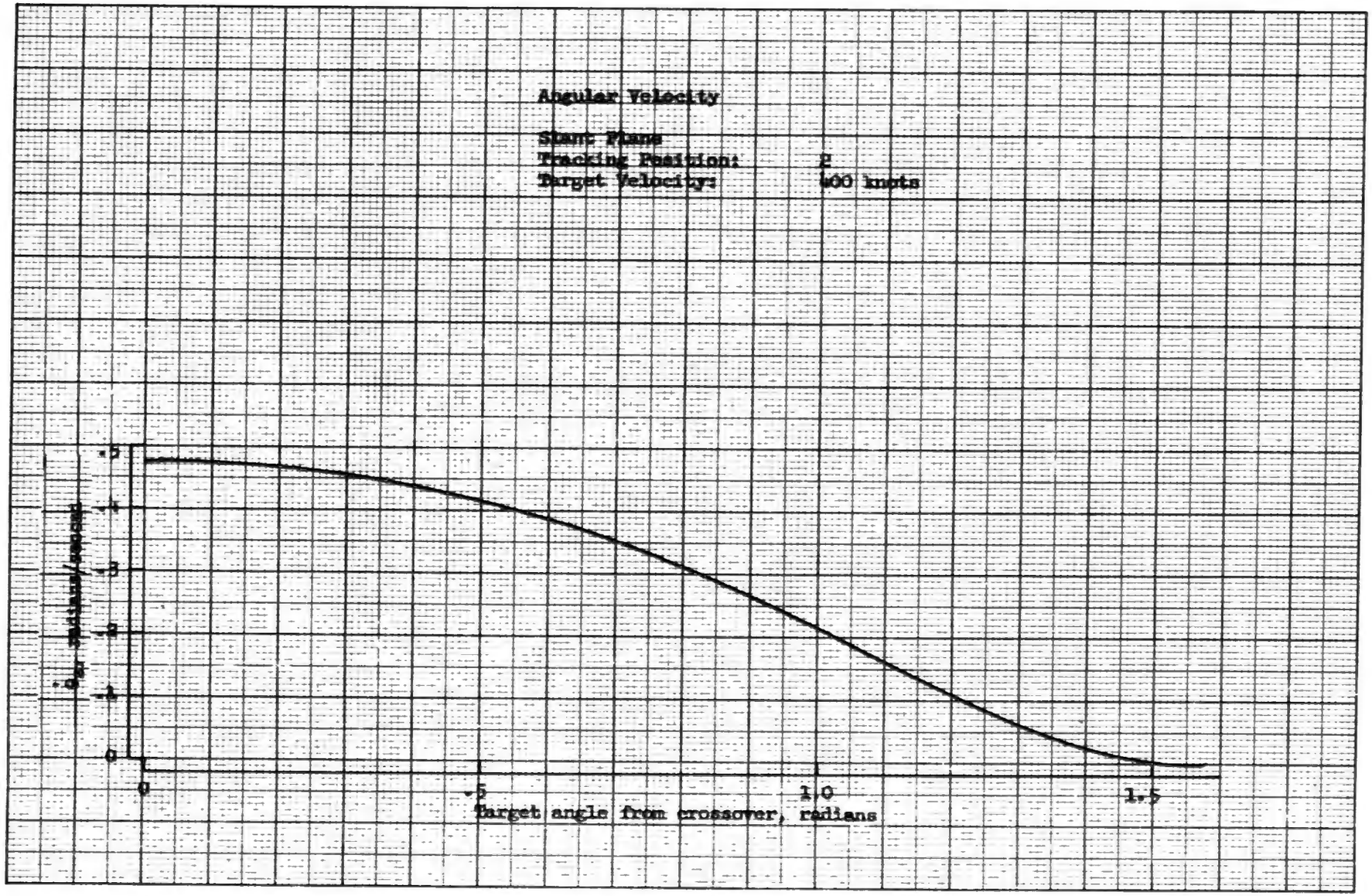

Angular Velocity
Horizontal Plane
Tracking Position: P
Target Velocity: 400 knots
.7
.6
.5
.4
.3
.2
.1
0
.5
1.0
1.5
Target angle from crossover, radians

Figure 128-I


Angular Velocity
Stern Plane
Tracking Position: P
Target Velocity: 400 knots
.5
.4
.3
.2
.1
0
radians/second
0
.5
1.0
1.5
Target angle from crossover, radians

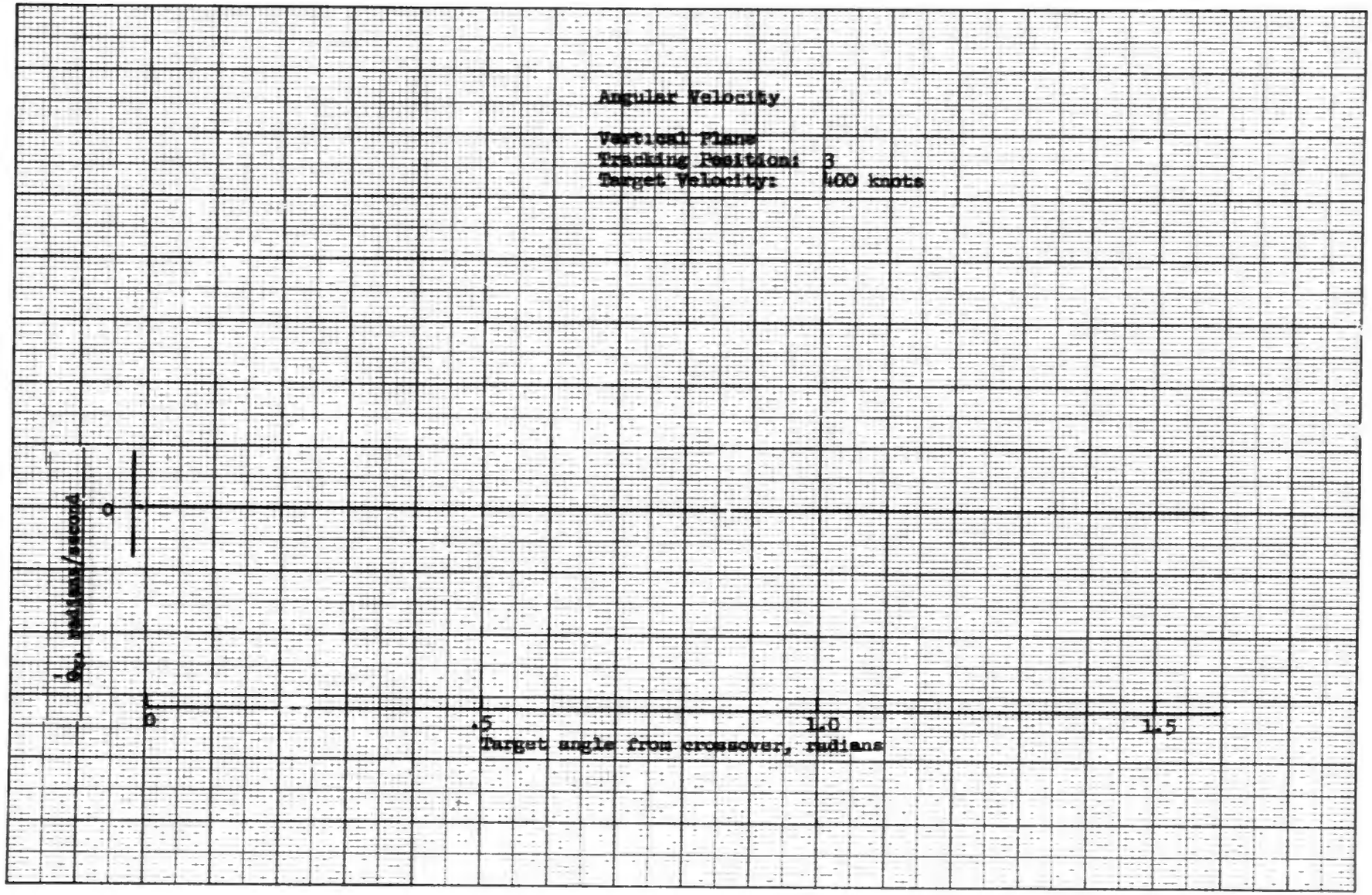
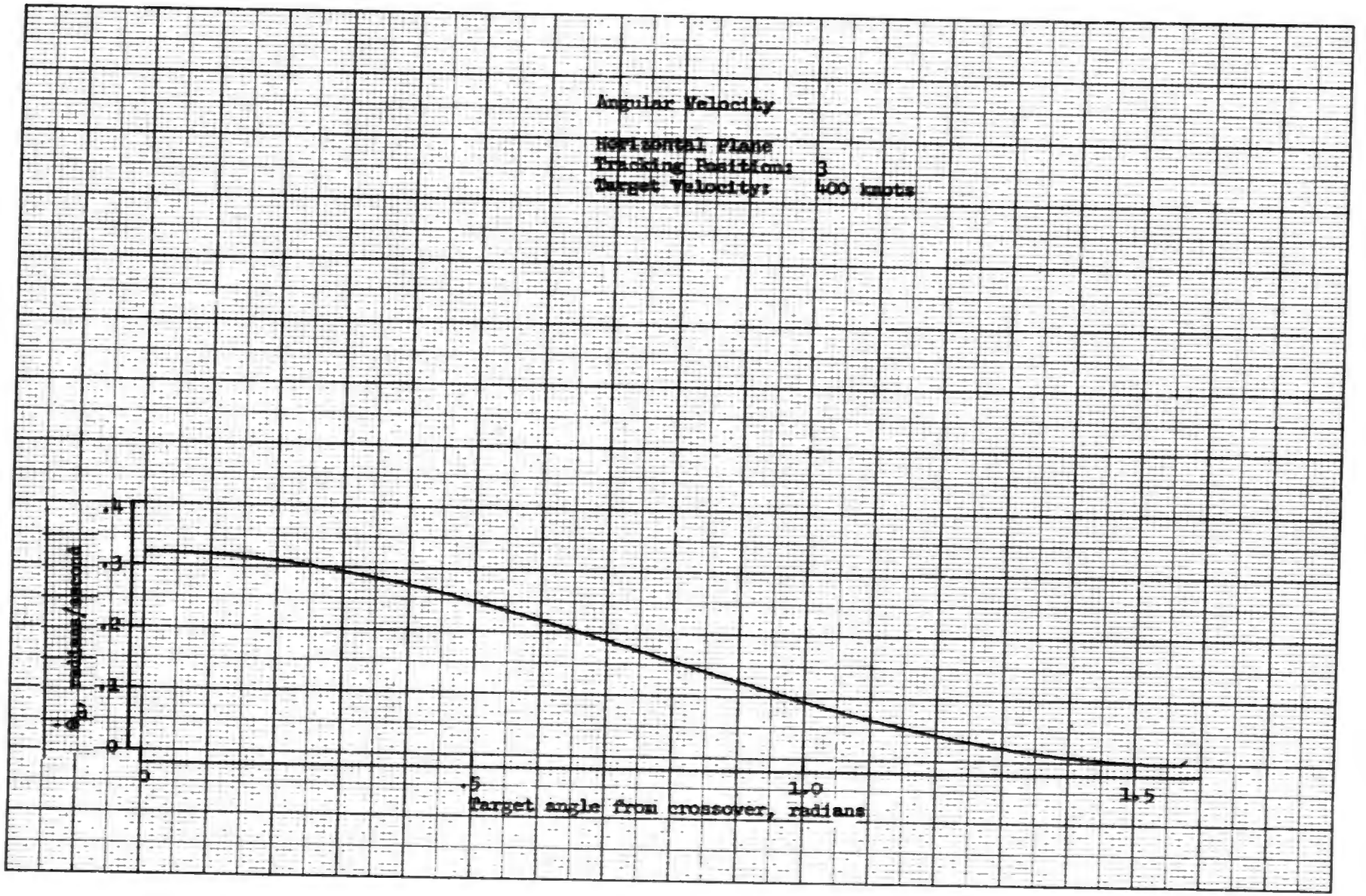

Angular Velocity
Vertical Plane
Tracking Position: 3
Target Velocity: 400 knots
-dφ, Milliradians/second
0
0
.5
1.0
1.5
Target angle from crossover, radians

Figure 130-I


Angular Velocity
Horizontal Plane
Tracking Position: 3
Target Velocity: 400 knots
.4
.3
.2
.1
0
0
.5
1.0
1.5
Target angle from crossover, radians

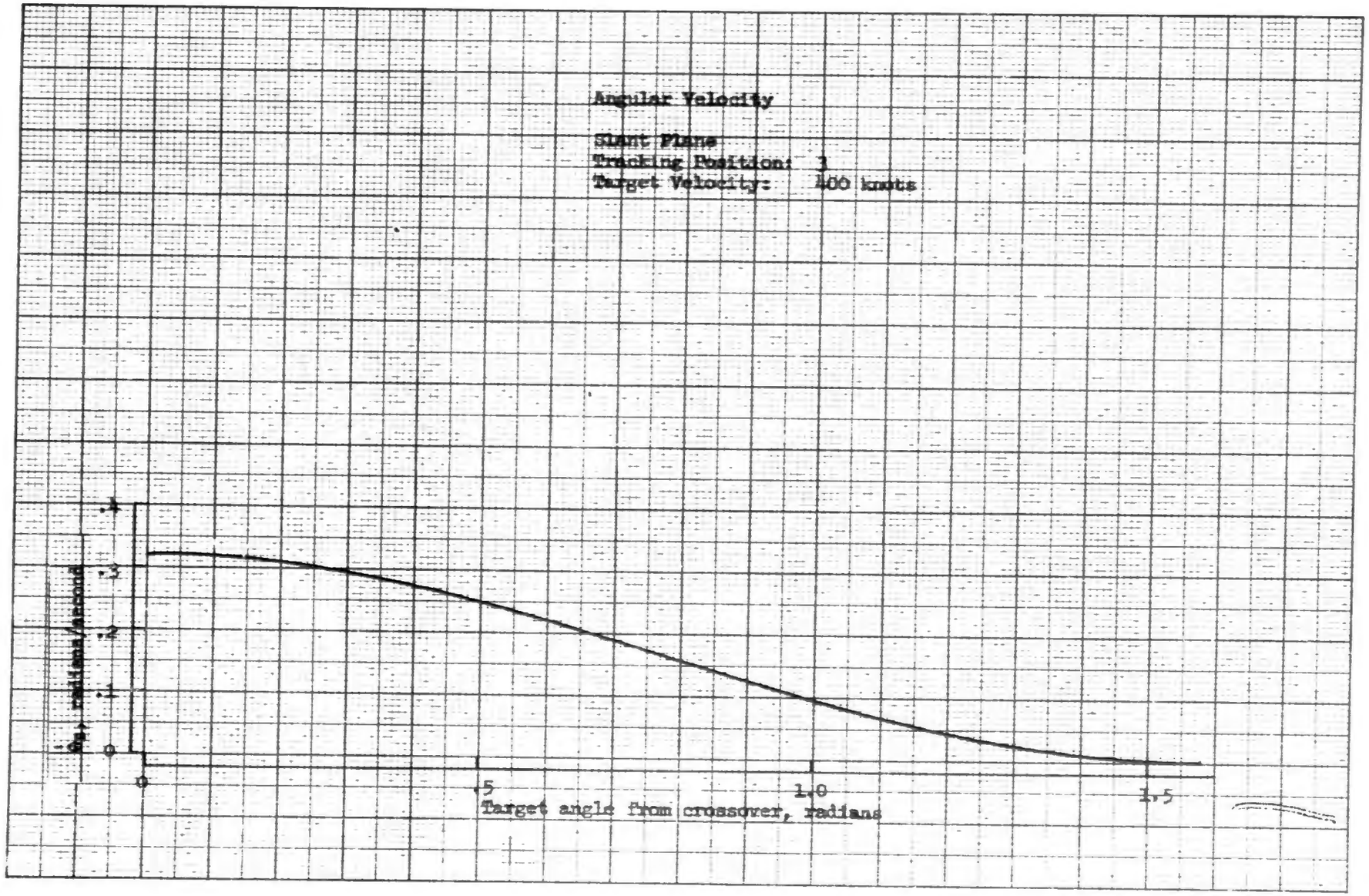
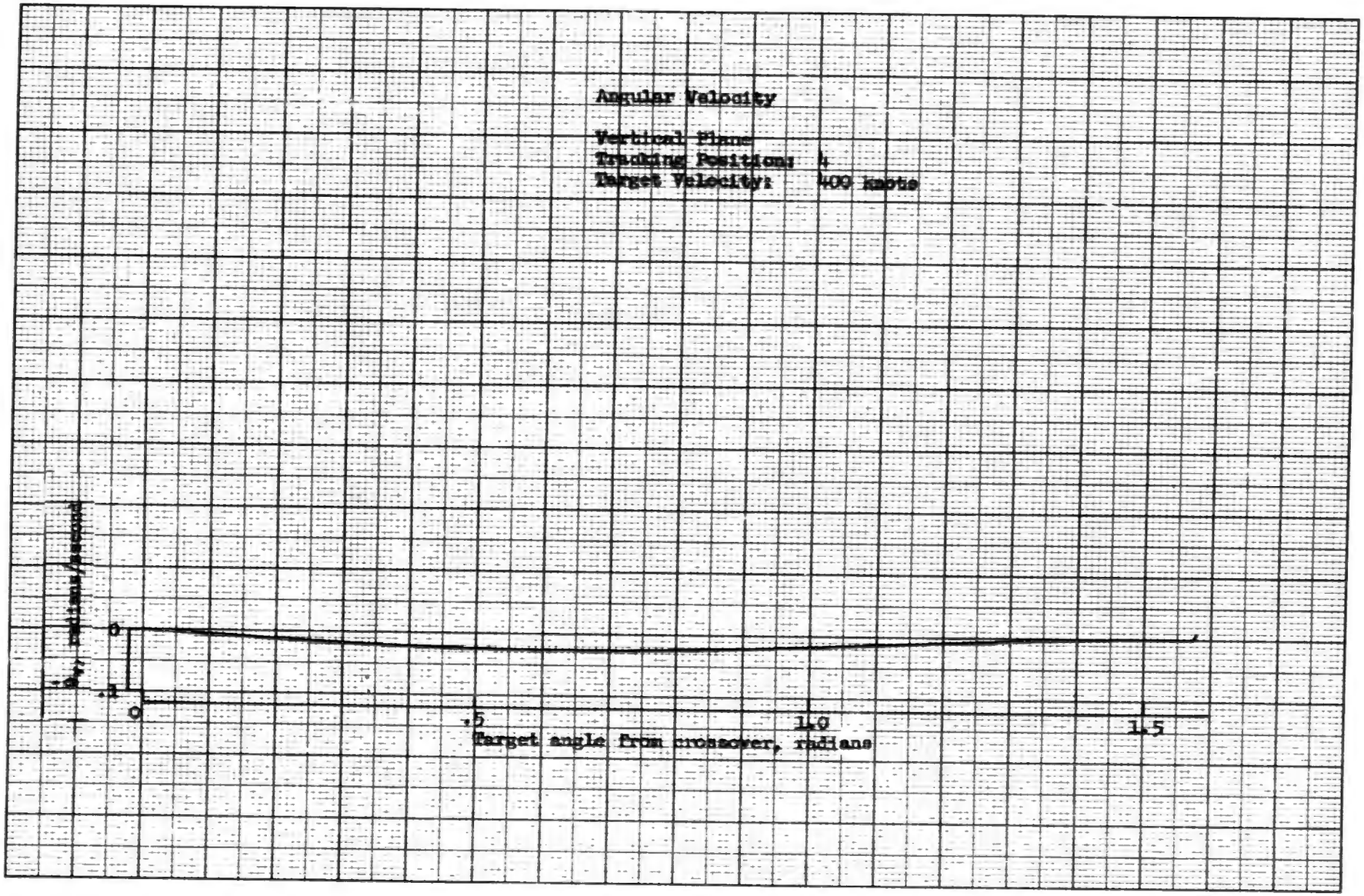

Angular Velocity
Slant Plane
Tracking Position: 3
Target Velocity: 400 knots
$\dot{\theta}_{rel}$, radians/second
.4
.3
.2
.1
0
0
.5
1.0
1.5
Target angle from crossover, radians

Figure 13C-I


Angular Velocity
Vertical Plane
Tracking Position: 4
Target Velocity: 400 knots
0
-.2
-.4
0
.5
1.0
1.5
Target angle from crossover, radians

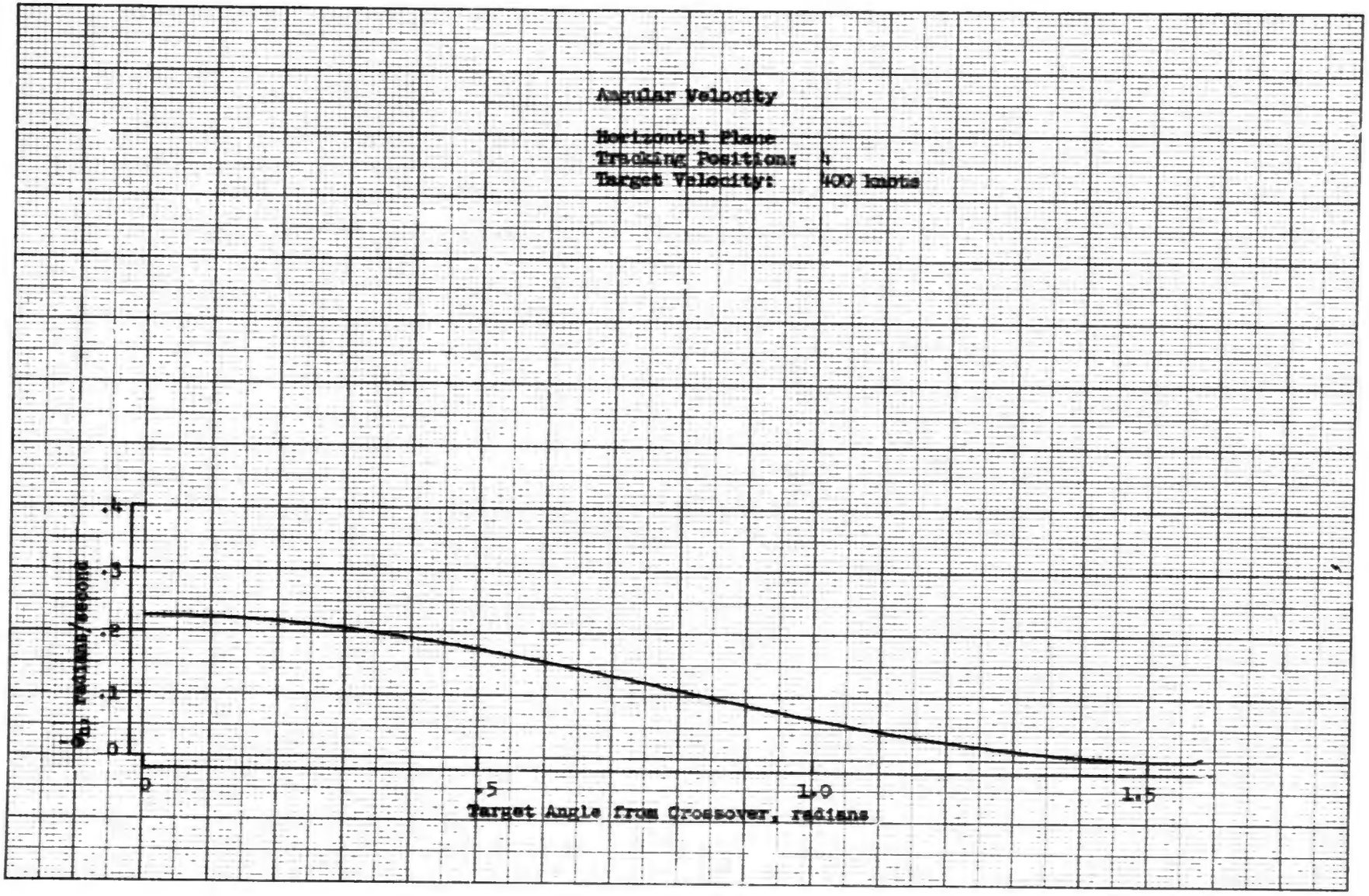
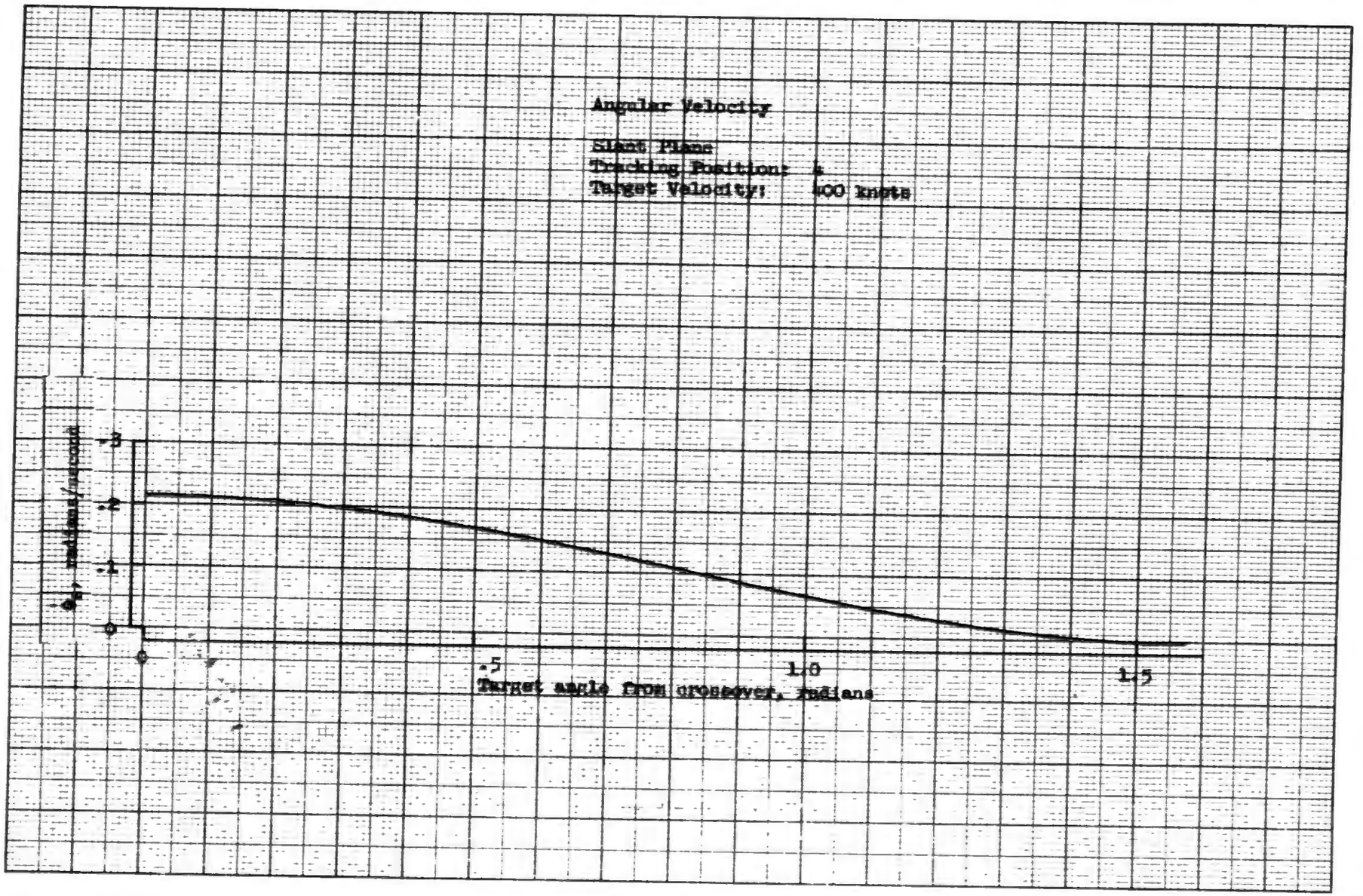

Angular Velocity
Horizontal Plane
Tracking Position: 4
Target Velocity: 400 knots
.4
.3
.2
.1
0
-dB
Target Angle from Crossover, radians
.5
1.0
1.5

Figure 134-I


Angular Velocity
Slant Plane
Tracking Position: 4
Target Velocity: 400 knots
radians/second
-3
-2
-1
0
0
.5
1.0
1.5
Target angle from crossover, radians

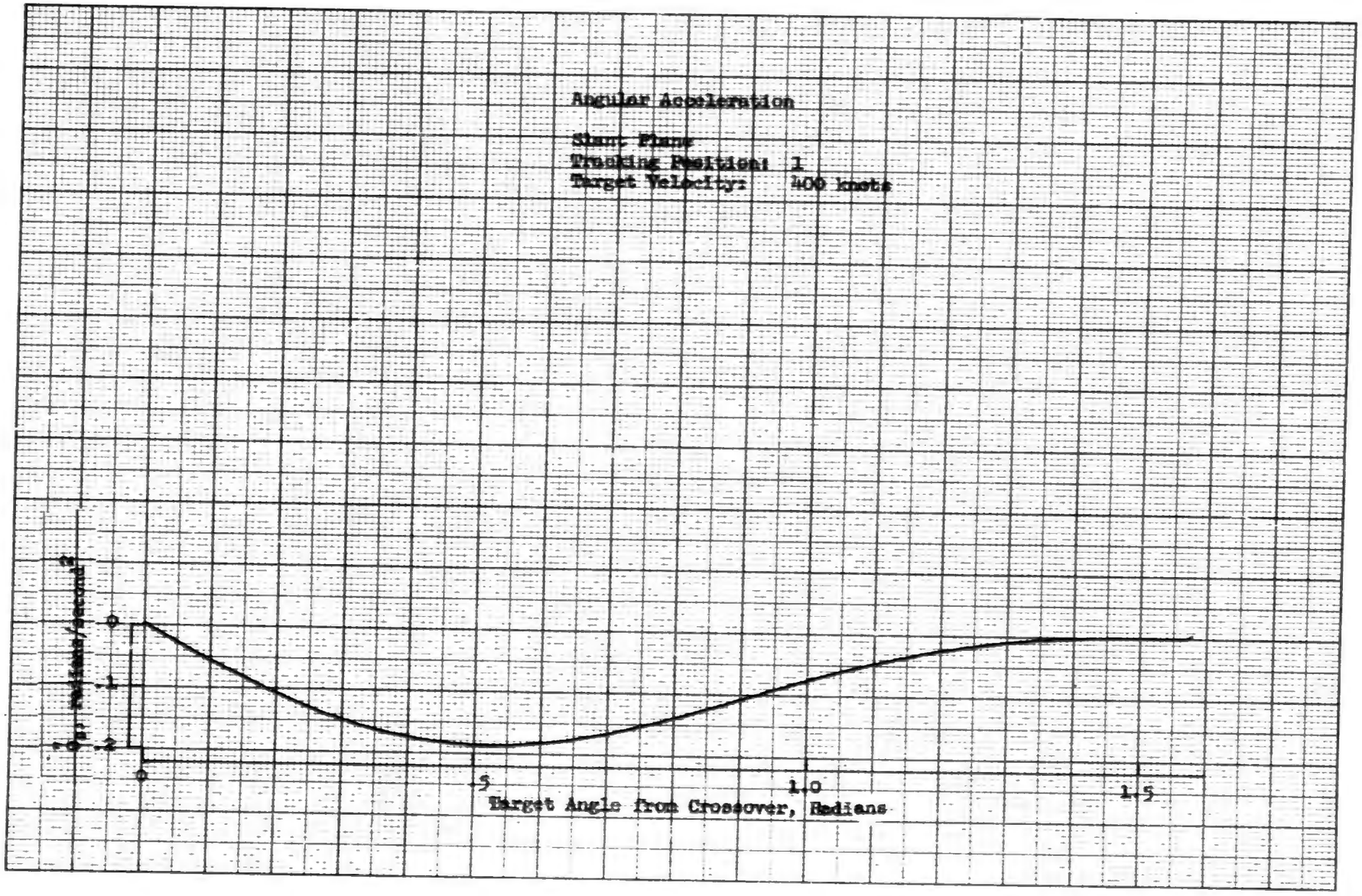

Angular Acceleration
Plane
Tracking Position: 1
Target Velocity: 400 knots
0
-.1
-.2
.5
1.0
1.5
Target Angle from Crossover, Radians

Figure 136-I

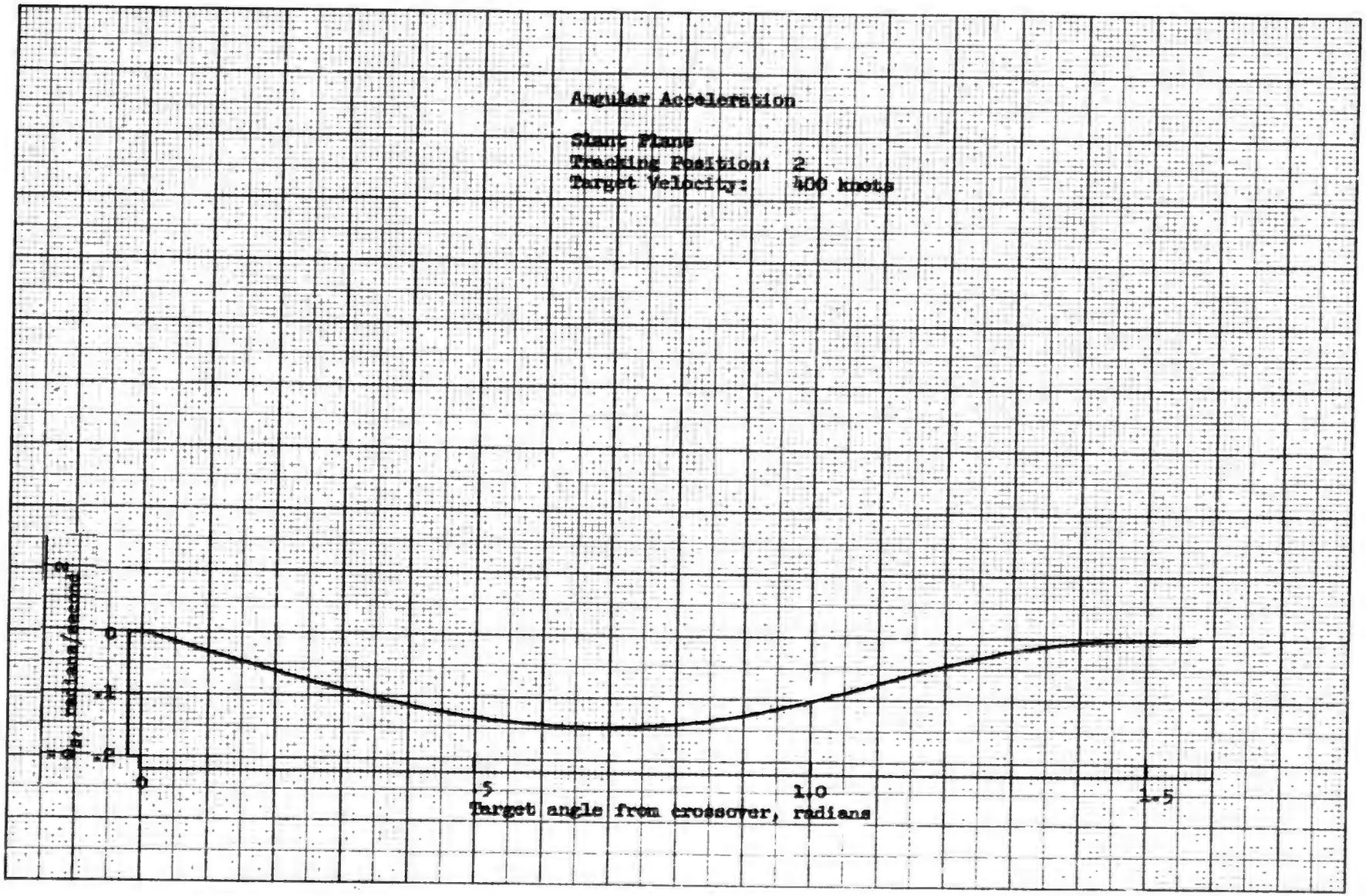

Angular Acceleration
Slant Plane
Tracking Position: 2
Target Velocity: 400 knots
Radians/second²
0
+1
+2
-1
-2
.5
1.0
1.5
Target angle from crossover, radians

Figure 137-I

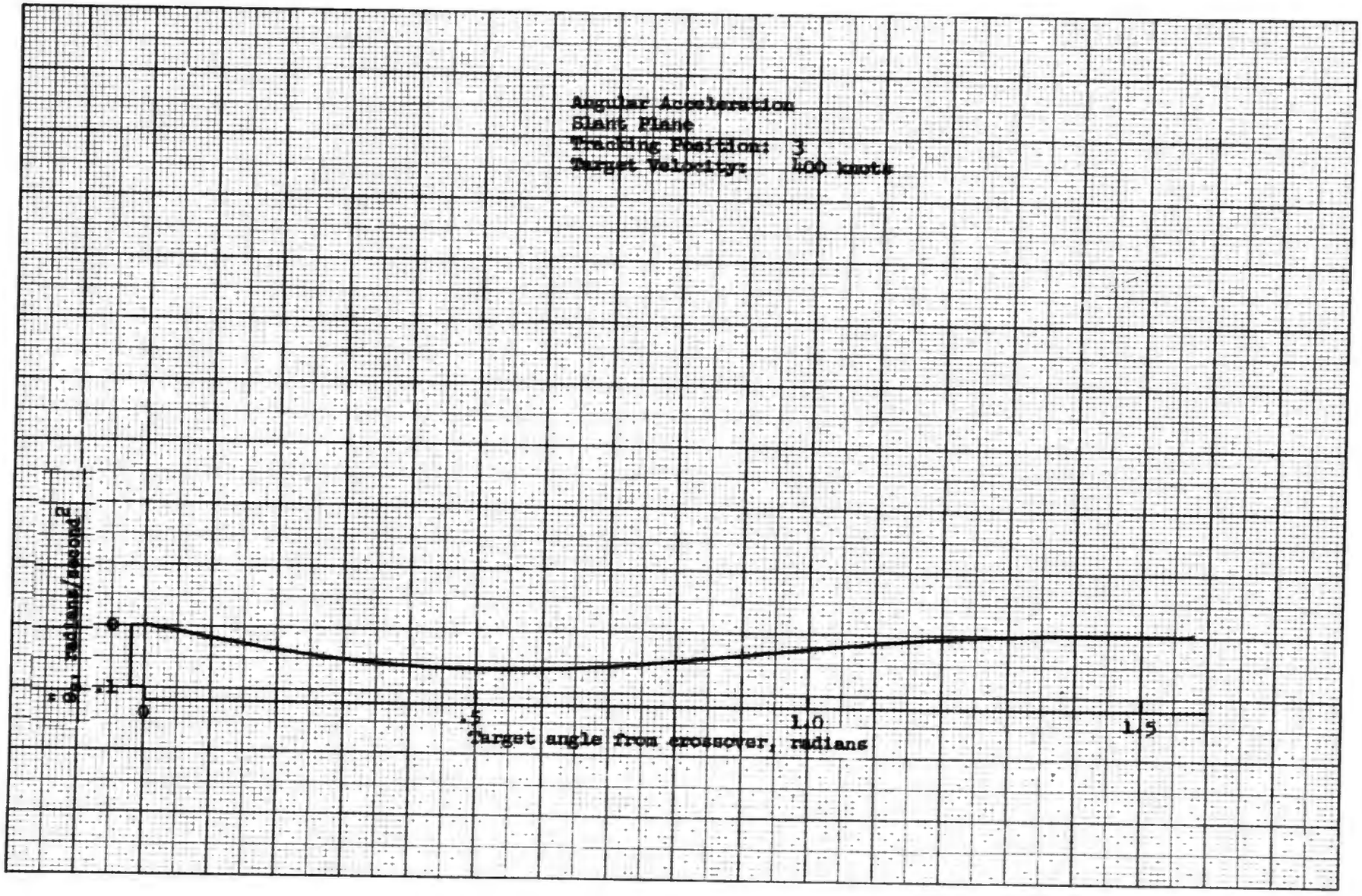
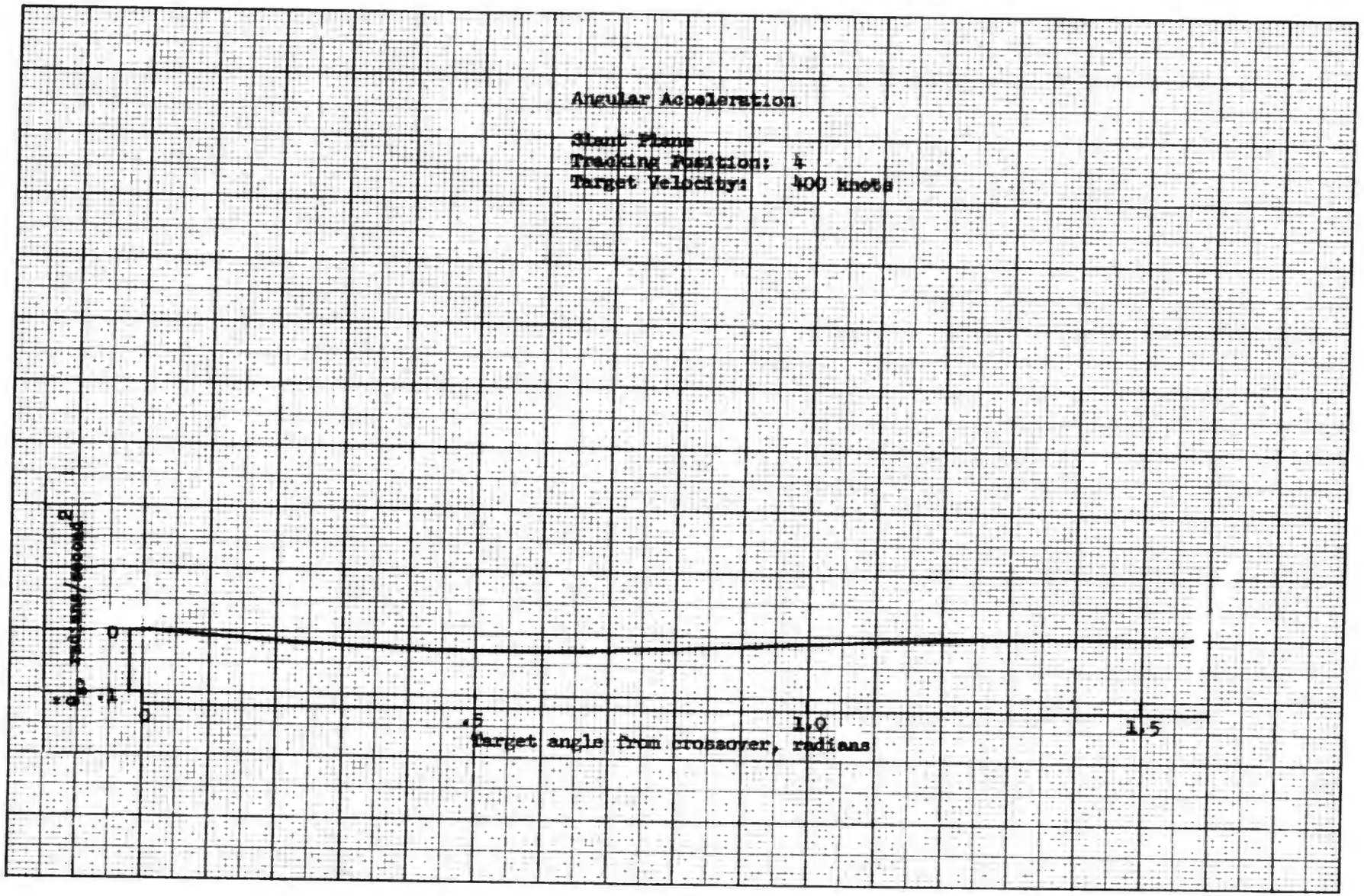

Angular Acceleration
Slant Plane
Tracking Position: 3
Target Velocity: 400 knots
$\dot{\Omega}$, radians/second^2
.5
1.0
1.5
Target angle from crossover, radians

Figure 138-I


Angular Acceleration
Short Plane
Tracking Position: 4
Target Velocity: 400 knots
0
-.4
0
.5
1.0
1.5
target angle from crossover, radians

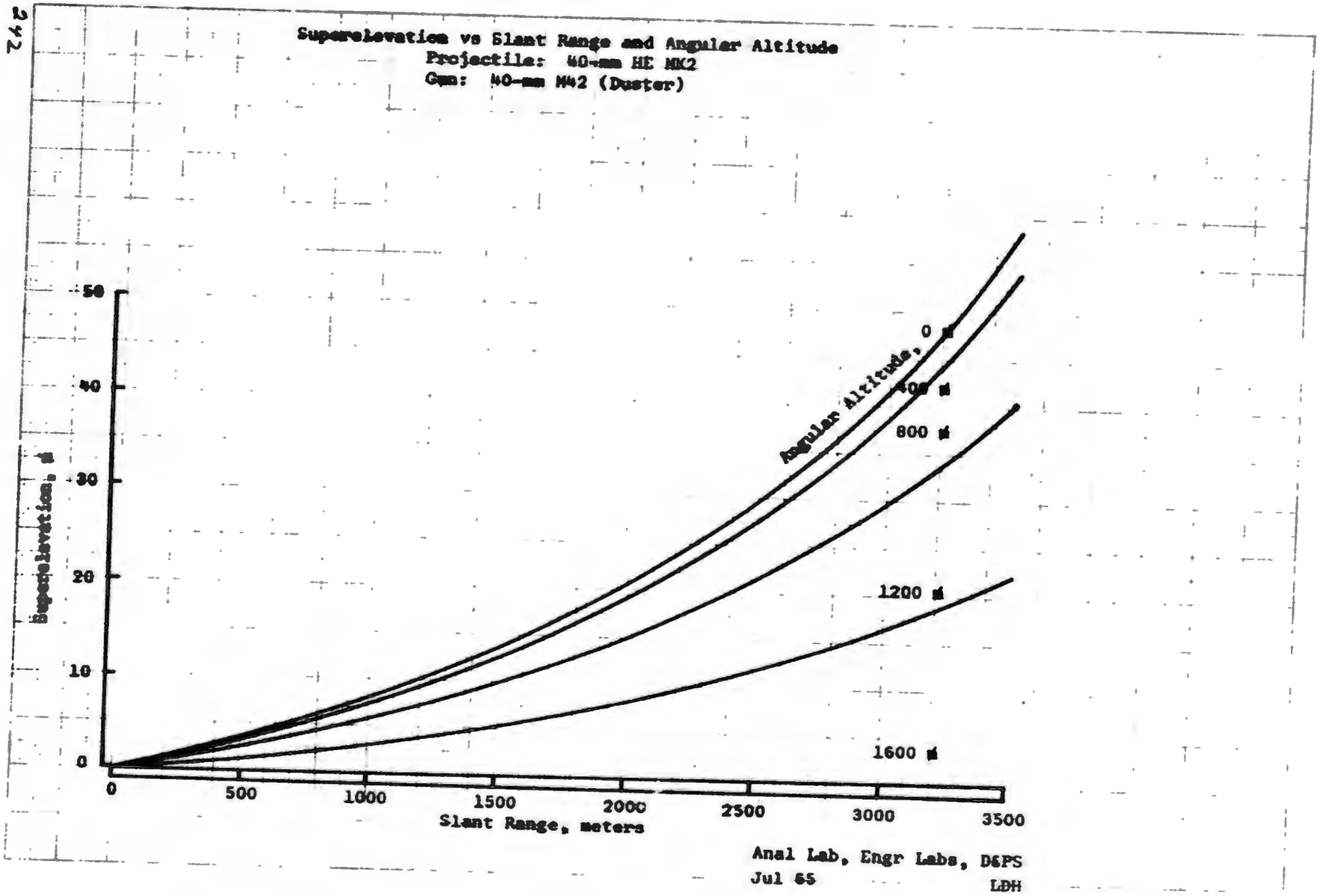
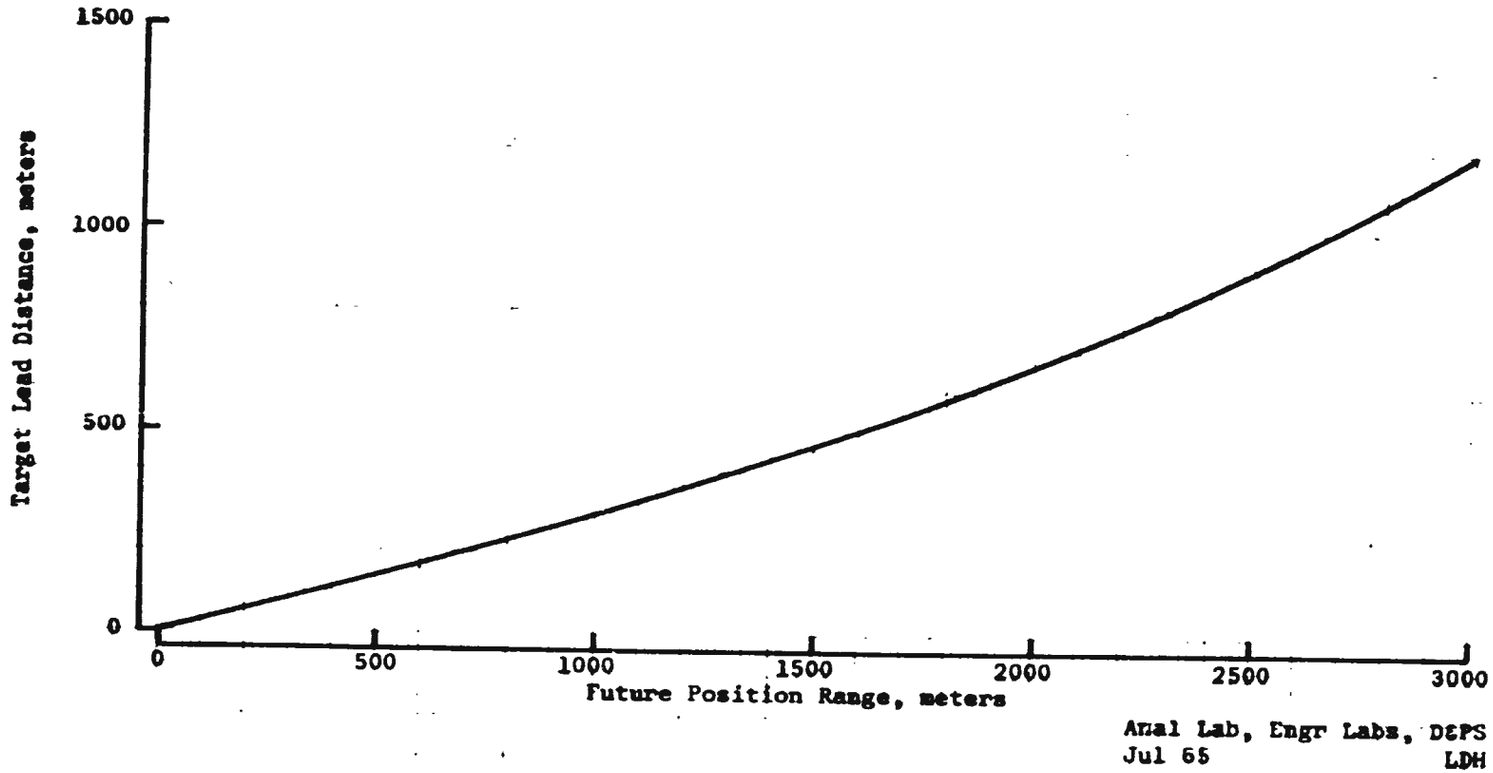

Superelevation vs Slant Range and Angular Altitude
Projectile: 40-mm HE MK2
Gun: 40-mm M42 (Duster)
Superelevation, mils
0
10
20
30
40
50
Angular Altitude, 0 mils
800 mils
1200 mils
1600 mils
0
500
1000
1500
2000
2500
3000
3500
Slant Range, meters
Anal Lab, Engr Labs, D&PS
Jul 65
LDH

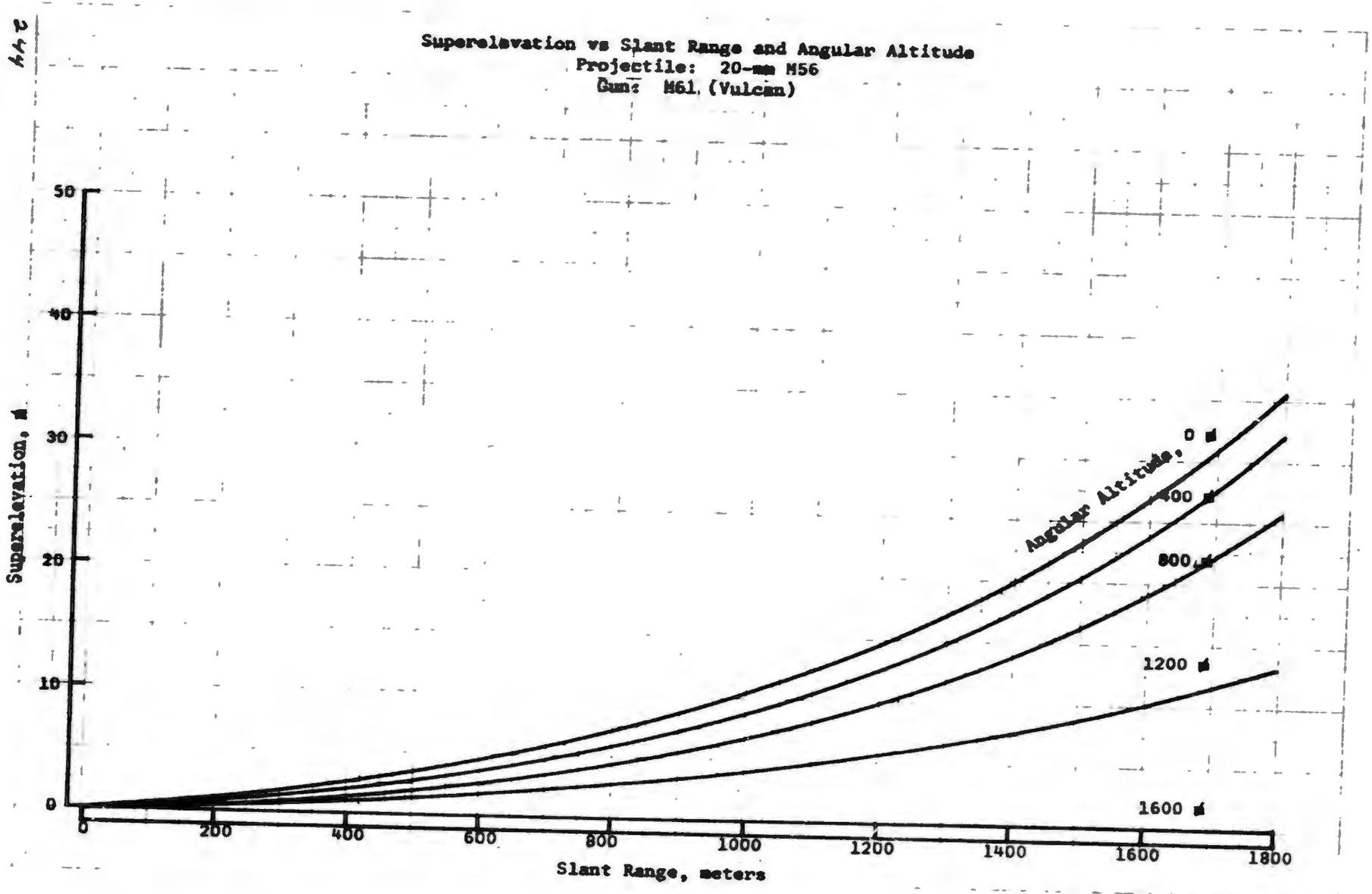
Figure 140-I

Target Lead Distance vs Range
Target Velocity: 450 knots
Projectile: 40-mm HE MK2
Gun: 40-mm M42 (Duster)



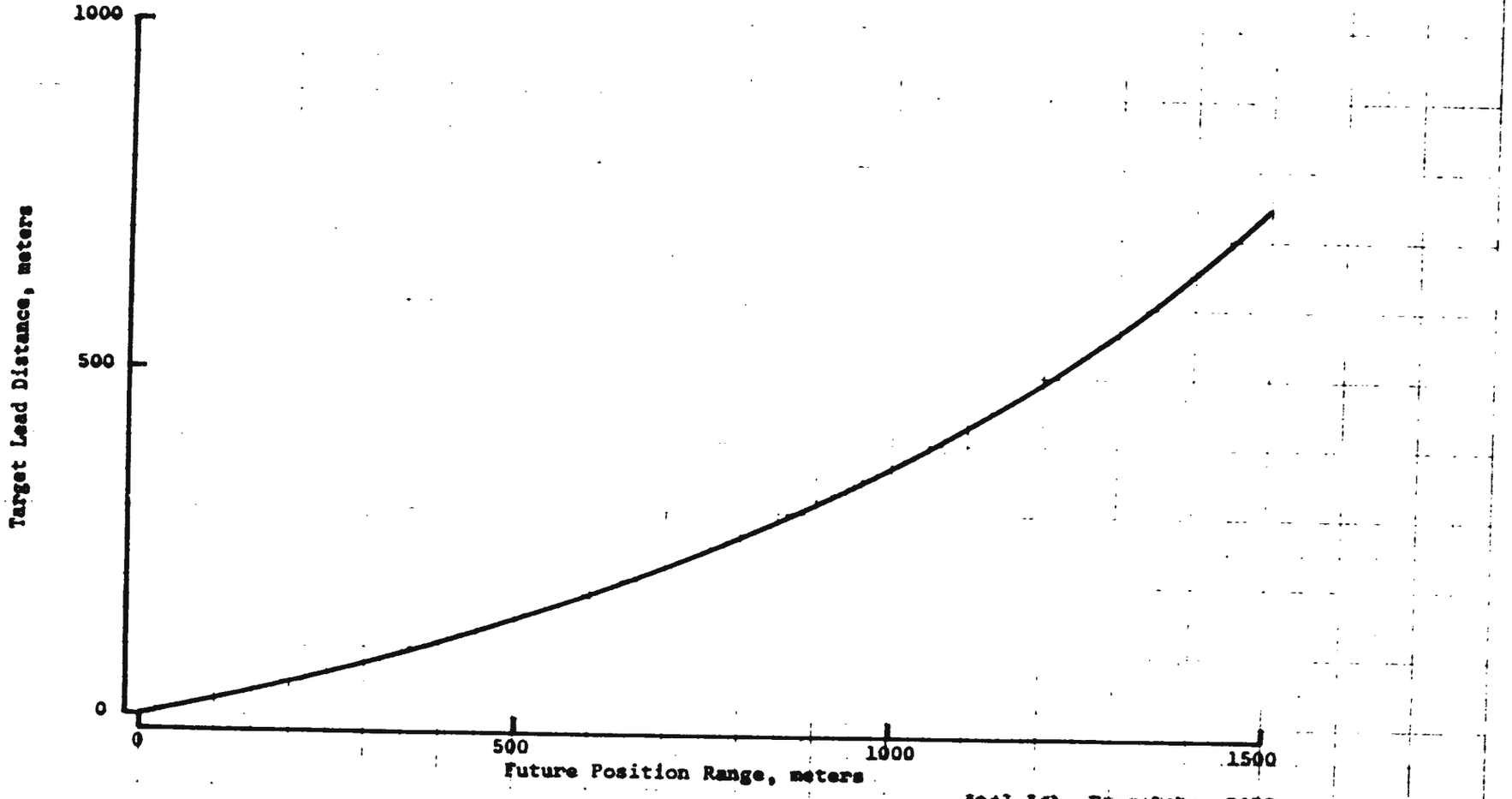
Anal Lab, Engr Labs, D&PS
Jul 65 LDH

Figure 1-1-I



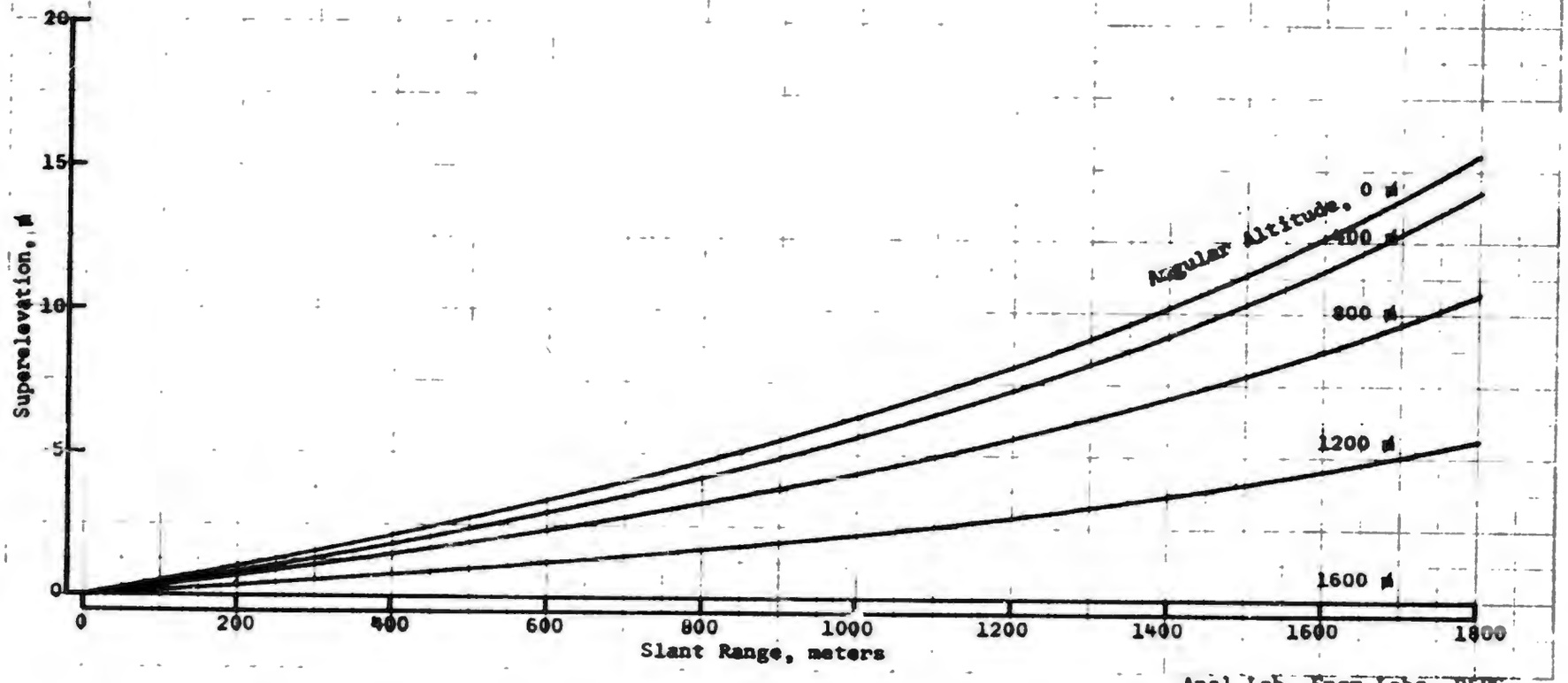
Anal Lab, Engr Labs, D&PS
Jul 65 LDH
Figure 142-I

Target Lead Distance vs Range
Target Velocity: 450 knots
Projectile: 20-mm M56
Gun: M61 (Vulcan)



Anal Lab, Engr Labs, D&PS
Jul 65
LDH

Superelevation vs Slant Range and Angular Altitude
Projectile: 20-mm HEIT
Gun: Hispano Suiza, HSS 820-A



Anal Lab, Engr Labs, DTPS
Jul 65 LDH
Figure 144-I

Target Lead Distance vs Range
Target Velocity: 450 knots
Projectile: 20-mm HEIT
Gun: Hispano Suiza, HSS 820-A
Anal Lab, Engr Labs, DSFS
Jul 65
Target Lead Distance, meters
Future Position Range, meters
0
500
1000
1500

APPENDIX 2-2

Physical Test Laboratory Reports

65-M-94

65-M-153

65-M-154

65-M-155

ENGINEERING LABORATORIES
PHYSICAL TEST LABORATORY REPORT

STEAP-DS-LP

TEST OF:

Various Springs from Self-Propelled Twin 40-MM, M42 Dusters M2A1.

OBJECT OF TEST:

To conduct a specification check of the springs.

INSTRUMENTATION:

Universal testing machine, 5000-pound capacity; measuring instruments and torque wrench, 0 to 100 ft-lb capacity.

PROCEDURE:

1. Initially the physical dimensions of all but the breech closing springs were measured. They were then individually placed in the testing machine and all but the recoil springs were compressed to the specified heights and to the solid heights. Finally the outside diameters of the springs were measured at solid height.

2. The breech closing springs were placed in their containers and assembled to the retaining slot on the gun. Torque was applied through the specified angle with a torque wrench and the load noted.

3. The recoil springs were compressed six inches in one-inch increments and the load was noted at each increment. From these data the spring rate, solid height and the loads at specified heights were computed.

RESULTS:

For tabulated data see Appendix I.

Report No. 65-M-94

Sheet 1 of 2

Dates of Test 15 to 30 April 1965

Report Complete 14 May 1965

Conducted for Mr. P. Grepps
Artillery Weapons Branch

W. O. No. 324-016-50

References Dwg Nos. 5222407, 5222464, 5222592, 5222593, 5222646, 6260936, 6260937, 7197113, 7165198, and 7238632.

1 Incl
Appendix I

25/

SUBMITTED:

R L Huddleston
for C. L. HALL
Materials Evaluation Section

REVIEWED:

R L Huddleston
R. L. HUDDLESTON
Chief
Materials Evaluation Section

252

APPROVED:

Jack McKinley
J. M. McKINLEY
Chief
Physical Test Laboratory

Rammer Lever Plunger Spring, Dwg No. 5222407

	Specs.	Actual Measurements			
Vehicle No.		12H297	12H297	12H298	12H298
Side		Left	Right	Left	Right
Firing status (rounds)		AF 1437	AF 1370	BF at APG	BF at APG
*Outside diameter solid, not more than (in.)	0.500	0.471	0.482	0.476	0.479
Mean diameter free (basic) (in.)	0.396	0.394	0.402	0.393	0.393
*Inside diameter free, not less than (in.)[a]	-	0.314	0.322	0.313	0.313
Diameter of wire (in.)	0.080	0.080	0.080	0.080	0.080
No. of working coils	0.19	18.75	18.75	18.75	18.75
Free height, approx (in.)	2.930	[b] 2.67	[b] 2.81	[b] 2.73	[b] 2.68
*Solid Height, not more than (in.)	1.810	1.710	1.662	1.664	1.637
*Load at height of 1.85 in. (lb)	54 ± 6	54	[b]47	[b]42	[b]45
Outside diameter free (in.)	-	0.474	0.482	0.473	0.473

*Mandatory requirements.

[a]Computed.
[b]Did not meet specifications.

Feed Roller Plunger Spring, Dwg No. 5222464

	Specs.	Actual Measurements			
Vehicle No.		12H297	12H297	12H297	12H297
Side		Left	Left	Right	Right
Firing status (rounds)		AF 1437	AF 1437	AF 1370	AF 1370
*Outside diameter solid, not more than (in.)	0.672	0.660	0.656	0.657	0.661
Mean diameter free (basic) (in.)[a]	0.570	0.574	0.571	0.574	0.575
Inside diameter free, not less than (in.)[a]	0.469	0.494	0.490	0.494	0.493
Diameter of wire (in.)	0.080	0.080	0.081	0.080	0.082
No. of working coils	14	[b]12.5	[b]12.5	[b]12.5	[b]12.75
Free height, approx (in.)	2.88	2.87	[b] 2.79	2.83	2.81
*Solid height, not more than (in.)	1.26	1.17	1.22	1.21	1.20
*Load at height of 1.34 in. (lb)	35 ± 3.5	35.8	34.6	35.7	33.1
Outside diameter free (in.)	-	0.654	0.652	0.654	0.657

*Mandatory requirements.

[a]Computed.
[b]Did not meet specifications.

Vehicle No.		12H298	12H298	12H298	12H298
Side		Left	Left	Right	Right
Firing status (rounds)		BF at APG	BF at APG	BF at APG	BF at APG
*Outside diameter solid, not more than (in.)	0.672	0.658	0.658	0.662	0.663
Mean diameter free (basic) (in.)[a]	0.570	0.572	0.573	0.577	0.577
Inside diameter free, not less than (in.)[a]	0.469	0.490	0.491	0.497	0.494
Diameter of wire (in.)	0.080	0.082	0.082	0.080	0.083
No. of working coils	14	[b]12.5	[b]12.5	[b]12.5	[b]12.5
Free height, approx (in.)	2.88	2.90	2.80	2.89	[b] 2.77
*Solid height, not more than (in.)	1.26	1.17	1.21	1.17	1.19
*Load at height of 1.34 in. (lb)	35 ± 3.5	35.5	34.5	35.5	33.4
Outside diameter free (in.)	-	0.654	0.655	0.657	0.660

*Mandatory requirements.

[a]Computed.
[b]Did not meet specifications.

Firing Pin Springs, Drawing No. 5222592

	Specs.	Actual Measurements			
Vehicle No.		12H297	12H297	12H298	12H298
Side		Left	Right	Left	Right
Firing status (rounds)		AF 1437	AF 1370	BF at APG	BF at APG
Free height, min (in.)	2.350	[b] 2.30	[b] 2.34	[b] 2.27	[b] 2.34
Solid height, max (in.)	1.500	1.500	1.467	1.453	1.450
Wire diameter, approx (in.)	0.114	0.114	0.114	0.114	0.114
Outside diameter, max (in.)	0.646	0.638	0.632	0.638	0.637
Inside diameter (in.)[a]	-	0.410	0.404	0.410	0.409
Total No. of coils, approx	13	13.2	12.8	12.75	12.6
Load at 1.65 in. (lb)	116.8 +11.0 - 6.6	114	112	106[b]	112

[a]Computed.
[b]Did not meet specifications.

Breech Block Inner Cocking Lever Sear Plunger Spring,
Dwg No. 5222593

	Specs.	Actual Measurements			
Vehicle No.		12H297	12H297	12H298	12H298
Side		Left	Right	Left	Right
Firing status (rounds)		AF 1437	AF 1370	BF at APG	BF at APG
*Outside diameter solid, not more than (in.)	0.541	0.524	0.525	0.530	0.533
Mean diameter free (basic) (in.)[a]	0.468	0.4695	0.4715	0.4695	0.4755
*Inside diameter free, not less than (in.)[a]	0.396	0.422	0.424	0.422	0.428
Diameter of wire (in.)	0.0475	0.0475	0.0475	0.0475	0.0475
No. of working coils	9-1/2	8.75	8.75	8.75	8.75
Free height, approx (in.)	2.04	[b] 1.85	[b] 1.85	[b] 1.57	[b] 1.61
*Solid height, not more than (in.)	0.55	0.524	0.521	0.534	0.519
*Load at 0.709 in. (lb)	10 ± 1	9.65	9.20	[b] 7.60	[b] 7.35
Outside diameter free (in.)		0.517	0.519	0.517	0.523

*Mandatory requirements.

[a]Computed.
[b]Did not meet specifications.

Feed Rod Plunger Spring, Dwg No. 5222646

	Specs.	Actual Measurements			
Vehicle No.		12H297	12H297	12H297	12H297
Side		Left	Left	Right	Right
Firing status (rounds)		AF 1437	AF 1437	AF 1370	AF 1370
*Outside diameter solid, not more than (in.)	0.660	0.659	0.661	0.656	0.652
Mean diameter free (basic) (in.)[a]	0.490	0.497	0.498	0.494	0.488
*Inside diameter free, not less than (in.)[a]	0.320	0.336	0.337	0.334	0.325
Diameter of wire (in.)	0.1551	0.161 [b]	0.161 [b]	0.160 [b]	0.163 [b]
No. of working coils	18	18.2	18	18	18
Free height, approx (in.)	4.15	4.14	4.14	4.14	4.18
*Solid height, not more than (in.)	3.18	3.147	3.102	3.168	3.230 [b]
*Load at height of 3.31 in. (lb)	331 ± 33	316	313	336	365 [b]
Outside diameter free (in.)	-	0.658	0.659	0.654	0.651

*Mandatory requirements.

[a]Computed.
[b]Did not meet specifications.

		12H298	12H298	12H298	12H298
Vehicle No.					
Side		Left	Left	Right	Right
Firing status (rounds)		BF at APG	BF at APG	BF at APG	BF at APG
*Outside diameter solid, not more than (in.)	0.660	0.646	0.656	0.655	0.639
Mean diameter free (basic) (in.)[a]	0.490	0.483	0.494	0.492	0.481
*Inside diameter free, not less than (in.)[a]	0.320	0.321	0.333	0.330	0.324
Diameter of wire (in.)	0.1551	0.162 [b]	0.161 [b]	0.162 [b]	0.157
No. of working coils	18	17.75	18	18	17.75
Free height, approx (in.)	4.15	4.04 [b]	4.08 [b]	4.11	4.03 [b]
*Solid height, not more than (in.)	3.18	3.052	3.092	3.154	3.075
*Load at height of 3.31 in. (lb)	331 ± 33	330	320	328	314
Outside diameter free	-	0.645	0.655	0.654	0.638

*Mandatory requirements.

[a]Computed.
[b]Did not meet specifications.

Inner Rammer Tray Springs, Dwg No. 6260936

	Specs.	Actual Measurements			
Vehicle No.		12H297	12H297	12H298	12H298
Side		Left	Right	Left	Right
Firing status (rounds)		AF 1437	AF 1370	BF at APG	BF at APG
Free height, approx (in.)	17	[b]15.92	[b]16.41	[b]16.16	[b]15.79
Solid height, max (in.)	4.750	4.712	4.675	4.746	4.693
Wire diameter (in.)	0.120	0.120	0.120	0.120	0.120
Outside diameter (in.)	-	1.15	1.15	1.16	1.15
Inside diameter (in.)[a]	0.900 ± 0.020	0.910	0.910	0.920	0.910
Total No. of coils, approx	40	38.9	38.75	38.8	38.75
Load at 12.200 in. (lb)	33 ± 3	[b] 26	[b] 29	30	[b] 25
Load at 6.300 in. (lb)	75 ± 7	71	71	73	68

[a]Computed.
[b]Did not meet specifications.

Outer Rammer Tray Springs, Dwg No. 6260937

	Specs.	Actual Measurements			
Vehicle No.		12H297	12H297	12H298	12H298
Side		Left	Right	Left	Right
Firing status (rounds)		AF 1437	AF 1370	BF at APG	BF at APG
Free height, approx (in.)	17	[b]16.26	[b]16.14	[b]16.12	[b]15.97
Solid height, max (in.)	4.850	4.490	4.532	4.793	4.837
Wire diameter (in.)	0.177	0.175	0.174	0.176	0.176
Outside diameter (in.)	1.730 - 0.024	1.73	1.70	1.72	1.74
Inside diameter (in.)[a]	-	1.380	1.352	1.368	1.388
Total No. of coils, approx	27.5	[b]25.5	[b]25.7	27.3	27.3
Load at 12.200 in. (lb)	77 ± 7	[b]57	[b]61	[b]57	[b]56
Load at 6.300 in. (lb)	160 ± 15	148	160	[b]143	[b]144

[a]Computed.
[b]Did not meet specifications.

Breech Closing Springs, Dwg No. 7197113

	Specs.	Actual Measurements	
Vehicle No.		12H297	12H298
Side		Left	Left
Firing status (rounds)		AF 1437	BF at APG
Load at specified angle (ft lb)	54.7 ± 6.7	55	60

Breech Closing Springs, Dwg No. 7165198

	Specs	Actual Measurements	
Vehicle No.		12H297	12H298
Side		Right	Right
Firing status (rounds)		AF 1370	BF at APG
Load at specified angle (ft lb)	54.7 ± 6.7	58	50

Specifications: For 145.5° twist, the load is 181 ± 22 pounds at a radius of 3-5/8 inches.

$$\frac{181 \text{ lb} \times 3.625 \text{ in.}}{12 \text{ in./ft}} = 54.7 \text{ ft lb}$$

$$\frac{22 \text{ lb} \times 3.625 \text{ in.}}{12 \text{ in./ft}} = 6.6 \text{ ft lb}$$

Recoil Springs, Dwg No. 7238632

	Specs.	Actual Measurements					
Vehicle No.		121..97	1211297	1211298	1211298	New 1	New 2
Side		Left	Right	Left	Right	New	New
Firing status (rounds)		AF 1437	AF 1370	BF at APG	BF at APG	BF	BF
Free height (in.)	38 ± 2	37.11	36.30	37.35	37.07	37.57	37.30
Solid height, max (in.)[a]	11-5/8	10.914	10.932	10.968	10.857	10.950	10.932
Wire diameter (in.)	0.600 ± 0.003	0.598	0.599	0.601	0.599	0.600	0.599
Outside diameter (in.)	-	5.668	5.692	5.680	5.676	5.679	5.680
Inside diameter (in.)[a]	4-7/16 + 1/16 - 1/32	4.472	4.494	4.478	4.478	4.479	4.482
Total No. of coils, approx	19-1/4	19-1/4	19-1/4	19-1/4	19-1/8	19-1/4	19-1/4
Load at 20.6875 in. (lb)	1320 + 88 - 44	1330	[b]1265	1358	1311	1359	1346
Load at 11.8125 in.[a] (lb)	1980 +165 - 88	2049	1983	2081	2021	2073	2064
Spring rate (lb/in.)[a]	-	81	81	81.5	80	80.5	81

[a] ...puted.
[b] ...d not meet specifications.

ENGINEERING LABORATORIES
PHYSICAL TEST LABORATORY REPORT

STEAP-DS-LP

INSPECTION OF:

Components of Gun, Dual Automatic 40-MM, M2A1 from M42 Vehicle, No. 12H273. (After Fire)

OBJECT OF INSPECTION:

To locate possible defects in the two guns by magnetic particle inspection after firing 3163 rounds on the right gun and 3173 rounds on the left gun.

INSTRUMENTATION:

Magnaflux unit; wet continuous method, coil, and central conductor energized with low voltage to a maximum of 1800 amperes DC, fluorescent magnetic particles suspended in a petroleum base distillate bath, black light.

Report No. 65-M-153

Sheet 1 of 12

Dates of Inspection 12 through 14 July 1965

Report Complete 26 July 1965

Conducted for Mr. Grepps
Artillery Weapons Branch

W. O. No. 377-010-14

References Magnetic Particle Inspection Criteria. Dwg. Nos. 8768747, 7309991, 7309992, 8769123, 8769067. PTL Report No. 65-M-108

PROCEDURE:

The components were magnetized, washed with the bath and inspected under black light for patterns indicative of cracks or other flaws. The components were then demagnetized.

RESULTS:

1. The following listed components were inspected:

Component	Serial No. or Ord. Part No.	Gun	Results of the Inspection
Arm, Rammer, Control Intermediate Spindle, outer, right	B722101	Right	No defects
Arm, Rammer Control Intermediate Spindle, outer left	B5222409	Left	No defects

Component	Serial No. or Ord. Part No.	Gun	Results of the Inspection
Arm, Feed Control Lever Spindle	B5222403	Right	No defects
Arm, Rammer Control Spindle, Left	B5222601	Left	No defects
Arm, Rammer Control Spindle, Right	B7225103	Right and Left	No defects
Arm Feed Roller Catch Release Lever	B5222569	Right and Left	No defects
Arm, Rammer Cocking Lever Shaft, Right	B7165190	Right	No defects
Arm, Rammer Cocking Lever Shaft, Left	B5222480	Left	No defects
Arm, Feed Roller Catch, Right	B5222471	Right and Left	No defects
Arm, Feed Roller Catch, Left	B5222649	Right and Left	No defects
Arm, Rammer Control Intermediate Spindle Inner, Left	B5222603	Left	No defects
Arm, Breech Ring Control	B5222434	Right and Left	No defects
Arm, Extractor, Left	B7165194	Left	Contained cracks (see paragraph 2)
Arm, Extractor, Right	B6197107	Right	Contained cracks (see paragraph 3)
Arm, Rammer, Control Intermediate Spindle Inner, Right	B7225108	Right	No defects

Component	Serial No. or Ord. Part No.	Gun	Results of the Inspection
Bolt, Loader Tray Connecting	B5222427	Right and Left	No defects
Breechblock	F6550027 W1 CN9	Right	No defects
Breechblock	F6550027 Y2 CN2	Left	No defects
Cross-piece Loader	C7238622	Right and Left	No defects
Collar, Rammer Control Spindle	B5222599	Right and Left	No defects
Cover, Loader Crosspiece	C7238620	Right and Left	No defects
Cover, Firing Pin Spring	B5222588	Right	Contained cracks (see paragraph 4)
Cover, Firing Pin Spring	B5222588	Left	No defects
Catch, Breech Ring Barrel	C7165191	Right	No defects
Catch, Breech Ring Barrel	C6197153	Left	No defects
Crank, Breech Ring Outer, Right	C7165178	Right	No defects
Crank, Breech Ring Inner, Right	C5595004	Right	Contained cracks (see paragraph 5)
Crank, Breech Ring Inner, Left	C5595003	Right	Contained cracks (see paragraph 5)
Crank, Breech Ring Inner, Left	C5595003	Left	Contained cracks (see paragraph 5)

Component	Serial No. or Ord. Part No.	Gun	Results of the Inspection
Crank, Breech Ring Inner, Right	C5595004	Left	Contained cracks (see paragraph 5)
Case, Breech Closing Spring	C7165196	Right	No defects
Case, Breech Closing Spring	C6197102	Left	No defects
Cover, Breech Closing Spring	C7165197	Right	Contained cracks (see paragraph 6)
Cover, Breech Closing Spring	C6197103	Left	No defects
Crank, Breech Ring Outer, Left	C6197105	Left	No defects
Extractor, Cartridge Case	C6197126	Right	Contained cracks (see paragraph 7)
Extractor, Cartridge Case	C6197126	Left	No defects
Extractor, Cartridge Case	C6197146	Right and Left	No defects
Guide, Ammunition Charger Clip	C6197121	Left	No defects
Guide, Ammunition Charger Clip	C7225110	Right	Contained cracks (see paragraph 8)
Guide, Loader, Rear	F7225129	Right	No defects
Guide, Loader, Rear	F6550009	Left	Contained cracks (see paragraph 9)
Guide, Loader, Front	D7258623	Right and Left	No defects
Head, Feed Roller Catch, Left	C5222481	Left	No defects
Head, Feed Roller Catch, Right	C5222482	Left	No defects

Component	Serial No. or Ord Part No.	Gun	Results of the Inspection
Head, Feed Roller Catch	C5222482	Right	No defects
Holder, Feed Pawl, Left	D5595007	Right and Left	No defects
Holder, Feed Pawl, Right	D5595008	Right and Left	No defects
Holder, Stop Pawl, Left	D5595005	Right and Left	No defects
Holder, Stop Pawl, Right	D5595006	Right and Left	No defects
Lever, Feed Control	B5228613	Right and Left	No defects
Lever, Rammer Cocking, Inner	B5222415	Left	No defects
Lever, Feed Roller Catch, Release	B5222608	Right (2) and Left (2)	No defects
Lever, Rammer Catch, Feed Control, Left	B5222604	Left	No defects
Lever, Rammer Catch, Trigger, Left	B5222650	Left	No defects
Lever, Rammer Catch, Tray	B5222452	Right and Left	No defects
Lever, Rammer Cocking, Outer Left	C6197123	Left	No defects
Lever, Rammer, Right	B5222412	Right and Left	No defects
Lever, Rammer, Left	B5222411	Right and Left	No defects

Component	Serial No. or Ord. Part No.	Gun	Results of the Inspection
Lever, Breechblock, Inner Cocking	B5222586	Right and Left	No defects
Lever, Breechblock, Outer Cocking	C6197147	Right and Left	Levers from both guns contained cracks (see paragraph 10)
Link, Feed Roller Catch Release	B5222563	Right and Left	No defects
Lever, Rammer Cocking, Inner	B7165189	Right	No defects
Lever, Rammer Cocking, Outer	C7165188	Right	No defects
Lever, Rammer Catch, Feed Control	B7225107	Right	No defects
Lever, Rammer Catch, Trigger	B7225104	Right	No defects
Piston, Feed Roller Catch Release	B5222418	Right (2) and Left (2)	No defects
Pawl, Feed, Left	B5222641	Right (5) and Left (5)	No defects
Pawl, Feed, Right	B5222642	Right (5) and Left (5)	No defects
Pawl, For Stop Pawl Holder, Left	B5222645	Right (10) and Left (10)	No defects
Pin, Rammer Catch Lever, Axis	A5222652	Right and Left	No defects
Plunger, Feed Rod	B5222420	Right (2) and Left (2)	No defects

Component	Serial No. or Ord. Part No.	Gun	Results of the Inspection
Plunger, Feed Roller Crosspiece	B5222606	Right (2) and Left (2)	No defects
Pin, Firing	7309769	Right and Left	No defects
Plunger, Breechblock, Inner Cocking Sear	C6197148	Right and Left	No defects
Rail, Upper (Outer)	C7225132	Right	No defects
Rail, Inner	D7225130	Right	No defects
Rail, Lower (Outer)	C7225131	Right	No defects
Rail, Inner	C5595011	Left	No defects
Rail, Lower (Outer)	C6197154	Left	No defects
Rail, Upper (Outer)	C6197140	Left	No defects
Rod, Feed Control, Upper	A5222468	Right and Left	No defects
Rod, Feed Control, Lower	B5222450	Right and Left	No defects
Rod, Feed, Right	D5595010	Right and Left	No defects
Rod, Feed, Left	D5595009	Right and Left	No defects
Roller, Feed Assembly, Right	B7238627	Right and Left	No defects
Roller, Feed Assembly, Left	B7238626	Right and Left	No defects
Rod, Rammer	B6197115	Right and Left	No defects

Component	Serial No. or Ord. Part No.	Gun	Results of the Inspection
Ring, Breech	L-154 K7225145	Left	No defects
Ring, Breech	R-145 K7225144	Right	No defects
Shaft, Feed Roller, Assembly, Left	B7238630	Right and Left	No defects
Shaft, Feed Roller, Assembly, Right	B7238631	Right and Left	No defects
Shaft, Rammer Cocking Lever	324132-Stamped on part B7165181-Should be	Right	No defects
Shaft, Breech Ring Crank	C6197104	Right and Left	No defects
Spindle, Rammer Control	B5222561-Stamped on part B5222651-Should be	Right and Left	No defects
Spindle, Feed Roller Catch Head	A5222419	Right (2) and Left (2)	No defects
Shoe, Rammer	C6197122	Right and Left	No defects
Spindle, Extractor	B6197106	Right	No defects
Suppressor, Flash	D7308575	Right and Left	Defective (see paragraph 11)
Spindle, Feed Roller Catch Release	A5222466	Right and Left	No defects
Spindle, Rammer Control Intermediate	A5222460	Right and Left	No defects

Component	Serial No. or Ord. Part No.	Gun	Results of the Inspection
Spindle, Feed Control Lever	B5222402	Right and Left	No defects
Support, Feed Roller, Right	B5222413	Right and Left	No defects
Support, Feed Roller, Left	B5222414	Right and Left	No defects
Shaft, Rammer, Cocking Lever	B5222479	Left	No defects
Spindle, Extractor	B6197106	(Mounted in left gun, should have been in right one)	No defects
Spring, Rammer Catch Lever Plunger	A5222456	Right (3) and Left (3)	No defects
Spring, Rammer Control Torsion	B5222597	Left	No defects
Spring, Feed Roller Catch Head Torsion, Left	B5222459	Left	No defects
Spring, Pawl Torsion	A5222595	Right (20) and Left (20)	No defects
Spring, Rammer Control Torsion	B7225111	Right	No defects
Spring, Feed Roller Catch Head Torsion, Right	B5222594	Right	No defects
Spring, Rammer Lever Plunger	A5222407	Right and Left	No defects
Spring Feed Roller Plunger	A5222464	Right (2) and Left (2)	No defects
Spring Firing Pin	B5222592	Right and Left	No defects

Component	Serial No. or Ord. Part No.	Gun	Results of the Inspection
Spring, Breechblock Inner Cocking Lever Sear Plunger	A5222593	Right and Left	No defects
Spring, Feed Rod Plunger	A5222646	Right (2) and Left (2)	No defects
Spring, Rammer, Inner	C6260936	Right and Left	No defects
Spring, Rammer, Outer	C6260937	Right and Left	No defects
Spring, Breech Closing	C6197113	Left	No defects
Spring, Breech Closing	C7165198	Right	No defects
Spring, Recuperator	D7238632	Right and Left	No defects
Tappet, Rammer Control, Fixed	B7225123	Right	No defects
Tappet, Rammer Control, Free	B7165183	Right	No defects
Tray, Automatic Loader	F7305585	Right	No defects
Tappet, Rammer Control Fixed	B5222602	Left	No defects
Tappet, Rammer Control Free	B5222600	Left	No defects
Modified Trip Lever Firing Plunger Assembly Consisting Of:			
Synchronizing Lever	RD17309	Right (2) and Left (2)	No defects

Component	Serial No. or Ord. Part No.	Gun	Results of the Inspection
Pivot Crank	RD1C7308	Center of Right and Left Gun	No defects
Cross Shaft	RD17310	Right and Left	No defects
Pillow Block	RD17311	Right and Left	No defects
Firing Plunger Crank	RD17305	Right	No defects
Firing Plunger Crank	RD1C7306	Left	No defects
Teeter Bar	RD1C7304	Right and Left	No defects
Firing Plunger Assembly		Right and Left	No defects
Trip Lever		Right and Left	No defects
Rammer Catch Lever		Right and Left	No defects

2. The left extractor arm (B7165194) from the left gun contained cracks (see the photographs in Figure 1). No defects were noted in the extractor during the previous inspection.

3. The right extractor arm (B6197107) from the right gun contained cracks during the previous inspection (see the photographs in reference report 65-M-108, Figure 1). During additional firing, the cracks progressed in length (see the photographs in Figure 2 of this report).

4. The firing pin spring cover (B5222588) from the right gun contained cracks as shown in the photographs in Figure 3. No defects were noted in the cover during the previous inspection.

5. The two right and the two left breech-ring inner cranks (C5595004 and C5595003) from the right and left guns contained cracks during the previous inspection. No change was noted in the patterns during this inspection (see the photographs in Figures 4, 5, 6 and 7).

6. The breech-ring closing-spring cover (C7165197) from the right gun contained cracks (see the photographs in Figure 8). The cover contained no cracks during the previous inspection.

7. The cartridge case extractor (C6197126) from the right gun contained cracks (see the photographs in Figure 9). The extractor contained no defects during the previous inspection.

8. The ammunition charger clip (C7225110) from the right gun contained cracks as shown in the photographs in Figure 10. The guide contained no defects during the previous inspection.

9. The rear-loader guide (F6550009) from the left gun contained a crack pattern as shown in the photographs in Figure 11. No defects were noted in the guide during the previous inspection.

10. The levers (C6197147) from both guns contained cracks (see Figures 12 and 13). During the previous inspection, only the lever from the right gun was cracked. Comparison of the photograph of the right lever in this report and the photograph in PTL Report No. 65-M-108 will reveal the obvious propagation of this crack.

11. The braces around the three protruding fingers of the flash suppressors (D7308575) were torn loose at the welds. No other defects were noted. The braces were to be repaired and the suppressors placed back in service.

SUBMITTED:

C. L. Hall for
WILLIAM H. TAYLOR
Materials Evaluation Section

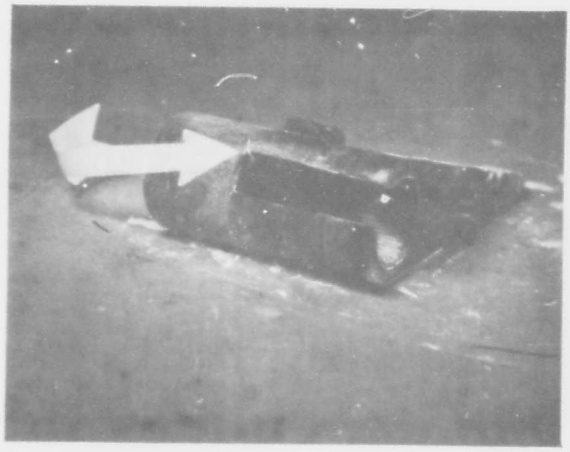
REVIEWED:

RL Huddleston
R. L. HUDDLESTON
Chief
Materials Evaluation Section

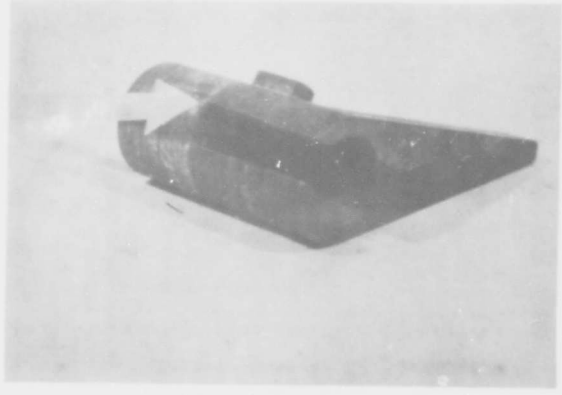
APPROVED:

Ralph Kenny for
J. M. McKINLEY
Chief
Physical Test Laboratory

1 Incl
Appendix I

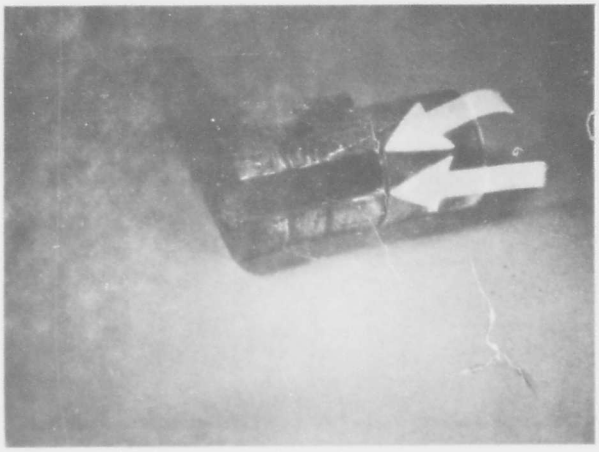


Magnetic Particle Crack Patterns in the Left Extractor (B7165194) from the Left Gun.

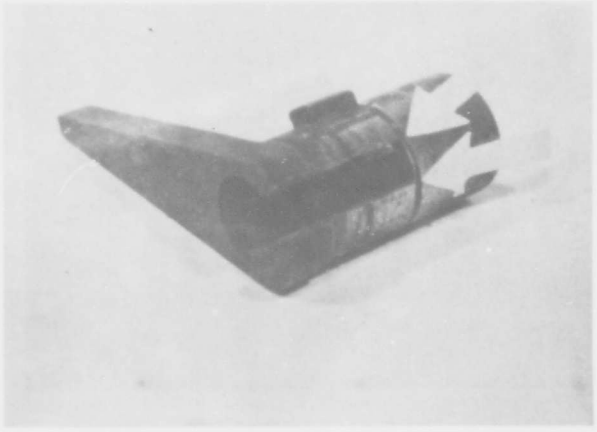


General View of the Same Area.

Figure 1

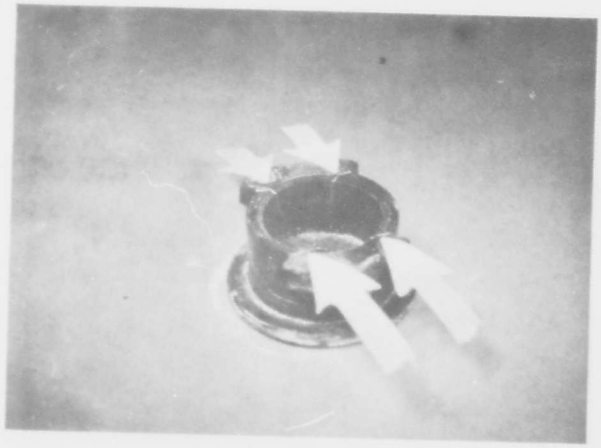


Magnetic Particle Crack Patterns in the Right Extractor (B6197107) from the Right Gun.



General View of the Same Area.

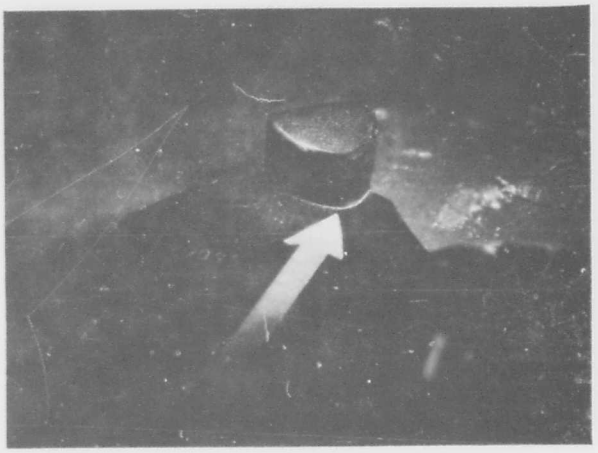
Figure 2



Magnetic Particle Crack Patterns in the Firing Pin Spring Cover (B5222588) from the Right Gun.

General View of the Same Area.

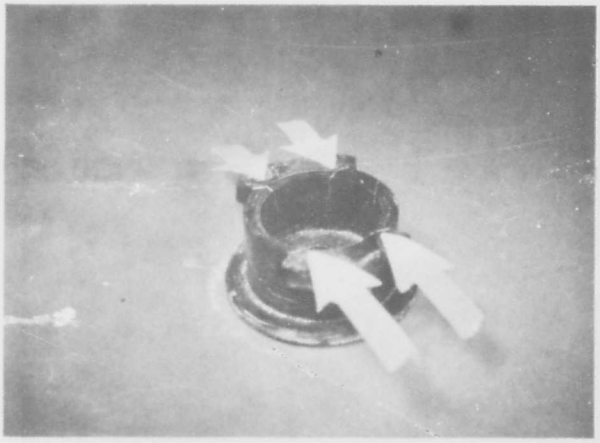
Figure 3



Magnetic Particle Crack Patterns in the Breech Ring Inner Crank (C5595004) from the Right Gun.

General View of the Same Area.

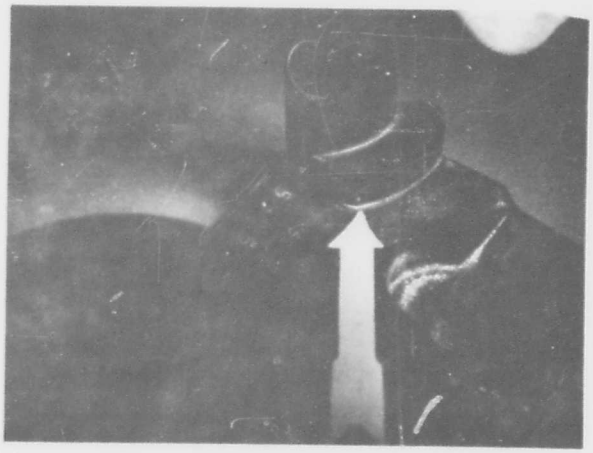
Figure 4



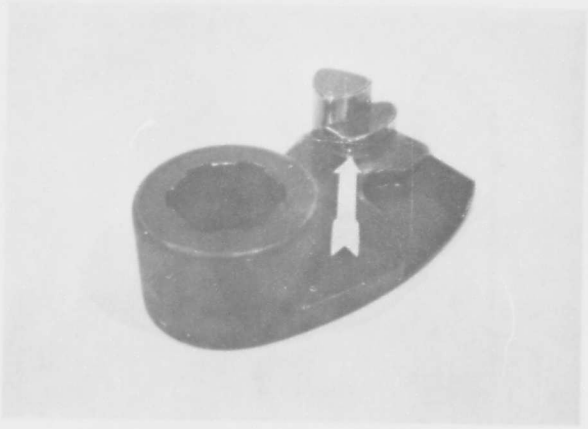
Magnetic Particle Crack Patterns in the Firing Pin Spring Cover (B5222588) from the Right Gun.

General View of the Same Area.

Figure 3

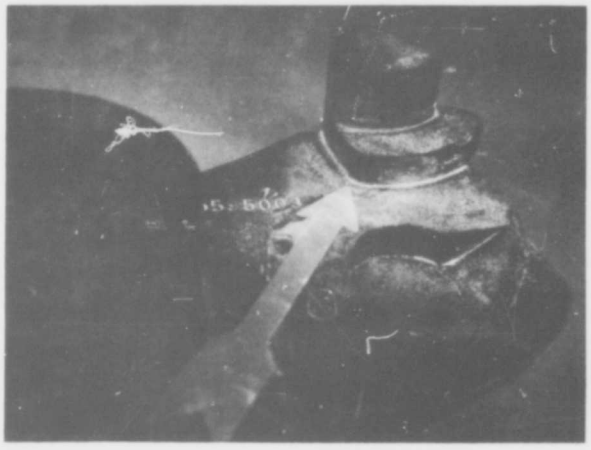


Magnetic Particle Crack Patterns in the Breech-Ring Inner Crank (C5595003) from the Right Gun.

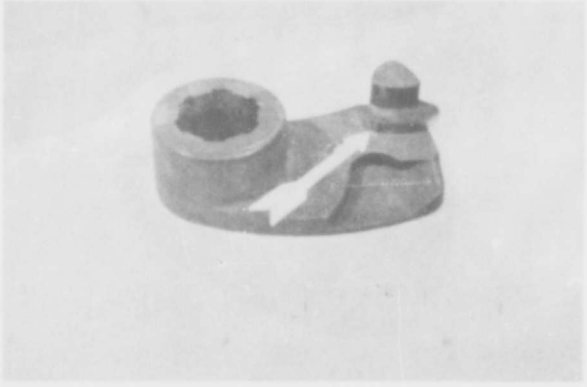


General View of the Same Area.

Figure 5

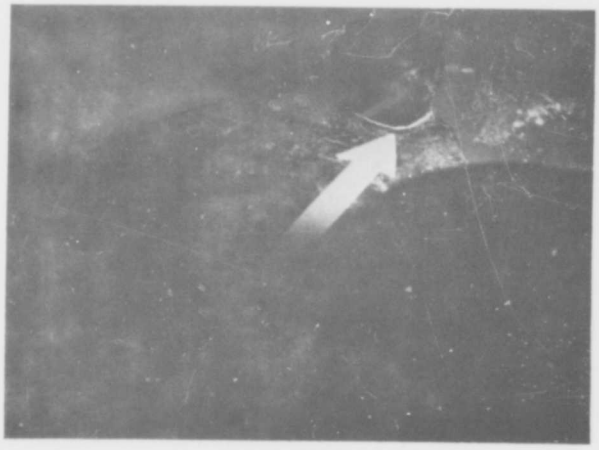


Magnetic Particle Crack Patterns in the Breech-Ring Inner Crank (C5595003) from the Left Gun.



General View of the Same Area.

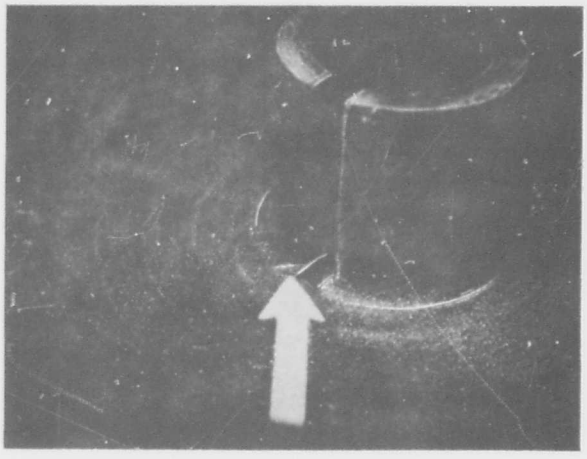
Figure 6



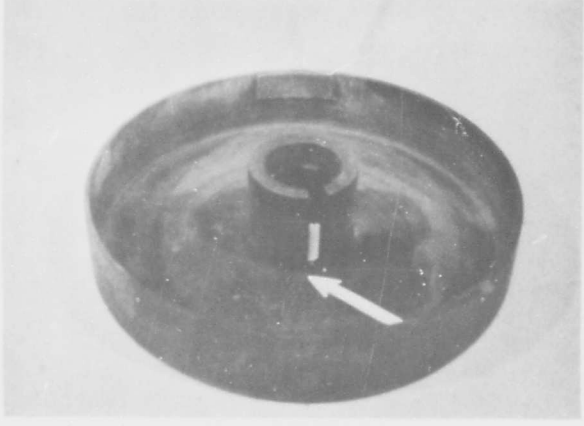
Magnetic Particle Crack Patterns in the Breech-Ring Inner Crank (C5595004) from the Left Gun.

General View of the Same Area.

Figure 7

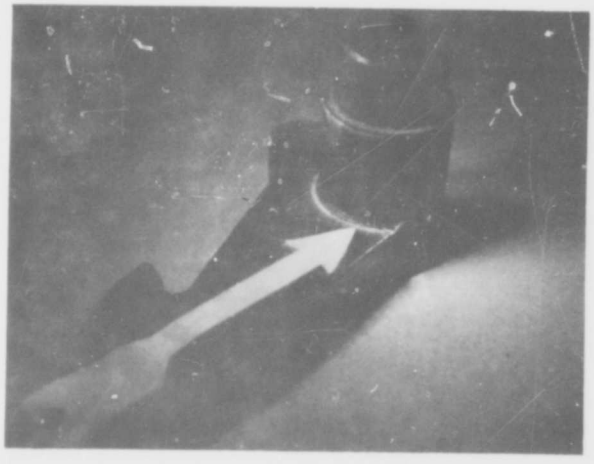


Magnetic Particle Crack Patterns in the Breech-Closing Spring Cover (C7165197) from the Right Gun.



General View of the Same Area.

Figure 8



Magnetic Particle Crack Patterns in the Cartridge-Case Extractor (C6197126) from the Right Gun.

General View of the Same Area.

Figure 9

Magnetic Particle Crack Pattern in the Ammunition Charger Clip Guide (C7225110) from the Right Gun.

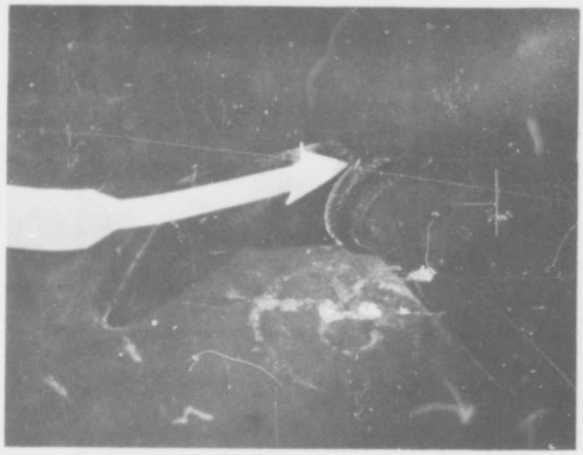
General View of the Same Area.

Figure 10

Magnetic Particle Crack Patterns in the Rear Loader Guide (F6550009) from the Left Gun.

General View of the Same Area.

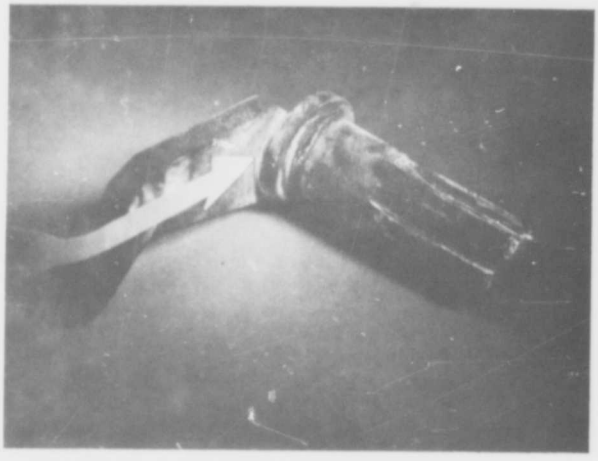
Figure 11



Magnetic Particle Crack Pattern in the Breechblock Outer Cocking Lever (C6197147) from the Right Gun.

General View of the Same Area.

Figure 12



Magnetic Particle Crack Patterns in the Breechblock Outer Cocking Lever (C6197147) from the Left Gun.

General View of the Same Area.

Figure 13

ENGINEERING LABORATORIES
PHYSICAL TEST LABORATORY REPORT

STEAP-DS-LP

TEST OF:

Various Springs from Gun, Dual Automatic, 40-MM, M2A1 from M42 Vehicle No. 121273. (After Fire)

OBJECT OF TEST:

To conduct a specification check of the springs.

INSTRUMENTATION:

Universal testing machine, 5000-pound capacity; measuring instruments and torque wrench, 0 to 100 ft-lb capacity.

PROCEDURE:

1. Initially the physical dimensions of all but the breech closing springs were measured. They were then individually placed in the testing machine and compressed to the specified heights and to the solid heights. Finally the outside diameters of the springs were measured at solid heights.

2. The breech closing springs were placed in the containers and assembled to the retaining slot on the gun. Torque was applied through the specified angle with a torque wrench and the value noted.

RESULTS:

For tabulated data see Appendix I.

Report No. 65-M-154

Sheet 1 of 2

Dates of Test 16 to 21 July 1965

Report Complete 23 July 1965

Conducted for Mr. P. Grepps
Artillery Weapons Branch

W. O. No. 377-010-12

References Dwg Nos. 5222407, 5222464, 5222592, 5222593, 5222646, 6260936, 6260937, 7197113, 7165198, and 7238632.

1 Incl
Appendix I

SUBMITTED:

C. L. Hall for
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REVIEWED:

R. L. Huddleston
R. L. HUDDLESTON
Chief,
Materials Evaluation Section

APPROVED:

for J. M. McKINLEY
Chief,
Physical Test Laboratory

Rammer Lever Plunger Springs, Dwg No. 5222407

	Specs	Actual Measurements	
Vehicle No.		1211273	1211273
Side		Left	Right
Firing status (total rounds)		3134	3156
*Outside diameter solid, not more than (in.)	0.500	0.471	0.475
Mean diameter free (basic) (in.)[a]	0.396	0.388	0.395
Inside diameter free, not less than (in.)[a]	-	0.308	0.315
Diameter of wire (in.)	0.080	0.080	0.080
No. of working coils	19	19	19
Free height, approx (in.)	2.930	[b]2.664	[b]2.825
*Solid height, not more than (in.)	1.810	1.695	1.662
*Load at height of 1.85 in. (lb)	54 ± 6	54	57
Outside diameter free (in.)	-	0.468	0.475

*Mandatory requirements.

[a]Computed.
[b]Did not meet specifications.

Feed Roller Plunger Springs, Dwg No. 5222464

	Specs	Actual Measurements			
Vehicle No.		12H273		12H273	
Side		Left	Left	Right	Right
Firing status (total rounds)		3134		3156	
*Outside diameter solid, not more than (in.)	0.672	0.660	0.653	0.659	0.672
Mean diameter free (basic) (in.)[a]	0.570	0.577	0.572	0.576	0.593
Inside diameter free, not less than (in.)[a]	0.469	0.494	0.492	0.495	0.513
Diameter of wire (in.)	0.080	0.083	0.080	0.081	0.080
No. of working coils	14	[b]12.5	[b]12.6	[b]12.5	[b]12.2
Free height, approx (in.)	2.88	2.79	2.91	2.89	2.87
*Solid height, not more than (in.)	1.26	1.21	1.18	1.16	1.13
*Load at height of 1.34 in. (lb)	35 ± 3.5	34	36	33	32
Outside diameter free (in.)	-	0.660	0.652	0.657	0.673

*Mandatory requirements.

[a]Computed.
[b]Did not meet specifications.

Firing Pin Springs, Drawing No. 5222592

	Specs	Actual Measurements	
Vehicle No.		12H273	12H273
Side		Left	Right
Firing status (total rounds)		3134	3156
Free height, min (in.)	2.350	2.404	2.443
Solid height, max (in.)	1.500	1.456	1.438
Wire diameter, approx (in.)	0.114	0.114	0.114
Outside diameter, max (in.)	0.646	0.642	0.635
Inside diameter (in.)[a]	-	0.414	0.407
Total No. of coils, approx	13	12.9	13
Load at 1.65 in. (lb)	116.8 + 11.0 - 6.6	111	120

[a]Computed.

Breech Block Inner Cocking Lever Sear Plunger Springs,
Dwg No. 5222593

	Specs	Actual Measurements	
Vehicle No.		1211273	1211273
Side		Left	Right
*Firing status (total rounds)		3134	3156
*Outside diameter solid, not more than (in.)	0.541	0.534	0.528
*Mean diameter free (basic)(in.)[a]	0.468	0.4755	0.4745
*Inside diameter free, not less than (in.)[a]	0.396	0.428	0.427
Diameter of wire (in.)	0.0475	0.0475	0.0475
No. of working coils	9-1/2	8.9	9
*Free height, approx (in.)	2.04	[b]1.775	[b]1.878
*Solid height, not more than (in.)	0.55	0.51	0.49
*Load at 0.709 in (lb)	10 ± 1	9	10
Outside diameter free (in.)	—	0.523	0.522

*Mandatory requirements.

[a]Computed.
[b]Did not meet specifications.

Feed Rod Plunger Springs, Dwg No. 5222646

	Specs	Actual Measurements			
Vehicle No.		121273		121273	
Side		Left	Left	Right	Right
*Firing status (total rounds)		3134		3156	
*Outside diameter solid, not more than (in.)	0.660	0.659	0.653	b0.662	b0.661
Mean diameter free, not less than (in.)[a]	0.490	0.504	0.498	0.505	0.500
*Inside diameter free, not less than (in.)[a]	0.320	0.350	0.341	0.348	0.343
Diameter of wire (in.)	0.1551	0.154	0.157	0.157	0.157
No. of working coils	18	18	18	18	18
*Free height, approx (in.)	4.15	4.07	4.06	4.14	4.11
*Solid height, not more than (in.)	3.18	3.15	3.15	3.18	3.17
*Load at height of 3.81 in. (lb)	331 ± 33	302	321	321	324
Outside diameter free (in.)	=	0.658	0.655	0.662	0.657

*Mandatory requirements.

[a]Computed.
[b]Did not meet specifications.

Inner Rammer Tray Springs, Dwg No. 6260936

	Specs	Actual Measurements	
Vehicle No.		1211273	1211273
Side		Left	Right
Firing status (total rounds)		3134	3156
Free height, approx (in.)	17	[b]16.021	[b]16.155
Solid height, max (in.)	4.750	4.638	4.643
Wire diameter (in.)	0.120	0.120	0.120
Outside diameter (in.)	-	1.150	1.152
Inside diameter (in.)[a]	0.900 ± 0.020	0.910	0.912
Total No. of coils, approx	40	38.8	38.8
Load at 12.200 in. (lb)	33 ± 3	[b] 27	[b] 28
Load at 6.300 in. (lb)	75 ± 7	78	[b] 66

[a]Computed.
[b]Did not meet specifications

Outer Rammer Tray Springs, Dwg No. 6260937

	Specs	Actual Measurements	
Vehicle No.		1211273	1211273
Side		Left	Right
Firing status (total rounds)		3134	3156
Free height, approx (in.)	17	[b] 16.067	[b] 16.095
Solid height, max (in.)	4.850	4.792	4.805
Wire diameter (in)	0.177	0.177	0.177
Outside diameter (in)	1.730 - 0.024	1.721	[b] 1.690
Inside diameter (in.)[a]	-	1.367	1.336
Total No. of coils, approx	27.5	27.4	27.25
Load at 12.200 in. (lb)	77 ± 7	[b] 56.0	[b] 64.0
Load at 6.300 in. (lb)	160 ± 15	146.0	157.0

[a]Computed.
[b]Did not meet specifications.

Breech Closing Springs, Ewg No. 7197113
(Left) 7165198 (Right)

	Specs	Actual Measurements	
Vehicle No.		1211273	1211273
Side		Left	Right
Firing status (rounds)		3134	3156
Torque at specified angle (ft lb)	54.7 ± 6.6	60	55

Specifications: For 145.5° twist, the load is 181 ± 22 pounds at a radius of 3-5/8 inches.

$$\frac{181 \text{ lb} \times 3.625 \text{ in.}}{12 \text{ in./ft}} = 54.7 \text{ ft lb}$$

$$\frac{22 \text{ lb} \times 3.625 \text{ in.}}{12 \text{ in/ft}} = 6.6 \text{ ft lb}$$

ENGINEERING LABORATORIES
PHYSICAL TEST LABORATORY REPORT

STEAP-DS-LP

INSPECTION OF:

Components of Gun, Dual, Automatic, 40-MM, M2A1 from M42 Tracked Vehicle, USA12H298.

OBJECT OF INSPECTION:

To locate possible defects in the two guns by magnetic particle inspection before firing at APG and after firing 1502 rounds on each of the two guns.

INSTRUMENTATION:

Magnaflux unit; wet continuous method, coil, and central conductor energized with low voltage to a maximum of 1800 amperes DC, fluorescent magnetic particles suspended in a portoleum base distillate bath, black light.

Report No. 65-M-155

Sheet 1 of 15

Dates of Inspection 8 June through 21 July 1965

Report Complete 28 July 1965

Conducted for Mr. Gropps Artillery Weapons Branch

W. O. No. 377-010-12

References Magnetic Particle Inspection Criteria. Drawings No. 8768747, 7309991, 7309992, 8769123, 8769067.

PROCEDURE:

The components were magnetized, washed with the bath and inspected under black light for patterns indicative of cracks or other flaws. The components were then demagnetized.

RESULTS:

1. The following listed components were inspected:

Component	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Arm, Rammer, Control Intermediate Spindle, outer, right	B722501	Right	Before fire and after 1502 rounds.	No defects.
Arm, Rammer, Control Intermediate Spindle, outer left	B5222409	Left	Before fire and after 1502 rounds.	No defects.
Arm, Feed Control Lever Spindle	B5222403	Right and Left	Before fire and after 1502 rounds.	No defects.

Component	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Arm, Rammer Control Spindle, Left	B5222601	Left	Before fire and after 1502 rounds.	No defects.
Arm, Rammer Control Spindle, Right	B7225103	Right	Before fire and after 1502 rounds	No defects.
Arm, Feed Roller Catch Release Lever	B522569	Right and Left	Before fire and after 1502 rounds.	No defects.
Arm, Rammer Cocking Lever Shaft, Right	B7165190	Right	Before fire and after 1502 rounds.	No defects.
Arm, Rammer Cocking Lever Shaft, Left	B5222480	Left	Before fire and after 1502 rounds.	No defects.
Arm, Feed Roller Catch, Right	B5222471	Right and Left	Before fire and after 1502 rounds.	No defects.
Arm, Feed Roller Catch, Left	B5222649	Right and Left	Before fire and after 1502 rounds.	No defects.
Arm, Rammer Control Intermediate Spindle Inner, Left	B5222603	Left	Before fire and after 1502 rounds.	No defects.
Arm, Breech Ring Control	B5222434	Right and Left	Before fire and after 1502 rounds.	No defects
Arm, Extractor, Left	B7165194	Left	Before fire and after 1502 rounds.	Contained cracks (see paragraph 2).
Arm, Extractor, Right	B6197107	Right	Before fire and after 1502 rounds.	Contained cracks (see paragraph 2).
Arm, Rammer, Control Intermediate Spindle Inner, Right	B7225108	Right	Before fire and after 1502 rounds.	No defects.

Component	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Breechblock	F6550027 W-6CN1	Right	Before fire.	No defects.
Breechblock	F6550027 C-4BC8	Left	Before fire.	No defects
Replacement Breech-block	F6550027 A11CH10	Right	1502 rounds.	No defects
Replacement Breech-block	F6550027 X6CH5	Left	1502 rounds.	No defects.
Cross-Piece Loader	C7238622	Right and Left	Before fire and after 1502 rounds.	No defects.
Collar, Rammer Control Spindle	B5222599	Right and Left	Before fire and after 1502 rounds.	No defects.
Cover, Firing Pin Spring	B5222588	Right and Left	Before fire.	Contained cracks (see paragraph 3).
Cover, Firing Pin Spring	B5222588	Right and Left	1502 rounds.	Contained cracks (see paragraph 3).
Catch, Breech Ring Barrel	C7165191	Right	Before fire and after 1502 rounds.	No defects.
Catch, Breech Ring Barrel	C6197153	Left	Before fire and after 1502 rounds.	No defects.
Crank, Breech Ring Outer, Right	C7165178	Right	Before fire and after 1502 rounds.	No defects.
Crank, Breech Ring Inner, Right	C5595004	Right	Before fire.	Contained cracks. Replaced with one free of cracks.
Crank, Breech Ring Inner, Right	C5595004	Right	1502 rounds.	Contained cracks (see figure 4).
Crank, Breech Ring Inner, Left	C5595003	Right	Before fire.	Contained cracks. Replaced with one free of cracks.

Component	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Crank, Breech Ring Inner, Left	C5595003	Right	1502 rounds.	No defects.
Crank, Breech Ring Inner, Left	C5595003	Left	Before fire.	Contained cracks. Replaced with one free of cracks.
Crank, Breech Ring Inner, Left	C5595003	Left	1502 rounds.	Contained cracks (see Figure 5).
Crank, Breech Ring Inner, Right	C5595004	Left	Before fire.	Contained cracks. Replaced with one free of cracks.
Crank, Breech Ring Inner, Right	C5595004	Left	1502 rounds.	Contained cracks (see Figure 6).
Case, Breech Closing Spring	C7165196	Right	Before fire.	No defects. Replaced.
Case, Breech Closing Spring	C7165196	Right	1502 rounds.	No defects.
Case, Breech Closing Spring	C6197102	Left	Before fire.	No defects. Replaced.
Case, Breech Closing Spring	C6197102	Left	1502 rounds.	No defects.
Cover, Breech Closing Spring	C7165197	Right	Before fire.	Contained cracks. Replaced with one free of cracks.
Cover, Breech Closing Spring	C7165197	Right	1502 rounds.	No defects.
Cover, Breech Closing Spring	C6197103	Left	Before fire.	Contained cracks. Replaced with one free of cracks.
Cover, Breech Closing Spring	C6197103	Left	1502 rounds.	No defects.
Crank, Breech Ring Outer, Left	C6197105	Left	Before fire.	No defects. Replaced.

Components	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Crank, Breech Ring Outer, Left	C6197105	Left	1502 rounds.	No defects.
Extractor, Cartridge Case	C6197126	Right and Left	Before fire.	No defects. Replaced.
Extractor, Cartridge Case	C6197126	Right and Left	1502 rounds.	No defects.
Extractor, Cartridge Case	C6197146	Right and Left	Before fire.	No defects. Replaced.
Extractor, Cartridge Case.	C6197146	Right and Left	1502 rounds.	No defects.
Guide, Ammunition Charger Clip	C6197121	Left	Before fire and after 1502 rounds.	No defects.
Guide, Ammunition Charger Clip	C7226110	Right	Before fire and after 1502 rounds.	No defects.
Guide, Loader, Rear	F7225129	Right	Before fire and after 1502 rounds.	Contained cracks (see paragraph 4).
Guide, Loader Rear	F6550009	Left	Before fire and after 1502 rounds.	Contained cracks (see paragraph 4).
Guide, Loader Front	D7238623	Right and Left	Before fire and after 1502 rounds.	No defects.
Head, Feed Roller Catch, Left	C5222481	Right and Left	Before fire and after 1502 rounds.	No. defects
Head, Feed Roller Catch, Right	C5222482	Right and Left	Before fire and after 1502 rounds.	No defects.
Holder, Feed Pawl, Left	D5595007	Right and Left	Before fire and after 1502 rounds.	No defects.

Component	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Holder, Feed Pawl, Right	D5595008	Right and Left	Before fire and after 1502 rounds.	No defects.
Holder, Stop Pawl, Left	D5595005	Right and Left	Before fire and after 1502 rounds.	No defects.
Holder, Stop Pawl, Right	D5595006	Right and Left	Before fire and after 1502 rounds.	No defects.
Lever, Feed Control, Thumb	5222467	Right and Left	Before fire and after 1502 rounds.	No defects.
Lever, Feed Control	B5222613	Right and Left	Before fire and after 1502 rounds.	No defects.
Lever, Rammer Cocking, Inner	B5222415	Left	Before fire and after 1502 rounds.	No defects.
Lever, Feed Roller Catch Release	B5222608	Right and Left	Before fire and after 1502 rounds.	No defects.
Lever, Rammer Catch, Feed Control, Left	B5222604	Left	Before fire and after 1502 rounds.	No defects.
Lever, Rammer Catch, Trigger, Left	B5222650	Left	Before fire and after 1502 rounds.	No defects.
Lever, Rammer Catch, Tray	B5222452	Right and Left	Before fire and after 1502 rounds.	No defects.
Lever, Rammer Cocking, Outer Left	C6197123	Left	Before fire and after 1502 rounds.	No defects.
Lever, Rammer, Right	B5222412	Right and Left	Before fire.	No defects.

Component	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Lever, Rammer, Right	B5222412	Right and Left	1502 rounds.	No defects.
Lever, Rammer, Left	B5222411	Right and Left	Before fire.	No defects.
Lever, Rammer, Left	B5222411	Right and Left	1502 rounds.	No defects.
Lever, Breechblock Inner Cocking	B5222586	Right and Left	Before fire.	Lever from left gun contained cracks (see paragraph 5).
Lever, Breechblock Inner Cocking	B5222586	Right and Left	1502 rounds.	Lever from left gun contained cracks (see paragraph 5).
Lever, Breechblock Outer Cocking	C6197147	Right and Left	Before fire.	Contained cracks (see paragraph 6).
Lever, Breechblock Outer Cocking	C6197147	Right and Left	1502 rounds.	Contained cracks (see paragraph 6).
Link, Feed Roller Catch Release	B5222563	Right and Left	Before fire and after 1502 rounds.	No defects.
Lever, Rammer Cocking Inner	B7165189	Right	Before fire and after 1502 rounds.	No defects.
Lever, Rammer Cocking, Outer	C7165188	Right	Before fire and after 1502 rounds.	No defects.
Lever, Rammer Catch, Feed Control	B7225107	Right	Before fire and after 1502 rounds.	No defects.
Lever, Rammer Catch, Trigger	B7225104	Right	Before fire and after 1502 rounds.	No defects.

Component	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Piston, Feed Roller Catch Release	B5222418	Right (2) and Left (2)	Before fire and after 1502 rounds.	No defects.
Pawl, Feed, Left	B5222641	Right (5) and Left (5)	Before fire and after 1502 rounds.	No defects.
Pawl, Feed, Right	B5222642	Right (5) and Left (5)	Before fire and after 1502 rounds.	No defects.
Pawl, For Stop Pawl Holder, Left	B5222645	Right (5) and Left (5)	Before fire and after 1502 rounds.	No defects.
Pawl, For Stop Pawl Holder, Right	B5222645	Right (5) and Left (5)	Before fire and after 1502 rounds.	No defects
Pin, Rammer Catch Lever, Axis	A5222652	Right (2) and Left (2)	Before fire and after 1502 rounds.	No defects.
Plunger, Feed Rod, Left	B5222420	Right (2) and Left (2)	Before fire and after 1502 rounds.	No defects.
Plunger, Feed Roller Cross-Piece	B5222606	Right (2) and Left (2)	Before fire and after 1502 rounds.	No defects.
Plunger. Rammer Shoe	5222614	Right (2) and Left (2)	Before fire and after 1502 rounds.	No defects.
Pin, Firing	7309769	Right and Left	Before fire.	No defects.
Pin, Firing	7309769	Right and Left	1502 rounds.	No defects.

Component	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Plunger, Breechblock Inner Cocking Sear	C6197148	Right and Left	Before fire.	Contained cracks (see paragraph 7).
Plunger, Breechblock Inner Cocking Sear	C6197148	Right and Left	1502 rounds.	Contained cracks (see paragraph 7).
Plunger, Feed Rod, Right	B5222420	Right (2) and Left (2)	Before fire and after 1502 rounds.	No defects.
Rail, Upper (Outer)	C7225132	Right	Before fire and after 1502 rounds.	No defects.
Rail, Inner	D7225130	Right	Before fire and after 1502 rounds.	No defects.
Rail Lower (Outer)	C7225131	Right	Before fire and after 1502 rounds.	No defects.
Rail, Inner	C5595011	Left	Before fire and after 1502 rounds.	No defects.
Rail, Lower (Outer)	C6197154	Left	Before fire and after 1502 rounds.	No defects.
Rail, Upper (Outer)	C6197140	Left	Before fire and after 1502 rounds.	No defects.
Rod, Feed Control, Upper	A5222468	Right and Left	Before fire and after 1502 rounds.	No defects.
Rod, Feed Control, Lower	B5222450	Right and Left	Before fire and after 1502 rounds	No defects.
Rod, Feed, Right	D5595010	Right and Left	Before fire and after 1502 rounds.	No defects.
Rod, Feed, Left	D5595009	Right and Left	Before fire and after 1502 rounds.	No. defects.

Component	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Roller Feed Assembly, Right	B7238627	Right and Left	Before fire and after 1502 rounds.	No defects.
Roller, Feed Assembly, Left	B7238626	Right and Left	Before fire and after 1502 rounds.	No defects.
Rod, Rammer	B6197115	Right and Left	Before fire and after 1502 rounds.	No defects.
Ring, Breech	L-89 K7225145	Left	Before fire and after 1502 rounds.	No defects.
Ring, Breech	R-146 K7225144	Right	Before fire and after 1502 rounds.	No defects.
Shaft, Feed Roller, Assembly Left	B7238630	Right and Left	Before fire and after 1502 rounds.	No defects.
Shaft, Feed, Roller, Assembly Right	B7238631	Right and Left	Before fire and after 1502 rounds.	No defects.
Shaft, Rammer Cocking Lever	B7165181	Right	Before fire and after 1502 rounds.	No defects.
Shaft, Breech Ring Crank	C6197104	Left	Before fire	Contained cracks (see paragraph 8).
Shaft, Breech Ring Crank	C6197104	Right	Before fire and after 1502 rounds.	No defects.
Shaft, Breech Ring Crank	C6197104	Left	1502 rounds.	No defects.
Spindle, Rammer Control	B5222651	Right and Left	Before fire and after 1502 round.	No defects.

Component	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Spindle, Feed Roller Catch Head	A5222419	Right (2) and Left (2)	Before fire and after 1502 rounds.	No defects.
Shoe, Rammer	C6197122	Right	Before fire and after 1502 rounds.	No defects.
Shoe, Rammer	C61: 7122	Left	Before fire.	Contained cracks (see paragraph 9).
Shoe, Rammer	C6197122	Left	1502 rounds.	No defects.
Spindle, Extractor	B6197106	Right	Before fire.	Contained cracks (see paragraph 10).
Spindle, Extractor	B6197106	Right	1502 rounds.	No defects.
Suppressor, Flash	D7308575	Right and Left	1502 rounds.	No significant defects.
Spindle, Feed Roller Catch Release	A5222466	Right and Left	Before fire and after 1502 rounds.	No defects.
Spindle, Rammer Control Intermediate	A5222460	Right and Left	Before fire and after 1502 rounds.	No defects.
Spindle, Feed control Lever	B5222402	Right and Left	Before fire and after 1502 rounds.	No defects.
Support, Feed Roller, Right	B5222413	Right and Left	Before fire and after 1502 rounds.	No defects.
Support, Feed Roller, Left	B5222414	Right and Left	Before fire and after 1502 rounds.	No defects.
Shaft, Rammer, Corking Lever	B5222479	Left	Before fire and after 1502 rounds.	No defects.

Component	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Seat Feed Roller Plunger Spring	5222605	Right (2) and Left (2)	Before fire and after 1502 rounds.	No defects.
Spindle, Extractor	B7165193	Left	Before fire.	Contained cracks. Replaced with one from spare parts (See paragraph 10).
Spindle, extractor	B7165193	Left	1502 rounds.	No defects.
Spring, Rammer Catch Lever Plunger	A5222456	Right (3) and Left (3)	Before fire and after 1502 rounds.	No defects.
Spring, Rammer Control Torsion	B5222597	Left	Before fire and after 1502 rounds.	No defects.
Spring, Feed Roller Catch Head Torsion, Left	B5222459	Left (2)	Before fire and after 1502 rounds.	No defects.
Spring, Pawl Torsion	A5222595	Right (20) and Left (20)	Before fire and after 1502 rounds.	No defects.
Spring, Rammer Control Torsion	B7225111	Right	Before fire and after 1502 rounds.	No defects.
Spring, Feed Roller Catch Head Torsion, Right	B5222594	Right (2)	Before fire and after 1502 rounds.	No defects.
Spring, Rammer Lever Plunger	A5222407	Right and Left	Before fire.	No defects. Replaced.
Spring, Rammer Lever Plunger	A5222407	Right and Left	1502 rounds.	No defects.
Spring Feed Roller Plunger	A5222464	Right (2) and Left (2)	Before fire and after 1502 rounds.	No defects

Component	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Spring, Firing Pin	B5222592	Right and Left	Before fire.	No defects. Replaced.
Spring, Firing Pin	B5222592	Right and Left	1502 rounds.	No defects.
Spring, Breechblock Inner Cocking Lever Sear Plunger	A5222593	Right and Left	Before fire.	No defects. Replaced.
Spring, Breechblock Inner Cocking Lever Sear Plunger	A5222593	Right and Left	1502 rounds.	No defects.
Spring, Feed Rod Plunger	A5222646	Right (2) and Left (2)	Before fire and after 1502 rounds.	No defects.
Spring, Rammer, Inner	C6260936	Right and Left	Before fire.	No defects. Spring for right gun replaced.
Spring, Tray Pawl Plunger	5222463	Right and Left	Before fire and after 1502 rounds.	No defects.
Spring, Rammer, Outer	C6260937	Right and Left	Before fire.	No defects. Both springs replaced.
Spring, Rammer, Outer	C6260937	Right and Left	1502 rounds.	No defects.
Spring, Breech Closing	C6197113	Left	Before fire.	No defects. Replaced.
Spring, Breech Closing	C6197113	Left	1502 rounds.	No defects.
Spring, Breech Closing	C7165198	Right	Before fire.	No defects. Replaced.
Spring, Breech Closing	C7165198	Right	1502 rounds.	No defects.
Spring, Recuperator	D7238632	Right and Left	Before fire.	No defects. Spring from right gun replaced.

Component	Serial or Ord Part No.	Gun	Firing Status	Results of the Inspection
Spring, Recuperator	D7238632	Right and Left	1502 rounds.	No defects.
Tappet, Rammer Control Fixed.	B7225123	Right	Before fire and after 1502 rounds.	No defects.
Tappet, Rammer Control Free	B7165183	Right	Before fire and after 1502 rounds.	No defects.
Tray, Automatic Loader	F7305585	Right and Left	Before fire.	No defects.
Tray, Automatic Loader	F7305585	Right and Left	1502 rounds.	No defects.
Tappet, Rammer Control Fixed	B5222602	Left	Before fire and after 1502 rounds.	No defects.
Tappet, Rammer Control Free	B5222600	Left	Before fire and after 1502 rounds.	No defects.

2. Crack patterns were noted at the corners of the cut out sections of each of the two extractor arms (B7165194 and B6197107) from the two guns. The patterns were noted during the first inspection. During the second inspection the crack patterns had about doubled in length with smaller patterns extending from the large crack (see the photographs on figure 1 and 2).

3. During the first inspection of the firing pin covers (B5222588), the one from the right gun contained cracks. The cracks were similar to those shown in the photograph on figure 3. The cover from the left gun was crack free. Both of the covers were replaced with crack free ones from the spare parts. During the second inspection (1502 rounds) the cover from the left gun contained cracks as shown on figure 3. The cover from the right gun was crack free.

4. The shrinkage type of crack pattern on the two guides (F7225129 and (F6550009) from the right and left guns were noted during the first inspection. No change could be observed in the crack patterns during the second inspection (see the photographs on figures 7 and 8).

5. During the before fire inspection of the breechblock inner cocking lever (B5222586) from the left gun several crack patterns were noted. The patterns started in the fillet area of the splines. The lever from the right gun was crack free. The two levers were replaced with crack free levers. During the second inspection (1502 rounds) a crack pattern was noted in the lever from the left gun (see photographs on figure 9). No defects were noted in the lever from the right gun.

6. The two breechblock outer cocking levers (C6197147) from both guns contained cracks during the before firing inspection. The two levers were replaced with ones which were crack free. After firing 1502 rounds on the replaced parts the levers were inspected and crack patterns noted (see the photographs on figures 10 and 11).

7. Crack patterns were noted in each of the breechblock inner cocking sear plungers (C6197148) from each of the two guns during the first inspection. The two plungers were replaced with two which were crack free. During the next inspection, crack patterns were noted on the replacement items (see the photographs on figures 12 and 13).

8. Crack patterns were noted in the breech ring crack shaft (C6197104) from the left gun during the first inspection (see photographs on figure 14). The shaft was replaced with one which was crack free. No defects were noted in the replacement shaft during the after fire inspection.

9. Crack patterns were noted in the rammer shoe (C6197122) from the left gun during the first inspection. The location of the cracks were indicated by the arrows in the photograph shown on figure 15. The shoe was replaced and no defects were noted in the replacement after firing 1502 rounds.

10. Crack patterns were noted in the two extractor spindles (B6197106 and B7165193) from both guns, during the first inspection. See the photograph on figure 16. The spindles were replaced with ones which contained no cracks. No defects were noted in the two replacements after firing 1502 rounds.

1 Incl
Appendix I

SUBMITTED:

C. F. Hall for
WILLIAM H. TAYLOR
Materials Evaluation Section

REVIEWED:

J. Di Benedetto
pr R. L. HUDDLESTON
Chief
Materials Evaluation Section
313

APPROVED:

J. M. McKinley
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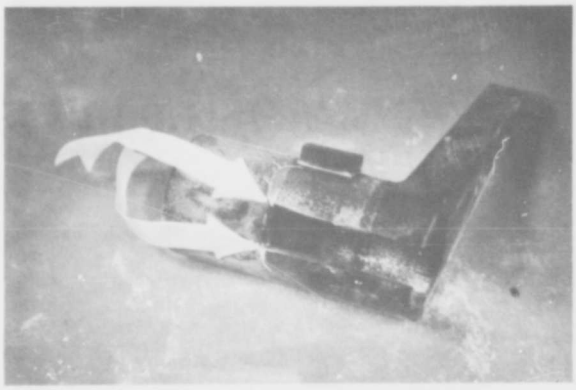
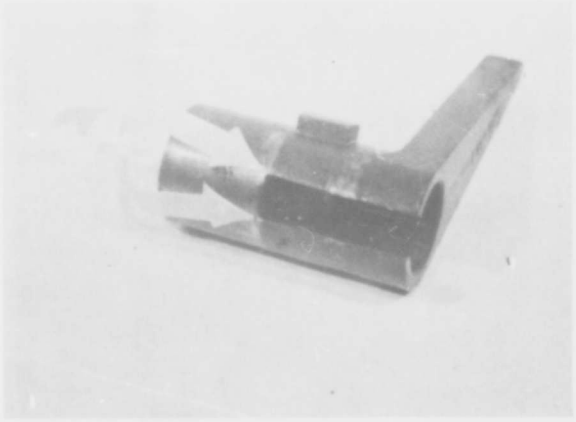


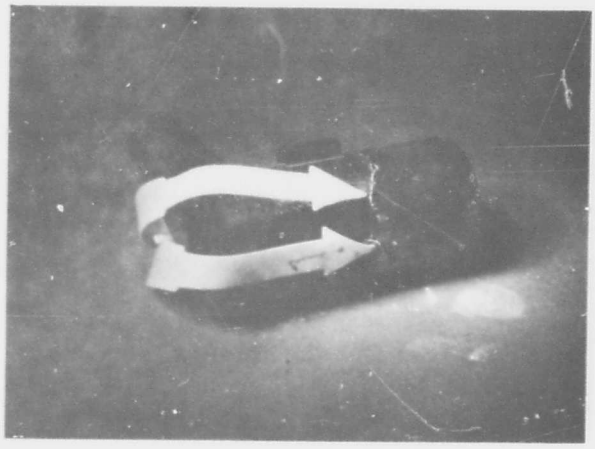
Magnetic Particle Crack Patterns in the Extractor Arm (B7165194) from the Left Gun after Firing.



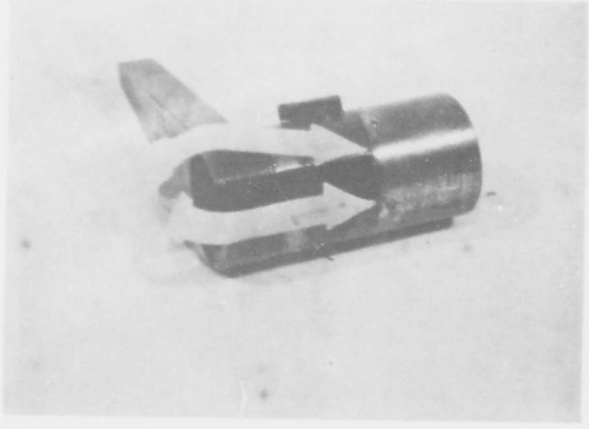
General View of the Same Area.

Figure 1

Appendix 1

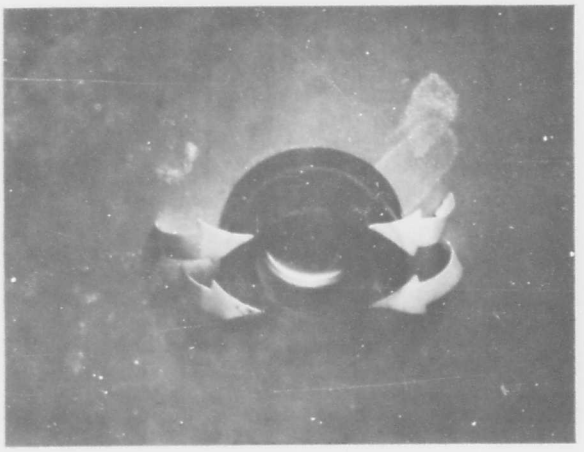


Magnetic Particle Crack Patterns in the Extractor Arm (B6197107) from the Right Gun after Firing.

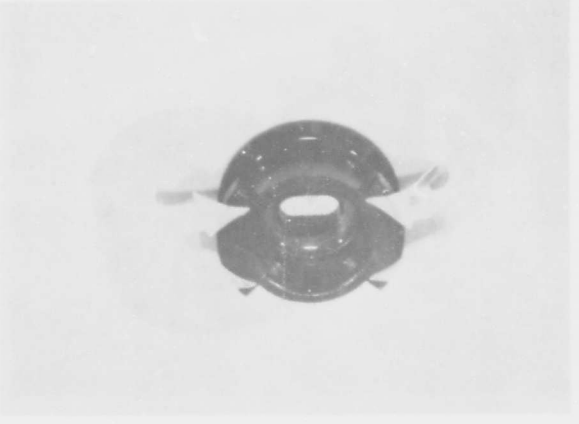


General View of the Same Area.

Figure 2



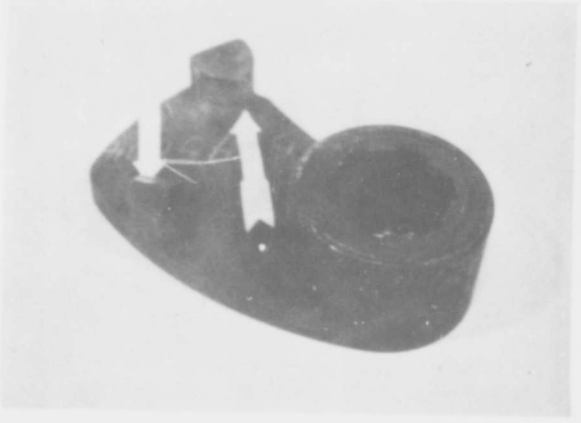
Magnetic Particle Crack Patterns in the Replacement Cover (B5222588) from the Left Gun after 1502 Rounds.



General View of the Same Area

Figure 3

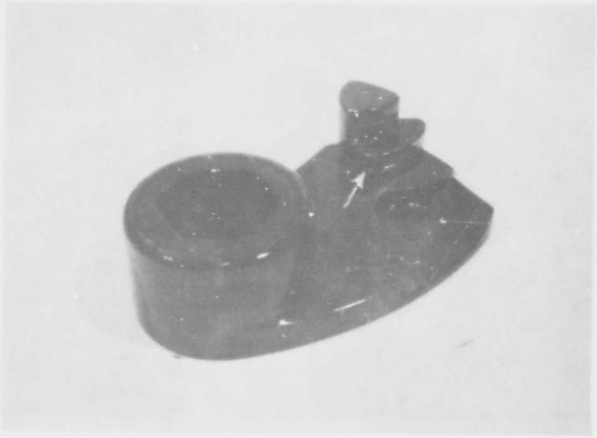
Magnetic Particle Crack Patterns in the Replacement Crank (C5595004) from the Right Gun after Firing 1502 Rounds.



General View of the Same Area.

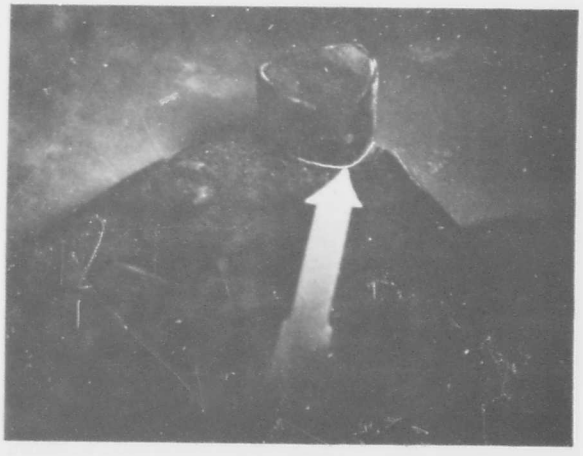
Figure 4

Magnetic Particle Crack Patterns in the Replacement Crank (C5595003) from the Left Gun after Firing 1502 Rounds.



General View of the Same Area.

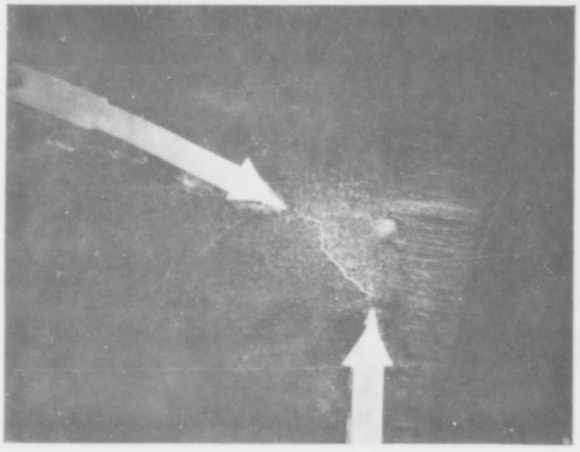
Figure 5



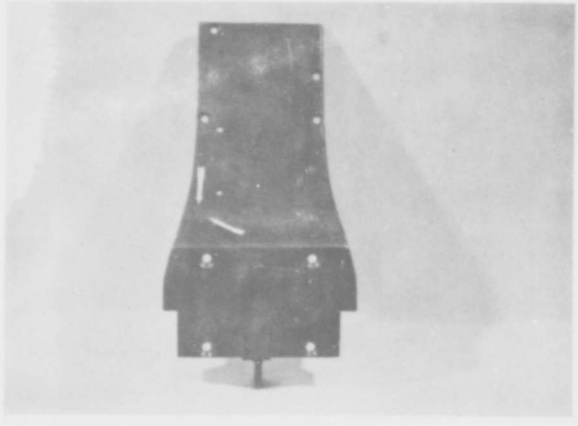
Magnetic Particle Crack Patterns in the Replacement Crank (C5595004) from the Right Gun after Firing 1502 Rounds.

General View of the Same Area.

Figure 6

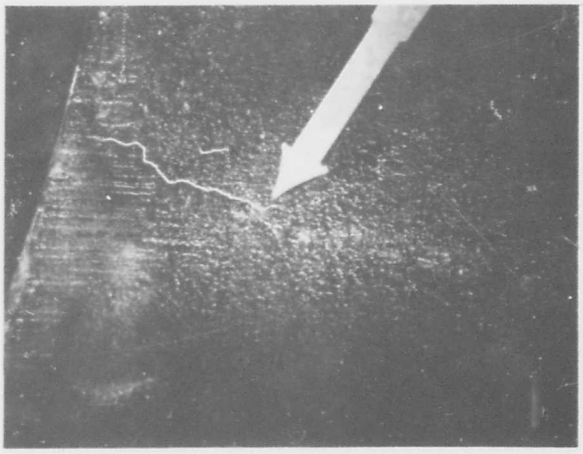


Magnetic Particle Crack Pattern in the Rear Loader Guide (F7225129) from the Right Gun.

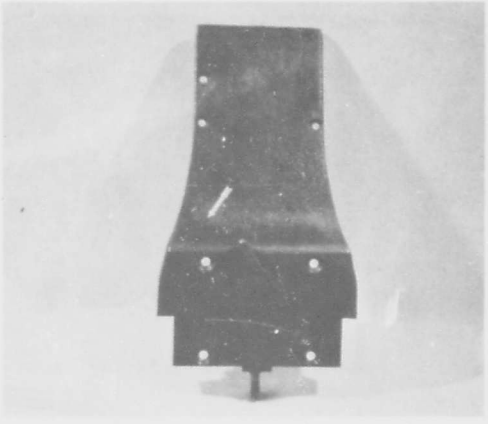


General View of the Same Area.

Figure 7



Magnetic Particle Crack Pattern in the Rear Loader Guide (F6550009) from the Left Gun.



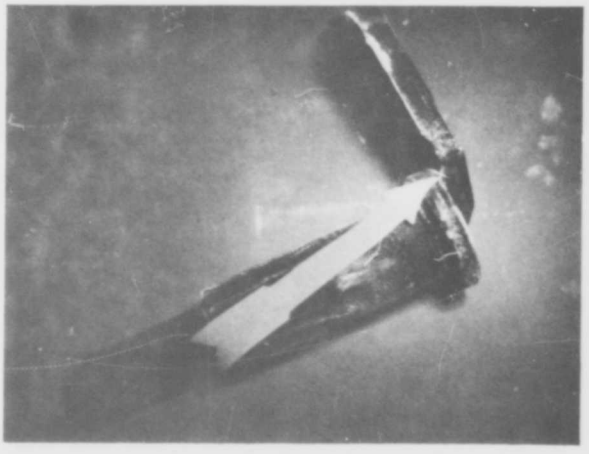
General View of the Same Area.

Figure 8

Magnetic Particle Crack Pattern in the Breechblock Inner Cocing Lever (5222586) from the Left Gun after 1502 Rounds.

General View of the Same Area.

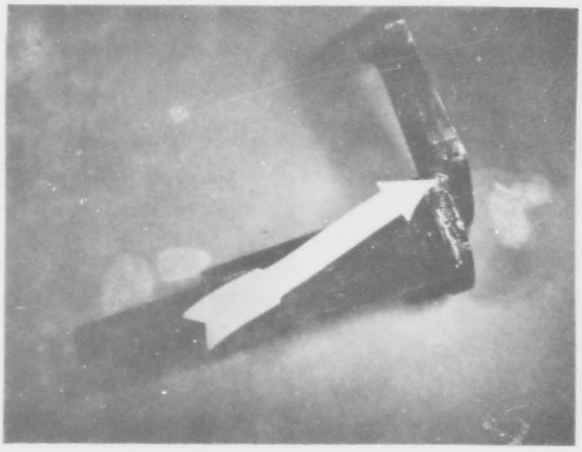
Figure 9



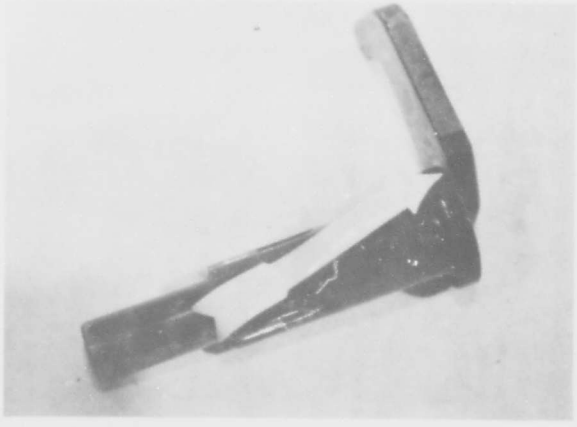
Magnetic Particle Crack Patterns in the Breechblock Outer Cocking Lever (C6197147) from the Left Gun after Firing 1502 Rounds.

General View of the Same Area.

Figure 10

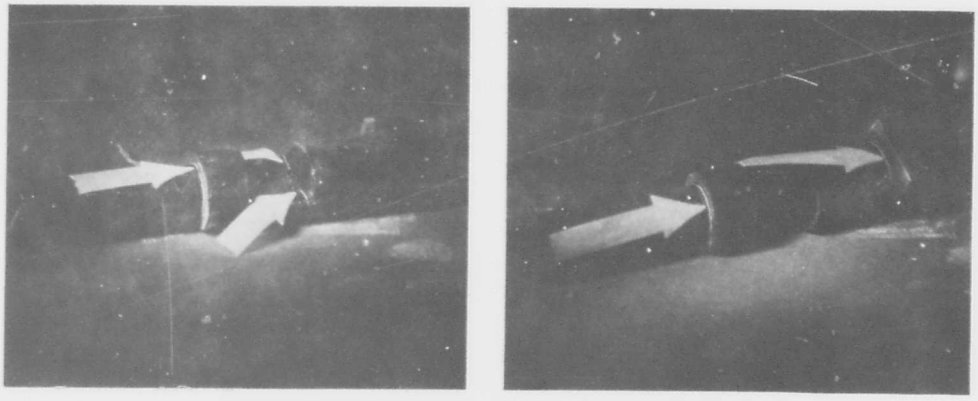


Magnetic Particle Crack Pattern in the Breechblock Outer Cocking Lever (C6197147) from the Right Gun after Firing 1502 Rounds.

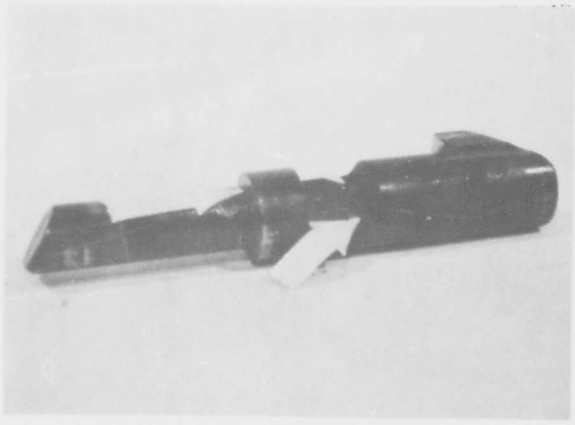


General View of the Same Area.

Figure 11

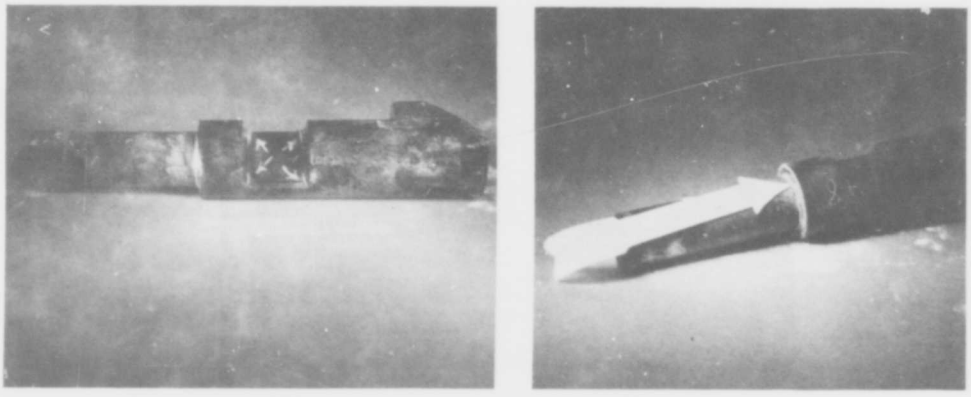


Magnetic Particle Crack Patterns in the Breechblock Inner Cocking Sear Plunger (C6197148) from the Right Gun after Firing 1502 Rounds.

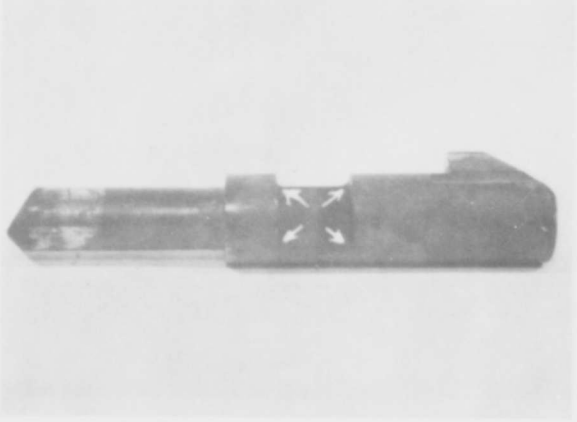


General View of the Same Area.

Figure 12
Appendix I

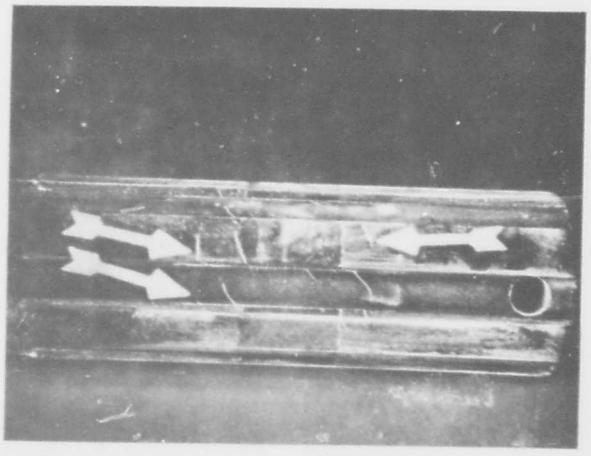


Magnetic Particle Crack Patterns in the Breechblock Inner Cocking Sear Plunger (C6197148) from the Left Gun after Firing 1502 Rounds.

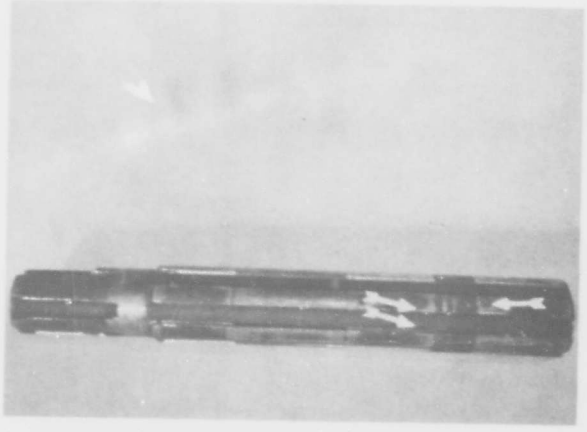


General View of the Same Area.

Figure 13

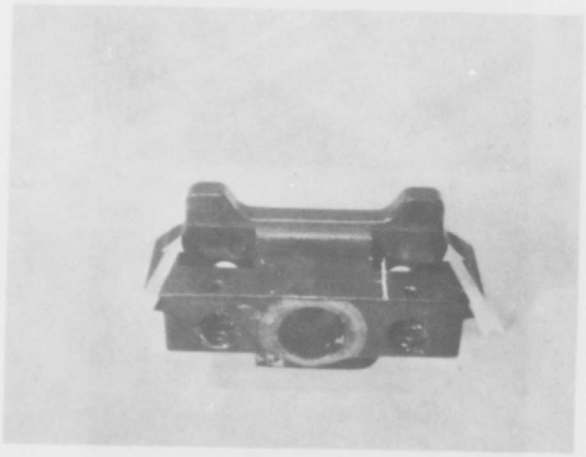


Magnetic Particle Crack Pattern in the Breech Ring Crank Shaft (C6197104) from the Left Gun after Firing 1502 Rounds.



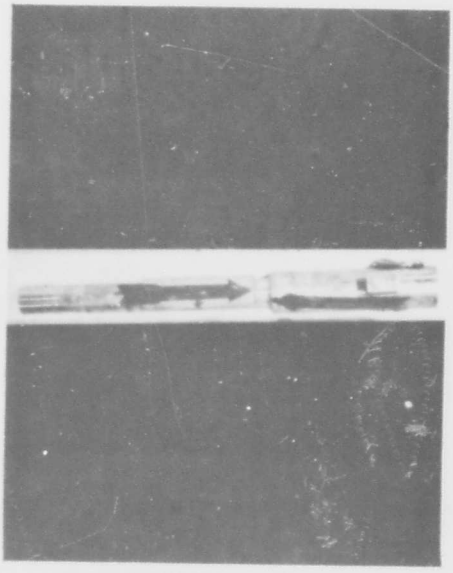
General View of the Same Area.

Figure 14



General View of the Rammer Shoe (C6197122) from the Left Gun. The Arrows Indicate the Cracked Areas Noted during the First Inspection.

Figure 15



General View of the Extractor Spindle (6197106 or 7165193). The Arrows Indicate the Cracked Areas Noted during the First Inspection of the Spindles from Both the Right and Left Guns.

Figure 16