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# DESIGN REQUIREMENTS FOR AEROPLANES *for the* ROYAL AIR FORCE

This handbook is issued for the information and guidance of all concerned.

*By Command of the Air Council*

C. Ll. Bullock

AIR MINISTRY



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| *Number.* | *Date.* | | |
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CHAPTER IV—NON-FACTOR REQUIREMENTS—*contd.* *Para. No.*

CHAPTER V.—MISCELLANEOUS DATA IN CONNECTION WITH CHAPTERS II, III AND IV



CHAPTER VI.—THE STRENGTH OF SPARS



CHAPTER VII.—THE AERODYNAMIC LOAD DISTRIBUTION ON TAPERED AND TWISTED WINGS

# INTRODUCTION—SCOPE OF HANDBOOK AND ARRANGEMENT

**1. Scope of the handbook**

The requirements given in this handbook apply to all aeroplanes built to Air Ministry contract. The handbook is intended to amplify the requirements given in aeroplane specifications. In the event of any conflict between the requirements of an aeroplane specification and those of this handbook, the requirements given in the aeroplane specification take precedence.

**2. Arrangement**

(i) All requirements affecting the airframe are collected into three chapters.—

Chapter II, Strength requirements based on flight conditions,
Chapter III, Strength requirements based on other than flight conditions,
Chapter IV, Non-factor requirements.

Chapters V to VIII inclusive of the handbook consist of methods of calculation and other details needed for the precise interpretation of the requirements of Chapters II, III and IV.

(ii) The non-factor requirements of Chapter IV comprise such items as flutter prevention, welding regulations, etc. They are characterized by the fact that they do not admit of specification in terms of a factor.

(iii) Chapter IX consists of airscrew requirements.

**3.**

Reference to any particular portion of the handbook should be made by quoting the chapter (Section for Chapters V, VIII and IX), paragraph and line number.

**4. Indications of amendments**

At the top of each page affected by amendment action will be found the number of the Amendment List concerned. A black line printed on the left-hand side of the text or illustrations indicates that the matter against the line has been amended or added by the Amendment List quoted. This indication on any particular page will appear only against the matter on that page affected by that Amendment List.

## INTRODUCTION—SCOPE OF HANDBOOK AND ARRANGEMENT

[illegible] of the handbook

[illegible] given in this handbook apply to all [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] take precedence.

[illegible] Arrangement

(1) All requirements affecting the [illegible] [illegible] [illegible] chapters—

Chapter II, Strength requirements [illegible] flight conditions.

Chapter III, Strength requirements based on [illegible]

Chapter IV, [illegible] requirements.

Chapters V to VIII [illegible] of the handbook [illegible] [illegible] Chapters II, III and IV.

(2) The [illegible] requirements [illegible] [illegible] [illegible] [illegible] a [illegible]

(3) Chapter IX consists of [illegible]

[illegible] should be made by quoting the chapter [illegible] for Chapters V, VI [illegible] and IX [illegible]

4. [illegible] of amendments

At the [illegible] of each page affected by amendment [illegible] will be found the number of the Amendment [illegible] [illegible] A black line [illegible] the text or [illegible] has been amended or added by the Amendment [illegible] The [illegible] [illegible] the matter of that [illegible] by [illegible] Amendment List.

# CHAPTER I.—GENERAL REQUIREMENTS GOVERNING THE ESTIMATION OF STRUCTURAL STRENGTH

## 1. Methods of strength estimation : calculation and test

(i) Any technically sound method of estimating the strength of airframes under the specified externally applied loads is acceptable. Credit may be taken for all redundancies provided sufficient information is available as to the effect of such redundancies. Compliance with strength requirements will usually be based upon calculated strength rather than upon the strength as determined by mechanical tests on a complete component. Allowable stresses to be used in such calculations are given in Chapter VIII.

(ii) When the type of construction is not amenable to strength calculation or when there is reason to doubt the accuracy of such calculations as can be made, the strength will be determined by *ad hoc* mechanical tests. Prior official concurrence should be obtained for such tests and they should be carried out under approved conditions.

## 2. Proof factor and ultimate factor

All calculations and mechanical tests are to be made in the light of the following requirements.

(i) Any standard structure or component shall not collapse before withstanding on strength test the external loads corresponding to the *specified ultimate factor*.

(ii) Any standard structure or component shall be capable on strength test of carrying for a period of one minute 75 per cent. of the loads corresponding to the specified ultimate factor, during and after which it shall still be in an airworthy condition. This 75 per cent. of the specified ultimate factor will be referred to as the *specified proof factor*.

The factors given in this handbook and in aeroplane specifications are specified ultimate factors unless otherwise stated. Compliance with the proof factor requirement should be checked both when approval is based entirely upon calculations and when recourse is had to mechanical tests.

## 3. Definition of standard and typical structures and components

(i) A *standard component* is the weakest component that could be made complying with the drawings and material specifications, all limits and tolerances being taken in the most adverse direction. Standard compression members, in addition to satisfying these conditions, are to be regarded as having the maximum allowable eccentricity.

(ii) A *typical component* is a component constructed in accordance with usual workshop procedure.

(iii) *Standard* and *typical structures* are structures built throughout of *standard* or *typical components* respectively.

(iv) *Typical,* not *standard,* structures and components will usually be available for mechanical tests, and hence the test results will have to be corrected down to standard structure conditions. Such correction will usually only be possible when the item tested is of simple design and fails in a manner to which the specified material properties are directly applicable. In other cases it will be necessary to obtain on test factors 20 per cent. greater than those specified. In the case of a test on a complete unit a convenient procedure, when practicable, is to patch up in an approved manner such members as fail prematurely in order to continue the test. Corrections to standard component conditions need then be applied only to the members which fail before the full 20 per cent. extra load has been applied.

(v) When correction down to standard component conditions is possible and reasonably easy to apply it is not permissible to waive such correction in favour of compliance with the 20 per cent. expedient. Doubtful cases should be referred to the Airworthiness Department, Royal Aircraft Establishment, South Farnborough.

**4. Critical loading cases for particular components**

(i) The majority of the strength requirements given in the succeeding chapters are stated without specific reference to the particular components for which they may be expected to give critical loads. Unless otherwise stated the loads corresponding to the various conditions specified should be traced through the structure sufficiently far to ensure that the aeroplane has at least the specified factors throughout the whole structure, but this does not imply that the whole structure need be stressed for every specified condition. Many of the stressing cases overlap and when it can be shown that any particular case will not give critical loads it will be unnecessary to consider that case further.

(ii) Tables are given at the beginning of Chapters II and III summarizing the requirements specified in each of these chapters and indicating the particular components for which each requirement may be expected to give design loads. It will, however, always be necessary unless otherwise stated to check that the aeroplane *as a whole* complies with all the specified requirements.

(iii) Most of the requirements of Chapter IV apply to the whole aerostructure, so that the table at the beginning of Chapter IV does not indicate the components of the aerostructure relevant to each requirement.

(iv) Table I which follows is in effect a re-arrangement of the Chapter II and III Tables, together with a few items from the Chapter IV Table, the various requirements being grouped to show which will normally need to be considered for each of the main components of the aerostructure. This list is not to be taken as over-riding the proviso that the aeroplane as a whole must comply with all the specified requirements unless otherwise stated.

TABLE I

| *Component.* | *Relevant requirements.* | *For particulars see* Chap. | Para. |
|---|---|---|---|
| Main planes | Normal flight, C.P. forward | II | 2 |
| | Strength requirements for wings with tip slots (super-stall) | II | 13 |
| | Normal flight, C.P. back | II | 3 |
| | Terminal velocity dive | II | 4 |
| | Fast glide (seldom critical for main planes) | II | 5 and 6 |
| | Aileron wing loads | II | 8 |
| | Up and down gusts | II | 9 |
| | Inverted flight, high negative incidence | II | 10 |
| | Strength of aeroplanes under automatic control | II | 21 |
| | Catapulting | III | 10 |
| | Catapulting | V | Sect. IV. |
| | Landing | III | 4–7 |
| | Engine mounting (when engines are in the wings) | II | 18 |
| | Wires cut | II | 23 |
| | Static thrust and torque | III | 17 |
| | Aileron mass-balance | IV | 2 |
| | Wings folded | III | 16 |
| | Jacking loads | III | 15 |
| | Relative strength of lift and anti-lift wires | II | 25 |
| | Duplicate wires | II | 24 |
| | Wing tip float (side loads) | III | 6 and 7 |
| | Rib removed | III | 22 |
| | Rib tests | III | 24 |
| | Aerodynamic loading on long struts | II | 26 |
| | Trailing edge flaps | II | 12 |

TABLE I—*continued*

| *Component.* | *Relevant requirements.* | *For particulars see* Chap. | Para. |
|---|---|---|---|
| Centre section | As for main plaines. Also— | | |
| | One wheel landing | III | 4 |
| | Side load (at axle) | III | 4 |
| | Somersault landing | III | 13 |
| | Slinging | III | 12 |
| | Salvage | III | 14 |
| Front fuselage | Normal flight, C.P. forward | II | 2 |
| | Engine mounting (if engine is in front fuselage) | II | 18 |
| | Static thrust and torque | III | 17 |
| | Side load | II | 19 |
| | Jacking loads | III | 15 |
| | Safety belt and harness loads | III | 20 |
| Rear fuselage | Terminal velocity dive | II | 4 |
| | Over-riding minimum tail load | II | 7 |
| | Fast glide | II | 5 and 6 |
| | Normal flight, C.P. forward | II | 2 |
| | Normal flight, C.P. back | II | 3 |
| | Fin and rudder loads | II | 16 |
| | Fin and rudder loads | V | Sect. II. |
| | Over-riding torsional loading from tail plane | II | 17 |
| | Landing | III | 4–7 |
| | Catapulting | III | 10 |
| | Catapulting | V | Sect. IV. |
| | Arrested landing | III | 11 |
| | Wires cut | II | 23 |
| | Jacking loads | III | 15 |
| | Fixing of ballast weights and other large masses | III | 19 |
| | Safety belt and harness loads | III | 20 |
| Engine mounting | Six times gravity loads | II | 18 |
| | Turning | II | 18 |
| | Static thrust and torque | III | 17 |
| | Side loads | II | 19 |
| | Landing—as for undercarriage | III | 4–7 |
| | Fitting of ring cowlings | III | 27 |
| Ailerons and their attachments | Mass-balance | IV | 2 |
| | 20° aileron angle in horizontal flight | II | 11 |
| | Tail-to-wind loads | III | 18 |
| | Aileron instability | IV | 3 |
| | Torsional stiffness of ailerons | IV | 43 |
| | Mass-balance arms | II | 28 |
| Undercarriage | Landing cases | III | 4–7 |
| | Wheels (including tail wheels) | IV | 15 |
| | Wheel brakes | IV | 14 |
| | Brake operating gear | II | 20 |
| | Arrested landing | III | 11 |

TABLE I—*continued*

| *Component.* | *Relevant requirements.* | *For particulars see* Chap. | Para. |
|---|---|---|---|
| Undercarriage—*continued* | Wings folded | III | 16 |
| | Safe limit of deterioration of shock absorber legs | IV | 33 |
| | Static thrust and torque | III | 17 |
| | Retractable undercarriage | IV | 41 |
| | Undercarriage springing characteristics | IV | 42 |
| Hull. (Boat seaplanes) | Landing tail up | III | 6 |
| | Two wave landing | III | 6 |
| | Pressure over planing bottom | III | 6 |
| | Static thrust and torque | III | 17 |
| | Also relevant cases specified for the front and rear fuselage | (*see* above) | |
| Floats. (Seaplanes) | Landing tail up | III | 7 |
| | Two wave landing | III | 7 |
| | Pressure over planing bottom | III | 7 |
| | Static thrust and torque | III | 17 |
| Tail plane and elevator | Terminal velocity dive | II | 4 |
| | Over-riding minimum tail load | II | 7 |
| | Fast glide | II | 5 and 6 |
| | Normal flight, C.P. forward | II | 2 |
| | Normal flight, C.P. back | II | 3 |
| | Over-riding torsional loading | II | 17 |
| | Tail-to-wind (elevator) | III | 18 |
| | Wires cut | II | 23 |
| | Tail adjusting gear to be irreversible | II | 20 |
| | Rib tests | III | 24 |
| | Rib removed | III | 22 |
| | Divided elevators | IV | 12 |
| | Relative strength of lift and anti-lift wires | II | 25 |
| | Duplicate wires | II | 24 |
| | Aerodynamic loading on long struts | II | 26 |
| | Tail plane flutter | IV | 4 |
| | Torsional stiffness of elevators | IV | 44 |
| Fin and rudder | Rudder mass-balance | IV | 4 |
| | Side load | II | 16 |
| | Side load | V | Sect. II. |
| | Tail-to-wind (rudder) | III | 18 |
| | Wires cut | II | 23 |
| | Rudder power | IV | 13 |
| | Clearance between fin and rudder | IV | 12 |
| Control circuits | Pilot's effort loads | II | 20 |
| | Tail-to-wind | III | 18 |
| | Automatic control mechanism | II | 22 |
| | Duplication | IV | 6 |
| | Elastic stretch | IV | 3 |
| | Locking of controls | IV | 10 |
| | Cables and chains | IV | 7 and 8 |
| | Bearings | IV | 9 |
| | Trimming tab control circuits | IV | 4 |

TABLE I—*continued*

| *Component.* | *Relevant requirements.* | *For requirements see* Chap. | Para. |
|---|---|---|---|
| Seats, bomb racks, etc. .. | General cases .. .. .. .. .. | III | 21 |
| | Fixing of ballast weights and other large masses .. .. .. .. .. | III | 19 |
| | Catapulting .. .. .. .. .. | III | 10 |
| | Catapulting .. .. .. .. .. | V | Sect. IV. |
| Windscreens .. .. .. | General cases .. .. .. .. .. | II | 27 |
| Ancillary structure .. .. | .. .. .. .. .. .. .. .. | III | 23 |
| | Beaching chassis and tail trolleys of boat seaplanes .. .. .. .. .. | III | 26 |

**5. Definitions** (*see* also British Standard Glossary of Aeronautical Terms, 1933.)

*Specified ultimate factor* (*see* Chapter I, para. 2).—In general the loads corresponding to the specified ultimate factor are intended to be twice the greatest loads which are expected during manœuvres appropriate to the type. The specified ultimate factor thus usually includes a factor of safety of 2.

*Specified proof factor* (*see* Chapter I, para. 2.)

*Reserve factor.*—The ratio of the load which a component or structure is capable of carrying to the load corresponding to the specified ultimate factor. A component just complying with requirements, therefore, will have a reserve factor of 1·0.

*Factor of safety.**—The factor by which the greatest expected loads are to be multiplied to give the loads corresponding to the specified ultimate factor.

*Realized factor.*—The reserve factor multiplied by the specified ultimate factor.

*Note on loads aising from accelerated motion.*—In calculating the greatest loads which are expected during manœuvres appropriate to the type (*see* definition of "specified ultimate factor" above) it is usual to consider the aeroplane as being in accelerated motion on a horizontal portion of its flight path. Thus for an aeroplane of weight $W$ the external loads corresponding to an ultimate factor of $N$ are, when $N$ exceeds 2, to be interpreted as being *twice* the loads necessary to give balance at the specified attitude for a vertical force of $\frac{N}{2}W$ downwards through the centre of gravity of the aeroplane. These loads will correspond to a vertical acceleration of approximately $\left(\frac{N}{2} - 1\right)g$, though accelerometers are commonly calibrated so that in these circumstances an accelerometer reading of approximately $\frac{N}{2}g$ would be obtained. This has given rise to the common but erroneous practice of regarding the ultimate factor $N$ as corresponding to a factor of safety of 2 on the the loads due to an acceleration of $\frac{N}{2}g$.

*Chord line of an aerofoil.*—The chord line is the straight line through the centres of curvature of the leading and trailing edges of an aerofoil section.

*Maximum speed* is the maximum indicated air speed attainable in level flight at any altitude (or at one specified altitude) and at any engine r.p.m. up to and including the maximum emergency (i.e. "all-out level") r.p.m. within the limits of permissible level flight boost. In calculating this speed an arbitrary airscrew efficiency of 85 per cent. is to be assumed for all types of variable pitch and fixed pitch airscrews.

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* It should be noticed that the Factor of Safety as thus defined is different from that generally used in other branches of engineering (*e.g. Theory of Structures*, p. 28, by A. Morley).