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HUGHES TOOL COMPANY · AIRCRAFT DIVISION

Culver City, California

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Report No. HTC-63-56

20MM MK 4 MOD O GUN POD
FLIGHT TEST OF THREE PODS INSTALLED
ON A4 AIRPLANE

At Naval Ordnance Test Station
China Lake, California

15 April to 20 July 1963

HUGHES TOOL COMPANY -- AIRCRAFT DIVISION
Culver City, California



Figure 1. Ammunition Shown is $\frac{1}{3}$ of the 2250 Rounds Loaded into Three 20mm Mk 4 Gun Pods on the A4 Aircraft.

SUMMARY

1. The tests at NOTS--China Lake demonstrated that one, two, or three 20mm Mk 4 Gun Pods can be installed, flown, and fired from the A4 airplane without aircraft structural changes or added flight restrictions.

2. The three-pod installation increased the firepower capability of the A4 airplane to 12,600 shots-per-minute.

3. Pilots reported no adverse flight conditions during any flight maneuver and no adverse effects to control functions during either symmetrical or asymmetrical firing of a multiple pod system. Vibration and muzzle blast effects were at an acceptable level. Performance was the same as that with comparable inert stores.

4. Operational limits were pushed upward during these tests above what has previously been used for a single pod installation. Firing was accomplished under accelerations of 5.5 "G", a 50% increase. Burst length was increased to a four second maximum in flight. Firepower was increased to 12,600 shots per minute, a 300% increase. Rounds capacity was increased to 2250, a 300% increase.

5. The successful operation of the Mk 4 Pod under high altitude, low temperature and icing conditions (cold-sweat-cold) and during sustained speeds within a range of 280 - 450 KIAS was demonstrated.

6. A total of 22 productive flights were made. Ten flights were with a single pod installed on the centerline station of an A4 aircraft. Twelve flights were with a three-pod installation, one on the centerline station and two on the intermediate wing stations of the same aircraft. A total of 11,111 rounds of target practice, armor piercing-tracer and high explosive-incendiary ammunition was fired in flight. Of this total 8200 were fired from the three-pod installation.

7. Each Mk 4 Gun Pod is a complete gun system containing the 20mm Mk 11 gun and 750 rounds of ammunition. The pod fires Mk 100 Series ammunition at a rate of 4200 shots per minute. It is a supersonic shape 22-1/2 inches in diameter, 16-1/2 feet long, and weighs 1350 lbs. loaded. An internal 3000 psi pneumatic supply provides power for gun charging and ammunition boost. The pod is controlled electrically from the aircraft.

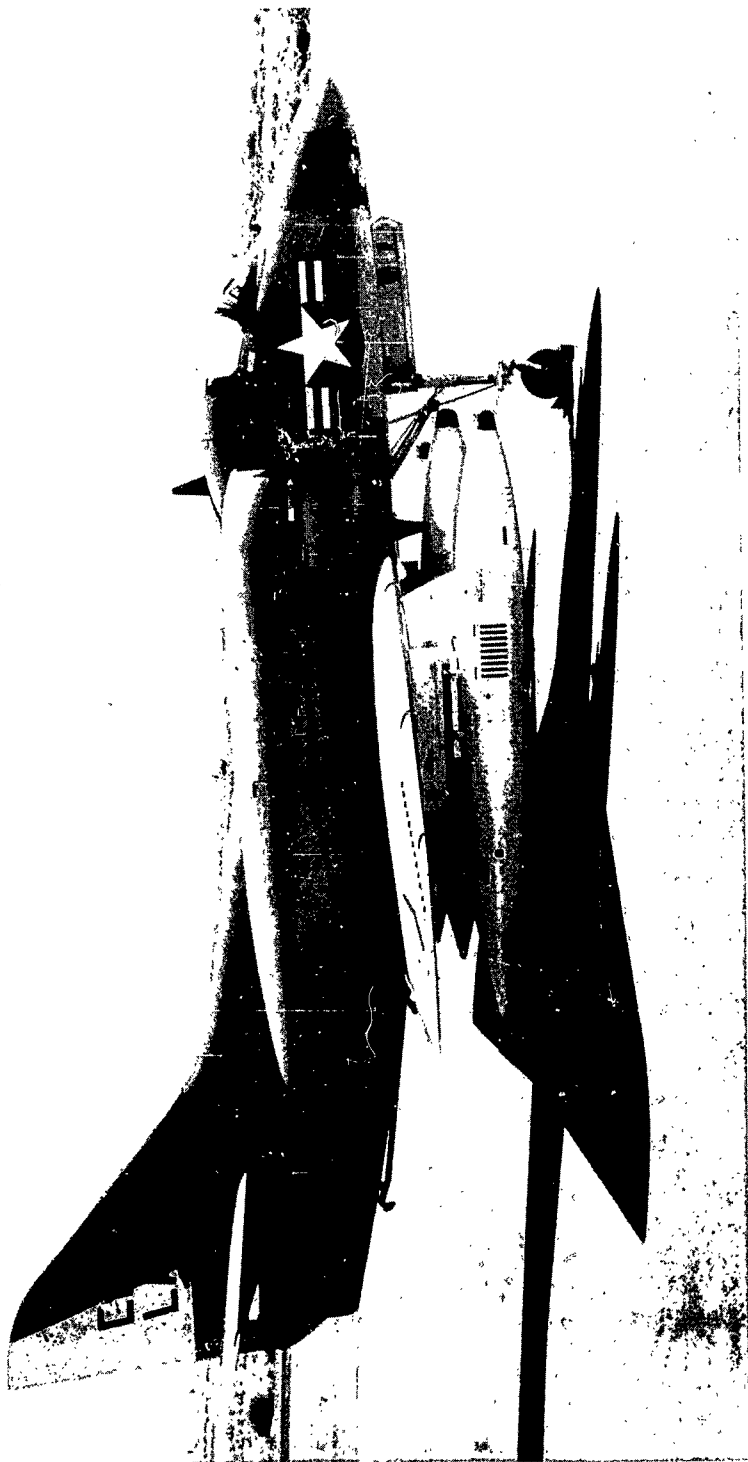


FIGURE 2. RIGHT HAND SIDE VIEW OF A4D AIRPLANE WITH THREE MK 4 GUN PODS

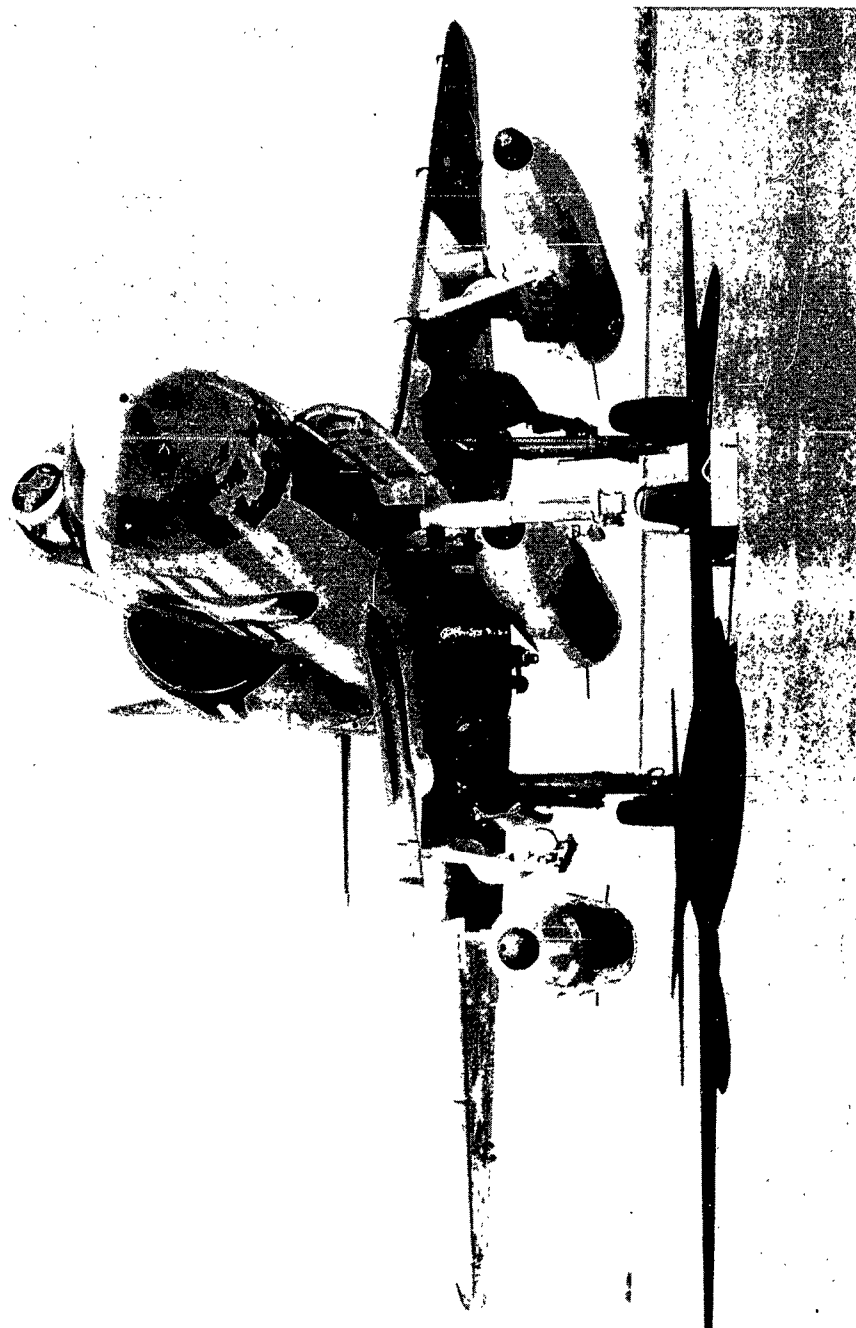


FIGURE 3. FRONT VIEW OF A4D AIRPLANE WITH THREE MK 4 GUN PODS

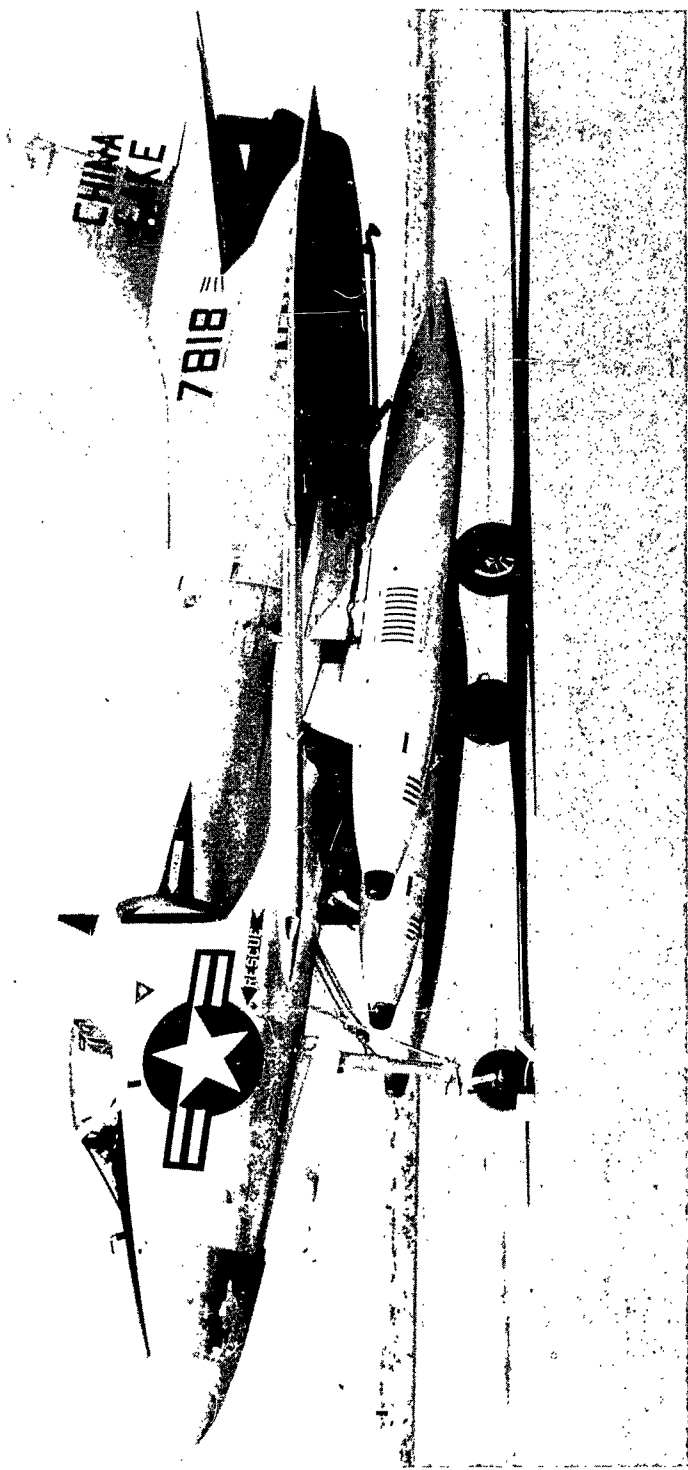


FIGURE 4. LEFT HAND SIDE VIEW OF A4D AIRPLANE WITH THREE MK 4 GUN PODS.

TEST OBJECTIVES

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TEST OBJECTIVES

GENERAL

The purpose of the test was threefold:

(1) Flight test the improvements made in the pod system since the previous flight tests.

(2) Establish the feasibility of the three-pod installation on an A4 airplane.

(3) Demonstrate the three-pod system in a weapons presentation for the President of the United States and Military and Defense officials.

DISCUSSION

The previous flight tests were made at the Naval Air Test Station, Patuxent River, Maryland, in the spring of 1961. In the two years elapsed time, a number of improvements had been incorporated into the gun and pod and tested by ground firing. Flight tests were required to complete the verification of the design changes.

A combined study by NOTS--China Lake, Douglas Aircraft Company, and Hughes Tool Company--Aircraft Division, indicated that a three-pod installation on the centerline and intermediate wing stations of an A4 aircraft was feasible without any structural changes. The flight tests were conducted as an initial checkout of the three-pod installation.

On 7 June 1963, a weapon demonstration for the President of the United States and other Government and Military officials was conducted to demonstrate new weapons under development by the Navy. The three-pod installation on an A4 airplane was entered as an event and flown by Lt. David Callahan in this demonstration. The purpose of the event was to demonstrate 12,600 shots-per-minute 20mm gun firepower from the A4 airplane as compared to the existing 4000 shots-per-minute from the F8B.

SPECIFIC

Specific purposes of the tests were as follows:

- (1) Determine the effects of muzzle blast on the aircraft structure and any other objectionable effects such as noise, vibration, or flashing.
- (2) Determine the capability of firing under high "G" loads, high altitudes, low temperatures, and icing conditions (cold-sweat-cold).
- (3) Determine qualitatively the handling and performance characteristics of the aircraft with a three-pod installation during both normal flying conditions and while firing.
- (4) Evaluate qualitatively the tactical use of the three-pod system. Determine any effects on aircraft handling such as excessive vibration, pitching or yawing while firing the three-pod installation.
- (5) Record firing results by means of chase plane and ground cameras.

TEST SETUP

TEST SETUP

The excellent cooperation provided by NOTS--China Lake, BuWeps, and Douglas Aircraft made possible a successful test program in the very short time available. Douglas provided the necessary go-ahead authority on a tight schedule. Three airplanes were wired for the pods by NOTS so that test flexibility was provided.

Three Mk 4 Mod O Gun Pods (converted from EX-1) were used in the test. Mk 6 Mod 3 ammunition links fitted with radhaz caps were also used. These links in final form were later designated as Mk 6 Mod 4. The mounting of the pods at the wing stations required adapters. These were supplied as a no-cost item by Hughes Tool Company to expedite the tests. The items used in the tests are described in the following paragraphs.

AIRCRAFT

Two of the three A4 aircraft (Tail Nos. 818 and 063) that were modified for mounting three Mk 4 Gun Pods by NOTS--China Lake, were used in the flight tests. The only modification necessary was electrical to provide control power to the pods and the switch in the cockpit. The pylons themselves were not altered except to supply an electrical pigtail to connect to the pod. Structurally there were no changes.

Instrumentation. A three-camera rack was mounted on each of the out-board wing stations. 16mm cameras running at 64 frames per second were

used. Usually the muzzle and ejection areas of the pods were photographed by the cameras. At times one camera was oriented to a forward direction showing aim line and target views. Pod or aircraft structure instrumentation was not used.

A photo-chase airplane and long range ground cameras were used on some flights. Radar and optical tracking devices were used at the target ranges.

MK 4 GUN POD

In the elapsed time between the last flight tests and these tests, a number of major design improvements were made. These included a new blast deflector, pneumatic ammunition feed system, radhaz link, valveless gun booster block, new gun round retainer, and numerous smaller changes in the gun and in the electrical system.

The Mk 4 pods which contained all these changes were being manufactured but not available in time for tests. The EX-1 pods used had been modified to include the changes. The flight tests were productive in verifying the design changes.

The pods assigned to the test were Serial Nos. 5, 6, and 7, and were the same ones used during the 300,000 round reliability test at HTC. The pod design improvements had been incorporated during the reliability test, but not all of the gun improvements had been so tested. The pods had a considerable firing history (approaching 100,000 rounds each) prior to this flight test and had reached the end of their reliable life.

Blast Deflector. Of particular concern was the checkout of new steel blast deflector. The previous blast deflector, made from aluminum, was not satisfactory from a life standpoint and did not give quite the desired protection to the fuselage structure.

The functions of the new deflector, pictured in Figure 5, are shown in the diagram, Figure 6. In addition to serving as a blast protector, the deflector has three additional features - (1) a muzzle brake to lessen the recoil forces of pod to the aircraft (2) upward reaction to lessen the tuck tendencies and (3) a barrel guide to control dispersion.

The results from these 22 flights indicate that the blast protection provided is excellent. No damage to the fuselage structure could be found.



Figure 5. Close-up of Blast Deflector Nose on Mk 4 Gun Pod.

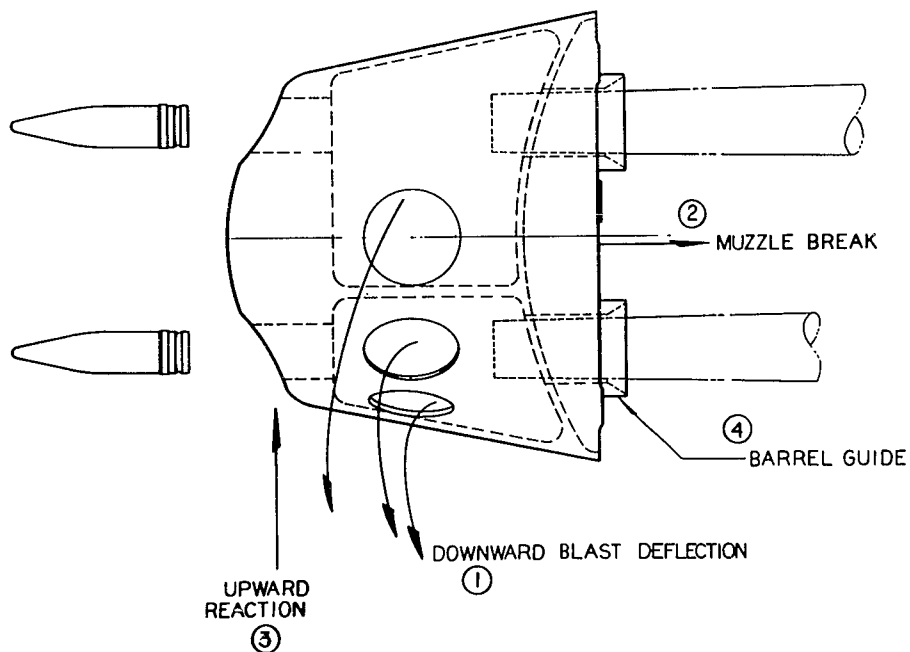


Figure 6. Functions of the Blast Deflector

There was speculation that the exhaust ports in the blast deflector might produce a siren effect in the airstream. The purging air used at the Hughes firing tunnel during ground firing did produce a whistle as it passed over the nose. No such effect was observed during the air tests.

Ammunition Feed System. The new ammunition feed system is shown schematically in Figure 7. A pneumatic drive replaces the previous pulsating electric drive. This change eliminated the a-c power requirement from the aircraft and permitted the feed chuting in the pod to be made rigid instead of flexible. A peripheral magazine drive was incorporated to eliminate backlash problems inherent to the former central drive shaft drive. The pneumatic boost system performed successfully at 5-1/2 "G" at China Lake and at 6 "G" in later tests at Eglin AFB.

RADHAZ LINKS

A new ammunition link incorporating a cap which covers the primer of the round was developed to increase the safety of handling linked ammunition in high level electromagnetic radiation areas such as exist on carrier decks. This link is shown in Figure 8. The radhaz link was introduced after the start of testing.

Concurrently, a simplified booster block had been incorporated into the gun, primarily to eliminate troublesome gas valves but incidentally to improve case ejection by increased case ejection velocity. The higher ejection velocities made it mandatory that the stronger link with the radhaz cap be used. An

older lot of links was reworked to include the radhaz cap. These less-than-optimum links were directly responsible or contributing factors in a third of the malfunctions in these tests. In the later tests at Eglin Field, where production run links were used, only one stoppage was attributed to links. The old hardware in use (approximately 100,000 rounds on each pod) and the experimental nature of some components used in the NOTS test also contributed to stoppages.

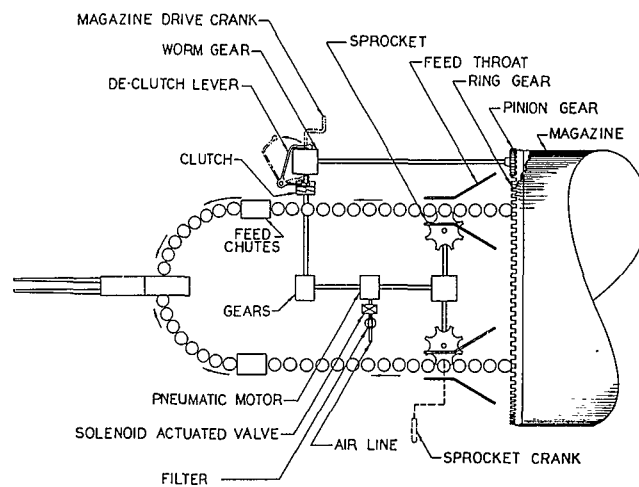


Figure 7. Ammunition Feed System Schematic Diagram

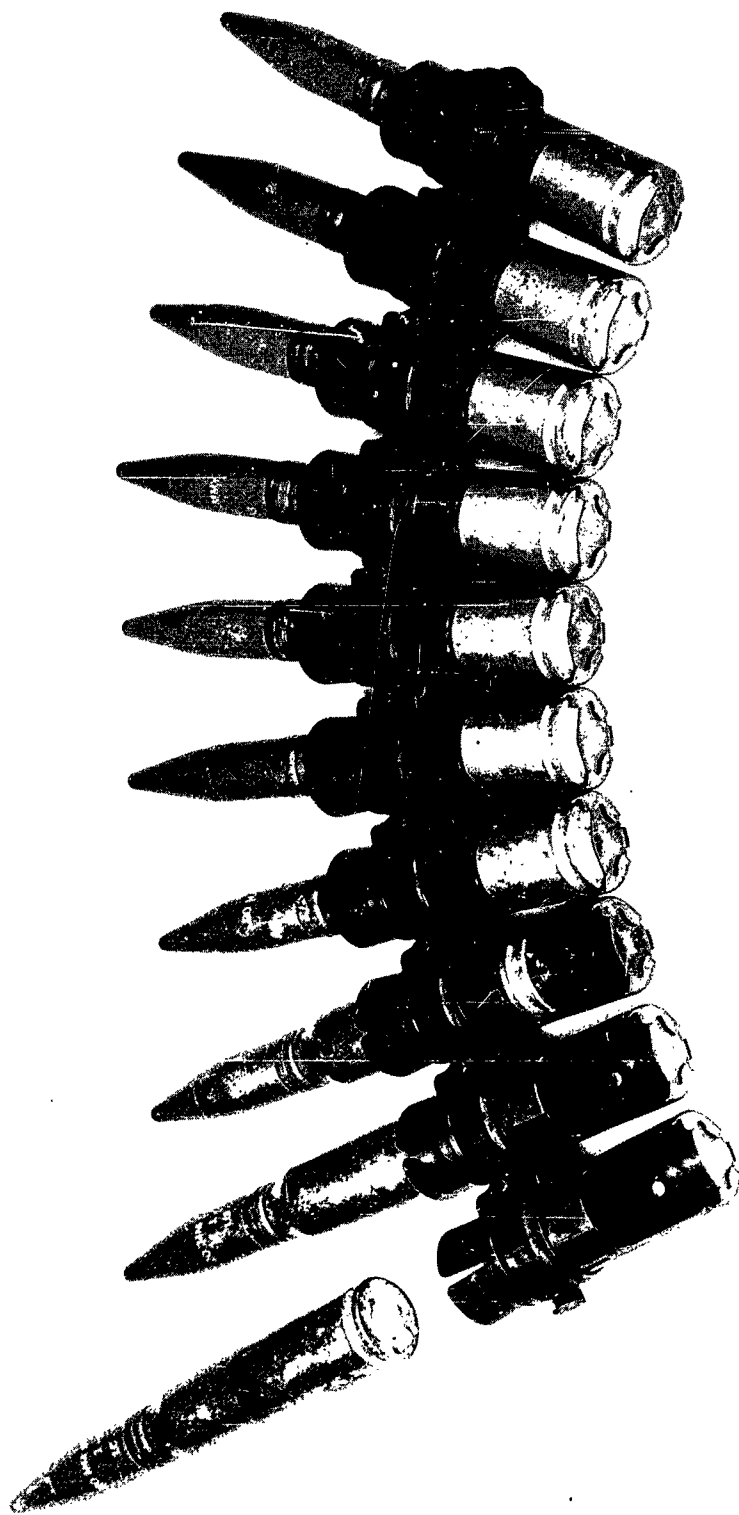


Figure 8 Radhaz Link

WING POD ADAPTERS

Two adapters were made to match the 30" lugs on the pod to the 14" hooks on the Aero 20A racks at the wing stations of the A4 airplane. The modified EX-1 gun pods, used in the test, were designed to mount on the Aero 7A rack on the centerline station with 30" lug spacing. The electrical connection on the Aero 20A racks has to attach at the rear of the rack, whereas the connection on the EX-1 pods is located forward of the lugs. The adapters incorporate an electrical cable to transfer the electrical connection from the forward position on the pods to the rearward connection on the Aero 20A racks. Figure 9 is a view of the adapter.

GROUND HANDLING EQUIPMENT

Other than the expected increase in handling of three pods as compared with one, no problems were encountered in ground handling. Mk 7 bomb dollies were used for mounting the pods on the wing stations in the same manner as on the centerline station. (See Figure 10) The Mk 7 dollies can be towed in tandem with one vehicle. (See Figure 11)

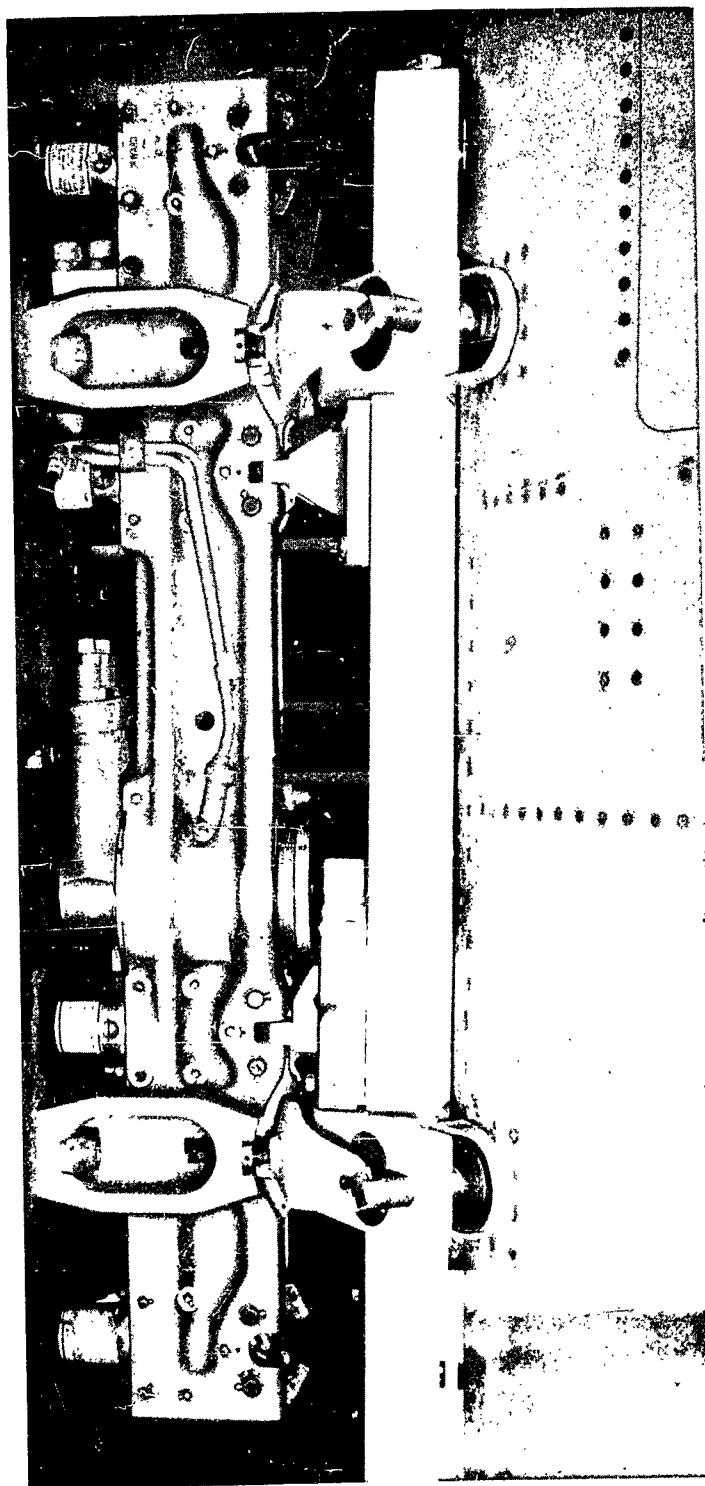


FIGURE 9. EXTERNAL TEST ADAPTOR FOR A4 WING STATION

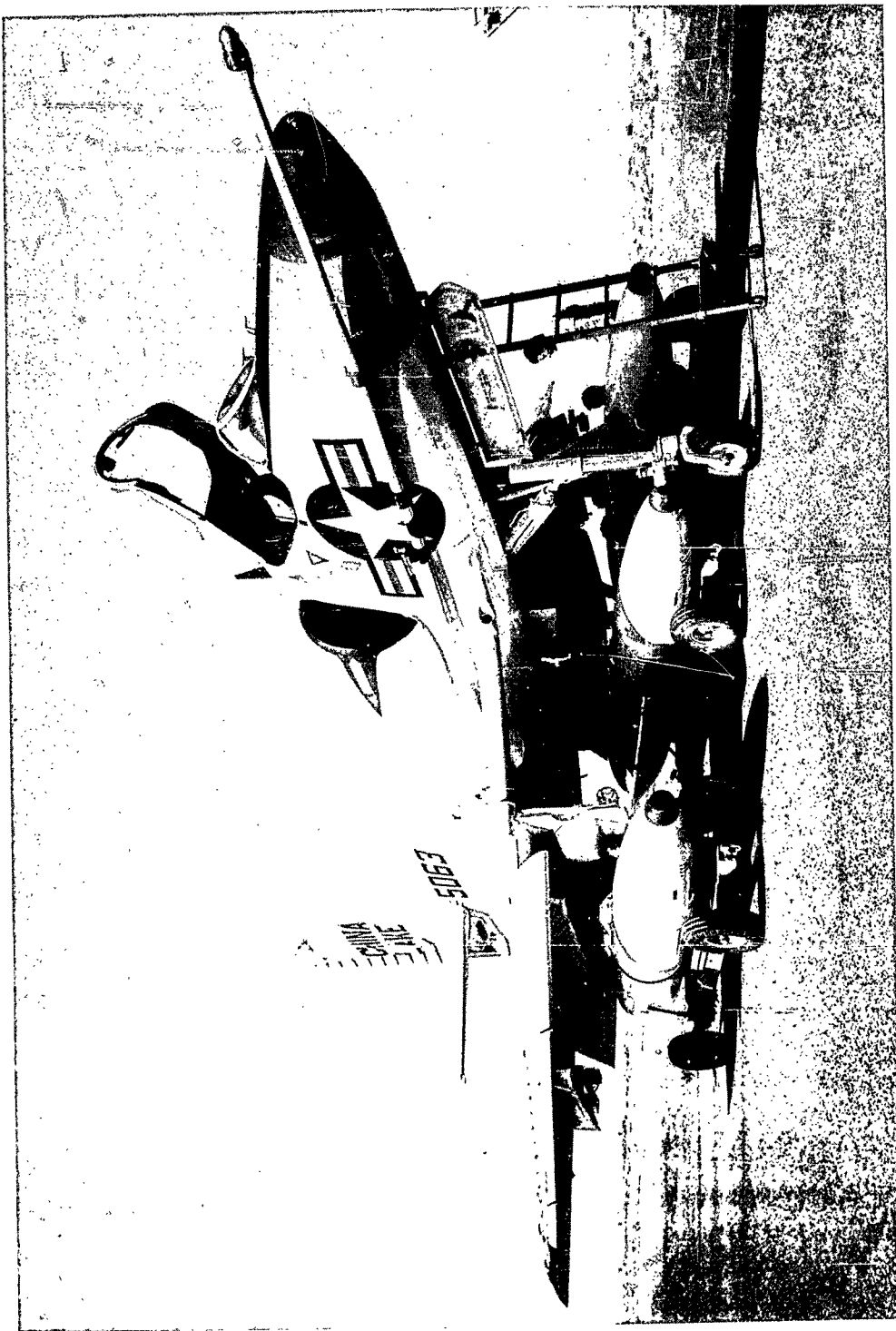


FIGURE 10. MOUNTING MK 4 GUN PODS FROM MK 7 BOMB DOLLIES TO A4 AIRPLANE

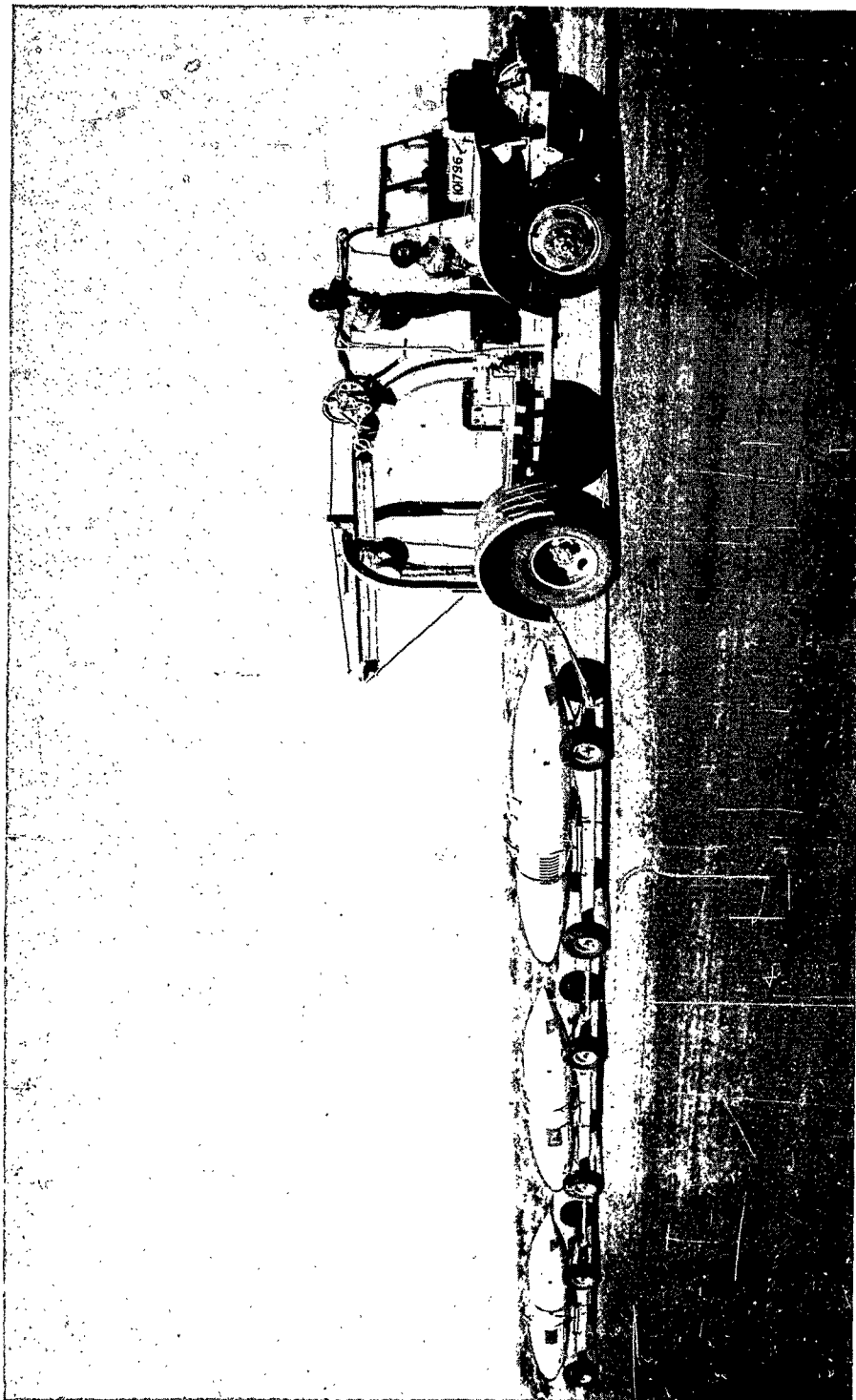


FIGURE 11. DEPLOYING THREE MK 4 GUN PODS ON MK 7 BOMB DOLLIES FROM ARMAMENT BAY TO AIRPLANE HOT LINE.

RESULTS OF TESTS

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FIGURE 12. LT. CALLAHAN PREPARING TO FLY AND FIRE THE A4 AIRPLANE WITH THREE MK 4 GUN PODS

RESULTS OF TESTS

RESUME' OF FLIGHTS

A total of 26 flights were made during these tests. Eleven thousand one hundred and eleven (11,111) rounds were fired during 22 productive flights. Two flights were made for "fly through" practice, in which no firing was contemplated, in preparation for the demonstrations. Two flights were cut short without firing because of electrical trouble in the aircraft.

Ten flights were completed and 2911 rounds fired with a single pod on the centerline station of the A4A and A4C aircraft. Twelve flights were completed and 8200 rounds fired with three pods on the same aircraft.

Eleven flights were fired air-to-air and eleven air-to-ground. In six of the air-to-ground flights horizontal targets were used. In three flights for the firepower demonstrations the target was a group of vehicles. In two flights for tactical demonstration a medium tank was used as a target.

A detailed listing of flights in chronological sequence is given in Table I.

TABLE I - RESUME OF FLIGHTS

Flight No.	Date	A/C No.	Pilot	Pod, Gun, Loader No.	Rounds		Test Purpose	Results
					Fired	Type		
1	16APR63	818	J	6,909,10	110	TP	A/C Checkout -	3 Bursts - Belt Separation
2	17APR63	818	J	6,909,10	196	TP	Pilot Familiarization	3 Bursts - Belt Separation
3	29APR63	818	S	6,911,7	186	TP	Pilot Familiarization	3 Bursts - Belt Separation
4	1MAY63	818	C	7,913,5	135	TP	Pilot Familiarization	1 Burst - Ejection Jam Case Went Thru Link
5	2MAY63	818	S	7,913,5	386	TP	Nose Cone Checkout	100% Fireout - 4 Bursts
6	2MAY63	818	R	7,913,5	252	TP	High Altitude - Low Temp. 40,000 - 60°F	3 Bursts - Belt Separation
7	3MAY63	818	S	7,913,5	386	TP	"G" Loading	100% Fireout - 4 Bursts 1) 2"G" 2) 4"G" 3) 5-1/2"G" 4) 5-1/2"G" Lost Door On Tail Cone. Both Magazine Doors Opened
8	8MAY63	818	R	7,913,5	386	TP	Cold - Sweat - Cold	100% Fireout - 4 Bursts
9	9MAY63	818	C	7,913,5	750	TP	A/C Shake Down in Maneuvers	100% Fireout - 15 Bursts
10	10MAY63	063	C	6,911,7	26	TP	First 3-Pod Fly & Fire	100% Fireout - 1 Burst
				7,913,5	190	TP	Captive Structural Test	3 Bursts - Ejection Jam
				5,912,8	26	TP	Firing 5 "G" Turn	100% Fireout - 1 Burst
11	13MAY63	063	C	6,911,7	90	TP	3-Pod Firing At Ground	2 Bursts - Ram
				7,913,5	386	TP	Targets	100% Fireout - 7 Bursts
				5,912,8	240	TP		4 Bursts - Broken Ram Finger
11A	14MAY63	063	C	6,911,7	0	2TP	Practice Flight In	
				7,913,5	0	1APT	Formation For	No Firing Attempted
				5,912,8	0	ETC	Demonstration	
11B	15MAY63	063	C	6,911,7	0	2TP	Practice Flight In	
				7,913,5	0	1APT	Formation For	No Firing Attempted
				5,912,8	0	ETC	Demonstration	
12	15MAY63	063	C	6,911,7	122	2TP	Target Firing - 15°-20° Dive	2 Bursts - Ejection Jam
				7,913,5	386	1APT	350 - 400 Kias.	100% Fireout - 6 Bursts
				5,912,8	186	ETC		3 Bursts - Electrical
13	16MAY63	063	C	6,911,7	386	2TP	Target Firing	100% Fireout - 6 Bursts
				7,913,5	386	1APT		100% Fireout - 6 Bursts
				5,912,8	386	ETC		100% Fireout - 6 Bursts
14	22MAY63	818	C	7,913,5	125	HE, TP	Demonstration	1 Burst - Broken Gas Eject Tube
15	27MAY63	818	C	6,911,7	386	2TP	Target Firing	100% Fireout - 7 Bursts
				7,913,5	386	1APT		100% Fireout - 7 Bursts
				5,912,8	125	ETC		3 Bursts - Ram
16	29MAY63	818	C	6,911,7	125	3HE	Demonstration	1 Burst - Belt Separation
				7,913,5	240	1APT		1 Burst - Ejection Jam
				5,912,8	240	ETC		100% Fireout
17	4JUNE63	818	C	6,911,7	0	2TP	Target Firing	No Firing - Airplane
				7,913,5	0	1APT		Electrical
				5,912,8	0	ETC		
18	4JUNE63	818	C	6,911,7	0	2TP	Target Firing	No Firing - Airplane
				7,913,5	0	1APT		Electrical
				5,912,8	0	ETC		
19	5JUNE63	818	C	6,911,7	386	2TP	Target Firing - But	100% Fireout - 25 Bursts
				7,913,5	0	1APT	Used For Checkout	0 Bursts - Electrical
				5,912,8	302	ETC	Only - 40 K Winds	20 Bursts - Ram
20	7JUNE63	818	C	6,911,7	226	3HE	Demonstration For	1 Burst Loader "S" Tube
				7,913,5	261	1APT	President & Other	100% Fireout - Nearly 4 Seconds
				5,912,8	139	ETC	Officials	1 Burst Seq. Switch
21	25JUNE63	063	C	6,911,7	386	2TP	Firing At Ground	100% Fireout - 9 Bursts
				7,913,4	386	1APT	Targets	100% Fireout - 9 Bursts
				5,912,8	3	ETC		1 Burst - Ram
22	27JUNE63	063	C	6,911,7	728	5HE	Firing At Hard	Ram
				7,913,4	300	1APT	Target (Tank)	Buffer Piston
				5,912,8	391	ETC		Belt Separation
23	28JUNE63	063	C	6,911,7	1	HE	Firing At Hard	No Resear on Charge
				7,913,4	380	HE	Target (Tank)	100% Fireout
				5,912,8	20	HE		1 Burst - Ejection Jam
24	19JULY63	063	S	6,912,8	346	APT	Pilot Familiarization	Ram
				7,913,7	360	APT		Eject. Jam
				5,911,4	20	APT		Ejection Jam.
TOTAL 11,111								
* S - CMDR. Sickel								
J - LCMR. Jones								
R - LCMR. Rochester								
C - LT. Callahan								

Table I - Resume of Flights

AIR-TO-AIR FIRING

Air-to-air firing was used for:

- (a) Pilot familiarization.
- (b) Checking out airplane performance and handling characteristics.
- (c) Checking capabilities of the pod under environmental conditions.

Pilot Comments. The single-pod installation was flown by four different pilots, LCDR Jones, LCDR Rochester, Lt. Callahan and CDR Sickel. The three-pod installation was flown by Lt. Callahan and CDR Sickel. The majority of the flights were flown by Lt. Callahan.

These pilots concurred in reporting the following:

Normal flight conditions were encountered during all maneuvers attempted. No adverse control functions were experienced during either symmetrical or asymmetrical firing. A noticeable yaw did occur during the firing of a single wing pod. It was not determined whether the resulting yaw could be compensated for during accuracy firing. Vibrations were at acceptable levels and independent of the number of guns firing. It was not possible to tell by vibration alone whether one, two or three guns were firing. Muzzle blast of wing pods was not noticeable. Handling of aircraft with pods is the same as with inert stores of similar weight and configuration. A degradation in aircraft speed of 5 to 10 knots per pod occurred.

Environmental Tests. During the air-to-air phase of the tests, the Mk 4 pod--A4 Aircraft System was subjected to the environmental conditions listed below. Stoppages that occurred were not attributed to the environmental condition.

(a) Non-firing runs.

- (1) Attained speed of .92 IMN from 20,000' to 10,000' MSL.
- (2) Maximum rudder deflection in both directions at 350 KIAS at 10,000' MSL.
- (3) Entered moderate buffet during rapid "G" application.
- (4) Applied partial and full aileron deflection at high and low airspeeds and accelerations.
- (5) Subjected to zero "G" acceleration at 300 KIAS at 10,000' MSL.

(b) Firing runs.

- (1) Fired three 1-1/4 second bursts (90 rounds) at 40,000' MSL after soaking for 35 minutes at same altitude. Estimated air temperature was -60°F. Lubriplate #215 grease was in gun at the time.
- (2) Fired five 1-1/4 second bursts (90 rounds) after cold soaking for 30 minutes at 30,000' MSL, descending to surface at Pt. Mugu for sweating, and again climbing to 30,000' MSL and soaking for 35 minutes before firing.

Estimated air temperature was -40°F. A special low temperature lubrication, N3432, developed at the Naval Research Laboratory, was used in the gun. This lubricant appears to have good lubricating qualities at low temperature, but has a shorter life (perhaps 1000 rounds) than Lubriplate (over 3000 rounds). A slight leak (150 PSI drop per hour) developed in an aluminum pneumatic fitting in one pod. The fitting was later changed to steel.

- (3) Fired two 1-1/4 second bursts under an acceleration of 5.5 "G" obtained by pulling out of a dive. Fired one burst in a 5 "G" acceleration turn. The magazine inspection doors opened, and the pneumatic reservoir service door in the tail cone opened and ripped off in the airstream during the 5.5 "G" acceleration. It may have been a combination of high speed, vibration, and "G" loads that caused the doors to open. A similar tail cone door opened when firing in level flight at 580 KIAS during later tests at Eglin Field AFB on the F100 aircraft. These doors have since been improved by stiffening the door and using a double-action latch.
- (4) Firing at sustained speeds of a minimum of 280 KIAS and a maximum of 450 KIAS at 6000' to 3000' MSL.

AIR-TO-GROUND FIRING

Information on air-to-ground accuracy of the three-pod system was limited to a qualitative evaluation due to the short time available and the limited bore-sight adjustment in the interim wing rack adapters. Small ground targets (4' pylons and vehicles) were shot at in typical attacks and were hit. Most attacks were made at 350 to 400 knots at 10° to 15° dive angle with firing initiated at 3000' range.

Two firing runs with three pods were made against a light tank for photographic coverage of a tactical application. (See photographs, Figures 13, 14 and 15)

Both of the three-pod firing passes in the NOTS weapon demonstrations produced hits as evidenced by fires resulting in the target vehicles. The long bursts (three to four seconds) used in the demonstration were effective in emphasizing the firepower of the three Mk 4 Pods on an A4 aircraft. These long bursts, however, are unrealistic for the efficient use of the system in combat work since the commence-firing range has to be extended to approximately 4500' where effectivity is questionable.

In the later Air Force evaluation tests of two Mk 4 pods on the F100 airplane at Eglin Field, the accuracy of wing mounted gun pods was demonstrated in rigorously controlled air-to-ground firing against vertical 30' x 30' targets. The pilots quickly learned to compensate for tuck by applying force to the stick at the same time the trigger was depressed.

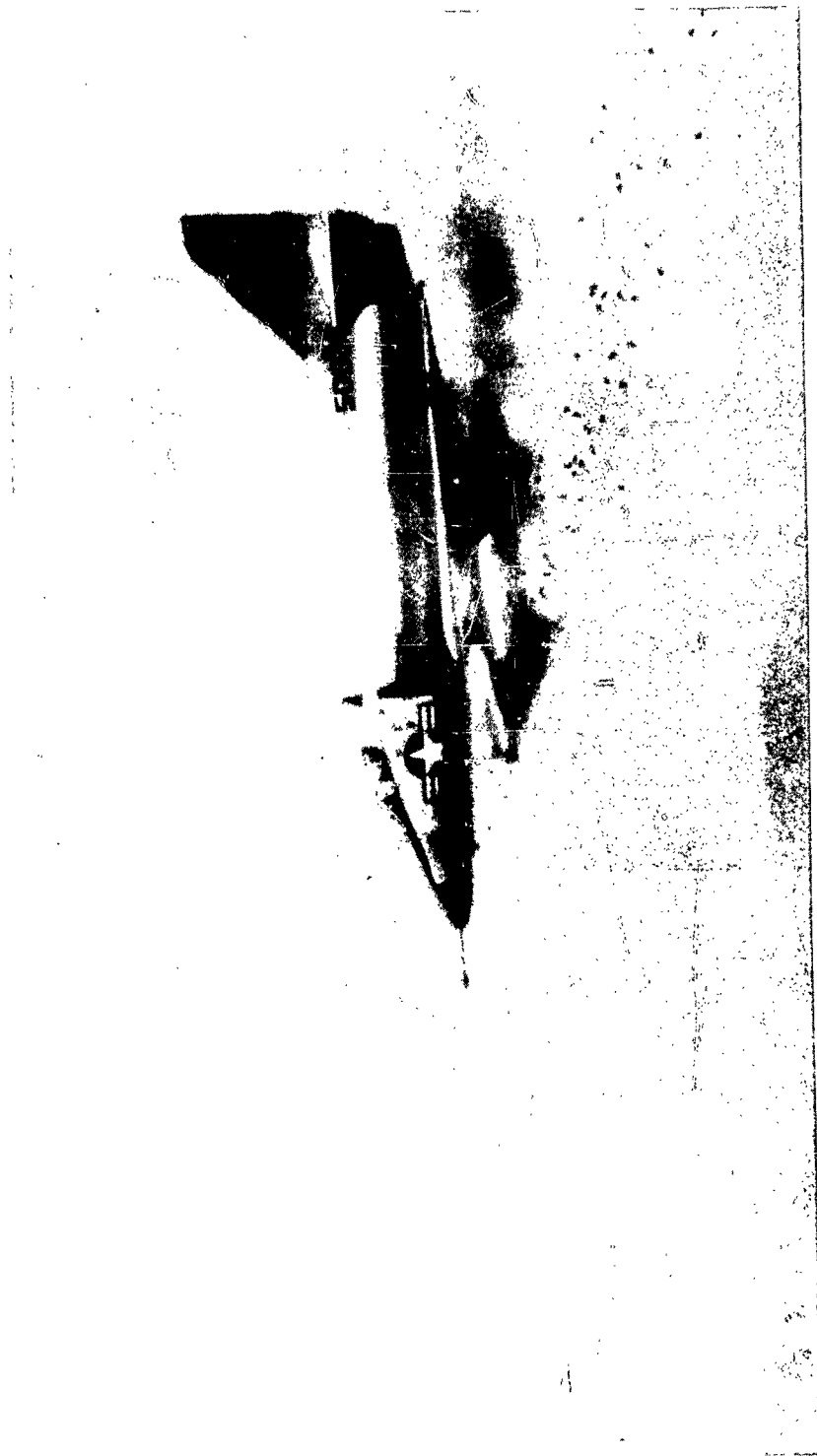


Figure 13. A4 Aircraft Firing 12, 600 Shots Per Minute of 20mm Ammunition from Three Mk 4 Gun Pods.



Figure 14 Attack on a Tank with 12,600 Shots Per Minute of 20mm.



Figure 15 Aftermath of 12, 600 Shots Per Minute 20mm Attack.

Yawing did not occur with the Mk 4 Gun Pods since reaction force from each pod was equal and constant throughout the burst. Yaw occurred when one wing pod was fired alone. It was not completely correctable with rudder in steady state. However respectable hit ratios were obtained when the pilot anticipated firing a single pod.

The F100 tests proved that the accuracy of wing mounted Mk 4 Gun Pods is as good as fuselage installed guns. Prior to this test, there was concern that the wing mount would sacrifice accuracy due to wing deflection, aircraft yaw and pitch (tuck) from gun firing, and parallax. The wing pod accuracy was demonstrated by LCDR Duane Varner and Air Force Capt. Reddoch.

The tests with three Mk 4 Gun Pods on the A4 airplane were an unqualified success. The way is now clear for multiple gun pod installations. The resulting increase in aircraft firepower by three fold and more is the Navy's bonus for developing the 4200 shot-per-minute Mk 11 gun and its Mk 4 pod. The greater firepower expands the capability of the 20mm gun by adding the armored vehicle (in particular, the tank) to its list of targets. The anti-armor capability combined with the recognized softer target versatility, low cost and ease of use projects the 20mm gun into the forefront of proven air-to-ground weapons.