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Lakehurst, New Jersey
08733

EVALUATION OF THE 44B-2E AIRCRAFT ARRESTING SYSTEM WITH DEADLOADS AND THE F-14 AIRCRAFT

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(AIR-5102B)
Washington, D.C. 20361

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The NAVAIRTESTFAC was directed to evaluate the 44B-2E aircraft arresting system with deadloads and the F-14 aircraft. The test program was conducted at the request of the Iranian Government in order that the IIAF *(Imperial Iranian Air Force)* may place a measure of confidence in the ability of the 44B-2E arresting system to safely arrest the F-14 aircraft.

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BLOCK 20 CONTINUED

Twenty ON-CENTER arrestments of 57,400- and 70,300-pound deadloads were conducted for the purpose of determining the performance characteristics of the system.

Thirty-eight ON- and OFF-CENTER arrestments of lightweight (54,200- to 57,900-pound) and heavyweight (68,100- to 70,000-pound) F-14 aircraft were conducted for two purposes: to establish the compatibility between the F-14 aircraft and the 44B-2E arresting system, and to establish the suitability of a modified (sharp toe) F-14A aircraft arresting-hook point.

The results of the tests show that the 44B-2E arresting system is capable of ON-CENTER and up to 25-foot OFF-CENTER arrestments of the F-14 aircraft at the field landing weight range of 54,200 to 57,900 pounds and the aborted takeoff weight range of 68,100 to 70,000 pounds at engaging speeds up to 135 and 126 knots respectively. Also, the modified (sharp toe) hook point is considered acceptable.

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I INTRODUCTION

A. BACKGROUND: The NAVAIRTESTFAC *(Naval Air Test Facility)* was directed by reference (a) to evaluate the 44B-2E aircraft arresting system with deadloads and an F-14 aircraft. The test program was conducted at the request of the Iranian Government in order that the IIAF *(Imperial Iranian Air Force)* may place a measure of confidence in the ability of the 44B-2E arresting system to safely arrest the F-14 aircraft.

B. TEST PROGRAM

1. DEADLOAD PHASE: The system was installed at RSTS *(Recovery Systems Track Site)* No. 4. Tests were conducted from 16 to 25 July 1975 in accordance with reference (b). The purpose of these tests was to determine the performance characteristics of the system with deadloads simulating the energy levels of the maximum field landing conditions and abort conditions of the F-14 aircraft.

2. AIRCRAFT PHASE: Following the completion of the deadload phase, the system was then installed at station 60 + 35 on the RALS *(Runway Arrested Landing Site)*. This phase had two purposes: to establish compatibility between the F-14 aircraft and the 44B-2E field arresting system and to establish the suitability of a modified (sharp toe) F-14A aircraft arresting-hook point. Tests were conducted from 25 August 1975 through 24 February 1976 in accordance with reference (c). This portion of the program was delayed due to the unavailability of the F-14A aircraft.

The results of these tests are presented in this report.

II TEST EQUIPMENT AND CONFIGURATION

A. 44B-2E AIRCRAFT ARRESTING SYSTEM

1. GENERAL DESCRIPTION

a. The 44B-2E aircraft arresting-system installation consists of two identical aircraft arrestment energy absorbers installed on opposite sides of the runway. Figure 1 (see following page) shows the installation of one energy absorber. Two nylon tapes of equal lengths are used as the purchase elements; each is wound on a storage reel of its respective unit, routed through a guide-sheave assembly (standard purchase-element guide bar replaced) and an arresting-sheave assembly, and connected to one end of the aircraft arresting-hook cable.

Ref: (a) AIRTASK No. A510-5102/071-6/501A-400-376 of 17 Mar 1975
(b) NAVAIRTESTFAC Project Directive No. 3-0-75G031 of 18 Jul 1975: Evaluation of the Iranian Arresting Gear Model 44B-2E (NOTAL)
(c) NAVAIRTESTFAC Project Directive No. 3-0-76G032 of 29 Jul 1975: Evaluation of the Iranian arresting gear Model 44B-2E with the F-14 aircraft (NOTAL)

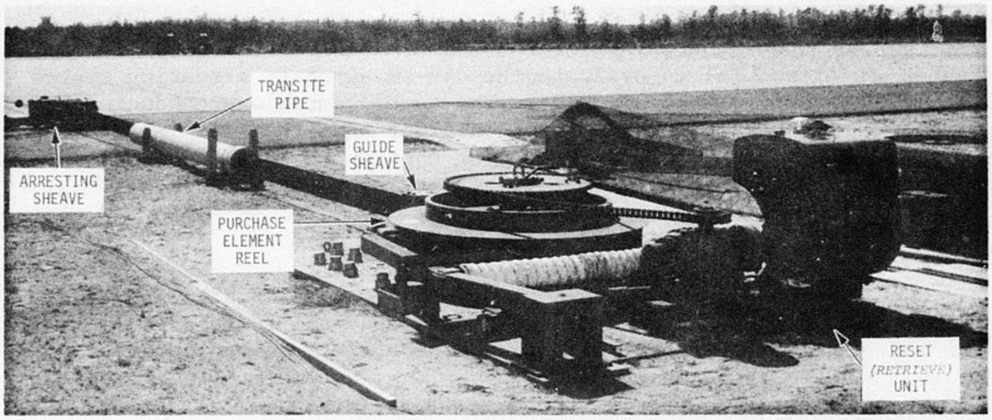


FIGURE 1 - INSTALLATION OF ONE 44B-2E ARRESTING-SYSTEM ENERGY ABSORBER

b. The energy absorbers are actuated when the aircraft arresting hook engages the hook cable, pulling out the attached purchase elements. As each purchase element unwinds, the reel turns a vaned rotor between stator vanes in a fluid-filled housing. The retarding torque developed by fluid resistance to rotor rotation is applied as a braking force on the aircraft. The aircraft's kinetic energy is thereby converted into heat by the resultant turbulance within the housing, and the aircraft is decelerated to a smooth stop.

c. After the aircraft has stopped and its arresting hook has disengaged the hook cable, the energy-absorber operator (one stationed at each energy absorber) actuates the gasoline-driven arresting-system reset unit which retracts the purchase element and tensions the hook cable. After the hook cable has been retrieved and tensioned, the arresting-system operation is entirely automatic during an arrestment. The system has the capability of making one arrestment while unattended.

2. <u>DETAILED DESCRIPTION</u>: The 44B-2E arresting system is composed of the following major assemblies, which are installed on each side of the runway: energy absorber and purchase-element storage reel, reset unit, pressure roller, and arresting sheave.

a. The energy absorber is composed of a 44-inch-diameter drum-shaped housing that contains a 35-inch-diameter 9-vane rotor centered between two sets of 8 stator vanes. The lower set of 8 vanes is welded to the inner surface of the bottom of the housing and the upper set to the removable top cover. The rotor and the 68-inch-diameter purchase-element storage reel are splined to a common shaft that extends through the top cover and rotates in self-aligning bearings: one bearing is mounted in the top cover and the other in the bottom of the housing. The housing is filled with a solution of 60% rust-inhibited ethylene glycol and 40% water which serves as the energy absorption medium and a bearing lubricant.

b. The reset-unit drive train consists of a 37-horsepower air-cooled gasoline engine with a manually actuated over-center type clutch power takeoff unit, a fluid coupling, a speed reducer, an over-running clutch, a drive sprocket, and a chain-driven reset sprocket. The reset unit is coupled to the energy absorber by means of a spring-loaded cam mechanism mounted on the reset sprocket. The cam engages a follower (post) attached to the purchase-element reel and mates the re-set unit to the energy absorber during purchase-element retrieval and when the system is placed in battery position. During an arrestment the cam mechanism releases the reset unit from the energy absorber when the purchase-element tension increases to approximately 5,000 pounds.

c. The pressure-roller assembly consists of a pivoted arm with a roller on one end and a tensioned bungee on the other. During retraction, the roller presses against the purchase element to assure that it is wrapped tightly on the reel.

d. The arresting-sheave assembly consists of two sheave-roller assemblies mounted within a housing. The purchase element is reeved between the rollers to the hook cable. The function of the arresting sheave is to guide and maintain the alignment of the purchase element.

e. The components of the 44B-2E energy absorbers were designed to be anchored directly on concrete pads; however, to simplify the installation, they were installed on a 1-1/4-inch-thick steel plate in accordance with NAVAIRTESTFAC Drawing 230042. The steel plates were then placed on leveled dirt fill and anchored with cruciform stakes and EAW-20 extendable earth anchors.

3. TEST CONFIGURATION

a. Standard

(1) Arresting-Sheave Span: 50 meters (164 feet) ON-CENTER.

(2) Split (centerline of absorber to centerline of arresting sheave): 15 meters (49 feet).

(3) Purchase-Element Connector Assembly: AAE *(All American Engineering)* PN 44735-1.

(4) Purchase Element: Nylon tape, AAE PN 44797-1, 8 inches wide x 0.25 inch thick x 1,075 feet long.

(5) Aircraft Arresting-Hook Cable Assembly: AAE PN 44797-3, 47 meters long (154 feet) x 1 inch diameter, 18x7 nonrotating preformed wire rope.

(6) Anchor System: Aluminum stakes and EAW-20 extendable earth anchors.

(7) Absorber Fluid: Solution of 60% ethylene glycol (MIL-H-5559A) and 40% water.

(8) Aircraft Arresting-Hook-Cable Supports: 6-inch-diameter donuts (symmetrically spaced 8 feet apart).

(9) Pressure Roller: Bungee actuated.

b. The following items were also installed, although they are not part of the standard configuration:

(1) Relief Valve: A relief valve set to relieve at 275 psi was installed on the fluid fill pipe of each energy absorber. This was done to prevent overpressurization of the absorber housing due to thermal effects caused by repetitive arrestments. The design pressure of the absorber housing is 300 psi.

(2) Fairlead Tube: One section of transite pipe (13 feet long x 12 inches inside diameter) was installed midway between the arresting sheave and guide sheave of each unit. This was installed to reduce excessive vertical motion of the purchase element between the sheaves and to minimize purchase-element edge wear.

(3) Pressure-Roller Assembly Stops: Stops were positioned on the guide so that the roller stops 2 inches from the purchase-element reel hub (see Section IV, paragraph D2).

(4) Purchase-Element Reel Guide Sheave: A guide sheave, NAEC PN 509940-1, was installed in lieu of the purchase-element guide, AAE PN 44773 (see Section IV, paragraph D1).

B. F-14 AIRCRAFT TEST CONFIGURATION: The aircraft was configured as follows:

1. LIGHTWEIGHT (54,200 TO 57,900 POUNDS): Stations 1 and 8 - multipurpose pylon, AIM 54 adapter, AIM 9 adapter, AIM 54 launcher, AIM 9 launcher; stations 2 and 7 - jettison release mechanism; stations 3 through 6 - weapons rail, AIM 54 launchers; stations 3 and 6 - Phoenix missiles; M-61 gun plus 620 rounds of 20mm dummy ammunition; and modified aircraft arresting-hook point (see Section IV, paragraph E).

2. HEAVYWEIGHT (68,100 TO 70,000 POUNDS): Stations 1 and 8 - AIM 54 adapters, AIM 9 sidewinders; stations 2 and 7 - full fuel drop tanks; stations 3 through 6 - three MK 82 inert bombs each; M-61 gun with 680 rounds of 20mm dummy ammunition; and modified aircraft arresting-hook point (see Section IV, paragraph E).

III TEST PROCEDURE

A. DEADLOAD TEST PHASE: ON-CENTER arrestments of deadloads weighing 57,400 and 70,300 pounds were conducted at RSTS No. 4. Tests with each deadload weight started at an approximate engaging speed of 110 knots. During subsequent events, the engaging speed was increased in 10-knot increments until a test limit was reached. Several events were then conducted at the limiting speeds so as to establish and confirm the performance of the arresting system.

B. AIRCRAFT TEST PHASE: All arrestments were unidirectional on RALS runway heading of 300 degrees magnetic. Long-field-landing type of emergency arrestments were simulated by taxi-in approaches to the hook cable. The F-14A aircraft, BUNO 158616, was used for the test program. ON- and OFF-CENTER arrestments of lightweight (54,200- to 57,900-pound) and heavyweight (68,100- to 70,000-pound) F-14 aircraft were conducted at the RALS in accordance with the following procedure:

1. ON-CENTER TESTS: Testing was begun with ON-CENTER arrestments of both the lightweight and the heavyweight F-14 aircraft. The initial engaging speed was approximately 90 knots. During subsequent events, the engaging speed was increased in increments of approximately 10 knots until a program test limit was reached. Two events were conducted at the maximum limiting engaging speed for both lightweight/heavyweight F-14 aircraft for the purpose of confirming data of these higher-energy events.

2. OFF-CENTER TESTS: The initial OFF-CENTER arrestment of both the lightweight and the heavyweight F-14 aircraft was conducted 12 feet to port to determine if any adverse effects would result. All the remaining OFF-CENTER events were conducted 25 feet OFF-CENTER to port. The initial engaging speed was approximately 90 knots. During subsequent events, the engaging speed was increased in increments of approximately 10 knots until a program test limit was reached. Two events were conducted at the maximum limiting engaging speed for both lightweight/heavyweight F-14 aircraft for the purpose of confirming data of these higher-energy events.

3. PILOT TECHNIQUE: The desired pilot technique was as follows: Power necessary to obtain the required engaging speed was maintained until hook-cable pickup was assured. The power was then reduced to IDLE for the remainder of the arrestment. If the arresting system two-blocked, power was added to prevent excessive walkback. Aircraft brakes were not applied at the end of the arrestment.

C. ARRESTING-SYSTEM MAINTENANCE

1. Because the 44B-2E has a sealed absorber housing, repetitive arrestments heat the absorber fluid to a point where damage could occur as a result of thermal effects. Therefore, when a series of tests was conducted in one day, the fluid was changed after every three arrestments. This was accomplished by connecting the

44B-2E absorber housing to a U.S. Navy E-28 arresting-system cooling tank and circulating the fluid. Prior to the next arrestment, the 44B-2E absorber housing was topped off and resealed.

2. The 44B-2E was operated and maintained as specified in reference (d). When possible, maintenance was accomplished after aircraft test operations were normally secured in order to increase system test-time availability.

a. The hook-cable replacement criteria followed during the test program were similar to those used for U.S. Navy arresting systems configured with one-inch-diameter hook cables. A limit of five arrestments per cable was established by reference (d). The hook-cable replacement criteria were as follows:

(1) Engagement at 150 knots or greater.

(2) Three or more broken wires per lay length.

(3) The hemp core is visible.

(4) The strands separate.

(5) Birdcaging is evident.

(6) The presence of 30 or more flat spots of 7/16 inch or more in length within one lay length.

(7) The hook cable exhibits kinking.

(8) Total of five arrestments.

b. The purchase elements were replaced in accordance with criteria established for U.S. Navy arresting systems which use similar purchase elements. The replacement criteria were as follows:

(1) Purchase element shows a visible crease.

(2) Purchase element has been cut through outer casing and into the longitudinal members, leaving a total uncut sectional width of less than 7-1/2 inches.

(3) Edge abrasion that reduces the purchase-element width to 7-1/2 inches.

Ref: (d) All American Engineering Company, SM-276, Handbook Maintenance and Overhaul Instructions with Illustrated Parts Breakdown; Model 44B-2E Arresting Gear

(4) Purchase element is split longitudinally.

(5) A sewn loop has three or more complete transverse rows of failed stitches.

D. DEADLOAD, AIRCRAFT, AND ARRESTING-SYSTEM INSTRUMENTATION: The parameters measured were recorded on magnetic tape by frequency division multiplexing methods or visually observed. The parameters and means of measuring are as follows:

Parameter	Means of Measurement	Accuracy Within (±)	Frequency Response (Hz)
Deadload-/aircraft-hook axial load	Strain gauge	5%	60
Longitudinal deceleration	Accelerometer	5%	20
Purchase-element tension	Strain gauge (tensiometer)	5%	60
Engaging speed	Deck coil (prime source)	2 Kn	-
Aircraft gross engaging weight (basic, stores, and fuel)	Aircraft fuel quantity gauge*	200 Lb	-
OFF-CENTER distance	Deck markings	2 Ft	-
Total runout	Deck markings	10 Ft	-
Energy-absorber and deadload-/aircraft-hook dynamics, and deadload/aircraft runout	High-speed motion-picture coverage	-	-

* Weight of fuel was added to basic weight of aircraft derived from the aircraft weight and balance handbook.

E. TEST LIMITS: The following test limits were established for this program:

Parameter		Test Limits: Deadload	Test Limits: F-14 Aircraft
Hook-cable tension (55% of minimum breaking strength)		45,250 Lb	45,250 Lb
Purchase-element tension (40% of ultimate tensile strength)		37,600 Lb	37,600 Lb
Hook axial load		157,000 Lb	157,000 Lb
Longitudinal deceleration	57,000-pound vehicle	3.15 G	3.15 G
	70,000-pound vehicle	1.50 G	1.50 G*
	At arg-system two-block	1.00 G	1.00 G
Walkback, stability, and control characteristics		NA	Within acceptable limits†
Fishtailing, swerving, and pitching characteristics		NA	"

NA = Not applicable.
* Lower limit for heavyweight aircraft because of fuel in the wings and drop tanks.
† As judged by pilot and project engineer.

F. DATA PRESENTATION

1. Maximum deadload-/aircraft-hook axial loads and purchase-element tensions were plotted versus engaging speed for both deadload and aircraft tests. The least-squares method was used to reduce the individual data points to mean curves and the standard deviation from the mean curves, utilizing the following load equation:

$$\text{Mean load (pounds)} = a\,V^{b}\ \text{(knots)}.$$

Constants a and b were also determined from the test data using the least-squares method.

2. The solid curves in Figures 2 through 5 (presented on pages 12 and 14) are mean or regression loads. The phantom curves in Figures 4 and 5 (presented on page 14) are upper one-sigma deviations from the mean curves, indicating the extent of the load scatter. The engaging-speed limit is derived at the point at which the upper one-sigma curve is intersected by the established purchase-element tension limit. Theoretically, the probability of realizing a load of less than one sigma is 0.84, and a load of more than one sigma is 0.16 for the data sample.

IV TEST RESULTS AND DISCUSSION

A. **SUMMARIZATION:** During the test program, 58 arrestments were conducted (20 with deadloads and 38 with the F-14 aircraft) into the 44B-2E arresting system. The data for the 58 events is tabulated in Appendix A and summarized in the following table:

DEADLOAD TESTS

	Test Vehicle			Maximum Range					
		OFF-CENTER Distance (Ft)							
No. of Events	Weight Range (1,000 Lb)	Initial	Final Range	Engaging Speed (Kn)	Deadload-/Aircraft-Hook Axial Load (1,000 Lb)	Purchase-Element Tension (1,000 Lb)	Long. Decel (G)	Vehicle Runout (Ft)	Remarks
					L = 157.0	L=37.6	L=3.15		
10	57.4	0	0-20S	106 - 153	31.9 - 81.7	17.3 - 37.9	0.95-1.69	1,082-1,128	
10	70.3	0	4S-25S	107 - 140	35.8 - 69.1	18.3 - 41.1	0.66-1.05	1,157-1,190	*
					F-14 AIRCRAFT TESTS				
					L = 157.0	L=37.6	L=3.15		
11	54.2 - 57.0	0	0- 2S	90 - 147	43.7 - 74.9	19.5 - 38.7	0.80-1.43	1,045-1,125	†
1	55.1	12 P	16P	109	42.5	22.5	0.84	1,105	†
9	56.1 - 57.9	25 P	28P-39P	102 - 132	39.4 - 67.3	20.0 - 38.5	0.71-1.12	1,045-1,085	†
					L = 157.0	L=37.6	L=1.50		
9	68.4 - 70.0	0	0-12S	92 - 132	33.9 - 66.0	15.6 - 36.6	0.52-1.07	1,100-1,148	†
1	68.5	12 P	12P	91	37.2	18.8	0.57	1,110	†
7	68.1 - 69.9	25 P	25P-40P	92 - 130	34.6 - 73.1	18.1 - 42.9	0.57-1.04	1,110-1,130	†

L = Test limit; P = Port; S = Starboard.

* Maximum loads occurred at arresting-system two-block during engagements at 139 and 140 knots.
† No evidence of aircraft damage, hook-cable contact, or excessive hook-bumper contact.

B. DEADLOAD TESTS

1. **MAXIMUM DEADLOAD-HOOK AXIAL LOAD VERSUS ENGAGING SPEED:** The maximum loads occurred during the hydraulic portion of all arrestments except those events conducted with the 70,300-pound deadload at engaging speeds of 139 and 140 knots. During those events, the maximum loads occurred at two-block of the arresting system. As can be seen in Figures 2A and 3A (page 12), the F-14 aircraft-hook axial load limit of 157,000 pounds was not approached during the deadload test phase.

2. **MAXIMUM PURCHASE-ELEMENT TENSION VERSUS ENGAGING SPEED:** The maximum tensions also occurred during the hydraulic portion of all arrestments except those events conducted with the 70,300-pound deadload at engaging speeds of 139 and 140 knots. During those events, the maximum tensions occurred at arresting-system two-block. Figures 2B and 3B (page 12) show that the purchase-element tension limit of 37,600 pounds was reached during arrestments of the 57,400- and 70,300-pound deadloads at engaging speeds of 149 and 139 knots respectively.

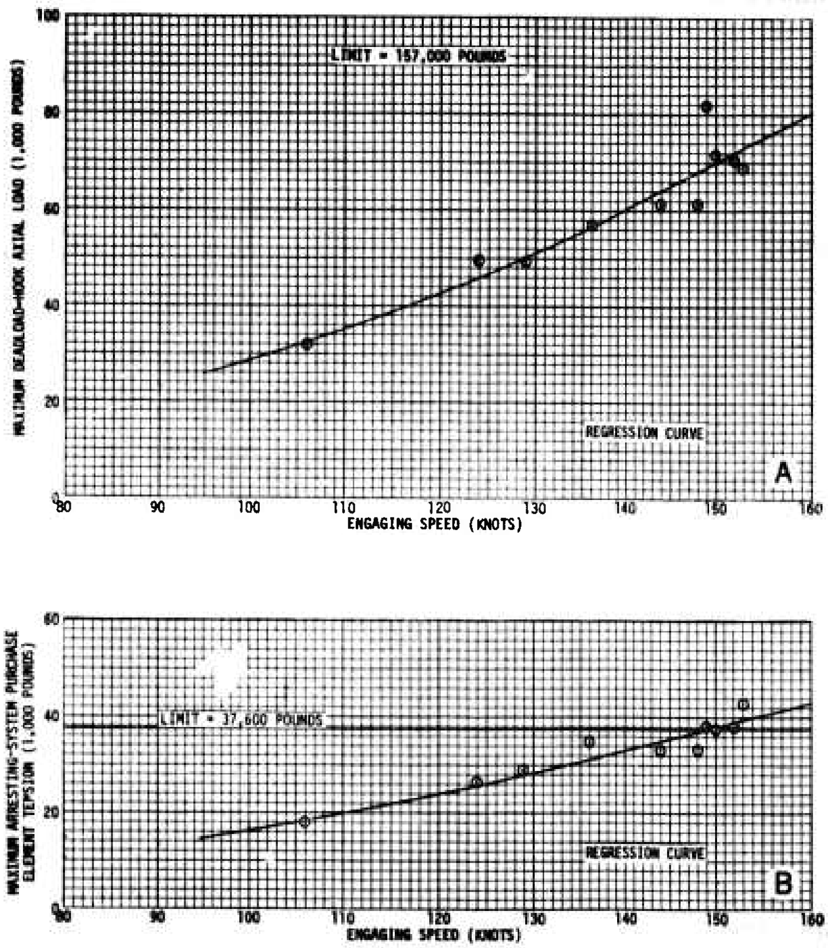


FIGURE 2 - COMPOSITE GRAPH OF MAXIMUM PARAMETERS VERSUS ENGAGING SPEED FOR ON-CENTER ARRESTMENTS OF THE 57,400-POUND DEADLOAD

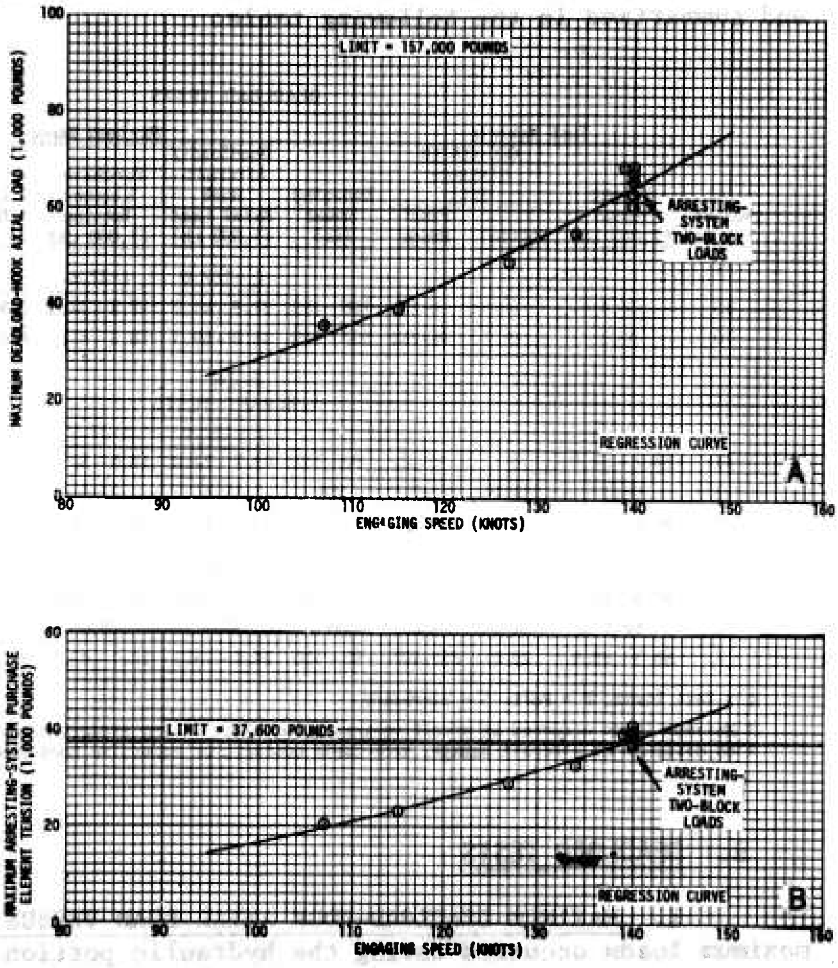


FIGURE 3 - COMPOSITE GRAPH OF MAXIMUM PARAMETERS VERSUS ENGAGING SPEED FOR ON-CENTER ARRESTMENTS OF THE 70,300-POUND DEADLOAD

C. AIRCRAFT TESTS: No significant problems occurred during the aircraft phase of the test program. During project event 53 (69,900-pound aircraft, 95-knot engaging speed, 25-foot OFF-CENTER to port arrestment), however, aircraft power was held at MRT *(military rated thrust)* for a longer-than-normal time and power was not reduced to IDLE until 8.0 seconds following hook-cable pickup; normally, the average time for reducing aircraft power from MRT to IDLE was 2.5 seconds. This deviation in pilot technique caused much-higher-than-normal loads to occur, which can be seen in Figure 5 on page 14. The data for this event had been plotted for a matter of interest only and was not used in determining the regression and upper one-sigma curves.

1. MAXIMUM AIRCRAFT-HOOK AXIAL LOAD VERSUS ENGAGING SPEED

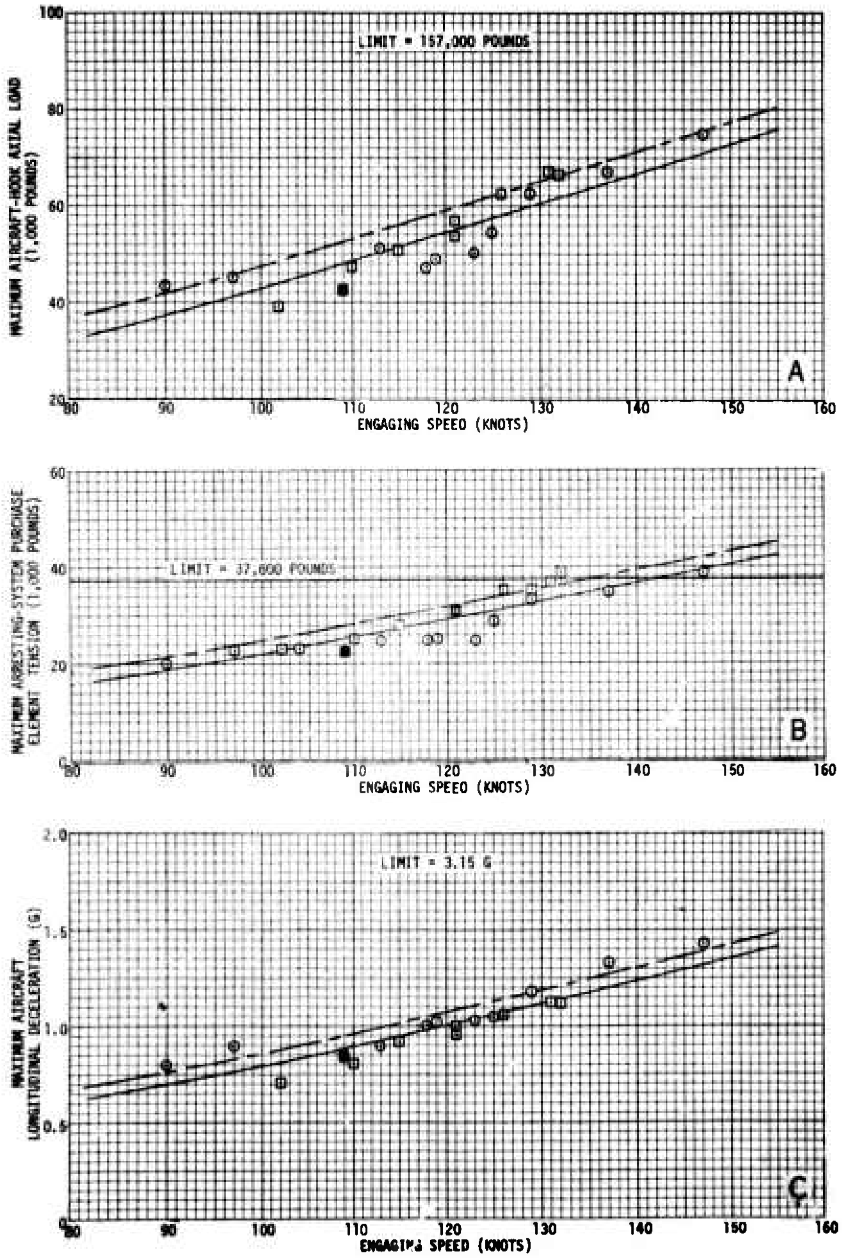
a. The maximum loads for both weight ranges of the F-14 aircraft occurred during the hydraulic portion of all arrestments. Figures 4A and 5A (page 14) show that the aircraft-hook load limit of 157,000 pounds was not approached during these tests. The maximum load attained was 74,900 pounds; it occurred during an ON-CENTER event conducted with the 57,000-pound aircraft at an engaging speed of 147 knots.

b. OFF-CENTER arrestments appear to generate slightly higher mean aircraft-hook axial loads than ON-CENTER arrestments of the 57,000-pound aircraft at higher engaging speeds and approximately the same loads as ON-CENTER arrestments of the 70,000-pound F-14 aircraft for all engaging speeds tested.

2. MAXIMUM PURCHASE-ELEMENT TENSION VERSUS ENGAGING SPEED: The maximum tensions also occurred during the hydraulic portion of all arrestments. From the one-sigma curves shown in Figures 4B and 5B (page 14), which include both ON-CENTER and OFF-CENTER tests, it has been determined that the purchase-element tension limit of 37,600 pounds would be reached at engaging speeds of 135 and 126 knots with the 57,000- and 70,000-pound F-14 aircraft respectively.

3. MAXIMUM AIRCRAFT LONGITUDINAL DECELERATION VERSUS ENGAGING SPEED: As shown in Figures 4C and 5C (page 14), the deceleration limits were not approached. The maximum deceleration realized was 1.43 G with the 57,000-pound F-14 aircraft at an engaging speed of 147 knots.

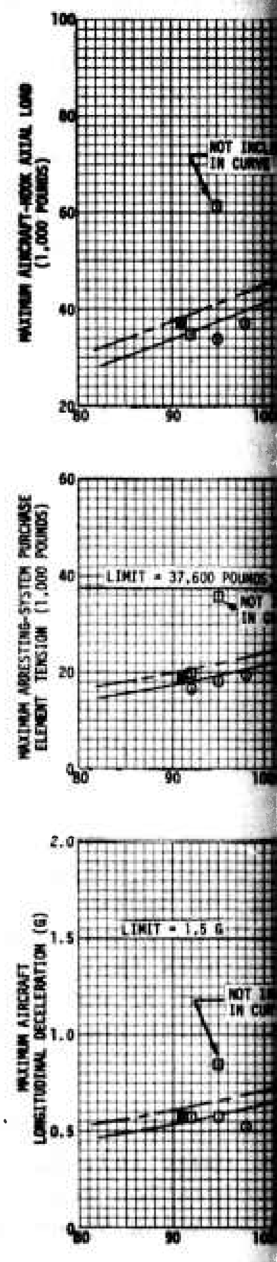
4. AIRCRAFT STABILITY: Aircraft stability during runout was satisfactory. ON-CENTER arrestments resulted for the most part in either no swerve or slight swerve; the maximum swerve distance was 12 feet. OFF-CENTER arrestments resulted in only gradual swerve with the maximum distance being 15 feet from point of engagement. There were no noticeable aircraft pitch and yaw motions during any of the arrestments. Only a slight amount of hook-cable wiping through the cable groove of the aircraft hook point occurred during the OFF-CENTER arrestments.



SYMBOL/ CURVE

- ○ ON-CENTER EVENTS
- ■ 12-FT OFF-CENTER TO PORT EVENT
- □ 25-FT OFF-CENTER TO PORT EVENTS
- ——— REGRESSION CURVE
- — - — ONE-SIGMA DEVIATION CURVE

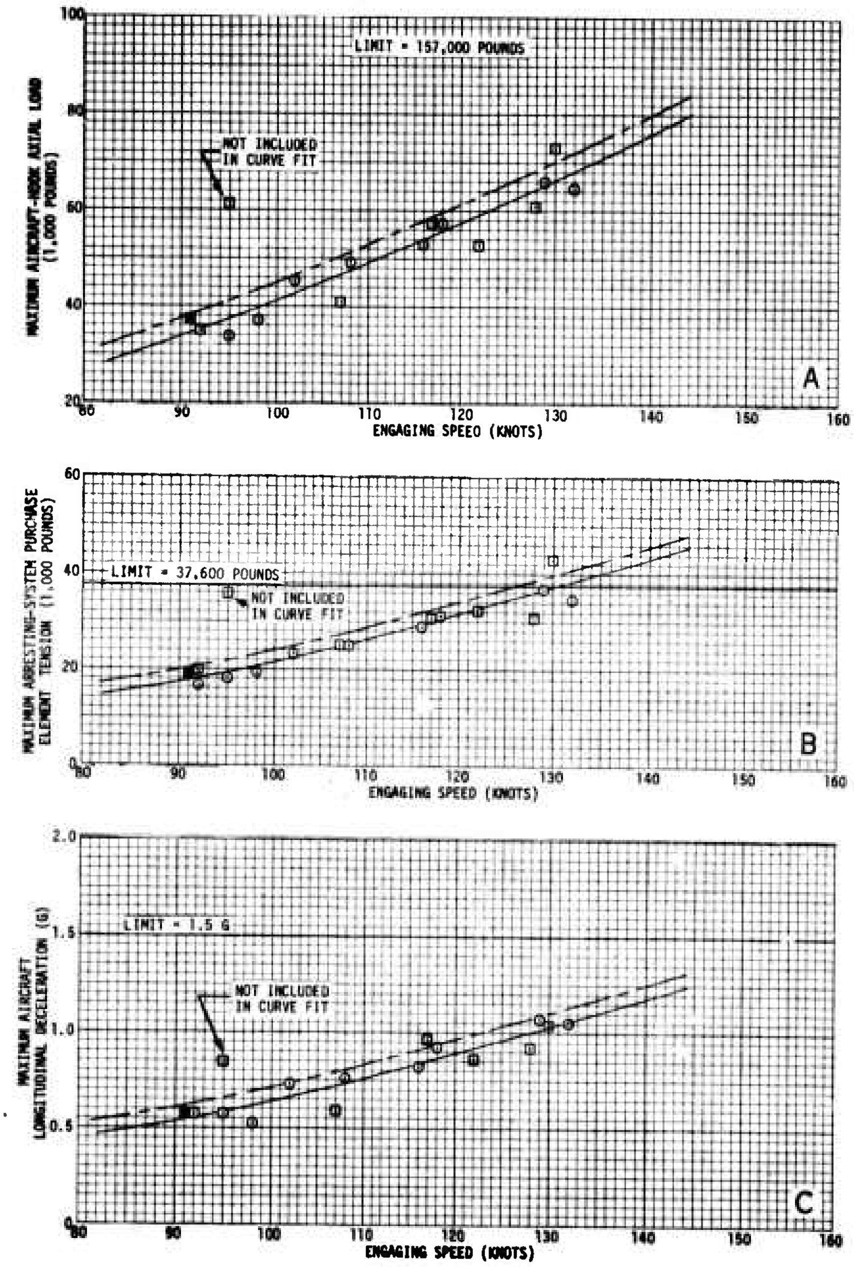
FIGURE 4 - COMPOSITE GRAPH OF MAXIMUM PARAMETERS VERSUS ENGAGING SPEED FOR ON- AND OFF-CENTER ARRESTMENTS OF THE 54,200- TO 57,900-POUND F-14 AIRCRAFT



SYMBOL/ CURVE

- ○ ON-CENTER
- ■ 12-FT OFF-
- □ 25-FT OFF-
- ——— REGRESSION
- — - — ONE-SIGMA

FIGURE 5 - COMPOSIT
ENGA
ARREST



SYMBOL/ CURVE	
○	ON-CENTER EVENTS
■	12-FT OFF-CENTER TO PORT EVENT
□	25-FT OFF-CENTER TO PORT EVENTS
———	REGRESSION CURVE
— - —	ONE-SIGMA DEVIATION CURVE

FIGURE 5 - COMPOSITE GRAPH OF MAXIMUM PARAMETERS VERSUS ENGAGING SPEED FOR ON- AND OFF-CENTER ARRESTMENTS OF THE 68,100- TO 70,000-POUND F-14 AIRCRAFT

5. AIRCRAFT WALKBACK AND ARRESTING-SYSTEM TWO-BLOCK

a. During tests with the 57,000-pound aircraft, the system did not two-block and hence there was no aircraft walkback.

b. During tests with the 70,000-pound aircraft, only mild two-blocking of the arresting system occurred. This caused minimal aircraft walkback, and no problems were encountered. This was in direct contrast to that which occurred during tests with the 70,300-pound deadload where severe two-blocking occurred during each arrestment with high loads being generated (see Appendix A). As mentioned in Section V, paragraph B, the maximum loads with the 70,300-pound deadload occurred at arresting-system two-block for engaging speeds of 139 and 140 knots. Disregarding project event 53, the maximum aircraft-hook load at arresting-system two-block was 16,800 pounds. A possible explanation for mild two-blocking during the aircraft tests would be that aerodynamic drag assisted the arresting system in decelerating the aircraft. (Aerodynamic drag is increased by the full-flap configuration used and by the programmed deployment of the spoilers when engine thrust is reduced to IDLE.)

6. AIRCRAFT STRUCTURE: Visual examination and high-speed motion-picture coverage showed no evidence of aircraft damage, hook-cable contact, or excessive arresting-hook bumper contact.

7. BOLTERS: No bolters occurred during the aircraft test phase.

D. 44B-2E AIRCRAFT ARRESTING-SYSTEM OPERATION

1. PURCHASE-ELEMENT GUIDE, AAE PN 44773: Past experience at the NAVAIRTESTFAC has shown that the purchase-element guide increases purchase-element edge wear and could contribute to a purchase-element-tuck* failure or wear failure. Because of this, the purchase-element guide was replaced with a roller and housing assembly (guide sheave), NAEC PN 509940-1, before the test program was begun. The guide sheave is shown in Figure 6. No purchase-element tucks occurred during the course of the test program.

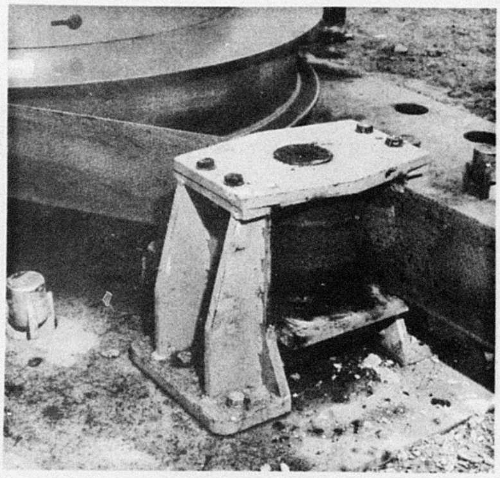


FIGURE 6 - GUIDE SHEAVE, NAEC PN 509940-1

* Outer wrap of element slips under element stack during an arrestment.

2. <u>PRESSURE-ROLLER ASSEMBLY, AAE PN 44270-1</u>: During a deadload arrestment, the pressure roller contacted the purchase-element pin (AAE PN 17SK096-3) at two-block of the arresting system. The contact caused a pivot anchoring bolt to shear on one unit, a pivot anchoring bolt to bend on the other unit, and the roller housings (AAE PN 17SK112-4) to spread open on both units (see Figure 7). To prevent this from reoccurring, stops were welded to the pressure-roller guide (see Figure 8). The stops were positioned so that the roller stops 2 inches from the purchase-element storage-reel hub. No problems occurred following installation of the stops.

FIGURE 7 - DAMAGED ROLLER HOUSING

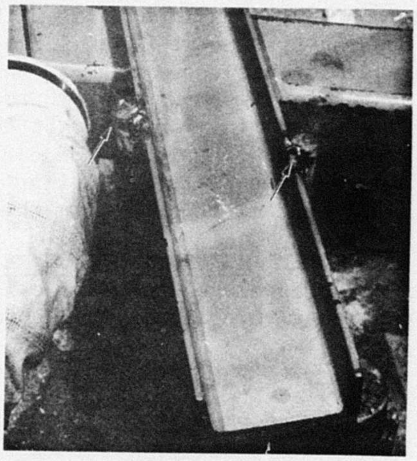


FIGURE 8 - STOPS WELDED TO PRESSURE-ROLLER GUIDE

3. <u>PURCHASE ELEMENTS, AAE PN 44797-1</u>: Six purchase elements were used during the course of the test program as summarized below:

Purchase Element (SN)	Phase Used	No. of Events	Reason for Replacement
11-74-1	Deadload	20	Precautionary
6-75-39	"	20	"
6-75-38	Aircraft	23*	"
6-75-40	"	23*	"
6-75-37	"	17	Program completed
9-75-55	"	17	" "

* Includes two checkout arrestments with an A-4 aircraft.

a. Prior to the start of the test program, the following damage to the nylon purchase elements was discovered while installing them on the arresting system:

(1) Purchase Element, SN 11-74-6: Twenty-six abrasion failures of the outer casing (exposing the longitudinal members (see Figure 9)), and severely abraded sewn-loop stitching on the uncoated end of the purchase element were found. This purchase element was not considered usable and was reinstalled on a shipping reel and placed in storage.

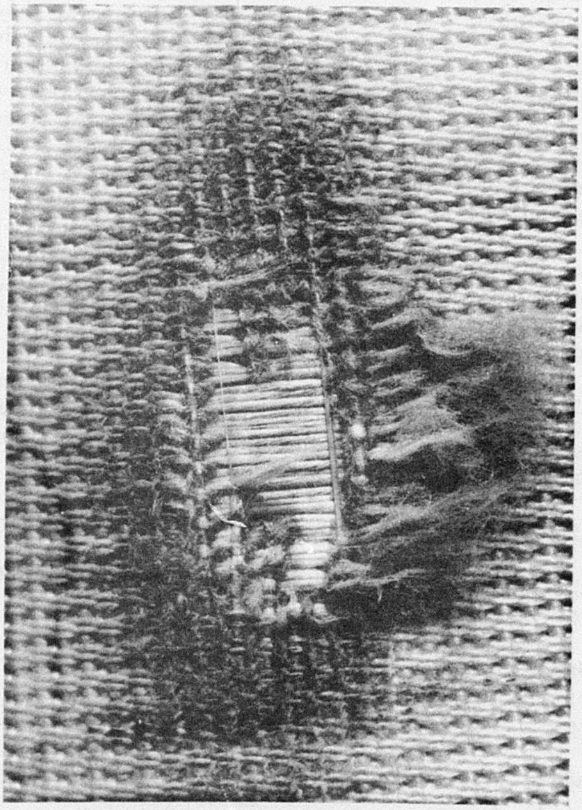


FIGURE 9 - TYPICAL ABRASION FAILURE OF PURCHASE-ELEMENT OUTER CASING EXPOSING LONGITUDINAL MEMBERS

(2) Purchase Element, SN 11-74-1: Six abrasion failures of the outer casing (exposing the longitudinal members) were found; however, this purchase element was considered usable. The worn spots were coated with GACO *(an abrasion-resistant coating)*, and the purchase element was installed on the arresting system. Additional outer-casing failures occurred in many other locations during the initial arrestments. These areas were also coated with GACO. The failure rate of the outer casing decreased as the test program continued.

b. Only one end of the purchase element is coated; as a result, a new purchase element must be completely pulled off the shipping reel before being reeved onto the gear because the coated end is on the outside of the shipping reel. It is necessary to install the coated end on the outside of the purchase-element reel to prevent degradation as a result of ultraviolet radiation and to minimize abrasion during use. If the coated end were on the inside of the shipping reel, the purchase element could be installed directly onto the purchase-element reel from the shipping reel. If both ends were coated, the same reeving procedure could be followed and the purchase element could be end-for-ended when necessary and thereby extend the service life.

c. Visual inspection of the sewn loops on all purchase elements used during this program revealed insufficient coating on the stitching. Two coats of GACO were applied to the stitching; this provided satisfactory protection against abrasion.

d. Purchase-element vertical motion between the arresting and guide sheaves and edge wear incurred during arrestment were minimized by the use of the transite pipe which was installed as a fairlead tube midway between the arresting and guide sheaves of each unit.

4. AIRCRAFT ARRESTING-HOOK CABLE, AAE PN 44797-3

a. Eighteen hook cables were used during the course of this test program as summarized below:

Hook Cable No.	Phase Used/ No. of Events	Reason for Replacement	Hook Cable No.	Phase Used/ No. of Events	Reason for Replacement
1	Deadload/4	4 broken wires	11	Aircraft/5	Reached service life
2	" 1	5 " "	12	" 5	" " "
3	" 2	4 " "	13	" 5	" " "
4	" 1	6 " "	14	" 5	" " "
5	" 4	4 "	15	" 5	" " "
6	" 1	Cable kinked	16	" 4	Precautionary
7	" 2	4 broken wires	17	" 5	Reached service life
8	" 3	8 " "	18	" 4	Program completed
9	" 1	5 " "			
10	Deadload/1 Aircraft/2*	Precautionary			

* Two checkout arrestments with an A-4 aircraft.

b. Eight of the 10 hook cables used during the deadload test phase were replaced as a result of reaching the replacement criterion of 3 broken wires.

c. An F-14 aircraft hook point with a modified toe was used during all aircraft tests. No damage was incurred by any of the 8 hook cables used during the aircraft test phase. The hook cables were replaced either when they reached their service life of 5 arrestments or as a precautionary measure.

5. ARRESTING-SYSTEM RESET UNIT, AAE PN 17SK437-24

a. The arresting system was equipped with a Wisconsin Engine retrieval system (reset unit), which is the element that returns the arresting system to the engagement position. The retrieval system was installed and maintained in accordance with reference (e).

b. The average arresting-system reset time was just over four minutes.

c. On several occasions, the aircraft hook failed to disengage from the hook cable following arrestment; it was necessary to use the reset unit to pull the aircraft back in order to free it from the hook cable. No problems were encountered in doing this.

d. Several problems that occurred with the reset unit are described below:

(1) During the deadload phase, the galvanized safety chain on the variable-speed governor control assembly of one reset engine was corroded and broke while being used. It was replaced with a piece of safety wire (see Figure 10 on following page), and no further problems occurred.

(2) Due to the close proximity and direction of the exhaust-gas discharge, foreign particles (rust, carbon, etc.) from the engine exhaust muffler were blown into the face of the engine operator on several occasions (in one event, an operator required medical treatment when a discharged particle became embedded in his eye). A similar problem occurred with the U.S. Navy E-28 arresting system and was remedied by reference (f), where the standard muffler is replaced with a 10-inch-long piece of pipe and 90° elbow, and the open end of the pipe is positioned so that it faces away from the operator (see Figure 11 on following page).

Ref: (e) All American Engineering Company, SM-363, Handbook of Installation, Operation and Service Instructions with Illustrated Parts Breakdown for Wisconsin Engine Retrieval System 17SK437-24

(f) E-28 Emergency Arresting Gear Service Change No. 17 of 21 May 1971: Retrieve Engine Exhaust System; modification of

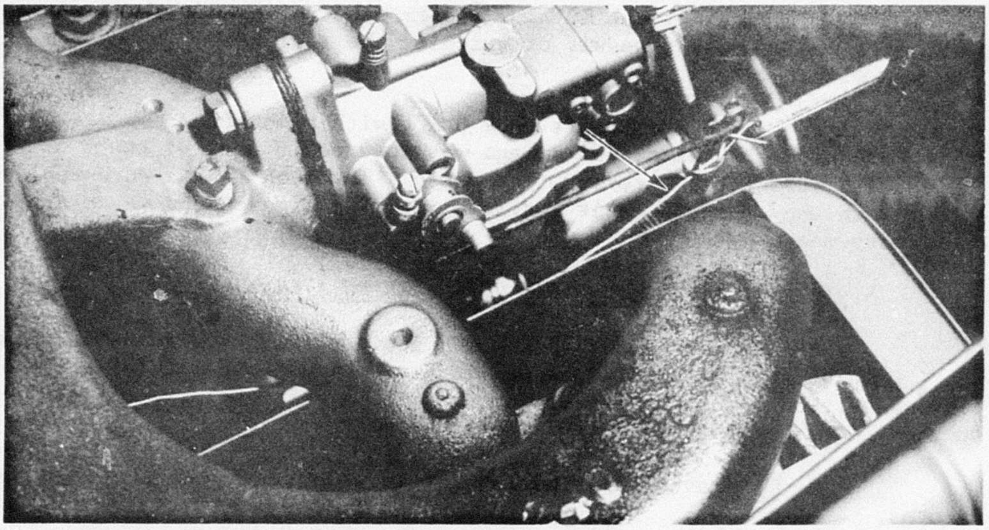


FIGURE 10 - SAFETY WIRE INSTALLED ON VARIABLE-SPEED GOVERNOR CONTROL ASSEMBLY

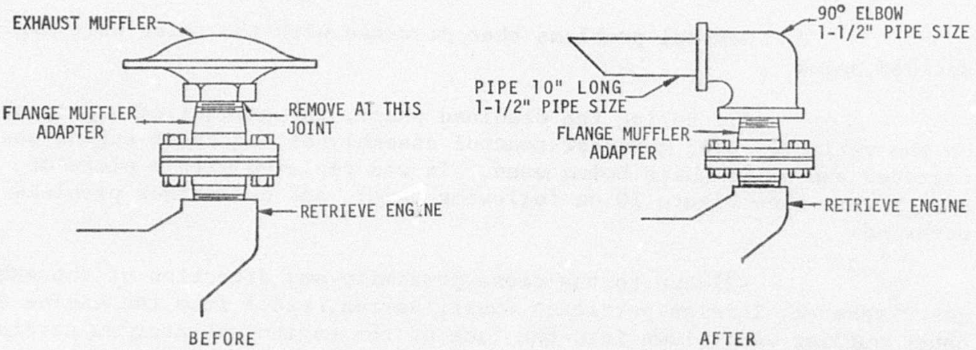


FIGURE 11 - MODIFICATION OF RESET-UNIT EXHAUST (U.S. NAVY E-28 EMERGENCY ARRESTING GEAR SERVICE CHANGE NO. 17)

(3) When securing the reset engine, the gasoline shutoff valve must be closed to prevent gasoline from draining through the carburetor, the manifold, and the cylinder to the crankcase and contaminating the engine oil.

E. EVALUATION OF MODIFIED AIRCRAFT ARRESTING-HOOK POINT: The standard blunt aircraft hook point on the U.S. Navy F-14 aircraft is designed to preclude multiple aircraft hook cable engagements. This design, unfortunately, increases the probability of aircraft arresting-hook skip when attempting to engage a shorebased arresting-system hook cable. To increase the probability of hook-cable engagement, a sharp-toed hook point (Figure 12) was designed and manufactured. This "sharp" hook point, Grumman Aerospace Corporation PN A53G1511T-1, was used for the aircraft test phase. No bolters occurred: 38 attempted engagements resulted in 38 successful hook-cable pickups. The nominal clearance between the runway and the hook cable was 2-1/2 inches.

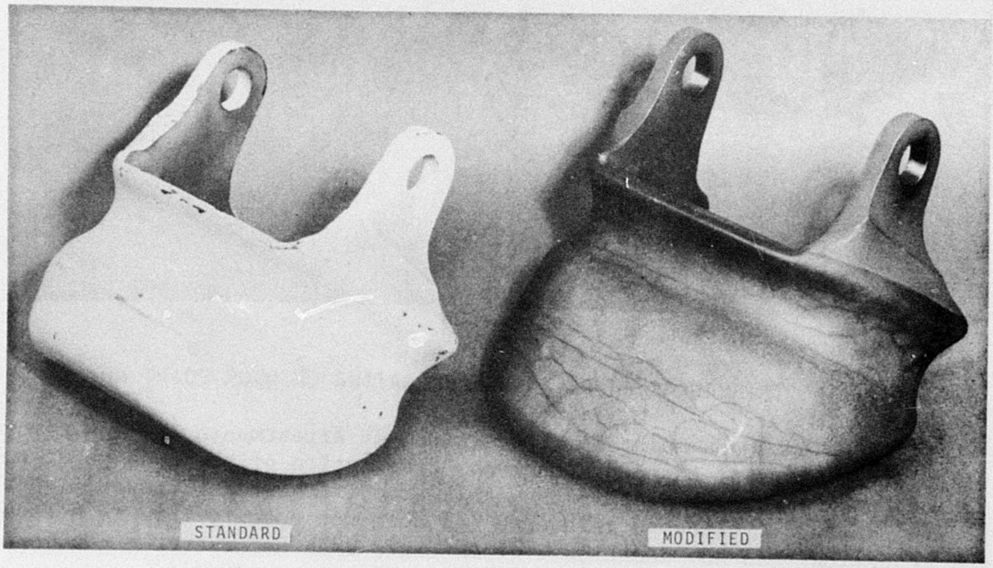


FIGURE 12 - STANDARD AND MODIFIED "SHARP TOE" F-14 AIRCRAFT ARRESTING-HOOK POINT

Two of the "sharp" hook points were used:

1. Test hook point No. 2 was removed after 14 arrestments because small, triangular-shaped chips occurred in the METCO coating at the extreme end of the cable groove (see Figure 13 on the following page). This probably resulted from abrasion caused by the hook point dragging on the runway prior to engagement of the hook cable. The hook point was dragged on the runway for approximately 500 feet during each event. This hook point was replaced as a precautionary measure although this is not required by reference (g).

Ref: (g) NAVAIRINST 13430.1 of 29 Sep 1970: Criteria for inspection, overhaul, test, and replacement of aircraft arresting hook assemblies and hook points

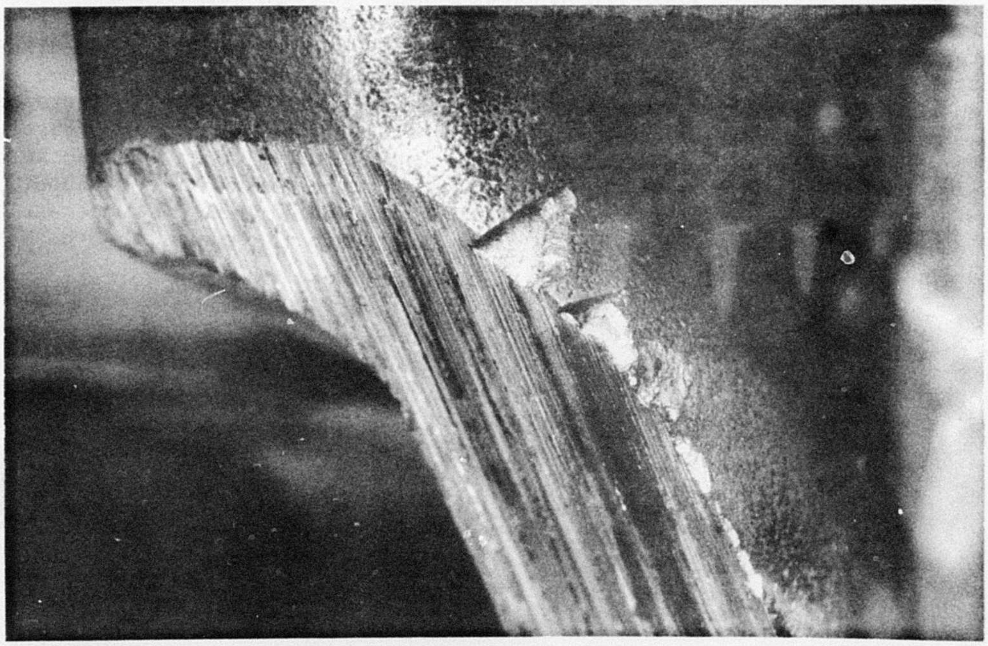


FIGURE 13 - TRIANGULAR CHIPS IN METCO COATING OF HOOK POINT NO. 2

2. Test hook point No. 1 sustained 24 arrestments and was removed at the completion of the test program. Examination of the hook point revealed a small spalled area in the cable groove (shown in Figure 14 on the following page). Although reference (g) does not specify this as a cause for rejection, had any additional arrestments been necessary, a new hook point would have been installed as a precautionary measure.

Figures 15 and 16 (pages 24 and 25) present photographs that show the accumulated wear on each hook point. The wear rate of the cable groove and the back face of both hook points was acceptable.

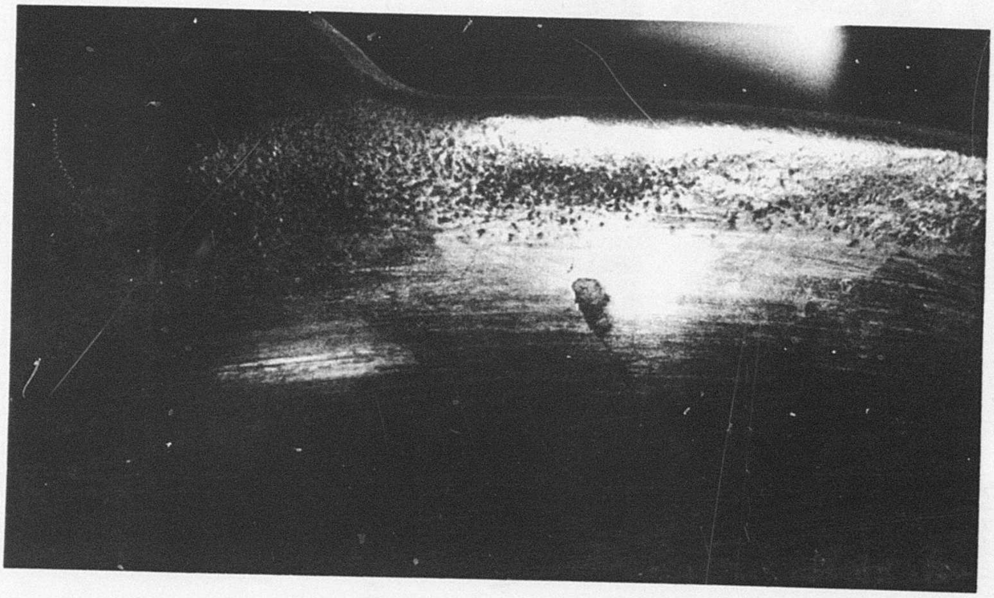
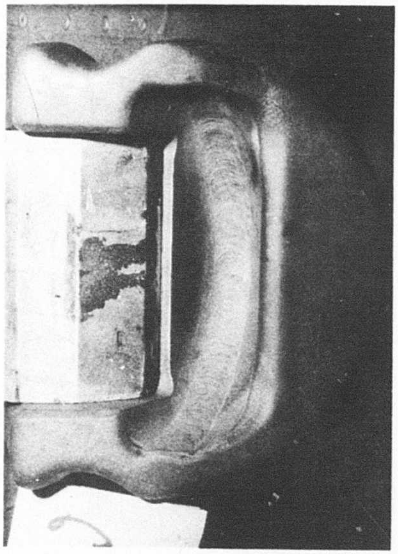
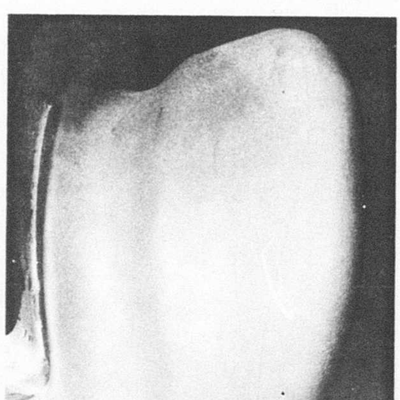


FIGURE 14 - SPALLED AREA IN CABLE GROOVE OF HOOK POINT NO. 1





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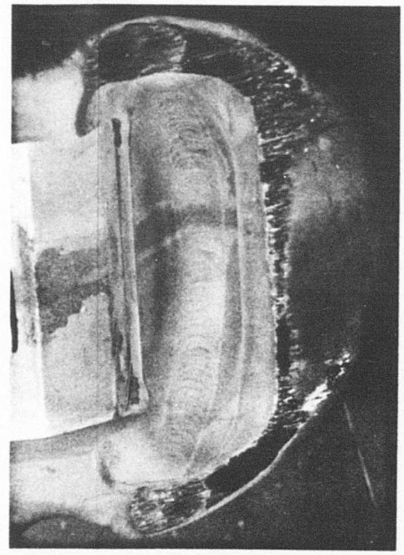

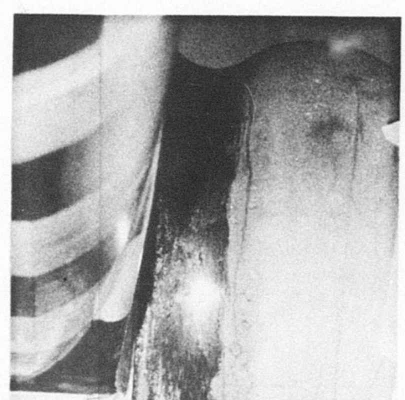

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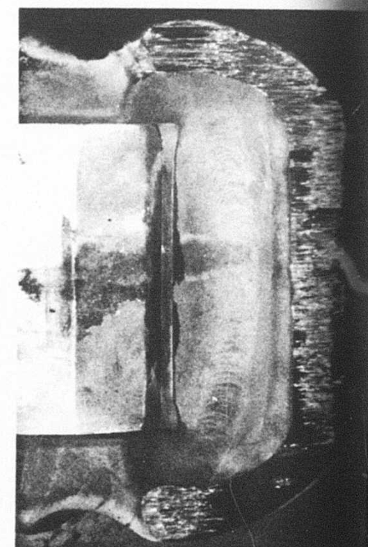
ARRESTS



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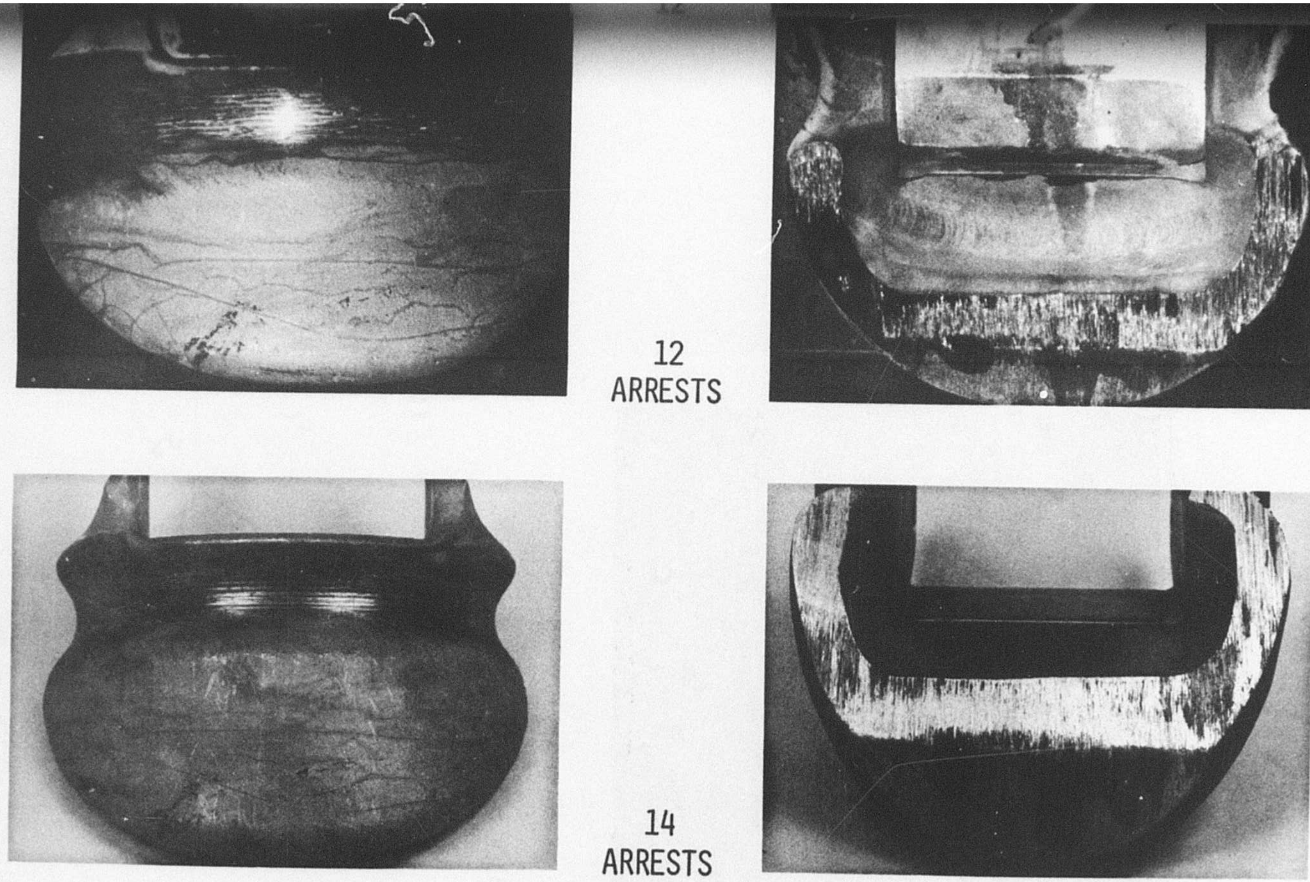
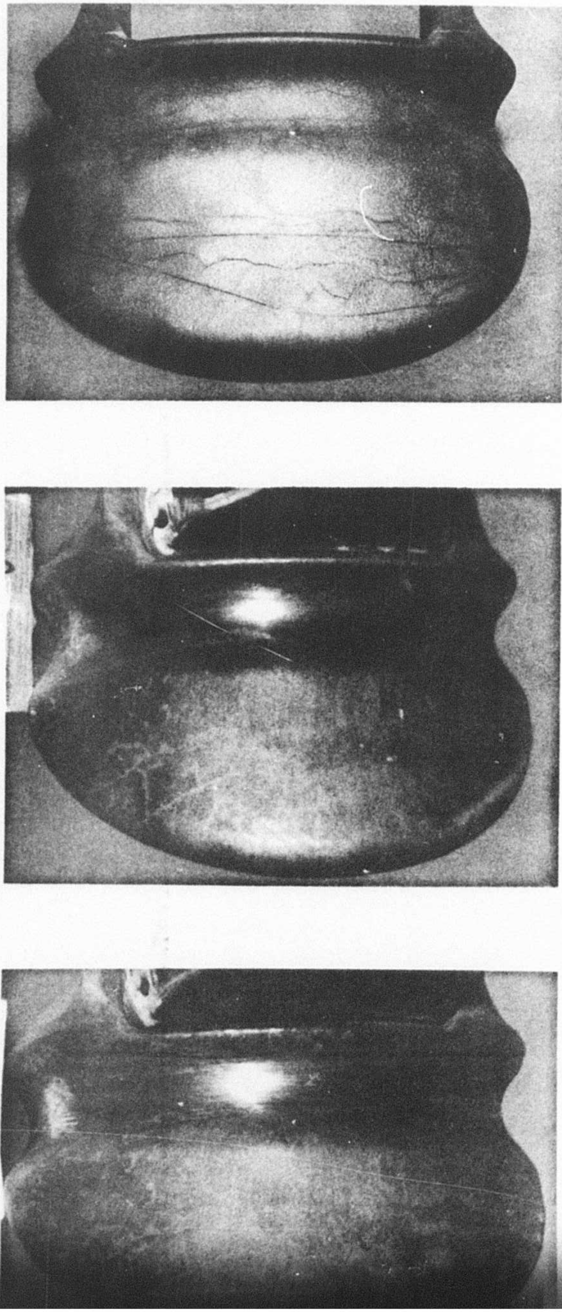


12
ARRESTS

14
ARRESTS

FIGURE 15 - PROGRESSIVE WEAR OF HOOK POINT NO. 2



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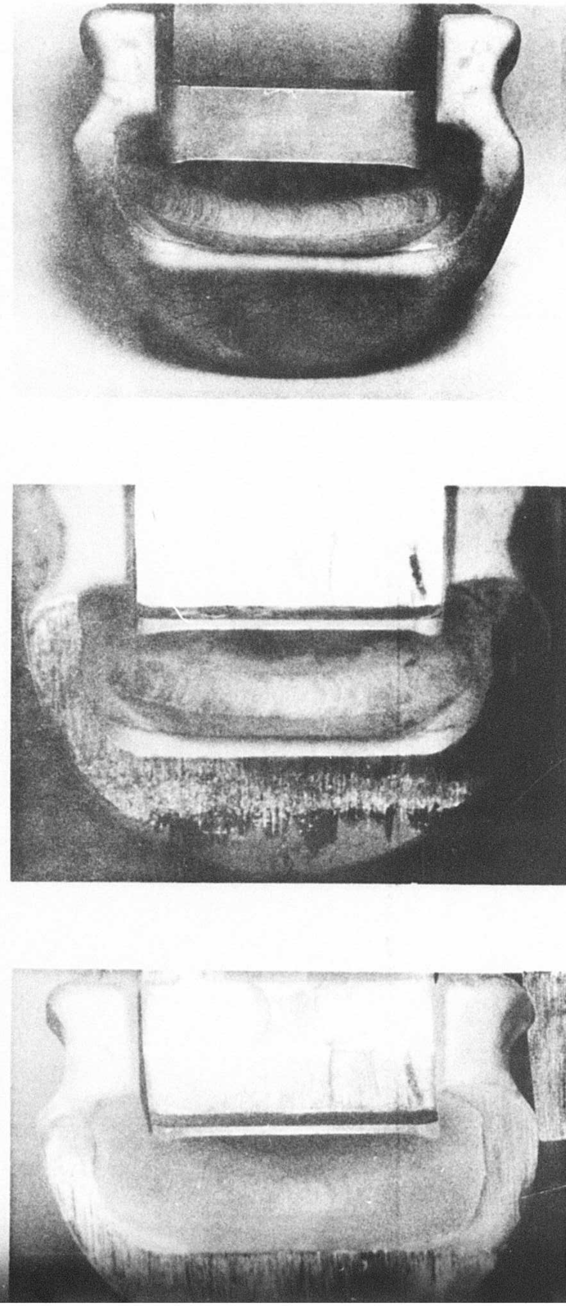

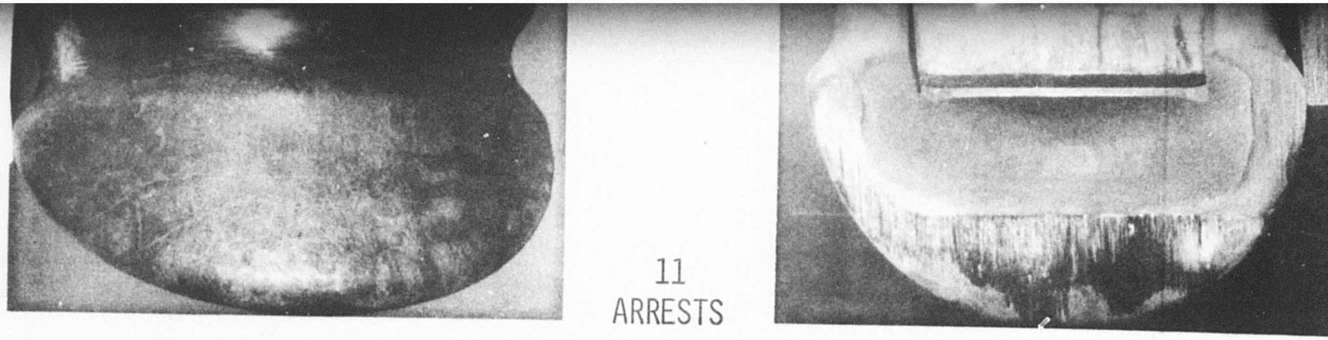

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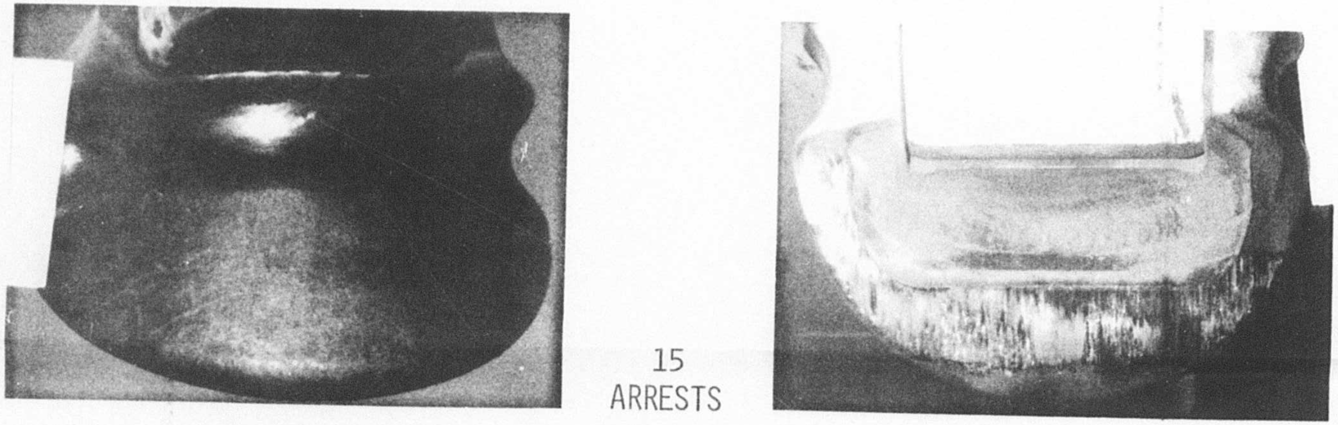
ARRESTS



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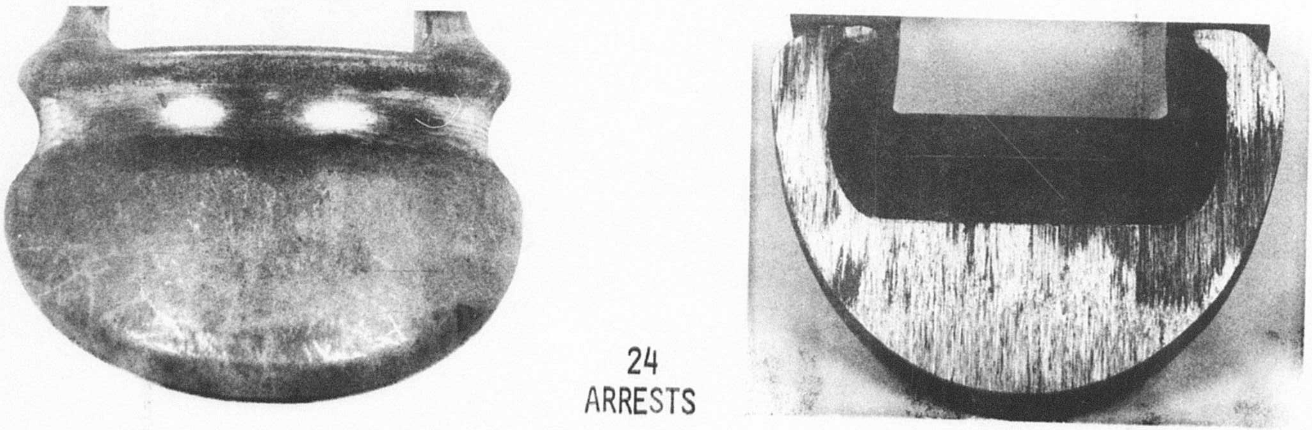
ARRESTS



24
ARRESTS

FIGURE 16 - PROGRESSIVE WEAR OF HOOK POINT NO. 1

V CONCLUSIONS

A. The 44B-2E arresting system is capable of ON-CENTER and up to 25-foot OFF-CENTER arrestments of the F-14 aircraft at the field landing weight range of 54,200 to 57,900 pounds and the aborted takeoff weight range of 68,100 to 70,000 pounds at engaging speeds up to 135 and 126 knots respectively. *(Section IV, paragraph C)*

B. If aircraft power is not reduced prior to hook-cable pickup, increased loading of the arresting system and the aircraft will result with a subsequent decrease in the capability of the arresting system. *(Section IV, paragraph C)*

C. No F-14 aircraft damage occurred as a result of engaging the 44B-2E arresting system. *(Section IV, paragraph C6)*

D. The stability of the F-14 aircraft was satisfactory during runout. *(Section IV, paragraph C4)*

E. The pressure-roller assembly, installed as supplied, can be damaged when the system is two-blocked. *(Section IV, paragraph D2)*

F. Installation of "stops" on the pressure-roller guides prevents damage to the pressure-roller assembly. *(Section IV, paragraph D2)*

G. No bolters occurred as a result of using the modified "sharp toe" F-14 hook point. *(Section IV, paragraphs C7 and E)*

H. The wear rate of the cable groove and the back face of the modified "sharp toe" F-14 hook point is considered to be acceptable. *(Section IV, paragraph E)*

I. Operation of the arresting system was satisfactory using a guide sheave in lieu of the standard purchase-element guide. *(Section IV, paragraph D1)*

J. A section of transite pipe installed as a fairlead tube midway between the arresting and guide sheaves of each arresting unit reduces excessive vertical motion of the purchase element between the sheaves and minimizes purchase-element edge wear. *(Section IV, paragraph D3d)*

K. The present reset-unit exhaust muffler can injure operating personnel. *(Section IV, paragraph D5d)*

L. Coating both ends of the purchase element facilitates installing the element on the system and increases the service life of the element. *(Section IV, paragraph D3b)*

M. The coating on the sewn-loop stitching is inadequate. *(Section IV, paragraph D3c)*

VI RECOMMENDATIONS

A. Accept the 44B-2E arresting system for ON-CENTER and up to 25-foot OFF-CENTER arrestments of the F-14 aircraft at the field landing weight range of 54,200 to 57,900 pounds and the aborted takeoff weight range of 68,100 to 70,000 pounds at engaging speeds up to 135 and 126 knots respectively.

B. Include a warning in the IIAF F-14 Aircraft Operating Manual to reduce aircraft power to IDLE prior to hook-cable pickup.

C. Install "stops" on the pressure-roller assembly.

D. The modified "sharp toe" hook point should be used on all IIAF F-14 aircraft.

E. Replace the purchase-element guide, AAE PN 44773, with a guide-sheave assembly, NAEC PN 509940-1.

F. Install a section of transite pipe as a fairlead tube midway between the arresting and guide sheaves.

G. Replace the present reset-unit exhaust muffler with one similar to that used on U.S. Navy E-28 arresting gear (Figure 11).

H. Coat both ends of the purchase element.

I. Apply a double coating of GACO to the sewn-loop stitching of all purchase elements.

VII REFERENCES

(a) AIRTASK No. A510-5102/071-6/501A-400-376 of 17 Mar 1975

(b) NAVAIRTESTFAC Project Directive No. 3-0-75G031 of 18 Jul 1975: Evaluation of the Iranian Arresting Gear Model 44B-2E (NOTAL)

(c) NAVAIRTESTFAC Project Directive No. 3-0-76G032 of 29 Jul 1975: Evaluation of the Iranian arresting gear Model 44B-2E with the F-14 aircraft (NOTAL)

(d) All American Engineering Company, SM-276, Handbook Maintenance and Overhaul Instructions with Illustrated Parts Breakdown; Model 44B-2E Arresting Gear

(e) All American Engineering Company, SM-363, Handbook of Installation, Operation and Service Instructions with Illustrated Parts Breakdown for Wisconsin Engine Retrieval System 17SK437-24

(f) E-28 Emergency Arresting Gear Service Change No. 17 of 21 May 1971: Retrieve Engine Exhaust System; modification of

(g) NAVAIRINST 13430.1 of 29 Sep 1970: Criteria for inspection, overhaul, test, and replacement of aircraft arresting hook assemblies and hook points

APPENDIX A - TABULATED DATA SHEET FOR DEADLOAD AND F-14 AIRCRAFT ARRESTMENTS CONDUCTED INTO THE 44B-2E ARRESTING SYSTEM

DEADLOAD ARRESTMENTS

Event No. Project	Event No. Site	Vehicle Weight (Lb)	Vehicle Engaging Speed (Kn)	Vehicle Runout (Ft)	OFF-CENTER Engaging Position (Ft) Initial	OFF-CENTER Engaging Position (Ft) Final	Maximum Deadload-/Aircraft-Hook Axial Load (Lb)	Maximum Purchase-Element Tension (Lb) Port	Maximum Purchase-Element Tension (Lb) Stbd	Maximum Longitudinal Deceleration (G)	Deadload-/Aircraft-Hook Axial Load at Arresting System Two-Block (Lb)
1	6,106	57,400	106	1,082	0	20 S	31,900	17,300	17,800	0.95	0
2	6,107	"	124	1,097	"	12 S	49,700	23,700	26,100	1.20	0
3	6,108	"	129	1,098	"	12 S	49,500	28,700	26,600	1.20	0
4	6,109	"	136	1,098	"	12 S	56,700	34,500	30,100	1.33	0
5	6,110	"	144	1,112	"	10 S	60,900	31,000	33,300	1.29	7,000
6	6,111	"	153	1,120	"	2 S	68,800	37,400	42,600	1.69	NR
7	6,112	"	148	1,126	"	6 S	61,500	31,800	33,500	1.39	11,300
8	6,113	"	150	1,127	"	2 S	71,700	31,800	36,900	1.34	11,400
9	6,114	"	152	1,128	"	10 S	70,200	37,200	37,900	1.54	12,200
10	6,115	"	149	1,128	"	0	81,700	32,500	37,900	1.33	10,600
11	6,116	70,300	107	1,157	"	8 S	35,800	18,300	20,200	0.66	23,600
12	6,117	"	115	1,165	"	4 S	39,200	21,600	23,100	0.77	28,500
13	6,118	"	127	1,170	"	25 S	49,600	27,600	29,200	0.84	39,300
14	6,119	"	134	1,175	"	20 S	55,500	31,000	32,500	0.87	51,400
15	6,120	"	140	1,177	"	10 S	61,400*	35,000*	37,100*	0.91	61,400
16	6,121	"	140	1,182	"	18 S	63,800*	37,500*	35,900	0.97	63,800
17	6,122	"	139	1,184	"	20 S	69,100*	37,600*	39,400*	1.05*	69,100
18	6,123	"	140	1,187	"	10 S	66,100*	39,900*	37,800*	0.99*	66,100
19	6,124	"	140	1,188	"	10 S	67,900*	39 900*	36,900*	0.98	67,900
20	6,125	"	140	1,190	"	10 S	68,800*	41,100*	38,100*	0.99*	68,800

F-14 AIRCRAFT ARRESTMENTS

Event No. Project	Event No. Site	Vehicle Weight (Lb)	Vehicle Engaging Speed (Kn)	Vehicle Runout (Ft)	OFF-CENTER Engaging Position (Ft) Initial	OFF-CENTER Engaging Position (Ft) Final	Maximum Deadload-/Aircraft-Hook Axial Load (Lb)	Maximum Purchase-Element Tension (Lb) Port	Maximum Purchase-Element Tension (Lb) Stbd	Maximum Longitudinal Deceleration (G)	Deadload-/Aircraft-Hook Axial Load at Arresting System Two-Block (Lb)
21	36,090	56,600	90	1,045	0	0	43,700	20,300	19,500	0.80	0
22	36,091	55,600	97	1,055	"	0	45,600	22,900	20,600	0.89	0
23	36,399	56,800	104	1,115	"	0	NR	23,200	20,900	NR	0
24	36,400	56,100	113	1,095	"	0	51,300	24,700	21,500	0.89	0
25	36,401	55,700	123	1,115	"	0	50,200	24,700	24,400	1.03	0
26	36,402	54,400	118	1,105	"	0	47,500	24,800	22,200	1.01	0
27	36,403	55,800	119	1,095	"	0	49,100	25,200	23,400	1.02	0
28	36,404	55,100	125	1,100	"	2 S	54,500	27,900	28,800	1.05	0
29	36,405	54,200	129	1,105	"	0	62,500	33,200	30,700	1.18	0
30	36,406	57,000	137	1,125	"	2 S	67,200	34,600	33,300	1.33	0
31	36,407	56,100	147	1,115	"	0	74,900	38,700	38,000	1.43	0
32	36,408	55,100	109	1,105	12 P	16 P	42,500	22,500	21,000	0.84	0
33	36,419	57,200	102	1,045	25 P	29 P	39,400	23,200	20,000	0.71	0
34	36,420	56,400	110	1,065	"	35 P	47,600	25,300	21,300	0.81	0
35	36,422	57,900	121	1,085	"	35 P	56,900	31,300	27,500	1.00	0
36	36,423	57,100	121	1,045	"	28 P	53,900	30,900	26,900	0.96	0
37	36,425	57,200	115	1,050	"	37 P	50,700	28,000	25,400	0.92	0
38	36,426	56,400	129	1,065	"	28 P	NR	35,600	27,400	NR	0
39	36,427	56,800	126	1,065	"	39 P	62,500	35,500	30,100	1.06	0
40	36,428	56,100	131	1,065	"	36 P	67,300	36,600	32,300	1.12	0
41	36,429	57,200	132	1,085	"	35 P	66,800	38,500	29,400	1.12	0
42	36,430	69,000	92	1,100	0	0	NR	16,400	15,600	NR	NR
43	36,554	69,700	98	1,125	"	3 P	37,100	19,500	19,400	0.52	9,400
44	36,555	69,000	95	1,110	"	0	33,900	18,200	17,400	0.57	7,800
45	36,556	68,400	102	1,125	"	4 P	45,500	23,400	22,400	0.73	10,500
46	36,557	69,800	108	1,122	"	4 S	49,400	25,100	22,400	0.76	9,400
47	36,558	70,000	116	1;140	"	2 P	52,800	28,900	26,400	0.82	15,600
48	36,559	69,400	118	1,135	"	4 P	57,400	31,600	28,900	0.92	12,700
49	36,560	68,800	129	1,148	"	0	66,000	36,600	33,100	1.07	14,700
50	36,561	69,300	132	1,140	"	12 S	64,600	34,500	33,200	1.05	14,600
51	36,562	68,500	91	1,110	12 P	12 P	37,200	18,800	16,600	0.57	5,700
52	36,563	68,100	92	1,110	25 P	40 P	34,600	19,800	18,100	0.57	5,500
53	36,564	69,900	95	1,120	"	33 P	61,500	35,800	28,300	0.84	32,400
54	36,565	69,300	107	1,120	"	28 P	40,900	24,900	19,800	0.59	10,500
55	36,566	68,100	122	1,130	"	26 P	52,700	32,200	25,600	0.86	11,500
56	36,567	69,800	117	1,130	"	32 P	57,400	30,500	27,300	0.96	10,500
57	36,568	69,300	128	1,130	"	30 P	60,700	30,900	26,700	0.92	12,600
58	36,569	68,700	130	1,130	"	25 P	73,100	42,900	30,500	1.04	16,800

P = Port; S = Starboard; NR = No record.
* Two-block (bottoming) load.

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