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TESTS OF CRASH-RESISTANT FUEL SYSTEM FOR GENERAL AVIATION AIRCRAFT

William M. Perrella, Jr.

DECEMBER 1978

FINAL REPORT

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FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

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16. Abstract

A significant percentage of general aviation aircraft accidents result in post-crash fires due to the ignition of fuel spillage, often contributing injury or death to the aircraft occupants.

Testing was performed to demonstrate the performance of light-weight, flexible, crash-resistant fuel cells combined with the use of frangible fuel line couplings. Included in these tests were four full-scale crash tests of a typical light twin aircraft. In three tests, the crash-resistant fuel system performed satisfactory. The fourth and final test, where the lightest weight tanks were used, resulted in tank failures and demonstrated a possible lower strength limit to the tank material.

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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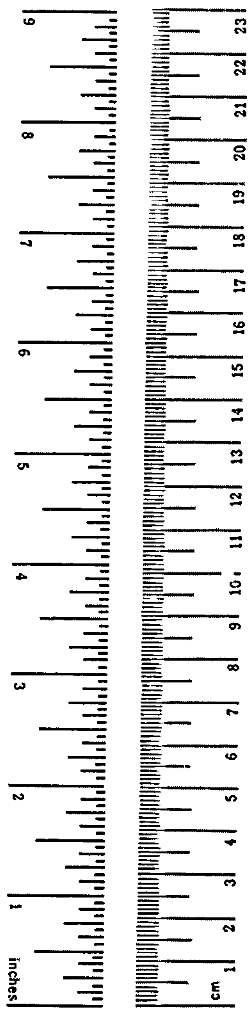
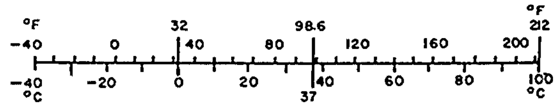
*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

From 1973 through 1976 the National Transportation Safety Board's (NTSB) yearly summary of general aviation accidents showed over 16 percent of all accidents result in fatalities, with 30 percent of these involving postimpact fire. It is apparent that once ignition occurs in the presence of large quantities of spilled fuel, the survival chances of the aircraft occupants are greatly reduced, even when fire-fighting equipment is immediately on the scene. The only feasible way to decrease the incidence of postcrash fires is by the reduction of fuel spillage and ignition sources. Therefore, the Federal Aviation Administration (FAA) initiated a program to evaluate a way of preventing massive spillage of fuel during a crash, i.e., crash resistant flexible bladder cells used with self-sealing frangible couplings at critical points in the fuel lines.

The United States (U.S.) Army has unquestionably established that fuel can be contained by flexible fuel tanks, thereby eliminating the potential of postcrash fire (reference 1). Though the Army does not now collate accident records, they do keep injury/fatality records. To date, these data show only five fire related injuries and one fatality that showed evidence of inhalation of fire by-products in a nonsurvivable accident. These tanks, while very effective, impose weight and cost penalities which could be significantly reduced for general aviation aircraft. Consequently, the major thrust of this program was to demonstrate by full-scale test, effective low-cost, lightweight, crash-resistant fuel cells.

A contract was awarded to the Uniroyal Corporation to design and fabricate crashworthy tanks for a typical light twin-engine aircraft (reference 2). These tanks were to be equipped with Aeroquip® type DE5175-1-8A frangible couplings on the filler and vent fittings. The contract specification is shown in appendix A and includes contract modifications (i.e., lightest weight tanks and values).

DISCUSSION

TANK CONSTRUCTION

Construction materials devised by industry to meet MIL-T-27422B provided a starting point for the program. The initial contract called for the construction of three left-hand tanks of two-ply construction, and three right-hand tanks of three-ply construction. To assist in reducing construction weight, the drop test requirement of the above specification was reduced from 65 feet to 39 feet. This reduction resulted in a change in impact velocity from 65 ft/s to 50 ft/s, which was considered more representative of a general aviation airplane accident environment. All tank fittings were initially specified to meet NIL-T-27422B requirements.

At the Uniroyal facility, a left-hand two-ply tank was filled with 59.2 gallons of water and dropped from a height of 39 feet. The tank successfully withstood the impact on its leading edge with no visible damage. Based on that fact and the results of a full-scale aircraft crash test described later, it was decided not to fabricate two of the three-ply cells; two single-ply types were specified. The tanks were to be fitted with Uniroyal-designed fittings similar to MS33581, with the addition of a third ring. These fittings are lighter in weight and lower in cost than the Uniroyal Wall Expansion® and Fibre-Lok® fittings used on the other tanks, and have been demonstrated as satisfactory in 65-foot free-fall impacts when mounted in a 2 foot by 2 1/2 foot by 2 1/2 foot test tank, per paragraph 4.6.6.2 of MIL-T-27422B. Table 1 summarizes the characteristics of the tanks delivered for testing at NAFEC.

The main bladder cells with which the aircraft is normally equipped weigh 9.6 pounds each. Refer to figure 1. The contractor was required to perform the following material tests per MIL-T-27422B:

(1) Constant rate tear (4.6.5.1)
(2) Impact penetration (4.6.5.2)
(3) Impact tear (4.6.5.3)
(4) Panel strength calibration (4.6.5.4).

Table 2 shows the results of these tests. The Army helicopter accident record with crash resistant fuel systems installed is impressive. It is believed that this technology can be transferred to small general

TABLE 1. FUEL TANK CHARACTERISTICS

Tank Type	Qty.	Uniroyal Construction Code No.	Fabric Plies	Fabric Weight (oz/sq yd)	Total Weight of Fittings (lb)	Tank Weight (lb)
L. H.	3	*US758	2	12.75	6.50	27.0
R. H.	1	US759	3	12.75	7.76	38.0
R. H.	1	**US756	1	25.50	2.75	24.2
R. H.	1	US764	1	12.75	2.75	18.0
R. H.	1	US762	1	8.00	2.75	17.5
L. H.	1	US768	1	5.50	2.75	15.0

* One of these tanks successfully passed the 39-foot drop test.

** This material has FAA Technical Standard Order (TSO-C80) approval.

TABLE 2. PHYSICAL PROPERTIES OF FUEL TANK CONSTRUCTION (MIL-T-27422B)

	CONSTRUCTIONS					
Test Data Required	US758 2-Ply 12.75 Oz. Fabric	US759 3-Ply 12.75 Oz. Fabric	US756 1-Ply 25.5 Oz. Fabric	US764 1-Ply 12.75 Oz. Fabric	US768(1) 1-Ply 5.5 Oz. Fabric	US762 1-Ply 8.0 Oz. Fabric
Constant Rate Tear-Foot Pounds						
Parallel Warp	257	321	210	138		22.4
90° Warp	251	369	213.6	136		28.7
45° L Warp	299	417	224.9	121		36.4
45° R Warp	271	454	249.5	127		32.0
Impact Penetration - Drop Height Passed - Feet						
Parallel Warp	5.5	11	8.5	4.5		2
90° Warp	6	11	8.5	4.58		2
45° L Warp	6	11	8.5	4.67		2
45° R Warp	6	11	8.5	4.67		2
Impact Tear - Drop Height Passed - Feet						
Parallel Warp	6	10	7	1.67		.58
90° Warp	5	9	9	2.00		.58
45° L Warp	9	10	10	3.17		.75
45° R Warp	9	10	10	3.17		.75
Panel Strength Calibration-Pounds	17402	18134	17926	11718		11160

(1) Data available upon request

aviation airplanes with appropriate consideration being given to different accident environments, structural configurations, and tank shapes. Tank crash loads in a small fixed-wing aircraft are generally different than in a rotor wing aircraft. A helicopter often has a significant vertical velocity component during a crash, whereas, the general aviation airplane has a more significant longitudinal velocity component. Since helicopter fuel tanks are generally located under the floor, concentrated mass loads overhead in the structure, such as engines and transmissions, can impact a tank from above while lower structure impacts from below, due to deformation caused by ground contact. Additionally, helicopter tanks are often of a shape close to cubical, so that very little deformation is required to develop high hydraulic loads. In most fixed-wing aircraft, there are no heavy masses to sandwich a tank against the ground.

Also, the shape of a typical wing tank is favorable in regard to hydraulic loads. Impacted against the leading edge, the tank volume will tend to increase to a larger percent of its former volume, so the hydraulic pressure will remain low. The primary design criteria for such tanks are tearing and puncture resistance. There are some aircraft which use belly tanks or nacelle tanks of compound shapes or shapes not conducive to volume increase upon impact. The testing performed in this program is not applicable to such tank types.

In any design of a crash-resistant fuel system, attention must be given to the tank/structure interaction in order to obtain optimum results. First, the tank must be placed in a cavity which will not fail so that sharp, broken components (ribs, stringers, etc.) will not penetrate the tank. In addition, for the lightest possible weight, the protective effect of the structure must be considered in the design process and in qualification testing. For example, a lighter tank could be used if it were located behind, instead of in front of the main spar. To modify an existing aircraft in that way would not be feasible; however, for new aircraft design, crashworthiness features could be very easily incorporated at minimal cost.

INSTALLATION OF TANKS IN AIRCRAFT. As crash-resistent tanks are stiffer than standard bladder cells, they could not be installed in the opening in the wing normally used for that purpose. Figure 1 shows main cell components while figure 2 illustrates a two-ply tank.

The crashworthy tanks were installed by removing the bulkhead rib at the wing root after the wing was removed from the aircraft. The tank was slid into the wing, after which the rib was riveted back in place, and the wing was reinstalled. Referring to figure 3, it is seen that the tanks occupy the wing leading edge. No modifications were done on the wing where the filler flange fittings, access, and gauge fittings were located. The frangible couplings (figure 4) were installed at the fuel outlet and vent fittings. As bulkhead ribs interfered with these fittings, 2-inch diameter clearance holes were cut in the ribs. To provide a more severed operating condition for the couplings, aluminum tubing was used in lieu of the flexible tubing normally used for fuel lines. Acuating arms were installed to impact these lines when the arms contacted the ground during the crash (figure 5).

It was found that there was a decrease in the volumetric capacity of the crash-resistant tanks relative to the existing aircraft cells, each of which holds 59 gallons: the three-ply tank held 53 gallons, the two-ply, 55 gallons, and the single-ply US764 held 57.6 gallons. The decrease in capacity occurred because these preproduction tanks did not closely conform to the inner contours of the wing. In a production tank, the fit would be more precise, probably resulting in a reduction in volume of less than a gallon.

A crashworthy fuel tank must not fail when the aircraft experiences "survivable" crash accelerations. An aircraft crash is considered survivable if the acceleration levels and durations are within certain limits which do not result in fatal injuries to the occupants. These tests are not designed to bring the cabin environment up to the limits of survivability, but they are designed to expose the fuel tank location to a destructive environment.

FULL-SCALE CRASH TESTS.

The crash tests were performed at the National Aviation Facilities Experimental Center (NAFEC) catapult facility. A compressed-air catapult was used to accelerate the test aircraft along a 90-foot track. At the end of the catapult stroke, the aircraft, which was pulled by its nose gear, was released to impact an earthern hill of 4° slope. At the base of the hill, a 12-inch by 12-inch I-beam was installed to break off the aircraft's landing gear. The nose gear was strengthened to withstand the catapult pulling force (figure 6), while the main landing gear mounting bolts were sawed in half to effect an easier separation from the wings. Spoilers were installed along the upper wing surface to keep the airplane from flying. At a distance of 10 feet from the I-beam, poles were sunk into the hill to a depth of 18 inches. These poles were spaced symmetrically off the centerline of the hill, at 42 inches and 108 inches each. The poles were hollow mild steel tubing, 4.375-inches outside diameter, 0.188-inch wall thickness and were 10 feet in length. Small rock piles were located on the hill to further increase the severity of the crash conditon (figure 7 and 8). There are no standards in general use for a crash site as is used in this type of test; hence, the selection of the type of poles, rocks, and hill were selected to produce a destructive environment to the fuel tank location. The crash site was intended to be at least as severe as a crash at an airfield involving airport structures such as approach lights.

In all tests, the aircraft main tanks were filled with water. Accelerometers, CEC type 4-203-0001, were installed on the floor of the aircraft at the longitudinal center of gravity location (station 126). Accelerations in the vertical and longitudinal direction were recorded on an oscillograph. The data were filtered at 90 hertz (Hz).

RESULTS

The acceleration pulses had the general form illustrated in figure 9. Time zero started as the nose gear struck the I-beam, resulting in the initial spike shown. This spike, typical in all tests, was about 100 g's longitudinal, for a duration of 5 milliseconds. Following this event, for a period of 0.27 to 0.33 seconds or so, depending on the test, there was no one acceleration peak distinguishable from the accelerations caused by the vibration of the structure. The aircraft was decelerating at an average level of approximately 2 g's. During this period of time, the main landing gear was broken off. The main acceleration pulse was typically about 0.1-second duration, during which the aircraft was experiencing retarding forces from ground contact, as well as rock impacts. Only in test 3 did the pole impacts on the wing happen to coincide with the main acceleration pulse. After an analysis of the high-speed films, it was found that the pole impacts, which occurred approximately 0.21 seconds into the crash event, did not produce any significant acceleration peaks within the cabin of the aircraft. While the effect of these impacts on the wing was severe, resulting in much damage, the inherent chord-wise flexibility of the wing prevented the force transferral to the fuselage.

It was necessary to keep the aircraft weight light in order to obtain the highest speed possible with the type of catapult used. Therefore, the empennage and engines were not installed on the airframe. From an analysis of the film, it was concluded that the probable effect of the engine mass on the local fuel cell impact loads would have been negligible. However, the dynamic behavior of the wing and aircraft after the impacts would have been significantly different had the engines and empennage been installed (reference 3).

Major results of the four crash tests are summarized in table 3. The first test evaluated three-ply and two-ply tanks. The left wing received the most severe impacts. It contained the two-ply tank, which, upon later visual inspection, was found to be undamaged. The self-sealing Aeroquip couplings all actuated with no leakage. The left wing was nearly torn from the fuselage, with only a small part of the spar web holding it (figures 10 and 11). Acceleration levels are shown in figure 12. The impact speed of the aircraft was 93 feet per second (ft/s).

TABLE 3. CRASH TEST DATA

				Aircraft Weight lb			Maximum Acceleration, g		
Test No.	Date	Fuel Tank L. H.	Fuel Tank R. H.	Empty	Tanks Full	Impact Speed, Ft/s	Fwd	Up	Damage
1	2/18/76	2-Ply* US758	3-Ply US759	1,700	2,600	93	15	5	None to either tank
2	8/8/76	2-Ply US758	Original Aircraft Bladder Cell	1,710	2,660	93	29	7.5	None to L. H. tank R. H. tank ruptured
3	5/18/77	2-Ply US758	1-Ply US764	1,660	2,598	95	27	55	None to either tank
4	6/30/78	1-Ply US768	1-Ply US762	1,680	2,590	95	-	-	Both tanks failed; R. H. tank received minor damage

*This tank was previously drop tested from 39 ft.

Test 2 compared the existing bladder cell (right wing) with a two-ply crashworthy cell. The two-ply tank survived the 93-ft/s impact with no damage, but the original bladder cell failed catastrophically, spraying out its contents almost instantaneously. The cell failed predominantly by tearing (figures 13 through 19). During impact, the aircraft rotated counterclockwise about its center of gravity as viewed from above, as the forces delivered to the left wing were higher due to the stiffening effect of the two-ply tank. It came to rest at about a 30° angle. Acceleration levels are shown in figure 20.

Slight leakage was observed from both frangible couplings on the two-ply tank after this test. Inspection revealed this was caused by corrosion in the flapper valve assemblies. The tanks had been filled with water for several weeks prior to the test. As the couplings are designed to operate with aviation fuels, this leakage was not considered a problem which would occur in service.

Test 3 was performed to evaluate the performance of a 12.75 oz single-ply tank installed in the right wing. A two-ply tank was run concurrently. Both of these tanks survived the 95-ft/s impact with no damage discernable to a visual inspection (figures 21 through 23). Acceleration levels are shown in figure 24.

Test 4 was run with a single-ply 8.0 oz tank in the right wing and a single-ply 5.5 oz tank in the left wing. At the impact speed of 95 ft/s, both tanks failed. The 5.5 oz tank failed by tearing, which propagated extensively (figures 25 to 27). The 8.0 oz tank was only slightly damaged, the tears were limited to less than 2 inches and occurred in three areas (figures 28 to 30). Due to instrumentation problems, acceleration data were not obtained. Refer to figures 31 through 34 for structural damage.

The single-ply 25.5 oz tank was not tested in view of the results with the single-ply 12.75 oz tank. The results obtained show that effective crash-resistant fuel systems can be constructed which have small weight and volume penalties. The use of these systems would undoubtedly result in the saving of lives which otherwise would be lost in postcrash fires.

CONCLUSION

It has been demonstrated that lightweight, flexible, crash-resistant fuel cells used with self-sealing, frangible, fuel-line couplings can effectively reduce postcrash fuel fires in general aviation aircraft equipped with wing tanks. A single-ply tank constructed with 12.75 oz nylon reinforcement was the lightest tank which sustained no damage. A single-ply 8.0 oz tank received only minor damage, and a 5.5 oz tank failed catastrophically.

REFERENCES

1. System Safety Newsletter, U.S. Army Agency for Aviation Safety, Vol. 4 No. 4, 1975.

2. Piper Navajo Fuel Tanks, FAA Crash Resistant Modifications, Tanks and Testing, Uniroyal Report FC-1641-77, March 1977.

3. Dynamic Response of Structures, Pergamon Press, N.Y., 1971.

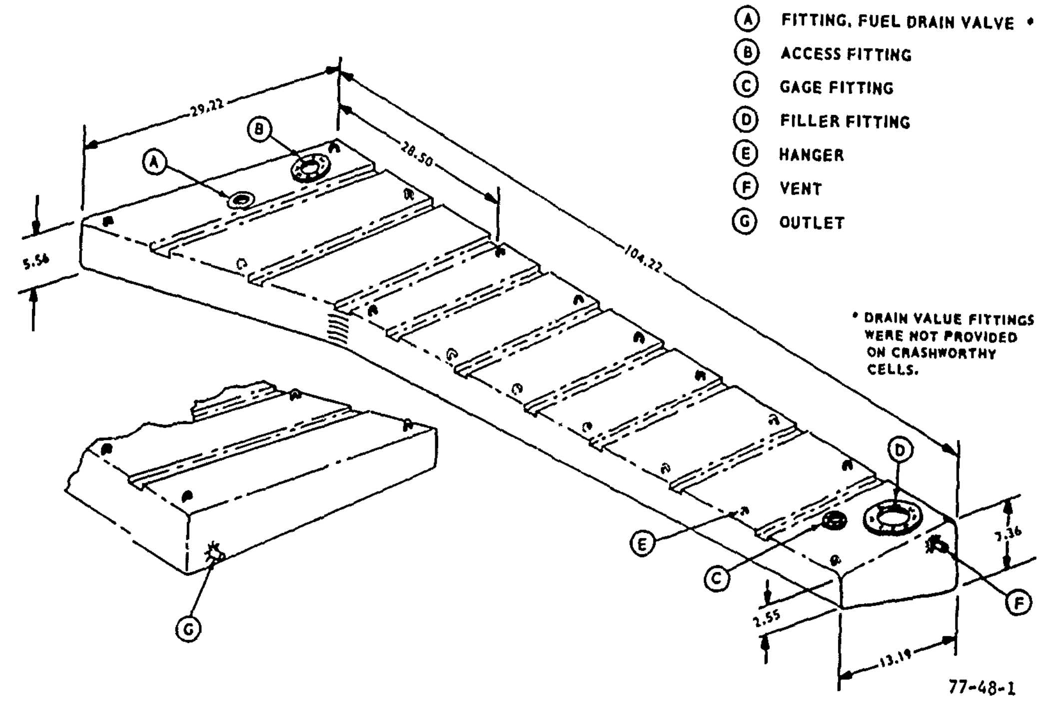

FIGURE 1. LEFT MAIN FUEL CELL

FIGURE 2. TWO-PLY FUEL TANK

FIGURE 3. INSTALLATION OF TWO-PLY FUEL TANK

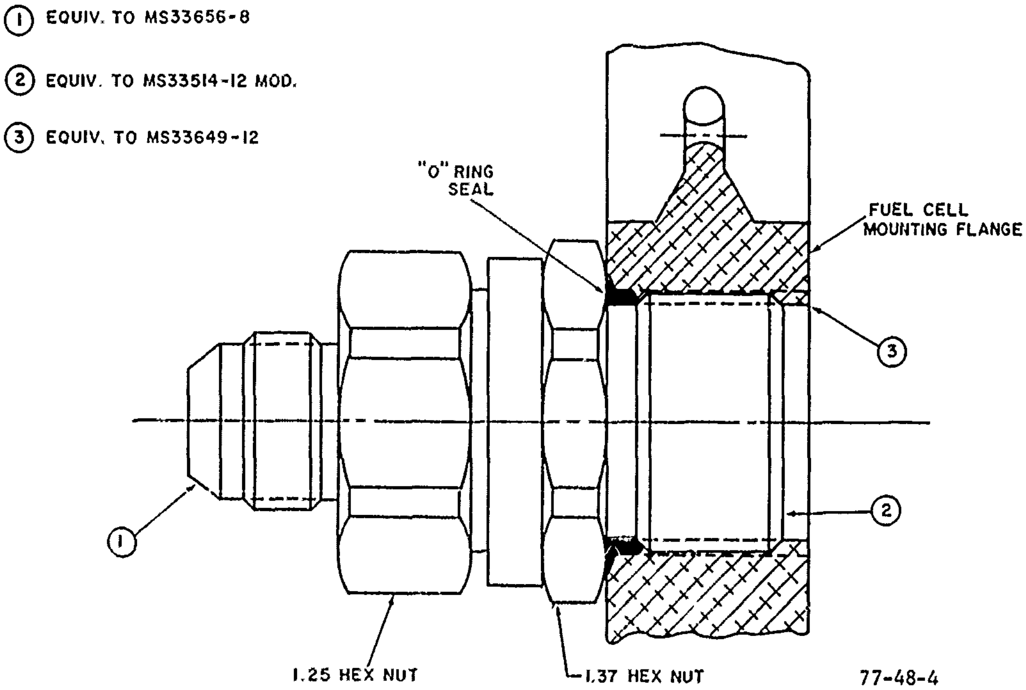

FIGURE 4. FRANGIBLE COUPLING MOUNTED TO FUEL CELL MOUNTING FLANGE

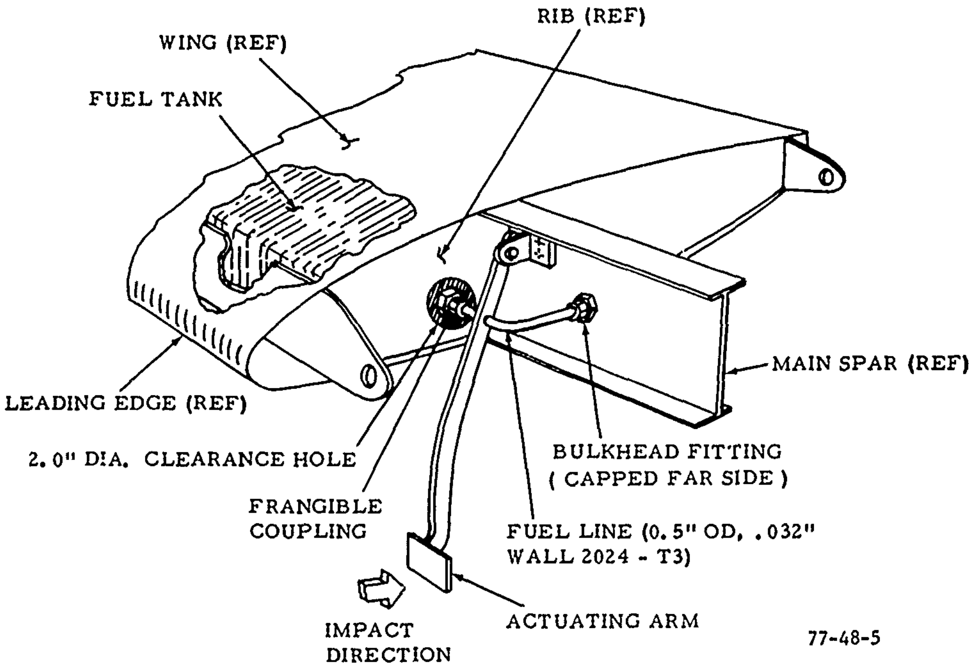

FIGURE 5. TYPICAL FRANGIBLE COUPLING INSTALLATION (WING ROOT)

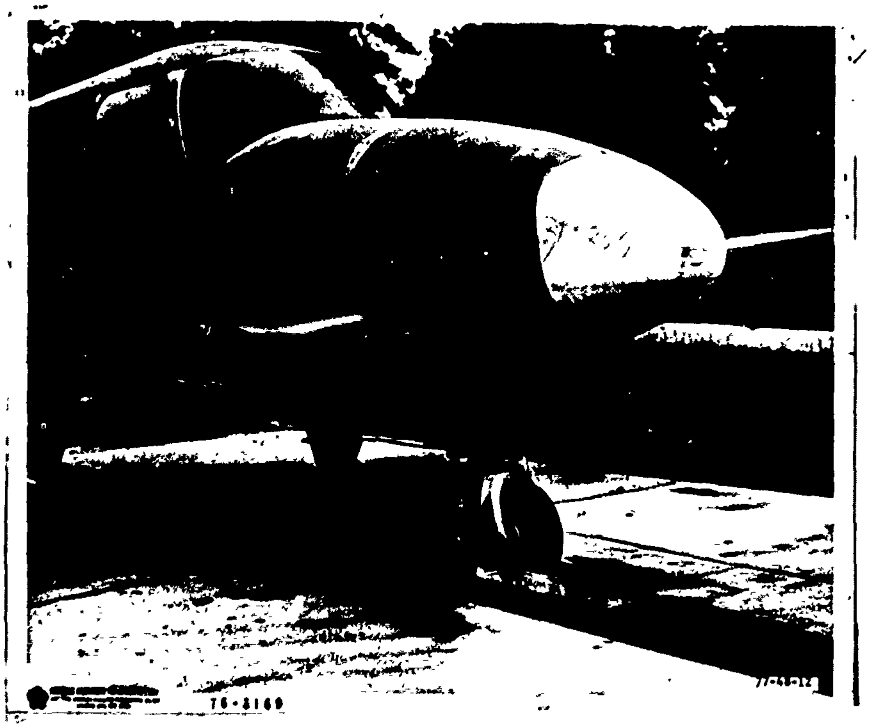

FIGURE 6. NOSE GEAR TOWING ATTACHMENT

FIGURE 7. CRASH TEST SITE

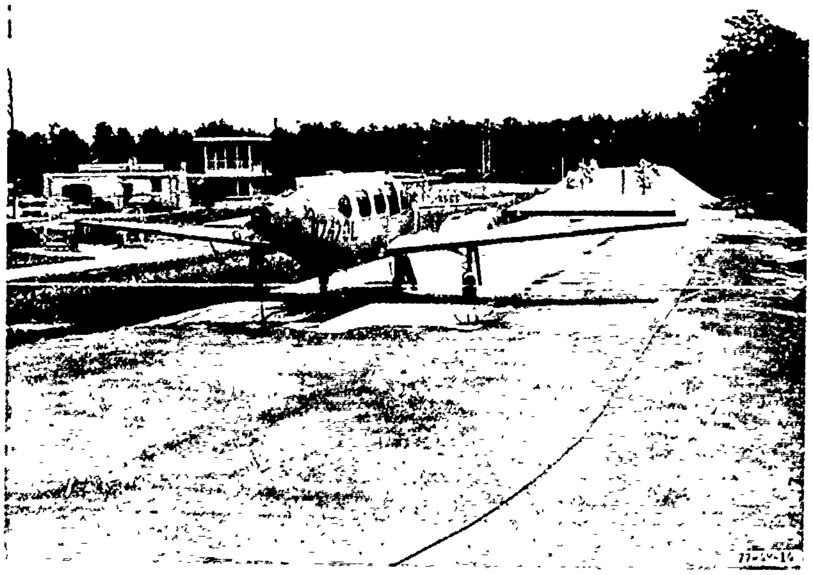

FIGURE 8. AIRCRAFT IN POSITION FOR TEST

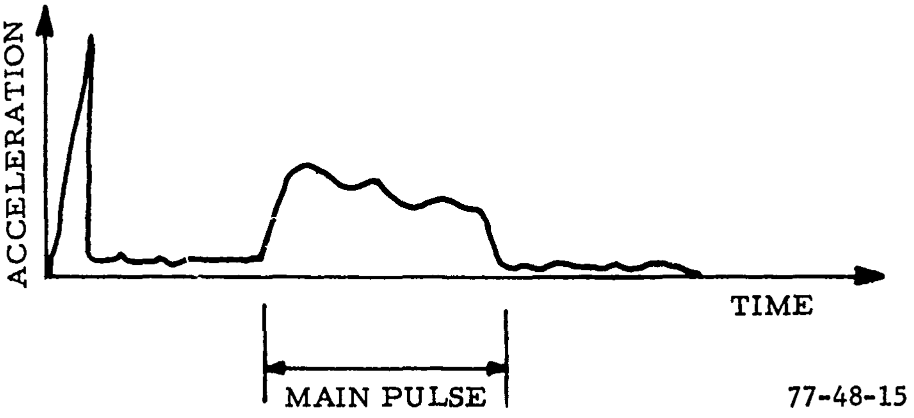

FIGURE 9. TYPICAL ACCELERATION PULSE

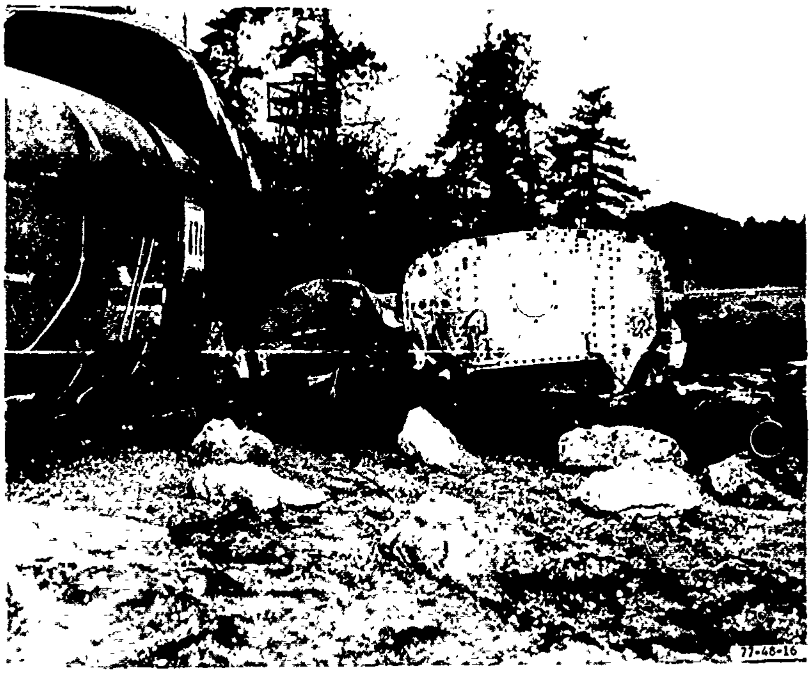

FIGURE 10. DAMAGE TO LEFT WING TWO-PLY FUEL TANK, TEST 1

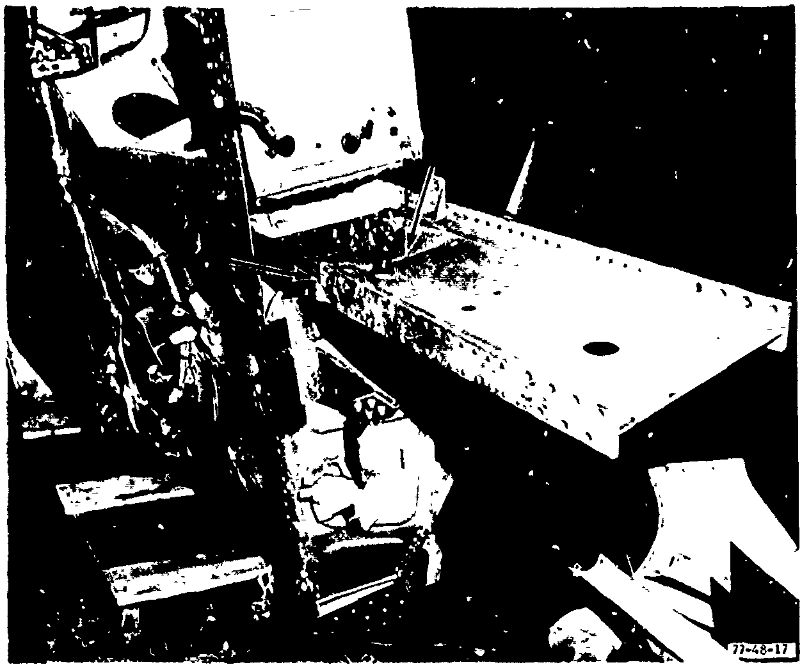

FIGURE 11. FAILURE OF MAIN SPAR, LEFT WING, TEST 1

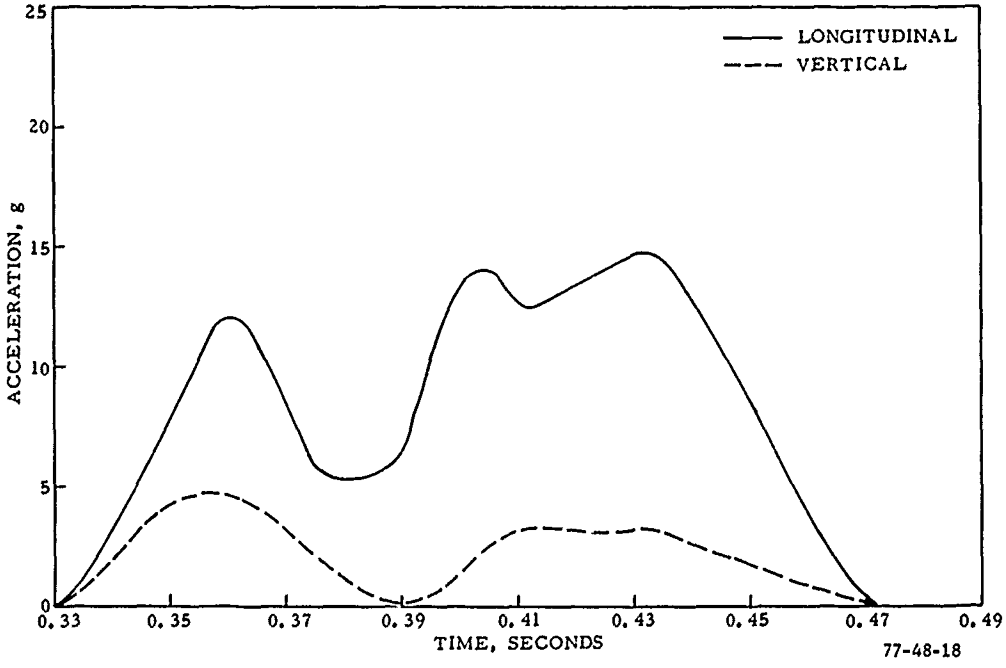

FIGURE 12. MAIN ACCELERATION PULSE, TEST 1

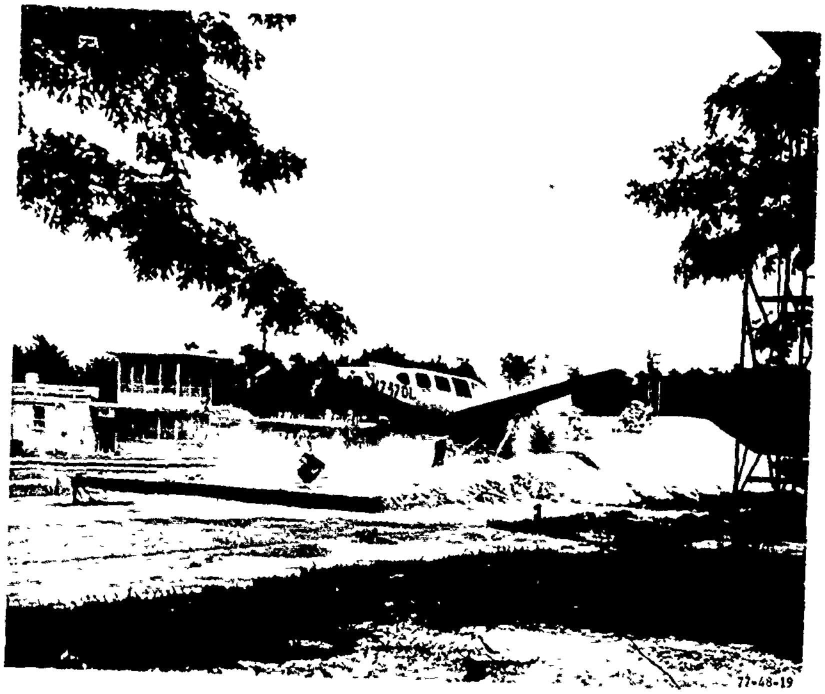

FIGURE 13. AIRCRAFT IMPACT, TEST 2, (NOTE WATER SPRAY FROM RIGHT WING)

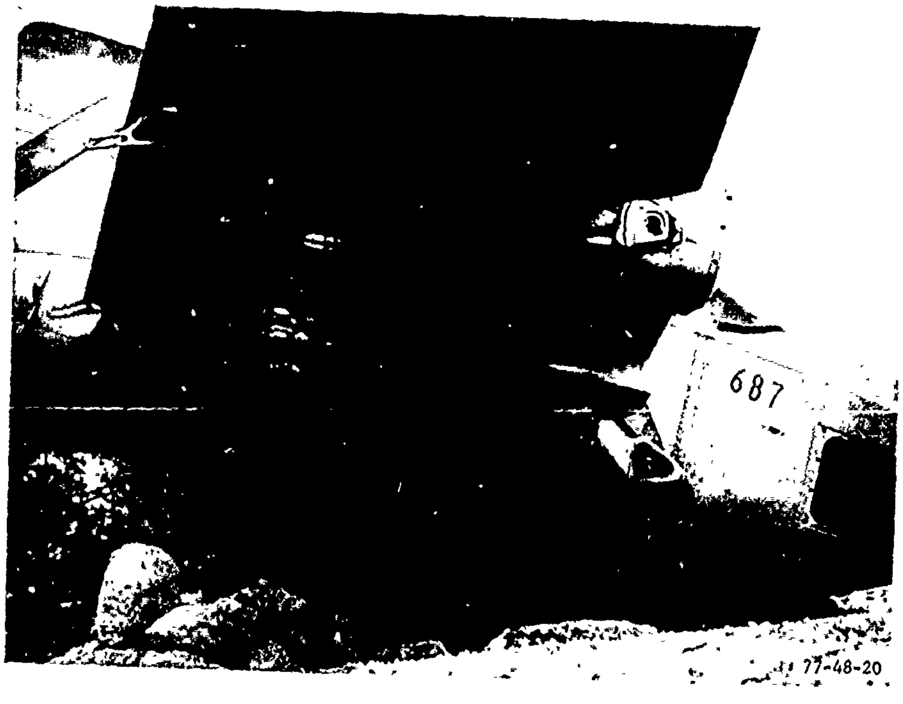

FIGURE 14. DAMAGE TO RIGHT WING, ORIGINAL AIRCRAFT BLADDER CELL, TEST 2

FIGURE 15. DAMAGE TO RIGHT WING, ORIGINAL AIRCRAFT BLADDER CELL, TEST 2

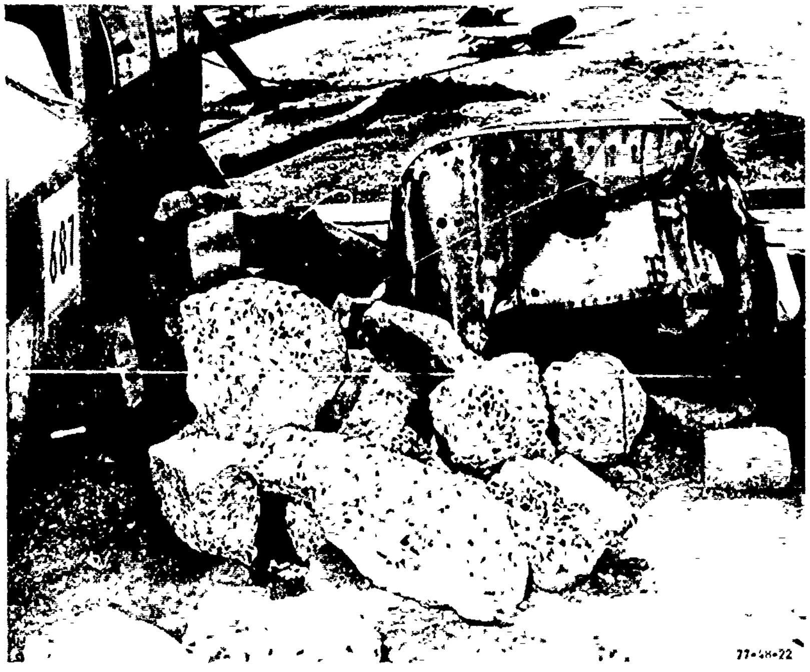

FIGURE 16. DAMAGE TO LEFT WING, TWO-PLY FUEL TANK, TEST 2

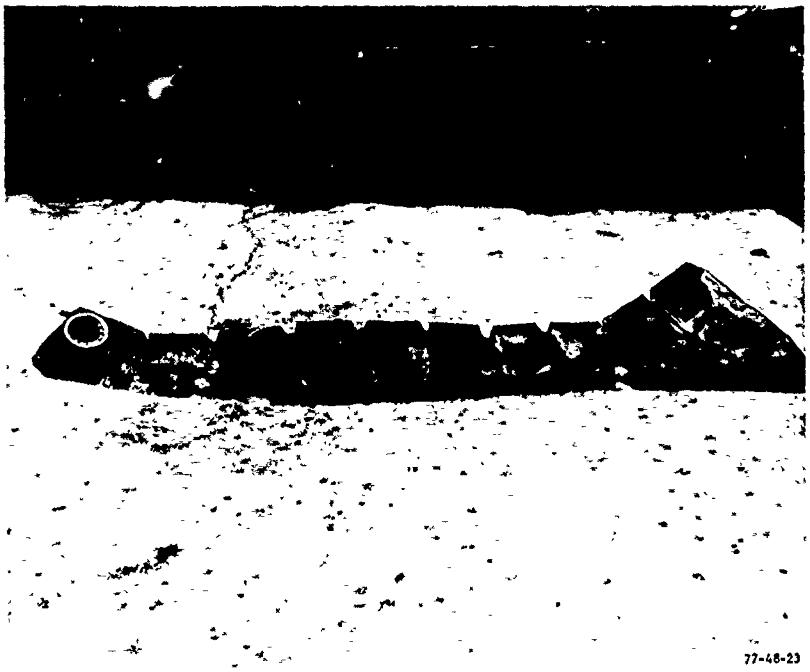

FIGURE 17. REGULAR (NON-CRASH-RESISTANT) BLADDER CELL AFTER IMPACT

FIGURE 18. DAMAGE TO REGULAR AIRCRAFT CELL DUE TO POLE IMPACT (INBOARD)

FIGURE 19. DAMAGE TO REGULAR AIRCRAFT CELL DUE TO POLE IMPACT (OUTBOARD)

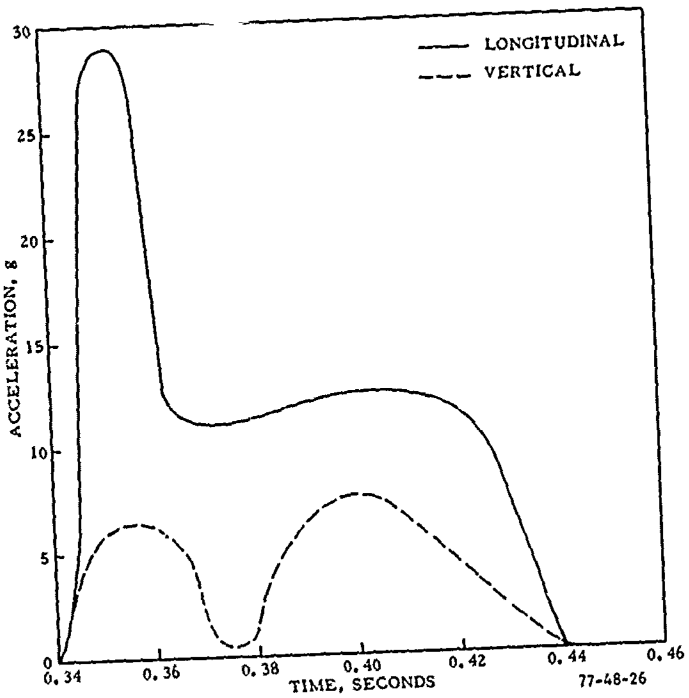

FIGURE 20. MAIN ACCELERATION PULSE, TEST 2

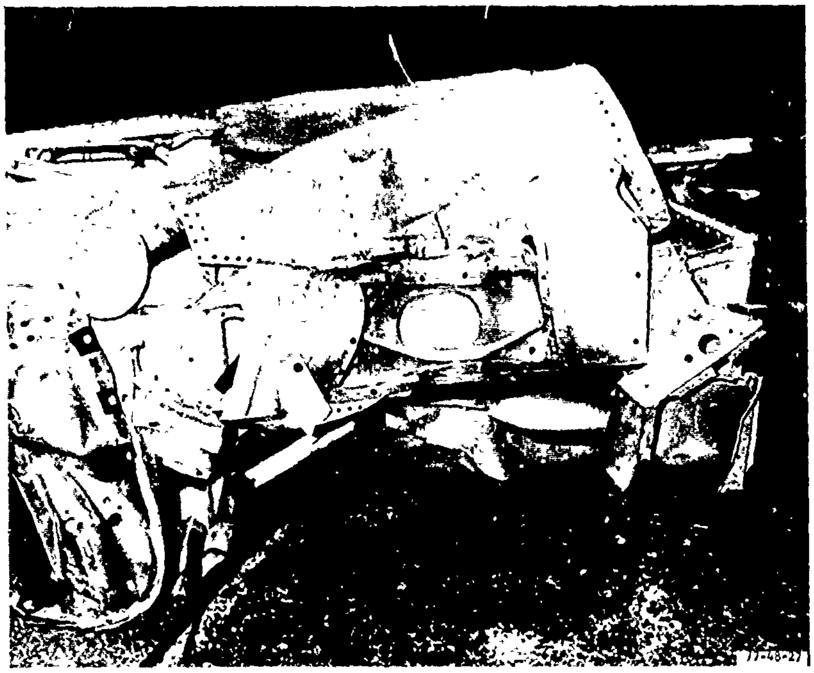

FIGURE 21. DAMAGE TO LEFT WING, TEST 3

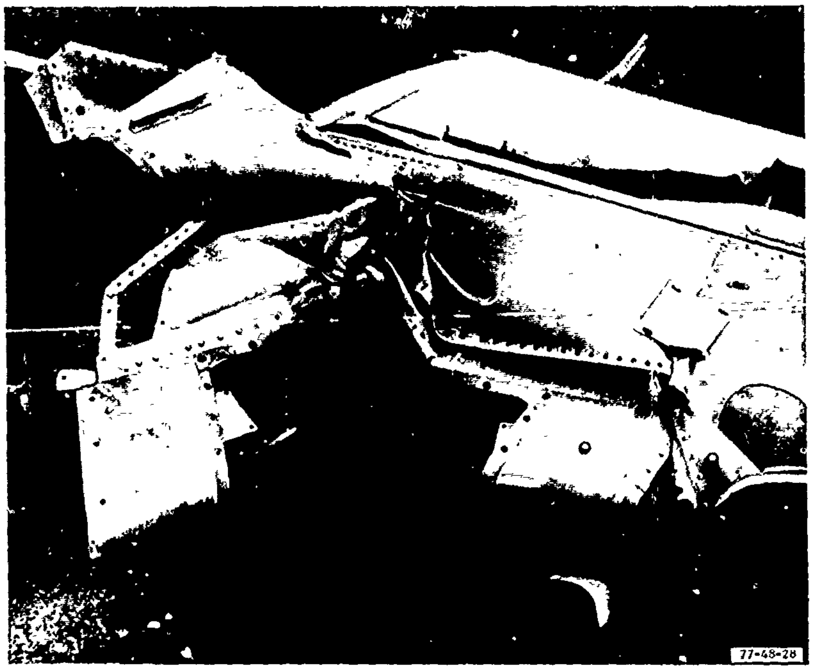

FIGURE 22. DAMAGE TO RIGHT WING, TEST 3

FIGURE 23. EFFECT OF ROCK IMPACT, TEST 3

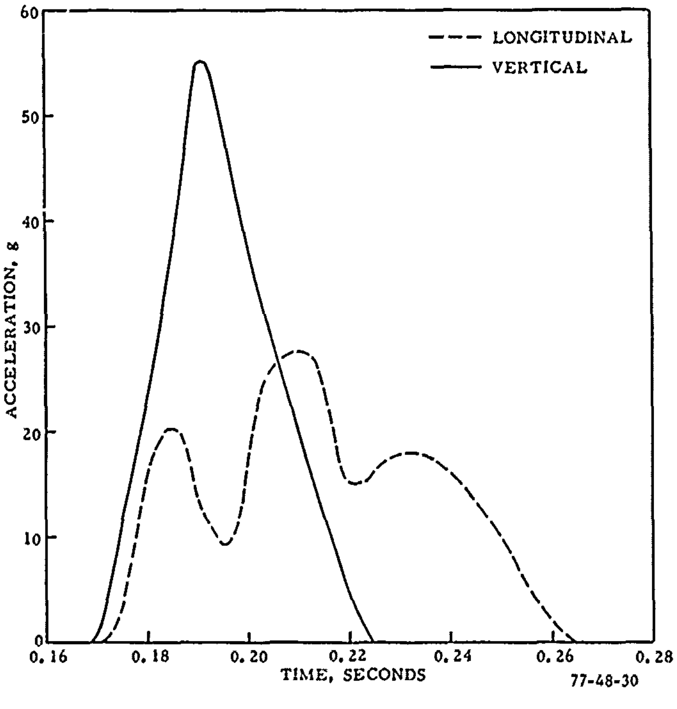

FIGURE 24. MAIN ACCELERATION PULSE, TEST 3

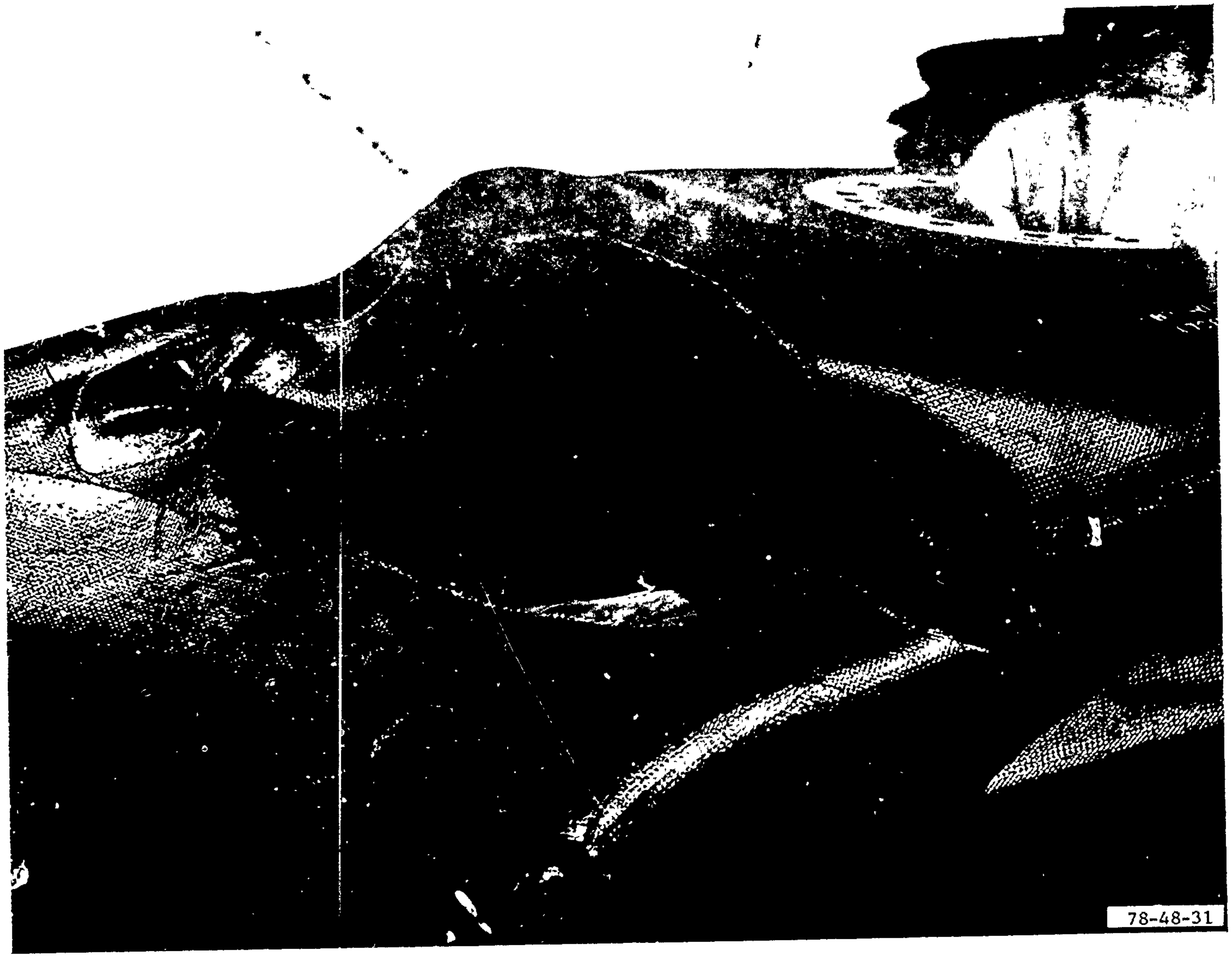

FIGURE 25. DAMAGE TO OUTBOARD AREA OF 5.5 OZ TANK

FIGURE 26. DAMAGE TO INBOARD AREA OF 5.5 OZ TANK

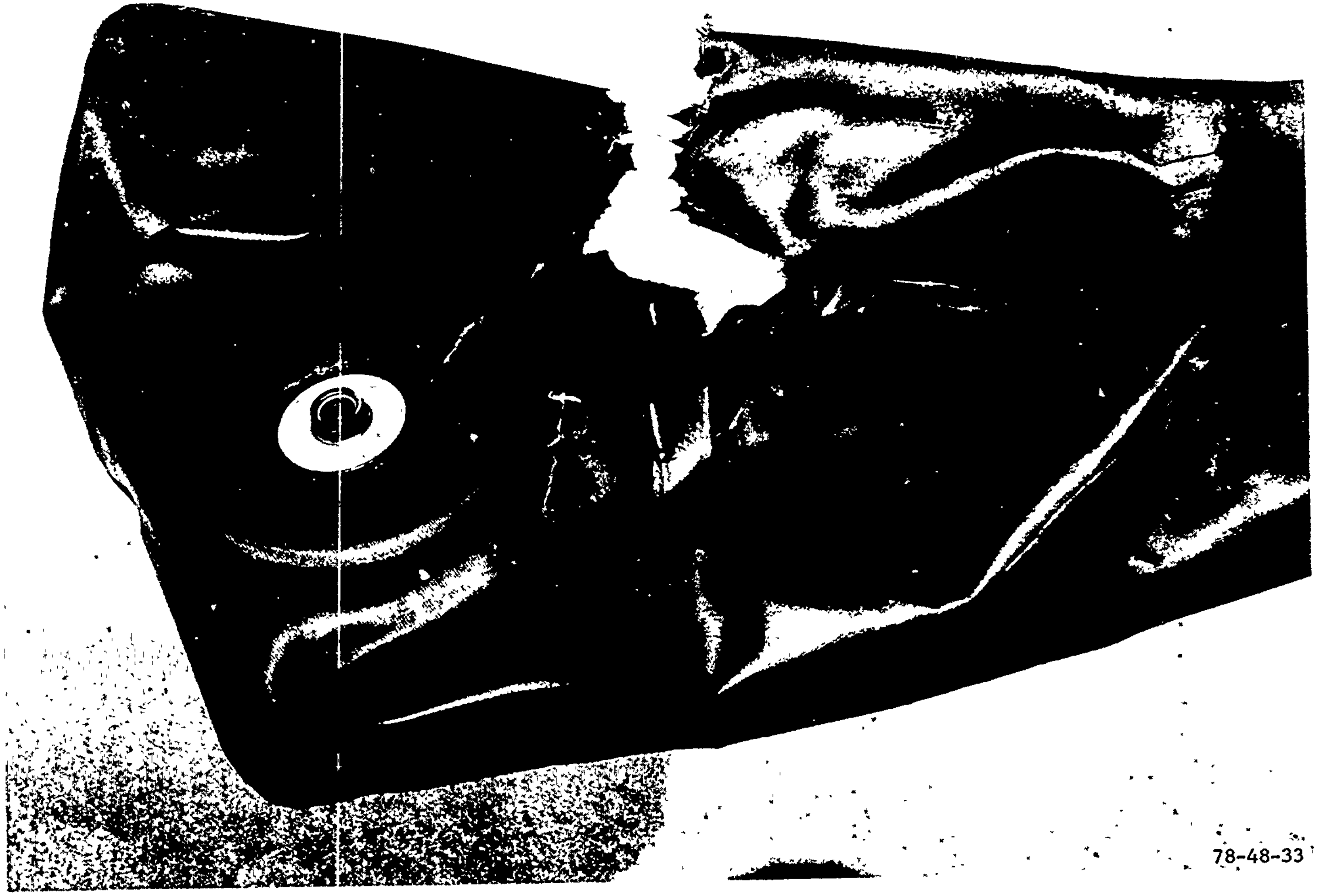

FIGURE 27. DAMAGE TO BOTTOM INBOARD AREA OF 5.5 OZ TANK

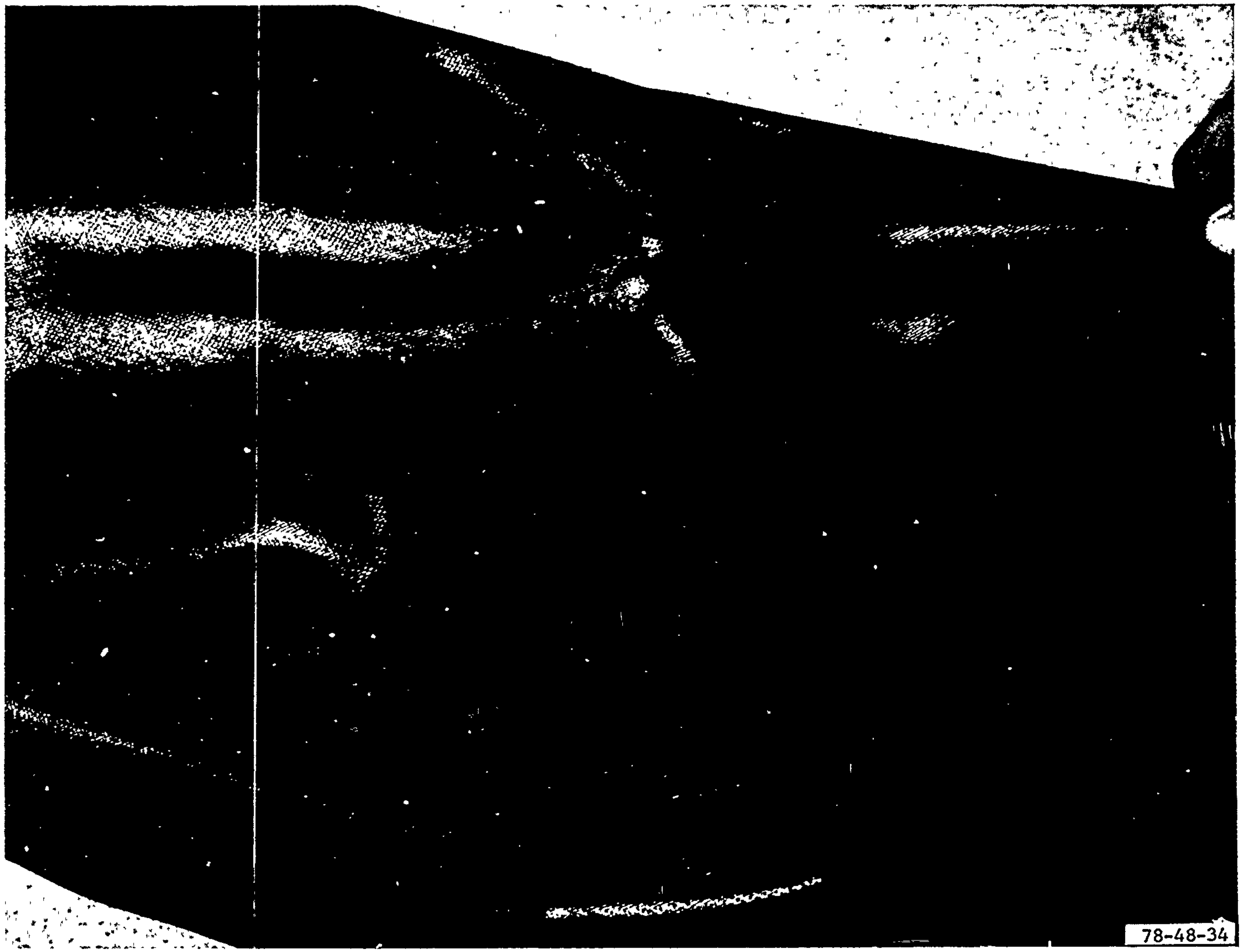

FIGURE 28. TEARS IN 8.0 OZ TANK FROM OUTBOARD POLE IMPACT

FIGURE 29. TEARS IN 8.0 OZ TANK FROM INBOARD POLE IMPACT

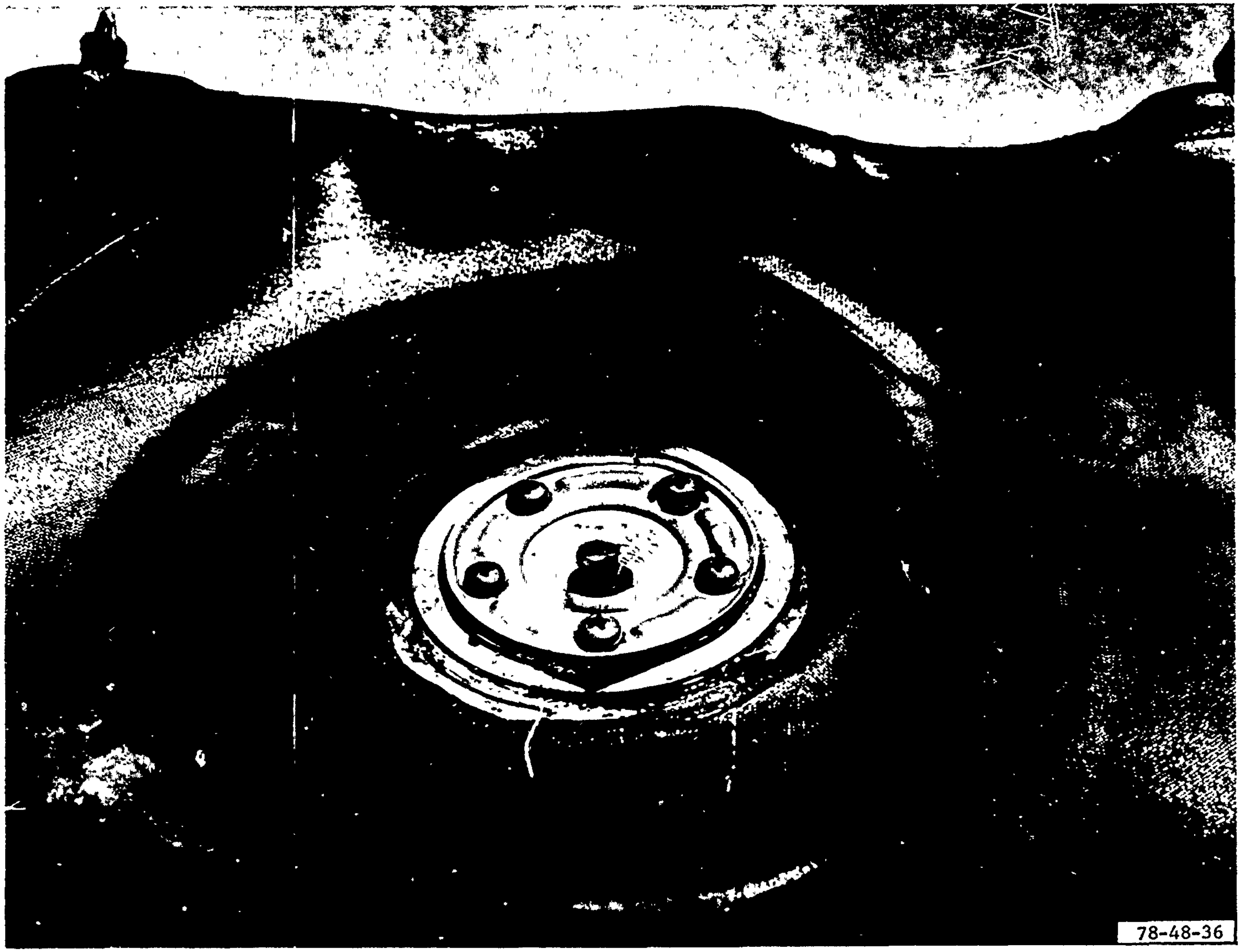

FIGURE 30. TEAR IN GAGE FITTING FLANGE OF 8.0 OZ TANK

FIGURE 31. DAMAGE TO INBOARD LEFT WING

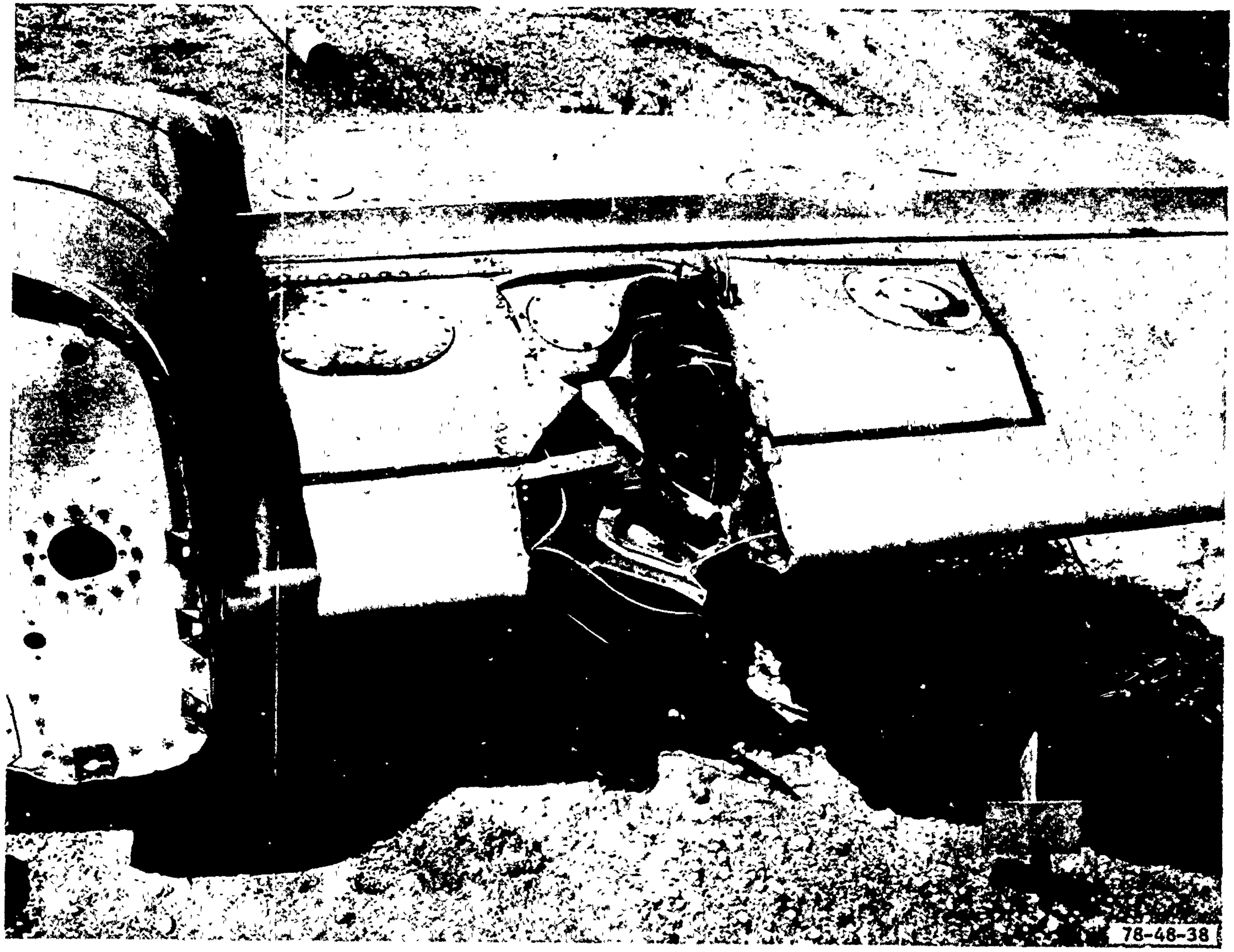

FIGURE 32. DAMAGE TO OUTBOARD LEFT WING

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FIGURE 33. DAMAGE TO OUTBOARD RIGHT WING

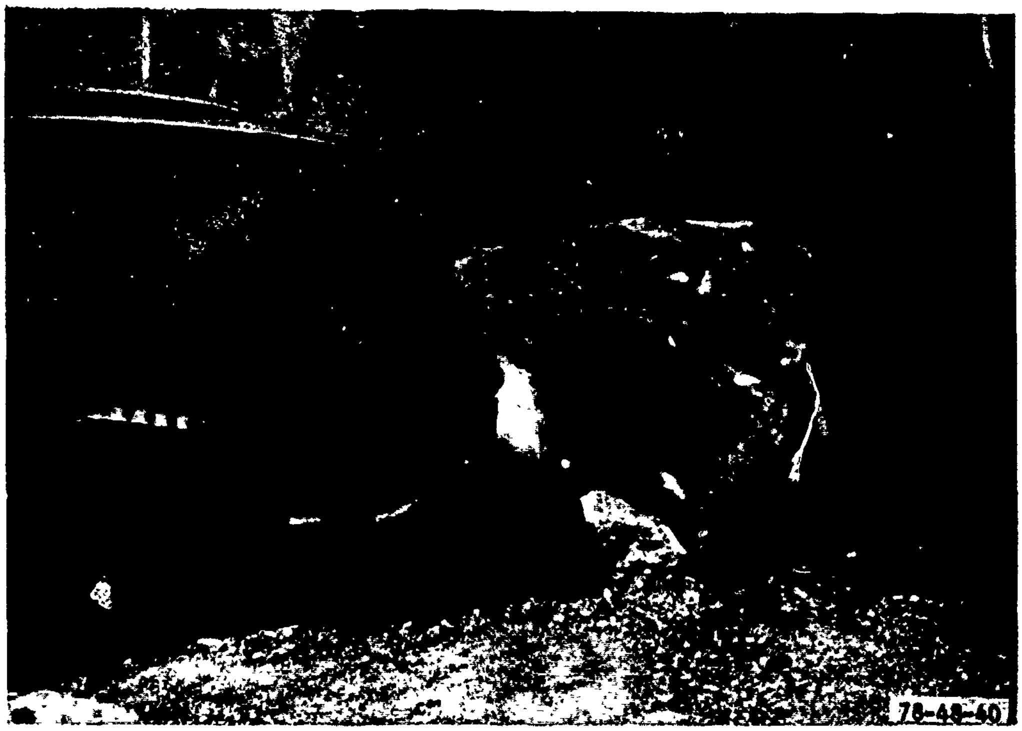

FIGURE 34. DAMAGE TO INBOARD RIGHT WING

APPENDIX A

ORIGINAL CONTRACT SPECIFICATIONS

STATEMENT OF WORK

A. Introduction

Postcrash fire accidents continue to cause a significant number of fatalities in general aviation operation. The most promising method of controlling postcrash fires, thus reducing these fatalities in small aircraft, is fuel containment. Suitable fuel containment can be provided by using flexible bladder-type fuel cells which through special construction are resistant to bursting and tearing when subjected to impact forces associated with survivable-type accidents.

Special areas for consideration are:

1. Tank seam failure or tank rupture
2. Tank impact penetration
3. Fitting pullout

United States Army Aviation Material Laboratories programs have developed crashworthy fuel cell materials for helicopter applications and have produced prototype cells for one currently-manufactured small fixed-wing aircraft. These cells, while most effective, impose weight and cost penalties which could be reduced for civil applications.

The purpose of this effort is to fabricate and test relatively lightweight, low-cost crash-resistant fuel cells which will prevent massive fuel spillage in small aircraft survivable accidents.

B. Detailed Requirements

The contractor shall provide the necessary qualified personnel, facilities, materials, equipment, and services to perform and conduct the following in the fabrication, testing, and installation of candidate crashworthy fuel cells for a typical general aviation aircraft.

1. Fabricate three crashworthy fuel cells for a typical light twin aircraft. These three cells (referred to herein as B.1 cells) are to conform in size and shape to the original main left fuel cell. All three cells shall contain two plies of 12-ounce-weight nylon fuel cell fabric.

One of these three cells will be used for the crash impact test of MIL-T-27422B, Part 4.6.7.9. as modified in paragraph B4 below. These cells shall include the following arrangement of materials in the construction.

a) An innerliner coating plus barriers and cements

b) Twelve-ounce nylon fabric, applied at 45°

c) Twelve-ounce nylon fabric, applied straight

d) An outercoat of fuel cell material

2. Fabricate three crashworthy fuel cells for a typical light twin aircraft conforming in size and shape to the original main right fuel cell. All three cells (referred to herein as B.2 cells) shall contain three plies of 12-ounce-weight nylon fuel cell fabric. If the left fuel cell fails when subjected to the crash impact test of MIL-T-27422B, Part 4.6.7.9, as modified in paragraph B.4 below, then one of these three cells will be used for the cited crash impact test. These cells shall include the following arrangement of materials in the construction.

a) An innerlayer coating plus barriers and cements

b) Twelve-ounce nylon fabric, applied at 45°

c) Twelve-ounce nylon fabric, applied straight

d) Twelve-ounce nylon fabric, applied at 45°

e) An outercoat of fuel cell material

3. All openings in the tanks shall incorporate fittings adaptable to the breakway valve or to the frangible tank port to wing surface structure, whichever is required. Valve fittings shall be sized to that breakaway tank to fuel line valve which is an off-the-shelf item and closest in size to the fuel lines used in a light twin aircraft system. Other port fittings shall conform to the sizes existing in the operational cells presently manufactured for a typical light twin aircraft. If required, additional openings shall be provided to facilitate installation of valves.

4. Four (4) samples each of the constructions of the two tanks, B.1 and B.2, shall be subjected to each of the five (5) composite construction tests of Part 4.6.5 of Military Specification MIL-T-27422B, and (1) each of tanks B.1 and B.2 shall be subjected to the crash impact test of MIL-T-27422B, Part 4.6.7.9, with the exception that the test tank shall be dropped from a height of 39 feet onto the forward or leading edge of the tank. If construction B.1 passes the 39-foot drop, construction B.2 need not be drop tested. All tests shall be conducted at Contractor's facilities.

5. All materials, including the fittings, will conform to the requirements of MIL-T-27422B.

6. All workmanship will be in conformance with the high quality requirements of MIL-T-27422B, and those of the aircraft industry.