ROYAL AIRCRAFT ESTABLISHMENT
(FARNBOROUGH)

TECHNICAL NOTE No. M.E. 382

THE ATTACK OF AIRCRAFT FUSELAGES
BY CONTINUOUS ROD WARHEADS
(3/16 and 1/4 inch Square-section rods)

by

SEPTEMBER, 1963

MINISTRY OF AVIATION

THIS DOCUMENT IS THE PROPERTY OF H.M. GOVERNMENT AND
ATTENTION IS CALLED TO THE PENALTIES ATTACHING TO ANY INFRINGEMENT OF THE OFFICIAL SECRETS ACTS, 1911-1939.

It is intended for the use of the recipient only, and for communication to other officers under him as may appear to be expedient in the course of their duties. The officers exercising this power of communication are responsible that such information is imparted with due caution and reserve. Any person other than the authorized holder, upon obtaining possession of this document, by finding or otherwise, should forward it, together with his name and address, in a closed envelope to

THE SECRETARY, MINISTRY OF AVIATION, LONDON, W.C2

Letter postage need not be prepaid, other postage will be refunded. All persons are hereby warned that the unauthorized retention or destruction of this document is an offence against the Official Secrets Act.

CONFIDENTIAL

UNCLASSIFIED
IS A

Continuous Eff. Work Shop
Aircraft Attack
Tangential Stress

Mallin, P.G.E.
ROYAL AIRCRAFT ESTABLISHMENT
FARNBOROUGH

THE ATTACK OF AIRCRAFT FUSELAGES BY CONTINUOUS ROD WARHEADS
(3/16 and 1/4 inch square-section rods)

by

SUMMARY

This Note records the results of a number of static and dynamic detonations of 3/16 and 1/4 inch square-section continuous rod (C.R.) warheads against Boeing "B.29", Vickers "Valiant", Handley Page "Victor" and some replica steel fuselage sections, most of which were either loaded to simulate straight and level flight conditions during attack and/or were subsequently loaded to determine residual strength. Rod effectiveness was found to depend, for all the targets, on the direction of rod approach to, and the construction of, the section attacked but at least for the 3/16 inch C.R., appeared to be independent of rod impact velocity in the range 3000 to 5000 f.p.s.

Stress analyses made of the damaged targets indicate that there may well be a correlation between the failing stresses in bending of fuselages of various forms of construction. Further work to confirm and extend this and other indications is proposed.
# CONTENTS

1. **INTRODUCTION**  
   Page 8

2. **OBJECTS OF THE TRIALS**  
   Page 8

3. **TRIALS PROGRAMME**  
   Page 9

4. **WARHEADS**  
   Page 9

5. **TARGETS**  
   Page 10

6. **INSTRUMENTATION**  
   Page 12

7. **TRIALS PROCEDURE**  
   Page 13

8. **TRIALS RESULTS**  
   Page 14

9. **STRESS ANALYSIS OF LOADED TARGETS**  
   Page 17

10. **DISCUSSION OF TRIALS RESULTS**  
    10.1 Loaded targets  
    Page 17  
    10.2 Unloaded targets  
    Page 19

11. **DISCUSSION OF STRESS ANALYSIS RESULTS**  
    Page 20

12. **CONCLUSIONS**  
    Page 23

13. **FURTHER WORK**  
    Page 24

14. **ACKNOWLEDGEMENTS**  
    Page 25

**REFERENCES**  
Page 25

**ADVANCE DISTRIBUTION**  
Page 26

**APPENDIX 1**  
Figs. 1-8 of Appendix 1  
Page 31

**APPENDIX 2**  
Tables 1-7 of Appendix 2  
Page 35

**TABLES 1-3**  
Page 36-42

**ILLUSTRATIONS - Figs. 1-28**  
Page 27-30

**DETACHABLE ABSTRACT CARDS**  
Page -
APPENDICES

Appendix 1
1. Details of target layouts and methods of loading 31
2. Stress analysis of damaged fuselage targets 35

TABLES

1. Summary of continuous rod firings against fuselage targets 27
2. Details of continuous rod warheads used in lethality trials 29
3. Summary of damage to fuselage targets 30

Appendix 2
1. Target No.1A, Stress analysis of 'Valiant' fuselage section 36
2. " No.1B, " " " 'Victor' " " 37
3. " No.2, " " " 'B,29' " " 38
4. " No.3B, " " " 'B,29' " " 39
5. " No.3A, " " " 'B,29' " " 40
6. " No.4A, " " " 'B,29' " " 41
7. " No.5A, " " " 'B,29' " " 42

ILLUSTRATIONS

Cross section of 'Valiant' and 'Victor' targets at attack stations 1
Cross section of 'B,29' fuselage at attack stations 2
Target 1A - Record of rod damage to 'Valiant Type 673' fuselage (1/4 in. rod) 3
" 1B - Record of rod damage to 'Victor' fuselage (1/4 in. rod) 4
" 6 - Record of rod damage to 'Victor' prototype target (1/4 in. rod) 5
" 7A - Record of rod damage to 'B,29' target (1/4 in. rod) 6
" 7B - " " " " " " " " " 7
<table>
<thead>
<tr>
<th>Target 2</th>
<th>Description</th>
<th>Fig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3B</td>
<td>Record of rod damage to 'B.29' target (1/4 in. rod)</td>
<td>8</td>
</tr>
<tr>
<td>3A</td>
<td>Record of rod damage to 'B.29' target (3/16 in. rod)</td>
<td>9</td>
</tr>
<tr>
<td>4A</td>
<td>Record of rod damage to 'B.29' target (3/16 in. rod)</td>
<td>10</td>
</tr>
<tr>
<td>5A</td>
<td>Record of rod damage to 'B.29' target (3/16 in. rod)</td>
<td>11</td>
</tr>
<tr>
<td>4B</td>
<td>Record of rod damage to 'SS.1' replica steel fuselage section (3/16 in. rod)</td>
<td>12</td>
</tr>
<tr>
<td>5B</td>
<td>Record of rod damage to 'SS.1' replica steel fuselage section (3/16 in. rod)</td>
<td>13</td>
</tr>
<tr>
<td>8</td>
<td>Record of rod damage to steel honeycomb sandwich target (3/16 in. rod)</td>
<td>14</td>
</tr>
<tr>
<td>1A</td>
<td>Loaded 'Valiant' rear fuselage before attack</td>
<td>15</td>
</tr>
<tr>
<td>1A</td>
<td>Damage to rod 'entry' side of fuselage showing failure</td>
<td>16a</td>
</tr>
<tr>
<td>1A</td>
<td>Damage to rod 'exit' side of 'Valiant' fuselage</td>
<td>16b</td>
</tr>
<tr>
<td>1A</td>
<td>Detail of fuselage failure at the starboard side end of rod cut</td>
<td>16c</td>
</tr>
<tr>
<td>1A</td>
<td>Rod behaviour near end of cut on port side of 'Valiant' fuselage</td>
<td>16d</td>
</tr>
<tr>
<td>1B</td>
<td>Unloaded 'Victor' fuselage before attack</td>
<td>16e</td>
</tr>
<tr>
<td>1B</td>
<td>Damage to rod 'entry' side of 'Victor' fuselage</td>
<td>17a</td>
</tr>
<tr>
<td>1B</td>
<td>Damage to rod 'exit' side of 'Victor' fuselage</td>
<td>17b</td>
</tr>
<tr>
<td>1B</td>
<td>Detail of rod cut end on starboard side of 'Victor' fuselage</td>
<td>17c</td>
</tr>
<tr>
<td>1B</td>
<td>Rod damage to interior of 'Victor' fuselage</td>
<td>17d</td>
</tr>
<tr>
<td>1B</td>
<td>Rod cut end after subsequent loading equivalent to '0.6g'</td>
<td>17e</td>
</tr>
<tr>
<td>1B</td>
<td>Failure of 'Victor' fuselage under subsequent loading equivalent to '0.94g'</td>
<td>17f</td>
</tr>
<tr>
<td>1B</td>
<td>'Victor' fuselage after failure under subsequent loading equivalent to '0.94g'</td>
<td>17g</td>
</tr>
</tbody>
</table>
ILLUSTRATIONS (Continued)

Target 6 - Rod damage to 'Victor' rear fuselage

" 7A - Rod damage to top of 'B.29' wing/fuselage junction 18a, b & c
" 7A - Rod 'entry' damage to wing box top surface inside 'B.29' fuselage 19a
" 7A - Damage to rod 'exit' side of 'B.29' wing/fuselage junction 19b
" 7A - Detail of rod cut end on fuselage starboard side 19c
" 7A - Damage to rod 'exit' side of 'B.29' wing/fuselage junction 19d
" 7B - Rod 'entry' damage to bottom of 'B.29' wing/fuselage junction 20a
" 7B - Rod 'exit' damage to wing box top surface inside 'B.29' fuselage 20b
" 2 - Unloaded 'B.29' aft bomb bay section before attack 21a
" 2 - Damage to rod 'entry' side of 'B.29' fuselage 21b
" 2 - Damage to rod 'exit' side of 'B.29' fuselage 21c
" 2 - Starboard side of damage 'B.29' fuselage under subsequent loading 21d
" 2 - Rod damage to longeron structure 21e, f, g & h
" 2 - Damage to longerons after rod attack, severing and loading to '2.3g' 21j, k
" 3B - Damage to rod 'entry' side of unloaded 'B.29' fuselage 22a
" 3B - Damage to rod 'exit' side of 'B.29' fuselage 22b
" 3B - Rod 'entry' side damage under subsequent loading equivalent to '2.8g' 22c, d
" 3B - Behaviour of severed longeron members under subsequent loading equivalent to '2.8g' 22e, f
" 3A - Damage to rod 'entry' side of '1g' loaded 'B.29' mid-crew compartment 23a
" 3A - Detail of damage at rod cut end on starboard side 23b
" 3A - Detail of damage at rod cut end on port side 23c
" 3A - Damage to rod 'exit' side of fuselage 23d

- 5 -
ILLUSTRATIONS (Continued)

Target 4A - Damage to rod 'entry' side of unloaded 'B.29' mid-crew compartment

" 4A - Detail of damage at rod cut end on starboard side
" 4A - Detail of damage at rod cut end on port side
" 4A - Damage to rod 'exit' side of fuselage
" 5A - Damage to rod 'entry' side of '1g' loaded 'B.29' mid-crew compartment
" 5A - Failure of fuselage under subsequent loading equivalent to '1.8g'
" 5A - Damage to rod 'exit' side of fuselage after subsequent failure
" 5A - Detail of failure under additional load of the compression loaded side of the fuselage

Rod behaviour near ends of cut on 'B.29' fuselage sections

Target 4B - Rod damage to water filled 'SS.1' target

" 5B - Rod damage to simulated equipment filled 'SS.1' target
" 8 - Damage to rod 'entry' side of steel honeycomb target
" 8 - Rod 'exit' side damage to steel honeycomb target
" 8 - Rod damage to honeycomb core and inner skin
" 8 - Detail of typical rod cut end on steel honeycomb target

Figs. to Appendix 1

Firing 1 - Target layout and methods of 'loading'

Target layout in Firing 2

Methods of subsequent loading of Targets 2 and 3B

Target layout and primary target loading system used in dynamic rod firings 3, 4 and 5

Target layout for static firing against loaded and unloaded targets (Firing 1)
Figs. to Appendix 1 (Continued)

Method of subsequently loading Victor target 1B  
Target layout for static firing against unloaded targets (Firing 2)  
Method of subsequently loading 'B.29' fuselage target (Firing 2)  
Typical target layout for dynamic warhead firings showing Target 4A tension loading gear (Firing 4)  
Typical target layout for dynamic warhead firings showing Target 3A compression loading gear (Firing 3)  
Details of typical target loading system for dynamic warhead firings (Targets 4A and 5A)  
3/16 in. Blue Jay rod warhead mounted on 2-stage rocket vehicle for dynamic warhead firing  
Method of subsequently loading 'B.29' fuselage target (Target 3B)  
Detail of tail support and counterbalance loading (Target 3B)
INTRODUCTION

1.1 As a continuation of a general investigation into the effectiveness of continuous-rod (C.R.) warheads, further field trials have been made against a selection of aircraft fuselage targets, to extend and amplify the data obtained from previous trials[1,2,3]. In particular, the results of firings against certain sections of loaded Boeing B.29 fuselages[3] had shown the marginal effectiveness, under the trials conditions used, of the C.R. types at present envisaged, in defeating fuselage structure. It was considered desirable, therefore, to make additional firings against targets of different construction and under different target loading and attack conditions.

1.2 Firings were made against fuselage sections of Boeing 'B.29A', Vickers 'Valiant' Type 673, Handley Page 'Victor' second prototype aircraft, and against replica targets representative of a modern supersonic bomber and based on the Avro 730 project. Some of the targets were attacked in the unloaded condition, some loaded subsequent to attack and others loaded to level flight conditions during attack. The choice of targets was mainly dictated by their availability, but nevertheless they represent a range of materials and types of construction which may be expected in both present and future Soviet aircraft.

1.3 All the firings recorded in this Note were made at the Proof and Experimental Establishment, at either Shoeburyness or Pendine, between November 1960 and July 1962. Firings in which the Pendine long test track was used were made jointly with R.A.R.D.E.

OBJECTS OF THE TRIALS

2.1 The main object of the trials was to obtain further data on the effectiveness of 3/16 inch and 1/4 inch square-section continuous-rods in the attack of aircraft fuselage structures, the data being required for the assessment of conditional kill probabilities applicable to likely warhead/target engagement conditions.

Within this general objective were the following specific requirements:

(a) To compare the results of attacks against similar targets loaded when attacked and loaded subsequent to attack.

(b) To establish the extent and nature of rod damage on fuselage structures of different types of construction and to compare their residual strengths.

(c) To determine the influence of rod impact velocity on the extent and nature of damage to fuselage targets of similar construction, and on the residual strength of the structures.

(d) To determine the effectiveness of continuous-rods against compression loaded areas of fuselages of different forms of construction.

(e) To determine the effectiveness of continuous-rods in the attack of experimental steel fuselage sections either empty or containing simulated fuel and internal equipment.

(f) To attempt a correlation of trials results by simple stress analysis methods.
TRIALS PROGRAMME

3.1 Since, in general, a continuous-rod projected from a G.W. warhead is equally likely to strike an aircraft fuselage at any section and from any direction, the programme of firings was designed to cover attacks from above and below against fuselage sections of varying detailed construction, e.g. bomb bay, rear fuselage etc. It was however decided that all rod strikes should impact the fuselages so as to give circumferential cuts in the structures, in order to make the damaged sections amenable to simple stress analysis.

3.2 Thirteen separate fuselage sections were attacked, involving eight warhead firings, four of which projected 1/4 inch square-section C.R's and the remaining four, 3/16 inch square-section C.R's. All the four 1/4 inch and one of the four 3/16 inch warheads were detonated statically, whilst the remainder of the 3/16 inch warheads were detonated dynamically on the Pendine long test track in order to achieve high rod striking velocities.

3.3 Of the thirteen targets, three were loaded to 'fg' at the time of attack, to reproduce straight and level flight stresses at the attack station, and, where necessary, subsequently loaded to failure or to the maximum attainable load. Four targets were not loaded during attack but were subsequently loaded. The remaining six targets were not loaded, being used merely to obtain data on extent and nature of damage.

3.4 Of the loaded targets, four rear fuselages, i.e. the 'Victor', 'Valiant' and two 'B.29's', were attacked in tension loaded regions, whilst two 'B.29' bomb bays and one 'B.29' rear fuselage were attacked in normally compression loaded areas. The six unloaded targets, i.e. one 'Victor' rear fuselage, two 'B.29' centre fuselages and three steel specimens, were attacked from either above or below.

3.5 A summary of the firing programme and the results is given in Table 1.

WARRHEADS

4.1 All firings were made using experimental models of Blue Jay, Red Dean or VR.725 warheads to project 3/16 and 1/4 inch square-section continuous-rods. The major details of these warheads are given in Table 2.

4.2 For the 1/4 inch C.R. static firings the Red Dean and VR.725 warheads were detonated at suitable distances above the ground on base plates secured to simple wooden or tubular steel structures. The stand-off distances from warhead centre to the point of first impact on most of the targets was adjusted to be 85% of the rod theoretical maximum hoop radius (M.H.R.) i.e. 32 ft stand-off for the Red Dean. Exceptionally, for reasons of target layout geometry, the target attacked by VR.725 was positioned at 80 ½ M.H.R., i.e. 46 ft stand-off. In three of the four 1/4 inch rod firings (Nos. 2, 6 and 7), the rods were ejected in the horizontal plane, and in the vertical plane for the remaining firing (No.1).

4.3 All but one firing (No. 8) of the 3/16 inch Blue Jay warheads were made dynamically using the Pendine long test track. For this purpose each warhead was mounted, with its major axis vertical, at the front end of a two-stage rocket-propelled vehicle. The warheads were detonated at the end of the track,
when moving at approximately 3000 f.p.s., and ejected their hoops in a horizontal plane. The effective stand-off distance for these firings was approximately 20 ft, i.e. 85% M.H.R.

4.4 The fourth Blue Jay warhead (Firing No.3) was detonated statically, mounted on an angled baseplate secured to a simple wooden support. The rods were ejected in a plane approximately 30° to the horizontal and at a stand-off distance from the target of 20 ft.

5 TARGETS

5.1 The fuselage targets used in the trials consisted of the following:

(a) **Vickers 'Valiant Type 673'**

This unique aircraft, derived from the standard 'Valiant B Mk.1' was specially designed for intruder missions involving high speed and high 'g' at low altitudes. Consequently, it was considerably stronger, structurally, than the B Mk.1. For this reason, its fuselage strength and construction (conventional skin and closely spaced Z-stringers) were considered to be similar in parts to that likely to be used in more modern supersonic medium bombers such as the Soviet 'Blinder' aircraft which C.R. warheads may be required to defeat.

For the purposes of the trial, the full-length 'Valiant 673' fuselage was assembled, complete with inner wings, and mounted in the normal flying attitude on supports under the wing roots. Dead loads were applied to the upper surface of the tailplane to reproduce the approximate level-flight bending and shear stresses at the attack station. The target was attacked at Stn.963, in the bomb bay deflector region, in mainly tension and shear loaded material, from a direction of 45° above abeam.

(b) **Handley Page 'Victor'**

Of the two 'Victor' targets attacked, the largest comprised the centre fuselage (Stns.263 to 1005) containing the whole of the bomb bay and the wing carry-through structure of the second prototype aircraft (Fig.17a). Construction of the bomb bay region was mainly of conventional skin and closely spaced Z-stringer type, with longerons, and was typical of the bomb bay of a high subsonic medium bomber, occupying most of the fuselage depth. It could well be broadly similar to the bomb bay region of the Soviet 'Blinder' aircraft, particularly in view of its location behind the wing-box structure. For the firing, the section was simply supported at each end by sandbag cradles, and attacked in the unloaded condition at Stn.740, i.e. near the aft end of the bomb bay, from a direction of 45° above abeam, so that mainly tension and shear loaded structure was struck by the rod. Subsequently, the damaged fuselage was supported under the forward end and also just forward of the damaged station and then loaded by means of a downward load applied to the tail end, in order to determine its residual strength.

The second 'Victor' target was a section of the rear fuselage (Stns.967 to 1045) which had been used as a strength test specimen and had also been attacked in a previous trial. Since, in the present firing, the object was merely to record the nature and magnitude of the damage, the target was simply supported on
one of its ends with its longitudinal axis vertical, and attacked, in the unloaded condition, at Stn.940.

(c) **Boeing 'B.29A'**

'B.29A' fuselage sections were used in the trials since they were available in limited quantity and could thus be used for comparative firings. Furthermore, the 'B.29' is of conventional construction and is considered to be broadly similar in structural features to the Soviet 'Badger' subsonic medium bomber. Two bomb bay sections (Stns.218 to 646), fitted with dummy bomb doors, were attacked, one in the forward section (Target 3B, Stn.300), and one in the rear (Target 2, Stn.566), i.e. forward and aft of the wing box structure, from a normal below direction of attack (Figs.22a and 21a respectively). Both were unloaded during attack and subsequently assembled into a complete fuselage and inner wings, and supported under the wing roots for loading. Downward loads were applied to nose and tail, as appropriate, to determine the residual strengths of the specimens.

In addition, three 'B.29' mid-crew compartments (Stns.646 to 834), aft of the bomb bay, were attacked at Stn.760, two from 45° above abeam and one from normal below (Targets 4A, 5A and 3A). Two of these targets (3A and 5A) - Figs.23a and 25a - were loaded during attack to simulate level flight stresses at the attack station and, since failure did not occur, subsequently subjected to increased loading. The remaining section (4A - Fig.24a) was attacked in the unloaded condition and later loaded to the limit of the straining gear. Two rod attacks were also made against that part of the 'B.29' fuselage incorporating the very heavy wing carry-through structure (Stns.383 to 485). As the two targets (7A and 7B, Figs.19a and 20a) were salvaged sections from previous trials they were simply supported on one end with their longitudinal axes vertical and not loaded during or after attack. Normal above and normal below directions of attack were used, at Stn.434.

(d) **SS.1**

This target was a replica of one version of the projected Avro 730 supersonic reconnaissance aircraft. It represented a 20 ft section of fuselage at about mid-length and just forward of the wings. It was of conventional skin, frame and closely-spaced Z-stringer construction, but built entirely of S.3 steel. It had been designed to represent an integral fuel tank, as in the 'Avro 730', but was not capable of being loaded. Two rod attacks were made against this type of target, one in which the target (No.4B - Fig.26) was filled with water to represent fuel and the other (No.5B - Fig.27) containing simulated dense internal equipment.

(e) **Honeycomb sandwich target**

This cylindrical target 6 ft 4 in. diameter and 7 ft 6 in. long was of steel honeycomb sandwich construction (Target No.8 - Fig.28a). It was manufactured by A.V. Roe and Co. in 1956, when the firm were investigating steel sandwich structures for the Avro 730 project. Although it is typical of a section of an aircraft, it was produced mainly to assess the design of fixtures used in its manufacture. Consequently, core to skin strength was not emphasized and may have been below standard. Construction was of 18 SWG (0.048") Rex 448 steel.
steel skins with the honeycomb core of 0.003\" mild steel material. Skin joints were partly welded and partly riveted, the jointing members being of 16 SWG (0.064\") DTD.171 material. The cylinder was closed by a diaphragm at one end and was mounted with its longitudinal axis vertical and resting on the open end. The attack was made transversely, at approximately 30° to normal, at mid-length. It was not suitable for loading.

5.2 Details of the layouts and methods of loading of the various targets are given in Appendix I. General arrangement drawings of the layouts are given in Figs.1 to 4 of Appendix 1, and shown pictorially in Figs.5 to 8 of Appendix 1.

5.3 Cross-sections of each of the targets which were subjected to loading, showing the location and areas of the various structural members at the stations attacked, are given in Figs.1 and 2 of the Note.

6 INSTRUMENTATION

6.1 The extent and type of instrumentation used in the trials varied, to some degree, with each firing, but consisted essentially of equipment for the determination of rod velocities and high speed camera coverage of rod and target behaviour during and after attack. Broadly, the instrumentation may be considered separately for the static and dynamic warhead firings, as follows:-

6.1.1 Static firings

(a) In all static firings, other than that concerning the honeycomb sandwich target, the times taken for the continuous rods to travel between the point of detonation and the target were measured by micro-second counter chronometer (M.C.C.) actuated by an infra-red photo-cell directed at the warhead and a number of 'make' screens or wires secured to the target at the attack station. The rod mean velocities were then calculated using the averages of the times obtained from each channel. Striking velocities were then computed from rod retardation data and are given in Table 1.

In the remaining static firing, in which the honeycomb target was attacked, rod travel times were measured by an Argon Lamp Chronograph actuated by warhead detonation and 'break' wires spaced at intervals on the target. Mean and striking velocities were then calculated as above.

(b) In the static firing against the loaded 'Valiant' fuselage it was desired to investigate the behaviour of the C.R. hoop in the vicinity of one of the tangents to the fuselage - drawn from the point of warhead detonation. To achieve this, a searchlight illuminated translucent screen of thin plastic was used to provide a background for the rod which was photographed using a Fastax high-speed camera running at approximately 14,000 half-frames/sec. This technique was successful, as shown in Fig.16e.

(c) Other instrumentation in the static firings consisted of 16 mm cine-photographic coverage of spring-balance readings in cases where targets were loaded after attack through a cable system. Additionally, full still photographic coverage was used throughout the trials.
6.1.2 Dynamic firings

(a) In all the C.R. dynamic firings, rod mean velocities were obtained from the rod flight times measured by an Argon Lamp Chronograph actuated by warhead detonation and 'break' wires on the targets. Striking velocities were computed by R.A.R.D.E. from retardation data. The range of velocities at the targets are given in Table 1. Detailed analyses of the velocity measurements are given in separate R.A.R.D.E. reports.

(b) As in the 'Valiant' fuselage static firing, it was also desired to investigate rod behaviour in the loaded target tangent zones. The method adopted was similar to that used in the static firing except that, owing to the vertical disposition of the target, the Fastax camera was mounted on a tall tower and viewed downwards along the fuselage side towards a flash bulb illuminated white background screen laid on the ground (Figs. 7a and 7b of Appendix I). Good results were obtained in all three dynamic firings, as shown by the examples in Figs. 25e and f. In each case rod velocity was in the region of 5300 f.p.s.

(c) Loaded target behaviour, both during attack and under subsequent additional loading, was recorded by Fairchild cameras running at approximately 250 frames/sec.

(d) In addition to the above instrumentation, mainly concerned with target response, the following data were recorded by, or at the request of, R.A.R.D.E., who participated jointly in the dynamic trials:

(i) Warhead point of detonation, by means of a Fastax camera viewing at right angles to the test track - the expected detonation zone, and running at approximately 14,000 half-frames/sec.

(ii) Rod development, by the 'Flare Path' technique using a Fastax camera viewing, through a mirror, the arc of rod projected in the direction of warhead motion. Film speed was again 14,000 half-frames/sec.

(iii) A general view of the target arena during firing, by means of an Acmade camera running at about 1000 frames/sec.

(iv) Space-time data of both primary and secondary rocket vehicles, using the magnet and coil system installed on the long test track.

(v) Warhead ignition delay, by means of a duplicated M.C.C. and fuse-timer system operated by the warhead firing current and the detonation flash.

Further details concerning the above are given in the relevant R.A.R.D.E. reports.

6.2 In all firings the instrumentation was provided and operated by the staff of either P. & E.E.(S.), P. & E.E.(P) or R.A.R.D.E.

7 TRIALS PROCEDURE

7.1 The procedure adopted in each trial varied slightly according to whether the firing was to be static or dynamic and the targets loaded or unloaded.
However, in each firing, after assembling (where necessary) and positioning of the targets and in certain cases applying the simulated '1g' level flight loads, the warhead was detonated. The resulting damage was recorded and in cases where the loaded targets did not fail under attack they were subjected to additional incremental loads until failure occurred or a limiting load was reached. In the four cases where unloaded fuselage targets were subsequently loaded, the damaged portions were assembled into complete fuselages and then subjected, firstly, to the level flight loading and then, where necessary, to increased loading up to failure or, again, until a limiting load was reached. In all cases the maximum attainable loads were noted or the residual strengths of the targets determined.

8 **TRIALS RESULTS**

8.1 The conditions under which each firing was made are given in Table 1, and the damage to each of the fuselage targets from rod attack is summarised in Table 3, shown diagrammatically in Figs.3 to 15, and illustrated in Figs.16 to 28.

8.2 Fuselage failing loads, where applicable, and the residual strengths of the loaded targets are detailed in Table 1.

8.3 The results of the trials, in terms of lethality, may be summarised as follows:
<table>
<thead>
<tr>
<th>Firing and target No.</th>
<th>Rod size and velocity</th>
<th>Direction of attack</th>
<th>Target and attack str.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>3/16&quot; sq., high velo.</td>
<td>45° above aseam</td>
<td>'Valiant' 673, rear fuselage, Sta. 963</td>
<td>Failed on attack.</td>
</tr>
<tr>
<td>1B</td>
<td>3/16&quot; sq., high velo.</td>
<td>45° above aseam</td>
<td>'Victor' prototype, bomb bay, Sta. 740</td>
<td>Failed at 'O.9]g', on loading after attack.</td>
</tr>
<tr>
<td>6</td>
<td>1/8 sq., low velo.</td>
<td>45° above aseam</td>
<td>'Victor' prototype, rear fuselage, Sta. 940</td>
<td>Probably lethal</td>
</tr>
<tr>
<td>7A</td>
<td>1/8 sq., low velo.</td>
<td>Normal above</td>
<td>'B-29' fuselage at wing junction, Sta. 434</td>
<td>Assessment based on comparison with previous target (1B).</td>
</tr>
<tr>
<td>7B</td>
<td>1/8 sq., low velo.</td>
<td>Normal below</td>
<td>'B-29' fuselage at wing junction, Sta. 434</td>
<td>Assessment based on presence of heavy wing structure.</td>
</tr>
<tr>
<td>2</td>
<td>1/8 sq., low velo.</td>
<td>Normal below</td>
<td>'B-29' fuselage rear bomb bay, Sta. 966</td>
<td>Assessment based on expected butting of damaged longeron compression members.</td>
</tr>
<tr>
<td>3A</td>
<td>3/16&quot; sq., high velo.</td>
<td>45° above aseam</td>
<td>'B-29' fuselage forward bomb bay, Sta. 300</td>
<td>No failure in subsequent loading to ' 2.0]g'.</td>
</tr>
<tr>
<td>3B</td>
<td>3/16&quot; sq., high velo.</td>
<td>45° above aseam</td>
<td>'B-29' mid-crow compartment, Sta. 768</td>
<td>No failure in subsequent loading to ' 2.0]g'.</td>
</tr>
<tr>
<td>Firing and target No.</td>
<td>Rod size and velocity</td>
<td>Direction of attack</td>
<td>Target and attack strn.</td>
<td>Loading</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------</td>
<td>---------------------</td>
<td>------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>4A</td>
<td>3/16&quot; sq. high velo.</td>
<td>45° above abeam</td>
<td>'B.29' mid-crew compartment Strn. 768</td>
<td>Zero on attack subsequently loaded</td>
</tr>
<tr>
<td>5A</td>
<td>3/16&quot; sq. high velo.</td>
<td>45° above abeam</td>
<td>'B.29' mid-crew compartment Strn. 768</td>
<td>'1g' on attack subsequently loaded</td>
</tr>
<tr>
<td>4B</td>
<td>3/16&quot; sq. high velo.</td>
<td>Symmetrical target</td>
<td>Steel replica fuselage mid-length</td>
<td>None</td>
</tr>
<tr>
<td>5B</td>
<td>3/16&quot; sq. high velo.</td>
<td>Symmetrical target</td>
<td>Steel replica fuselage mid-length</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>3/16&quot; sq. low velo.</td>
<td>Symmetrical target</td>
<td>Steel honeycomb fuselage mid-length</td>
<td>None</td>
</tr>
</tbody>
</table>

**NOTE:** The assessments relate to the probability of structural failure of the fuselage targets in bending, and assume a Category 'K' (15 second kill) standard of judgement.
9 STRESS ANALYSIS OF LOADED TARGETS

9.1 In order to obtain as much technical information as possible from full-scale trials of the type considered in this Note, and with the expectation of devising 'damage laws' for use in C.R. warhead lethality assessments, data on the maximum stresses achieved in damaged structures subjected to loads, either during or after attack, are being collected. The intention is to make a full investigation of the subject when further evidence has been obtained. Thus, in all recent trials in which fuselage specimens were loaded to establish their residual strength, the apparent maximum tensile and compressive stresses developed in the damaged structures at failure (or at maximum achievable loading) have been calculated. These stresses normally occurred at the extremities of the rod cuts, but in some attacks from 'below' the aircraft they occurred in heavy longeron members which were not completely severed and which effectively butted under load.

9.2 Concerning the trials recorded in this Note, stress analyses have been made of the seven fuselage targets which were either loaded during attack and/or subsequently loaded. The method of analysis used is similar to that employed by most aircraft manufacturers for the simple stressing of a fuselage in pure bending. In the case of the 'Valiant' and 'Victor' targets the manufacturers themselves were consulted, and for the 'B.29' targets the method was that used by the Boeing Airplane Co. in the design of the 'B.29', as noted in a U.S. report.

9.3 The analyses were confined to pure bending since visual examination of failed targets showed no evidence of shear failure or of torsional effects due to asymmetric damage. Frame damage was neglected because of its minor nature in the purely circumferential cuts inflicted in the trials. Rod 'exit' damage was also neglected because, although quite substantial in the dynamic warhead firings against empty fuselage sections, it appeared to have little or no effect on the mode of failure or on the maximum stresses achieved and, furthermore, would be a rare occurrence in modern aircraft fuselages densely filled with bombs, fuel or equipment.

Details of the stress analyses relating to the seven loaded targets are given in Appendix 2.

10 DISCUSSION OF TRIALS RESULTS

10.1 Loaded targets

10.1.1 The two attacks against the '1g' loaded 'Valiant' and the subsequently loaded 'Victor' aircraft (Targets 1A and 1B) showed that the ½ in. C.R., at the low impact velocity of about 3400 f.p.s., was capable of defeating, from the 45° above abeam direction, the rear fuselages of aircraft employing closely spaced stringer construction typical of modern subsonic and low supersonic bombers (Figs. 16b and c, 17h, j and k). It may be inferred that the rods would be equally effective at any attack direction from normal above to 45° on either side of this position.

On the other hand, the 3/16 in. C.R. was incapable, in two attacks (Targets 4A and 5A), of defeating the rear fuselage of the 'B.29' from the 45°
above abeam approach direction and at a striking velocity of approximately 5100 f.p.s. (Figs. 24a, b, c and d, 25a). This may be largely due to the relative toughness of the B.29's widely spaced extruded stringer construction as shown by a comparison between similar fuselage sections of the 'Valiant' and the 'B.29' (Stns. 963 and 566 respectively). In the 'Valiant' section a level flight bending moment of approximately 7.5 x 10^6 lb in. is taken by a cross-sectional area of about 39 in.\(^2\) whereas the 'B.29' section bending moment of 4.75 x 10^6 lb in. is supported by as much as 31.4 in.\(^2\) of material.

10.1.2 Three attacks against forward and rear bomb bay sections, and a rear fuselage section, of the B.29 (Targets 3B, 2 and 3A), showed that neither the \(\frac{1}{6}\) in. C.R. at approximately 3400 f.p.s. nor the \(\frac{3}{16}\) in. C.R. at approximately 5100 f.p.s., were capable of causing fuselage failure in attacks from normal below, under level flight loads. In two attacks the longeron members were not completely severed (Figs. 21e and g, 23a) and butting of the damaged sections occurred, whilst in the other case (Target 3B) the longerons were completely severed but even so butting still took place, and persisted despite the application, eventually, of a fluctuating load (Figs. 22e and f).

It would appear from these results that the \(\frac{3}{16}\) and \(\frac{1}{6}\) in. C.R.'s are unlikely to prove effective against compression loaded fuselage structure incorporating relatively heavy extruded stringers or longerons and may only be effective against light skin and sheet stringer structure under compression loading.

10.1.3 The results of the two \(\frac{3}{16}\) in. rod attacks (Targets 4A and 5A) made against similar sections of the B.29 rear fuselage under similar attack conditions, except for the loading, (Figs. 24a and 25a), showed that the residual strength of a target attacked in the unloaded condition and subsequently loaded could be up to 17\(\frac{3}{4}\) greater than one attacked in the loaded condition, even though slightly less structure was severed in the target loaded during attack. It is evident that this indication should be investigated so that due allowance can be made when using the results of unloaded trials for assessment purposes. The magnitude of the difference cannot, at present, be even approximately estimated since identical structures can show considerable variations in strength and the nature of rod damage is not always consistent under similar attack conditions.

10.1.4 It was intended that the effects of increased rod striking velocity should be shown by comparison of the results of two attacks, Target No. 5A and Firing No. 2 of Ref. 3 against similar sections of the B.29 rear fuselage. Unfortunately, the high velocity rod impact (Fig. 25a) resulted in a continuous cut some 13° of arc smaller, and cutting approximately 3\(\frac{3}{4}\) less material of the 'attack' side, than the corresponding low velocity strike. Hence, the residual strengths of the two targets corresponded to '1.8g' and '1.5g' loadings, for the high and low velocity strikes, respectively. That this lower order of damage was not typical of high velocity impacts was shown by the results from Target No. 4A against a similar B.29 section, where the rod 'entry' damage (Fig. 24a) was virtually identical to that in the low velocity firing. However, the residual strengths of these targets are not strictly comparable because of the differing loading conditions during attack.
10.1.5 Although, from these few firings it is difficult to estimate the
effect on fuselages of rod striking velocity, it must be noted that neither in
Target 4A nor 5A did the higher striking velocity produce more rod 'entry'
damage than the lower velocity strike. Rod 'exit' damage was, however, found
to be consistently greater for the high velocity impacts on nearly empty
targets.

10.1.6 It is also worth noting, at this point, that no 3/16 in. C.R.
attack of a fuselage target, either described in this Note or previously
reported, under a variety of attack conditions, has been found capable of
defeating the target under '1g' level flight loading.

10.1.7 All but two attacks of the loaded targets produced values of
'arc of rod cut to arc visible' of greater than 90%, the exceptions being high-
velocity strikes (Targets 3A and 5A), where there was evidence of breaks in the
rod hoop occurring near the ends of the rod cut on the target, thus reducing
the rates of 'arc cut' to 'arc visible' to 80% and 83% respectively.

10.1.8 All the seven attacks of loaded targets, except Target 2, where
heavy longonors were present, give percentages of structural material severed
in the rod 'entry' surface to that of the cross-sectional area of the whole
section varying only between 33% and 37%. This result is perhaps surprising
in view of the different trials conditions involved such as target construction,
direction of attack, rod striking velocity etc. If both rod 'entry' and 'exit'
damage are added, then the percentage of the total cross-sectional area of the
section cut by the rod rises to between 41% and 53%. This much larger variation
seems to be independent of the attack conditions and is probably attributable
to the widely differing quantity and location of internal equipment and secondary
structure within the various targets, all of which affects the 'exit' damage
considerably.

10.2 Unloaded targets

10.2.1 The results of Firing No.6 against the 'Victor' rear fuselage
largely confirmed the result obtained from the secondary target in Firing No.1
of Ref.3, in that all the rod 'entry' side structure, such as skin, closely
spaced stringers and longeron members, within the 155° arc of cut, was severed.
In addition, it showed that the arc of rod cut as a percentage of arc visible,
i.e. 91%, was of the same order as obtained on circular fuselage sections
employing other forms of light-alloy construction. Rod 'exit' damage, however,
was considerable, in the absence of the strong structural members near the
fuselage centre line which were present in the earlier firing, and accounted for
approximately one third of the total structural cross-sectional area severed
(Figs.5 and 18).

10.2.2 The damage to Targets 7A and 7B showed conclusively that ¼ in.
C.R's, after passing through either the top or bottom fuselage skins of a B.29
wing/fuselage junction, were incapable of severely damaging the wing box
structure, largely due to rod break-up on the fuselage 'entry' skinning
(Figs.19b and 20b). In both attacks structure severed on the rod 'entry' side
could account for no more than 15-20% of the total structural cross-sectional
area as compared with some 35% commonly obtained on cylindrical shell target
sections. Consequently, neither of these two attacks could be assessed as
fuselage structural kills because of the very heavy wing carry-through structure which, since only lightly damaged, would probably be capable of carrying fuselage loads transmitted to it by the severance of fuselage skinning. This assessment is, of course, confined to the fuselage and does not consider the effects of spanwise damage to the inner wings which would inevitably occur in practice with this type of attack.

10.2.3 Both firings against steel cylindrical sections (Targets 4B and 5B) having very closely spaced stringers showed a relatively low percentage of 'arc of rod cut to arc of target visible', being about 83 to 85% as compared with the normal for light alloy targets of over 90%. This may well be accounted for by the comparatively higher resistance to the rod of the stringers near the point of tangency despite the high impact velocity. This is supported by the clear evidence of the gradually decreasing damage to the 10 or so stringers just before the end of the rod cut in the skin.

In the case of the water-filled target (No.4B) the damage (Figs.13 and 26) was such that, had it been in a mainly tensile loaded region, the aircraft might possibly have survived longer than the 15 seconds required for a Cat.'K' kill, owing to the relatively low arc of cut. Had it occurred in a mainly compression loaded region, however, the result would probably have been catastrophic.

In the attack of the target (No.5B) with simulated equipment, no exit damage was produced and since the arc of cut on the target at rod entry was restricted to 132° and severed only 36% of the total cross-sectional area (Fig.27), it seems likely that the target would have survived whether the damage had been in tension or compression loaded material.

10.2.4 The single attack against the target (No.8) of steel honeycomb construction yielded the unusually low ratio of 'arc cut to arc visible' of 71%. Examination of the damage (Fig.28) showed this to be due to the bunching-up of the honeycomb core between the steel skins at the rod cut extremities. This presented a very solid barrier to further progress of the rod, and probably caused it to break prematurely. It was also noted that the cut skins of the target exhibited a marked degree of petalling (Fig.28o) particularly on the inner skin, a phenomenon which did not occur with light-alloy skins under either low or high velocity rod impact nor on the steel skin and stringer target in Firing 5B (Fig.27).

11 DISCUSSION OF STRESS ANALYSIS RESULTS

11.1 In order to indicate the nature of the evidence which is being obtained from the stress analyses, the results from the seven loaded target trials covered in this Note and five results from earlier trials, are discussed.

11.2 The approximate maximum stresses, neglecting possible stress-concentration effects, occurring at failure or at maximum achievable loading, in the seven loaded specimens of this Note, were found to be as follows:-
Approx. Maximum stress
lb/in.²

<table>
<thead>
<tr>
<th>Target No.</th>
<th>Target aircraft</th>
<th>Target station</th>
<th>Rod size in. x in.</th>
<th>Direction of attack</th>
<th>Rod striking velocity f.p.s.</th>
<th>Loading condition</th>
<th>Maximum stress lb/in.²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Valiant</td>
<td>963</td>
<td>⅛ x ⅛</td>
<td>⅟₅ above abeam</td>
<td>3450</td>
<td>At failure during attack at 1g</td>
<td>28,800 10,000</td>
</tr>
<tr>
<td>2B</td>
<td>Victor</td>
<td>740</td>
<td>⅛ x ⅛</td>
<td>⅟₅ above abeam</td>
<td>3450</td>
<td>At failure under 0.94g loading</td>
<td>19,100 7,850</td>
</tr>
<tr>
<td>4A</td>
<td>B-29</td>
<td>758</td>
<td>⅜/₁₆ x ⅜/₁₆</td>
<td>⅟₅ above abeam</td>
<td>5000</td>
<td>Under 1g loading after attack Under max. loading of 2.18g</td>
<td>9,060 5,590</td>
</tr>
<tr>
<td>5A</td>
<td>B-29</td>
<td>758</td>
<td>⅜/₁₆ x ⅜/₁₆</td>
<td>⅟₅ above abeam</td>
<td>5100</td>
<td>Under 1g loading after attack At failure under 1.8g loading</td>
<td>16,500 9,900</td>
</tr>
<tr>
<td>3A</td>
<td>B-29</td>
<td>768</td>
<td>⅜/₁₆ x ⅜/₁₆</td>
<td>Normal below</td>
<td>5100</td>
<td>Under 1g loading after attack Under max. loading of 2₃₂₈g</td>
<td>9,570 14,950</td>
</tr>
<tr>
<td>2</td>
<td>B-29</td>
<td>566</td>
<td>⅛ x ⅛</td>
<td>Normal below</td>
<td>3380</td>
<td>Under 1g loading after attack Under max. loading of 2₃₂₈g</td>
<td>9,040 5,060</td>
</tr>
<tr>
<td>3B</td>
<td>B-29</td>
<td>300</td>
<td>⅜/₁₆ x ⅜/₁₆</td>
<td>Normal below</td>
<td>5200</td>
<td>Under 1g loading after attack Under max. loading of 2.8g</td>
<td>12,840 23,200</td>
</tr>
</tbody>
</table>

* Failing loads could not be attained in these tests

11.3 Combining the current and earlier trials, eight of a total of 12 results involved normally tensile loaded structure, whilst the remaining four involved compression loaded material. Since the mode of failure of tensile and compressive loaded structure is quite different, they must be considered separately.

11.4 The calculated maximum tensile stresses are noted first, and are as follows:
CALCULATED MAXIMUM TENSILE STRESS LB/IN.²

<table>
<thead>
<tr>
<th>Target or firing No.</th>
<th>Rod size and velocity</th>
<th>Aircraft</th>
<th>Fuselage station</th>
<th>Attack condition</th>
<th>At failure under attack</th>
<th>At failure under increased load</th>
<th>At maximum load applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>¾&quot; L.V.</td>
<td>Valiant</td>
<td>963</td>
<td>Loaded</td>
<td>28,800</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1B</td>
<td>¾&quot; L.V.</td>
<td>Victor</td>
<td>740</td>
<td>Unloaded</td>
<td>-</td>
<td>19,100</td>
<td>-</td>
</tr>
<tr>
<td>1A</td>
<td>3/16&quot; H.V.</td>
<td>B.29</td>
<td>768</td>
<td>Unloaded</td>
<td>-</td>
<td>19,650 (No failure)</td>
<td>-</td>
</tr>
<tr>
<td>2A</td>
<td>3/16&quot; H.V.</td>
<td>B.29</td>
<td>768</td>
<td>Loaded</td>
<td>-</td>
<td>16,450</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>¾&quot; L.V.</td>
<td>B.29</td>
<td>768</td>
<td>Loaded</td>
<td>11,500</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>3/16&quot; L.V.</td>
<td>B.29</td>
<td>768</td>
<td>Loaded</td>
<td>16,400</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>5/16&quot; L.V.</td>
<td>B.29</td>
<td>566</td>
<td>Loaded</td>
<td>22,600</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>3/16&quot; L.V.</td>
<td>B.29</td>
<td>566</td>
<td>Loaded</td>
<td>25,500</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Data from Ref. 3

11.5 From the four cases where fuselage failure occurred on gradually increasing the loading it appears that the range of failing stress could be from about 16,000 to 23,000 lb/in.². This is not contradicted by the single case where no failure occurred at a stress of 19,650 lb/in.², since this target was unloaded during attack and might therefore be expected to have a somewhat higher residual strength. Furthermore, it was not possible at the time to continue the loading to a stress level of around 23,000 lb/in.². Of the three targets which failed during attack, two probably failed under stresses considerably lower than the 'apparent' maximum values calculated. The remaining target, however, failed at the exceptionally low nominal stress of 11,500 lb/in.², some 5000 lb/in.² less than the maximum stress values of two similar targets which failed during increased loading after the attacks. This low-stress result, obtained from the first rod warhead firing against a loaded fuselage target conducted in the U.K., could be due to inexperience, at that time, in determining precisely the extent of rod damage in targets which failed under attack. This isolated result should, therefore, be treated with reserve.

11.6 From the few results available so far, the broad indications are that for C.R. attacks against tensile-loaded surfaces of cylindrical semi-monocoque fuselages employing different forms of construction, the fuselages are liable to fail if the calculated maximum tensile stresses, in the damaged section, equal or exceed the following values:

(a) 16,000 lb/in.² for skin, frame and light extruded stringer construction.

(b) 17,000 lb/in.² for skin, frame and closely spaced sheet stringer construction.

(c) 22,000 lb/in.² for skin, frame and widely spaced heavy extruded stringer construction.
At present, these must be regarded as tentative deductions. Nevertheless, they are thought to be reasonable in view of the narrowness of the band of stress values covering the three types of structure so far investigated.

11.7 In all, four attacks have been made against fuselage compression loaded surfaces. The calculated maximum compressive stresses achieved are as follows:

<table>
<thead>
<tr>
<th>Target or firing No.</th>
<th>Rod size and velocity</th>
<th>Target aircraft</th>
<th>Fuselage station</th>
<th>Attack condition</th>
<th>Calculated maximum compressive stress lb/in²</th>
</tr>
</thead>
<tbody>
<tr>
<td>3A</td>
<td>3/16&quot; H.V.</td>
<td>B.29</td>
<td>768</td>
<td>Loaded</td>
<td>14,950</td>
</tr>
<tr>
<td>2</td>
<td>1/2&quot; L.V.</td>
<td>B.29</td>
<td>566</td>
<td>Unloaded</td>
<td>21,200</td>
</tr>
<tr>
<td>3B</td>
<td>3/16&quot; H.V.</td>
<td>B.29</td>
<td>300</td>
<td>Unloaded</td>
<td>23,200</td>
</tr>
<tr>
<td>1</td>
<td>1/2&quot; L.V.</td>
<td>B.29</td>
<td>566</td>
<td>Unloaded</td>
<td>29,750</td>
</tr>
</tbody>
</table>

* Data from Ref. 7

11.8 These results, although consistent, are too few for even tentative deductions to be made at this stage, particularly in view of the probably wider band of failing stress values than for the tension loaded surfaces. It appears, both from the compressive stress values and from the behaviour of the targets under the maximum achievable loads, that the stress for failure will increase considerably where longerons are present. This could be due to the difficulty experienced by C.R's in cutting completely all the members of a built-up section and hence the high probability of butting of semi-severed structure.

11.9 Using the estimated failing stress values obtained by the foregoing method, and in conjunction with theoretical analyses of the influence of direction of attack on the maximum stresses in rod-damaged fuselages of different types of construction, it should, eventually, be possible to predict, with fair accuracy, the results of C.R. strikes on likely target aircraft. At present, accuracy is limited by the relatively few trials results, the few types of construction investigated and the simple attack conditions so far considered.

12 CONCLUSIONS

12.1 The following general indications may be deduced from the results of the trials described in this Note and, in certain cases, from consideration of the results of previous work:

(a) The 1/2 in. C.R. should be capable of causing failure in level flight of the rear fuselage of a modern subsonic or low supersonic bomber, employing closely spaced light alloy stringer and skin construction, when attacking from above.

(b) Neither the 1/2 in. C.R. at low impact velocity, nor the 3/16 in. C.R. at high impact velocity, appears capable of causing failure in level flight of
the entire lower half, nor the centre section upper half, of the fuselage of a
subsonic bomber of similar construction to the Boeing 'B.29'.

(a) The 3/16 in. C.R. even at high impact velocity, may be incapable of
causin failure in level flight of a supersonic (M2 to 3) bomber fuselage of
steel skin and closely spaced stringer construction, except for strikes on
integral fuel tank sections containing fuel.

(d) There is evidence that steel honeycomb fuselage structure, typical of
high supersonic aircraft, may be appreciably more resistant to C.R. attack than
consideration of the structure might suggest.

12.2 In addition, the following specific points arise from the trials:-

(a) No significant difference has been found in the extent and nature of
rod 'entry' damage from 3/16 in. C.R's impacting similar targets at approximately
3200 f.p.s. and 5200 f.p.s., although rod 'exit' damage was greater for the high
velocity impacts on virtually empty targets.

(b) The compression-loaded under-surfaces of fuselages were found to be
capable of withstanding attack, because of the liability to butting of the
damaged material, which occurred even when relatively light longeron members
were severed.

(c) The residual strengths of targets attacked by C.R. in the loaded
condition are likely to be considerably less than those of targets attacked in
the unloaded condition and subsequently loaded.

12.3 A simple bending stress analyses of loaded targets, as described in this
Note, if used in conjunction with studies of the influence of direction of
attack on maximum stresses in damaged targets of various forms of construction,
should - when more data become available - enable fair estimates to be made of
the results of actual C.R. attacks against likely types of aircraft targets.

13 FURTHER WORK

13.1 The work described in this Note has, by its limited nature, revealed only
indications and trends likely to be important in the attack of fuselage
structures by C.R's. It is necessary that further trials should be made to
confirm and extend these indications. These might include:

(a) Firings of 3/16 in. and 1 in. C.R. against loaded sections of
fuselage structures of various types in order to obtain more data on the
behaviour of the different forms of construction, in particular those in steel.
Stress analyses of such firings should provide a better understanding of the
failing stresses of structures damaged by C.R's.

(b) Firings of 1 in. C.R's at high velocity against fuselage structures
to determine whether the performance of this size of rod is enhanced by higher
impact velocity.

(c) Firings of C.R's against fuselages such as to produce more complex
attack conditions, e.g. angled cuts etc.
13.2 In addition, it is considered that the investigation on the influence of direction of attack on the stresses in a damaged fuselage, commenced in Ref. 11, should be extended to other fuselages of different construction in order that present and future trials results may become more generally applicable to various potential targets and also may be used with greater confidence.

14 ACKNOWLEDGEMENTS

14.1 Acknowledgements are made to:

(a) The Superintendents of the Proof and Experimental Establishments at Shoeburyness and Pendine, and their Staffs, for their co-operation in preparing and carrying out the trials.

(b) The Director, R.A.R.D.E., and members of P.7 and P.8 Divisions for their co-operation in the planning, preparation and carrying out of the dynamic warhead trials and also the Instrumentation Section for their assistance in the excellent high-speed photographic coverage.

REFERENCES

<table>
<thead>
<tr>
<th>No.</th>
<th>Author</th>
<th>Title, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hancock, D.A.</td>
<td>Continuous rod warhead lethality tests against static aircraft targets (3/16&quot; x 3/16&quot; cross-section rods).</td>
</tr>
<tr>
<td>2</td>
<td>Hancock, D.A.</td>
<td>Continuous rod warhead lethality tests against static aircraft targets (4/&quot; x 4/&quot; cross-section rods).</td>
</tr>
<tr>
<td>3</td>
<td>Mallin, R.G.E.</td>
<td>Continuous rod warhead lethality trials against B.29 aircraft fuselages (3/16, 1/2 and 5/16 in. square-section rods).</td>
</tr>
<tr>
<td>4</td>
<td>Baigent, P.</td>
<td>Report of RAE trial ME/B3/9072/RGEM/1, Firings 1 and 2 (P &amp; EE(P) Trial 20/61.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RARDE Ref. FHM/W/272/56 (PSW), December 1961. Secret-Discreet</td>
</tr>
<tr>
<td>5</td>
<td>Baigent, P.</td>
<td>Report of RAE trial ME/B3/9072/RGEM/1, Firing 3 (P &amp; EE(P) Trial 93/61.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RARDE Ref. FHM/W/272/56 (PSW), March 1962. Secret-Discreet</td>
</tr>
<tr>
<td>6</td>
<td>Zapf, D.</td>
<td>Summary report on sidewinder warhead effectiveness study.</td>
</tr>
</tbody>
</table>
REFERENCES (Continued)

No.  Author                        Title, etc.

                              Secret-Discreet

                              Confidential


11   Leeming, D.A.                  The influence of direction of attack on the bending stresses in a fuselage section damaged by continuous rods. RAE Note to be published.
                              Secret

ATTACHED: -

Appendices 1 and 2
Tables 1-3
Figs.1-15 - Drg. Nos. SME 88679/R to SME 88694/R
Figs.16-28 - Neg. Nos. 164007 to 164035
Detachable abstract cards

ADVANCE DISTRIBUTION: -

DGAW/S  Director, RAE
D/GW(X)  - Action
D/GW(T)  DDRAE(A)
DGAGS    DDRAE(B)
DG/RAF   Head of Structures Dept
DA Mech  " " Weapons Dept
DA Arm   RAE Library
AD/GW (P & W)  RAE Bedford Library
20 (for TTCP-D6 Panel)
AD/GW (G & C)  PATS 1/RAE
TIL        Sec RAE - GW Warhead Fuze System
            Lethality Panel

--------

- 26 -

CONFIDENTIAL
### TABLE 1 - Summary of continuous-rod firings against fuselage targets

<table>
<thead>
<tr>
<th>Firing and target No.</th>
<th>Rod cross-section in. x in. and type of trial</th>
<th>Direction of rod approach</th>
<th>Stand off distance ft</th>
<th>Rod mean velocity ft.p.s.</th>
<th>Estimated rod striking velocity ft.p.s.</th>
<th>Target</th>
<th>Attack station</th>
<th>'Target loading during attack</th>
<th>Result of attack</th>
<th>Target loading after attack</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>½ x ½ static</td>
<td>45° above beam</td>
<td>32</td>
<td>3663</td>
<td>3450</td>
<td>Vickers Valiant B Mk.2 rear fuselage</td>
<td>963</td>
<td>1g flight loads 27,216 lb at Stn. 1210 giving B.M. = 7,660,000 lb in. B.F. = 31,540 lb at Stn. 363</td>
<td>Fuselage failed see Fig. 16</td>
<td>Subsequently loaded by applying 21,250 lb at Stns. 372 and 1005 giving B.M. = 5,620,000 lb in. B.F. = 25,820 lb at Stn. 724 equivalent to 0.94g. Fuselage did not fail</td>
</tr>
<tr>
<td>1B</td>
<td>½ x ½ static</td>
<td>45° above beam</td>
<td>32</td>
<td>3663</td>
<td>3450</td>
<td>Handley Page Victor prototype bomb bay</td>
<td>74.0</td>
<td>Unloaded</td>
<td>See Fig. 17 None</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>½ x ½ static</td>
<td>45° above beam</td>
<td>46</td>
<td>3700(2)</td>
<td>3500</td>
<td>Handley Page Victor prototype rear fuselage</td>
<td>94.0</td>
<td>Unloaded</td>
<td>See Fig. 18 None</td>
<td></td>
</tr>
<tr>
<td>7A</td>
<td>½ x ½ static</td>
<td>Normal above</td>
<td>30</td>
<td>3700(2)</td>
<td>3500</td>
<td>Boeing B.29A wing/fuselage junction</td>
<td>43.4</td>
<td>Unloaded</td>
<td>See Fig. 19 None</td>
<td></td>
</tr>
<tr>
<td>7B</td>
<td>½ x ½ static</td>
<td>Normal below</td>
<td>30</td>
<td>3700(2)</td>
<td>3500</td>
<td>Boeing B.29A wing/fuselage junction</td>
<td>43.4</td>
<td>Unloaded</td>
<td>See Fig. 20 None</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>½ x ½ static</td>
<td>Normal below</td>
<td>32</td>
<td>3591</td>
<td>3300</td>
<td>Boeing B.29A rear bomb bay</td>
<td>566</td>
<td>Unloaded</td>
<td>See Fig. 21 Subsequently loaded by applying 18,360 lb at Stn. 1059 giving B.M. = 11,160,000 lb in. B.F. = 25,710 lb at Stn. 366, equivalent to 0.5g. Fuselage did not fail</td>
<td></td>
</tr>
<tr>
<td>3B</td>
<td>3/16 x 3/16 dynamic</td>
<td>Normal below</td>
<td>32 true 20 effective</td>
<td>5500 min.(x) 5975 max.</td>
<td>5030 min. 56.59 max.</td>
<td>Boeing B.29A forward bomb bay</td>
<td>300</td>
<td>Unloaded</td>
<td>See Fig. 22 Subsequently loaded by applying 23,508 lb at Stns. 30 and 191 giving B.M. = 6,175,700 lb in. B.F. = 23,200 lb at Stn. 300, equivalent to 2.8g. Fuselage did not fail</td>
<td></td>
</tr>
</tbody>
</table>

- CONFIDENTIAL
<table>
<thead>
<tr>
<th>Firing and target No.</th>
<th>Rod cross-section in. x in. and type of trial</th>
<th>Direction of rod approach</th>
<th>Stud off distance ft</th>
<th>Rod mean striking velocity fps</th>
<th>Estimated rod striking velocity fps</th>
<th>Target</th>
<th>Attack station</th>
<th>Target loading during attack</th>
<th>Result of attack</th>
<th>Target loading after attack</th>
</tr>
</thead>
<tbody>
<tr>
<td>3A</td>
<td>3/16 x 3/16 dynamic</td>
<td>Normal below</td>
<td>33.2</td>
<td>5335 min. 19600 max. (2)</td>
<td>6650 min. 5410 max.</td>
<td>Boeing B.29A mid-deck compartment See Fig. 2b</td>
<td>768</td>
<td>1g flight loads, 8600 lb at Stn.1050 giving B.M. = 2,420,000 lb in. S.P. = 8600 lb at Stn.768</td>
<td>Fuselage did not fail See Fig. 23</td>
<td>Load increased to 16,600 lb at Stn.1050 giving B.M. = 4,700,000 lb in. S.P. = 16,600 lb at Stn.768, equivalent to 2.4g. <strong>FUSELAGE DID NOT FAIL</strong></td>
</tr>
<tr>
<td>4A</td>
<td>3/16 x 3/16 dynamic</td>
<td>45° above abeam</td>
<td>33.5</td>
<td>5264 min. 5733 max.</td>
<td>4950 min. 5260 max.</td>
<td>Boeing B.29A mid-deck compartment See Fig. 2b</td>
<td>768</td>
<td>Unloaded</td>
<td>See Fig. 24</td>
<td>Subsequently loaded by applying 17,679 lb at Stn.1050 giving B.M. = 4,700,000 lb in. S.P. = 17,679 lb at Stn.768, equivalent to 2.4g. <strong>FUSELAGE DID NOT FAIL</strong></td>
</tr>
<tr>
<td>5A</td>
<td>3/16 x 3/16 dynamic</td>
<td>45° above abeam</td>
<td>33.5</td>
<td>5354 min. 5913 max.</td>
<td>4900 min. 5300 max.</td>
<td>Boeing B.29A mid-deck compartment See Fig. 2b</td>
<td>768</td>
<td>1g flight loads, 8864 lb at Stn.1050 giving B.M. = 2,495,000 lb in. S.P. = 8864 lb at Stn.768</td>
<td>Fuselage did not fail See Fig. 25</td>
<td>Load increased to 16,864 lb at Stn.1050 giving B.M. = 3,610,000 lb in. S.P. = 16,864 lb at Stn.768, equivalent to 3.4g. <strong>FUSELAGE FAILED</strong></td>
</tr>
<tr>
<td>6A</td>
<td>3/16 x 3/16 dynamic</td>
<td>Symmetrical target</td>
<td>33.5</td>
<td>5264 min. 5733 max.</td>
<td>4950 min. 5260 max.</td>
<td>SS.1 steel replica fuselage section Mid-length</td>
<td>Unloaded but filled with water See Fig. 26</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7A</td>
<td>3/16 x 3/16 dynamic</td>
<td>Symmetrical target</td>
<td>33.5</td>
<td>5334 min. 5623 max.</td>
<td>4900 min. 5300 max.</td>
<td>SS.1 steel replica fuselage section Mid-length</td>
<td>Unloaded but filled with simulated equipment See Fig. 27</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8A</td>
<td>3/16 x 3/16 static</td>
<td>Symmetrical target</td>
<td>20</td>
<td>3550</td>
<td>3990</td>
<td>Steel honeycomb sandwich fuselage section Mid-length</td>
<td>Unloaded See Fig. 28</td>
<td>None</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

'2' denotes an estimated rod velocity in cases where recordings were incomplete
'min.' and 'max.' denote minimum and maximum rod velocities recorded on the targets in the dynamic firings
<table>
<thead>
<tr>
<th>Firing Note</th>
<th>Warhead weight</th>
<th>Warhead length</th>
<th>Rod size</th>
<th>Rod arrangement</th>
<th>Linear charge</th>
<th>H.E. filling weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>3, 4, 5, 8</td>
<td>10.9</td>
<td>8</td>
<td>3/16 x 3/16</td>
<td>2-tier</td>
<td>57.3</td>
<td>5.12</td>
</tr>
<tr>
<td>12 &amp; 7</td>
<td>10.5</td>
<td>14.8</td>
<td>5/8 x 1</td>
<td>2-tier</td>
<td>37.3</td>
<td>5.12</td>
</tr>
<tr>
<td></td>
<td>14.25</td>
<td>14.25</td>
<td>3/4 x 1</td>
<td>2-tier</td>
<td>37.5</td>
<td>5.12</td>
</tr>
</tbody>
</table>

All static detonated warheads were initiated by a centrally positioned No. 53 electric detonator and a 14 dram CS pellet. All dynamically detonated warheads were initiated by a centrally positioned ICI seismic detonator.
### Table 1 - Summary of rod damage to fuselage targets

<table>
<thead>
<tr>
<th>Firing and target No.</th>
<th>Rod section in. x in.</th>
<th>Direction of rod approach</th>
<th>Target</th>
<th>Area of fuselage visible from marked position (A)</th>
<th>Actual area of strike on fuselage</th>
<th>Percentage B/A %</th>
<th>Total fuselage structural cross-sectional area, in.²</th>
<th>Approx. percentage of total fuselage structural C.S.A. severed on entry side %</th>
<th>Approx. percentage of total fuselage structural C.S.A. severed on exit side %</th>
<th>Additional structure severed</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>$\frac{1}{2} \times \frac{1}{2}$ (L.V.)</td>
<td>$45^\circ$ above beam</td>
<td>Stn. 963 Valiant fuselage</td>
<td>165</td>
<td>151$^1$</td>
<td>92</td>
<td>39.5</td>
<td>37</td>
<td>45</td>
<td>1 frame</td>
<td>Fuselage failed on attack under '1g' loading</td>
</tr>
<tr>
<td>13</td>
<td>$\frac{1}{2} \times \frac{1}{2}$ (L.V.)</td>
<td>$45^\circ$ above beam</td>
<td>Stn. 760 Victor fuselage</td>
<td>164</td>
<td>151</td>
<td>92</td>
<td>35.6</td>
<td>36</td>
<td>53</td>
<td>1 frame</td>
<td>Fuselage failed under '0.36g' loading</td>
</tr>
<tr>
<td>6</td>
<td>$\frac{1}{2} \times \frac{1}{2}$ (L.V.)</td>
<td>$45^\circ$ above beam</td>
<td>Stn. 940 Victor fuselage</td>
<td>170</td>
<td>155</td>
<td>91</td>
<td>35.4</td>
<td>40</td>
<td>62</td>
<td>1 frame</td>
<td>Not loaded</td>
</tr>
<tr>
<td>7A</td>
<td>$\frac{1}{2} \times \frac{1}{2}$ (L.V.)</td>
<td>Normal above beam</td>
<td>Stn. 54 3.29 fuselage</td>
<td>134</td>
<td>134</td>
<td>100</td>
<td>72.6</td>
<td>20</td>
<td>33</td>
<td>None</td>
<td>Not loaded</td>
</tr>
<tr>
<td>7B</td>
<td>$\frac{1}{2} \times \frac{1}{2}$ (L.V.)</td>
<td>Normal below beam</td>
<td>Stn. 54 3.29 fuselage</td>
<td>130</td>
<td>130</td>
<td>100</td>
<td>67.1</td>
<td>15</td>
<td>20</td>
<td>None</td>
<td>Not loaded</td>
</tr>
<tr>
<td>2</td>
<td>$\frac{1}{2} \times \frac{1}{2}$ (L.V.)</td>
<td>Normal below beam</td>
<td>Stn. 566 B.29 fuselage</td>
<td>166</td>
<td>161</td>
<td>97</td>
<td>31.3</td>
<td>27</td>
<td>41</td>
<td>1 frame</td>
<td>Fuselage did not fail under '2.3g' loading</td>
</tr>
<tr>
<td>3B</td>
<td>$\frac{1}{2} \times \frac{1}{2}$ (H.V.)</td>
<td>Normal above beam</td>
<td>Stn. 300 B.29 fuselage</td>
<td>158</td>
<td>147</td>
<td>93</td>
<td>27.4</td>
<td>33</td>
<td>44</td>
<td>None</td>
<td>Fuselage did not fail under '2.8g' loading</td>
</tr>
<tr>
<td>3A</td>
<td>$\frac{1}{2} \times \frac{1}{2}$ (H.V.)</td>
<td>Normal below beam</td>
<td>Stn. 768 B.29 fuselage</td>
<td>161</td>
<td>128$^2$</td>
<td>80</td>
<td>27.3</td>
<td>35</td>
<td>43</td>
<td>None</td>
<td>Fuselage did not fail under '2g' loading</td>
</tr>
<tr>
<td>4A</td>
<td>$\frac{1}{2} \times \frac{1}{2}$ (H.V.)</td>
<td>$45^\circ$ above beam</td>
<td>Stn. 768 B.29 fuselage</td>
<td>161</td>
<td>146</td>
<td>91</td>
<td>27.1</td>
<td>36</td>
<td>47</td>
<td>2 frames</td>
<td>Fuselage did not fail under '2.1g' loading</td>
</tr>
<tr>
<td>5A</td>
<td>$\frac{1}{2} \times \frac{1}{2}$ (H.V.)</td>
<td>$45^\circ$ above beam</td>
<td>Stn. 768 B.29 fuselage</td>
<td>161</td>
<td>134</td>
<td>83</td>
<td>27.1</td>
<td>33</td>
<td>41</td>
<td>2 frames</td>
<td>Fuselage failed under '2.1g' loading</td>
</tr>
<tr>
<td>4B</td>
<td>$\frac{1}{2} \times \frac{1}{2}$ (H.V.)</td>
<td>Symmetrical target</td>
<td>Mid-length SS.1 steel replica</td>
<td>160</td>
<td>136</td>
<td>85</td>
<td>36.1</td>
<td>36</td>
<td>36</td>
<td>4 frames</td>
<td>Not loaded</td>
</tr>
<tr>
<td>5B</td>
<td>$\frac{1}{2} \times \frac{1}{2}$ (H.V.)</td>
<td>Symmetrical target</td>
<td>Mid-length SS.1 steel replica</td>
<td>160</td>
<td>132</td>
<td>83</td>
<td>36.1</td>
<td>36</td>
<td>36</td>
<td>1 frame</td>
<td>Not loaded</td>
</tr>
<tr>
<td>8</td>
<td>$\frac{1}{2} \times \frac{1}{2}$ (H.V.)</td>
<td>Steel honeycomb target</td>
<td>Mid-length</td>
<td>165</td>
<td>117</td>
<td>71</td>
<td>26.6</td>
<td>28</td>
<td>32</td>
<td>None</td>
<td>Not loaded</td>
</tr>
</tbody>
</table>

**Notes:**
1. Including $25^\circ$ break
2. Break in rod hoop before impact

L.V. = Low velocity rod strike a $3400$ f.p.s.
H.V. = High velocity rod strike a $5100$ f.p.s.
FIG. 1(a & b) HALF-SECTIONS OF 'VALIANT' AND 'VICTOR' FUSELAGES AT ATTACK STATIONS.

I (a) STN. 963 VICKERS 'VALIANT' TYPE 673' (TARGET 1A)
I (b) STN. 740 HANDLEY PAGE 'VICTOR' 2ND PROTOTYPE (TARGET 1B)

NOTE: CROSS-SECTIONAL AREAS REFER TO HALF TARGET ONLY.
FIG. 2(a) HALF-SECTION OF 'B 29' FUSELAGE AT ATTACK STATION.
(TARGET 3 B.)
FIG. 2 (b & c) HALF-SECTIONS OF 'B.29' FUSELAGES AT ATTACK STATIONS.

2(b) STN. 768. (MID CREW COMPARTMENT) (TARGETS 3A, 4A, & 5A).

2(c) STN. 566. (AFT BOMB BAY) (TARGET 2).

NOTE:- CROSS-SECTIONAL AREAS REFER TO HALF TARGET ONLY.

<table>
<thead>
<tr>
<th>STRUCTURAL MEMBERS</th>
<th>CROSS-SECTIONAL AREA SQ. IN.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>1.478</td>
</tr>
<tr>
<td>A. J. R. V. Y.</td>
<td>0.402</td>
</tr>
<tr>
<td>Q. U. W. H.</td>
<td>0.395</td>
</tr>
<tr>
<td>L. O.</td>
<td>0.301</td>
</tr>
<tr>
<td>N.</td>
<td>0.279</td>
</tr>
<tr>
<td>D. F. B. M. P. T.</td>
<td>0.173</td>
</tr>
<tr>
<td>C. E. G. I. K.</td>
<td>0.122</td>
</tr>
<tr>
<td>SKIN (0.05&quot;)</td>
<td>2.26</td>
</tr>
<tr>
<td>SKIN (0.04&quot;)</td>
<td>4.16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STRUCTURAL MEMBERS</th>
<th>CROSS-SECTIONAL AREA SQ. IN.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>0.940</td>
</tr>
<tr>
<td>T</td>
<td>2.534</td>
</tr>
<tr>
<td>P</td>
<td>0.732</td>
</tr>
<tr>
<td>A</td>
<td>0.402</td>
</tr>
<tr>
<td>B. F. Q. S. C.</td>
<td>0.395</td>
</tr>
<tr>
<td>H. J. M.</td>
<td>0.301</td>
</tr>
<tr>
<td>D.</td>
<td>0.198</td>
</tr>
<tr>
<td>K. L. N. O.</td>
<td>0.173</td>
</tr>
<tr>
<td>E. G. I.</td>
<td>0.122</td>
</tr>
<tr>
<td>SKIN (0.05&quot;)</td>
<td>7.14</td>
</tr>
</tbody>
</table>
N.B. SEVERED MEMBERS ARE SHOWN DOTTED

EXTENT OF CUT IN SKIN (15° INCLUDING 25° BREAK)

DIRECTION OF ROD APPROACH

BOMB BAY ROOF AND WALLS HOLED BY FRAGMENTS.

80% OF SKIN AND 7 STRINGERS SEVERED BY FRAGMENTS.

BOMB DOOR EXTENSION DETACHED AT EDGES.

RESULT: FUSELAGE SECTION ATTACKED IN THE ‘1g’ LOADED CONDITION, FAILED ON ATTACK.

STN. 963 OF LOADED ‘VALIANT 673’ FUSELAGE

FIG. 3. TARGET IA. RECORD OF ROD DAMAGE TO ‘VALIANT TYPE 673’ FUSELAGE. (1/4 IN. ROD. LOW VEL.)
RESULT: FUSELAGE SECTION ATTACKED IN THE UNLOADED CONDITION. FUSELAGE FAILED UNDER SUBSEQUENT APPLICATION OF LOAD. EQUIVALENT TO 0.94g.

STN. 740 OF LOADED 'VICTOR' FUSELAGE.
FIG. 5. TARGET 6. RECORD OF ROD DAMAGE TO 'VICTOR' PROTOTYPE TARGET (¼ IN. ROD. LOW VEL.)
FIG. 6. TARGET 7A. RECORD OF ROD DAMAGE TO 'B 29' TARGET (1/4 IN. ROD. LOW VEL.)

STN. 434 OF UNLOADED B 29 FUSELAGE.
CONFIDENTIAL.

FIG. 7.

CENTRE SECTION HATCH NOT FITTED.

HOLES 6" X 6" OR SMALLER.

75% SEVERED. Holes 75% SEVERED

CONTINUOUS CUT

50% SEVERED

10% SEVERED 20% SEVERED

CENTRE SECTION HATCH WITH CENTRAL BLISTER NOT FITTED

EXTENT OF CUT IN SKIN (130°)

DIRECTION OF ROD APPROACH

STN. 434 OF UNLOADED B.29 FUSELAGE.

FIG. 7. TARGET 7 B. RECORD OF ROD DAMAGE TO 'B.29' TARGET (1/4 IN. ROD, LOW VEL.)
RESULT: FUSELAGE SECTION ATTACKED IN THE UNLOADED CONDITION, DID NOT FAIL UNDER SUBSEQUENT APPLICATION OF 11,160,000 LB. IN. BENDING MOMENT EQUIVALENT TO 239' LOADING.

STN. 566 OF B.29 FUSELAGE.

FIG. 8. TARGET 2. RECORD OF ROD DAMAGE TO 'B29' TARGET (4 IN. ROD. LOW VEL.)
CONFIDENTIAL

N.B. SEVERED MEMBERS ARE SHOWN DOTTED.

50% SEVERED

SEVERED

HOLE 15" x 12"

SEVERED

HOLED AND TORN BY FRAGMENTS

10% SEVERED

DATUM

EXTENT OF CUT IN SKIN (147°)

BOMB DOORS SEVERED.

ESTIMATED DIRECTION OF ROD APPROACH.

RESULT:- FUSELAGE SECTION ATTACKED IN THE UNLOADED CONDITION. DID NOT FAIL UNDER SUBSEQUENT APPLICATION OF 6,175,700 LB. IN. BENDING MOMENT EQUIVALENT TO '2.8 g' LOADING.

STN. 300 OF 'B.29' FUSELAGE.

FIG.9. TARGET 3B. RECORD OF ROD DAMAGE TO 'B. 29' TARGET. (3/16 IN. ROD. HIGH VEL.)
N.B. SEVERED MEMBERS ARE SHOWN DOTTED.

RESULT:—FUSELAGE SECTION ATTACKED IN THE '1g' LOADED CONDITION. DID NOT FAIL AFTER APPLICATION OF 4,700,000 LB. IN. BENDING MOMENT EQUIVALENT TO '2g' LOADING.

STN. 768 OF 'B.29' FUSELAGE.

FIG. 10. TARGET 3 A. RECORD OF ROD DAMAGE TO 'B.29' TARGET. (3/16 IN. ROD. HIGH VEL.)
RESULT: FUSELAGE SECTION ATTACKED IN THE UNLOADED CONDITION. DID NOT FAIL UNDER SUBSEQUENT APPLICATION OF 4,980,000 LB. IN. BENDING MOMENT EQUIVALENT TO 2.1g LOADING.

STN. 768 OF 'B.29' FUSELAGE (NOTE STRINGERS 'C' & 'E' OF FIG. 2B NOT PRESENT IN THIS TARGET)

FIG. 11. TARGET 4A. RECORD OF ROD DAMAGE TO 'B.29' TARGET. (3/16 IN. ROD. HIGH VEL.)
CONFIDENTIAL

EXTENT OF CUT IN SKIN. (134°)

N.B. SEVERED MEMBERS ARE SHOWN DOTTED.

DIRECTION OF ROD APPROACH.

SKIN CRACKED AND TORN IN THIS REGION.

FAILED IN TENSION

40% SEVERED

5" HOLE

7" HOLE

2" HOLE

3" HOLE

12 HOLE

2 HOLE

FRAME 768 AND 746 SEVERED IN THIS REGION.

RESULT: FUSELAGE SECTION ATTACKED IN THE 19° LOADED CONDITION DID NOT FAIL. FAILED AFTER APPLICATION OF 4,210,000 LB. IN. BENDING MOMENT, EQUIVALENT TO 1.83° LOADING.

STN. 768 OF 'B 29' FUSELAGE.

(NOTE STRINGERS 'C' & 'E' OF FIG. 28 NOT PRESENT IN THIS TARGET.)

FIG. 12. TARGET 5 A. RECORD OF ROD DAMAGE TO 'B 29' TARGET. (3/16 IN. ROD. HIGH VEL.)
CONSTRUCTION: ALL RIVETED
SKIN - 18 S.W.G. (0.048") STEEL SHEET (53)
STRINGERS - 20 S.W.G. (0.036") STEEL SHEET (63)
FRAMES - 16 S.W.G. (0.064") STEEL SHEET (53)

300 STRINGERS EQUALLY
PITCHED ROUND
CIRCUMFERENCE.

WATER FILLED
INTEGRAL TANK

8 STRINGERS
PARTLY SEVERED

14 STRINGERS
PARTLY SEVERED.

91 STRINGERS SEVERED
AND TARGET OPENED UP
OVER 46' LONGITUDINALLY.

EXTENT OF CUT
IN SKIN (136°)

DIRECTION OF
ROD APPROACH.

MID-LENGTH OF UNLOADED 'S.S.I' TARGET.

FIG. 13. TARGET 4B. RECORD OF ROD DAMAGE TO 'S.S.I'.
REPLICA STEEL FUSELAGE SECTION. (3/16 IN. ROD, HIGH VEL.)
FIG. 14. TARGET 5B. RECORD OF ROD DAMAGE TO "SS. I" REPLICA STEEL FUSELAGE SECTION. (\(\frac{3}{16}\) IN. ROD, HIGH VEL.)
CONSTRUCTION: BRAZED HONEYCOMB SANDWICH.
SKINS - 18.S.W.G. STAINLESS STEEL (REX.448)
CORE - 0.003” MILD STEEL

MID-LENGTH OF STEEL HONEYCOMB SANDWICH TARGET.

FIG.15. TARGET 8. RECORD OF ROD DAMAGE TO STEEL
HONEYCOMB SANDWICH TARGET (3/16 IN. ROD. LOW VEL.)
FIG. 16a. TARGET 1a. LOADED VALIANT REAR FUSELAGE BEFORE ATTACK

FIG. 16b. TARGET 1a. DAMAGE TO ROD "ENTRY" SIDE OF FUSELAGE SHOWING FAILURE

(LOW VEL. 1/4in. ROD. STN. 963)

CONFIDENTIAL
FIG. 16c. TARGET Ia. DAMAGE TO ROD "EXIT" SIDE OF "VALIANT" FUSELAGE
(LOW VEL. 1/8in. ROD. STN. 963)

FIG. 16d. TARGET Ia. DETAIL OF FUSELAGE FAILURE
AT STARBOARD SIDE END OF ROD CUT
(LOW VEL. 1/8in. ROD. STN. 963)
CONFIDENTIAL
FIG. 16e. TARGET 1a. ROD BEHAVIOUR NEAR END OF CUT ON PORT SIDE OF "VALIANT" FUSELAGE (LOW VEL. ½in. ROD. STN. 963)
FIG. 17a. TARGET 1b. UNLOADED "VICTOR" FUSELAGE BEFORE ATTACK

FIG. 17b. TARGET 1b. DAMAGE TO ROD "ENTRY" SIDE OF "VICTOR" FUSELAGE
(Low Vel. 1/4 in. Rod. STN. 740)
FIG. 17c. TARGET 1b. DAMAGE TO ROD "EXIT" SIDE OF "VICTOR" FUSELAGE (LOW VEL. 1/16 in. ROD. STN. 740)

FIG. 17d. TARGET 1b. DETAIL OF ROD CUT END ON STARBOARD SIDE OF "VICTOR" FUSELAGE (LOW VEL. 1/16 in. ROD. STN. 740)
FIG. 17e AND f. TARGET 1b. ROD DAMAGE TO INTERIOR OF "VICTOR" FUSELAGE

(LOW VEL. 1/4in. ROD. STN. 740)
FIG. 17g. TARGET 1b. ROD CUT END AFTER SUBSEQUENT LOADING EQUIVALENT TO 0.6 g.
COMPARE WITH FIG.17d.

FIG. 17h. TARGET 1b. FAILURE OF "VICTOR" FUSELAGE UNDER SUBSEQUENT LOADING EQUIVALENT TO 0.94 g.
FIG. 17j & k. TARGET 1 lb. "VICTOR" FUSELAGE AFTER FAILURE UNDER SUBSEQUENT LOADING EQUIVALENT TO 0.94g.

FIG. 17j, ROD "ENTRY" SIDE

FIG. 17k, ROD "EXIT" SIDE
FIG. 18a. STARBOARD SIDE ROD "ENTRY" DAMAGE

FIG. 18b. TOP ROD "ENTRY" DAMAGE

FIG. 18c. ROD "EXIT" DAMAGE

FIG. 18a, b, AND c. TARGET 6. ROD DAMAGE TO "VICTOR" REAR FUSELAGE (LOW VEL. 1/2 in. ROD. STN. 940)
FIG. 19a. TARGET 7a. ROD DAMAGE TO TOP OF B29 WING/FUSELAGE JUNCTION (LOW VEL. 1/8 in. ROD. STN. 434)

FIG. 19b. TARGET 7a. ROD "ENTRY" DAMAGE TO WING BOX TOP SURFACE INSIDE "B29" FUSELAGE (LOW VEL. 1/8 in. ROD. STN. 434)
FIG. 19c. TARGET 7a. DETAIL OF ROD CUT END ON FUSELAGE STARBOARD SIDE (PORT SIDE SIMILAR)
(LOW VEL. 3/8in. ROD. STN. 434)

FIG. 19d. TARGET 7a. DAMAGE TO ROD EXIT SIDE OF B29 WING/FUSELAGE JUNCTION
(LOW VEL. 3/8in. ROD. STN. 434)
FIG. 20a. TARGET 7b. ROD "ENTRY" DAMAGE TO BOTTOM OF B29 WING/FUSELAGE JUNCTION

(LOW VEL. ¼ in. ROD. STN. 434)

FIG. 20b. TARGET 7b. ROD "EXIT" DAMAGE TO WING BOX TOP SURFACE INSIDE "B29" FUSELAGE

(LOW VEL. ¼ in. ROD. STN. 434)
FIG. 21 a & b.

TARGET 2. DAMAGE TO ROD "ENTRY" SIDE OF "B29" FUSELAGE

LOW VEL., ROD. STN. 566

TARGET 2. UNLOADED "B29" AFT BOMB BAY SECTION BEFORE ATTACK

CONFIDENTIAL
FIG. 21c. TARGET 2. DAMAGE TO ROD "EXIT" SIDE OF "B29" FUSELAGE (LOW VEL. ¼ in. ROD. STN. 566)

FIG. 21d. TARGET 2. STARBOARD SIDE OF DAMAGED "B29" FUSELAGE UNDER SUBSEQUENT LOADING
NOTE: SKIN WRINKLING
FIG. 21e. STARBOARD LONGERON

FIG. 21f. STARBOARD CATWALK

FIG. 21g. PORT LONGERON

FIG. 21h. PORT CATWALK

FIG. 21e. to h. TARGET 2. ROD DAMAGE TO LONGERON STRUCTURE
(LOW VEL. 1/4 in. ROD. STN. 566)

CONFIDENTIAL
FIG. 21j. STARBOARD LONGERON SHOWING PERMANENT DEFORMATION (COMPARE WITH FIG. 21e.)

FIG. 21k. PORT LONGERON (COMPARE WITH FIG. 21g.)

FIG. 21j. AND k. TARGET 2. DAMAGE TO LONGERONS AFTER ROD ATTACK, SEVERING, AND LOADING TO 2.3 g (LOW VEL. 1/8 in. ROD. STN. 566)
FIG. 22a. TARGET 3b. DAMAGE TO ROD "ENTRY" SIDE OF UNLOADED "B29" FUSELAGE (HIGH VEL. 1/8 in. ROD. STN. 300)

FIG. 22b. TARGET 3b. DAMAGE TO ROD "EXIT" SIDE OF "B29" FUSELAGE (HIGH VEL. 1/8 in. ROD. STN. 300)
FIG. 22c. PORT SIDE. NOTE:- SKIN BUTTING

FIG. 22d. STARBOARD SIDE

FIG. 22c. AND 22d. TARGET 3b. ROD "ENTRY" SIDE DAMAGE UNDER SUBSEQUENT LOADING EQUIVALENT TO 2.8g
FIG. 22e. PORT SIDE. NOTE: BUTTING OF SEVERED MEMBERS

FIG. 22f. STARBOARD SIDE. NOTE: BUTTING OF SEVERED MEMBERS

FIG. 22e. AND f. TARGET 3b. BEHAVIOUR OF SEVERED LONGERON MEMBERS UNDER SUBSEQUENT LOADING EQUIVALENT TO 2.8 g.
FIG. 23a. TARGET 3a. DAMAGE TO ROD "ENTRY SIDE OF "1 g" LOADED "B-29" MID-CREW COMPARTMENT
(HIGH VEL. \( \frac{1}{4} \) in. ROD. STN. 768)

FIG. 23b. TARGET 3a. DETAIL OF DAMAGE AT ROD CUT END ON STARBOARD SIDE
(HIGH VEL. \( \frac{1}{4} \) in. ROD. STN. 768)

CONFIDENTIAL
FIG. 23c. TARGET 3a. DETAIL OF DAMAGE AT ROD CUT END ON PORT SIDE
(HIGH VEL. \( \frac{1}{2} \) in. ROD. STN. 768)

FIG. 23d. TARGET 3a. DAMAGE TO ROD "EXIT" SIDE OF FUSELAGE
(HIGH VEL. \( \frac{1}{2} \) in. ROD. STN. 768)
FIG. 24a. TARGET 4a. DAMAGE TO ROD "ENTRY" SIDE OF UNLOADED "B29" MID-CREW COMPARTMENT
(HIGH VEL. \( \frac{7}{8} \) in. ROD. STN. 768)

FIG. 24b. TARGET 4a. DETAIL OF DAMAGE AT ROD CUT END ON STARBOARD SIDE
(HIGH VEL. \( \frac{3}{4} \) in. ROD. STN. 768)
FIG. 24c. TARGET 4a. DETAIL OF DAMAGE AT ROD CUT END ON PORT SIDE
(HIGH VEL. 1/4 in. ROD. STN. 768)

FIG. 24d. TARGET 4a. DAMAGE TO ROD "EXIT" SIDE OF FUSELAGE
(HIGH VEL. 1/4 in. ROD. STN. 768)
FIG. 25a. TARGET 5a. DAMAGE TO ROD "ENTRY" SIDE OF "1 g" LOADED "B29" MID-CREW COMPARTMENT
(HIGH VEL. ¹/₁₀ in. ROD. STN. 768)

FIG. 25b. TARGET 5a. FAILURE OF FUSELAGE UNDER SUBSEQUENT LOADING EQUIVALENT TO "1.8 g"
FIG. 25c. TARGET 5a. DAMAGE TO ROD "EXIT" SIDE OF FUSELAGE AFTER SUBSEQUENT FAILURE (HIGH VEL. 1/4 IN. ROD. STN. 768)

FIG. 25d. TARGET 5a. DETAIL OF COMPRESSION LOADED SIDE OF FUSELAGE AFTER SUBSEQUENT FAILURE (HIGH VEL. 3/8 IN. ROD. STN. 768)
FIG. 25e. TARGET 4a.
FIRING 4a.

FIG. 25f. TARGET 5a.
FIRING 5a.

FIG. 25e AND f. ROD BEHAVIOUR NEAR END OF CUT ON "B29" FUSELAGE SECTIONS
(HIGH VEL. ½ in. ROD. STN. 768)

CONFIDENTIAL
FIG. 26. TARGET 4b. ROD DAMAGE TO WATER FILLED S.S.I TARGET
(HIGH VEL. 7/16in. ROD)

FIG. 27. TARGET 5b. ROD DAMAGE TO SIMULATED EQUIPMENT
FILLED S.S.I TARGET (NO "EXIT" DAMAGE)
(HIGH VEL. 7/16in. ROD)
FIG. 28a. TARGET 8. DAMAGE TO ROD "ENTRY" SIDE OF STEEL HONEYCOMB TARGET (LOW VEL. 1/8 IN. ROD)

FIG. 28b. TARGET 8. ROD "EXIT" SIDE DAMAGE TO STEEL HONEYCOMB TARGET (LOW VEL. 1/8 IN. ROD)
FIG. 28c. TARGET 8. ROD DAMAGE TO HONEYCOMB CORE AND INNER SKIN
(LOW VEL. 1/4-in. ROD)

FIG. 28d. TARGET 8. DETAIL OF TYPICAL ROD CUT END ON STEEL HONEYCOMB TARGET
(LOW VEL. 1/4-in. ROD)
ATTENDIAX 11

DETAILS OF TARGET LAYOUTS AND METHODS OF LOADING

(All figure numbers quoted refer to figures at the end of this Appendix)

1 TARGET LAYOUT

1.1 The attacks on thirteen aircraft fuselage sections described in this Note involved eight actual warhead firings. Thus, in five of the firings two fuselage sections were attacked simultaneously. It should also be noted that in several of the firings, other targets, such as aircraft wings etc., were included. The wing target attacks are to be reported in a separate Note.

In the case of the seven attacks in which the targets were loaded, three different loading methods were used and hence it is necessary to describe the target layouts and methods of loading used in each firing, as follows:

1.2 Firing No. 1

(a) In this firing, the Vickers 'Valiant' Type 673 was attacked in the '1g' loaded condition and the Handley Page 'Victor' second prototype in the unloaded state. For the purposes of the trial the 'Valiant' fuselage was assembled complete with inner wings and tail unit, and mounted as shown in Figs. 1 and 5a.

It was desired that the target loading should produce stresses in the target, at the station attacked, representative of those occurring when the aircraft was flying straight and level in non-turbulent air at 0.81 M, at an all-up weight of 135,000 lb (i.e. with full bomb load and half fuel load). Owing to the complex loading system that would have been required to reproduce these stresses exactly, it was decided to load the fuselage by means of weights, placed on the aircraft tailplane, such that the errors in Bending Moment (B.M.) and Shear Force (S.F.), at the station attacked, were as small as possible. The required values of B.M. and S.F., together with the actual trials values were as follows:

<table>
<thead>
<tr>
<th></th>
<th>Level flight values (1g)</th>
<th>Trials values (Stn.963)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending moment (B.M.)</td>
<td>7,539,000 lb in.</td>
<td>7,660,000 lb in.</td>
</tr>
<tr>
<td>Shear Force (S.F.)</td>
<td>30,680 lb</td>
<td>31,940 lb</td>
</tr>
</tbody>
</table>

Counterbalance weights were provided in the form of sand and water in containers located in the pressure cabin, radome bay and forward services bay. Details of the fuselage section weights, applied loads and points of application are given in Fig. 1.
(b) The secondary target in this firing consisted of the entire centre fuselage of the Handley Page 'Victor' second prototype mounted, for the firing, as shown in Figs. 1 and 5a. After firing and re-mounting, loads were then applied to the damaged section by a combination of steel plates, acting through a wooden platform over the fin-root attachments, and by a vertical cable attached to the fin-post, passing through a pulley secured to a strong point in the ground, via a spring balance and to a tractor (see Fig. 5b). The '1g' level flight B.M. and S.F., at the station attacked, when the aircraft is flying at 0.875 M and at an all-up weight of 116,200 lb (i.e. with full bomb load and half fuel load) are compared, below, with those applied at failure of the fuselage under load.

<table>
<thead>
<tr>
<th>Bending moment (B.M.)</th>
<th>Level flight values (1g) (Stn.740)</th>
<th>Approx. values at failure (Stn.740)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6,040,000 lb in.</td>
<td>5,680,000 lb in.</td>
</tr>
<tr>
<td>Shear force (S.F.)</td>
<td>18,300 lb</td>
<td>25,280 lb</td>
</tr>
</tbody>
</table>

The target layout and different loading methods used in Firing No. 1 are shown in Fig. 1.

1.3 Firing No. 2

In this firing the primary target consisted of a 'B.29' centre fuselage, attacked in the unloaded condition, together with miscellaneous secondary targets (not dealt with in this Note) all positioned in a circular array round the warhead, as shown in Fig. 2. For the firing, the fuselage section was mounted as shown in Fig. 6a. To remove the axial load inherent in this mounting, the target was supported by means of a wooden beam passing under the rear spar and supported by wooden posts. After attack, the target was carefully assembled to the remainder of a B.29 fuselage and also the inner wings, as illustrated in Fig. 6b. The attack station was then loaded by means of weights placed on the aircraft tailplane up to the equivalent of the '1g' loads occurring when the aircraft is flying in non-turbulent air at an all-up weight of 117,000 lb (i.e. with full bomb load and half fuel load). Since the fuselage did not fail, additional loading was imposed by a tractor and cable system similar to that used for the 'Victor' target after Firing No. 1. The B.M. and S.F. at the attack station in level flight, and also at the maximum load it was possible to apply in the trial, were as follows:

<table>
<thead>
<tr>
<th>Bending moment (B.M.)</th>
<th>Level flight values (1g) (Stn.566)</th>
<th>Maximum values applied (Stn.566)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4,763,000 lb in.</td>
<td>11,160,000 lb in.</td>
</tr>
<tr>
<td>Shear force (S.F.)</td>
<td>18,300 lb</td>
<td>25,710 lb</td>
</tr>
</tbody>
</table>

Details of the loading method are given in Figs. 3 and 6b.
1.4 Firings Nos.3, 4 and 5

These three firings were made using the Pendine long test track. For each firing, the warhead was mounted on the front end of a two-stage rocket propelled vehicle as shown in Fig.7d. The warhead was then propelled along the track and detonated on an expendable section of rail near the centre of a circular arena containing two aircraft fuselage sections and other miscellaneous targets, as shown in Figs.7a and 7b.

(a) In each firing the primary target, a B.29 mid-crew compartment, either loaded during attack, or subsequently loaded, by means of a loading rig (Fig.7c) consisting of a ground frame to one end of which the target was bolted. To the other end of the frame, a tower, also of Bailey bridge structure was secured. Two tower locations were provided on the frame. A triangulated loading arm was attached to the upper end of the target at Stn.646 and, for the two firings against the fuselage tension loaded surfaces, a cable was attached to the apex of the arm and thence over a pulley in the top of the tower to a large tank suspended within the tower and whose weight gave the required '1g' B.M. and S.F. at the target attack station. If the target did not fail under attack the forces at the attack station could be increased to the '2g' condition by filling the tank with water.

In the case where the target compression surface was attacked the second tower position was used (Fig.7b) and the cable loading system replaced by a strut connected by a cable to the water tank so that a pushing force was applied to the loading arm apex and hence to the target. The B.M.'s and S.F.'s, at the station attacked, for '1g' level flight conditions in non-turbulent air at an all-up weight of 117,000 lb (full bomb load and half fuel load), are given below together with the actual trials values:

<table>
<thead>
<tr>
<th>Level flight values (1g)</th>
<th>Target No.3A</th>
<th>Target No.4A</th>
<th>Target No.5A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>During attack</td>
<td>Max. values applied</td>
<td>During attack</td>
</tr>
<tr>
<td>Bending moment (B.M.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,314,000 lb in.</td>
<td>2,420,000 lb in.</td>
<td>4,700,000 lb in.</td>
<td>Not loaded</td>
</tr>
<tr>
<td>Shear force (S.F.)</td>
<td>8225 lb</td>
<td>8600 lb</td>
<td>16,600 lb</td>
</tr>
</tbody>
</table>

The small discrepancies between the required level flight values and the trials values are due to practical difficulties of loading; they are, however, well within the range of fluctuating values to be expected in level flight.

(b) In two of the firings, the secondary targets (4B and 5B) consisted of replica steel supersonic fuselage sections not designed to be loaded. They were mounted, relative to the track, at the position shown in Figs.4 and 7a.

In the third firing the secondary target (3B) was a B.29 centre fuselage mounted in a similar position, as shown in Fig.7b. After attack in the unloaded condition, the target was assembled to the remaining sections of a 'B.29' fuselage.

CONFIDENTIAL
and also the inner wings, as shown in Fig. 8a. In this case, the required counterbalance weights were applied to the aircraft tailplane, as illustrated in Fig. 8b, the tail being supported by a cradle. The attack station was then loaded up to '1g' level flight conditions by means of water-filled tanks positioned in the pressure cabin. Since failure did not occur, additional load was applied, by the previously described tractor and cable system, to the nosewheel pivot point, up to the maximum achievable. This load was then relaxed and re-applied five times in quick succession in order to simulate gust loading conditions. Failure did not result.

The B.M's and S.F's at the attack station for '1g' level flight in non-turbulent air at an aircraft all-up weight of 117,000 lb (with full bomb load and half fuel load) are given below together with the maximum applied during the loading procedure:

<table>
<thead>
<tr>
<th></th>
<th>Level Flight Maximum values (1g)</th>
<th>Maximum values applied (Stn.300)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending moment (B.M.)</td>
<td>2,174,400 lb in.</td>
<td>6,175,700 lb in.</td>
</tr>
<tr>
<td>Shear force (S.F.)</td>
<td>13,809 lb</td>
<td>29,200 lb</td>
</tr>
</tbody>
</table>

Target layouts for Firings Nos. 3, 4 and 5 are shown in Figs. 4, 7a and 7b and the loading method for Targets 4A, 5A in Fig. 7c. Fig. 7b shows the loading system for Target 3A.

1.5 Firings Nos. 6, 7 and 8

Four fuselage specimens (Nos. 6, 7A, 7B and 8) included in these firings were secondary targets in layouts involving miscellaneous other targets not dealt with in this Note. They were not suitable for loading either during or after attack, and were positioned in the target arenas with their longitudinal axes vertical and resting on one end. All sustained circumferential rod guts except that in Firing No. 8 where the cut was inclined at approximately 30° to the normal to the fuselage surface.
FIG. 4. TARGET LAYOUT AND PRIMARY TARGET LOADING SYSTEM USED IN DYNAMIC ROD FIRING No. 3. (SIMILAR ARRANGEMENT USED IN FIRINGS 4 & 5) (SCALE-\(1/8 = 1\))
FIG. 5a of Appendix I. Target layout for static firing against loaded and unloaded targets (firing I.)

FIG. 5b of Appendix I. Method of subsequently loading Victor target I.b.
FIG. 6a. OF APPENDIX I. TARGET LAYOUT FOR STATIC FIRING AGAINST UNLOADED TARGETS (FIRING 2.)

FIG. 6b. OF APPENDIX I. METHOD OF SUBSEQUENTLY LOADING B29 FUSELAGE TARGET (FIRING 2.)
FIG. 7a. OF APPENDIX I. TYPICAL TARGET LAYOUT FOR DYNAMIC WARHEAD FIRING SHOWING TARGET 4a. TENSION LOADING GEAR (FIRING 4.)

FIG. 7b. OF APPENDIX I. TYPICAL TARGET LAYOUT FOR DYNAMIC WARHEAD FIRING SHOWING TARGET 3a. COMPRESSION LOADING GEAR (FIRING 3.)
FIG. 7c. OF APPENDIX I. DETAILS OF TYPICAL TARGET TENSION LOADING SYSTEM FOR DYNAMIC WARHEAD FIRINGS (TARGETS 4a. AND 5a.)

FIG. 7d. OF APPENDIX I. 1/2 in. BLUE JAY ROD WARHEAD MOUNTED ON 2-STAGE ROCKET VEHICLE FOR DYNAMIC WARHEAD FIRING
FIG. 8a. OF APPENDIX I. METHOD OF SUBSEQUENTLY LOADING B29 FUSELAGE TARGET (TARGET 3b.)

FIG. 8b. OF APPENDIX I. DETAIL OF TAIL SUPPORT AND COUNTERBALANCE LOADING (TARGET 3b.)
STRESS ANALYSIS OF DAMAGED FUSELAGE TARGETS

1. METHOD OF ANALYSIS

1.1 As a continuation of the investigation commenced in Ref. 3 of the Note, simple bending stress analyses have been made of the seven damaged fuselage sections which were loaded during or subsequent to attack. The limitations and assumptions to which the analyses are subject have already been described in para 9 of the Note. The method of analysis may be briefly described as follows:

(a) In each analysis the location of the apparent neutral axis of the damaged section was first determined.

(b) The total effective cross-sectional area of the remaining structure was then calculated and used to locate the effective neutral axis.

(c) The total moment of inertia was then determined and substituted in the relation:

\[ \sigma = \frac{My}{I} \]

where \( \sigma \) = apparent maximum stress (lb/in\(^2\))
\( M \) = bending moment (lb in.)
\( y \) = distance from effective neutral axis (in.)
\( I \) = moment of inertia of section (in\(^4\))

By this means, the magnitude and location of the apparent maximum stresses in the damaged section were determined. The detailed calculations are given in Tables 1 - 7 of this Appendix. The maximum stresses at the various loading conditions, such as level flight, failure or maximum applied, are given for the purposes of comparison.

ATTACHED:

Tables 1 - 7
**TABLE 1**

*Stress analysis of damaged 'Valiant' fuselage section (Stn. 261)*

<table>
<thead>
<tr>
<th>Number (see Figs. 1a and 3)</th>
<th>Distance of member from neutral axis in.</th>
<th>Effective skin area in.</th>
<th>Effective stringer area in.</th>
<th>Total area in.</th>
<th>Distance of member from effective neutral axis in.</th>
<th>Moment of inertia lb in.</th>
<th>Maximum stress (&quot;g&quot; loading) lb/in.</th>
<th>Maximum stress (trial loading) lb/in.</th>
<th>Maximum stress applied lb/in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>65.9</td>
<td>0.163</td>
<td>0.122</td>
<td>0.285</td>
<td>65.9</td>
<td>1238</td>
<td>6281</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>11</td>
<td>65.9</td>
<td>0.163</td>
<td>0.122</td>
<td>0.285</td>
<td>63.8</td>
<td>1170</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>12</td>
<td>61.5</td>
<td>0.163</td>
<td>0.122</td>
<td>0.285</td>
<td>59.1</td>
<td>996</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>13</td>
<td>59.1</td>
<td>0.163</td>
<td>0.122</td>
<td>0.285</td>
<td>56.6</td>
<td>913</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>14</td>
<td>56.6</td>
<td>0.163</td>
<td>0.122</td>
<td>0.285</td>
<td>53.9</td>
<td>826</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>15</td>
<td>55.9</td>
<td>0.163</td>
<td>0.122</td>
<td>0.285</td>
<td>50.4</td>
<td>1173</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>16</td>
<td>50.4</td>
<td>0.163</td>
<td>0.122</td>
<td>0.285</td>
<td>47.0</td>
<td>643</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>17</td>
<td>47.0</td>
<td>0.163</td>
<td>0.128</td>
<td>0.291</td>
<td>43.9</td>
<td>651</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>18</td>
<td>43.9</td>
<td>0.163</td>
<td>0.128</td>
<td>0.291</td>
<td>40.7</td>
<td>648</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>19</td>
<td>40.7</td>
<td>0.163</td>
<td>0.128</td>
<td>0.291</td>
<td>37.6</td>
<td>641</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>20</td>
<td>37.6</td>
<td>0.163</td>
<td>0.128</td>
<td>0.291</td>
<td>34.3</td>
<td>643</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>21</td>
<td>34.3</td>
<td>0.163</td>
<td>0.128</td>
<td>0.291</td>
<td>30.9</td>
<td>278</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>22</td>
<td>30.9</td>
<td>0.163</td>
<td>0.128</td>
<td>0.291</td>
<td>27.6</td>
<td>444</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>23-23'</td>
<td>27.6</td>
<td>0.326</td>
<td>0.256</td>
<td>0.582</td>
<td>24.3</td>
<td>344</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>24-24'</td>
<td>24.3</td>
<td>0.326</td>
<td>0.256</td>
<td>0.582</td>
<td>20.9</td>
<td>254</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>25-25'</td>
<td>20.9</td>
<td>0.326</td>
<td>0.256</td>
<td>0.582</td>
<td>17.5</td>
<td>178</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>26-26'</td>
<td>17.5</td>
<td>0.326</td>
<td>0.256</td>
<td>0.582</td>
<td>14.1</td>
<td>171</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>27-27'</td>
<td>14.1</td>
<td>0.326</td>
<td>0.256</td>
<td>0.582</td>
<td>9.7</td>
<td>59</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>28-28'</td>
<td>9.7</td>
<td>0.326</td>
<td>0.256</td>
<td>0.582</td>
<td>6.9</td>
<td>30</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>29-29'</td>
<td>6.9</td>
<td>0.363</td>
<td>0.286</td>
<td>0.628</td>
<td>4.1</td>
<td>5</td>
<td>6420</td>
<td>6420</td>
<td>6420</td>
</tr>
<tr>
<td>30</td>
<td>4.1</td>
<td>0.102</td>
<td>0.128</td>
<td>0.312</td>
<td>Not required (see note 2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>1.4</td>
<td>0.102</td>
<td>0.128</td>
<td>0.312</td>
<td>1.4</td>
<td>0.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>-1.2</td>
<td>0.184</td>
<td>0.128</td>
<td>0.312</td>
<td>-1.2</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>-5.9</td>
<td>0.184</td>
<td>0.173</td>
<td>0.357</td>
<td>-5.9</td>
<td>5.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34-34'</td>
<td>-6.4</td>
<td>0.368</td>
<td>0.366</td>
<td>0.74</td>
<td>-6.4</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35-35'</td>
<td>-6.9</td>
<td>0.368</td>
<td>0.366</td>
<td>0.74</td>
<td>-6.9</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36-36'</td>
<td>-11.4</td>
<td>0.368</td>
<td>0.366</td>
<td>0.74</td>
<td>-11.4</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37-37'</td>
<td>-13.7</td>
<td>0.368</td>
<td>0.366</td>
<td>0.74</td>
<td>-13.7</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38-38'</td>
<td>-16.0</td>
<td>0.368</td>
<td>0.366</td>
<td>0.74</td>
<td>-16.0</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39-39'</td>
<td>-18.1</td>
<td>0.372</td>
<td>0.366</td>
<td>0.716</td>
<td>-18.1</td>
<td>236</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40-40'</td>
<td>-20.2</td>
<td>0.363</td>
<td>0.366</td>
<td>0.709</td>
<td>-20.2</td>
<td>236</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41-41'</td>
<td>-22.8</td>
<td>0.248</td>
<td>0.200</td>
<td>0.448</td>
<td>-22.8</td>
<td>236</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42-42'</td>
<td>-25.3</td>
<td>0.248</td>
<td>0.200</td>
<td>0.448</td>
<td>-25.3</td>
<td>236</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Distance from neutral axis to datum = 28.3 in.

(3) Aircraft 'g' bending moment $h' = 7,539,000$ lb in.

(2) $\bar{y} = 0$ (since skin in compression is assumed 100% effective under "g" loads)

(4) Trials bending moment $h'' = 7,660,000$ lb in.

- 36 -

**CONFIDENTIAL**
<table>
<thead>
<tr>
<th>Number (see Pages 18 and 4)</th>
<th>Distance of member from neutral axis in.</th>
<th>Effective skin area in.</th>
<th>Effective stringer area in.</th>
<th>Total area in.</th>
<th>Distance of member from effective neutral axis in.</th>
<th>Moment of inertia I in.⁴</th>
<th>Maximum stress ('tq' loading) lb/in.²</th>
<th>Maximum stress (trial loading) lb/in.²</th>
<th>Maximum stress applied lb/in.²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>2</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>3</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>4</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>5</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>6</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>7</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>8</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>9</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>10</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>11</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>12</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>13</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>14</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>15</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>16</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>17</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>18</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>19</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>20</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>21</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>22</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>23</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>24</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>25</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>26</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>27</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>28</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>29</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>30</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>31-31¹</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>32</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>33-10% or 33¹</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
<tr>
<td>34-23% of 33¹</td>
<td>1.0</td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
<td>1.0</td>
<td>25.9</td>
<td>140.4</td>
<td>140.4</td>
<td>140.4</td>
</tr>
</tbody>
</table>

(1) Distance from neutral axis to datum = 6.0 in.
(2) σ = 0 (since skin in compression is assumed 100% effective under 'tq' loads)
(3) Aircraft 'tq' bending moment M = 6,040,000 lb in.
(4) Total bending moment M' = None
(5) Rolling bending moment M" = 5,680,000 lb in.

- 37 -

CONFIDENTIAL
### TABLE 3

Stress analysis of damaged B-29 fuselage section (Stn.566)

Target No.2 - \(\frac{1}{2}\) in. rod low velocity

(Bending loads only, rod exit damage neglected)

<table>
<thead>
<tr>
<th>Member (see Figs. 2c and 8)</th>
<th>Distance of member from neutral axis in</th>
<th>Effective skin area tension in(^2)</th>
<th>Effective skin area compression in(^2)</th>
<th>Effective stringer area in(^2)</th>
<th>Total area in(^3)</th>
<th>Distance of member from effective neutral axis in</th>
<th>Moment of inertia (m&quot; loading) in(^4)</th>
<th>Maximum stress (m&quot; loading) lb/in(^2)</th>
<th>Maximum stress (trial loading) lb/in(^2)</th>
<th>Maximum stress applied lb/in(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>45.3</td>
<td>0.451</td>
<td>-</td>
<td>0.402</td>
<td>0.853</td>
<td>38.7</td>
<td>42.9</td>
<td>1573</td>
<td>6,920</td>
<td>16,200</td>
</tr>
<tr>
<td>B-B'</td>
<td>44.6</td>
<td>2x0.451</td>
<td>-</td>
<td>2x0.395</td>
<td>1.692</td>
<td>75.5</td>
<td>42.2</td>
<td>3020</td>
<td>2733</td>
<td></td>
</tr>
<tr>
<td>C-C'</td>
<td>42.6</td>
<td>2x0.451</td>
<td>-</td>
<td>2x0.395</td>
<td>1.692</td>
<td>72.0</td>
<td>40.2</td>
<td>1758</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-D'</td>
<td>37.2</td>
<td>2x0.451</td>
<td>-</td>
<td>2x0.398</td>
<td>1.290</td>
<td>50.8</td>
<td>36.8</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-E'</td>
<td>37.0</td>
<td>-</td>
<td>-</td>
<td>2x0.122</td>
<td>0.264</td>
<td>9.0</td>
<td>34.6</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-F'</td>
<td>34.6</td>
<td>2x0.451</td>
<td>-</td>
<td>2x0.395</td>
<td>1.692</td>
<td>58.5</td>
<td>32.2</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-G'</td>
<td>28.8</td>
<td>2x0.451</td>
<td>-</td>
<td>2x0.122</td>
<td>1.146</td>
<td>33.0</td>
<td>28.4</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-H'</td>
<td>22.1</td>
<td>2x0.451</td>
<td>-</td>
<td>2x0.122</td>
<td>1.146</td>
<td>40.8</td>
<td>30.0</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-I'</td>
<td>14.6</td>
<td>2x0.451</td>
<td>-</td>
<td>2x0.122</td>
<td>1.146</td>
<td>12.2</td>
<td>12.2</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J-J'</td>
<td>6.5</td>
<td>2x0.451</td>
<td>-</td>
<td>2x0.301</td>
<td>1.504</td>
<td>9.5</td>
<td>29.3</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-K'</td>
<td>-2.3</td>
<td>0.451</td>
<td>0.077</td>
<td>2x0.173</td>
<td>0.974</td>
<td>-1.9</td>
<td>-4.6</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-L'</td>
<td>-11.0</td>
<td>-</td>
<td>0.077</td>
<td>2x0.173</td>
<td>0.974</td>
<td>-5.5</td>
<td>-3.4</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M-M' of H'</td>
<td>-19.8</td>
<td>-</td>
<td>0.077</td>
<td>2x0.301</td>
<td>0.529</td>
<td>-10.5</td>
<td>-22.2</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>-28.3</td>
<td>-</td>
<td>-</td>
<td>0.173</td>
<td>0.173</td>
<td>-4.9</td>
<td>-20.7</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50% of C-50% of 0'</td>
<td>-36.6</td>
<td>-</td>
<td>-</td>
<td>0.173</td>
<td>0.173</td>
<td>-4.9</td>
<td>-20.7</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-P' of H'</td>
<td>-40.3</td>
<td>-</td>
<td>-</td>
<td>1x0.732</td>
<td>0.915</td>
<td>-42.7</td>
<td>1657</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q-Q'</td>
<td>-50.3</td>
<td>-</td>
<td>-</td>
<td>2x0.940</td>
<td>1.880</td>
<td>-75.8</td>
<td>-42.7</td>
<td>293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-R'</td>
<td>-60.3</td>
<td>-</td>
<td>-</td>
<td>2x0.334</td>
<td>3.801</td>
<td>-204.0</td>
<td>11950</td>
<td>293</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Distance from neutral axis to datum = +11 in.

(2) \(\bar{y} = \frac{1}{2}\bar{E}\) = 21.616 in. + 1.1 in.

(3) Aircraft 'm" bending moment \(M = 4,765,000\) lb in.

(4) Trials bending moment \(m'' = 4,765,000\) lb in.

(5) Maximum applied bending moment \(m''' = 11,160,000\) lb in.
## TABLE A

**Stress analysis of damaged B-29 fuselage section (Stn. 20)**

Target No. 35 - 3/16 in. rod high velocity
(Bending loads only, rod exit damage neglected)

<table>
<thead>
<tr>
<th>Member (see Fig. 2a, and 9)</th>
<th>Distance of member from neutral axis</th>
<th>Effective skin area</th>
<th>Effective stringer area</th>
<th>Total area</th>
<th>Distance of member from effective neutral axis</th>
<th>Moment of inertia</th>
<th>Maximum stress ('ig' loading)</th>
<th>Maximum stress (trial loading)</th>
<th>Maximum stress applied (2.5g loading)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>36.2</td>
<td>0.358</td>
<td>0.102</td>
<td>0.760</td>
<td>27.5</td>
<td>702</td>
<td>725</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>B-B'</td>
<td>35.5</td>
<td>2x0.358</td>
<td>1.506</td>
<td>3.34</td>
<td>29.7</td>
<td>1328</td>
<td>1366</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>C-C'</td>
<td>33.4</td>
<td>2x0.358</td>
<td>1.506</td>
<td>3.34</td>
<td>29.7</td>
<td>1366</td>
<td>1366</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>D-D'</td>
<td>30.0</td>
<td>2x0.358</td>
<td>1.112</td>
<td>2.24</td>
<td>21.9</td>
<td>652</td>
<td>672</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>E-E'</td>
<td>27.7</td>
<td>2x0.358</td>
<td>1.044</td>
<td>2.67</td>
<td>21.9</td>
<td>652</td>
<td>672</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>F-F'</td>
<td>25.3</td>
<td>2x0.408</td>
<td>1.606</td>
<td>4.62</td>
<td>19.5</td>
<td>610</td>
<td>610</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>G-G'</td>
<td>19.5</td>
<td>2x0.457</td>
<td>1.158</td>
<td>22.6</td>
<td>13.7</td>
<td>218</td>
<td>218</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>H-H'</td>
<td>12.7</td>
<td>2x0.457</td>
<td>1.156</td>
<td>19.2</td>
<td>6.9</td>
<td>72</td>
<td>72</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>I-I'</td>
<td>5.1</td>
<td>2x0.457</td>
<td>1.156</td>
<td>5.9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>J-J'</td>
<td>-3.2</td>
<td>2x0.408</td>
<td>0.758</td>
<td>-4.4</td>
<td>-9.0</td>
<td>61</td>
<td>61</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>K-K'</td>
<td>-11.9</td>
<td>2x0.408</td>
<td>0.758</td>
<td>-5.0</td>
<td>-17.7</td>
<td>157</td>
<td>157</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>L</td>
<td>-20.6</td>
<td>0.078</td>
<td>0.251</td>
<td>-5.2</td>
<td>-26.6</td>
<td>178</td>
<td>178</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>M</td>
<td>-29.7</td>
<td>0.114</td>
<td>0.251</td>
<td>-12.3</td>
<td>-55.5</td>
<td>523</td>
<td>523</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>N</td>
<td>-38.4</td>
<td>0.173</td>
<td>0.251</td>
<td>-9.6</td>
<td>-44.2</td>
<td>490</td>
<td>490</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>O</td>
<td>-46.7</td>
<td>0.173</td>
<td>0.251</td>
<td>-11.7</td>
<td>-52.5</td>
<td>692</td>
<td>692</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>P</td>
<td>-49.4</td>
<td>0.173</td>
<td>0.251</td>
<td>-12.2</td>
<td>-55.0</td>
<td>2995</td>
<td>2995</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>Q</td>
<td>-54.3</td>
<td>0.173</td>
<td>0.251</td>
<td>-22.7</td>
<td>-178</td>
<td>1728</td>
<td>1728</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>R</td>
<td>-59.2</td>
<td>0.172</td>
<td>0.251</td>
<td>-33.7</td>
<td>-55.0</td>
<td>3364</td>
<td>3364</td>
<td>4,525</td>
<td>12,840</td>
</tr>
<tr>
<td>E</td>
<td>15.457</td>
<td>189.8</td>
<td>14645</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Distance from neutral axis to datum = +20.8 in.
2. \( \bar{y} = \frac{\Sigma y}{\Sigma A} = 15.457 \) = 5.8 in.
3. Aircraft 'ig' bending moment \( M = 2,174,400 \) lb in.
4. Trials bending moment \( M' = 2,174,400 \) lb in.
5. Maximum applied bending moment \( M'' = 6,175,700 \) lb in.
### Table 5

#### Stress analysis of damaged B-39 fuselage section (Str.766)

<table>
<thead>
<tr>
<th>Member (see Figs. 2b and 10)</th>
<th>Distance of member from neutral axis in.</th>
<th>Effective skin area in²</th>
<th>Effective stringer area in²</th>
<th>Total area in²</th>
<th>Distance of member from effective neutral axis in.</th>
<th>Moment of inertia (&quot;ig&quot; loading) in⁴</th>
<th>Maximum stress (&quot;ig&quot; loading) lb/in²</th>
<th>Maximum stress (trial loading) lb/in²</th>
<th>Maximum stress applied lb/in²</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>36.1</td>
<td>0.378</td>
<td>0.402</td>
<td>0.780</td>
<td>28.2</td>
<td>33.3</td>
<td>865</td>
<td>4.4,710</td>
<td>+3,570</td>
</tr>
<tr>
<td>B-B'</td>
<td>35.5</td>
<td>2x0.378</td>
<td>0.366</td>
<td>1.102</td>
<td>39.1</td>
<td>32.7</td>
<td>1180</td>
<td>4.925</td>
<td></td>
</tr>
<tr>
<td>C-C'</td>
<td>34.7</td>
<td>-</td>
<td>0.264</td>
<td>0.264</td>
<td>8.5</td>
<td>31.9</td>
<td>268</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-D'</td>
<td>33.8</td>
<td>2x0.378</td>
<td>0.264</td>
<td>1.102</td>
<td>37.3</td>
<td>31.0</td>
<td>1099</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-E'</td>
<td>32.4</td>
<td>-</td>
<td>0.264</td>
<td>0.264</td>
<td>7.9</td>
<td>29.6</td>
<td>214</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-F'</td>
<td>31.0</td>
<td>2x0.378</td>
<td>0.264</td>
<td>1.102</td>
<td>34.2</td>
<td>28.6</td>
<td>178</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-G'</td>
<td>28.9</td>
<td>-</td>
<td>0.264</td>
<td>0.264</td>
<td>7.1</td>
<td>26.1</td>
<td>166</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-H'</td>
<td>27.1</td>
<td>2x0.378</td>
<td>0.264</td>
<td>1.102</td>
<td>34.2</td>
<td>28.6</td>
<td>178</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-I'</td>
<td>25.3</td>
<td>2x0.378</td>
<td>0.264</td>
<td>1.102</td>
<td>34.2</td>
<td>28.6</td>
<td>178</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J-J'</td>
<td>16.3</td>
<td>2x0.378</td>
<td>0.264</td>
<td>1.102</td>
<td>34.2</td>
<td>28.6</td>
<td>178</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-K'</td>
<td>10.3</td>
<td>0.297</td>
<td>0.264</td>
<td>0.569</td>
<td>6.1</td>
<td>7.5</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-L'</td>
<td>4.3</td>
<td>2x0.378</td>
<td>0.366</td>
<td>0.698</td>
<td>3.0</td>
<td>1.5</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M-M'</td>
<td>-3.9</td>
<td>2x0.378</td>
<td>0.366</td>
<td>0.644</td>
<td>-1.7</td>
<td>-6.7</td>
<td>19.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>-11.1</td>
<td>0.276</td>
<td>0.279</td>
<td>0.395</td>
<td>-3.9</td>
<td>-13.9</td>
<td>68.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>-18.5</td>
<td>0.276</td>
<td>0.301</td>
<td>0.369</td>
<td>-6.5</td>
<td>-21.3</td>
<td>138</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>-25.7</td>
<td>0.276</td>
<td>0.173</td>
<td>0.221</td>
<td>-5.7</td>
<td>-28.5</td>
<td>180</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>-32.5</td>
<td>0.276</td>
<td>0.173</td>
<td>0.221</td>
<td>-4.4</td>
<td>-33.3</td>
<td>351</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>-44.5</td>
<td>0.091</td>
<td>2.808</td>
<td>2.899</td>
<td>-129.0</td>
<td>-47.3</td>
<td>6485</td>
<td>-7,365</td>
<td>-7,710</td>
</tr>
<tr>
<td>S</td>
<td>-67.0</td>
<td>0.091</td>
<td>2.808</td>
<td>2.899</td>
<td>-129.0</td>
<td>-47.3</td>
<td>6485</td>
<td>-7,365</td>
<td>-7,710</td>
</tr>
<tr>
<td>U</td>
<td>-89.3</td>
<td>0.091</td>
<td>2.808</td>
<td>2.899</td>
<td>-129.0</td>
<td>-47.3</td>
<td>6485</td>
<td>-7,365</td>
<td>-7,710</td>
</tr>
<tr>
<td>E</td>
<td>16.088</td>
<td>+2.8</td>
<td>16.270</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Distance from neutral axis to datum = 11.1 in.
2. \( \bar{y} = \frac{E(7)}{E(6)} = \frac{45.1}{16.088} = +2.8 \) in.
3. Aircraft "ig" bending moment \( M = 2,318,000 \) lb in.
4. Trials bending moment \( M' = 2,420,000 \) lb in.
5. Maximum applied bending moment \( M'' = 4,700,000 \) lb in.
### Table 6

**Stress analysis of Aug 34 B52 fuselage section (top view)**

**Target No. 4A - 3/16 in. red high velocity**

(Bending loads only; red exit damage neglected)

<table>
<thead>
<tr>
<th>Member (see Figs. 6 and 11)</th>
<th>Distance of member from neutral axis (in)</th>
<th>Effective skin area (in²)</th>
<th>Effective stringer area (in²)</th>
<th>Total area (in²)</th>
<th>Moment of inertia (in⁴)</th>
<th>Maximum stress (in lb/in²)</th>
<th>Maximum stress (in lb/in²)</th>
<th>Maximum stress applied (in lb/in²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>61.2</td>
<td>0.378</td>
<td>0.173</td>
<td>0.551</td>
<td>35.7</td>
<td>57.0</td>
<td>1790</td>
<td>1790 +9060</td>
</tr>
<tr>
<td>F</td>
<td>56.4</td>
<td>0.378</td>
<td>0.173</td>
<td>0.551</td>
<td>32.2</td>
<td>54.2</td>
<td>1619</td>
<td>None</td>
</tr>
<tr>
<td>G</td>
<td>56.3</td>
<td>0.378</td>
<td>0.173</td>
<td>0.551</td>
<td>33.7</td>
<td>57.0</td>
<td>1619</td>
<td>+19,550</td>
</tr>
<tr>
<td>H</td>
<td>56.3</td>
<td>0.378</td>
<td>0.173</td>
<td>0.551</td>
<td>32.2</td>
<td>54.2</td>
<td>1619</td>
<td>None</td>
</tr>
<tr>
<td>J</td>
<td>37.7</td>
<td>0.297</td>
<td>0.301</td>
<td>0.598</td>
<td>18.5</td>
<td>26.7</td>
<td>426</td>
<td>None</td>
</tr>
<tr>
<td>M</td>
<td>23.7</td>
<td>0.297</td>
<td>0.301</td>
<td>0.598</td>
<td>19.9</td>
<td>27.9</td>
<td>470</td>
<td>470</td>
</tr>
<tr>
<td>N</td>
<td>18.3</td>
<td>0.297</td>
<td>0.301</td>
<td>0.598</td>
<td>18.5</td>
<td>26.7</td>
<td>426</td>
<td>None</td>
</tr>
<tr>
<td>O</td>
<td>18.3</td>
<td>0.297</td>
<td>0.301</td>
<td>0.598</td>
<td>19.9</td>
<td>27.9</td>
<td>470</td>
<td>None</td>
</tr>
<tr>
<td>P</td>
<td>5.7</td>
<td>0.223</td>
<td>0.008</td>
<td>0.409</td>
<td>0.7</td>
<td>2.5</td>
<td>2</td>
<td>None</td>
</tr>
<tr>
<td>Q</td>
<td>-5.1</td>
<td>0.040</td>
<td>0.435</td>
<td>0.435</td>
<td>-23.3</td>
<td>-9.3</td>
<td>123</td>
<td>None</td>
</tr>
<tr>
<td>R</td>
<td>-14.7</td>
<td>0.104</td>
<td>0.566</td>
<td>0.566</td>
<td>-4.2</td>
<td>-15.6</td>
<td>133</td>
<td>None</td>
</tr>
<tr>
<td>S</td>
<td>-21.1</td>
<td>2x0.048</td>
<td>2x0.178</td>
<td>3.052</td>
<td>-52.2</td>
<td>-21.3</td>
<td>1384</td>
<td>None</td>
</tr>
<tr>
<td>T</td>
<td>-19.6</td>
<td>2x0.048</td>
<td>2x0.173</td>
<td>3.442</td>
<td>-83.7</td>
<td>-23.8</td>
<td>250</td>
<td>None</td>
</tr>
<tr>
<td>U</td>
<td>-21.9</td>
<td>2x0.048</td>
<td>2x0.393</td>
<td>0.836</td>
<td>-19.4</td>
<td>-25.1</td>
<td>603</td>
<td>None</td>
</tr>
<tr>
<td>V</td>
<td>-20.3</td>
<td>2x0.122</td>
<td>2x0.422</td>
<td>1.048</td>
<td>-21.0</td>
<td>-30.0</td>
<td>943</td>
<td>None</td>
</tr>
<tr>
<td>W</td>
<td>-29.6</td>
<td>2x0.331</td>
<td>2x0.395</td>
<td>0.652</td>
<td>-24.4</td>
<td>-32.8</td>
<td>917</td>
<td>None</td>
</tr>
<tr>
<td>X</td>
<td>-30.3</td>
<td>2x0.331</td>
<td>2x0.173</td>
<td>0.408</td>
<td>-12.4</td>
<td>-36.5</td>
<td>486</td>
<td>None</td>
</tr>
<tr>
<td>Y</td>
<td>-30.9</td>
<td>0.200</td>
<td>0.402</td>
<td>0.602</td>
<td>-18.6</td>
<td>-35.1</td>
<td>742</td>
<td>None</td>
</tr>
</tbody>
</table>

(1) Distance from neutral axis to datum = 46.3 in.

(3) Aircraft 'ig' bending moment M = 2,314,000 lb in.

(4) Trials bending moment M' = None

(5) Maximum applied bending moment M" = 4,580,000 lb in.

**Note:** Stringers 'C' and 'E' not present in this target.

- 41 -

CONFIDENTIAL
<table>
<thead>
<tr>
<th>Member (see Figs. 2b and 0)</th>
<th>Distance of number from neutral axis in.</th>
<th>Effective skin area in²</th>
<th>Effective stringer area in²</th>
<th>Total area in²</th>
<th>Distance of number from effective neutral axis in.</th>
<th>Moment of inertia (1g loading) lb-in²</th>
<th>Maximum stress (1g loading) lb/in²</th>
<th>Maximum stress (trial loading) lb/in²</th>
<th>Maximum stress applied lb/in²</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>61.7</td>
<td>0.378</td>
<td>0.173</td>
<td>0.551</td>
<td>33.9</td>
<td>57.5</td>
<td>1820</td>
<td>+9,040</td>
<td>+9,740</td>
</tr>
<tr>
<td>F</td>
<td>58.9</td>
<td>0.378</td>
<td>0.173</td>
<td>0.551</td>
<td>32.5</td>
<td>54.7</td>
<td>1647</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>56.6</td>
<td>0.378</td>
<td>0.172</td>
<td>0.512</td>
<td>6.9</td>
<td>52.6</td>
<td>357</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>54.0</td>
<td>0.378</td>
<td>0.173</td>
<td>0.773</td>
<td>42.5</td>
<td>50.8</td>
<td>1999</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>50.2</td>
<td>0.378</td>
<td>0.172</td>
<td>0.500</td>
<td>25.1</td>
<td>46.0</td>
<td>1057</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>44.2</td>
<td>0.378</td>
<td>0.122</td>
<td>0.739</td>
<td>32.7</td>
<td>40.0</td>
<td>1182</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>38.2</td>
<td>0.297</td>
<td>0.122</td>
<td>0.419</td>
<td>16.0</td>
<td>34.0</td>
<td>464</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>31.4</td>
<td>0.297</td>
<td>0.122</td>
<td>0.290</td>
<td>10.8</td>
<td>27.2</td>
<td>443</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>24.2</td>
<td>0.297</td>
<td>0.122</td>
<td>0.173</td>
<td>11.4</td>
<td>20.0</td>
<td>228</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>16.8</td>
<td>0.297</td>
<td>0.227</td>
<td>0.570</td>
<td>9.7</td>
<td>12.6</td>
<td>92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>9.4</td>
<td>0.297</td>
<td>0.301</td>
<td>0.596</td>
<td>5.6</td>
<td>5.2</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>2.2</td>
<td>0.340</td>
<td>0.006</td>
<td>0.449</td>
<td>0.9</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>-4.6</td>
<td>0.006</td>
<td>0.443</td>
<td>0.395</td>
<td>2.0</td>
<td>-8.8</td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-E'</td>
<td>-10.9</td>
<td>2x0.048</td>
<td>2x0.042</td>
<td>1.092</td>
<td>-11.9</td>
<td>-15.1</td>
<td>249</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-S'</td>
<td>-16.6</td>
<td>2x0.048</td>
<td>2x0.042</td>
<td>3.052</td>
<td>-30.7</td>
<td>-30.6</td>
<td>1318</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-E'</td>
<td>-19.1</td>
<td>2x0.051</td>
<td>2x0.048</td>
<td>0.442</td>
<td>-23.3</td>
<td>-23.3</td>
<td>239</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-T'</td>
<td>-23.4</td>
<td>2x0.051</td>
<td>2x0.048</td>
<td>0.856</td>
<td>-18.9</td>
<td>-25.6</td>
<td>581</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V-E'</td>
<td>-25.3</td>
<td>2x0.051</td>
<td>2x0.050</td>
<td>1.068</td>
<td>-26.5</td>
<td>-29.5</td>
<td>912</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V-V'</td>
<td>-28.1</td>
<td>2x0.051</td>
<td>2x0.050</td>
<td>0.852</td>
<td>-23.9</td>
<td>-32.3</td>
<td>808</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-E'</td>
<td>-29.8</td>
<td>2x0.051</td>
<td>2x0.050</td>
<td>0.406</td>
<td>-12.2</td>
<td>-30.0</td>
<td>471</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-X'</td>
<td>-30.4</td>
<td>2x0.050</td>
<td>2x0.050</td>
<td>0.602</td>
<td>-18.3</td>
<td>-34.6</td>
<td>720</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>15.16</td>
<td>-55.2</td>
<td>16,755</td>
<td>15.14</td>
<td>12.5</td>
<td>16,755</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Distance from neutral axis to datum = -16.6 in.
(2) \( \bar{y} = \frac{3}{2} (\frac{7}{6}) = \frac{61}{16} = \pm 4.2 \) in.
(3) Aircraft '1g' bending moment \( M = 2,514,000 \) lb in.
(4) Trials bending moment \( M' = 2,495,000 \) lb in.
(5) Failing bending moment \( M'' = 4,210,000 \) lb in.

NOTE: Stringers 'C' and 'E' not present in this target
These abstract cards are inserted in Reports and Technical Notes for the convenience of Librarians and others who need to maintain an Information Index.

Detached cards are subject to the same Security Regulations as the parent document, and a record of their location should be made on the inside of the back cover of the parent document.
Stress analyses made of the damaged targets indicate that there may well be a correlation between the failing stresses in bending of fuselages of various forms of construction. Further work to confirm and extend this and other indications is proposed.

Stress analyses made of the damaged targets indicate that there may well be a correlation between the failing stresses in bending of fuselages of various forms of construction. Further work to confirm and extend this and other indications is proposed.
DETACHABLE ABSTRACT CARDS

The abstract cards detached from this document are located as follows:

1 ______________ 2 ______________
3 ______________ 4 ______________
Signed ______________________ Date ________