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.

* 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).

Normal top speed is 87 per cent. of the maximum indicated air speed as defined above.

Determination of stalling speed

(i) The stalling speed should be determined from full scale or model test results, available data being employed in the order of preference given below.

(ii) Full scale.—For the purpose of strength requirements stalling speed as deduced from full scale tests is defined as the lowest speed at which the aeroplane can be held in a straight glide, engine off, for a period of one minute. The speed corresponding to ground level conditions is to be taken.

(*a*) Official full scale tests, if available, on the actual aeroplane.

(*b*) Official full scale tests on an aeroplane aerodynamically similar.

(iii) Model.—Stalling speed as deduced from model tests is defined as the air speed at which, under ground level conditions, the total lift on the aeroplane is equal to the weight, the attitude of the aeroplane being such that the lift coefficient is a maximum. No allowance for slipstream should be made.

(*a*) Approved model tests on a complete model of the actual aeroplane.

(*b*) Approved model tests on wings of the same arrangement.

(*c*) Approved model tests on a monoplane wing.

Where model tests at different values of Vl are available, tests at the highest Vl should be taken. Corrections, based on approved tests, for aspect ratio, gap, stagger, body lift, scale effect, etc., may be applied, but no increased velocity in the slipstream is to be assumed.

Note.—When flaps or slots are fitted to give an artificially low stalling speed the normal value (corresponding to the flaps and slots in the neutral position) should be taken for stressing purposes.

(iv) Requirements specified in terms of stalling speed are to be complied with at ground level air density.