DEPARTMENT OF THE NAVY
NAVAL AIR TEST FACILITY
Lakehurst, New Jersey
08733

Report NATF-EN-1111

PERFORMANCE CAPABILITY OF THE 44B-2C EMERGENCY ARRESTING GEAR AT ABORTED TAKEOFF CONDITIONS OF THE F-5, A-4, F-102, F-105, AND F-4J AIRCRAFT (12 March 1969 to 29 April 1970)

Final Report
12 April 1971

by

Waldemar Wastallo
Recovery Division

Prepared under Naval Air Systems Command
AIRTASK A5375373 2045 1537000043
Work Unit No. A5373B-07

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ABSTRACT

A test program was conducted to determine the performance capability of the 44B-2C emergency arresting gear configured on a 50-meter (164-foot) deck span during arrestments of the F-5, A-4, F-102, F-105, and F-4J aircraft at aborted takeoff weight conditions. The weight classes of these aircraft were simulated by use of a 21,000- and 24,500-pound F-8 aircraft, a 33,000-pound F-4A aircraft, and a 48,000-pound A-3 aircraft. Arrestments of the F-8 and F-4A were conducted ON-CENTER and 30 feet OFF-CENTER over an engaging-speed range of approximately 100 to 160 knots, and arrestments of the A-3 were conducted ON-CENTER at speeds ranging from 52 to 118 knots.

Based on the test results, the F-5, F-102, and F-105 aircraft are limited by arresting-hook load; the F-4J aircraft is limited by arresting-gear capacity; and the A-4 aircraft is not subject to a limit up to the test-program speed of 160 knots. Purchase-tape and deck-pendant tension limits were not exceeded. In general, higher aircraft arresting-hook loads and higher purchase-tape tensions in the short-side tape occurred during the OFF-CENTER arrestments. Aircraft runout characteristics were satisfactory. No arresting-hook/bumper contact damage occurred, and the aircraft structures showed no evidence of deck-pendant contacts. Arrestments of aircraft weighing more than 48,000 pounds are not recommended.

During the initial portion of the aircraft program, it was found that the arresting-gear tape guide provided insufficient tape guidance for safe operation of the arresting gear and caused several failures of the tight-wrap roller bracket, bearings, and shaft. These problems were eliminated by the installation of a guide-sheave assembly.

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I INTRODUCTION

Tests of the All American Engineering Company (AAE) Model 44B-2C emergency arresting gear were conducted at the Naval Air Test Facility as authorized by reference (a). The purpose of these tests was to determine the performance capability of the gear during arrestments of the F-5, A-4, F-102, F-105, and F-4J aircraft at aborted takeoff weight conditions. The program was conducted as follows:

1. Deadload Phase: The gear was installed at the Recovery Systems Track Site (RSTS) No. 3 for an evaluation of its performance as a primary gear on a 50-meter (164-foot) deck span and as a secondary (backup) gear on a 63-meter (207-foot) deck span. Tests with deadloads weighing from 19,000 to 55,000 pounds were conducted from 22 November 1968 to 2 March 1969. The results of these tests, which showed no significant difference between arresting-gear performance on either deck span, were reported in reference (b).

2. Aircraft Phase: Because a greater number of arrestments is expected to be made by the primary system, the 50-meter (164-foot) deck-span configuration was selected for the aircraft test phase at the Runway Arrested Landing Site (RALS). Tests were conducted on 12 and 13 March 1969 (demonstration arrestments for FRG representatives) and from 21 August 1969 to 29 April 1970. F-8, F-4A, and A-3 aircraft were used to simulate the aborted takeoff weight conditions of the F-5, A-4, F-102, F-105, and F-4J aircraft. The results of these tests are presented in this report.

II TEST EQUIPMENT AND CONFIGURATION

A. Model 44B-2C Emergency Arresting-Gear System

1. General Description

a. The 44B-2C emergency arresting-gear system installation, which has a design energy capacity of 48 million foot-pounds, consists of two identical arresting engines installed on opposite sides of the runway. Figure 1 shows the installation of one arresting engine. Two nylon tapes of equal lengths are used as the purchase members: each is wound on a storage reel of its respective unit, routed through a guide-sheave assembly (standard tape guide bar replaced) and a deck-sheave assembly, and connected to one end of the crossdeck pendant.

b. The arresting engines are actuated when the aircraft arresting hook engages the crossdeck pendant, pulling out the attached purchase tapes. As each tape 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 turbulence within the housing, and the aircraft is decelerated to a smooth stop.

c. After the airplane has stopped and its arresting hook has disengaged the pendant, the engine operator stationed at each arresting engine actuates the gasoline-engine driven retrieve system which retracts the tape and tensions the pendant. After the pendant has been retrieved and tensioned, the arresting-gear operation is entirely automatic during an arrestment. The system has the capability of making one arrestment while unattended.

2. Detailed Description: The 44B-2C arresting gear is composed of the following major assemblies, which are installed on each side of the runway: energy absorber and tape storage reel, retrieve system, pressure roller, and deck sheave.

a. The energy absorber is composed of a 44-inch-diameter drum-shaped housing that contains a 31-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 66-inch-diameter tape 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 retrieve system 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 overrunning clutch, a drive sprocket, and a chain-driven retrieve sprocket. The retrieve system is coupled to the energy absorber by means of a spring-loaded cam mechanism mounted on the retrieve sprocket. The cam engages a follower (post) attached to the tape reel and mates the retrieve system to the energy absorber during tape retrieval and when the system is placed in battery position. When in battery position, the overrunning clutch holds the deck pendant tensioned at 1,500 to 2,000 pound. During an arrestment the cam mechanism releases the retrieve system from the energy absorber when the tape tension increases to approximately 5,000 pounds. The cam mechanism was modified as described in reference (b).

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 tape to assure that it is wrapped tightly on the reel. The roller load on the tape surface reaches a maximum of approximately 1,300 pounds when the tape is fully retracted.

d. The deck-sheave assembly consists of two sheave-roller assemblies mounted within a housing. The tape is reeved between the rollers to the deck pendant. The function of the deck sheave is to guide and maintain the alignment of the tape. Deck-sheave-assembly reinforcing T-sections were installed as described in reference (b).

3. Miscellaneous

a. The tape guide sheave, AAE PN 44773, was replaced after the initial nine aircraft arrestments with a roller and housing assembly (guide sheave), NAEC PN 509940-1, to provide additional tape guidance and to improve the alignment of the tape on the storage reel (see paragraph VIE for details).

b. The components of the 44B-2C arresting engines 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 NATF Drawing No. 230042. The arresting engines were then placed on leveled dirt fill and anchored with cruciform stakes and EAW-20 extendible earth anchors.

c. A 1-1/2-inch pipe-size pressure relief valve set to relieve at 275 psi was installed on the fluid fill pipe of each energy absorber, to prevent possible overpressurization of the absorber housing due to thermal effects caused by repetitive arrestments.

4. Test Configuration

a. RALS runway width - 200 feet (61 meters)

b. Deck-sheave span - 164 feet (50 meters) ON-CENTER

c. Tape-reel to deck-sheave split distance - 49 feet (15 meters)

d. Uncoated nylon purchase tapes - 840 feet (256 meters) long x 8 inches wide x 0.35 inch thick

e. Deck pendant - 154 feet (47 meters) long x 1 inch diameter, 18 x 7 fiber core nonrotating wire rope, AAE PN 44944PR-7 (equipped with nineteen 6-inch-diameter do-nut pendant supports, AAE PN 44996-8).

B. Aircraft: The F-8, F-4A, and A-3 aircraft were used to simulate the aborted takeoff of the F-5, A-4, F-102, F-105, and F-4J aircraft, as follows:

Test Aircraft	Weight Range (Lb)	Simulated Aircraft (Model)
F-8	19,800-21,300	F-5
F-8*	22,000-24,500	A-4*
F-4A†	30,300-34,100	F-102
A-3	47,500-48,500	F-105, F-4J†

* The A-4 aircraft, which is restricted to a maximum field landing weight of 16,000 pounds, was simulated by the F-8 aircraft for the abort A-4 weight (22,000 - 24,500 pounds).

† The F-4A aircraft was not used to simulate the F-4J aircraft because of arrested landing weight restrictions.

III TEST PROCEDURE

A. Test Outline: ON- and OFF-CENTER tests were conducted in accordance with the following procedure (see paragraph D of this Section for list of limiting parameters):

1. ON-CENTER Tests: Testing with each aircraft weight class was begun ON-CENTER. The initial engaging speeds were as follows: F-8 (21,000 pounds), 111 knots; F-8 (24,500 pounds), 97 knots; F-4 (33,000 pounds), 110 knots; and A-3 (48,000 pounds), 52 knots. The speed of each aircraft during subsequent events was increased in increments of approximately 10 knots until a program test limit was reached.

2. OFF-CENTER Tests: An initial 15-foot OFF-CENTER to port arrestment of the F-8 aircraft was satisfactorily completed, and then all arrestments were conducted 30 feet OFF-CENTER to port. Initial engaging speeds were approximately the same as those noted above, and the speeds were increased in increments of approximately 10 knots until a program test limit was reached. No OFF-CENTER arrestments of the A-3 aircraft were conducted: walkback control difficulty was experienced with this aircraft during the ON-CENTER events, and this difficulty was expected to increase during OFF-CENTER events.

3. All arrestments were unidirectional and all OFF-CENTER arrestments were conducted to the port side of the arresting-gear system centerline. These limitations were necessary due to the location of the system in relation to the RALS control tower and other test equipment on the runway. The taxi-in and roll-in methods of aircraft approach to the arresting-gear deck pendant were used for the majority of arrestments. Fly-in approaches were used only when necessary.

B. Pilot Technique: Power necessary to obtain the desired engaging speed was maintained until pendant pickup was assured. Power then was reduced to and maintained at IDLE for the remainder of the arrestment. At the end of the arrestment, power was increased when required to prevent excessive walkback.

C. Aircraft and Arresting-Gear Instrumentation: The parameters measured were recorded on magnetic tape displayed on oscillograms or visually observed. The parameters and methods of measuring are on the following page:

Parameter	Recording Method	Accuracy Within (±)
Arresting-hook axial load	Strain gage	5%
Longitudinal deceleration	Accelerometer	5%
Purchase-tape tension*	Strain gage (tensiometer)	5%
Engaging speed	Deck coil (prime source), GSN-5 radar	2 knots
Gross engaging weight (basic, stores, and fuel)	Electronic load cells and aircraft fuel quantity gage	200 pounds
OFF-CENTER distance	Deck markings	2 feet
Runout	Deck markings	10 feet
Arresting engine, arresting hook, and aircraft runout monitors	High-speed motion-picture coverage	-

* Tensiometers were available for measurement of tape tensions for all arrestments of the F-8 and F-4 aircraft but for only the 118-knot arrestment of the A-3 aircraft.

D. Test Limits: The following test limits were established for this program:

Parameter	Test Limits
Engaging Speed	160 knots*
Deck-pendant tension (60% of minimum breaking strength)	46,000 pounds
Purchase-tape tension	55,000 pounds†

* The reference (c) maximum engaging-speed requirement for the F-8 aircraft was reduced from 160 to 150 knots during tests because of the excessive bolter rate caused by aircraft's performance characteristics.

† Stitched loops are proof-tested to 55,000 pounds. The average breaking strength of tapes now in use is 168,500 pounds.

Parameter		Test Limits
Aircraft arresting-hook load:		
	F-8	118,800 pounds
	F-4A	118,500 pounds
	A-3	191,000 pounds
Aircraft longitudinal deceleration:		
	F-8	5.47 G
	F-4A	3.95 G
	A-3	4.80 G
Aircraft walkback, stability, and control characteristics		Within acceptable limits‡
Aircraft fishtailing, swerving, and pitching characteristics		" " "
Energy absorber temperature condition		Sustained vapor discharge

‡ As judged by pilot and project engineer.

E. Arresting-Gear Maintenance: The arresting gear was operated and maintained as specified in reference (d), except as noted in the following paragraphs:

1. Deck-Pendant Replacement Criteria

a. It exhibits a total of six broken wires.

b. It exhibits four or more broken wires per lay length.

c. The hemp core is visible.

d. The strands separate.

e. It exhibits evidence of birdcaging.

f. It exhibits 20 or more flat spots of 1/2 inch or more in length within one complete strand for one cable pitch length.

g. It exhibits kinking.

2. Purchase-Tape Replacement Criteria

a. It is cut through the outer weave into the longitudinal (load carrying) members with a cut larger than 1/2 inch.

b. It is split longitudinally.

c. It is worn more than 1/2 inch on either side, or its width beyond 60 feet of the pendant connector assembly is less than 7-1/4 inches.

IV DATA PRESENTATION

A. The maximum arresting-hook loads and purchase-tape tensions were plotted versus engaging speed for each aircraft weight range. 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:

$$\text{Mean load (pounds)} = aV^b \text{ (knots)}.$$

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

B. In Figures 2 through 5, the solid and dash curves are the mean or best-fit loads and the long-short dash curves are the upper 1-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 1-sigma curve is intersected by the simulated aircraft's established arresting-hook-load or pendant-/tape-tension limit. Theoretically, the probability of realizing a load less than 1-sigma is 0.84, and a load more than 1-sigma is 0.16.

V TEST RESULTS AND DISCUSSION

A. During this program, 83 successful aircraft arrestments were conducted; also, 38 bolters were recorded (see paragraph A7 for discussion of bolters). The data for the 83 events is tabulated in Appendix A and summarized in the following table:

	Aircraft						Range			
No. of Events	Test Model	Simulated Model	Gross-Weight Range (1,000 Lb)	OFF-CENTER Distance (Ft) Init	OFF-CENTER Distance (Ft) Final	Engaging Speed Range (Kn)	Arresting Hook Axial Load (1,000 Lb)	Purchase Tape Tension (1,000 Lb)	Long. Decel (G)	Acft Runout (Ft)
							L=118.8	L=55.0	L=5.47	
14	F-8	F-5	20.0-21.3	0	3 P-18 S	111-151	24.2-53.8	17.3-27.8	1.09-2.60	735-840
12	F-8	F-5	19.8-21.2	30 P	20 P-39 P	109-149	23.5-52.0	21.7-32.0	1.47-2.22	660-815
20	F-8	A-4	22.0-24.5	0	20 P-14 S	97-156	29.2-54.2	15.2-33.8	0.84-2.10	600-835
1	F-8	A-4	23.5	15 P	20 P	118	32.4	19.7	0.98	805
6	F-8	A-4	23.5-24.2	30 P	55 P-17 S	114-154	28.2-51.7	20.6-37.2	0.84-2.06	790-865
							L=118.5	L=55.0	L=3.95	
14	F-4A	F-102	30.3-34.1	0	0-3S	110-159	36.3-63.1	17.3-34.0	1.03-2.26	835-875
10	F-4A	F-102	31.3-33.0	30 P	26 P-38 P	109-166	29.7-78.1	16.7-40.0	0.96-2.30	865
							L=191.0	L=55.0	L=4.80	
6	A-3*	F-105, F-4J	47.5-48.5	0	0-10P	52-118	14.8-80.3	NR - 44.0	0.40-1.57	865-965

L = Test limit (refer to pages 6 and 7).
NR = Not recorded.
* No OFF-CENTER test conducted with this aircraft because of difficulties (see paragraphs IIIA3 and VA5c).

Data for the 83 test events is plotted in Figures 2 through 5: the procedure by which these illustrations were prepared is contained in Section IV. ON- and OFF-CENTER performance data is combined in graphs A and B of Figures 2 through 4 to establish engaging-speed limits for the F-5, A-4, and F-102 aircraft at aborted takeoff weight conditions. ON- and OFF-CENTER performance data is compared in graphs C, D, and E of Figures 2 through 4. The engaging-speed limit for the F-105 aircraft at aborted takeoff weight conditions is based on the ON-CENTER performance data shown in Figure 5, and that of the F-4J aircraft at aborted takeoff weight conditions is based on Figure 5 and specifically the results of the 118-knot ON-CENTER arrestment of the A-3 aircraft.

1. Aircraft Arresting-Hook Axial Loads

a. OFF-CENTER arrestments generated higher mean arresting-hook axial loads than ON-CENTER arrestments for the entire engaging-speed range of the F-8 aircraft and at engaging speeds greater than 135 knots for the F-4A aircraft.

b. The mean arresting-hook axial load curves of the 21,000- and 24,500-pound F-8 aircraft (Figures 2 and 3) and the 33,000-pound F-4A aircraft (Figure 4) compare favorably with those of reference (b) for the 19,000-, 24,500-, and 32,000-pound deadloads. The mean arresting-hook axial load curve of the 48,000-pound A-3 aircraft (graph A, Figure 5) does not compare as favorably with those of reference (b) for the 48,000-pound deadload, possibly because of the increased effect of aircraft thrust at this engaging weight.

c. A comparison of graphs B and C of Figure 5 shows that the maximum engaging speed of the F-105 aircraft is limited by the arresting-hook axial loads that occur at arresting-engine two-block rather than those that occur during the hydraulic region of the arrestment.

2. Arresting-Gear Purchase-Tape Tensions

a. The purchase-tape tension limit of 55,000 pounds and the deck-pendant tension limit of 46,000 pounds were not exceeded. A maximum tape/pendant tension of 44,000 pounds was reached at two-block of the arresting engines during the 118-knot arrestment of the A-3 aircraft.

b. The highest mean purchase-tape tensions were produced in the short-side tape during OFF-CENTER arrestments.

3. Time of Load Occurrence: The times at which the maximum aircraft and arresting-gear loads occurred after deck-pendant pickup were widely spread, as shown in the following table:

Aircraft		Time of Maximum Load (Seconds)					
		Purchase Tape			Arresting Hook		
Model	Weight (Lb)	Min	Avg	Max	Min	Avg	Max
F-8	21,000	0.04	0.17	0.69	0.29	0.53	1.18
F-8	24,500	0.06	0.17	0.75	0.23	0.69	1.07
F-4A	33,000	0.09	0.65	1.48	0.45	1.04	1.65
A-3	48,000	*	*	*	4.46	5.91	8.40

* Tensiometers not installed.

4. Aircraft Stability: Aircraft stability during runout was satisfactory. ON- and OFF-CENTER arrestments resulted in gradual swerve to either port or starboard of the initial engaging position, with mild-to-moderate pitch and yaw motion. Maximum final distances of 20 feet to port and 24 feet to starboard were realized during ON-CENTER arrestments, and 55 feet to port and 17 feet to starboard during 30-foot OFF-CENTER to port arrestments. Aircraft fishtailing and pendant wiping around the arresting-hook point groove increased noticeably during OFF-CENTER arrestments.

5. Aircraft Walkback and Arresting-Engine Two-Blocking

a. Walkback at the end of the majority of F-8 aircraft arrestments was insufficient to clear the deck pendant from the arresting hook. When the pendant remained attached to the aircraft, the arresting-gear retrieve systems were used to roll the aircraft aft a short distance to remove the residual tension and facilitate deck-pendant removal. The arresting engines did not two-block during arrestments of the F-8 aircraft.

b. Arresting-engine two-blocking occurred during all but one arrestment of the F-4A aircraft. The maximum arresting-hook axial load at two-block was 12,900 pounds. Walkback distances of approximately 5 to 20 feet were sufficient to disengage the deck pendant from the F-4A aircraft during practically all arrestments.

c. The arresting engines two-blocked during all arrestments of the A-3 aircraft. The resultant loads caused mild-to-violent walkback during which aircraft directional control was difficult. Pilots used the full power of the aircraft engines in order to minimize walkback; however, walkback distances of up to 75 feet were realized.

Arresting-hook axial loads at two-block ranged from a minimum of 14,800 pounds at an engaging speed of 68 knots to a maximum of 80,300 pounds at an engaging speed of 118 knots (see Figure 5B).

6. Aircraft Structure: Visual examination of the F-8, F-4A, and A-3 aircraft structures and motion-picture camera coverage of the arresting hooks showed normal arresting-hook/bumper contacts with no damage to the bumper-impact areas or evidence of deck-pendant contacts.

7. Bolters: Thirty-eight bolters occurred during this program. High engaging speeds combined with prevailing headwinds caused the majority of these bolters to occur with the lightweight F-8 aircraft because of the aircraft's performance characteristics under these conditions. The bolter rates of the other aircraft are considered normal. The causes for the bolters and the bolter rate of each aircraft are presented in the following table:

Aircraft		No. of	No. of Bolters				Bolter
Model	Weight Range (Lb)	Attempted Arrestments	No Hook	Late Hook	High Hook	Hook Skip	Rate (%)
F-8	19,500-21,000	54	2	0	23	3	52
F-8	22,500-24,500	33	0	0	2	4	18
F-4A	31,000-33,000	28	0	1	0	3	14
A-3	45,000-48,000	6	0	0	0	0	0

8. Based on the above and using the method described in Section IV, the 44E-2C arresting-gear system configured on a 50-meter deck span is capable of ON-CENTER and up to 30-foot OFF-CENTER arrestments of the simulated aircraft at aborted takeoff weight conditions as follows:

Test Aircraft			Simulated Aircraft Weight Class				
Fig.	Model	Weight Range (Lb)	Model	Arresting-Hook Axial Load Limit (Lb)	Engaging-Speed Limit (Kn)	Purchase-Tape Tension at Limit Speed (Lb)*	Limiting Parameter
2A	F-8	19,800-21,300	F-5	37,750	127	26,500	Arresting-hook axial load
3A	F-8	22,000-24,500	A-4	76,000	160	35,500	Program limit

* Deck-pendant tension limit is 46,000 pounds; purchase-tape tension limit is 55,000 pounds.

	Test Aircraft		Simulated Aircraft Weight Class				
Fig.	Model	Weight Range (Lb)	Model	Arresting-Hook Axial Load Limit (Lb)	Engaging-Speed Limit (Kn)	Purchase-Tape Tension at Limit Speed (Lb)*	Limiting Parameter
4A	F-4A	30,300-34,100	F-102	47,000	128	27,800	Arresting-hook axial load
5B	A-3	47,500-48,500	F-105	50,000†	99	23,500	" " "
5A‡	A-3	47,500-48,500	F-4[illegible]	143,000	118	44,000	Arresting-gear capacity

* Deck-pendant tension limit is 46,000 pounds; purchase-tape tension limit is 55,000 pounds.

† Arresting-hook load limit reached at two-block of the arresting engines will cause a 1 G deceleration during walkback.

‡ Excessive walkback at end of the 118-knot arrestment. Loads at two-block of the arresting engines were: arresting-hook axial load, 80,300 pounds; purchase-tape tension, 44,000 pounds; and longitudinal deceleration, 1.57 G.

VI ARRESTING-GEAR OPERATION AND MAINTENANCE

A. General: After replacement of the tape guide with the roller and housing assembly (paragraph VIE), routine inspection and maintenance procedures (paragraph IIIE) were sufficient to maintain the arresting gear in operating condition for the remainder of the tests.

B. Deck Pendants: Eight deck pendants were used during this test program and had a service life as follows:

Number of Arrestments	Reason for Replacement
20	Failed at arresting-hook point during arrestment
0	One broken strand (aircraft boltered--not counted as an arrestment)
8	One broken strand
18	Precautionary--high number of arrestments
4	Five broken wires in one lay length
7	Birdcaged
16	Excessive number of flat spots
10	Program completed--pendant still usable

C. Pendant Supports: Each deck-pendant assembly came preassembled with nineteen 6-inch-diameter do-nut pendant supports, AAE PN 44996-8. The general procedure was to position four of the do-nuts 7 and 21 feet on each side of the intended engaging position. The remaining do-nuts were scattered along the port and starboard sides of the pendant and were used as replacements for the engaging-position do-nuts when necessary (see Figure 6). During the arrestments, do-nuts failed and were thrown off the pendant as a result of pendant dynamics; however, the number of do-nuts remaining was always sufficient to support the pendant for additional arrestments. During tests with the F-8 and F-4A aircraft, five and three bolters, respectively, occurred which were caused by arresting-hook skip: aircraft tires, arresting-hook points, and other structures were not damaged by the do-nuts. The do-nuts reduced each pendant's contact with the runway surface during tape retraction and thereby reduced pendant abrasive wear.

D. Purchase Tapes: Four purchase tapes manufactured by the Buffalo Belting and Weaving Company were used during this test program and had a service life as follows:

Arresting-Gear Unit	No. of Events	Reason for Replacement
Port	82*	1-inch x 200-foot section stripped off top edge
Port	45	Worn extensively
Port	16	Program completed--tape usable
Stbd	143*	Program completed--tape scrapped because of extensive wear

* Includes 60 previous deadload arrestments.

The wide difference between the service lives of the port and starboard purchase tapes is attributed to the higher loads imposed on the port tape (short side) during 30-foot OFF-CENTER to port arrestments.

E. Tape Guide, AAE PN 44773

1. While retracting the tapes following each of the initial nine aircraft arrestments, the bottom edge of each purchase tape flared on the tape guide and on the lower flange of the storage reel. As a result, the diameter of the storage-reel tape stack was larger at the bottom than at the top. The tape-stack flare exerted sufficient upward force on the tight-wrap roller to cause several failures of the roller bracket, bearings, and shaft (see Figure 7). The failures, however, were not the primary concern: based on the results of tests with similar arresting-gear systems, a flared tape stack increases the probability of tape tuck failure and subsequent serious aircraft damage during an arrestment.

2. Because of the above, the tape guide (Figure 8) was replaced with a roller and housing assembly (guide sheave), NAEC PN 509940-1 (Figures 1 and 8). Following the installation of the guide sheave, no tight-wrap-roller failure and no tape-stack flare occurred during the remaining 74 aircraft arrestments.

VII CONCLUSIONS

A. The 44B-2C emergency arresting-gear system configured on a deck span of 50 meters (164 feet) is capable of ON-CENTER and up to 30-foot OFF-CENTER arrestments of F-5, A-4, F-102, F-105, and F-4J aircraft at aborted takeoff weight conditions as outlined in paragraph VB.

B. The maximum operational capacity of the arresting-gear system was reached during the 118-knot arrestment of the 48,000-pound A-3 aircraft. (Paragraphs VA and VB)

C. Even though the engine power of a 48,000-pound aircraft is reduced to a minimum (IDLE) when pendant pickup is assured, walkback of the F-105 and F-4J aircraft may be uncontrollable after two-block of the arresting engines and the arresting-hook load limit of the F-105 aircraft may be exceeded. (Paragraphs VA5c and VB)

D. Arresting-gear structural and operational reliability was improved by the installation of a guide sheave in place of the tape guide. (Paragraph VIE)

VIII RECOMMENDATIONS

A. Accept the 44B-2C emergency arresting-gear system configured on a 50-meter deck span for ON-CENTER and up to 30-foot OFF-CENTER emergency arrestments of aircraft as follows:

Aircraft		
Model	Gross Weight (Lb)	Engaging Speed (Knots)
F-5	21,000	127
A-4	24,500	160
F-102	33,000	128
F-105	48,000	90*
F-4J	48,000	110†

* The engaging speed is 9 knots below the 99-knot capability of the system in order to reduce the possibility of excessive arresting-hook axial load and walkback at two-block of the arresting engines.

† The engaging speed is 8 knots below the 118-knot capability of the system in order to reduce the excessive walkback at two-block of the arresting engines.

B. Limit the 44B-2C emergency arresting-gear system to arrestments of aircraft weighing not more than 48,000 pounds.

C. During all arrestments of 48,000-pound aircraft, the pilot must reduce power to a minimum when the arrestment is assured and then use power after the arresting engines are two-blocked in order to minimize and control walkback.

D. Replace the tape guide, AAE PN 44773, with a guide-sheave assembly, NAEC PN 509940-1.

IX REFERENCES

(a) NAVAIRSYSCOM ltr AIR-5373C/85:HD of 19 Apr 1968: 44B-2C Arresting Gear

(b) NATF Letter Report of Test Results No. NATF-R51 of 15 Oct 1969: Model 44B-2C Emergency Arresting Gear; interim report on

(c) NATF ltr 4210 of 24 May 1968 to NAVAIRSYSCOM: Model 44B-2C arresting gear

(d) All American Engineering Company, SM-251A, Handbook Maintenance and Overhaul Instructions with Illustrated Parts Breakdown, Model 44B-2C Arresting Gear.

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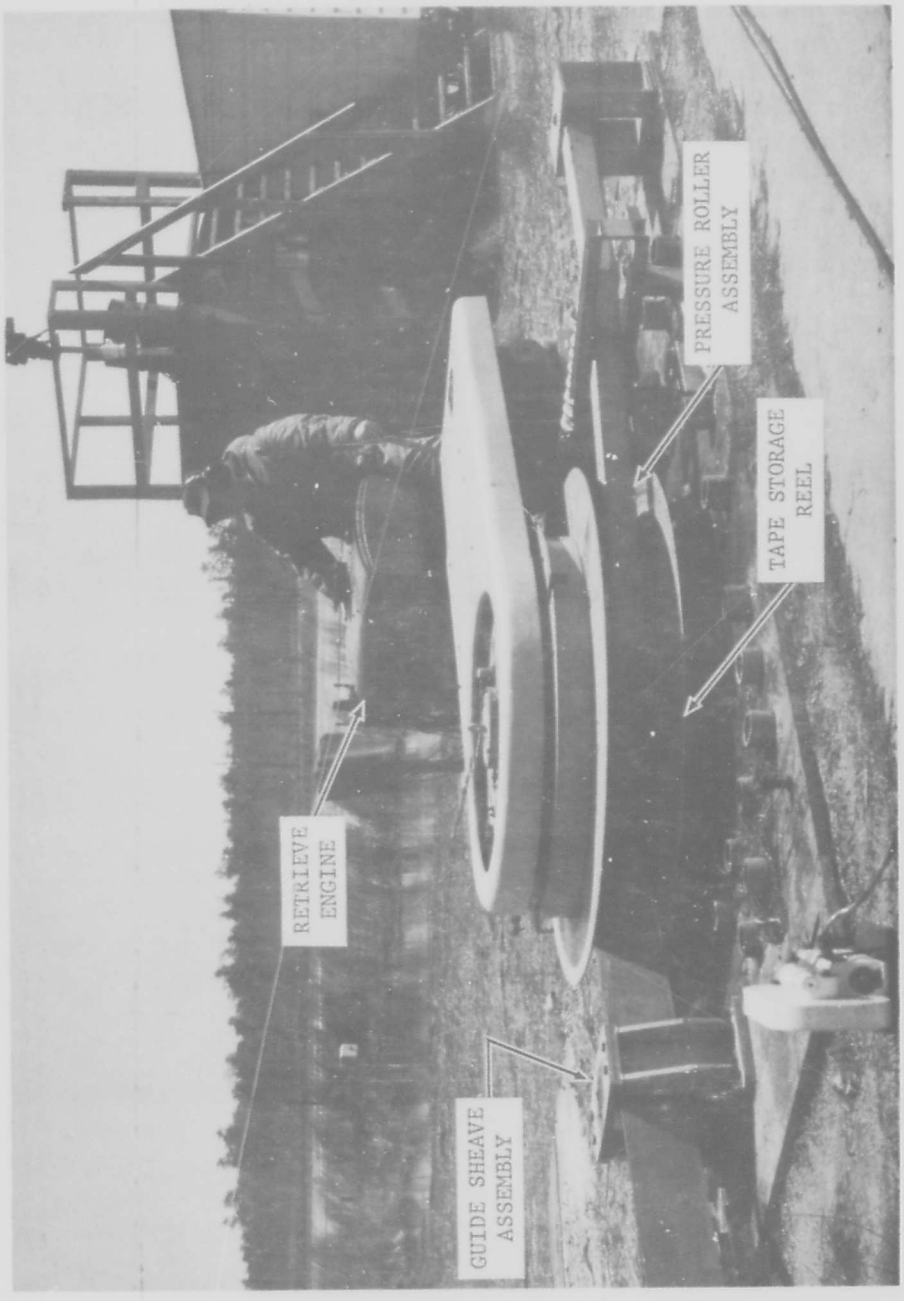


Figure 1 - Port 44B-2C Emergency Arresting-Gear Unit

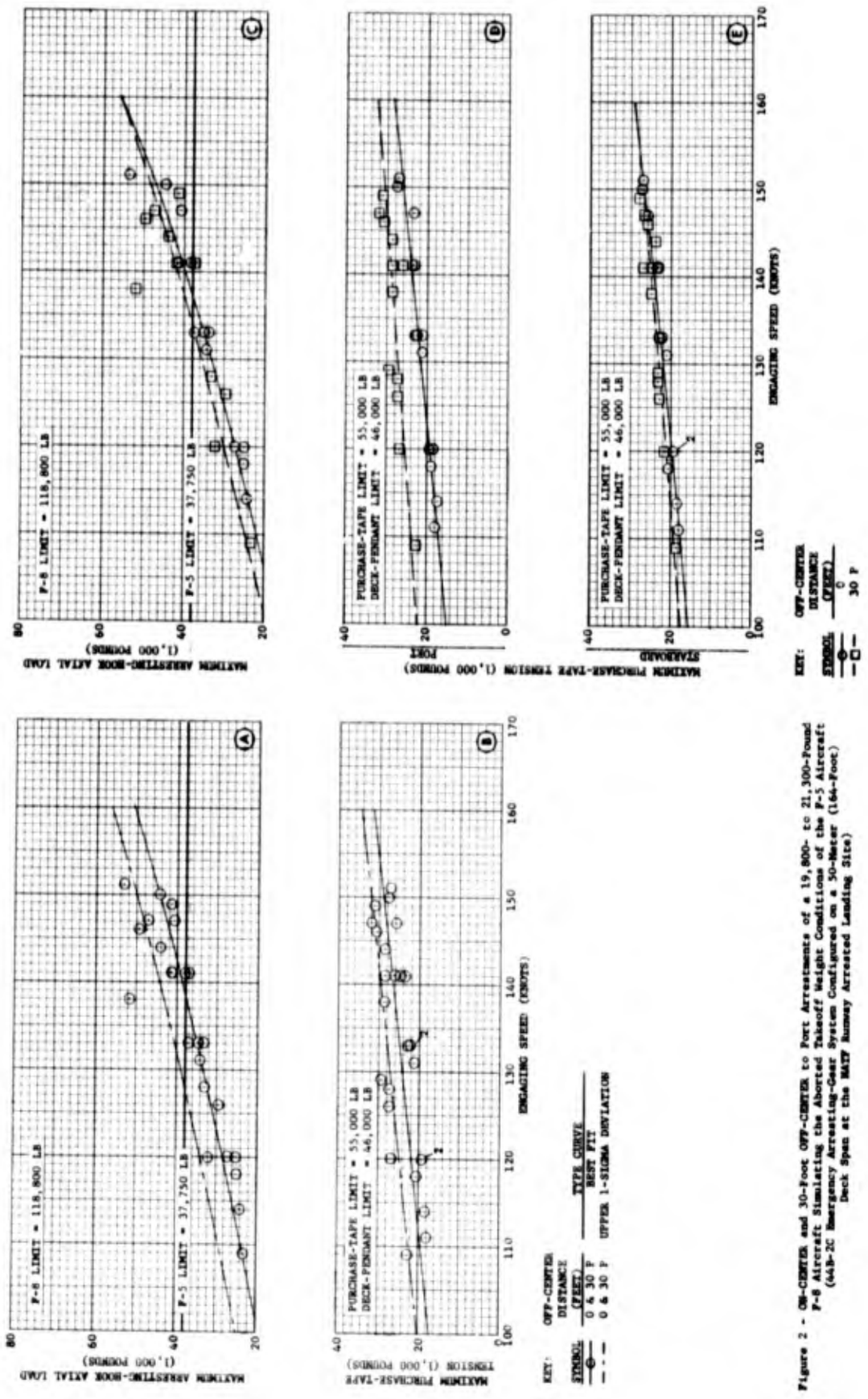


Figure 2 - ON-CENTER and 30-Foot OFF-CENTER to Port Arrestments of a 19,800- to 21,300-Pound F-8 Aircraft Simulating the Aborted Takeoff Weight Conditions of the P-5 Aircraft (44b-2C Emergency Arresting-Gear System Configured on a 30-Meter (164-Foot) Deck Span at the NATF Runway Arrested Landing Site)

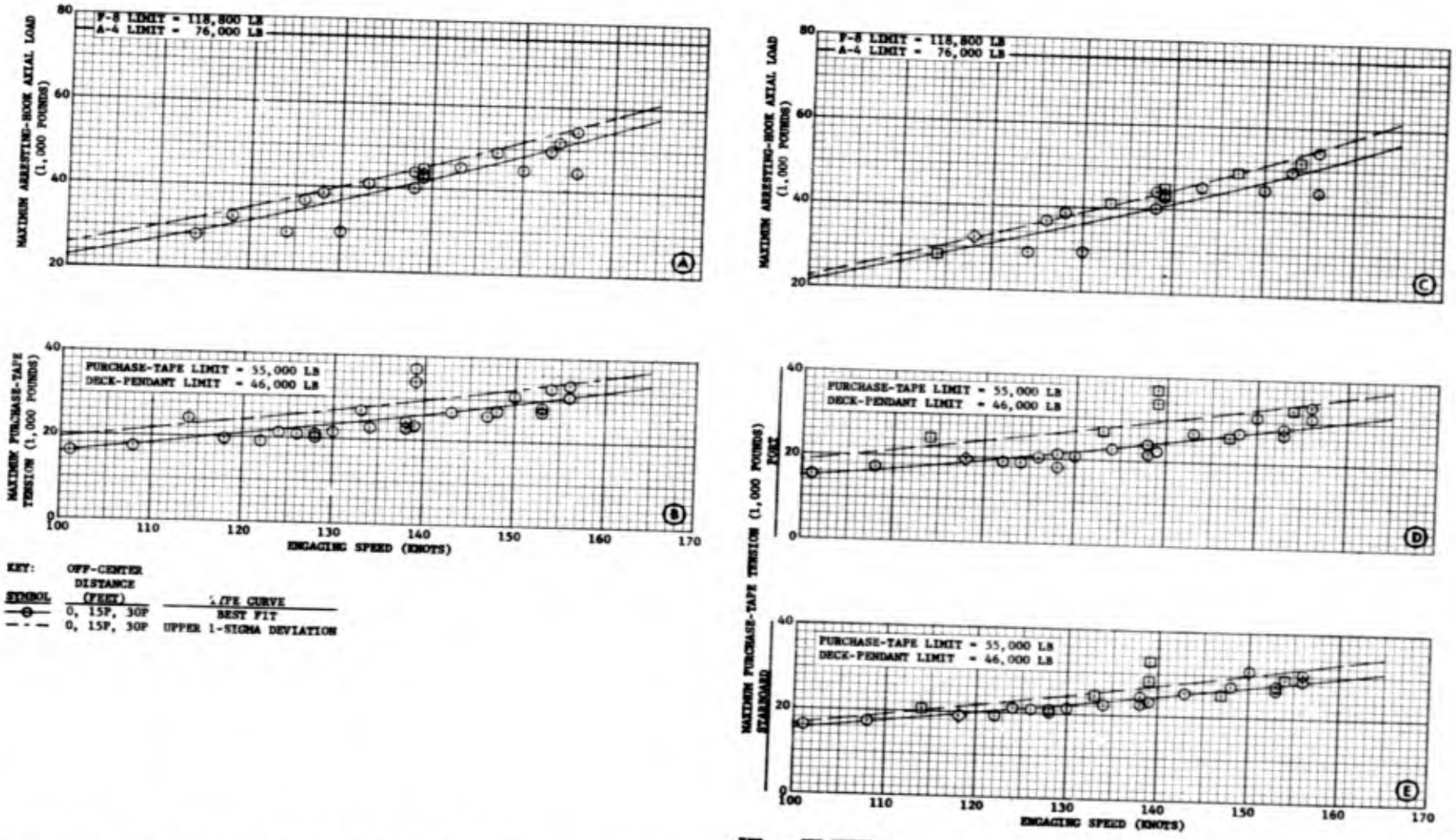


Figure 3 - ON-CENTER and OFF-CENTER Arrestments of a 22,000- to 24,500-Pound F-8 Aircraft Simulating the Aborted Takeoff Weight Conditions of the A-4 Aircraft (44B-2C Emergency Arresting-Gear System Configured on a 50-Meter (164-Foot) Deck Span at the NATF Runway Arrested Landing Site)

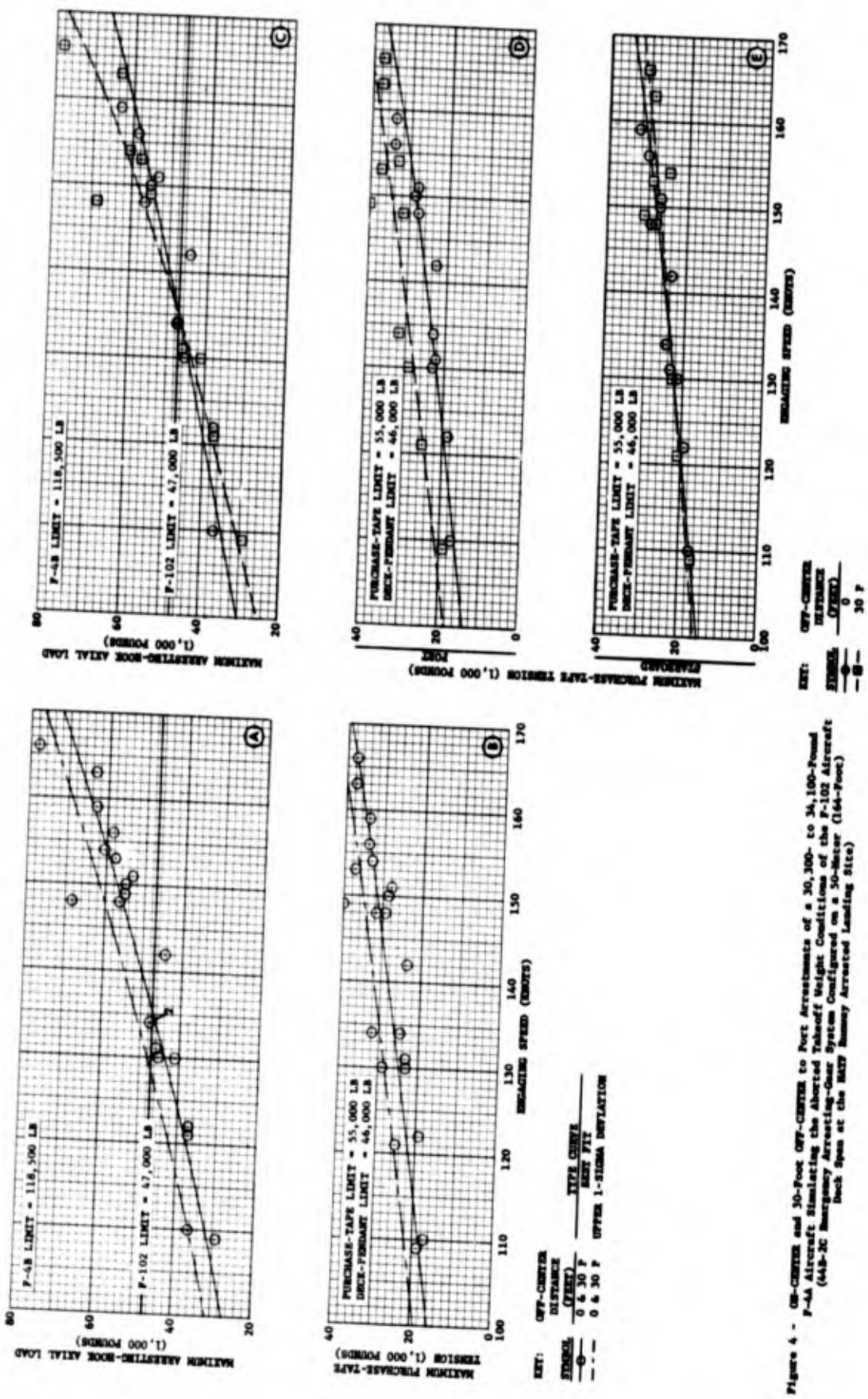
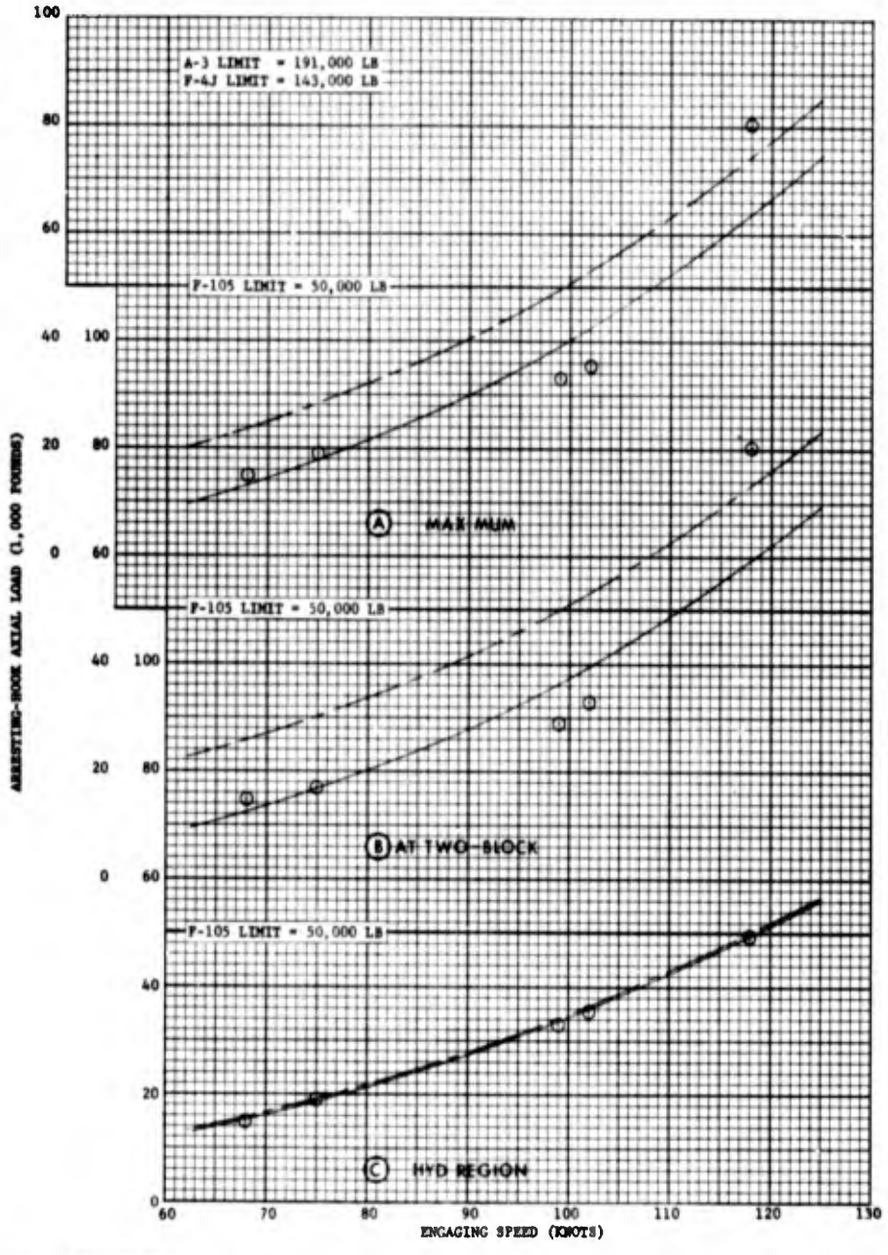


Figure 4 - ON-CENTER and 30-Foot OFF-CENTER to Port Arrestments of a 30,300- to 34,100-Pound F-4A Aircraft Simulating the Aborted Takeoff Weight Conditions of the F-102 Aircraft (448-2C Emergency Arresting-Gear System Configured on a 50-Meter (164-Foot) Deck Span at the NATF Runway Arrested Landing Site)



KEY:

SYMBOL	OFF-CENTER DISTANCE (FEET)	TYPE CURVE
—⊙—	0	BEST FIT
– · –	0	UPPER 1-SIGMA DEVIATION

NOTES:
1. NO OFF-CENTER TESTS WITH A-3 BECAUSE OF WALKBACK CONTROL DIFFICULTIES DURING ON-CENTER TESTS.
2. CURVE "B" SHOWS THAT THE F-105 AIRCRAFT ARRESTING-HOOK LOAD LIMIT OF 50,000 POUNDS WILL BE REACHED AT 99 KNOTS AT TWO-BLOCK OF THE ARRESTING ENGINES.
3. PURCHASE-TAPE TENSION WAS MEASURED DURING ONLY THE 118-KNOT EVENT (MAXIMUM TENSION, 44,000 POUNDS); THEREFORE, NO GRAPH IS PRESENTED FOR THIS PARAMETER.

Figure 5 - ON-CENTER Arrestments of a 47,500- to 48,500-Pound A-3 Aircraft Simulating the Aborted Takeoff Weight Conditions of the F-105 and F-4J Aircraft (44B-2C Emergency Arresting-Gear System Configured on a 50-Meter (164-Foot) Deck Span at the NATF Runway Arrested Landing Site)

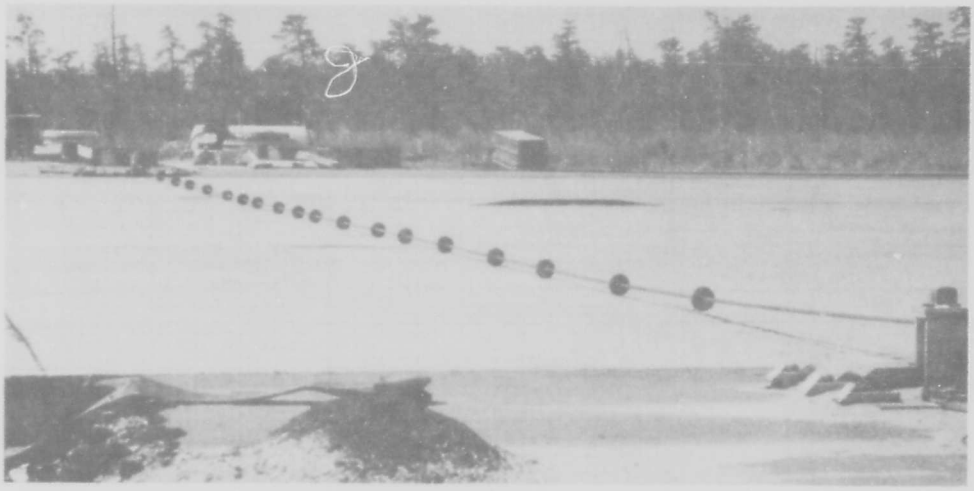


Figure 6 - Do-Nut Pendant Supports, AAE PN 44996-8, on Wire Rope Deck Pendant (44B-2C Emergency Arresting-Gear System)

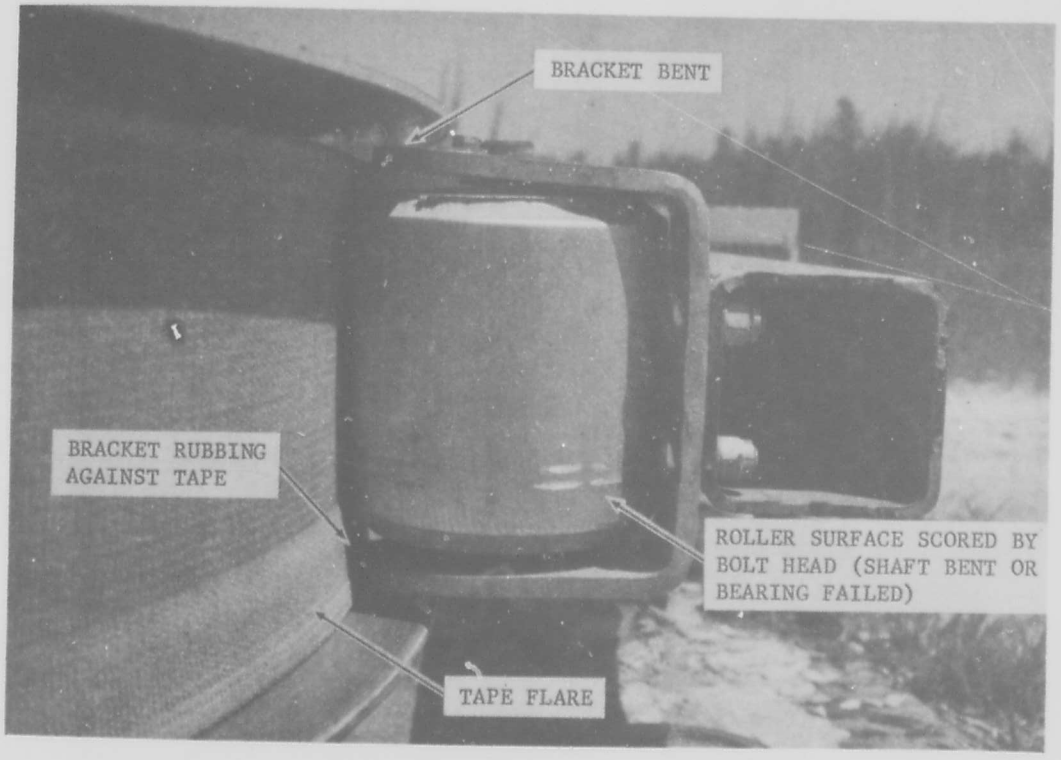


Figure 7 - Failure of the Tight-Wrap Roller
(44B-2C Emergency Arresting-Gear System)

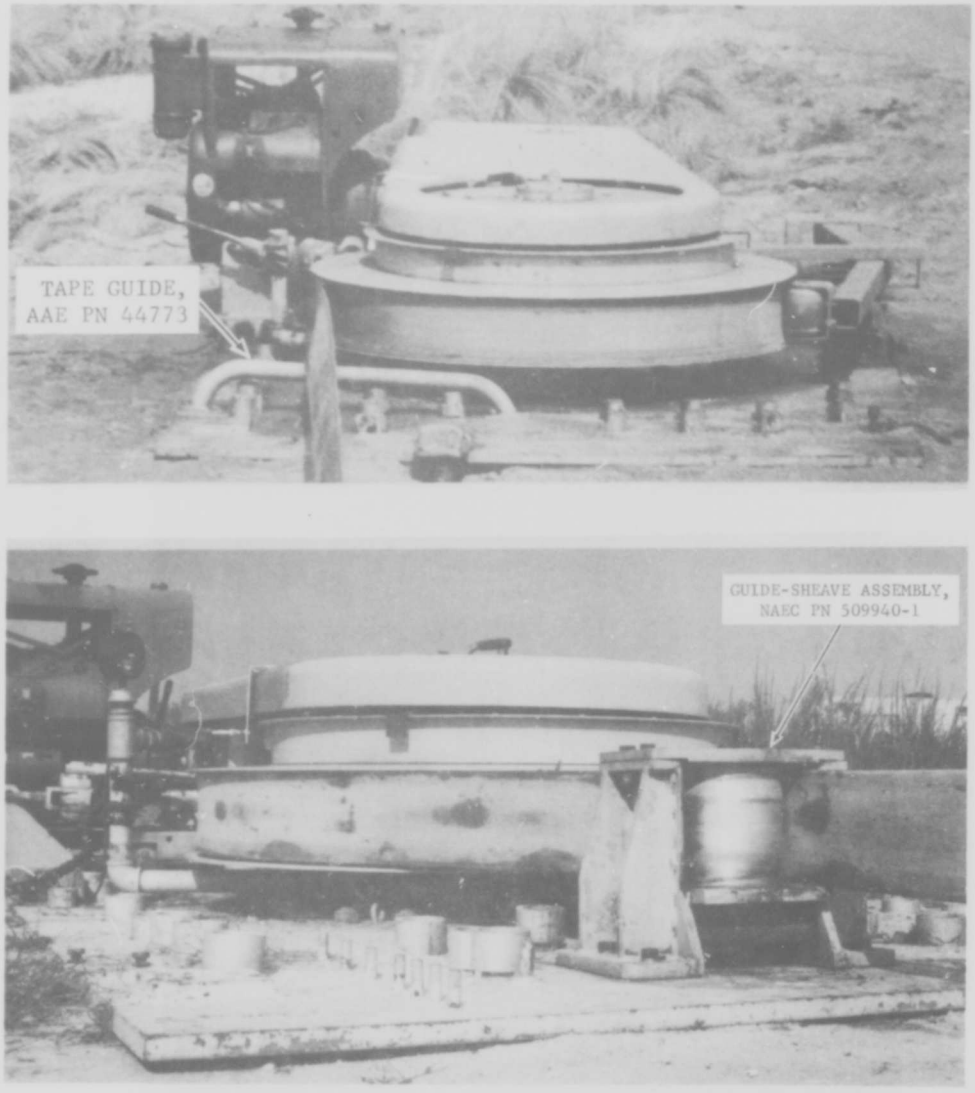


Figure 8 - Tape Guide Replaced by Guide-Sheave Assembly
(44B-2C Emergency Arresting-Gear System)

APPENDIX A - VERTICAL DATA SHEETS FOR AIRCRAFT AT ABORTED TAKEOFF CONDITIONS (44B-2C EMERGENCY ARRESTING-GEAR SYSTEM CONFIGURED ON A 50-METER (164-FOOT) DECK SPAN)

Event No. Proj	Site	1969 Date	Aircraft Model	Aircraft Weight (Lb)	OFF-CENTER Distance (Ft) Init	Final	Engaging Speed (Kn)	Maximum Arresting-Hook Axial Load (Lb)	Maximum Arresting-Hook Axial Load at Two-Block (Lb)	Purchase-Tape Tension (Lb) Port	Stbd	Long. Decel (G)	Long. Decel at Two-Block (G)	Aircraft Runout (Ft)
1	24,963	12 Mar	A-3	47,700	0	0	52	*	*	*	*	*	*	865
2	24,964	"	"	48,500	0	0	68	14,800	14,800	*	*	0.50	0.24	865
3	24,965	"	"	47,900	0	0	75	19,000	17,000	*	*	0.40	0.27	865
4	24,966	"	"	47,700	0	0	99	33,300	28,800	*	*	0.61	0.48	915
5	24,967	"	"	47,500	0	10 P	102	35,700	33,100	*	*	0.85	0.59	925
6	24,968	13 Mar	F-4A	34,100	0	0	120	*	†	*	*	*	*	875
7	24,969	"	"	33,500	0	0	124	*	†	*	*	*	*	865
8	24,970	"	"	33,200	0	0	127	*	†	*	*	*	*	865
9	25,693	21 Aug	A-3	47,800	0	0	118	49,500	80,300	‡44,000	38,900‡	1.24	1.57	965
10	26,118	29 Sep	F-8	24,200	0	0	97	*	⊕	15,200	15,400	0.84	⊕	600-700
11	26,119	"	"	24,100	0	0	101	*	⊕	15,600	16,200	0.97	⊕	600-700
12	26,120	"	"	23,800	0	0	108	*	⊕	17,600	17,600	1.04	⊕	600-700
13	26,121	"	"	23,700	0	0	122	*	⊕	19,200	19,300	1.57	⊕	600-700
14	26,122	"	"	23,400	0	0	128	*	⊕	18,100	20,200	1.51	⊕	600-700
15	26,123	"	"	23,300	0	0	134	*	⊕	22,600	22,300	1.83	⊕	600-700
16	26,124	1 Oct	"	24,500	0	0	126	36,900	⊕	20,200	20,800	1.61	⊕	765
17	26,125	"	"	24,100	0	0	138	40,100	⊕	21,700	22,400	1.72	⊕	770
18	26,126	"	"	23,800	0	0	139	42,700	⊕	22,500	23,500	1.97	⊕	810
19	26,127	"	"	23,700	0	0	143	45,500	⊕	26,800	25,700	2.06	⊕	810
20	26,130	"	"	22,900	0	*	153•	⊕	⊕	28,200	26,300	1.20	⊕	⊕
21	26,132	2 Oct	"	22,700	0	0	156	44,400	⊕	33,800	30,200	2.10	⊕	765
22	26,143	6 Oct	"	24,400	0	20 P	150	45,100	⊕	30,800	30,800	2.03	⊕	815
23	26,144	10 Oct	"	24,500	0	0	128	38,400	⊕	21,200	20,800	1.24	⊕	815
24	26,145	"	"	23,500	0	0	156	54,200	⊕	30,800	28,600	2.05	⊕	820
25	26,146	"	"	23,500	15 P	20 P	118	32,400	⊕	19,700	19,100	0.98	⊕	805
26	26,147	"	"	23,500	30 P	35 P	114	28,200	⊕	24,200	20,600	0.84	⊕	790
27	26,163	16 Oct	"	23,700	0	0	153	49,700	⊕	26,600	27,500	1.92	⊕	835
28	26,164	"	"	23,500	30 P	17 S	147	49,300	⊕	26,000	25,300	1.73	⊕	815
29	26,165	"	"	21,000	0	18 S	133	37,500	⊕	21,400	22,600	1.61	⊕	795
30	26,166	17 Oct	"	24,500	0	14 S	138	44,100	⊕	24,000	24,300	1.51	⊕	815
31	26,167	"	"	24,100	30 P	24 P	133	41,000	⊕	27,000	24,300	1.56	⊕	815
32	26,168	"	"	23,900	30 P	36 P	139	45,000	⊕	34,000	28,200	1.55	⊕	815
33	26,169	"	"	21,100	0	16 S	114	24,200	⊕	17,300	18,300	1.09	⊕	755
34	26,171	"	"	20,800	0	14 S	120	27,400	⊕	19,400	19,600	1.28	⊕	765
35	26,179	23 Oct	"	22,800	0	3 S	124	29,200	⊕	19,200	21,300	1.55	⊕	775
36	26,180	"	"	22,000	0	5 S	130	29,400	⊕	20,600	21,500	1.71	⊕	755
37	26,182	"	"	21,300	0	0	120	25,100	⊕	18,400	19,600	1.48	⊕	760
38	26,184	"	"	20,900	0	3 P	118	25,100	⊕	19,000	20,400	1.44	⊕	765
39	26,185	"	"	20,600	0	3 P	133	35,100	⊕	22,800	23,200	1.91	⊕	775
40	26,192	24 Oct	"	20,600	0	0	133	33,800	⊕	22,600	22,800	1.97	⊕	745
41	26,194	"	"	20,900	0	3 S	111	*	*	18,000	18,000	*	⊕	735
42	26,195	"	"	20,800	30 P	39 P	126	28,700	⊕	27,400	22,800	1.69	⊕	765
43	26,196	"	"	20,400	30 P	36 P	120	32,200	⊕	26,700	21,700	1.68	⊕	760
44	26,197	"	"	20,300	30 P	34 P	109	23,500	⊕	22,600	18,500	1.47	⊕	750
45	26,198	"	"	20,100	30 P	36 P	128	33,200	⊕	27,500	23,400	1.65	⊕	765
46	26,199	"	"	21,200	30 P	36 P	129	*	⊕	29,400	23,500	*	⊕	770
47	26,200	27 Oct	"	21,000	0	10 S	147	40,900	⊕	23,800	26,000	2.24	⊕	790
48	26,202	"	"	20,600	0	3 S	131	34,200	⊕	21,200	21,100	1.97	⊕	750
49	26,205	"	"	20,000	0	6 S	141	38,200	⊕	24,000	25,200	2.45	⊕	750
50	26,219	28 Oct	"	20,900	0	2 P	141	41,800	⊕	23,800	23,600	2.24	⊕	775

* NO RECORD.
† LIGHT TWO-BLOCK.
‡ AT ARRESTING-ENGINE TWO-BLOCK.
⊕ NOT APPLICABLE.
• DECK PENDANT FAILED.

Event No. Proj	Site	1969/1970 Date	Aircraft Model	Aircraft Weight (Lb)	OFF-CENTER Distance (Ft) Init	Final	Engaging Speed (Kn)	Maximum Arresting-Hook Axial Load (Lb)	Maximum Arresting-Hook Axial Load at Two-Block (Lb)	Purchase-Tape Tension (Lb) Port	Stbd	Long. Decel (G)	Long. Decel at Two-Block (G)	Aircraft Runout (Ft)
51	26,227	31 Oct	F-8	24,100	0	6 S	148	*	⊕	27,200	27,600	*	⊕	*
52	26,440	19 Mar	F-4A	32,800	0	3 S	110	36,300	†	17,300	17,400	1.03	†	865
53	26,441	"	"	32,000	0	3 S	122	37,500	⊕	18,400	19,500	1.14	⊕	835
54	26,442	"	"	31,500	0	3 S	131	46,000	†	22,200	23,500	1.44	†	865
55	26,443	"	"	31,000	0	0	134	47,700	†	23,000	24,600	1.41	†	865
56	26,445	"	"	30,300	0	0	150	55,500	†	28,400	26,900	1.71	†	865
57	26,446	20 Mar	"	33,000	0	0	148	56,300	9,600	27,900	29,500	1.51	⊕	875
58	26,723	13 Apr	"	33,000	0	0	130	45,400	†	23,000	21,500	1.56	†	865
59	26,725	"	"	32,100	0	0	151	53,300	†	28,000	26,600	1.77	†	865
60	26,726	"	"	31,700	0	0	142	44,500	†	23,200	23,700	1.48	†	865
61	26,727	16 Apr	F-8	24,100	30 P	55 P	139	43,400	⊕	37,200	32,800	1.98	⊕	815
62	26,729	"	F-4A	32,000	0	0	156	58,400	7,300	34,000	30,200	1.90	0.15	865
63	26,730	"	"	31,700	30 P	38 P	109	29,700	†	19,000	16,700	0.96	†	865
64	26,731	"	"	31,300	30 P	38 P	121	37,400	†	25,000	20,400	1.21	†	865
65	26,732	"	"	33,000	30 P	35 P	130	41,200	8,400	28,800	22,600	1.37	0.17	865
66	26,733	"	"	32,600	30 P	32 P	134	47,600	11,900	31,700	24,400	1.69	0.27	865
67	26,734	"	"	32,100	30 P	32 P	149	55,200	12,900	40,000	30,700	1.64	0.30	865
68	26,735	17 Apr	"	33,000	0	0	159	63,100	6,700	34,000	32,600	2.26	0.12	865
69	26,736	"	"	32,800	30 P	26 P	153	57,900	†	37,600	28,700	1.77	†	865
70	26,737	"	F-8	24,200	30 P	30 P	154	51,700	6,800	32,700	29,300	2.06	0.10	865
71	26,739	"	"	20,900	0	3 S	151	53,800	⊕	27,500	27,100	2.60	⊕	840
72	26,741	"	"	20,500	0	3 S	150	44,600	⊕	27,800	27,700	2.27	⊕	815
73	26,744	"	"	20,000	30 P	24 P	141	41,900	⊕	26,200	23,600	2.22	⊕	815
74	26,745	"	"	20,800	30 P	20 P	144	44,000	⊕	28,700	24,000	2.01	⊕	815
75	26,746	"	"	20,200	30 P	30 P	141	37,600	⊕	28,600	26,900	2.02	⊕	815
76	26,747	"	"	19,800	30 P	30 P	149	41,700	⊕	31,300	28,000	1.81	⊕	765
77	26,752	22 Apr	"	20,800	30 P	30 P	138■	52,000	⊕	28,500	25,100	▲	⊕	660
78	26,754	29 Apr	"	21,000	30 P	28 P	146	49,900	⊕	30,500	26,000	2.19	⊕	*
79	26,755	"	"	20,600	30 P	24 P	147	47,600	⊕	32,000	26,600	1.76	⊕	*
80	26,756	"	F-4A	33,000	30 P	36 P	148	68,400	6,300	31,800	28,000	1.64	▲	865
81	26,757	"	"	32,400	30 P	36 P	163	63,600	7,200	37,700	29,000	1.90	▲	865
82	26,758	"	"	31,800	30 P	34 P	154	60,500	4,200	33,200	24,600	1.71	▲	865
83	26,759	"	"	31,400	30 P	36 P	166	78,100	7,200	37,800	30,500	2.30	▲	865

* NO RECORD.
† LIGHT TWO-BLOCK.
⊕ NOT APPLICABLE.
▲ NOT REDUCED.
■ IN-FLIGHT ENGAGEMENT: AIRCRAFT DAMAGED.

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13. ABSTRACT

A test program was conducted to determine the performance capability of the 44B-2C emergency arresting gear configured on a 50-meter (164-foot) deck span during arrestments of the F-5, A-4, F-102, F-105, and F-4J aircraft at aborted takeoff weight conditions. The weight classes of these aircraft were simulated by use of a 21,000- and 24,500-pound F-8 aircraft, a 33,000-pound F-4A aircraft, and a 48,000-pound A-3 aircraft. Arrestments of the F-8 and F-4A were conducted ON-CENTER and 30 feet OFF-CENTER over an engaging-speed range of approximately 100 to 160 knots, and arrestments of the A-3 were conducted ON-CENTER at speeds ranging from 52 to 118 knots.

Based on the test results, the F-5, F-102, and F-105 aircraft are limited by arresting-hook load; the F-4J aircraft is limited by arresting-gear capacity; and the A-4 aircraft is not subject to a limit up to the test-program speed of 160 knots. Purchase-tape and deck-pendant tension limits were not exceeded. In general, higher aircraft arresting-hook loads and higher purchase-tape tensions in the short-side tape occurred during the OFF-CENTER arrestments. Aircraft runout characteristics were satisfactory. No arresting-hook/bumper contact damage occurred, and the aircraft structures showed no evidence of deck-pendant contacts. Arrestments of aircraft weighing more than 48,000 pounds are not recommended.

During the initial portion of the aircraft program, it was found that the arresting gear tape guide provided insufficient tape guidance for safe operation of the arresting gear and caused several failures of the tight-wrap roller bracket, bearings, and shaft. These problems were eliminated by the installation of a guide-sheave assembly.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
EMERGENCY ARRESTING GEAR						
448-2C ARRESTING GEAR						
PERFORMANCE CAPABILITY						
AIRCRAFT RECOVERY EQUIPMENT						
SHORE BASED ARRESTING GEAR						

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