Report 1783

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SHOCK TESTING OF FT4A GAS TURBINE ENGINE GAS GENERATOR ON THE FLOATING SHOCK PLATFORM - PHASE I

by

R. E. Oliver

Prepared for the Bureau of Ships

Distributed only upon their authorization

STRUCTURAL MECHANICS LABORATORY
UNDERWATER EXPLOSIONS RESEARCH DIVISION
PORTSMOUTH, VIRGINIA

RESEARCH AND DEVELOPMENT REPORT

August 1963 15 Report 1783

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Report 1783
SS051 000
Task 3884

CONTENTS

ABSTRACT iv
INTRODUCTION 1
ASSIGNMENT 1
OBJECTIVE 1
PROCEDURE 1
INSTALLATION OF EQUIPMENT 1
INSTRUMENTATION 4
TESTING 5
TEST RESULTS 6
INSTRUMENTATION TEST DATA 6
DAMAGE SURVEY 7
Test 1 (60-ft standoff) 7
Test 2 (40-ft standoff) 8
Test 3 (30-ft standoff) 9
Test 4 (25-ft standoff) 11
Test 5 (20-ft standoff) 14
SUMMARY AND CONCLUSIONS 17
REFERENCES 18
INITIAL DISTRIBUTION 19

TABLES

1. Gauge Locations 4
2. Test Geometries 5
3. Instrumentation Data 6
4. Rotor and Breather Line Data 8

FIGURES

1. Engine Installation - Front View 2
2. Engine Installation - Side View 3
3. Engine Installation - Rear View 3
4. Schematic of Instrumentation Locations 4
5. Schematic of Test Geometry 5
6. Velocity Histories - Test 5 7
7. Ignition Box Weld Failure 9
8. Movement of Oil Breather Tubes 10
9. Bent Port Side Suspension Box 10
10. Fractured Bolt Port Side Suspension Bar 11
11. Damaged Suspension Bar Bolts 12
12. Elongated Hole in Suspension Bar 12

13. Damaged 90° Mount Ring Coupling 13
14. Elongated Hole in 90° Mount Ring Coupling 13
15. Fractured Forward Mount Link, Punctured Oil Tank,
and Crushed Line 14
16. Fractured Bolt in Starboard Side Suspension Bar 15
17. Bent Horizontal Bar 16
18. Fractured Forward Mount Link 16

ABSTRACT

A Pratt & Whitney J-75P-5 turbojet engine which is to be used as a generator for the FT4A gas turbine was installed on the Floating Shock Platform (FSP) and subjected to the five standard shock tests outlined in MIL-S-901C(NAVY). The generator was operating by means of an air starter for Tests 1, 3, and 5.

The turbojet gas generator passed the FSP tests. The forward mount structure failed to pass the tests because of a support linkage fracture: the linkage requires redesign. The rear mount structure was used for this test phase only and was not considered a test item. Mount structures will be re-evaluated in Phase II FT4A gas turbine shock tests.

INTRODUCTION

ASSIGNMENT

The Pratt & Whitney Aircraft, Division of United Aircraft Corporation, is developing for the Bureau of Ships the FT4A gas turbine engine to be used as booster propulsion aboard naval vessels. This engine consists of a Pratt & Whitney J-75P-5 turbojet engine, that is employed as a gas generator to supply heated compressed gas to a free power turbine. Since the J-75P-5 turbojet engine was designed for aircraft use, its behavior under naval shock conditions is not known. Therefore, the Underwater Explosions Research Division (UERD), David Taylor Model Basin, has been requested [1,2] to shock test a J-75P-5 engine on the Floating Shock Platform (FSP),[3] and to also include in this investigation as a test item a forward mount structure which duplicates the suspension proposed for shipboard installation. The rear mount structure, an interim mount, is not to be considered a test item.

This series of shock tests is the first phase of the FT4A gas turbine engine acceptance tests: another series which will include the free power turbine is scheduled for the fall of 1963.

OBJECTIVE

The objective of this investigation was to evaluate the performance of a J-75P-5 turbojet engine and its forward mount structure when subjected to the standard series of shock tests on the FSP.

PROCEDURE

INSTALLATION OF EQUIPMENT

The Bureau of Ships provided UERD with the following equipment:

one J-75P-5 turbojet engine.
one forward mount structure, and
one Hamilton starter.

Pratt & Whitney Aircraft provided UERD a plan to fabricate an interim rear mount structure to support the turbojet engine. The mount was designed to retain the flexibility of the prototype system. The Pratt & Whitney design for the rear structure was predicated on the use of AM5613 type steel having a yield of 90,000 psi. However, UERD was unable to procure this type steel in the sizes required and therefore redesigned the mount to utilize available steel but yet retain the original design strength. The suspension bars and bolts were fabricated from B-14 type steel.[4]

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[1] References on page 18.

The rear mount structure was positioned on the FSP and welded to four pads attached (welded) to the deck. The forward mount was secured to welded deck pads by $5/8$-inch-diameter bolts of B-14 type steel (4 to each pad) with 585 ft-lb maximum torque. A maximum 245 ft-lb torque was applied to the upper flange bolts (sixteen $3/4$-inch-diameter) on the forward mount. A circular steel section, the weight of which was to simulate the effect of the free turbine, was attached to the rear engine casing. General views of the complete installation are presented in Figures 1, 2, and 3.

The engine was checked for proper operation by a Hamilton Air Starter with air regulated to 31 psig. By this method, engine speeds of 1360 rpm on N2 rotor and 400 rpm on N1 rotor were obtained.

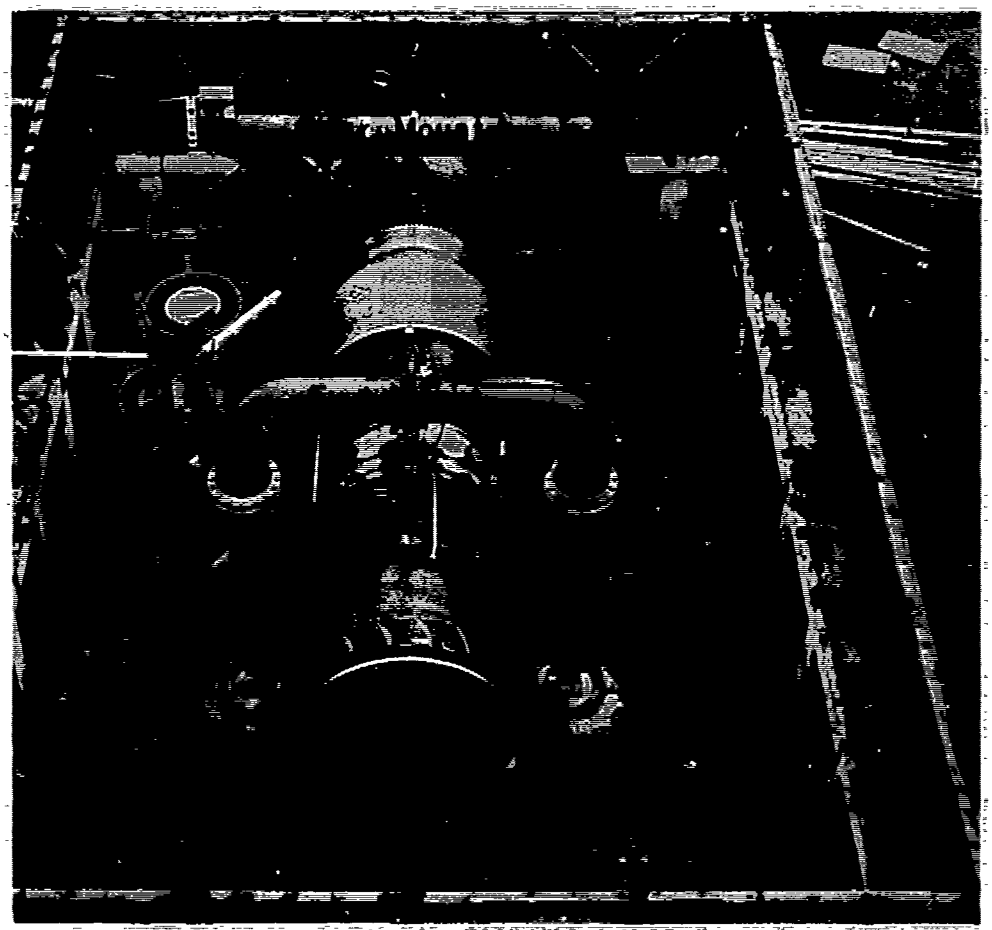

Figure 1 - Engine Installation - Front View

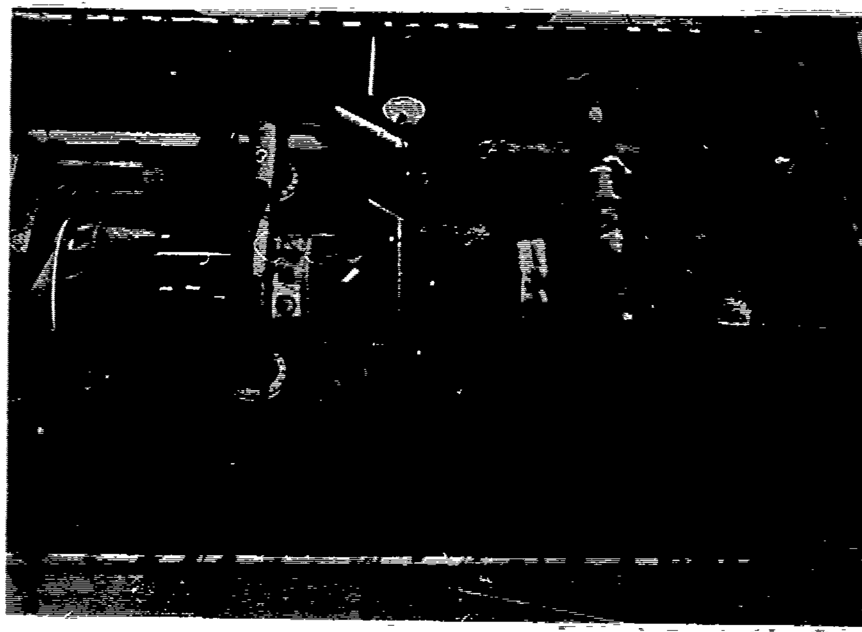

Figure 2 - Engine Installation - Side View

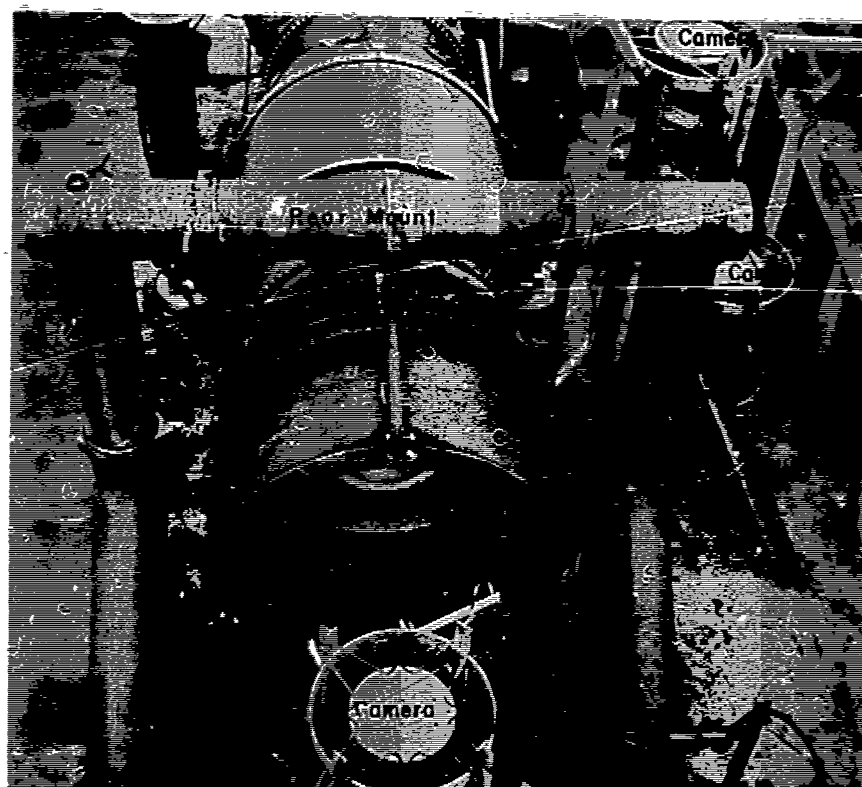

Figure 3 - Engine Installation - Rear View

INSTRUMENTATION

The instrumentation consisted of velocity meters to measure the input to the mount structures and accelerometers to measure the response of the engine. The locations of the gauges are shown in Figure 4 and are tabulated in Table 1.

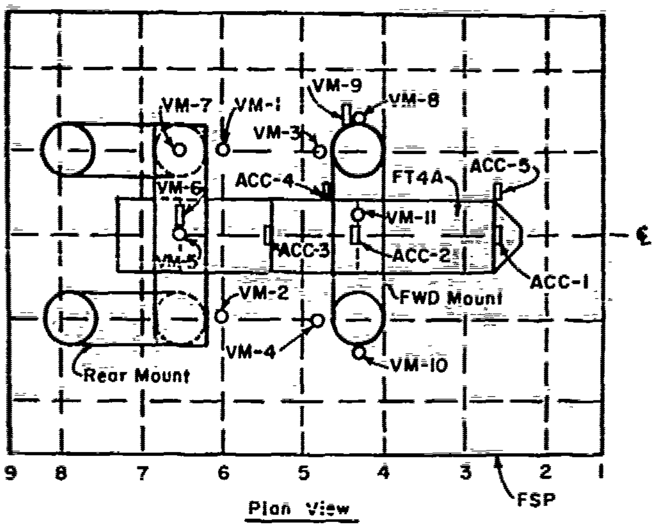

Figure 4 - Schematic of Instrumentation Locations

TABLE 1
Gauge Locations

Gauge	Position	Location
VM-1	Vertical	FSP deck at base of rear mount - port side
VM-2	Vertical	FSP deck at base of rear mount - starboard side
VM-3	Vertical	FSP deck at base of forward mount - port side
VM-4	Vertical	FSP deck at base of forward mount - starboard side
VM-5	Vertical	Top of rear mount ¢
VM-6	Horizontal	Top of rear mount adjacent VM-5
VM-7	Vertical	Top of rear mount - port side
VM-8	Vertical	Side of forward mount just above bolting flange - port side
VM-9	Horizontal	Side of forward mount adjacent VM-8 - port side
VM-10	Vertical	Side of forward mount just above bolting flange - starboard side
VM-11	Vertical	Top of forward mount just off ¢ to port
ACC-1	Vertical	Inlet case at top ¢
ACC-2	Vertical	At turbine casing forward support point
ACC-3	Vertical	At combustion chamber flange ¢
ACC-4	Vertical	N2 gearbox - port side
ACC-5	Horizontal	Inlet case - port side

Three high-speed cameras (Figure 3) were installed to document motions of the forward mount linkage, the rear bearing support, and the gear box.

TESTING

The engine was operating on the air starter for Tests 1, 3, and 5: the N2 rotor at approximately 1360 rpm and the N1 rotor at approximately 400 rpm. The running time was not to exceed 5 minutes since the starter was susceptible to heat damage beyond this running time. The underwater explosion attacks, 60-lb HBX-1 charges at 24-ft depth, were conducted against the FSP in the turning basin at the Norfolk Naval Shipyard, 17 through 24 June 1963. A schematic of the test geometry is presented as Figure 5 and the input velocity is given in Table 2.

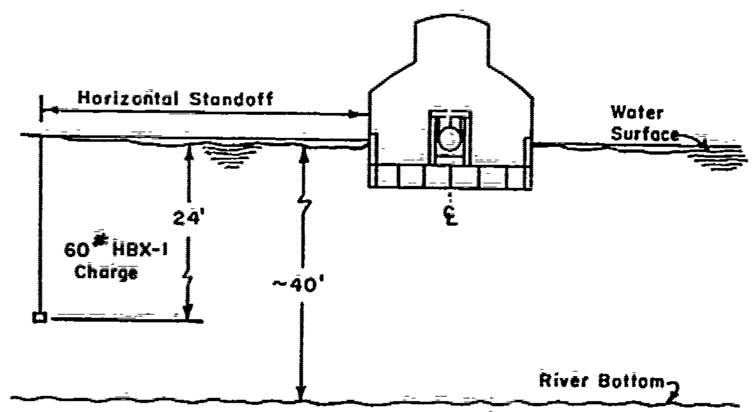

Figure 5 - Schematic of Test Geometry

TABLE 2
Test Geometries

Test No.	Charge Horizontal Standoff (ft)	Charge Depth (ft)	Charge Weight (lb)	Peak Input Velocity* (fps)
1	60	24	60	5.7
2	40	24	60	8.5
3	30	24	60	11.6
4	25	24	60	13.3
5	20	24	60	15.5

* Recorded at base of forward mount on the attack side (VM-3).

TEST RESULTS

INSTRUMENTATION TEST DATA

The peak velocities and accelerations for each attack are given in Table 3.

TABLE 3
Instrumentation Data

Gauge	Test 1	Test 2	Test 3	Test 4	Test 5
			Peak Velocities (fps)		
VM-1	4.9	8.0	9.9	11.9	13.1
VM-2	4.5	6.2	9.3	10.2	12.1
VM-3	5.7	8.5	11.6	13.3	15.5
VM-4	4.8	6.8	10.2	12.4	15.1
VM-5	7.9	13.0	17.7	22.3	25.1
VM-6	4.4	7.3	11.6	*	*
VM-7	6.5	9.7	11.4	17.6	18.3
VM-8	7.6	10.9	14.1	17.0	19.2
VM-9	3.3	6.5	6.8	8.6	15.4
VM-10	8.6	13.3	17.7	18.6	23.7
VM-11	5.6	8.6	11.6	14.6	24.0
			Peak Accelerations (g's)		
ACC-1	64	112	164	159	220
ACC-2	284	335	435	600	600
ACC-3	112	162	*	273	443
ACC-4	99	104	110	121	151
ACC-5	64	74	89	*	265

* Record not valid.

Figure 6 presents four typical velocity histories from Test 5 to illustrate the shock input and shock response: the plots represent the input to the forward mount at the FSP deck; the input to the forward mount bolting flange; the input to the center of forward mount; and the response of the engine casing at the forward mount suspension.

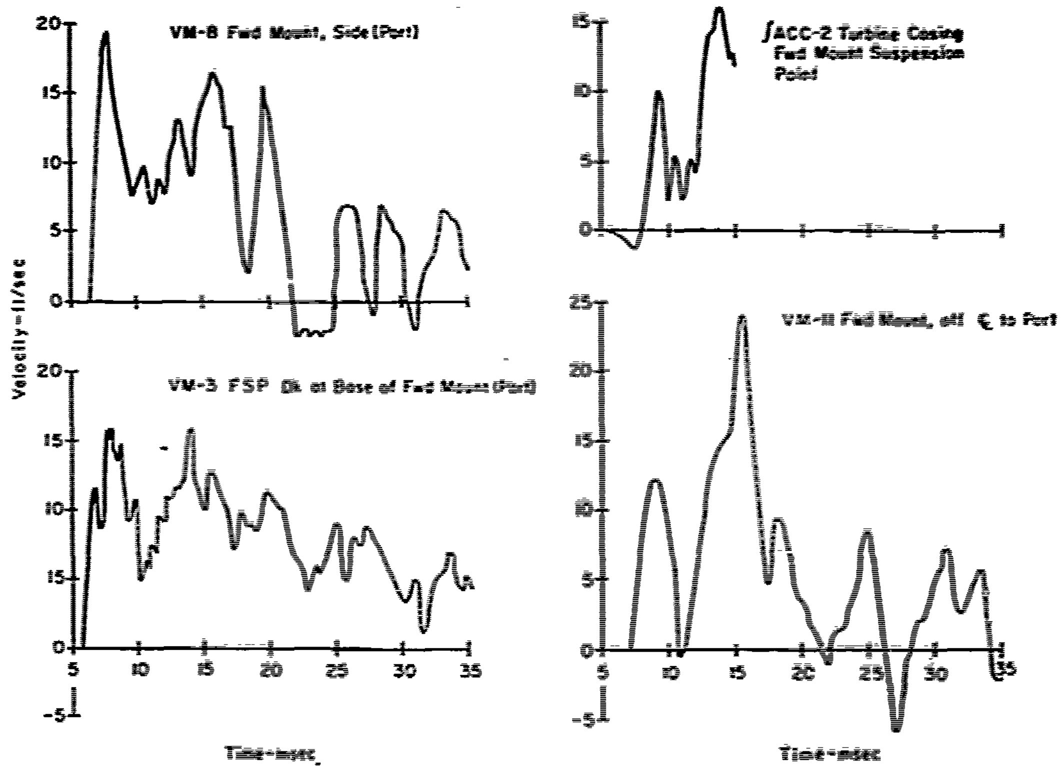

Figure 6 - Velocity Histories - Test 5

DAMAGE SURVEY

The post-test inspections and damage surveys of the engine and mounts were performed by the combined efforts of Pratt & Whitney Aircraft and UERD personnel. In the following damage description the survey of the engine will be described first and then the survey of the mounts.

Test 1 (60-ft standoff)

Preparation for Test

The engine was operating on the air starter during the attack.

Engine Survey

The engine was shut off immediately after the test; no damage was detected during the rundown. The rotors were turned by hand after the rundown and no rubbing was found. The engine was then started and brought up to speed; again no damage was detected. The bearing compartments were pressurized to 20 psig with air to check leakage through breather lines (this check was not made prior to Test 1). The results of the operating speed and breather line checks for this test, as well as those for the other tests, are tabulated in Table 4.

TABLE 4
Rotor and Breather Line Data

Test No.		Speed (rpm) N1 (Rotor)	Speed (rpm) N2 (Rotor)	Breather Line Air Leakage (psig) In	Breather Line Air Leakage (psig) Out
1	Before	400	1360	*	*
	During	400	1360		
	After	400	1360	20	12
2	Before	400	1360	20	12
	During	Not run	Not run		
	After	400	1360	20	$11\frac{1}{2}$
3	Before	400	[illegible]	20	$11\frac{1}{2}$
	During	400	[illegible]		
	After	325	1425	20	$11\frac{1}{2}$
4	Before	400	1360	20	$11\frac{1}{2}$
	During	Not run	Not run		
	After	390	1425	20	$11\frac{1}{2}$
5	Before	390	1425	20	$11\frac{1}{2}$
	During	390	1425		
	After	390	1425	20	$10\frac{1}{2}$**

* Not recorded.
** Oil tank leak.

Mount Survey

The bolts on the rear mount were examined for damage. On the support rods, the top bolts showed slight evidence of shear. The forward mount bolts were checked for tightness; no change in torque values was noted.

Test 2 (40-ft standoff)

Preparation for Test

The engine was inert during this attack.

Engine Survey

Th· engine rotors were turned by hand; no rubbing or other damage was detected. The engine was brought up to speed with the air starter; no damage was found. The breather lines were pressurized but no air leakage was detected (Table 4).

Mount Survey

The rear mount bolts were removed and checked for damage. All four support rod bolts now showed shear indentations. The torque on the forward mount structure bolts was checked; no change w[illegible] evident.

Test 3 (30-ft standoff)

Preparation for Test

The engine was operating on the air starter during this attack.

Engine Survey

The engine was shut down immediately after the test; no rubbing or associated damage was detected during the rundown. The rotors were turned by hand prior to restarting and again no rubbing was evident. The engine was started and brought up to speed; no defects were observed. The breather lines were pressurized; no drop in pressure was noted (Table 4). Partial failures occurred in all weldments attaching the supporting studs of the ignition box (Figure 7).

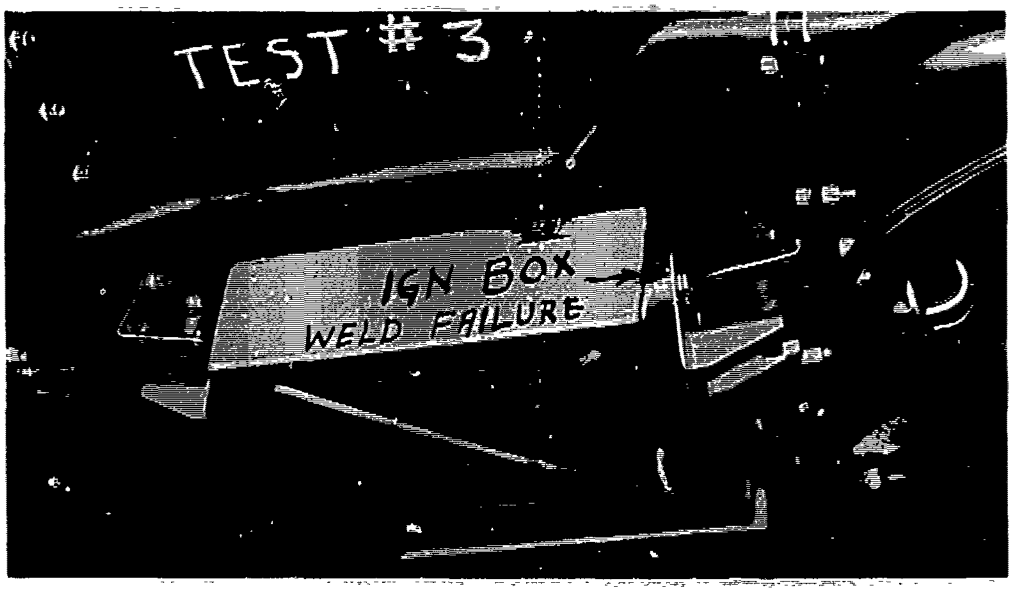

Figure 7 - Ignition Box Weld Failure

The oil tank breather tubes moved at tube cli s on starboard side (Figure 8). The anti-icing line also showed evidence of somc xial movement at inlet case fitting.

Mount Survey

The rear mount suspension bar port side was bowed about 1/8 inch (Figure 9) and the four suspension bar bolts (2 port, 2 starboard) showed severe signs of shearing and some bending. The torque for the forward mount was checked; no change was found. One port side mount linkage bolt was removed and examined; no signs of shearing or bending were evident.

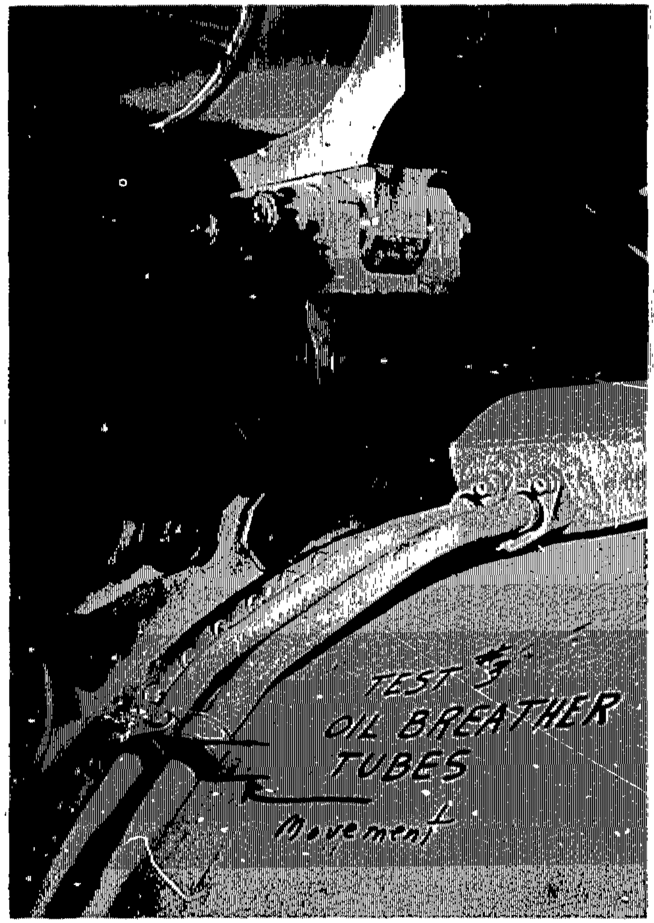

Figure 8 - Movement of Oil Breather Tubes

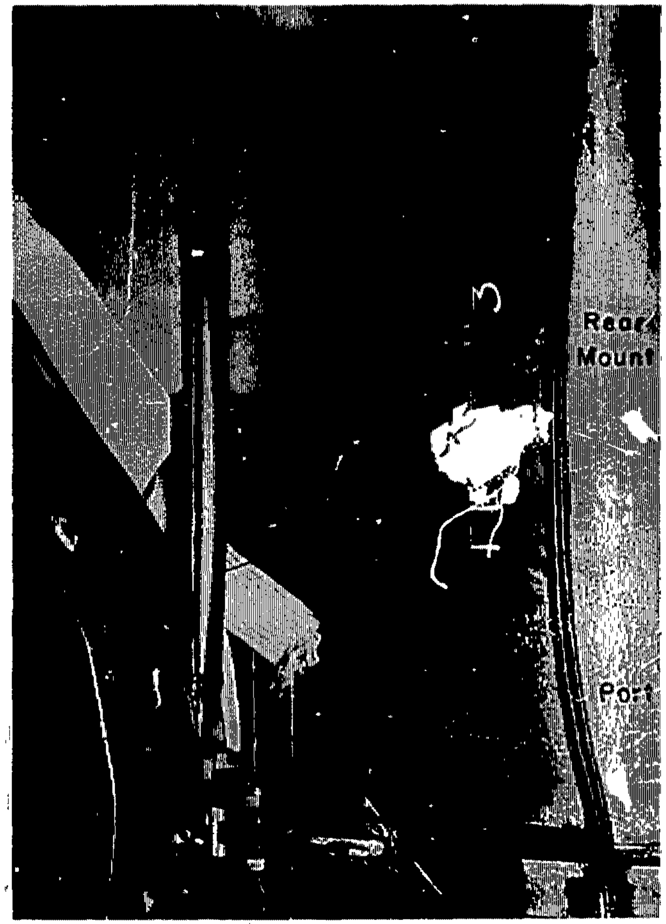

Figure 9 - Bent Port Side Suspension Box

Test 4 (25-ft standoff)

Preparation for Test

The rear mount suspension bar port side was interchanged with the starboard bar and all bolts were replaced with bolts of same size and strength. An elastic shock cord was placed around the ignition boxes to retain them in position in the event the stud weld should fail completely.

The engine was not operating for the test.

Engine Survey

The engine was started and brought up to speed; no rubbing or other damage was detected. The breather lines were pressurized and no leaks were found (Table 4). The igniter box stud-weld failures experienced on Test 3 increased. On the port side, the ignition lead fitting failed at its connection to the composite box. The top oil tank strap failed and the bottom strap was stretched.

Mount Survey

The rear mount suspension linkage sustained failures as follows:

The bottom bolt on the port side suspension bar was sheared and the remaining bolts showed severe shear indentations. The sheared bolt failure is shown in Figures 10 and 11. The other damaged bolts are also shown in Figure 11.

Figure 10 - Fractured Bolt Port-Side Suspension Bar

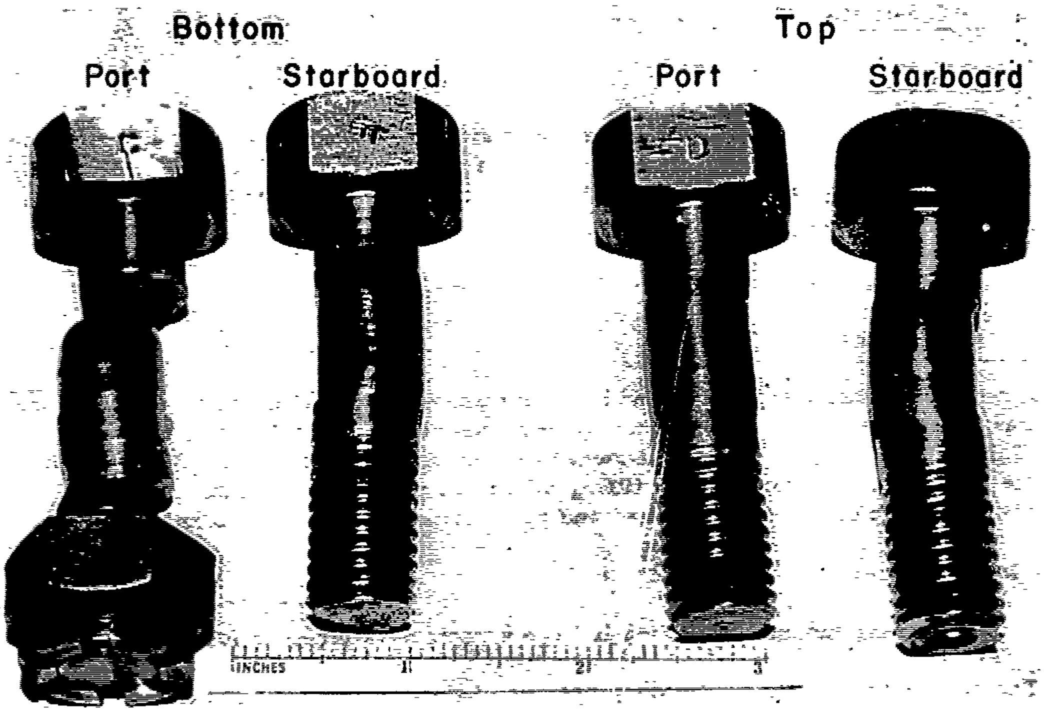

Figure 11 - Damaged Suspension Bar Bolts

The suspension rod bottom bolt hole was elongated (Figure 12).

The 90° mount ring coupling port side sustained bending (Figure 13) and an elongation of the bolt hole (Figure 14). (Note indentation of bolt threads inside hole.) The forward mount sustained no visible damage; the linkage bolts were inspected but no shear or bending of the bolts was evident. The flange and holddown mount bolts were checked for torque; no change was noted.

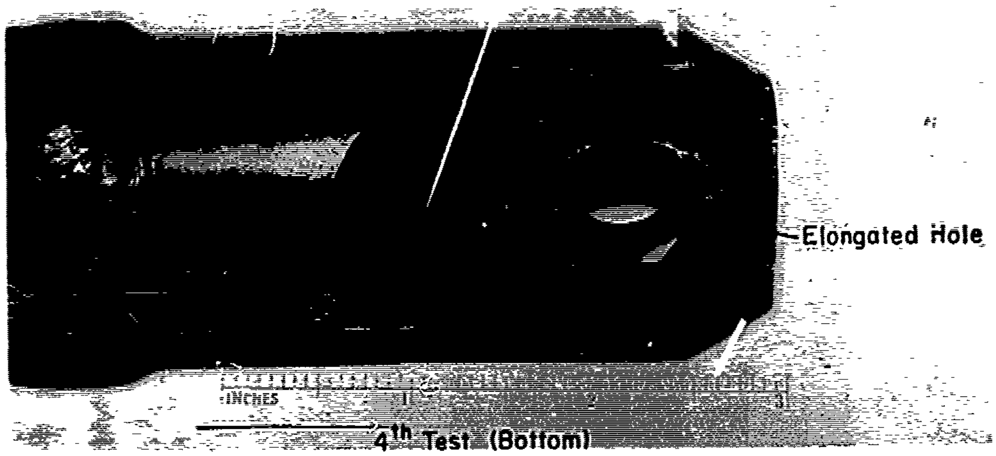

Figure 12 - Elongated Hole in Suspension Bar

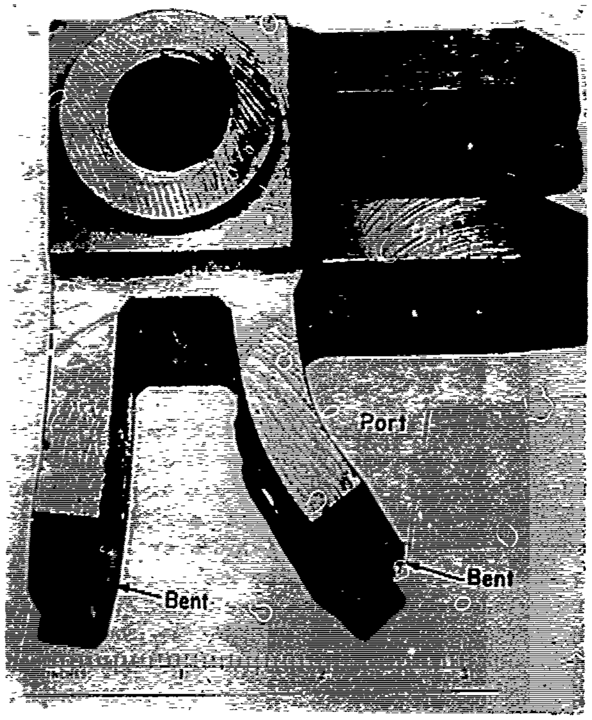

Figure 13 - Damaged 90° Mount Ring Coupling

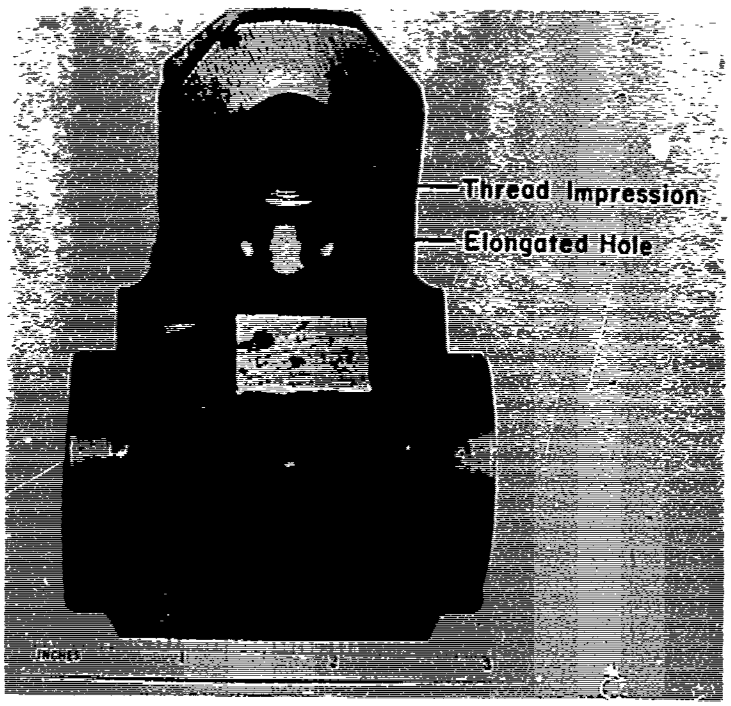

Figure 14 - Elongated Hole in 90° Mount Ring Coupling

Test 5 (20-ft standoff)

Preparation for Test

The oil tank straps were removed and new straps (same strength) were installed. The suspension bars on rear mount were cold straightened. The lower bolt hole section on the port side was replaced. All bolts for the suspension and athwartship bars were replaced with bolts of equal strength. The athwartship bar was replaced with a bar of equal strength. The port and starboard mount ring couplings were replaced with ones of equal strength. The engine was operating for this attack on the air starter.

Engine Survey

The engine was shut down immediately after the test; no rubbing or other noise was detected. The rotors were turned by hand prior to restarting and again no rubbing was found. The engine was started and brought up to speed for about 1 minute: no damage was in evidence. The breather lines were pressurized and a slight drop in pressure was noted (Table 4); this drop was caused by a small hole in the oil tank. The stud weld failures on the ignition boxes increased; however, the boxes were kept in place mainly by the shock cord. The oil tank was punctured and the scavenge line was crushed (Figure 15) by the forward mount port side as the engine swung owing to failure of the linkage (this linkage failure is described in the Mount Survey).

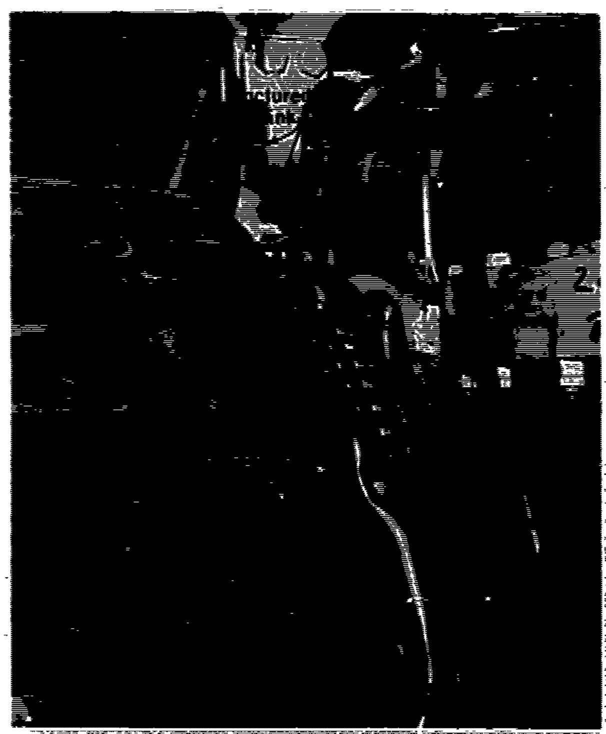

Figure 15 - Fractured Forward Mount Link, Punctured Oil Tank, and Crushed Line

Mount Survey

The connection bolts on the rear mount suspension bars failed and allowed the engine to drop free (Figures 16 and 17). On the forward mount, the port side link failed in tension and left the engine supported only by the starboard side link. A general view of the link failure is shown in Figure 15 while a close-up of the fractures is shown in Figure 18. At first it was thought that the rear mount failure influenced the forward link fracture but a view of the high speed film indicated that this was not true. The linkage bolts were examined but no shear or bending deformations were evident. The holddown and flange bolts for the forward mount were checked for looseness but no change in torque was found.

Figure 16 - Fractured Bolt in Starboard Side Suspension Bar

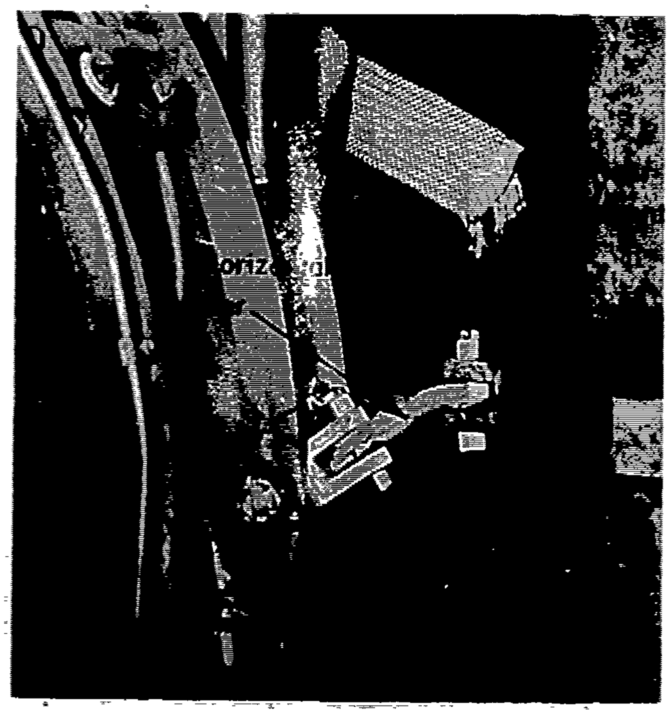

Figure 17 - Bent Horizontal Bar

Figure 18 - Fractured Forward Mount Link

SUMMARY AND CONCLUSIONS

The Pratt & Whitney J-75P-5 engine to be used as the gas generator for the FT4A gas turbine engine withstood the five shock tests without critical damage. However, two items on the engine failed: the straps to the oil tank failed on Test 4, and the ignition box stud welds began to fail on Test 3. The straps were replaced for Test 5 and held during that test. No attempt was made to correct the stud weld failures since a redesign of the stud connection would have been necessary. These failures did not impair the operation of the engine.

The forward mount linkage failure which occurred at Test 5 was considered critical since it allowed the engine to drop; this failure would have caused serious misalignment had the power turbine been attached. The rear mount, however, was used only to support the engine for this series of tests; this mount will be replaced by a free power turbine support in Phase II tests.

In accordance with MIL-S-901C, the J-75P-5 engine passed the standard series of shock tests on the FSP. The linkage of the forward mount requires redesign and further evaluation prior to acceptance.

REFERENCES

1. Bureau of Ships letter 9410/ 7 Ser 645-635 of 30 July 1962 to David Taylor Model Basin.

2. Bureau of Ships letter 9410/ 7 Ser 645-64 of 28 January 1963 to David Taylor Model Basin.

3. "Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements for," MIL-S-901C(NAVY) (15 January 1963).

4. "Studs, Continuous Thread (Bolt Studs); Nuts, Plain, Hexagon; and Steel Bars, Round - High Temperature Service," MIL-S-1222C, Amendment 1 (8 February 1957).

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The turbojet gas generator passed the FSP tests.

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3. Generator (Gas FT4A)--Pratt & Whitney Air-

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3. Generator (Gas FT4A)--Pratt & Whitney Air-

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3. Generator (Gas FT4A)--Pratt & Whitney Air-

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craft J-75P-5 turbojet--
Ship boost propulsion

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The forward mount structure failed to pass the tests because of a support linkage fracture: the linkage requires redesign. The rear mount structure was used for this test phase only and was not considered a test item. Mount structures will be re-evaluated in Phase II FT4A gas turbine shock tests.

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craft J-75P-5 turbojet--
Ship boost propulsion

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