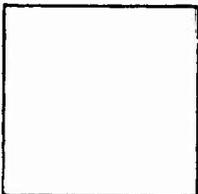


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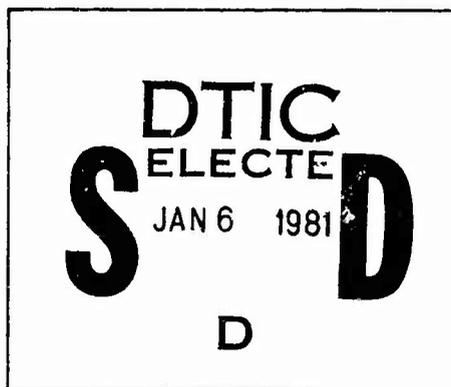
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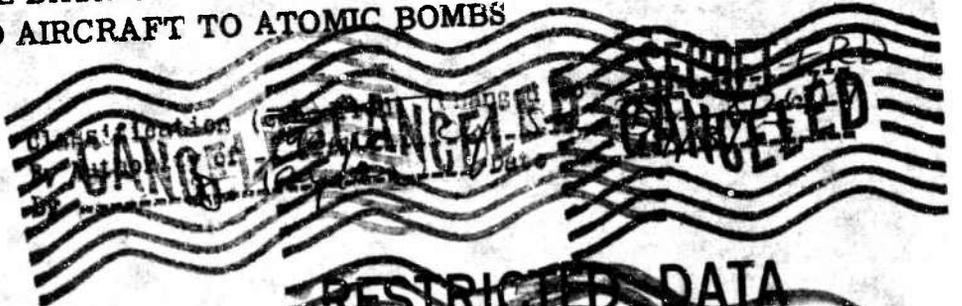
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ADDITIONAL DATA ON THE VULNERABILITY  
OF PARKED AIRCRAFT TO ATOMIC BOMBS



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**OPERATION UPSHOT-KNOTHOLE**

Project 8.1b

**ADDITIONAL DATA ON THE VULNERABILITY  
OF PARKED AIRCRAFT TO ATOMIC BOMBS**

*REPORT TO THE TEST DIRECTOR*

by

E. J. Freeh and Staff

Division of Research  
University of Dayton

and

G. T. James, Captain, USAF  
and

L. J. Breidenbach

Wright Air Development Center

October 1954

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**ABSTRACT**

Additional data on the vulnerability of parked aircraft to nuclear detonations were obtained during Operation UPSHOT-KNOTHOLE by the exposure of five fighter aircraft and three bomber aircraft for a total of 16 aircraft-exposures in six different shots. All but one aircraft had been previously exposed in Operation TUMBLER-SNAPPER. The extrapolations of previous vulnerability data to higher overpressures were checked, the higher than average damage level for a given peak overpressure was again observed in the region of precursor formation, and a preliminary investigation of the effect of strong tie-downs and thermal radiation shields was conducted. In general, the damage sustained by aircraft, tested under conditions comparable to those of previous investigations, was in reasonable agreement with predicted values based upon extrapolation of prior experimental data. The higher damage/overpressure ratio observed on aircraft exposed in the precursor region during TUMBLER 4 was again observed during Shot 10 where there was precursor formation. This higher damage level cannot yet be completely attributed to the precursor since insufficient comparative data exist from non-precursor forming, low bursts at corresponding distances in the Mach region. Although some fighter aircraft would possibly escape complete destruction at overpressures above 10 psi in a region of clean shock formation, it is believed that no present-day aircraft exposed without protection would escape complete destruction at overpressures above 10 psi within the region of precursor wave formation. The limited evaluation of tie-downs shows them to be most effective in reducing total aircraft damage for the nose-in orientation in a certain overpressure region below that required for destruction. The aluminized asbestos cloth thermal radiation shield tested was found to provide protection against damage resulting from both thermal and overpressure causes.



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FOREWORD

This report is one of the reports presenting the results of the 78 projects participating in the Military Effects Tests Program of Operation UPHOT-KNOTHOLE, which included 11 test detonations. For readers interested in other pertinent test information, reference is made to WT-782, Summary Report of the Technical Director, Military Effects Program. This summary report includes the following information of possible general interest.

- a. An over-all description of each detonation, including yield, height of burst, ground zero location, time of detonation, ambient atmospheric conditions at detonation, etc., for the 11 shots.
- b. Compilation and correlation of all project results on the basic measurements of blast and shock, thermal radiation, and nuclear radiation.
- c. Compilation and correlation of the various project results on weapons effects.
- d. A summary of each project, including objectives and results.
- e. A complete listing of all reports covering the Military Effects Tests Program.

  
  
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## PREFACE

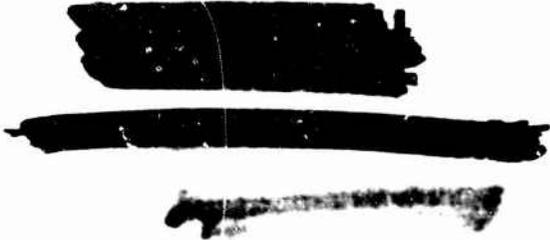
A number of aircraft remaining from the TUMBLER vulnerability tests were considered suitable for re-exposure as test vehicles for preliminary studies of the effect of certain parameters on aircraft damage and also to check the validity of certain extrapolations made to the higher overpressure regions. In view of the desirability of the data obtainable from the already exposed aircraft and the comparatively small effort and expense involved in the re-exposure, it was deemed advisable to include in the plans of Project 8.1 a program for obtaining additional data on the vulnerability of parked aircraft. In perusal of the data presented herein it should be remembered that, because of the original condition of some test vehicles, certain answers tend toward the qualitative rather than the more desirable quantitative presentation. The data obtained are applicable to the problem of determining practical expedients to be employed in the passive defense of parked aircraft. Limited material and topographical features prevented even a preliminary investigation of the degree of protection afforded by certain fabricated devices or the shielding effect of hills and heavily wooded areas.

The authors take this opportunity to thank all those whose efforts contributed toward the successful completion of this project. Special acknowledgment is made to the Air Materiel Command aircraft inspectors, E. E. Berkebile and C. M. Luttrell, for their conscientious efforts applied to the collection of aircraft damage data and to personnel from Oklahoma City Air Materiel Area for the transporting and assembling of the B-29 aircraft. The cooperation of the Field Command organization is gratefully acknowledged; in particular, the directors of Programs 8 and 9 are singled out.



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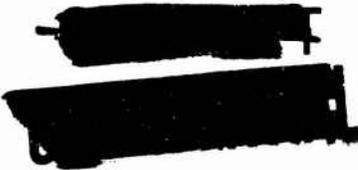
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## CHAPTER I

### INTRODUCTION

#### 1.1 GENERAL

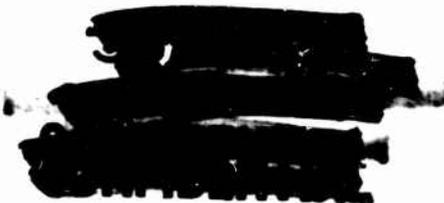
The effect of nuclear weapons on aircraft parked or flying in the vicinity of a nuclear explosion is of vital interest to the USAF in regard to both offensive and defensive operations. Knowledge of parked aircraft vulnerability is necessary for efficient application of nuclear weapons against enemy air installations and at the same time provides information that can be applied to the problem of defending friendly aircraft against enemy attack.

Initial data relating to the effects of nuclear weapons on aircraft were obtained during Operation CROSSROADS and Operation GREENHOUSE, wherein various components such as wing panels, fuselage sections, and control surfaces were exposed. On Operation BUSTER-JANGLE, one fighter aircraft and one bomber aircraft were tested to provide the first information on the vulnerability of complete aircraft parked on the ground. These data were considerably extended by full scale experiments during Operation TUMBLER-SNAPPER, wherein 28 aircraft were utilized. The test aircraft were preponderately of the World War II type with only a few modern aircraft included; consequently, present information on the vulnerability of modern aircraft is based primarily on the extension of limited data.

Analysis of the data from TUMBLER-SNAPPER indicated the desirability of checking several data points and of point checking the validity of certain extrapolations. Further, certain protective devices and procedures evolved during the analytical phase. Project 8.1b was designed to supplement the vulnerability work done in TUMBLER-SNAPPER. The specific objectives are given in the paragraph below.

#### 1.2 OBJECTIVE

The objective of Project 8.1b was to supplement previous data



on the vulnerability of parked aircraft to atomic bombs. Specifically, it was desired to determine the protection afforded by a thermal radiation shield, to study the effectiveness of using strong tie-downs, and to obtain additional information on the destruction envelope of certain fighter and bomber aircraft for the least vulnerable orientation, i. e., the nose-in orientation.

### 1.3 NATURE AND SCOPE

Experimental work necessary for the accomplishment of the above objectives was determined by the Structures Branch of the Aircraft Laboratory, WADC, and was carried out as a part of Project 8.1. The obtaining of the data necessitated little additional expense, since construction requirements were small and since, also, all but one of the test aircraft, having previously participated in Operation TUMBLER-SNAPPER, were readily available at the test site. The only aircraft acquired specifically for the test was a structurally sound, but non-operational, B-29 aircraft.

The program included the exposure of three bomber and five fighter aircraft, in six shots, for a total of 16 aircraft-exposures. The aircraft included a B-17, a B-29, a B-45, an F-86; and four F-47's. The aircraft were positioned to receive damage ranging from light to complete destruction. All aircraft were instrumented for peak skin temperature determination. Several fighter aircraft were photographed during the test phase using high speed and standard speed motion picture cameras. A preliminary investigation of the effect of strong tie-downs and thermal radiation shielding was included.

## CHAPTER 2

### PROCEDURE

#### 2.1 GENERAL

Parked fighter and bomber aircraft were subjected to the thermal and blast inputs produced by nuclear explosions to determine their structural damage vulnerability to inputs of this type. Eight non-operational aircraft were employed. Three bomber aircraft (a B-17, a B-29, and a B-45) were exposed in the Yucca Flat Area during the UPSHOT-KNOTHOLE series. The B-29 aircraft participated in four different shots, the B-17 and B-45 aircraft in one shot each. The Yucca Flat Area was chosen for bomber exposures primarily because it was more accessible to bomber aircraft than was the Frenchman Flat Area.

Five fighter aircraft (one F-86 and four F-47's) were exposed in the Frenchman Flat Area during Shots 9 and 10. Several aircraft were rigidly tied down for each shot. One fighter aircraft was shielded from thermal radiation by means of a heat resistant cloth. The response of four fighter aircraft on Shot 9 and one fighter aircraft on Shot 10 was recorded by motion picture photography during the test phase. Pre-shot and postshot still photographs were taken of all aircraft. Following exposure, all aircraft were examined by aircraft inspectors to determine the nature and extent of damage inflicted during the previous exposure.

#### 2.2 AIRCRAFT TIE-DOWNS AND THERMAL RADIATION SHIELDS

Aircraft tie-downs and thermal radiation shields were employed in an attempt to reduce thermal and blast damage to parked aircraft. The thermal radiation shield consisted of a loosely fitted cover of aluminized asbestos cloth (Asbeston) that completely covered the aircraft or portion of the aircraft to be shielded. The cover was held in

place by means of rope covered with thin aluminum foil to prevent burning. Figure 3.21 shows aircraft F-47 (297) equipped with the thermal shield prior to Shot 9.

The purpose of the tie-downs was to restrain the aircraft from being tossed about during the blast phase and thus to minimize damage caused by ground contact. To provide sufficient restraint, tie-downs must be considerably stronger than those specified in standard field tie-down procedures. The maximum attainable strength of a tie-down is limited by the strength of the mooring fitting or the structure to which the fitting is attached. Steel mooring cables 3/8 in. in diameter, having approximately the same strength as the fittings, were used in the tests conducted. These cables were anchored to cylindrical concrete deadmen 8 ft long and 18 in. in diameter, which were set vertically in the ground, flush with the grade level. All cable tie-downs were made taut by use of a cable stretcher.

### 2.3 BOMBER AIRCRAFT

A schematic drawing showing range and orientation of all bomber aircraft taking part in Shots 1, 3, 7, and 8, is given in Fig. 2.1. Relative location of ground zeros is not to scale; range and bearing of aircraft from ground zero are given as measured. Aircraft B-29 (066) was exposed in Shots 1, 3, 7, and 8, as shown. It was originally intended to include this aircraft in only three tests; however, because of the lower than anticipated yield of Shot 3, the side-in exposure was repeated in Shot 7. The B-17 and B-45 aircraft were tested in Shot 8 only. Aircraft were moored according to standard field tie-down procedures except for having extra strong cables on the nose tie-downs of the B-45 and B-29 during Shot 8. To reduce the possibility of fires, organic material was removed from the interior of the aircraft, and aluminum foil was placed inside all translucent media. The range, orientation, and anticipated overpressure are listed below.

<u>Shot</u>	<u>Aircraft</u>	<u>Orientation and Range (ft) from GZ*</u>	<u>Anticipated Overpressure</u>
1	B-29 (066)	Tail-in 7700	1.5
3	B-29 (066)	Side-in 2800	3
7	B-29 (066)	Side-in 6200	3
8	B-17 (730)	Nose-in 4450	6
8	B-29 (066)	Nose-in 4450	6
8	B-45 (481)	Nose-in 3700	8.5

\* Ground Zero

## 2.4 FIGHTER AIRCRAFT

The five fighter aircraft, one F-86 and four F-47's, were exposed in Shots 9 and 10 on the Frenchman Flat testing area. All five aircraft had been damaged to various degrees in the TUMBLER tests. The aircraft were placed at medium to high input levels on Shot 9 and then moved up to the high or very high level for Shot 10.

### 2.4.1 Shot 9

Deployment of fighter aircraft on Frenchman Flat for the Shot 9 test is shown in Fig. 2.2. All aircraft were located on an azimuth approximately northwest from ground zero with the nearest aircraft at 1725 ft and the farthest aircraft at 5300 ft. A list of the fighter exposures for Shot 9 is given below.

<u>Aircraft</u>	<u>Orientation and Range (ft) from GZ*</u>	<u>Anticipated Overpressure (psi)</u>	<u>Remarks</u>
F-47 (828)	Nose-in 1725	15	Strong tie-downs
F-47 (072)	Nose-in 2300	12	Strong tie-downs
F-86 (597)	Nose-in 2300	12	Strong tie-downs
F-47 (065)	Side-in 5300	7	
F-47 (297)	Side-in 5300	7	Thermal Radiation Shield

#### \*Ground Zero

The three nose-in aircraft in the 12 to 15 psi region were tied down with steel cable in the manner described in para. 2.2. The remaining two aircraft were tied down according to standard field procedure, except that several arrowhead anchors were used in place of one. The thermal radiation shield employed on aircraft F-47 (297) is discussed in para. 2.2. An aerial view of the four aircraft farthest from ground zero is shown in Fig. 2.3.

### 2.4.2 Shot 10

Positioning of the fighter aircraft for Shot 10 is shown in Fig. 2.4. This arrangement was designed to investigate further the damage produced in the higher overpressure regions and to provide additional data on the effect of thermal shielding at higher inputs. All aircraft were oriented nose-in at ground ranges of from 1560 ft to 2300 ft. Aircraft F-47 (297), equipped with a thermal shield during Shot 9, was moved to the 2300 ft range and the left wing and left horizontal stabilizer refitted with a thermal radiation shield. The F-86

aircraft and the F-47 aircraft from the 5300 ft station, Shot 9, were moved up to 1850 ft and securely tied down to concrete deadmen. The method of exposure is given below.

<u>Aircraft</u>	<u>Orientation and Range (ft) from GZ*</u>	<u>Anticipated Overpressure (psi)</u>	<u>Remarks</u>
F-47 (072)	Nose-in 1560	20	
F-47 (065)	Nose-in 1850	15	Strong tie-downs
F-86 (597)	Nose-in 1850	15	Strong tie-downs
F-47 (828)	Nose-in 2100	12	
F-47 (297)	Nose-in 2300	10	Thermal Radiation Shield

\*Ground Zero

## 2.5 INSTRUMENTATION

Peak skin temperature instrumentation and photographic instrumentation were employed. Peak skin temperature instrumentation involved the determination of the maximum temperature achieved by the aircraft skin as a result of thermal radiation from the fireball. Photographic instrumentation was utilized to record the thermal and/or blast phase reactions of certain fighter aircraft. All motion picture requirements were met by Program 9.

Peak skin temperatures were determined by use of maximum temperature indicating devices known as temp-tapes. Physically, temp-tapes consist of 24 small circles of temperature sensitive pigments and alloys placed on the adhesive side of a heat resistant tape 2 in. wide and 3 in. long. As the temperature of the temp-tape is raised, each sensing element melts as its melting point is reached. In application, the maximum temperature to which the device was subjected is determined by locating the highest-temperature sensing element to indicate a change and then referring to a calibration chart to find the peak temperature required to cause this change under the dynamic conditions obtaining. The temp-tapes utilized cover the temperature range from 123°F to 635°F.

Proper installation of a temp-tape must provide for the best possible heat transfer between the sensing element and the metal surface to which it is attached. To accomplish this, the surface is thoroughly cleansed to remove all paint and foreign matter. The adhesive side of the tape is placed against the clean, dry surface and pressed firmly in place to assure good contact of all the sensing elements. Temp-tapes are always placed on the side opposite that being irradiated.

Temp-tapes were installed on all parked aircraft participating

in UPSHOT-KNOTHOLE. Primarily because of accessibility considerations, most tapes were placed inside the fuselage or inside the wings. For the most part, temp-tapes were placed on unsupported areas of skin such that the nearest ribs, stringers, or bulkheads were at least 2 in. from the edge of the tape. Occasionally the structural configuration was such that areas of the required size were not provided at the desired locations, necessitating installation in the proximity of heat sinks. Interpretation of the data must take into account the effect of these heat sinks on recorded peak temperatures. Exact location of each temp-tape is given with the data.

Test phase photography was confined to the Frenchman Flat Area; consequently, only fighter aircraft were photographed. Figures 2.3 and 2.4 show the camera towers and the subject aircraft for both shots. Only five of the ten fighter aircraft-exposures were covered by motion picture photography, partially because of the high cost of the ground stabilization required for dust control. Two types of cameras were employed, namely the GSAP (Gun Sight Aiming Point) and the High-speed Eastman. The GSAP camera is an electrically driven, governor-controlled, 16 mm magazine camera. It was operated at a speed of 64 frames per second on a 50 ft magazine giving it a running time of approximately one-half minute. The High-speed Eastman was also an electrically driven 16 mm camera but was not governor controlled. So that exact frame speeds could be determined, the Eastman cameras were equipped with timing devices to place timing marks on the film. The cameras were operated at speeds of from 400 to 600 frames per second giving them about 8 sec of running time for a 100 ft roll of film. Three different types of film were used. For a particular application, the selection depended upon expected gamma radiation and the available light either from the sun or the fireball. The film used and allowable dosages were as follows: Microfile film, 600R; Background X film, 25R; Kodachrome film, 25R. Kodachrome film was employed wherever light and nuclear radiation considerations permitted its use.

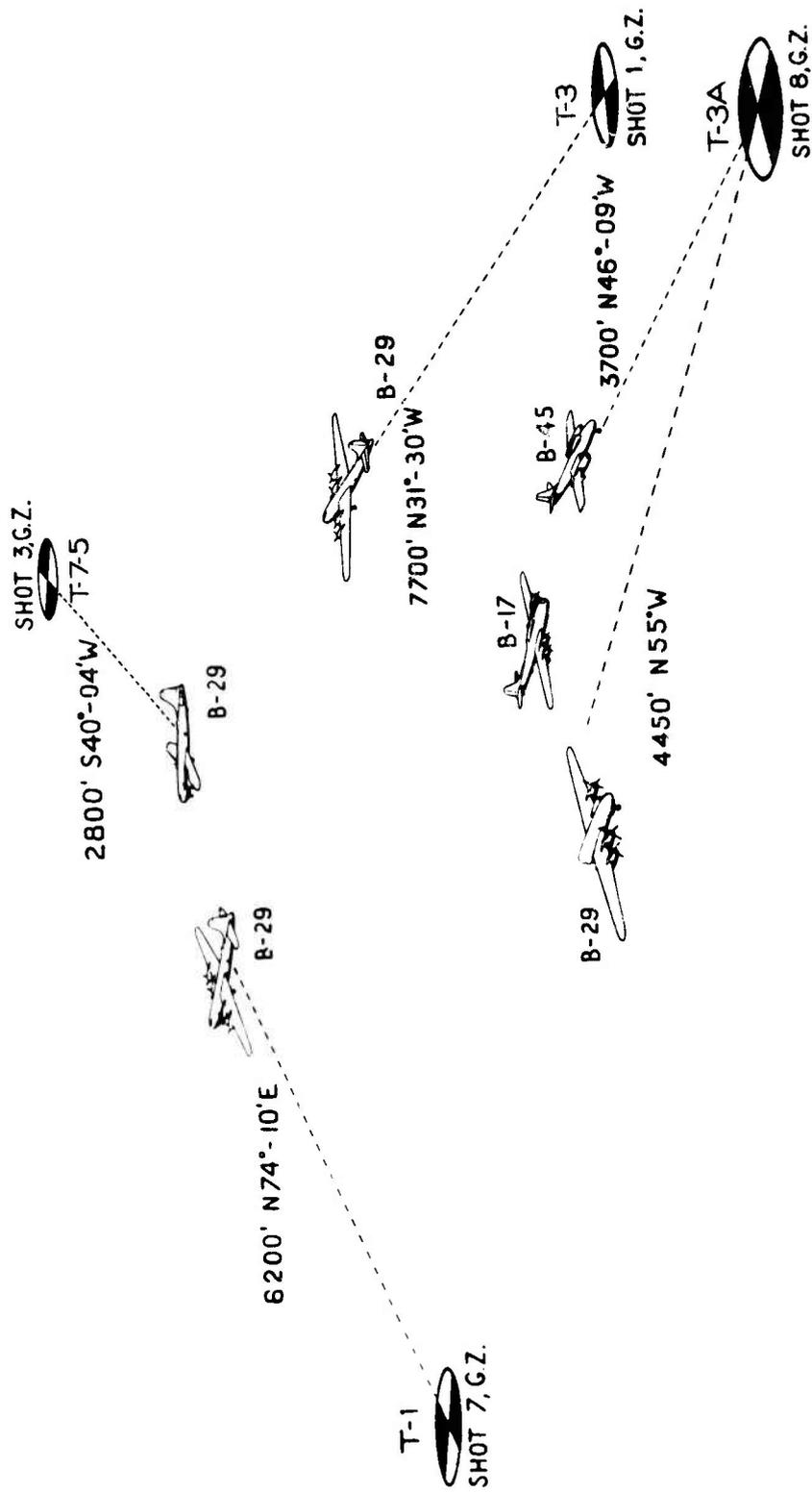


Fig. 2.1 Schematic View, Showing Range and Orientation of All Bomber Aircraft That Were Present in Shots 1, 3, 7, and 8.



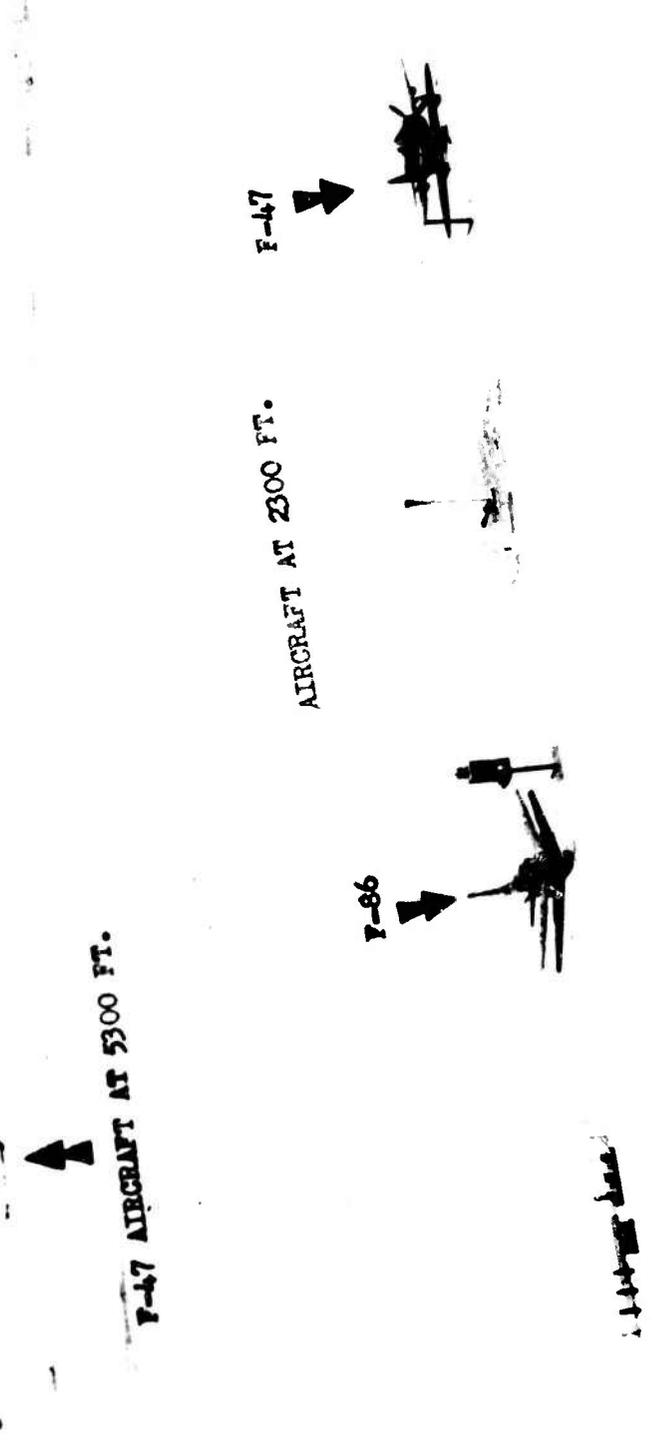


Fig. 2.3 Aerial View of Four Fighter Aircraft Farthest from Ground Zero; Shot 9

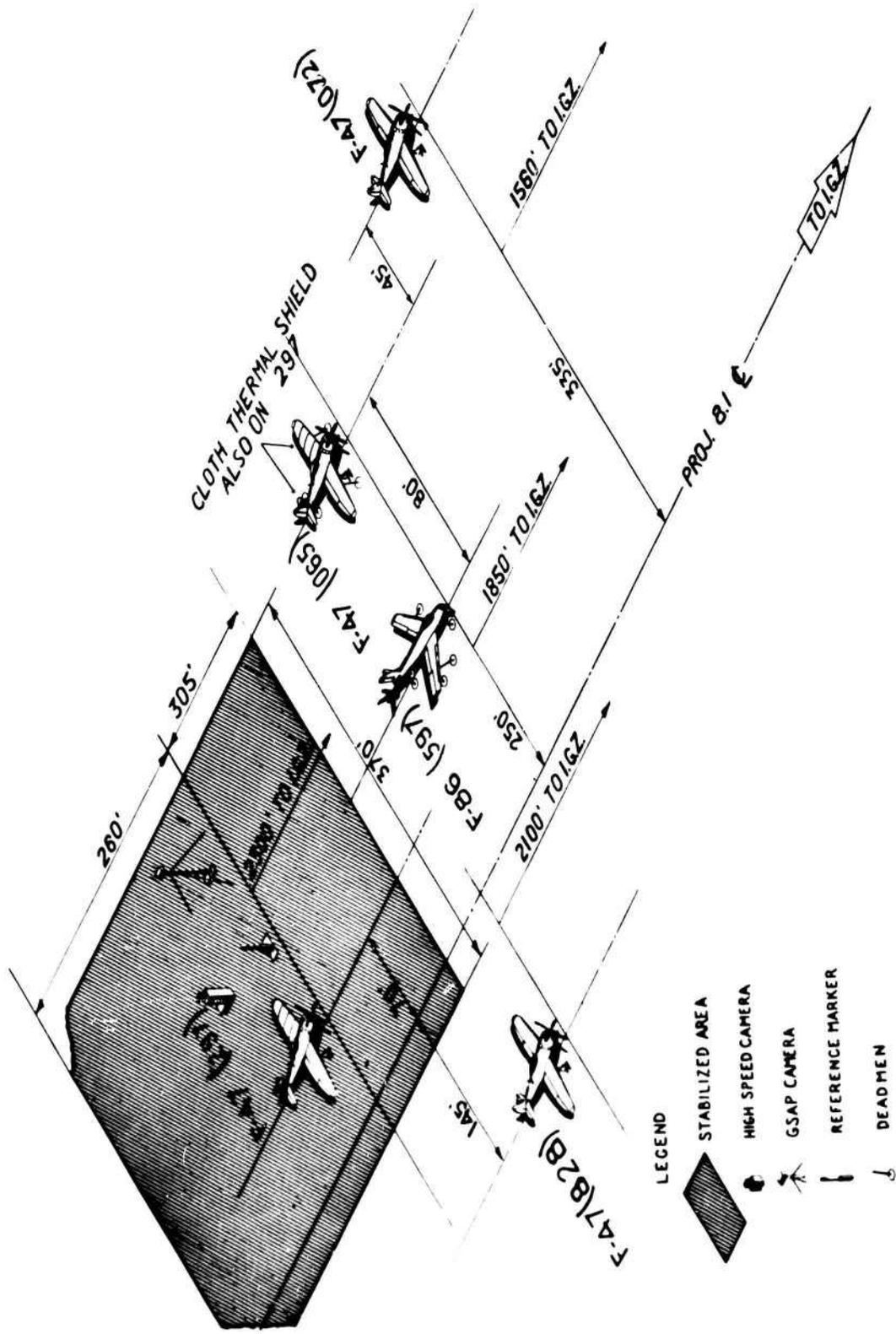


Fig. 2.4 Schematic View Showing Deployment of Fighter Aircraft for Shot 10

## CHAPTER 3

### RESULTS

#### 3.1 GENERAL

Data relating to the parked aircraft vulnerability problem were obtained by Project 8.1b participation in Shots 1, 3, 7, 8, 9, and 10. The data herein reported represent the results obtained in the multiple exposure of eight test aircraft for a total of 16 aircraft-exposures. The results are reported in the form of verbal description of the damage sustained and are supplemented by still photographs of the preshot and postshot condition of the aircraft. In addition, the damage report contains the estimated number of man-hours required to return the aircraft to an operational status if the aircraft is reparable. The damage assessment is based upon a careful before and after examination of the aircraft by Air Materiel Command aircraft inspectors. Since much of the descriptive damage is reported on the basis of aircraft station numbers, illustrations giving a rough idea of the station layout of each aircraft type exposed are presented in Figs. 3.1 to 3.5. Because of the inherent errors involved in determining the damage sustained by a previously exposed aircraft in a subsequent test, more reliability should be placed in data derived from initial exposures. The problem of multiple exposures is treated further in Discussion, Chapter 4.

The results are presented in order of increasing shot number, with the bomber aircraft results followed by the fighter aircraft results. The data on each aircraft exposure are reported separately according to the following classifications: wing, fuselage, empennage, and miscellaneous. The miscellaneous category includes such items as canopies, landing gear, windows, engine nacelles, and any other damage not considered as affecting the structure of the wing, fuselage, or empennage. The range given with each aircraft exposure is the distance in feet from the aircraft to actual ground zero. Thermal and

overpressure inputs given are from measured values when obtainable; otherwise, values quoted are based upon the reported weapon yield and upon the scaling of experimentally determined prediction curves developed from TUMBLER-SNAPPER data. Overpressures reported are peak pressures above ambient; thermal energy values represent total thermal energy per unit area incident upon a surface oriented normal to the direction of energy propagation. The aircraft orientation denotes the heading of the aircraft with respect to intended ground zero.

### 3.2 BOMBER AIRCRAFT

Detailed results of the bomber aircraft exposures are given below according to shot number. In all instances the aircraft were exposed in the Mach region. Photographs of damaged aircraft or portions thereof are presented at the end of this section in order of reference.

Prior to the test, the B-29 aircraft was classified as a "Class 26" aircraft. It had been in storage and was brought to the Nevada Proving Grounds by trailer and assembled there. The aircraft was complete from the structural standpoint but contained no electronic equipment, armament equipment, or instruments. Both the B-17 aircraft and B-45 aircraft had suffered moderate damage in the TUMBLER tests.

#### 3.2.1 Shot 1

The Shot 1 nuclear device was detonated at the top of a 300 ft tower in the Yucca T-3 Area on 17 March 1953. The reported yield was 16.2 KT. Aircraft B-29 (066) was located tail-in at a range of 7700 ft from ground zero at a bearing of N 31° 30' W, where it was subjected to an overpressure of 1.8 psi and a thermal energy of 6.2 cal/sq cm. These inputs caused only light damage to the aircraft. Complete repair would have required 322 man-hours. Approximately 45 man-hours would have been required to ready the aircraft for a one trip flight to a rear area repair depot. A description of the damage is given below with a list of figure references at the end.

#### Wing

1. Left wing tip damaged on rear inboard side adjacent to the aileron at Station 820.
2. Left-hand aileron twisted and bent upward on outer end at Station 820.
3. Fabric of left-hand aileron torn at three places on top side.

4. Left flap tail cone fairing, buckled top and bottom.
5. Rivets pulled on top of right wing from rear spar to trailing edge of wing at Station 236 and midway between rear spar and trailing edge of wing at Station 388.
6. Fabric of right-hand aileron torn at three places.
7. Right flap tail cone fairing buckled, top and bottom.

#### Fuselage

1. Left forward bomb-bay door buckled extensively.
2. Right forward bomb-bay door dented slightly.
3. Skin of panel assembly - oxygen support torn and buckled from Station 395 to Station 472. Formers twisted and torn from approximately Stations 415 to 472.
4. Skin buckled and torn, former twisted and torn rear of aft bomb-bay door from Station 612 to Station 627 for the width of the bomb-bay doors.

#### Empennage

No damage observed.

#### Miscellaneous

No additional damage noted.

#### Repair Estimate

Estimated man-hours required for complete repair, 322.

#### Figure Reference

Figure 3.6.

### 3.2.2 Shot 3

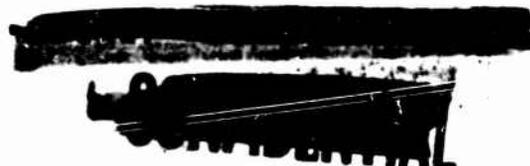
The Shot 3 detonation occurred at the top of a 300 ft tower in the T-7-5 Area of Yucca Flat on 31 March 1953. The reported yield of 0.20 KT was considerably below that expected and caused only minor damage to the B-29 aircraft parked side-in at a ground range of 2800 ft. Approximate overpressure and thermal inputs at this range were 1.2 psi and 0.8 cal/sq cm, respectively. The only component sustaining significant damage was the vertical stabilizer, which was bent sufficiently by the side-in loading to produce buckles on the compression side and a slight permanent set. An estimated 128 man-hours would have been required to ready the aircraft for an emergency flight; if new parts were available emergency repair would have required approximately 47 man-hours. The damage description follows:

#### Wing

Tail cone fairing assembly, No. 3 engine, dented on upper right-hand (outboard side). Indentations approximately 1/4 in. deep.

#### Fuselage

Skin torn and dented on oxygen support panel Station 395 to Station 472.



### Empennage

1. Left (compression) side of vertical stabilizer buckled diagonally from Station 176 to lower rudder hinge.
2. Rudder trim tab blown from rudder (not properly secured before the test).
3. Door, rear fuselage escape at Station 666, dented and bent in at top section approximately 1/2 in. over the top radius.
4. Rear running light fairing buckled.

### Miscellaneous

No damage.

### Repair Estimate

Estimated man-hours required for complete repair, 150.

### Figure Reference

Figure 3.7.

### 3.2.3 Shot 7

A 300 ft tower in the T-1 Area of Yucca Flat was chosen for the 43.4 KT Shot 7 nuclear device detonated on 25 April 1953. The same B-29 aircraft that participated in Shots 1 and 3 was parked side-in at a ground range of 6200 ft from the T-1 tower, where it was expected to receive an overpressure input of 3 psi. The yield of 43.4 KT was higher than expected, producing inputs of 3.5 psi and 30.8 cal/sq cm for blast and thermal, respectively. The blast loading caused complete failure of the fuselage aft of the trailing edge of the wings and considerable damage to the wings and forward fuselage. The aircraft was obviously damaged beyond repair. Damage noted is listed below.

### Wing

1. Left-hand outboard wing:
  - a. Skin dished and buckled from Station 603 to Station 819, top and bottom.
  - b. Trailing edge of wing buckled, twisted, and rivets pulled aft of rear spar from Station 519 to Station 819.
2. Left-hand inboard wing:
  - a. Tail cone fairing of flap assembly buckled, twisted, and rivets pulled, top and bottom.
  - b. Under section of flap twisted and canned from Station 62 to Station 510.
  - c. Wing to fuselage fillet damaged beyond repair.
  - d. Stress plate buckled under inboard fuel cell, and wing structure aft of rear spar is buckled, twisted, and rivets pulled from Station 62 to 510, top side.

3. Left-hand aileron assembly, frame twisted, fabric and ribs damaged.
4. Right-hand outboard wing:
  - a. Wing tip buckled and canted.
  - b. Trailing edge of wing from rear spar aft, Station 510 to Station 819, damaged by positive pressure; ribs, stiffeners, and skin buckled and twisted, top and bottom.
  - c. Skin on main wing structure overstressed, top and bottom, from Station 603 to Station 819 with diagonal twist on top side from leading edge of wing tip to rear spar, Station 603.
5. Right-hand inboard wing:
  - a. Wing crushed on inboard end of trailing edge.
  - b. Skin dished in and rivets pulled aft of rear spar and trailing edge twisted from Station 62 to Station 510.
  - c. Tail cone fairing buckled, twisted, and rivets pulled, top and bottom.
  - d. Undersection of flap warped and twisted from Station 62 to Station 510.
  - e. Inboard trailing edge of flap crushed from Station 62 to Station 89.
6. Right-hand aileron assembly, aileron frame twisted, fabric torn and ribs damaged.

#### Fuselage

1. Forward pressurized cabin, Station 6 to Station 218:
  - a. Formers broken and twisted and extrusions twisted on left-hand side, Stations 63, 81, 99, 117, 135, 169, and 185.
  - b. Skin buckled and twisted from Station 63 to Station 218.
2. Bomb bay, Station 218 to Station 646:
  - a. Fuselage broken off around entire periphery at Station 485 and Station 646. Rivets sheared, skin torn, and formers broken, lower left longeron bent extensively, left-hand catwalk broken, right-hand catwalk and longeron broken.
  - b. Fuselage tunnel broken off completely at Station 503 and Station 672.
  - c. Formers twisted on left-hand side at Station 238 and 258.
  - d. All four bomb-bay doors suffered major damage.
  - e. Skin buckled on left-hand side of fuselage from Station 218 to Station 646, top to bottom of fuselage.
  - f. Oxygen bottle support panel from Station 383 to 484 damaged; skin torn, formers broken, extensive

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damage to reinforcing structure.

3. Pressurized compartment Station 646 to Station 834:
  - a. All formers broken and/or twisted; extrusions, gussets and structures twisted on left-hand side Station 646 to Station 834.
  - b. Right-hand side damaged from Station 646 to Station 666.
  - c. Aft-section of tunnel at Station 646 badly twisted.
  - d. Bulkhead at Station 634 twisted and broken.
  - e. Skin buckled and twisted, rivets pulled and main structures twisted from Station 646 to Station 834.

#### Empennage

1. Vertical stabilizer crushed, skin dished in, formers twisted, and rivets pulled.
2. Left-hand horizontal stabilizer, top and bottom skin dented, structures twisted, skin dented and rivets pulled.
3. Skin, right-hand horizontal stabilizer, pressure dented; stabilizer pulled loose at fuselage junction from Station 992 to Station 1040.
4. Left and right-hand elevator twisted, broken, and fabric torn.
5. Dorsal fin crushed, skin dished in and torn, formers twisted, rivets pulled.
6. Frame of rudder assembly twisted and damaged by fire, fabric burned.

#### Miscellaneous

1. Engines and nacelles:
  - a. Cowl flaps dented and twisted.
  - b. Ring cowls buckled.
  - c. Nacelle buckled from aft of cowl flaps to nacelle tail cone; skin dented, rivets pulled, extrusions bent.
2. Left and right-hand main wheel well doors buckled, dented, and twisted.
3. No damage to landing gear and windows. No equipment installed in aircraft. Damage to hydraulic systems, oxygen systems and the like not recorded.

#### Repair Estimate

Aircraft damaged beyond repair.

#### Figure Reference

Figures 3.8, 3.9.

#### 3.2.4 Shot 8

The eighth experimental nuclear device to be tested during the series was burst atop a 300 ft tower in the T-3A Area of Yucca Flat on 19 May 1953. The weapon yield was 27.0 KT. All three

bomber aircraft participated in this shot. The B-17 aircraft and B-29 aircraft were parked 4450 ft from ground zero where they were subjected to a peak overpressure of 4.8 psi and a total thermal energy of 38.2 cal/sq cm. The entire fuselage of the B-29 aircraft aft of the wing trailing edge had to be removed prior to re-location for Shot 8 because of the severe damage suffered during the Shot 7 test. Hence, the B-29 aircraft entry was considered primarily a wing test. Considerable additional damage to the outer wing panels and wing trailing edges was sustained; however, the basic structure of the center wing appeared to be practically undamaged. The B-17 aircraft was damaged beyond economical repair. This nose-in aircraft became airborne during the blast phase, rose to an unknown height and returned to earth again approximately 20 ft to the rear of its original location. Apparently, the loads induced when the aircraft settled to earth caused the failure of both main landing gear. Engine mounts were damaged or failed when the propellers were driven into the ground. The entire under surface of the aircraft and the basic wing structure was damaged. The B-45 aircraft at 3700 ft was subjected to respective blast and thermal inputs of 56.7 cal/sq cm and 6.7 psi which caused considerable additional damage, especially in the aft fuselage section. The relatively invulnerable wings, almost undamaged prior to this test, suffered considerable overpressure damage. Description of the damage sustained by each aircraft is given individually and in greater detail in the paragraphs following:

#### 3.2.4.1 Aircraft B-17 (730)

Aircraft B-17 (730) was oriented nose-in at a ground range of 4450 ft and tied down according to standard field procedures, except for use of additional arrowhead anchor stakes. The inputs realized based upon prediction curves and reported yield, were 4.8 psi and 38.2 cal/sq cm for peak overpressure and total thermal energy, respectively. The damage description follows:

##### Wing

1. Left-hand wing assembly, inboard:
  - a. Inboard wing - ribs buckled and skin canted from Station 55 to Station 315, top and bottom sides, between front and rear spar.
  - b. Wing flap assembly - skin and formers broken, buckled, and twisted.
  - c. Fairings - wing to fuselage and wing nacelle fairings buckled and dished in.
  - d. Leading edge - ribs buckled and skin dented.
  - e. Trailing edge to rear spar - ribs and skin buckled

and bent (major damage).

2. Left-hand wing assembly, outboard:
  - a. Ribs buckled and/or broken and skin dished in from Station 315 to Station 548, top and bottom sides, between front and rear spar (major damage).
  - b. Wing tip - crushed by positive pressure, ribs buckled.
  - c. Rear spar to trailing edge - ribs buckled and/or broken, skin twisted and canned (major damage).
  - d. Leading edge - skin buckled, thermal damage to de-icer boot.
  - e. Aileron - frame buckled and fabric burned off.
3. Right-hand wing assembly - damage to the right-hand wing is approximately the same as the damage to the left-hand wing in regard to both location and extent.

#### Fuselage

1. Forward section:
  - a. Formers and bell frame buckled and/or broken over entire area from Station 0 to Station 409. Skin in this area severely buckled and torn at several places.
  - b. Pilot compartment enclosure buckled, torn, and
  - c. Right and left-hand bomb-bay doors heavily bent, skin torn and buckled.
2. Fuselage rear section:
  - a. Skin buckled and canned from Station 409 to Station 808.
  - b. Light to moderate skin canning over entire surface.

#### Empennage

1. Dorsal fin - formers buckled and/or broken, skin dished in.
2. Horizontal stabilizer, right and left - twisted, buckled, and skin overstressed (major damage).
3. Vertical fin - deformed, skin buckled.
4. Rudder - ribs buckled and fabric torn.
5. Right and left elevators - ribs buckled and fabric burned.
6. Right and left de-icer boots - thermal damage, not serviceable.

#### Miscellaneous

1. Engines and nacelles:
  - a. Nacelles and nacelle fairings buckled, twisted and skin overstressed.
  - b. Cowl flaps buckled.
  - c. All cowling buckled and canned.
  - d. Engine mounts buckled or broken.
  - e. Propeller blades bent.

2. Landing gear, right and left-hand:
  - a. Left landing gear retracting screw and linkage broken; gear collapsed, forcing retracting screw up through nacelle.
  - b. Extensive damage in right and left wheel well area.
  - c. Right landing gear retracting screw and linkage broken, gear collapsed.
3. Windows:
  - a. Nose section and all navigator's side windows broken.
  - b. Pilot's and co-pilot's side windows broken.
  - c. Top stationary windows and removable windows broken.
  - d. Tail gunner window and right and left waist gunner windows broken.

Repair Estimate

Aircraft damaged beyond economical repair.

Figure Reference

Figures 3.10, 3.11.

3.2.4.2 Aircraft B-29 (066)

The B-29 aircraft minus the aft fuselage was oriented nose-in at 4450 ft from ground zero adjacent to the B-17 aircraft. The nose mooring fitting, located atop the forward landing gear, was tied to a concrete deadman using 3/8 in. steel cable.

From scaling of height-of-burst curves, it was determined that the aircraft was subjected to the following approximate inputs: peak overpressure, 4.8 psi; total thermal energy, 38.2 cal/sq cm. A description of the damage sustained is presented below.

Wing

1. Left-hand inboard wing:
  - a. Stress plate buckled under inboard fuel cell.
  - b. Trailing edge of wing aft of rear spar buckled, twisted, rivets pulled, ribs bent and/or broken from Station 62 to Station 510.
  - c. Wing to fuselage fillets dented and torn.
  - d. Flap assembly - over-all structure of flap deformed, skin canning over entire area, top and bottom.
2. Left-hand outboard wing:
  - a. Trailing edge of wing aft of rear spar buckled, ribs and stiffeners buckled and/or broken, skin stretched and torn (major damage).
  - b. Skin of outboard wing buckled and rivets pulled, ribs buckled and/or broken between front and rear spar.

- c. Wing tip assembly - tip twisted, rivets pulled, ribs buckled and/or broken, skin collapsed on top and bottom side.
- d. Aileron assembly - frame twisted, ribs buckled, and fabric blown from aileron.
- 3. Right-hand inboard wing:
  - a. Wing crushed on inboard end of trailing edge aft of rear spar, skin dished in, ribs buckled and/or broken, rivets pulled and general buckling from Station 62 to Station 510.
  - b. Wing to fuselage fillets dented and torn.
  - c. Flap assembly - surface and general structure distorted over entire length, top and bottom.
- 4. Right-hand outboard wing:
  - a. Station 510 to Station 820 - skin overstressed, diagonal buckles on top side of wing from outboard leading edge to rear spar at Station 510; ribs are buckled and/or broken and rivets pulled; ribs, stiffeners, and skin of wing trailing edge from rear spar aft bent and buckled (major damage).
  - b. Wing tip assembly - twisted, rivets pulled, ribs buckled and/or broken, skin collapsed on top and bottom sides.
  - c. Aileron assembly - frame twisted, ribs buckled and/or broken, fabric blown from aileron.

#### Miscellaneous

- 1. Landing gear:
  - a. Nose strut torsion links bent.
  - b. Nose strut yoke bent.
  - c. Nose wheel well doors damaged extensively.
  - d. Shimmy damper damaged.
  - e. Strut assembly of right and left-hand main landing gear subjected to excessive lateral stress.
  - f. Main wheel well doors buckled, twisted, skin dented and rivets pulled.
- 2. Engine nacelles:
  - a. Nacelle buckled from aft of engine cowl flaps to nacelle tail cone.
  - b. Skin dented, rivets pulled, and extrusions buckled.
  - c. Nacelle tail cone fairing dented, twisted, and rivets pulled.
  - d. Gear box for main wheel well door actuator broken.
- 3. Forward fuselage not re-inspected.

#### Repair Estimate

Aircraft damaged beyond repair.

Figure Reference

Figure 3.12.

3.2.4.3 Aircraft B-45 (481)

The closest aircraft to ground zero during Shot 8 was the nose-in B-45 aircraft at a range of 3700 ft. The aircraft was tied down conventionally, except for an extra strong nose tie-down. Calculated overpressure and thermal inputs at this range were 6.7 psi and 56.7 cal/sq cm, respectively. A detailed description of damage is given below.

Wing

1. Left-hand wing assembly:
  - a. Skin and wing trailing edge buckled from Station 29 to Station 517 and from rear spar aft to trailing edge, top and bottom.
  - b. Ribs buckled and skin dished in on left-hand flaps, inboard and outboard.
  - c. Aileron skin buckled and canned.
  - d. Wing tip skin buckled and overstressed, top and bottom sides.
  - e. Fillets buckled, inboard and outboard of nacelle, from wing leading edge and engine nacelle.
  - f. Slight buckle in leading edge just outboard of nacelle from Station 212 to Station 235.
  - g. Minor skin stretching over entire wing area, top and bottom.
2. Right-hand wing assembly damaged at approximately the same locations and to the same extent as left-hand wing except for item (f).

Fuselage

1. Formers buckled or broken, skin torn and buckled from Station 475 to Station 774, rear fuselage section.
2. Left forward bomb-bay door buckled and torn (right forward bomb-bay door not installed).
3. Bulkhead at Station 475 caved in; door to pilot's end of forward bomb bay demolished, life-raft compartment door demolished.
4. Left-hand forward escape and bombardier's escape hatch crushed in.
5. Entrance door to non-pressurized compartment blown in.
6. Entire radome area demolished.
7. Damage to forward fuselage only slightly greater than preshot.

8. Negligible additional damage to the intermediate fuselage.

#### Empennage

1. Skin of right and left-hand horizontal stabilizer buckled and canned.
2. Ribs of vertical stabilizer buckled and skin canned over entire area.
3. Skin of right and left-hand elevators and trim tabs buckled and canned.
4. Rudder assembly - ribs buckled and skin dished in.
5. Dorsal fin - buckled on right and left sides from Station 525 to Station 713.

#### Miscellaneous

1. Engine nacelle covering, Station 35 to 160 - entire upper surface damaged, formers buckled, skin canned; thermal damage to upper skin.
2. Forward engine nacelle doors buckled and skin dented.
3. Intermediate nacelle door buckled.
4. Rear nacelle door buckled and skin canned.
5. Hinge torn off main wheel-well door.
6. Canopy cracked.
7. Internal equipment not inspected.

#### Repair Estimate

Aircraft damaged beyond economical repair.

#### Figure Reference

Figures 3.13, 3.14.

### 3.3 FIGHTER AIRCRAFT

Results of fighter aircraft exposures are given below according to shot number, beginning with the aircraft closest to ground zero and proceeding outward in order of increasing range. Photographs to supplement the verbal description of aircraft damage are presented at the end of this section and are arranged in order of reference. Pre-shot and postshot photographs are included.

All five aircraft used in this study were damaged to varying degrees prior to participation in Shots 9 and 10. In the two shots the aircraft were subjected to peak overpressures ranging from 5.1 to 14 psi and total thermal energies of from 20 to 82 cal/sq cm. Damage ranged from moderate to complete destruction. An itemized presentation of the damage sustained by each aircraft is given below according to shot number.

#### 3.3.1 Shot 9

The Shot 9 weapon, an air-drop, was detonated at a height of

2423 ft above the Frenchman Flat Area on 8 May 1953. Actual ground zero was 837 ft south and 15 ft west of intended ground zero. The reported yield was 26.0 KT, 5.0 KT below predicted yield.

Because of bombing error and reduced yield inputs, especially at the close-in stations, were considerably below anticipated values. Also, thermal and blast incidence angles were affected by the error. Five fighter aircraft were deployed on the lake bed along the Project 8.1 azimuth. The aircraft closest to ground zero suffered major damage as a result of the 12.5 psi peak overpressure and 58 cal/sq cm total thermal energy realized at this range. The unprotected F-47 aircraft farthest from ground zero sustained moderate to heavy damage. Thermal and blast inputs at this range were 5.1 psi and 20 cal/sq cm, respectively. Damage to the two intermediate aircraft was heavy, with the F-47 aircraft sustaining greater damage than the F-86 aircraft. The detailed damage description and supplemental photographs for each participating aircraft is given below.

#### 3.3.1.1 Aircraft F-47 (828)

The aircraft closest to ground zero, F-47 (828), was parked nose-in at a ground range of 2441 ft from actual ground zero and tied down to concrete deadmen. Actual blast incidence was  $12.1^{\circ}$  right of head-on because of the southerly bombing error. The aircraft was subjected to a peak overpressure of 12.5 psi and a total thermal energy of 58 cal/sq cm. These inputs caused heavy damage to the entire aircraft. The empennage was severely damaged; the horizontal stabilizers were torn loose from the aircraft. The major portion of the fuselage was buckled and twisted and had many broken formers. The wings were in relatively better shape but were nevertheless damaged beyond economical repair. The inspection report is given below.

#### Wing

1. Left-hand wing assembly:
  - a. Wing twisted and buckled, skin dished in, top and bottom, Station 9 to Station 232.
  - b. Trailing edge buckled, skin dented and rivets pulled, Station 9 to Station 232.
  - c. Wing tip collapsed.
  - d. Structural damage to skin and ribs from Station 202 to Station 232.
  - e. Gun-bay door buckled and severely deformed.
  - f. Extensive skin damage to ammunition-bay door; skin dented, rivets pulled and door twisted.
  - g. Holes burned in skin on leading edge between Station 202 and Station 212.

- h. Gun-port cover torn and holes burned in skin.
- i. Spar web and stiffeners in main wheel well buckled and twisted from Station 27 to Station 60.
- k. Running light cover burned.

Note: Flaps and ailerons were not installed. Previous experience indicates these components would probably have been blown off or suffered extensive damage, if subjected to inputs of this magnitude.

#### Fuselage

- 1. Fuselage buckled and skin dented over entire area from Station 71 to Station 180.
- 2. Fuselage buckled, twisted, and formers broken from Station 180 to Station 385, both sides, top and bottom.
- 3. Flap to fuselage fillet torn and buckled.
- 4. All wing to fuselage fillets and fairings torn and/or buckled.
- 5. Tail fairing buckled and twisted from Station 71 to Station 267.
- 6. Supercharger airduct and fairing damaged extensively.

#### Empennage

- 1. Horizontal stabilizers, right and left-hand, torn from aircraft and demolished.
- 2. Vertical stabilizer - buckled, spar twisted, skin overstressed, and rivets pulled.

Note: Elevators and rudder assembly not installed prior to test.

#### Miscellaneous

- 1. Left-hand main strut assembly severely bent.
- 2. Main doors for left and right main landing gear buckled extensively.
- 3. Drop-tank fairing buckled.
- 4. All propeller cuffs burned and blown off.
- 5. Right and left side of engine cowling torn and dented; evidence of thermal damage.
- 6. Bottom side cowling buckled and torn.
- 7. Two engines' cowl flaps severely bent.
- 8. Engine accessory cowling right and left sides buckled and dented.

Note: Pilot's canopy not installed; internal inspection not made.

#### Repair Estimate

Aircraft damaged beyond economical repair.

#### Figure Reference

Figure 3.15.

3.3.1.2 Aircraft F-47 (072)

Aircraft F-47 (072) was parked nose-in and strongly tied down at a distance of 2300 ft from intended ground zero. Since actual ground zero was over 800 ft south of target ground zero, the actual horizontal range to ground zero became 2981 ft and the aircraft heading changed to  $10.7^{\circ}$  left from true nose-in. The peak overpressure of 12 psi and total thermal energy of 49 cal/sq cm realized at this range caused extensive damage to the aircraft structure. The wings, damaged beyond economical repair, represented the major component in the best condition. The blast loading failed the tail and right wing tie-downs. Motion pictures show that the aircraft actually became airborne during the blast phase. The damage description follows.

Wing

1. Left-hand wing assembly:
  - a. Skin dented and buckled, stringers bent aft of rear spar from Station 9 to Station 232, top and bottom.
  - b. Ribs and structure extensively damaged from Station 182 to Station 232.
  - c. Aileron assembly - twisted and torn, skin crushed.
  - d. Trailing edge, Station 9 to Station 232 - buckled and bent, top and bottom sides.
  - e. Leading edge - warped and dented, holes burnt in skin at Station 182 to Station 232.
  - f. Gun-bay door buckled, skin dented, formers bent.
  - g. Ammunition door - formers bent, skin dented.
  - h. Left-hand running light assembly damaged by thermal radiation.
  - i. Flap assembly buckled, twisted, skin overstressed and torn.
  - j. Pitot tube blown off, adjacent skin torn.
  - k. Gun port torn and burned.
  - l. Stiffeners and spar, aft side of main wheel well, buckled and twisted, rivets pulled at gussets.
  - m. Wing tip crushed, major sub-structure damage.
  - n. Wing to fuselage fillets buckled.
2. Right-hand wing assembly - the damage to the right-hand wing is approximately the same and at the same locations as that quoted above for the left-hand wing. Additional item noted: aileron assembly torn from aircraft.

Fuselage

1. The fuselage was a complete loss. From Station 71 to Station 180 the fuselage was buckled and the skin heavily canned around entire periphery.

2. From Station 180 to Station 385, the fuselage was buckled and twisted with many formers broken and skin canted over entire area.
3. Tail fairing buckled and twisted from Station 71 to Station 267.
4. All wing to fuselage fillets and fairings torn and/or broken.
5. Supercharger airducts and fairing damaged extensively.

#### Empennage

1. Vertical stabilizer buckled, twisted and torn.
2. Left and right-hand horizontal stabilizers demolished; stabilizer rear spar broken off approximately 6 in. outboard of inner elevator hinge.
3. Left and right-hand horizontal stabilizer fuselage fillet torn and buckled.
4. Rudder assembly - skin torn and buckled, entire structure deformed, top 18 in. blown off.

#### Miscellaneous

1. Left-hand main wheel brake plate broken.
2. Main struts bent.
3. Main wheel door buckled.
4. Propeller cuffs burned and broken.
5. Engine cowling dented, some thermal damage to leading edge.
6. Engine accessory cowling buckled and dented.
7. Canopy not installed; inspection of internal components and equipment not made.

#### Repair Estimate

Aircraft damaged beyond economical repair.

#### Figure Reference

Figures 3.16, 3.17.

### 3.3.1.3 Aircraft F-86 (597)

The F-86 aircraft was parked adjacent to F-47 (072) oriented nose-in, and rigidly tied down. The true ground range was 2951 ft, 651 ft farther than intended. Overpressure and thermal inputs were 12 psi and 49 cal/sq cm, respectively. Normal and high speed motion pictures of the test phase reaction of the aircraft were obtained. The tie-down fitting to the right wing broke but the aircraft remained essentially in the same position. The forward and rear fuselage sections suffered heavy damage. Damage to wings and empennage was moderate. The intermediate fuselage (between wings) suffered light to moderate damage. The damage description is presented below.

#### Wing

1. Left-hand wing assembly:

- a. Skin dented and buckled on bottom of leading edge, over entire area, Station 7 to Station 251.
  - b. Skin on trailing edge of wing from rear spar to trailing edge, overstressed minor buckles, top and bottom, Station 70 to Station 262.
  - c. Skin canned and dented, Station 251 to Station 262.
  - d. Wing tip antenna covering damaged by thermal radiation.
  - e. Running light covering cracked.
  - f. Skin top side of leading edge, overstressed, dented and lightly buckled from Station 7 to Station 35.
  - g. Flap assembly - skin dished and buckled and structure twisted over entire area, top and bottom.
2. Right-hand wing assembly:
- a. Damage is approximately the same in regard to both location and extent as that noted above for the left-hand wing assembly.
  - b. Right and left-hand ailerons were not installed.

#### Fuselage

- 1. Laminated nose section crushed and charred.
- 2. Extensive damage to fuselage aft section from Station 245 to Station 308, right and left-hand sides; formers broken, bent and twisted, main longerons bent, skin buckled and torn.
- 3. Radar and battery compartment access door crushed in and surrounding fuselage damaged.
- 4. Access doors to right and left hand gun compartments crushed in.
- 5. Speed brake doors buckled.

#### Empennage

- 1. Vertical stabilizer - leading edge skin buckled and dented.
- 2. Right and left-hand horizontal stabilizer leading edges buckled on top side.
- 3. Both elevators buckled and twisted, skin canned.
- 4. Rudder buckled and skin dished in.
- 5. Dorsal fin lightly buckled.

#### Miscellaneous

- 1. Main door for main landing gear buckled.
- 2. Pilot's windshield side glass broken.
- 3. Canopy not installed; internal equipment not inspected.
- 4. Weld failure in right wing tie-down fitting (defective weld).

#### Repair Estimate

Aircraft damaged beyond economical repair.

#### Figure Reference

Figure 3.18, 3.19.

3.3.1.4 Aircraft F-47 (065)

Aircraft F-47 (065) was parked side-in at a range of 5936 ft from ground zero where it received a peak overpressure of 5.1 psi and an incident total thermal energy of 20 cal/sq cm. These inputs caused moderate to heavy damage to the aircraft. Damage was heaviest on the blast side of the fuselage and the empennage. The side-on loading broke the tail tie-down and the left wing tie-down. Part of the rudder was blown off. The test phase reaction of the aircraft was recorded by motion picture photography. The inspection report is given below.

Wing

1. Left-hand wing assembly:
  - a. Station 202 to Station 232 - wing buckled, skin and substructure damaged.
  - b. Ammunition-bay door - skin buckled and dished.
  - c. Gun-bay door - skin buckled and dished.
  - d. Wing scorched from Station 202 to Station 232.
  - e. Skin of wing tip buckled and canned.
  - f. Spar web and stiffeners in aft side of main wheel well buckled from Station 27 to Station 64.
  - g. Ailerons and flaps not installed.
2. Right-hand wing assembly - damage to right wing essentially identical to that quoted above for the left-hand wing assembly.

Fuselage

1. Fuselage formers bent, skin buckled and torn, right and left side, from Station 164 to Station 358. Right-hand side sustained greater damage.
2. Supercharger airduct fairing buckled and bent.
3. Fillet between leading edge of right wing and fuselage buckled.
4. Baggage compartment door blown from aircraft.
5. Tail fairing buckled and canned.

Empennage

1. Vertical stabilizer - buckled, twisted, skin canned, top and bottom.
2. Lower two-thirds of rudder blown off aircraft.
3. Right and left horizontal stabilizers bent and buckled over entire area, top and bottom.
4. Elevators not installed.

Miscellaneous

1. Left tail wheel door broken.
2. Right side engine cowling buckled.



3. Entire accessory cowling section buckled.
4. Canopy not installed; aircraft interior not inspected.

Repair Estimate

Aircraft damaged beyond economical repair.

Figure Reference

Figure 3.20.

3.3.1.5 Aircraft F-47 (297)

Aircraft F-47 (297) was parked left side-in at a range of 5936 ft from actual ground zero. Blast incidence was  $5.5^{\circ}$  from true side-on. This aircraft was equipped with a cloth thermal radiation shield, as discussed under Procedure. A peak overpressure of 5.1 psi and a total thermal energy input of 20 cal/sq cm was realized at this parking station. The thermal radiation caused some charring of the shield where the incidence angle was low and the reflectivity of the aluminized surface was greatly reduced because of the dust and grime. The blast phase caused considerable damage to the loose fitting cloth cover. Over-all damage to the aircraft was considerably less than that sustained by the control aircraft, F-47 (065). The left side of the fuselage suffered the greatest damage. The damage description is given below.

Wing

1. Left-hand wing assembly:
  - a. Skin buckled from Station 202 to Station 232, top and bottom, rivets pulled and several ribs bent.
  - b. Inboard trailing edge of aileron buckled.
  - c. Flap assembly buckled, top and bottom.
  - d. Skin of gun-bay door canned.
2. Right-hand wing assembly:
  - a. Skin canned from Station 202 to Station 232.
  - b. Skin of ammunition-bay door canned.

Fuselage

1. Left side of fuselage - skin canned, formers buckled and rivets pulled from Station 180 to Station 353.
2. Right side of fuselage - skin and stringer broken at two places between Station 215 and Station 250.
3. Skin formers, and stringers buckled from Station 321 to Station 358, (check photo to determine which side).
4. All fairing under fuselage from Station 71 to Station 285 buckled.

Empennage

1. Rudder buckled and twisted, lower hinge bracket torn loose from rudder.



2. Skin canned on left-hand side of vertical stabilizer.
3. Right-hand elevator buckled on inboard edge (caused by overswing of rudder).

#### Miscellaneous

1. Engine cowling dented on left-hand side and top and bottom.
2. Cowl flaps buckled on left-hand side.
3. Heavy canning of accessory cowling, left-hand side and top and bottom.
4. Pilot's canopy and frame broken.

#### Repair Estimate

Estimated man-hours required for complete repair, 2550.

#### Figure Reference

Figures 3.21, 3.22.

### 3.3.2 Shot 10

The second shot in the Frenchman Flat Area, Shot 10 of the series was delivered by the 280 mm atomic cannon on 25 May 1953. The device was detonated at a height of 524 ft above the lake bed with a yield of 14.9 KT, 0.9 KT above predicted yield. Actual ground zero was 139 ft south and 86 ft west of intended ground zero.

Since the closest aircraft was at a ground range of 1666 ft, all aircraft should have been in the Mach stem region and below the triple point. However, the aircraft were in a region where a strong precursor was developed, which may have resulted in an aberration of the triple point path. The four closest aircraft, at ranges from 1666 ft to 2151 ft, were completely demolished. Pieces of aircraft were found several hundred feet from the original location. The F-47 aircraft farthest from ground zero suffered moderate to heavy damage. The right wing tip was damaged when it struck the ground during the blast phase. The thermal radiation shield on the left wing and left horizontal stabilizer assembly was almost completely torn off. Presentation of the damage according to individual aircraft is given in the paragraphs below.

#### 3.3.2.1 Aircraft F-47 (072)

The closest aircraft to ground zero was F-47 (072) at a range of 1666 ft. This aircraft was literally torn apart and strewn over the area for distances of several hundred feet. The only major parts recognizable were the engine, the forward section of the cockpit and the inboard section of one wing. The approximate blast and thermal inputs at this range were 14 psi and 82 cal/sq cm, respectively. Figure 3.23 shows portions of the forward aircraft after the shot.



3.3.2.2 Aircraft F-47 (065)

This aircraft was completely destroyed by the combined overpressure and thermal inputs of 10.2 psi and 71 cal/sq cm realized at the 1896 ft range where the aircraft was parked. The steel cable tie-downs apparently provided little restraint in comparison to the total forces imposed on the aircraft by the gust. The aircraft was torn to pieces and scattered over a large area with pieces coming to rest several hundred feet to the rear of the original location. Only a few pieces could be identified as to their origin. Photographs of the general wreckage are shown in Fig. 3.23 referred to above.

3.3.2.3 Aircraft F-86 (597)

Aircraft F-86 (597) was parked nose-in, adjacent to aircraft F-47 (065), and rigidly tied-down. Inputs at this range of 1890 ft were 10.2 psi and 71 cal/sq cm for overpressure and thermal energy, respectively. The F-86 aircraft was annihilated. As with the preceding aircraft, the tie-downs had no apparent effect because of the magnitude of the inputs. The only major portion of the aircraft left relatively intact was the engine which was found some 500 ft further from ground zero than its original position. The complete destruction in the vicinity of the F-86 aircraft is likewise shown in Fig. 3.24.

3.3.2.4 Aircraft F-47 (828)

The F-47 (828) aircraft was parked at a range of 2151 ft from the Shot 10 ground zero, where it was subjected to a peak overpressure of 9.5 psi and a total thermal energy input of 60 cal/sq cm. Although this aircraft was not annihilated as were the preceding three, it was nevertheless damaged to the point where no major component was salvable. Much of the over-all structural deformation appeared to have been caused by flying missiles, some of considerable size. Pictures showing the postshot debris in the general area of this aircraft are presented in Fig. 3.23.

3.3.2.5 Aircraft F-47 (297)

The aircraft farthest from ground zero, F-47 (297), was parked nose-in at a range of 2345 ft. It was tied down using moderate strength tie-downs, and the left wing and left horizontal stabilizer-elevator assembly were equipped with cloth thermal radiation shields. Overpressure and thermal inputs at this range were 9.2 psi and 54 cal/sq cm, respectively. The aircraft suffered moderate to heavy



damage but was in much better condition than any of the four aircraft closer to ground zero. The tie-downs failed, and the right wing of the aircraft struck the ground. Wing and stabilizer sections covered by the thermal radiation shield suffered less damage than the openly exposed regions. The inspection report is given below.

#### Wing

1. Left-hand wing assembly (shielded):
  - a. Ribs bent, rivets pulled, and skin buckled from Station 202 to Station 232, top and bottom.
  - b. Flap assembly buckled, top and bottom.
  - c. Leading edge of wing buckled at Station 142.
  - d. Gun-bay door skin canned.
  - e. Inboard trailing edge of aileron buckled.
  - f. Holes and dents in leading edge of wing between Stations 40 and 140.
  - g. Trailing edge of wing buckled between Station 64 and Station 118.
2. Right-hand wing assembly (unshielded):
  - a. Wing tip and aileron bent upward at almost a 90° angle at Station 192 (result of ground contact).
  - b. Gun-bay door heavily buckled and canned.
  - c. Skin and substructure of ammunition-bay door buckled and bent.
  - d. Wing buckled between Station 132 and Station 182.
  - e. Entire leading edge dented, numerous holes.
  - f. Landing flap buckled, skin torn and twisted.

#### Fuselage

1. Skin dished in, formers buckled, and rivets pulled from Station 180 to Station 358, left side.
2. Skin, formers, and stringers buckled from Station 321 to Station 358, right side.
3. All fairing under fuselage bent and buckled from Station 71 to Station 285.
4. Skin and stringer broken at two places between Station 215 and Station 250, right side.

#### Empennage

1. Vertical stabilizer - skin buckled, left side.
2. Rudder - buckled, twisted, and skin overstressed; lower hinge bracket torn loose.
3. Horizontal stabilizer - hole torn in top side, skin bent and buckled, right side.
4. Skin of left elevator canned.
5. Right elevator buckled and twisted with heavy skin canning.

#### Miscellaneous

1. Left and right main gear door and fairing buckled and

- hole torn in fairing (left).
- 2. Engine cowling and accessory cowling buckled.
- 3. Propeller cuffs dented, several small holes.
- 4. Canopy not installed; internal inspection not made.

Repair Estimate

Aircraft damaged beyond economical repair.

Figure Reference

Figures 3.25, 3.26.

### 3.4 INSTRUMENTATION

General success of the motion picture effort is discussed below. Prints of the Project 8.1 films are available from the AFSWP film library. Detailed peak skin temperature data are presented in Appendix A. General results pertaining to the temp-tape data are presented in para 3.4.2.

#### 3.4.1 Photographic

All nine cameras, seven on Shot 9 and two on Shot 10, were triggered properly. The magazine of the GSAP camera covering F-47 (297) on Shot 9 jammed at blast arrival. Except for the one failure, all cameras operated satisfactorily. The employment of sand-cement stabilization minimized smoke and dust obscuration and contributed greatly to the successful photographic effort. In general, the subject remained clear until the start of the negative phase. No difficulty was experienced with fogging of film by nuclear radiation. Careful viewing of the film should provide a better understanding of how aircraft damage is caused by inputs of this type. Table 3.1 lists information pertinent to each of the nine films obtained.

#### 3.4.2 Peak Skin Temperature

A summary of the temp-tape data obtained in the peak skin temperature survey is presented in appendix A according to aircraft type. The summary includes a description of the sensing device location, skin thickness (when available) and peak temperature recorded. Installation diagrams are included for the bomber aircraft to describe more accurately the temp-tape location. If Technical Orders are not available, an approximate idea of station location may be obtained by reference to Figs. 3.1 through 3.5. The table below summarizes peak temperatures attained by skin of each aircraft for each exposure.

TABLE 3.1 - Motion Pictures of Project 8.1 Aircraft

Shot	Subject	Camera Type	Film Speed (Frames/sec)	Film (a) Type & No.	Remarks
9	F-47 (072)	GSAP	65	MF, 16644	Aircraft airborne
9	F-86 (597)	GSAP <sup>(c)</sup>	49	MF, 16645	
9	F-86 (597)	EHS <sup>(d)</sup>	444 <sup>(b)</sup>	MF, 16646	Thermal buckling
9	F-47 (065)	GSAP	64	KG, 16647	
9	F-47 (065)	EHS	578 <sup>(b)</sup>	BX, 16649	
9	F-47 (297)	GSAP	61	KC, 16648	Up to shock arrival
9	F-47 (297)	EHS	478 <sup>(b)</sup>	BS, 16650	
10	F-47 (297)	GSAP	54	MF, 16765	Shock arrival obscured
10	F-47 (297)	EHS	448	MF, 16766	Shock arrival obscured

(a) MF - microfile, KC - Kodachrome, BX - background X

(b) Speed at shock arrival

(c) Gun Sight Aiming Point

(d) Eastman High Speed

TABLE 3.2 - Summary of Peak Skin Temperatures

Shot	Aircraft and Orientation	Thermal Input (Cal/cm <sup>2</sup> )	Temperature (°F)	Thickness (in.)	Component
7	B-29 (066), S <sup>(a)</sup>	30.8	178-194	0.040	Fuselage
8	B-17 (730), N <sup>(b)</sup>	38.2	265-287	0.020	Fuselage
8	B-29 (066), N	38.2	232-252	0.020	Wing
8	B-45 (481), N	56.7	265-287	0.040	Nacelle
9	F-47 (828), N	58	253-264	0.051	Fuselage
9	F-47 (072), N	49	465-487	0.032	Wing and Fuselage
9	F-86 (597), N	49	540-634	0.032	Fuselage
9	F-47 (065), S	20	424-441	0.040	Fuselage
9	F-47 (297), S	20	144-170	0.040	Fuselage
10	F-47 (072), N	82	253-264	0.051	Fuselage
10	F-47 (065), N	71	288-308	0.032	Wing
10	F-86 (597), N	71	232	0.040	V. Stabilizer
10	F-47 (828), N	60	253-264	0.051	Fuselage
10	F-47 (297), N	54	178-194	0.051	Wing

(a) Side-in

(b) Nose-in

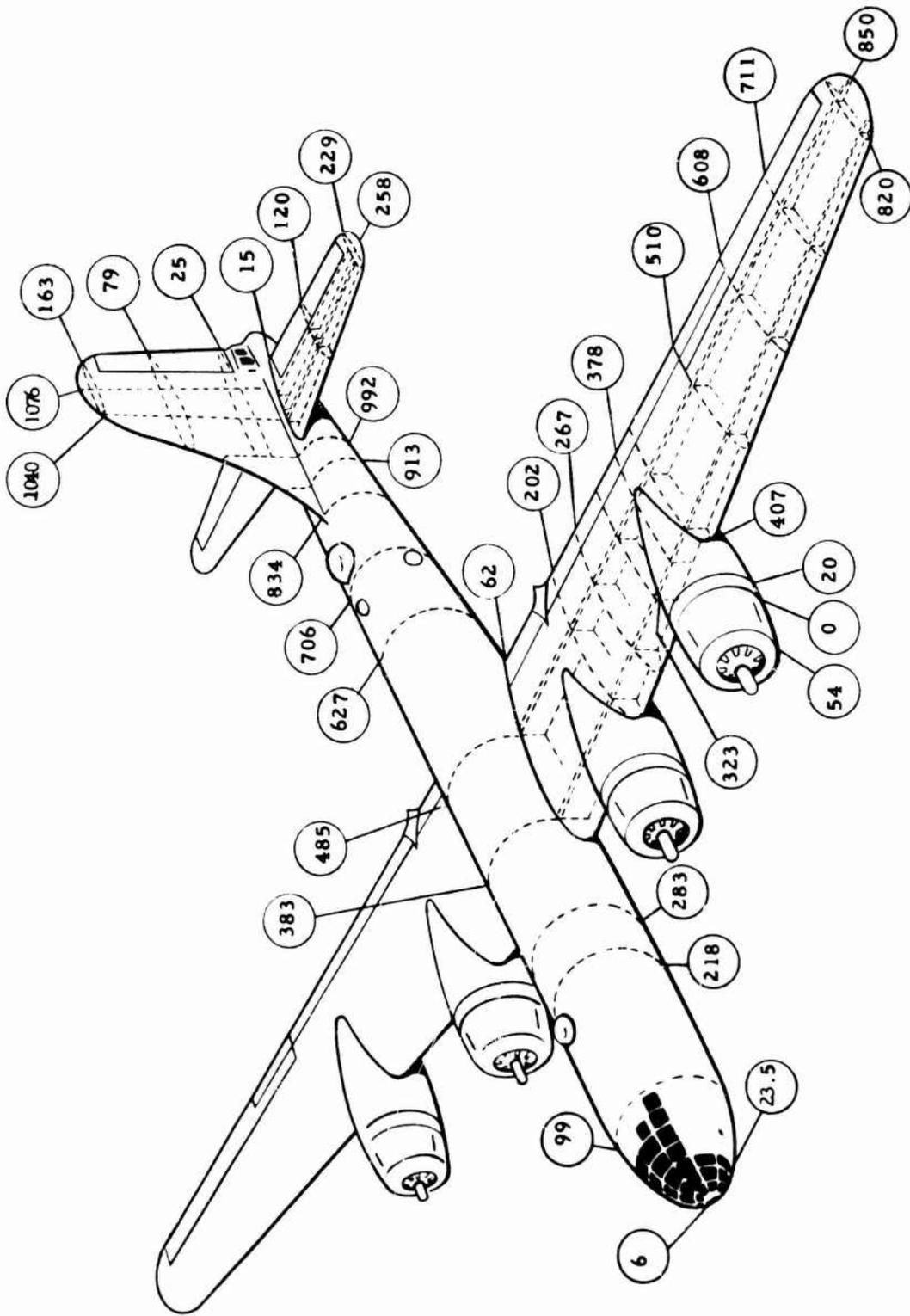


Fig. 3.1 Station Locations for B-29 Aircraft

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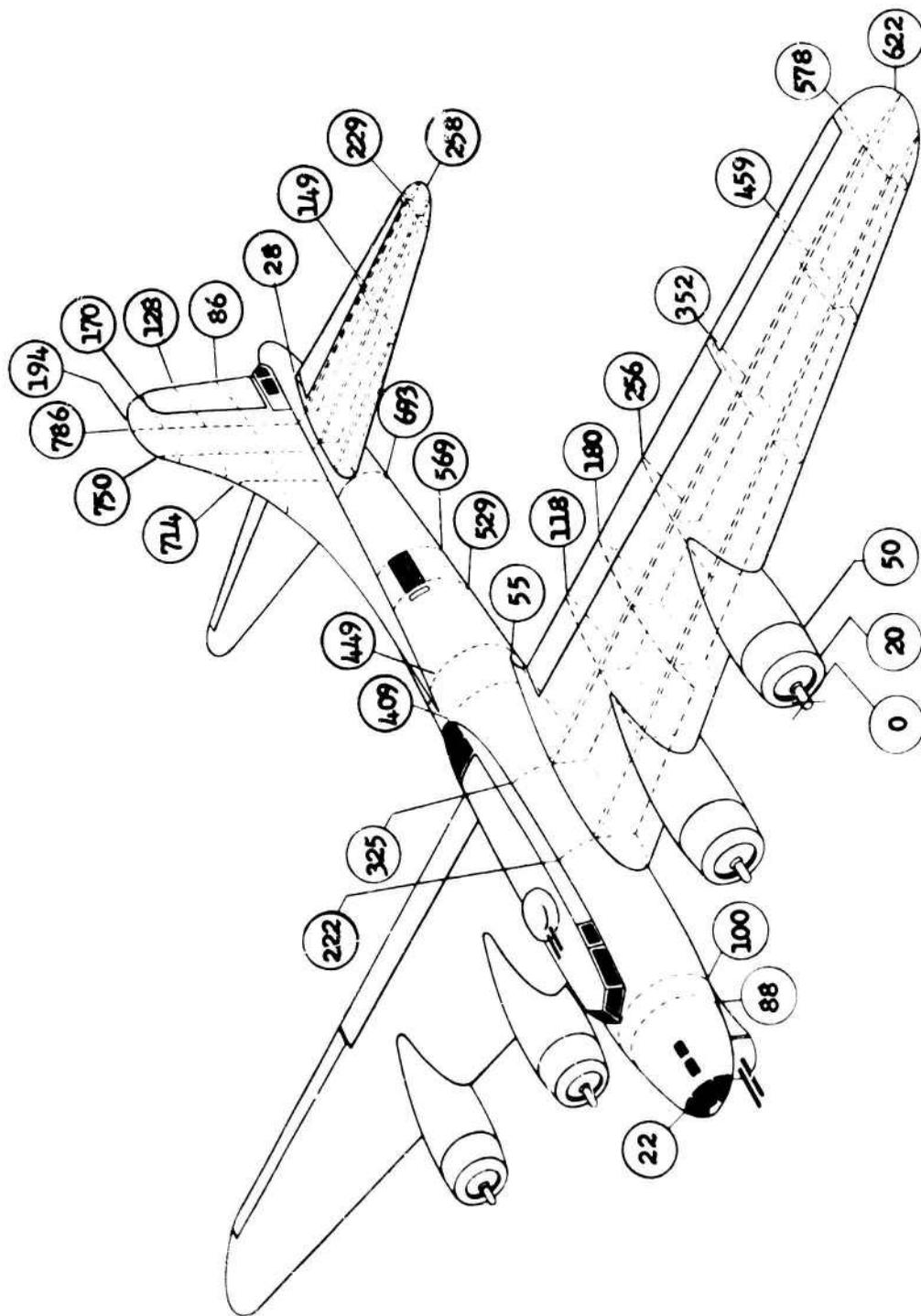


Fig. 3.2 Station Location for B-17 Aircraft

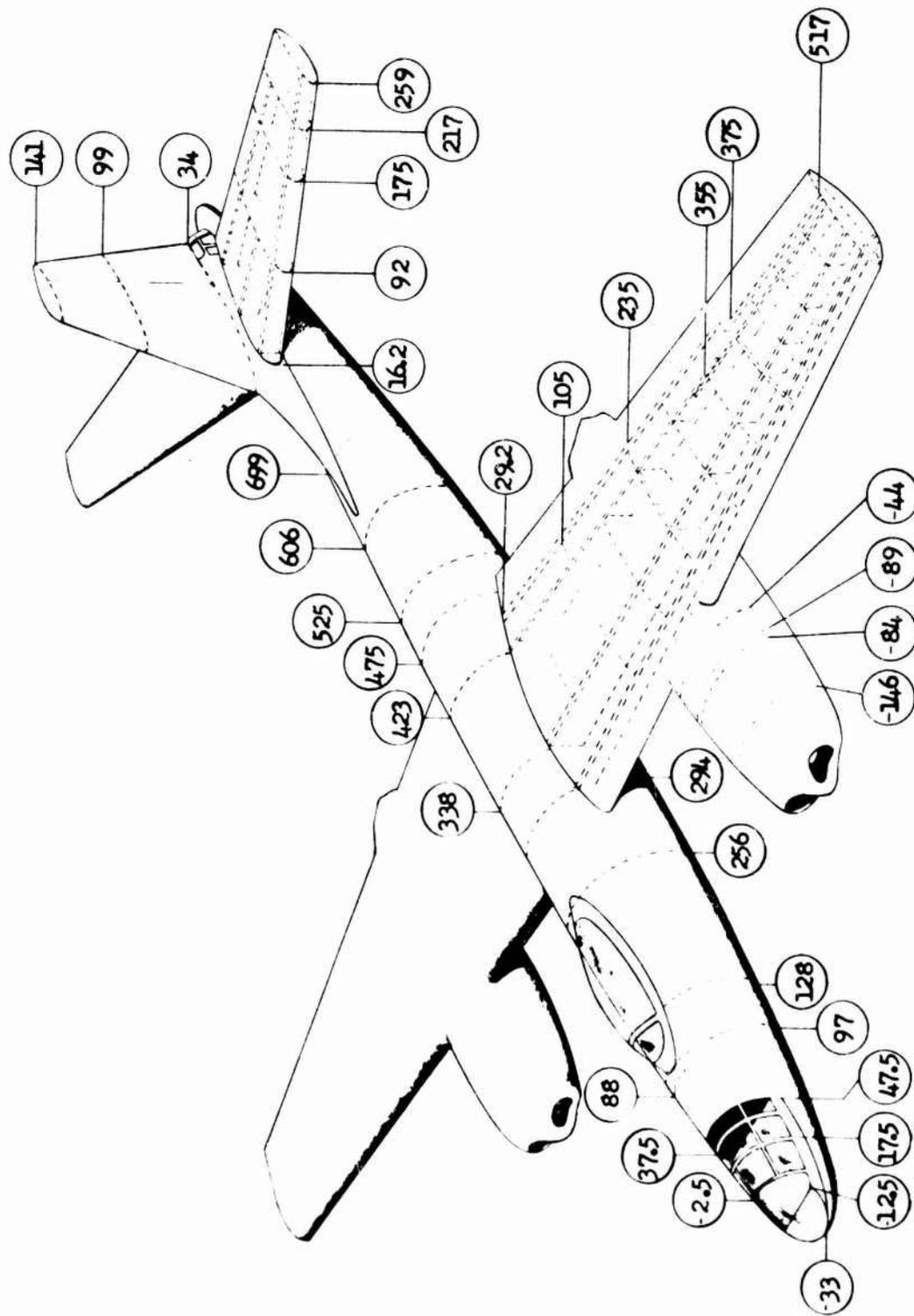


Fig. 3.3 Station Location for B-45 Aircraft

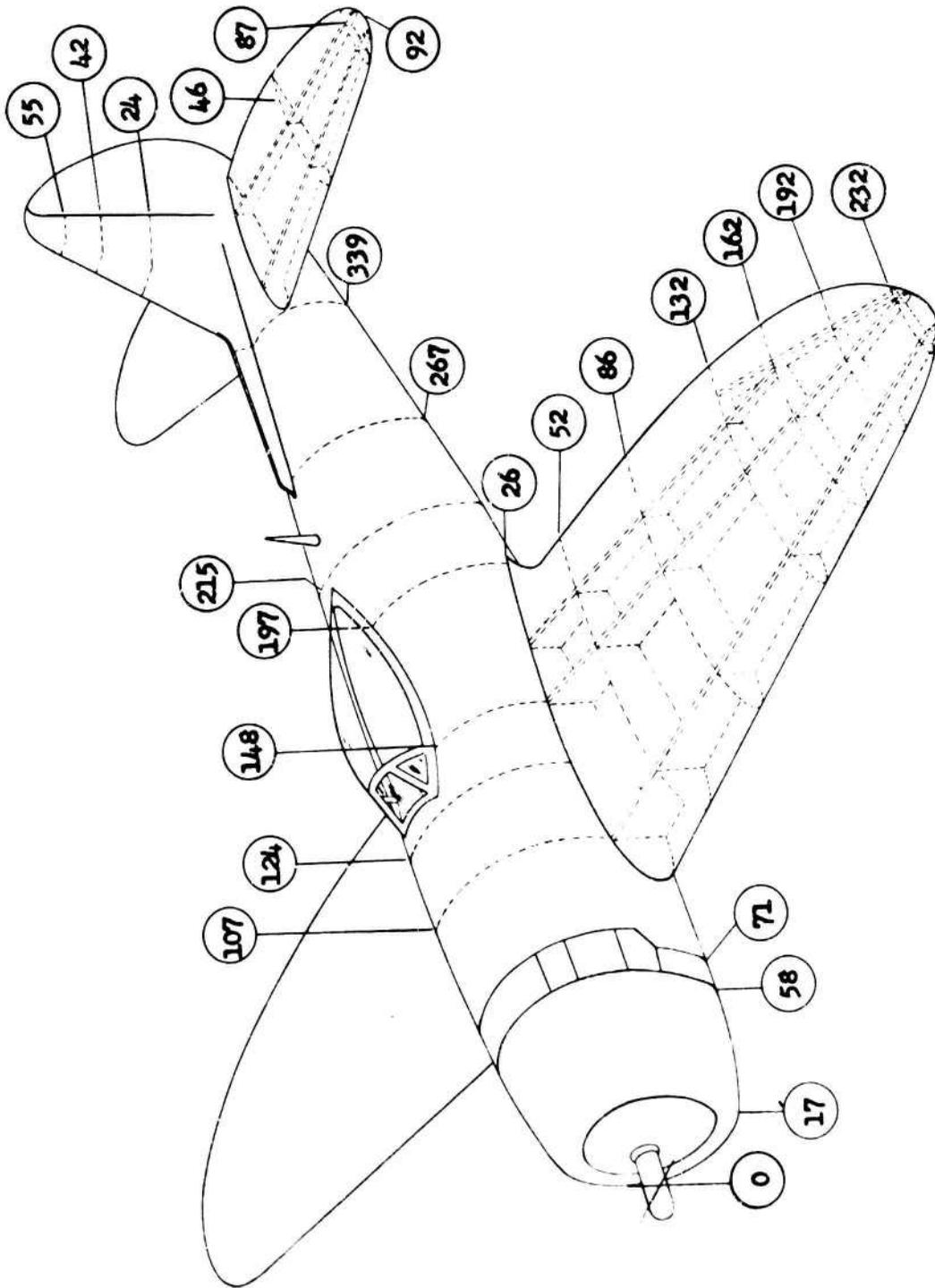


Fig. 3.4 Station Location for F-47 Aircraft

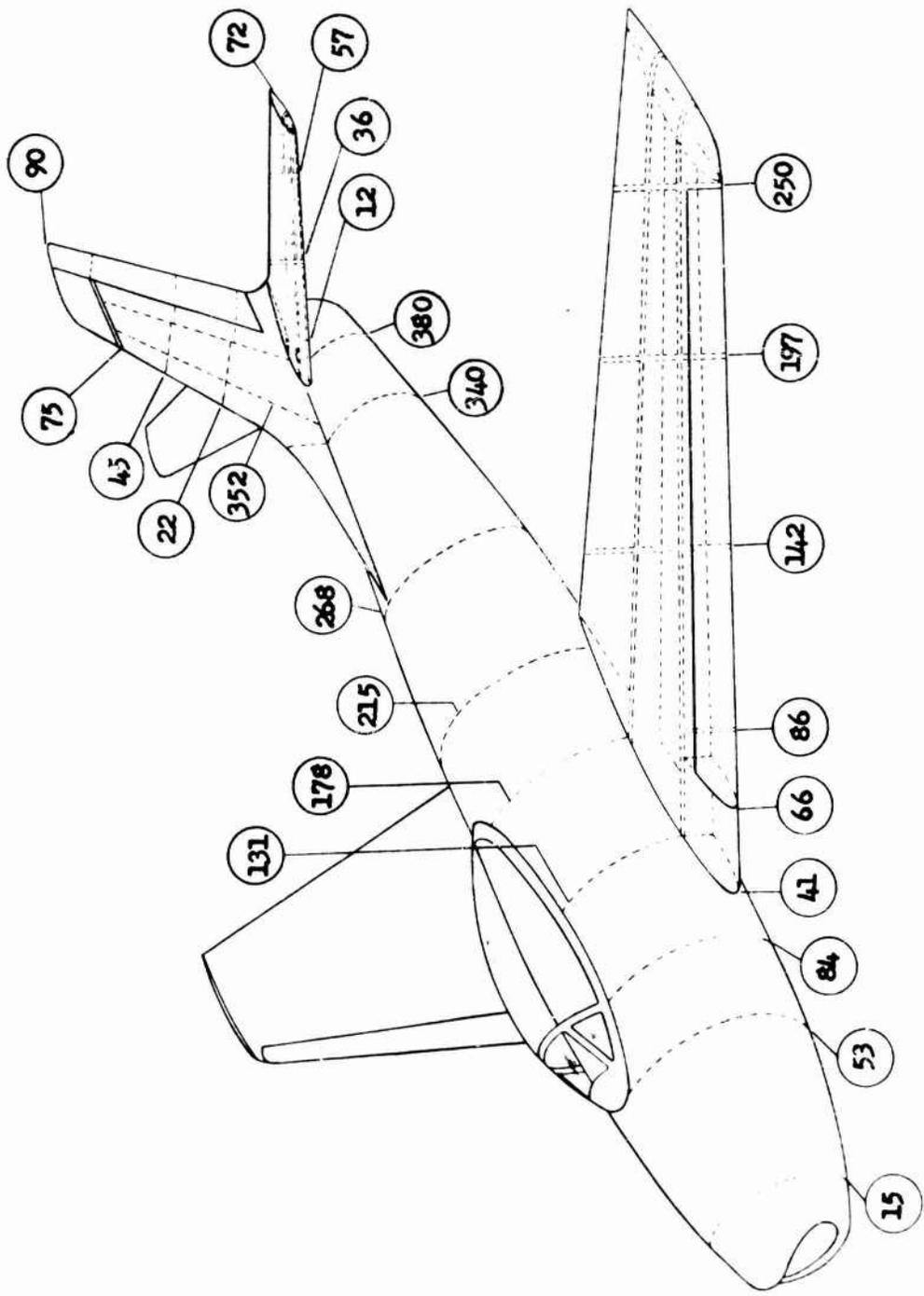


Fig. 3.5 Station Location for F-86 Aircraft

**SECRET**

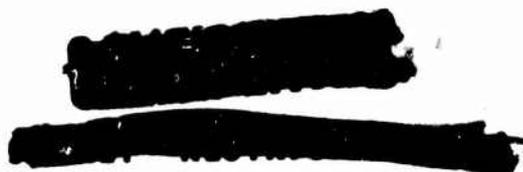


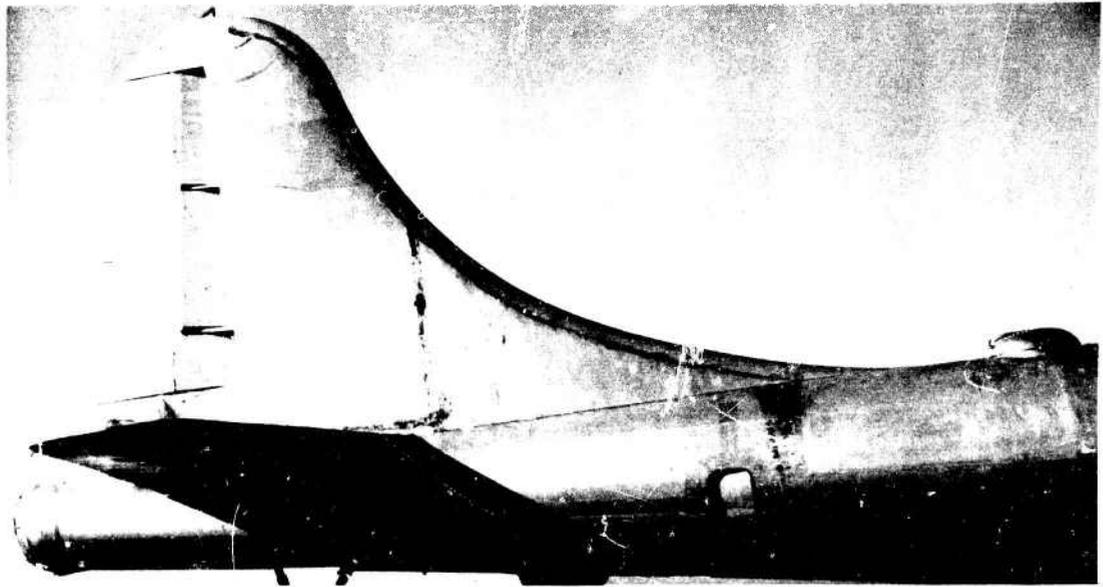
Condition of Aircraft After Exposure



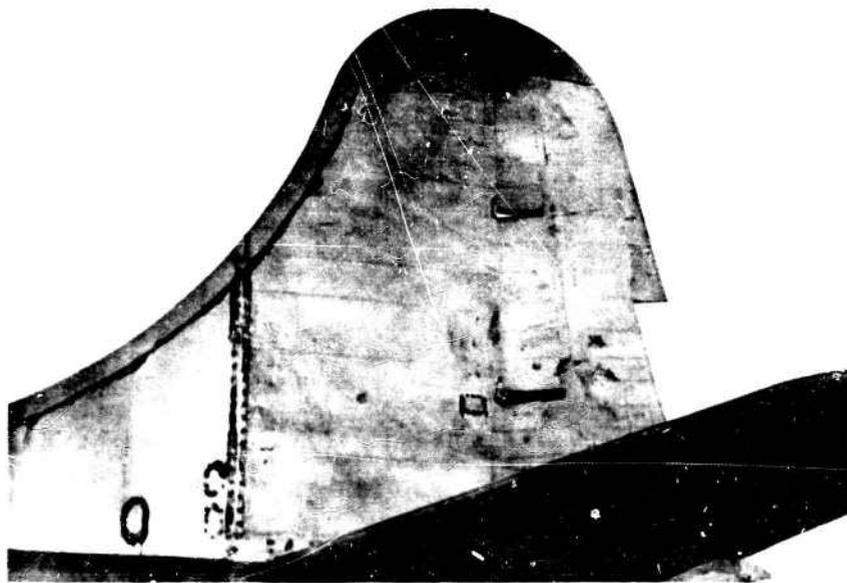
Left Wing After Exposure

Fig. 3.6 B-29 (066), Tail-in, 7700 Ft (1.8 psi), Shot 1





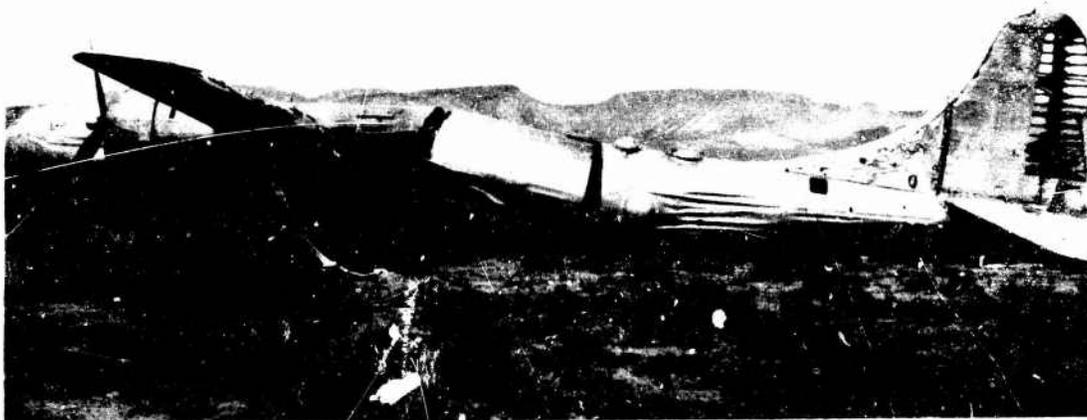
Rear of Fuselage and Empennage: Note Sprung Door and Missing Trim Tab



Compression Side of Empennage: Note Buckling of Vertical Stabilizer

Fig. 3.7 B-29 (066), Right Side-in. 2800 Ft (1.2 psi), Shot 3



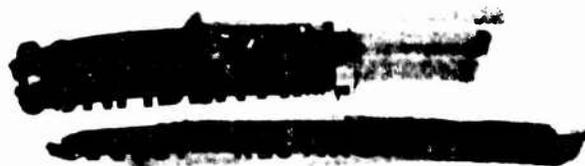


Over-all View of Damage Incurred: Note Double Break in Aft Section of Fuselage



Mid-fuselage, Showing Break in Skin

Fig. 3.8 B-29 (066), Left Side-in, 6200 Ft (3.5 psi), Shot 7



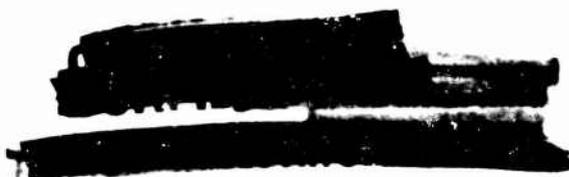


General View, Unexposed Side



Left Side of Forward Fuselage: Note Ring Failures

Fig. 3.9 B-29 (066), Left Side-in, 6200 Ft (3.5 psi), Shot 7



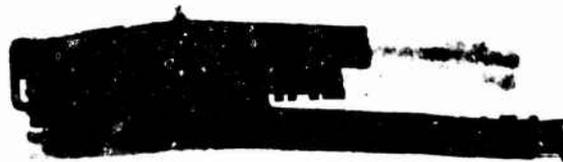


Condition of Aircraft Prior to Exposure



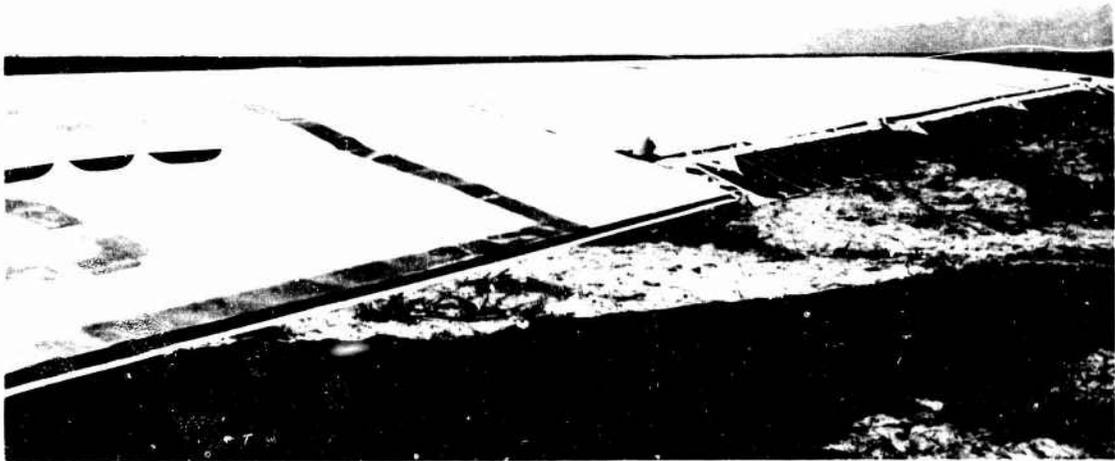
Postshot View

Fig. 3.10 B-17 (730), Nose-in, 4450 Ft (4.8 psi), Shot 8





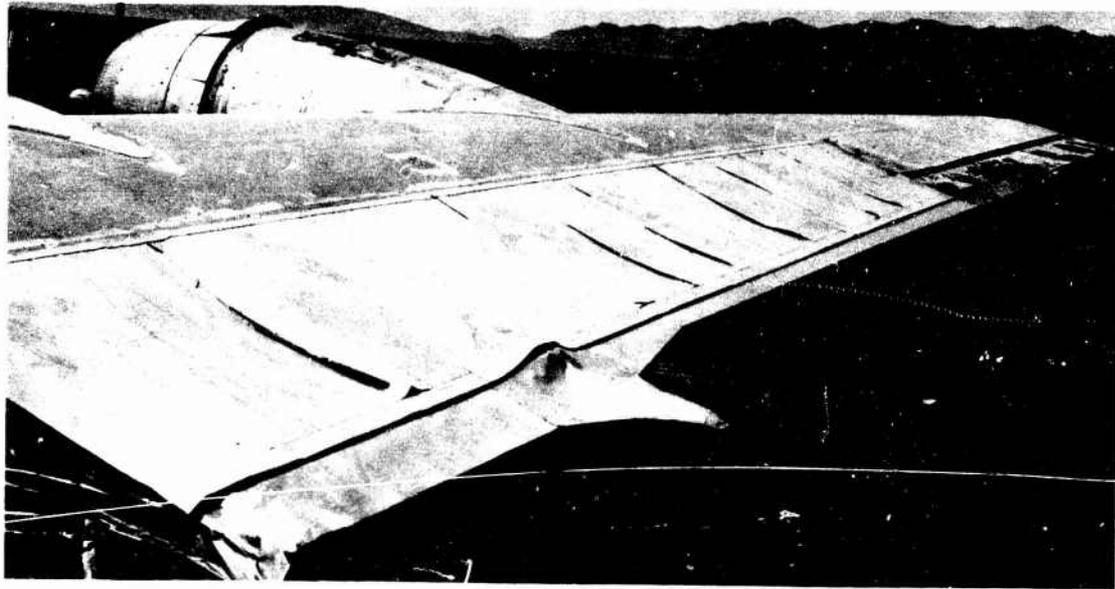
General View Showing Damage to Right Side: Note Damage to Forward Fuselage and Compression Buckles in Vertical Stabilizer



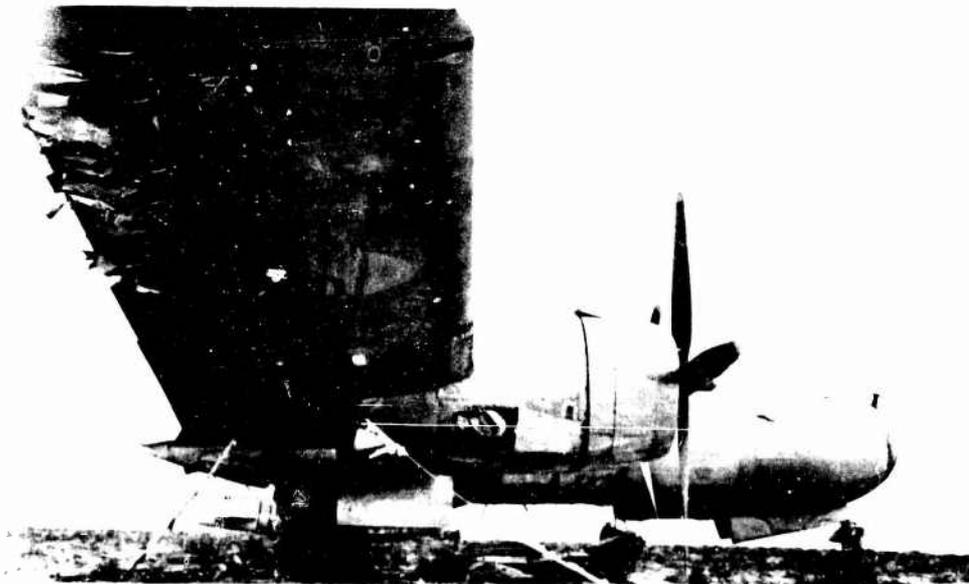
Damage to Trailing Edge and Outer Panel of Right Wing

Fig. 3.11 B-17(9730), Nose-in, 4450 Ft (4.8 psi) Shot 8





Damage to Right Wing: Note Heavy Damage to Trailing Edge



Under Side of Right Wing, Showing Damage to Outer Panel

Fig. 3.12 B-29 (066), Nose-in, 4450 Ft (4.8 psi) Shot 8





Right Side View Prior to Exposure



Vertical and Horizontal Stabilizer: Note Skin Buckling

Fig. 3.13 B-45 (481), Nose-in, 3700 Ft (6.7 psi) Shot 8

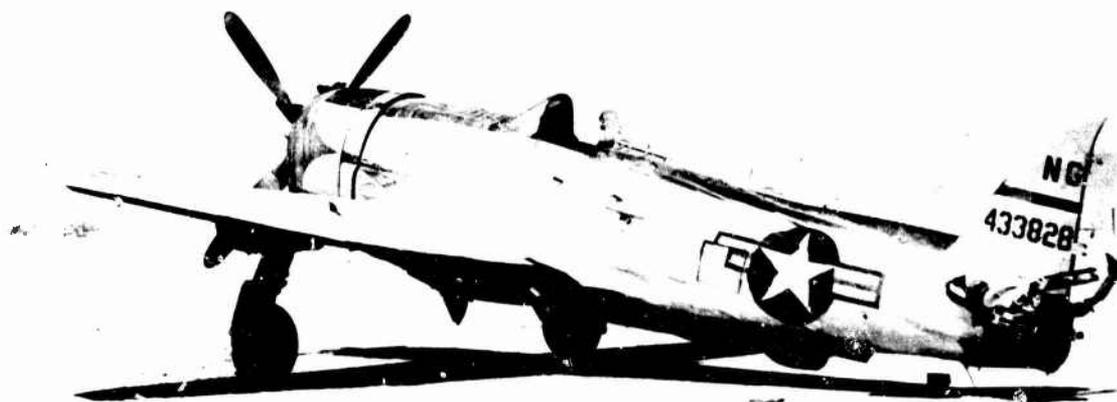




Fig. 3.14 B-45 (481), Nose-in, 3700 Ft (6.7 psi), Shot 8, Showing Over-all View of Left Side after Exposure



View of Empennage and Left Fuselage Prior to Exposure



Over-all Damage to Left Side: Note Buckling in Fuselage and Excessive Damage to Empennage

Fig. 3.15 F-47 (828), Nose-in, 2441 Ft (12.5 psi), Shot 9





Left Forward, Prior to Exposure



Over-all View, Left Side: Note Heavy Fuselage and Empennage Damage

Fig. 3.16 F-47 (072), Nose-in 2981 Ft (12 psi), Shot 9



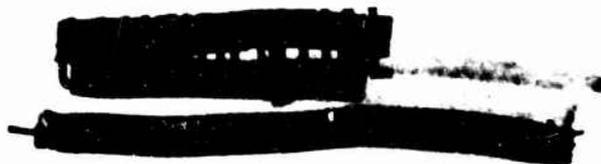


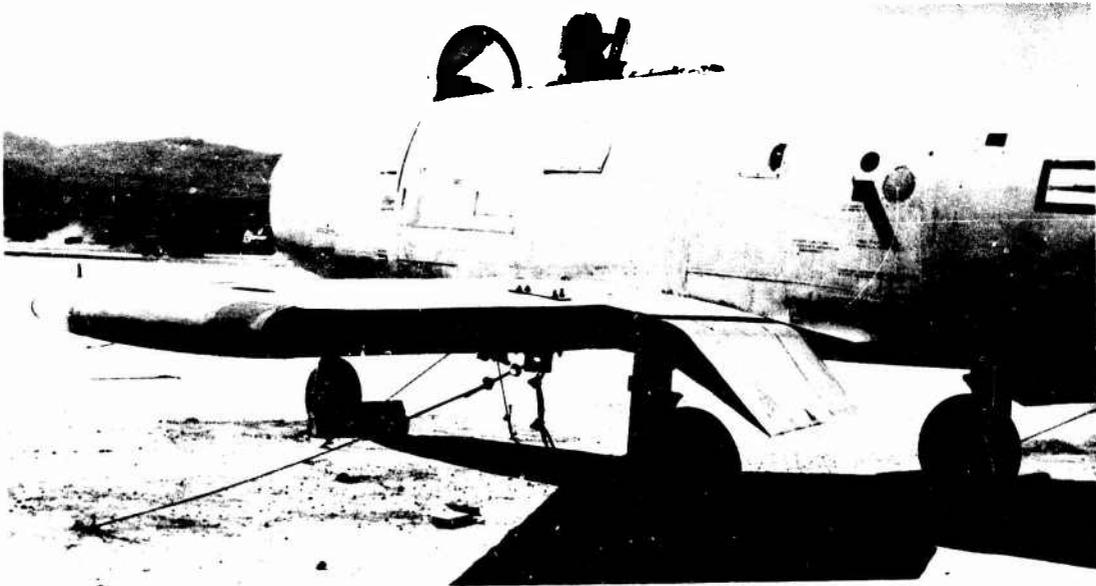
Over-all View Showing Damage to Right Side



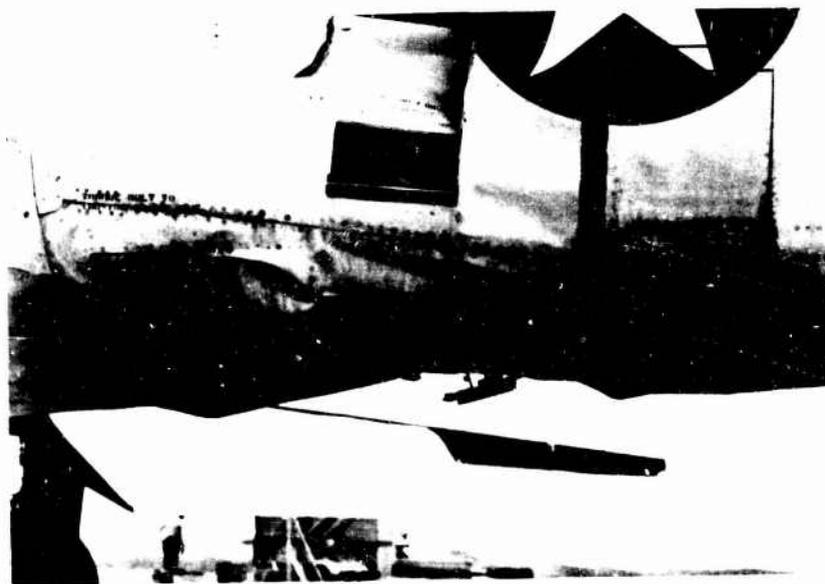
Empennage, Right Side: Note Demolished Right Stabilizer and Twisted and Torn Vertical Stabilizer

Fig. 3.17 F-47 (072), Nose-in, 2981 Ft (12 psi), Shot 9



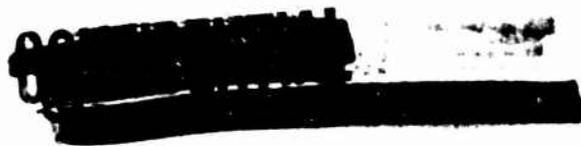


Left Forward Prior to Exposure



Fuselage Damage Aft of Fuselage Disconnect

Fig. 3.18 F-86 (597), Nose-in, 2951 Ft (12 psi), Shot 9



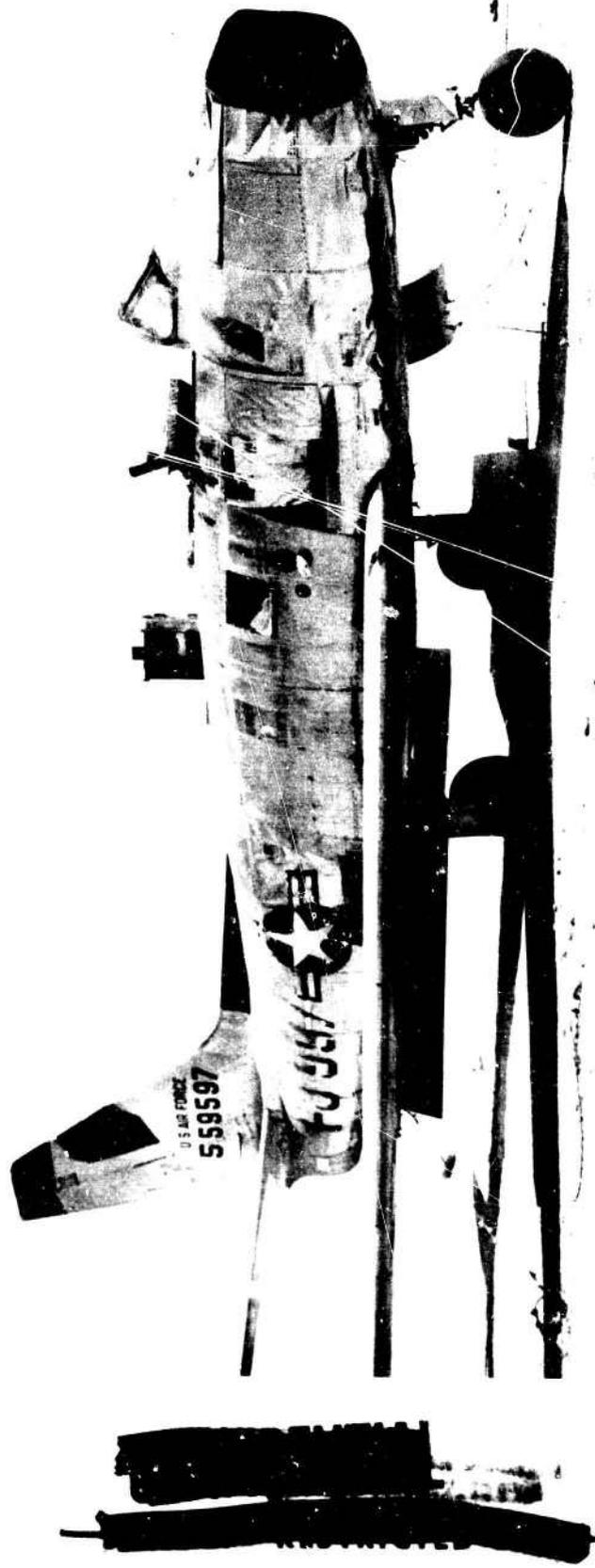


Fig. 3.19 F-86 (597), Nose-in, 2951 Ft (12 psi), Shot 9, Showing Right Side After Exposure

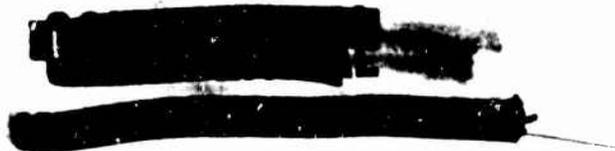


Preshot View of Right Front



Right Side Damage: Note Section of Rudder Blown Off, Also Buckling in Fuselage

Fig. 3.20 F-47 (065), Right Side-in, 5936 Ft (5.1 psi) Shot 9



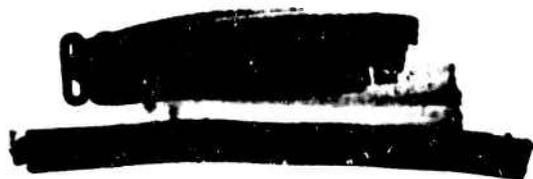


Preshot View Showing Thermal Shield



Postshot View: Note Charred Shield

Fig. 3.21 F-47 (297), Left Side-in, 5936 Ft (5.1 psi), Shot 9



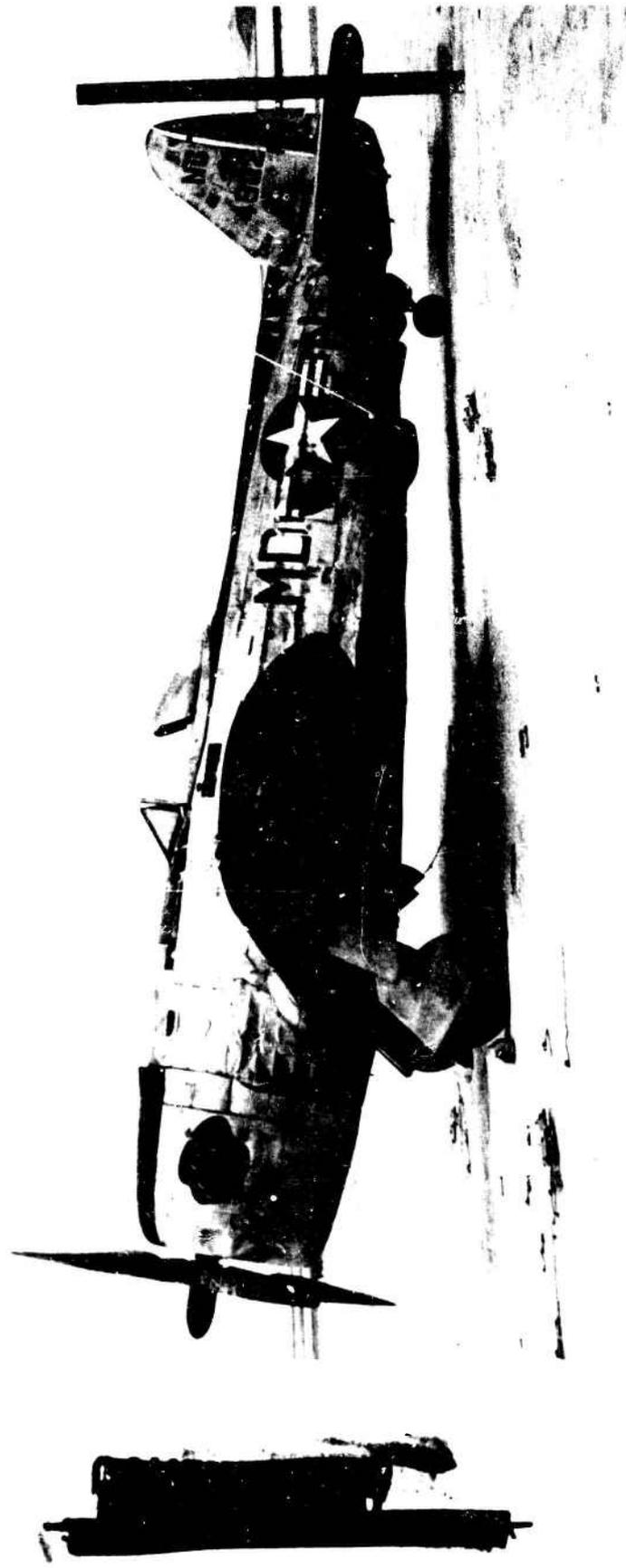


Fig. 3.22 F-47 (297), Left Side-in, 5936 Ft (5.1 psi), Shot 9, Showing Damage to Exposed Side of Aircraft: Note Extensive Buckling of Fuselage



Fig. 3.23 Shot 10, Remnants of F-47 Aircraft Exposed in Precursor Region

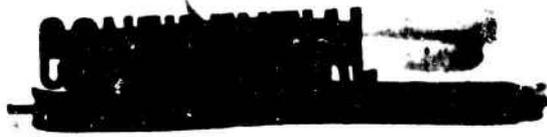
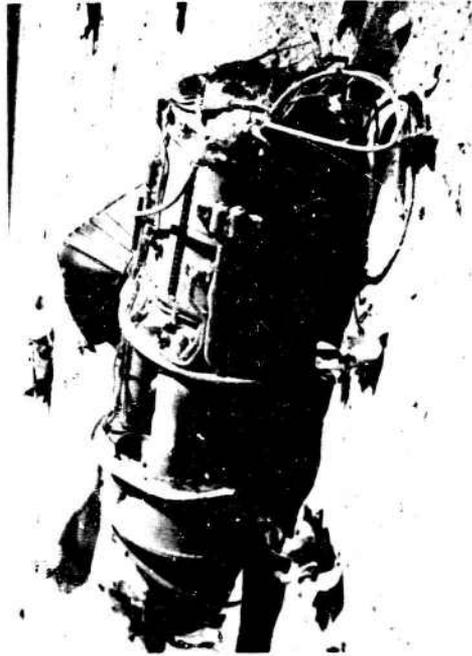
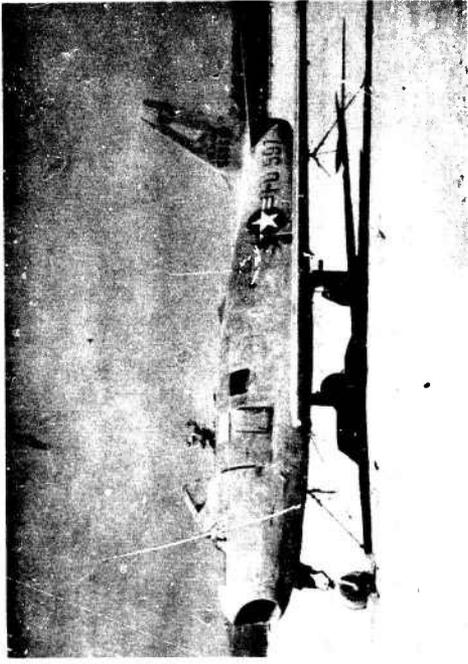
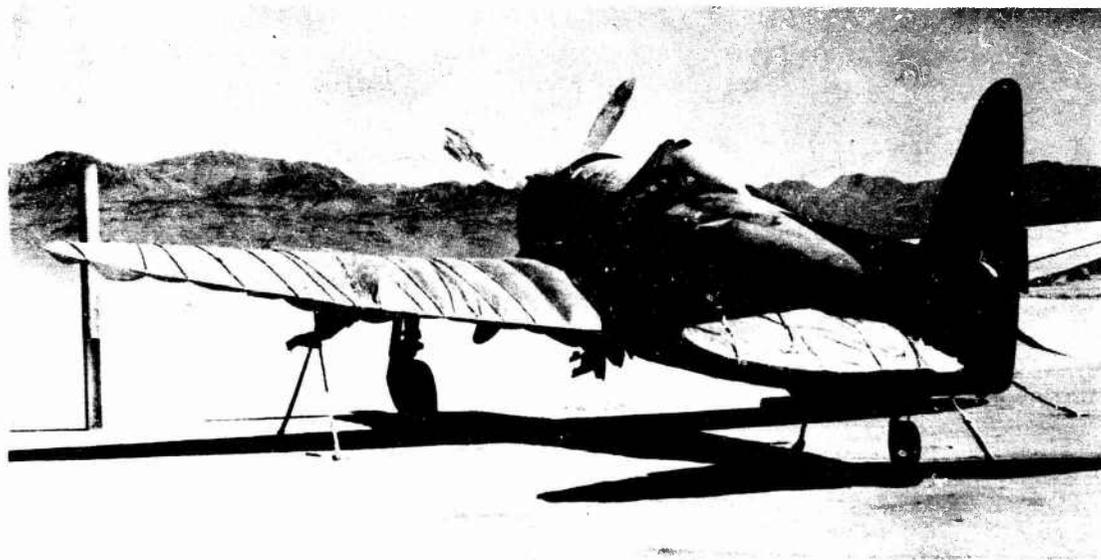


Fig. 3.24 F-86 (597), Nose-in, 1890 Ft (10.2 psi), Shot 10, Showing a Preshot View and Complete Destruction Following Exposure



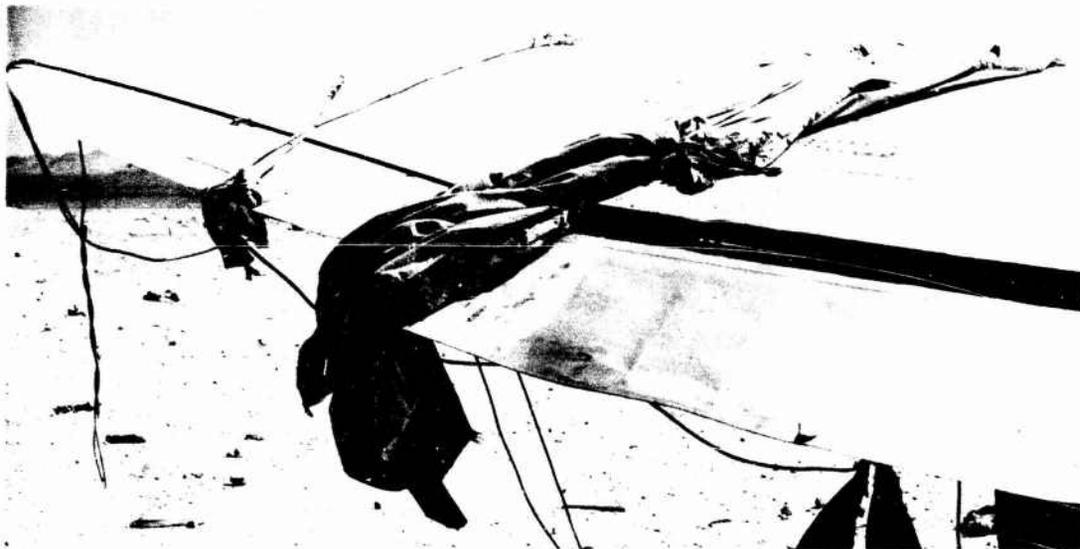
Preshot, Left Rear View Showing Thermal Shield on Left Stabilizer and Left Wing



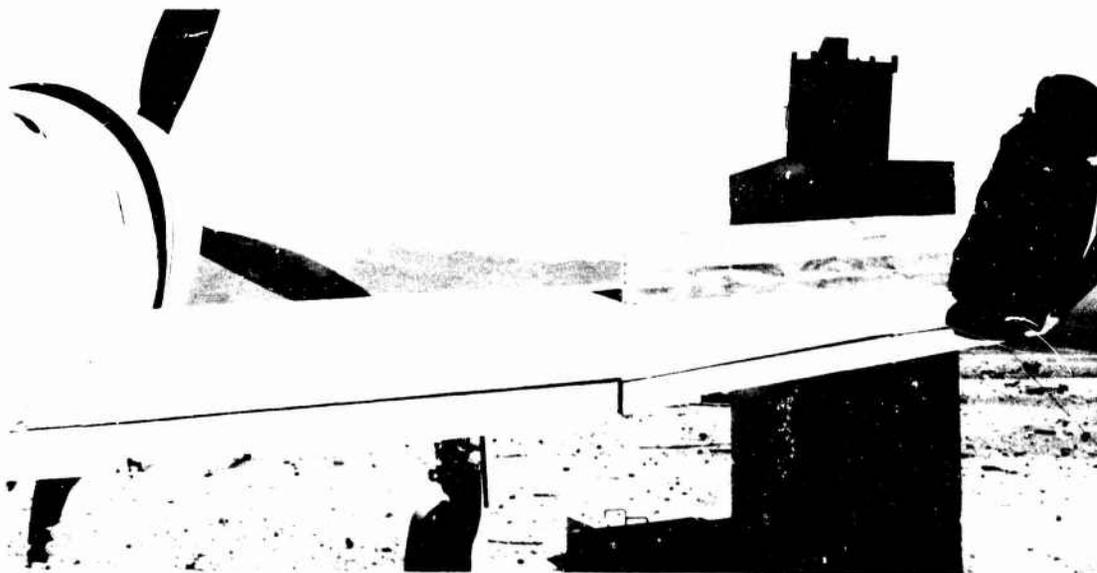
Right Side View; Wing Tip Bent Due to Ground Contact

Fig. 3.25 F-47 (297), Nose-in 2345 Ft (9.2 psi), Shot 10





Damage to Left Wing



Right Wing After Exposure

Fig. 3.26 F-47 (297), Nose-in, 2345 Ft (9.2 psi), Shot 10

## CHAPTER 4

### DISCUSSION

#### 4.1 GENERAL

The Project 8.1b program was planned as a supplement to the vulnerability study conducted by Project 3.1 during TUMBLER-SNAPPER. Plans were based primarily upon utilization of aircraft employed in the above mentioned operation with the provision that the testing program would constitute but a small part of the total Project 8.1 effort and expense. Inasmuch as all but one of the test vehicles were already available at the test site, test specimen procurement involved small expenditure of time and money. Time-history instrumentation of the aircraft was not included because of manpower and budget considerations and to some extent, because of the general condition of the aircraft. The aircraft were instrumented for maximum skin temperature determination at selected points suitable for temp-tape installations.

The TUMBLER-SNAPPER vulnerability study included a consideration of the damage sustained by the entire aircraft and also by the associated equipment, and systems. In general, it was found that structural damage to the airframe was the most critical item in limiting operational capabilities of the aircraft; further, repair of structural damage involved the greatest expenditure of time and money. The present investigation was concerned only with the structural damage sustained by the aircraft as a result of thermal and blast inputs. Although additional data on items such as the vulnerability of instruments, electronic equipment, and systems would have been desirable, though less important than airframe vulnerability data, the aircraft used during UPSHOT-KNOTHOLE were no longer suitable for a comprehensive investigation of this type.

Since the majority of data included in this report is based upon aircraft exposed to thermal and blast inputs during more than one

nuclear explosion, it is necessary to consider the effect of these multiple exposures on the data derived therefrom and establish, insofar as possible, the reliability and limitations of the data. In the case of the initial exposure of the B-29, the aircraft was inspected after the test and the total apparent damage ascertained. The procedure was straightforward and was limited only by the ability of the inspector to assess the damage. In certain damage regions, depending upon the particular component, the accuracy of the damage estimate suffers because of the inability to ascertain the exact degree of damage to the substructure. If the aircraft was re-exposed, it was generally placed so as to receive significantly higher input than on the previous exposure. The problem then became one of determining the damage that would have been sustained had the aircraft been structurally sound prior to the test. The solution is obviously not one of subtracting the damage inflicted in the first exposure from the total damage, because certain types of damage, such as the breaking of a window, would in all probability have re-occurred at the higher input level had the window been replaced. On the other hand, certain major structural components may have suffered no damage in previous exposures and, hence, will yield data equivalent to that obtainable from undamaged aircraft. It is necessary to consider individually each item of damage.

It is believed that the accuracy involved in determining the additional damage suffered by a structure such as a wing is quite good providing the two exposures are at input levels sufficiently different to cause a damage differential of several-fold. After the configuration had sustained noticeable damage to the primary structure, results from additional exposures become very questionable.

With a normally airtight or closed construction, such as a fuselage, the pressure relief afforded by a broken window or failed door may have a marked effect on the net overpressure damage suffered by the fuselage. This effect has been observed repeatedly but had never been adequately evaluated for even simple structures. For this reason, really reliable information on the overpressure crushing of the fuselage or similar structure must be derived from a relatively undamaged specimen.

This report has been written primarily as a data presentation; therefore, only a limited discussion is included. It is anticipated that Air Force Technical Note WCNS 52-2, will be revised to incorporate the results of the data presented herein.

Whereas thermal and blast input measurements were not made at the aircraft parking stations, it is believed the method of using blast line data or scaling from the height-of-burst curves provides values sufficiently accurate for use in this investigation. Overpressures are reported to the nearest 0.1 psi in all instances, even though values obtained by scaling do not warrant this accurate a presentation. As

with overpressure, measured thermal data, when available are used for inputs. When experimental thermal data were unavailable, values were obtained theoretically assuming only the normal atmospheric attenuation. These values may be considerably in error, particularly where aircraft are exposed close-in to a weapon detonated at a low scaled height of burst. Under actual conditions the thermal energy received can be 25 per cent or more below the theoretical unattenuated value. Perusal of the peak skin temperature data in Appendix A will aid in ascertaining the approximate thermal energy level at which a particular aircraft was exposed.

#### 4.2 BOMBER AIRCRAFT

Bomber aircraft exposures during UPGHOT-KNOTHOLE produced no results that would suggest a revision of the general conclusions regarding bomber aircraft damage arrived at on the basis of the TUMBLER tests. The results provide a better understanding of bomber aircraft vulnerability at the higher overpressures. The early exposures of the B-29 aircraft also provided vulnerability data at lower overpressures not previously investigated for this type aircraft.

In the first two exposures the B-29 aircraft was subjected to overpressure inputs of 1.8 psi, tail-in during Shot 1 and 1.2 psi, side-in during Shot 3. The total damage for the tail-in exposure was approximately as expected; however, the complete absence of detectable empennage damage was not anticipated. It was thought empennage damage would constitute a significant percentage of total damage for this orientation since the empennage, particularly the control surfaces, are generally the most vulnerable in tail-in exposures. The gust load on the vertical tail during the side-in exposure at 1.2 psi was sufficient to cause a slight permanent set. Other damage was minor.

The exposure of the B-29 aircraft, side-in at 3.5 psi during Shot 7, resulted in extremely heavy damage. The fuselage was broken in two places, and the empennage and both wings were heavily damaged. The observed result was roughly predictable from reaction of B-17 aircraft in the TUMBLER tests; however, the effect of the tri-cycle gear instead of a conventional gear was not known. It was thought that the absence of a tail wheel would allow the aircraft to rotate more freely and thus reduce the torsional stress in the fuselage, but by the same token, increase the bending stress. The difference in support of the two aircraft was somewhat offset by the action of the tie-downs. Four mooring points were utilized: left and right wing, nose gear, and tail-skid. The fuselage failure probably resulted from a combination of torsion and bending. The bending is indicated by the nature of the break and the rest position of the aft fuselage. That considerable twisting of the fuselage occurred was evidenced by the

diagonal buckle in the aft fuselage directly below the leading edge of the right horizontal stabilizer. If the aircraft had been parked on a hardstand and had not been tied down, it is possible that sufficient stress alleviation would have resulted from aircraft rotation that the fuselage would not have broken. The wing tie-downs definitely restricted the aircraft rotation. The left wing tie-down failed because of the combined lifting of the wing and turning of the aircraft. Since the right wing moved downward, the tie-down restraint was effective primarily in preventing aircraft rotation and the restraining force afforded was sufficient to cause diagonal buckling of the wing aft of the rear spar. This tie-down did not fail; however, the anchor was loosened in the ground. If the aircraft had been tied down except for the tail, the torque applied to the fuselage would have been less, but the bending stress would have been greater. Whether the tail-skid tie-down is desirable or undesirable from the standpoint of damage prevention cannot be determined directly from this investigation. Although supporting data are not available, it appears from the nature of the damage sustained that for an exposure of this type the damage would be minimized if the aircraft were free to rotate. In actual practice the problem of collision with less vulnerable aircraft or other objects must also be considered.

The B-29 aircraft was included in the Shot 8 test primarily for wing evaluation. The highest overpressure at which a B-29 aircraft had been exposed prior to Shot 8 was 3.8 psi on TUMBLER 4. This overpressure caused light to moderate wing damage which was confined to the wing tip and outer panel. The 4.8 psi realized in the nose-in exposure during Shot 8 damaged the wings beyond economical repair. The entire outer wing panels and wing trailing edges aft of the rear spar were heavily damaged. The general condition of the forward fuselage indicated the entire aircraft would be damaged beyond economical repair at this overpressure. Slightly higher inputs would be required to reduce the airframe to essentially zero salvage value.

Aircraft B-17 (730), also at the 4.8 psi overpressure level during Shot 8, was damaged beyond repair. Whereas the damage to the intermediate fuselage was not as high as might have been expected, the collapsing of the main landing gear and heavy damage to the remainder of the aircraft rendered the aircraft an almost total loss. It is possible that fuselage damage would have been greater had it not been for the pressure relief afforded by the broken windows and failed doors. The landing gear failure may have been caused in part by action of the landing gear tie-downs. Even if the landing gear had not failed, the aircraft would have been damaged beyond repair. It is, therefore, concluded that aircraft would be damaged beyond repair above 5 psi when placed in the nose-in, or least vulnerable orientation.

Aircraft B-45 (481) was exposed during Shot 8 to a calculated overpressure of 6.7 psi, which is essentially the same as the 6.5 psi

exposure during TUMBLER 4. It should, however, be emphasized that the 6.7 value was calculated and could conceivably have been 7.7 or even higher, whereas the 6.5 is a measured value. Despite the apparent slight difference in overpressure, there was considerably more damage sustained in the latter exposure. Of particular interest was the sharp increase in wing damage. It is possible that some of the damage inflicted during the TUMBLER tests was not apparent and would thus account for some of the increased damage experienced during Shot 8. It is also possible that light skin canning materially reduces the overpressure damage resistance of an aircraft. The aircraft was damaged to the extent that it would be uneconomical to repair under ordinary circumstances; however, the aircraft was still repairable, and conditions can be envisioned where repair would be undertaken. It is, therefore, concluded that for a B-45 aircraft, an overpressure somewhat in excess of 6.7 psi would be required for a sure kill.

#### 4.3 FIGHTER AIRCRAFT

Fighter aircraft were exposed primarily for preliminary evaluation of the effect of strong tie-downs and shielding against thermal radiation.

Fighter aircraft tested under conditions comparable to previous exposures, in general, responded as anticipated. For the most part, however, specific exposures are not directly comparable, differing in regard to shielding and degree of restraint. Further, the majority of exposures were in the region of moderately high to very high damage (damaged beyond repair) wherein only gross comparisons are meaningful. The exposure that is perhaps most readily compared with prior data is the side-in exposure of F-47 (065) at an input level of 5.1 psi during Shot 9. In this exposure the aircraft was damaged beyond economical repair. Heavy damage would have been predicted for this exposure; however, since the aircraft had already sustained heavy damage in a previous exposure it is not surprising that it was damaged beyond economical repair. With allowances for the effect of tie-downs on the F-47 (072) and the F-86 (597) aircraft at Station 2300 on Shot 9, the data may be said to agree with TUMBLER results. In summary then, there is no apparent disagreement between UPSHOT-KNOTHOLE and TUMBLER results; at the same time there is confirmation that aircraft sustain higher damage in the precursor region than would be predicted on the basis of peak overpressures experienced.

Two important features were apparent in the TUMBLER results; one, aircraft damage at the higher overpressures was greater for TUMBLER 4 than TUMBLER 3; two, there was a very sharp drop in

the degree of damage from the 2200 to the 2500 ft range on TUMBLER 4. Subsequent information obtained from other agencies on TUMBLER 4 phenomena indicated that the inordinately high damage was associated with the precursor phenomenon. In order to obtain a better understanding of aircraft damage in the precursor region, four aircraft were parked in this region for Shot 10. A strong precursor was developed; and aircraft damage, as before, was extremely high. Aircraft that withstood an overpressure of 12 psi on Shot 9 without suffering loss of any major component were literally torn apart at an overpressure of almost 2 psi lower. On Shot 9, when the peak overpressure was 12 psi, the strong tie-downs held the F-86 aircraft in place. On Shot 10, at an overpressure of 10.2 psi in the precursor region, the tie-downs were completely failed, the airframe demolished, and the jet engine carried 500 ft from its preshot position. The F 47 aircraft at 10 psi and above were likewise demolished. Aircraft F 47 (297) at 9.2 psi was on the edge of the area subjected to unusually high dynamic drag forces comparable to that experienced at this overpressure in shots of higher scaled heights of burst. It can be concluded, therefore, that aircraft damage in the presence of high drag forces is considerably higher for a given overpressure level than it is in the region where a clean low-impulse shock is formed. Also, the nature of the damage indicates the impulse for a given overpressure is considerably higher in the precursor region.

It should be remembered that the above comparison of aircraft damage inside and outside the precursor region is based solely upon a review of damage as a function of peak overpressure. Additional data evaluated on the basis of damage versus distance may show that the formation of a precursor may have little effect upon damage, since relatively lower peak overpressures may occur at equivalent distances.

#### 4.4 EFFECT OF STRONG TIE-DOWNS

The exact effect of increasing the restraining forces on an aircraft subjected to blast loading by increasing tie-down strength cannot be determined from this limited investigation. In fact, a quantitative analysis of its effect upon aircraft damage cannot even be made for the specific tests performed since, because of the very limited number of test vehicles, control aircraft were not provided. Nevertheless, it is felt that a preliminary evaluation of the effect of strong tie-downs can be made from the data obtained by comparing the results of the present tests with the exposures of TUMBLER tests. Exposures at roughly equivalent overpressures were realized in TUMBLER 3 and TUMBLER 4. The TUMBLER 3 results are not directly comparable for at least two reasons: first, the thermal input was considerably higher and, second, the aircraft were not in the Mach stem region. TUMBLER 4 results cannot be used for direct comparison because of

the aircraft at the overpressures of interest were subjected to high dynamic drag forces. By making allowances for the differences in test conditions, it is believed a reasonably accurate evaluation of the effect of strong tie-downs can be made for the specific exposures of Shot 9.

The function of strong tie-downs was to limit aircraft movement and thus prevent damage because of ground contact during the blast phase. If this could be done successfully without causing additional damage due to the high stresses induced at the mooring points, the tie-downs would be considered effective in reducing damage. Comparison of the damage sustained by the F-86 aircraft in Shot 9 with that of aircraft F-86 (209) in TUMBLER 4 shows that the latter aircraft was more severely damaged. <sup>1/</sup> Both wings and the aft fuselage were heavily damaged because of ground contact. This aircraft, F-86 (209), was subjected to a peak overpressure of 8.9 psi. Aircraft F-86 (597), strongly tied down at the 12 psi overpressure level in Shot 9, was prevented from striking the ground by the action of the tie-downs. The postshot condition of the aircraft is shown in Fig. 3.18. The fuselage forward of the leading edge of the wing and aft of the trailing edge of the wing was quite heavily damaged; no structural damage resulting from high loads at the mooring points was detected by visual inspection. The higher damage to the fuselage, especially the forward fuselage, of F-86 (597) can probably be accounted for on the basis of the higher overpressure. Whether fuselage damage would have been less had the aircraft been free to move cannot be determined; however, it is believed the effect would be small. The F-86 aircraft exposed in TUMBLER 4 was subjected to drag forces. It is doubtful, however, that the blast loading which caused translation and rotation of the entire aircraft was any higher in TUMBLER 4 at the precursor fringe, the 8.9 psi region, than it was for Shot 9 in the 12 psi region. If the above is accepted, then it can reasonably be concluded that strong tie-downs materially reduced the damage to aircraft F-86 (597).

Two F-47 aircraft, F-47 (828) and F-47 (072), were also strongly tied down for Shot 9. The aircraft were at roughly the same overpressure, 12 psi and 12.5 psi. Both were damaged extensively and obviously beyond economical repair. Although the right wing tie-down failed on each aircraft, neither aircraft evidenced damage resulting from ground contact. Further, no significant damage attributable to loads induced as a result of the tie-downs was observed. It is possible that the tie-downs would not have failed had it not been for the side loading caused by the southerly bombing error. The fact that both aircraft were damaged beyond economical repair does not, of course, indicate the tie-downs were ineffective; however, the utility of strong tie-downs for the specific aircraft type at this input level is definitely

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<sup>1/</sup> Vulnerability of Parked Aircraft to Atomic Bombs, Operation TUMBLER-SNAPPER, Report WT-525, p 215.

limited. That the tie-downs did reduce total damage can be seen by comparing the Shot 9 results with TUMBLER results, specifically: aircraft F-47 (9931)<sup>2/</sup>, 8.4 psi, TUMBLER 3; aircraft F-47 (8785)<sup>3/</sup>, 8.4 psi, TUMBLER 3; and aircraft F-47 (9719)<sup>4/</sup>, 8.9 psi, TUMBLER 4. All of the above aircraft suffered damage because of ground contact, yet these aircraft were exposed at significantly lower input levels. If the strong tie-downs were capable of preventing F-47 aircraft from being damaged by contact with the parking surface at an input level of 12 psi, then it is expected similar protection would have been afforded the above aircraft subjected to the lower inputs. It is, therefore, concluded that the tie-downs are effective in reducing damage but the value of this protection decreases sharply as the overpressure approaches the point where the aircraft is no longer salvable. In very high damage regions such as the close-in stations on Shot 10, (14 psi, precursor region), the effect of tie-downs is not detectable. Similarly, at the lower overpressures tie-downs become ineffective because the aircraft can withstand the gust loading without the aid of the tie-downs.

#### 4.5 EFFECT OF THERMAL RADIATION SHIELDING

A preliminary evaluation of the effect of thermally shielding aircraft exposed to nuclear detonations was conducted during Shots 9 and 10 employing F-47 aircraft as the test vehicles. The exposure of primary importance was the aircraft F-47 (297) exposure during Shot 9. This aircraft, parked side-in, was subjected to a thermal input of 20 cal/sq cm and a peak overpressure of 5.1 psi. This vehicle was exposed again during Shot 10 in a nose-in orientation but only selected areas were shielded from thermal radiation. The input level was 9.2 psi and 54 cal/sq cm. Another aircraft, F-47 (072), similarly shielded provided no usable data during the Shot 10 test because of severe overpressure damage.

Referring to the first mentioned exposure wherein the complete aircraft was shielded, it is seen by comparing total damage that the shielded aircraft sustained approximately one-half the damage sustained by the unshielded aircraft. Although the aircraft were not in equivalent condition prior to the test, it is believed the damage differential noted is realistic. However, if both aircraft had been undamaged before the test the damage ratio may have been somewhat under two. Because of the difference in preshot condition of test and control vehicles, it is not possible to make a point by point damage comparison; nevertheless, certain general observations relative to this particular exposure can be made.

<sup>2/</sup> Vulnerability of Parked Aircraft to Atomic Bombs, Operation TUMBLER-SNAPPER, Report WT-525, p 107.

<sup>3/</sup> Ibid., p 114.

<sup>4/</sup> Ibid., p 212.

1. Visible thermal damage to unshielded aircraft was low.
2. The majority of additional fuselage damage occurred on ground zero (impulse) side.
3. Little difference in fuselage damage was noted.
4. Lifting and control surfaces (wing and empennage) were definitely protected by the shield.
5. Angle of incidence of radiant thermal energy to above surfaces was quite low.
6. Temp-tape data show the thermal radiation shield efficiency was above 90 per cent.
7. Heating of air between thermal shield and aircraft caused the fabric to balloon and provide a cushioning effect.

From the above it would appear that a thermal radiation shield will definitely reduce total damage to an aircraft exposed under conditions similar to those tested, and further, that some of the protection afforded results from a reduction of overpressure damage. Its effect on damage produced by the impulse effect is apparently small.

In the Shot 10 exposure of aircraft F-47 (297), where the thermal input was considerably higher, the effect of thermal shielding was pronounced. An excellent example is the relative damage sustained by the left and right ammunition-bay doors shown in Fig. 3.26. The unshielded door suffered considerably more damage than did the shielded door. An over-all comparison of wing damage could not be made because the right, unshielded, wing tip struck the ground during the blast phase causing inordinately high wing damage.

In general, therefore, it is believed that a thermal radiation shield of the type employed in these tests will reduce damage to aircraft parked in the vicinity of a nuclear detonation. Aircraft structural configuration, skin thickness and surface absorptivity will influence the effectiveness of the shield. Defensively, effectiveness would also be a function of such unpredictable variables as weapon yield, burst height, input level, and aircraft orientation. Since the protection afforded by thermal shields to aircraft having reflective, bare metal surfaces was definitely noticeable, it is believed that the protection provided under less favorable absorptivity conditions, for instance aircraft with dark painted surfaces, would prove to be marked.

#### 4.6 TEST PHASE PHOTOGRAPHY

The motion picture photography employed during the thermal and blast phases of Shots 9 and 10 to record fighter aircraft response is summarized in para. 3.4.1. Requirements were established by Project 8.1 and the work performed by, and under the direction of, Program 9. The over-all results were quite satisfactory. Obscuration

of the object by dust and smoke presented almost no problem in comparison to that experienced in the TUMBLER operation. The only difficulty with dust was experienced during Shot 10 at the 2300 ft station, wherein blast arrival was obscured. The energy input at this range was sufficient to cause failure of the sand-cement stabilization. Pieces of stabilization several square feet in area were broken out and carried away.

The most interesting picture obtained was that of the blast phase response of aircraft F-47 (072) in Shot 9. This aircraft was parked nose-in and anchored to concrete deadmen. Bombing error caused the blast incidence azimuth to be  $10^{\circ}$  to the right of nose-in. As the blast wave struck, the aircraft moved backward failing the tail tie-down. The rush of air then lifted the aircraft off the ground in a normal flying attitude which it maintained for a short time (approximately 2 sec) until the right wing tie-down failed. The aircraft then veered off to the left, under restraint of the left tie-down, and settled to earth. The material velocity had diminished by this time and no apparent damage was suffered in the landing. The F-86 aircraft at the same station was held to the ground by the tie-downs although considerable flutter or vibration was apparent. The lower angle of attack and the aerodynamic characteristics of the F-86 wing considerably reduced the lift forces developed and the tie-downs were adequate to keep it on the ground. The high speed camera viewing the vertical tail of the F-86 aircraft shows clearly the development of thermally induced skin buckles.

The thermal shield on the F-47 aircraft at 5300 ft on Shot 9 smoked considerably during the thermal phase. Smoke was noticeably more dense in areas where the incidence angle approached the normal. Ballooning of the cloth cover as the trapped air was heated is best shown in the view of the empennage. Rudder failure and vertical stabilizer reaction was well recorded by the high speed camera viewing aircraft F-47 (065).

#### 4.7 PEAK SKIN TEMPERATURE MEASUREMENTS

Peak skin temperature data were obtained for use in analyzing aircraft damage results and to supplement similar data gathered during TUMBLER-SNAPPER. A complete presentation of peak skin temperature measurements is given as Appendix A; a table of the measured peak temperature achieved by each aircraft is included in para. 3.4.2. Measurements on the three close-in aircraft on Shot 10 were rather limited because the high degree of destruction made temp-tape recovery almost impossible.

Of particular interest are the peak temperatures measured on the shielded and unshielded aircraft exposed at the 20 cal/sq cm level

during Shot 9. One point on the fuselage of aircraft F-47 (065), unprotected, reached a temperature of 424-441<sup>o</sup>F. A similar point on the shielded aircraft, F-47 (297), attained a temperature of only 144-170<sup>o</sup>F. Assuming the preshot temperature of both aircraft was 100<sup>o</sup>F and the absorptivity of the unshielded aircraft 0.5, calculations indicate the thermal shield transmitted under 10 per cent of the incident thermal energy. Less than 5 per cent should have been transmitted by direct radiation through the shield. The additional energy transmitted could be accounted for on the basis of conduction and/or energy derived from the burning of combustibles deposited on and in the shield. In any event the shield effectively reduced the thermal energy absorption by the aircraft surface and kept temperatures to a fairly low level. On the Shot 10 exposure the maximum temperature of the shielded skin was too low even to be recorded by the temp-tape device, i. e., less than 123<sup>o</sup>F.

The difference in skin temperature rise between Shot 9 and Shot 10 for the same thermal input (above dust layer) was considerable. Aircraft F-47 (828) was at the 60 cal/sq cm level in both shots. In Shot 9 portions of the aircraft reached a peak temperature in the vicinity of 500<sup>o</sup>F. In Shot 10 the highest temperature recorded was 253-264<sup>o</sup>F. Part of the difference was the result of the higher incidence angles in Shot 10. Further, attenuation by dust and smoke was probably higher for the lower burst. In addition, the aircraft being considerably closer to the burst point on Shot 10, shock arrival occurred sooner and kicked up dust during the latter portion of the thermal phase. The aircraft were also being carried through the air, in pieces, during the blast phase which overlaps the thermal phase close-in.

## CHAPTER 5

### CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 CONCLUSIONS

It is concluded that:

1. At corresponding peak overpressure levels, aircraft damage is considerably higher in the precursor region than it is in the region where a clean shock is formed. It is doubtful that any present day aircraft would survive direct exposure to a low, precursor forming burst if placed at distances corresponding to an overpressure of 10 psi and above. Although a higher damage/overpressure ratio is obtained in the precursor region, destructive power of a weapon may not necessarily be increased by precursor formation because of a corresponding reduction of peak overpressure.

2. In the high overpressure region up to the level required for destruction, strong tie-downs are effective in reducing total damage to fighter aircraft parked nose-in.

3. Under the conditions investigated, cloth thermal shields will reduce damage to parked aircraft caused by both thermal and blast inputs from nuclear weapons. For higher yield weapons the protective effect against thermal radiation would be more pronounced.

4. Results of tests described herein tend to confirm general principles developed to explain aircraft damage phenomena observed in TUMBLER tests.

#### 5.2 RECOMMENDATIONS

It is recommended that:

1. Existing vulnerability data be thoroughly reviewed and analyzed to determine the best practical passive defense measures to be used in the event of an atomic attack.

2. Various types of inexpensive protective devices for aircraft be designed and their efficiency determined by actual experiment.

3. The feasibility of exploiting the destructive effect of low burst heights for particular target situations and configurations for tactical use be investigated.

## APPENDIX A

### PEAK SKIN TEMPERATURE DATA

The peak skin temperature attained by various aircraft skin surfaces was measured by means of a maximum temperature indicating device known as a temp-tape. The peak skin temperature data obtained on the bomber and fighter aircraft exposed in UPSHOT-KNOTHOLE are summarized in Table A.1 through Table A.6. The temp-tapes were located on the nonirradiated side of the skin at the locations listed in the tables. An approximate idea of the station locations for the five aircraft types instrumented may be obtained from the illustrations present in Figs. 3.1 through 3.5. Diagrams to facilitate reporting of temp-tape locations on bomber aircraft are presented in Figs. A.1 through A.4. These are to be used in conjunction with the tables.

TABLE A.1 - Peak Temperatures Attained on B-29 (066), Left Side-in, Range 6200 Ft, Shot 7  
(Temp-tape Data)

Left Wing Upper Surface				Right W1 Upper Surface			
Location	Thick. (in.)	Peak Temp (°F)	Location	Thick. (in.)	Peak Temp (°F)	Location	Peak Temp (°F)
Sta 806; 2" aft of Main Spar	0.020	144-170	Sta 808; 2" aft of Main Spar	0.020	144-170		144-170
Sta 546; 2" aft of Main Spar	0.020	144-170	Sta 546; 2" aft of Main Spar	0.020	144-170		144-170
Fuselage Station 801				Fuselage Station 90			
Location Code#	Thick. (in.)	Peak Temp (°F)	Location Code#	Thick. (in.)	Peak Temp (°F)	Location Code#	Peak Temp (°F)
a	0.051	<123	a	0.040	<123	k	<123
b	0.051	<123	b	0.040	178	l	<123
c	0.051	<123	c	0.040	144	m	<123
d	0.051	<123	d	0.040	<123	n	<123
e	0.051	<123	e	0.040	<123	p	<123
f	0.040	<123	f	0.040	<123	q	<123
g	0.040	<123	g	0.040	<123	r	<123
h	0.040	<123	h	0.040	<123	s	<123
k	0.040	<123	j	0.040	<123	t	<123

NOTE: For Location of Stations on Aircraft See Fig. 3.1  
\* See Fig. A.1

TABLE A.2 - Peak Temperatures Attained on B-29 (066), Nose-in, Range 4450 Ft, Shot 8  
(Temp-tape Data)

Left Wing Upper Surface				Right Wing Upper Surface				
Location	Thick. (in.)	Peak Temp (°F)	Location	Thick. (in.)	Peak Temp (°F)	Location	Thick. (in.)	Peak Temp (°F)
Sta 564; 2" aft of Main Spar	0.020	232-252	Sta 564; 2" aft of Main Spar	0.020	232-252			
Fuselage Sta 30			Fuselage Sta 90			Fuselage Sta 342		
Location Code*	Thick. (in.)	Peak Temp (°F)	Location Code*	Thick. (in.)	Peak Temp (°F)	Location Code*	Thick. (in.)	Peak Temp (°F)
a	0.051	265-287	a	0.040	<123	a	0.051	<123
b	0.051	265-287	b	0.040	178-194	b	0.051	<123
c	0.051	288-308	c	0.040	144-170	c	0.040	<123
			d	0.040	144-170	d	0.051	<123
			e	0.040	<123	e	0.051	<123
			f	0.040	<123			

NOTE: For Location of Stations on Aircraft See Fig. 3.1  
\* See Fig. A.2

TABLE A.3 - Peak Temperatures Attained on B-17 (730), Nose-in, Range 4450 Ft, Shot 8  
(Temp-tape Data)

Left Wing			Right Wing			Dorsal at Fuselage Sta 570					
Location	Thick. (in.)	Peak Temp (°F)	Location	Thick. (in.)	Peak Temp (°F)	Location Code*	Thick. (in.)	Peak Temp (°F)			
Upper Surface Sta 358	0.032	144-170	Upper Surface Sta 358	0.032	144-170	a	0.032	<123-141			
3 in. from Leading Edge Sta 574	0.016	144-170	3 in. from Leading Edge Sta 574	0.016	<123	b	0.025	144-170			
1 ft from Leading Edge			1 ft from Leading Edge			c	0.032	144-170			
Lower Surface Sta 358	0.032	195-224	Lower Surface Sta 358	0.032	195-224	d	0.025	<123-141			
1 ft from Leading Edge Sta 574	0.016	<123	1 ft from Leading Edge Sta 574	0.016	<123	e	0.032	<123-141			
1 ft from Leading Edge			1 ft from Leading Edge								
Fuselage Sta 26			Fuselage Sta 95			Fuselage Sta 227			Fuselage Sta 643		
Location Code*	Thick. (in.)	Peak Temp (°F)	Location Code*	Thick. (in.)	Peak Temp (°F)	Location Code*	Thick. (in.)	Peak Temp (°F)	Location Code*	Thick. (in.)	Peak Temp (°F)
a	0.020	<123	a	0.020	144-170	a	0.040	<123	a	0.032	<123
b	0.020	**	b	0.020	171-178	b	0.040	<123	b	0.032	<123
c	0.020	195-224	c	0.025	144-170	c	0.040	**	c	0.032	<123
d	0.025	**	d	0.020	178-194				d	0.032	<123
e	0.020	265-287	e	0.020	<123				e	0.032	<123
f	0.020	**							f	0.032	<123
g	0.020	195-224									

NOTE: For Location of Stations on Aircraft See Fig. 3.2

\* See Fig. A.3

\*\* Temp-tapes Destroyed

TABLE A.4 - Peak Temperatures Attained on B-45 (481), Nose-in, Range 3700 Ft, Shot  
8, (Temp-tape Data)

Location	Thick. (in.)	Peak Temp (°F)		Thick. (in.)	Fuselage Sta 124		
		Left Wing	Right Wing		Location Code*	Thick. (in.)	Peak Temp (°F)
Wing Sta 224; 3'4" from Trailing Edge (Upper Surface)	0.091	144-170	232-252	0.064	144-170		
Wing Sta 224; 3'4" from Trailing Edge (Lower Surface)	0.091	< 123	< 123-141	0.064	< 123		
Nacelle Top; 1'6" Left of Center; 3'3" frwd of Wing Leading Edge	0.040	253-264	253-264				
Nacelle Top; 1'6" Right of Center; 3'3" frwd of Wing Leading Edge	0.040	265-287	232-252				
Fuselage Sta 50		Fuselage Sta 514		Fuselage Sta 598			
Location Code*	Thick. (in.)	Peak Temp (°F)	Thick. (in.)	Peak Temp (°F)	Location Code*	Thick. (in.)	Peak Temp (°F)
a	0.064	232-252	0.040	< 123	a	0.040	< 123
b	0.064	171-177	0.040	144-170	b	0.040	< 123
c	0.064	144-170	0.040	144-170	c	0.040	< 123
d	0.064	< 123	0.040	< 123	d	0.040	< 123
			0.040	< 123	e	0.040	< 123

NOTE: For Location of Stations on Aircraft See Fig. 3.3  
\* See Fig. A.4

TABLE A. 5 - Peak Skin Temperatures Attained on F-47, Shots 9 and 10, (Temp-tape Data)

Aircraft No. Shot No. Range (ft.) Orientation	Thick. (in.)	Peak Temperatures (°F)										
		828 9 1725 Nose-In	072 9 2100 Nose-In	297 9 5300 L Side-In	065 9 5300 R Side-In	828 10 2100 Nose-In	065 10 1850 Nose-In	072 10 1560 Nose-In	297 10 2300 Nose-In			
<b>Left Wing Upper Surfaces</b>												
Sta 56; 1'6" from Leading Edge	0.051	465-487	253-264	123	123	195-223	123	178-194	253-264	123	178-194	*
Sta 95; 3' from Trailing Edge	0.040	309-330	265-287	123	144-170	*	144-170	*	232-252	*	178-194	13
Sta 167; 2'6" from Trailing Edge	0.032	488-514	465-487	123	178-194	*	144-170	*	178-194	*	144-170	13
Sta 217; 1'3" from Leading Edge	0.032			123	288-308	*	232-252	*	288-308	*	171-178	123
<b>Right Wing Upper Surfaces</b>												
Sta 58; 1'8" from Leading Edge	0.051	465-487	232-252	123	123	232-252	123	178-194	253-264	232-252	178-194	*
Sta 95; 3' from Trailing Edge	0.040	377-423	195-224	123	144-170	*	144-170	*	144-170	*	144-170	*
Sta 167; 2'6" from Trailing Edge	0.032	488-514	331-363	144-170	232-252	*	232-252	*	178-194	*	144-170	13
Sta 217; 1'3" from Leading Edge	0.032											123
<b>Fuselage</b>												
Sta 41; on Top	0.051	309-330	195-224	123	144-170	253-264	144-170	253-264	253-264	232-252	144-170	144-170
Sta 77; on Top	0.032	368-376	465-487	*	144-170	*	144-170	*	253-264	*	144-170	144-170
Sta 215; 1'8" down along L Side	0.032	465-487	171-177	123	331-363	123	331-363	123	171-177	171-177	144-170	144-170
Sta 331; 1' down along L Side	0.032	288-308	309-330	*	377-423	178-194	377-423	178-194	178-194	*	123	123
Sta 331; 1' down along R Side	0.032	465-487	331-363	*								123
<b>Fuselage (Side-In Aircraft Only)</b>												
Sta 47; 2'9" down along Exposed Side	0.051			123	288-308		288-308					297
Sta 215; 2'4" down along Exposed Side	0.032			123	288-308		288-308					10
Sta 215; on Top	0.040			144-170	424-441		424-441					2300
Sta 331; Exposed Side (At Center Line)	0.040			144-170	265-287		265-287					Nose-In

NOTE: 1. F-47 (297), Left Side-In at 5300 ft. Shot 9 was Completely Covered by an Aluminised Asbestos Thermal Shield  
 2. F-47 (065) at 1850 Ft. and F-47 (297) at 2300 Ft. Nose-In, Shot 10 Had Their Left Wing and Horizontal Stabiliser Covered by an Aluminised Asbestos Thermal Shield  
 3. For Location of Stations on Aircraft See Fig. 3-4  
 \* Temp-tape Destroyed

TABLE A.6 - Peak Temperatures Attained on F-86 (597) During Shots 9 and 10, (Temp-tape Data)

Shot No. Range (ft) Orientation		9 2300 Nose-in	10 1850 Nose-in
Location	Thick. (In.)	Peak Temperature (°F)	
Left Wing Upper Surface Sta 78; 6' from Leading Edge Sta 150; 3'9" from Leading Edge Sta 255; 1'9" from Leading Edge	0.102 0.068 0.040	377-423 232-252 288-308	* * *
Right Wing Upper Surface Sta 78; 6' from Leading Edge Sta 150; 3'9" from Leading Edge Sta 255; 1'9" from Leading Edge	0.102 0.068 0.040	* 195-224 265-287	* * *
Fuselage Sta 26; On Top Sta 42; On Top Sta 78; 4" down from Canopy Left Side Right Side Sta 178; 4" down along Right Side Sta 202; 9" down along Left Side Sta 214; 9" down along Right Side Sta 221; On Top	0.032 0.032 0.032  0.032 0.032 0.032 0.032	517-539 540-634  178-194 288-308 488-514 232-252 178-194 465-487	* *  * * * * * 144-170
Vertical Stabilizer; Sta 30 1'6" from Leading Edge; Left Side 1'6" from Leading Edge; Right Side	0.040 0.040	* 288-308	123 232

NOTE: For Location of Stations on Aircraft See Fig. 3.5  
\* Temp-tape Destroyed

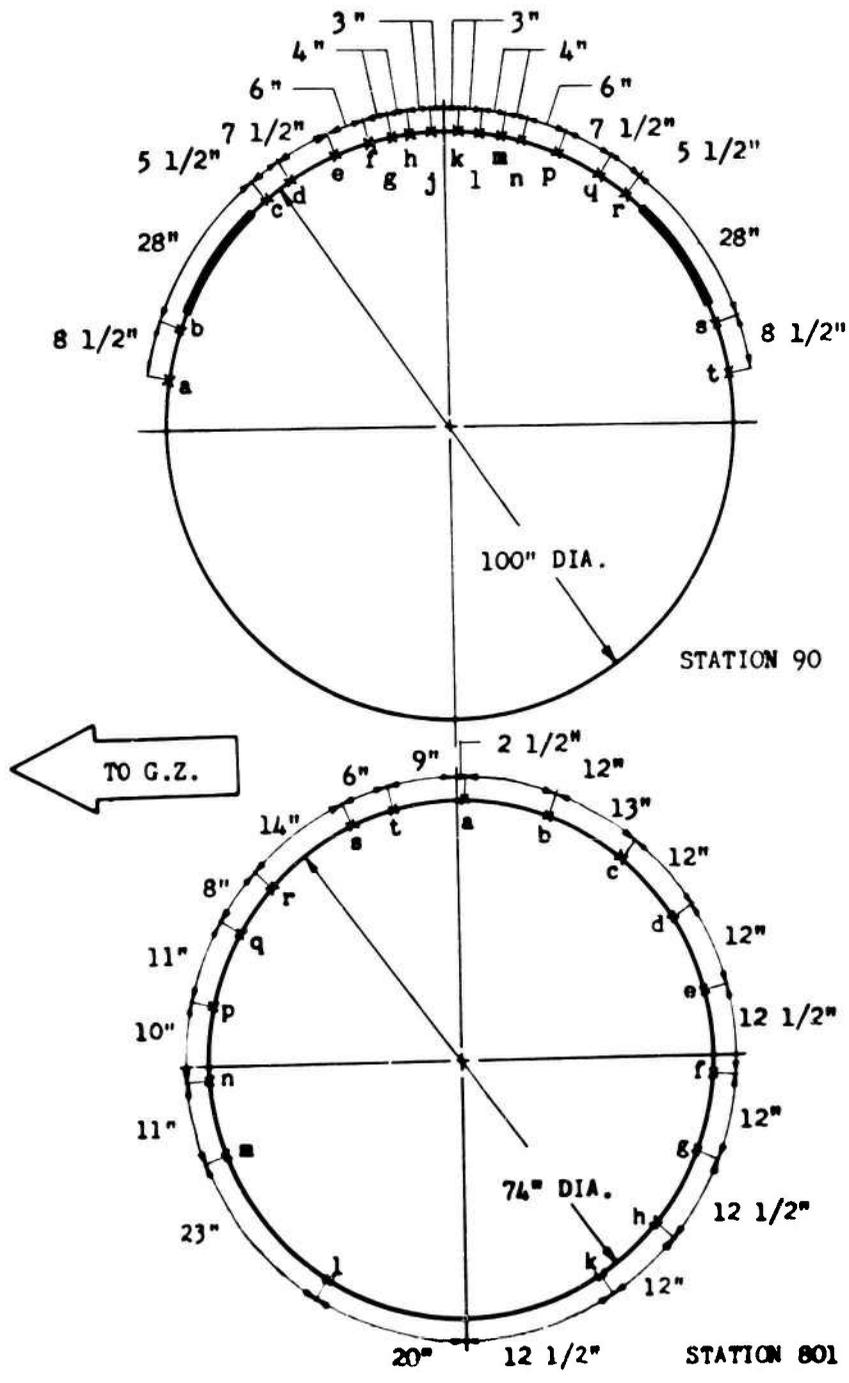


Fig. A.1 Temp-tape Locations on Fuselage of B-29, Shot 7, (For use in conjunction with Table A.1)



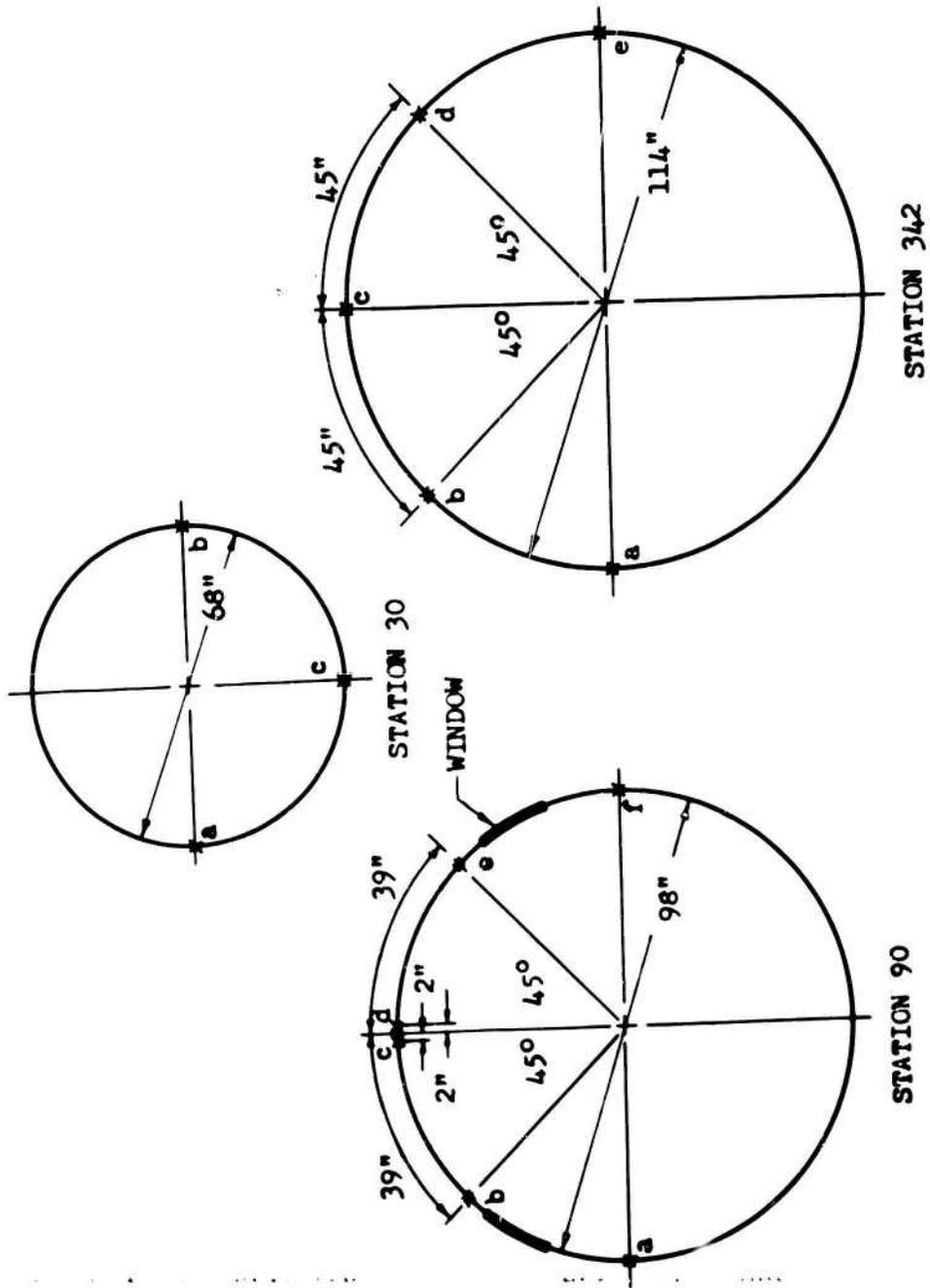


Fig. A.2 Temp-tape Locations on Fuselage of B-29, Shot 8, (For use in conjunction with Table A.2)

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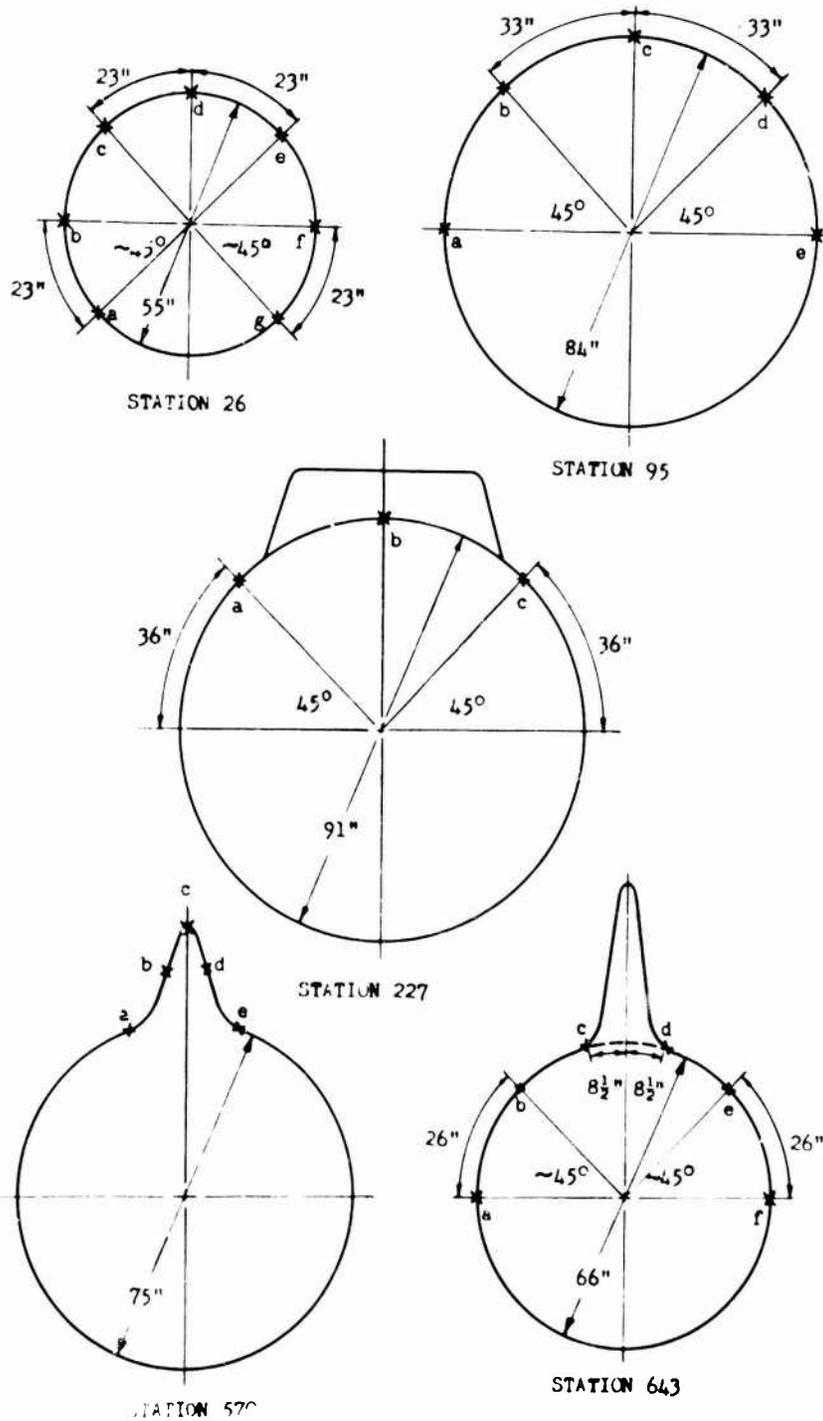


Fig. A.3 Temp-tape Locations on Fuselage of B-17, Shot 8, (For use in conjunction with Table A. 3)

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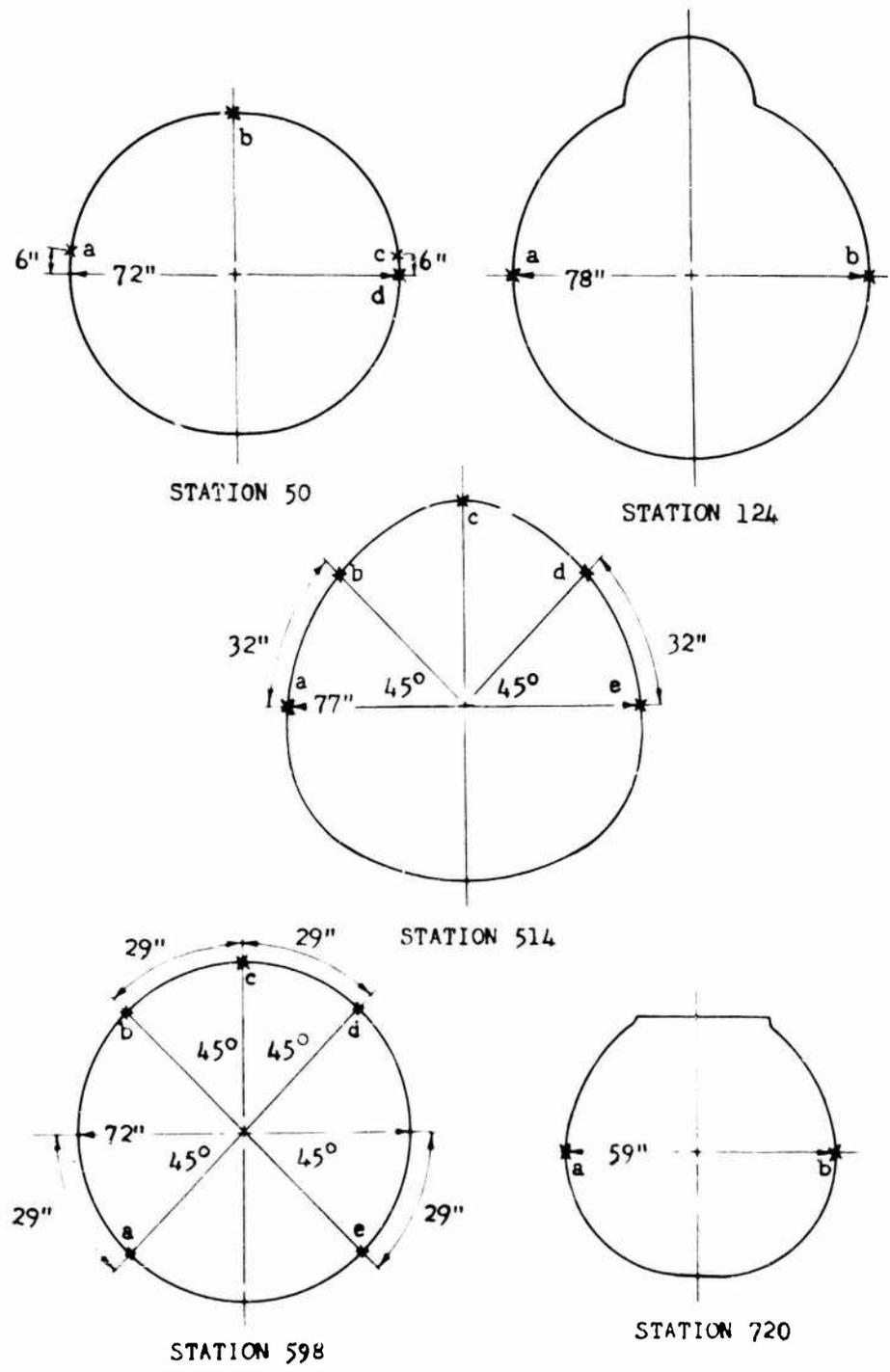


Fig. A.4 Temp-tape Locations on Fuselage of B-45, Shot 8, (For use in conjunction with Table A.4)



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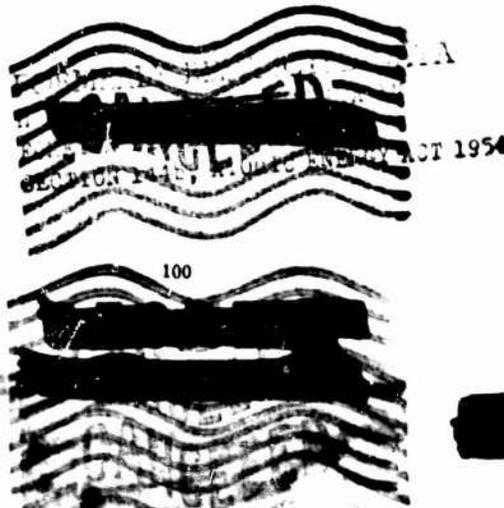
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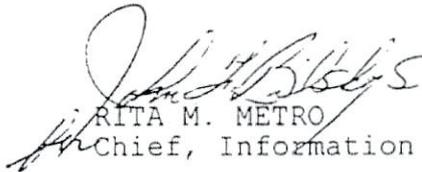
WT-602 through WT-607, WT-609 thru WT-618, WT-627 thru WT-631, WT-633, WT-635, WT-636, WT-639, WT-641 thru WT-644, WT-646, and WT-649.

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This memorandum supersedes the Defense Nuclear Agency, ISTS memorandum same subject dated August 17, 1995 and may be cited as the authority to declassify copies of any of the reports listed in the first paragraph above.

  
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