# Chapter 1.1 REPAIR PUBLICATIONS AND INSTRUCTIONS

## LIST OF CONTENTS

# FUNCTION OF A.P.2662B AND RELATIONSHIP TO VOL. 6

## Function

**1.** The function of A.P.2662B is to provide a comprehensive source of information on aircraft repairs and associated procedures, either in content or by reference to other publications or documents. For this reason, some items which have previously appeared in other 'standard' publications or in aircraft or component Vols. 6 are presented in this publication. To reduce the need for reference to other publications when only a limited amount of associated information is required, some items are included in this A.P. although covered more comprehensively in other publications such as A.P. 1464.

**2.** Much airframe and component repair information is 'specific to type' and therefore is not appropriate to this A.P. Whenever possible, references are made to other sources of information, either in the text or in the *List of Associated Publications*, but aircraft Volumes 6 are too numerous to be listed. Para. 1 of 1.1.2 explains why all 'specific to type' information applicable to airframe trades in the Services is not issued as a single complete unit in the aircraft Vol. 6.

## Relationship to aircraft Vol. 6

**3.** A.P.2662B is complementary to the aircraft Vol. 6 but its schemes, although usually suitable for use on several types of aircraft, are not automatically applicable to all aircraft. The reason is that repairs of a standard nature cannot always comply with design requirements for individual aircraft.

**The repair design authority is the relevant aircraft Vol. 6 and schemes in A.P.2662B are to be applied to aircraft only when sanctioned in the Vol. 6, either by direct reference to specific schemes or by general reference to A.P.2662B or to sections or chapters of A.P.2662B.**

* * *

# LOCATION OF SPECIFIC AIRCRAFT REPAIR INFORMATION

**Presentation of specific information in Vol. 6**

**1.** As a general guide, repair information specific to an aircraft is presented in the aircraft or component Vol. 6 on a design authority basis, not on the basis of the repairs applicable to airframe trades in the Services. Since, generally, the aircraft manufacturer is only basically responsible for the design of the aircraft structure, aircraft Vols. 6 normally only cover this aspect. Other items which are repaired by airframe tradesmen in the Services, such as hydraulic, pneumatic and undercarriage components, ejection seats and fuel tanks, are usually designed by accessory manufacturers and the repair information for each item is supplied by the manufacturer concerned. For this reason, it is usual practice for repair information for 'accessory' components to be directly incorporated in publications which deal with several similar components than for the information to reach the Users at second hand through the medium of the aircraft Vol. 6. ►◄

**Exceptions to para. 1**

**2.** When the aircraft manufacturer also designs an 'accessory' component, the relevant repair information may appear in the aircraft Vol. 6. If components manufactured by an accessory firm are only used on one type of Service aircraft, these components may not receive individual official approval for general application to other aircraft. In these circumstances, the design responsibility for the components devolves upon the aircraft manufacturer who thus becomes liable for the supply of repair information and may present this information in the aircraft Vol. 6. A major example of this latter case would be that of an aircraft initially designed for civil use, since Service requirements for maximum use of standard components would not be applicable during manufacture. However, the amount of work and time required for the reproduction of the accessory information in an 'ex-civil' aircraft A.P. may not be considered justifiable, particularly when the total number of aircraft involved is small. In this event, authority may be given for accessory manufacturers books or leaflets to be issued in conjunction with and regarded as part of the aircraft A.P., Vol. 1 and 6.

**Repair information in Vol. 1**

**3.** The most usual form of repair information published in an aircraft Vol. 1 is that of instructions for repair by replacement. For components which are completely interchangeable between aircraft of the same type, the Vol. 1 *removal* and *assembly* instructions provide the information required for repairs by replacement and this information is not repeated in the Vol. 6. Where components are supplied in the undrilled state, or with trim allowances, and additional fitting instructions are necessary, these instructions appear in the Vol. 6 and should be used in conjunction with the Vol. 1 dismantling and assembly procedures. Similarly, when *wear limits* are issued in Vol. 6 they should be used in conjunction with the Vol. 1. Repairs to systems consists almost entirely of repairs by replacement and the Vol. 1 and Vol. 3 usually provide full information.

* * *

# 1.1.3

# PUBLICATIONS PROCEDURE PRIOR TO REPAIR

### Initial sources of repair information

**1.** The aircraft Vol. 6 *Note to Readers* quotes, in general terms, sources of 'overriding authority'. These are the initial sources of repair information. Instructions such as those in Vol. 2 Leaflets, S.T.N., S.T.I. or S.I. may apply to the damaged area and incorporation of these instructions could eliminate the need for normal repair. The next source of information is the aircraft Vol. 6.

### Aircraft A.P. Vol. 6

**2.** The aircraft Vol. 6 is the basic design authority for all repairs applicable to airframe and closely allied trades. Therefore, reference must be made to this Vol. 6 before commencement of *any* repair (para. 3). Even when a particular form of damage is familiar due to previous experience on the same type of aircraft, the Vol. 6 should be studied. Procedures, materials or references to associated publications may have been altered or deleted by amendment action since the previous similar damage was repaired.

### Volume 6 Procedure

**3.** The procedure for finding information in Vol. 6 is as follows:—

(1) Ensure that all amendments are incorporated.

(2) Read the *Introduction* and *Prefaces* if applicable, then *Note to Readers* and Part 1 marker card note. Check the *Applicability of Repairs* to the Mark of aircraft.

(3) Check *Advance Information Leaflets* for applicability. ►◄

(4) Check the text of Chapter 1 and the relevant chapter for appropriate general information and warnings.

(5) In the relevant chapter refer, via the key diagram, to the structure illustration and associated *damage definition* table (para. 4).

(6) If the damage table contains no reference to a repair scheme, check the ◄appropriate portion of Part 2.►

(7) If no scheme is given in Part 1 or 2, check the text of the relevant chapter, Chap. 1 and the *List of Associated Publications* for references to associated publications.

(8) When neither scheme nor reference is given, or when a term such as *Special Application* is quoted in the *Repair Fig.* column of the damage table, follow the appropriate procedure published in the Vol. 6, Part 1 marker card note and in 1.1.4 of this A.P.

(9) When the repair will involve disconnection or removal of system or control components, check the Vol. 1 for test procedures and fits and clearances necessary after completion of the repair.

### Damage Table repair references

**4.** The Tables quoting definitions of damage may appear on or adjacent to the pages bearing the relevant structure illustrations, following the text at the begining of a specific chapter or in Chapter 1. References in the Tables may be to repair schemes in the specific chapter, in Chapter 1, in Part 2 or to schemes in A.P.2662B or in other associated publications.

* * *

# APPLICATIONS FOR ADDITIONAL REPAIR INFORMATION

## APPLICATIONS FOR REPAIR SCHEME

**1.** When no, or insufficient, information is given in the aircraft Vol. 6 or associated publications for repair of a particular form of damage, application should be made for a repair scheme if the appropriate specialist officer considers that repair is possible and within the scope of the Unit concerned. The cause of the damage and full details of all primary and secondary damage should be given, even in cases in which part of the damage is covered by published schemes. Sketches and/or photographs should be used to illustrate the exact location and extent of the damage. Part numbers of damaged components should be quoted. If modifications, S.T.I. etc., apply to the damaged area, the existing local state of incorporation of such instructions should be quoted.

### Application procedure

**2.** Applications for additional repair schemes should be submitted as follows:—

*R.A.F. aircraft*—through the usual channels to the Directorate of Aircraft Engineering.

*R.N. aircraft*—in accordance with the procedure quoted in A.P. (N) 140, Article 0518.

## REPAIR DRAWINGS LISTED IN VOLS. 6

### Repair drawings policy

◄**3.** In some early Vols. 6, the repair leaflets in Part 2 contained only text and were designed to be used in conjunction with manufacturers' repair drawings. Current policy, whenever practicable, requires all repair schemes in Vols. 6 to be self-contained in respect of drawings. Occasionally, however, repair drawings are unsuitable for reproduction in the Vol. 6. In these circumstances the manufacturers' drawings, which are marked with a large "R" in the bottom right-hand corner to distinguish them from production drawings, are listed.► In addition, drawings for special jigs, templates and tools required for repairs may be listed.

### Amendments to repair drawings

**4.** Amendments and later issues are not always automatically forwarded to holders of repair drawings, particularly when the drawings are demanded on an individual basis. Also, earlier issues of drawings may not be destroyed in all cases when superseding issues are received.

**WARNING . . .**

> **Before any repair drawing already held on a unit is used, it must be checked to ensure that it is the latest issue of the correct drawing for the Mark and Modification state of the aircraft concerned.**

### Applications for repair drawings

**5.** Applications for repair drawings listed in Vols. 6 should quote the Mark of aircraft and also the state of incorporation of Modifications, S.T.I.s etc., when this may affect the repair. The procedure for requisitioning listed repair drawings is given in:—

*R.A.F. aircraft*—A.P.3158, Vol. 2, Leaflet D.7.

*R.N. aircraft* —A.P. (N) 140, Article 0403.

## REPORTS OF UNSATISFACTORY FEATURES

**6.** Reports of unsatisfactory features of this and any other A.P. should be rendered as follows:—

*R.A.F. aircraft*—in accordance with A.P.113A and A.P.3158, Vol. 2, Leaflet D.6. The layout to be used for reports is shown in A.P.113A, Appendix "W".

*R.N. aircraft*—in accordance with A.P. (N) 140, Articles 1101 and 1105 by signals and/or on Forms A.21.

When the spaces for *Unsatisfactory feature* and *Recommendation for improvement* on the pro-forma or para. 6 and 7 on Form A.21 are insufficient, the additional information should be given on separate sheets of paper which should be securely attached to the pro-forma, together with any sketches or photographs used to clarify the report.

### Definitions of unsatisfactory features

**7.** The definitions in A.P.113A, A.P.3158 and A.P. (N) 140 should be interpreted to include such items as proposed revisions of procedures. For example, if an A.P. contains a repair procedure as a series of operations and, by experience, it is discovered that alteration of the sequence or complete revision of the procedure would result in a more efficient or quicker job, the revised method should be forwarded as a proposed amendment to the A.P. as instructed in para. 6.

★ ★ ★

# Chapter 1.2 GENERAL TECHNICAL CONSIDERATIONS

## LIST OF CONTENTS

# DESIGN REQUIREMENTS FOR REPAIRS

### Basic requirements

**1.** The basic design strength requirements for repairs are given in A.P.970 and are as follows:—

> "Repairs shall comply with all relevant design requirements for the aeroplane as a whole. The design of the repairs shall, in general, be such that the reserve factor of the repaired member is not lower than 1·2 or that of the undamaged member, whichever is the less. It is, however, undesirable to repair one member in such a manner that its strength is relatively much below that of the surrounding structure. If the application of a particular repair would considerably reduce the reserve factor of the member, care shall be taken to ensure that a combination of two or more repairs could not reduce the reserve factor below the safe limit. Alternatively, a warning shall be included drawing attention to, and prohibiting the application of, the dangerous combination." These requirements are analysed in para. 2, 3, 4 and 5.

### Reserve factor

**2.** A reserve factor (R.F.) of a member is obtained by dividing the strength of the member by the maximum factored load that would be applied to it under a given set of design loading conditions. The member may have several different reserve factors such as R.F. in tension, compression, buckling, bending, torsion, shear, etc., due to one or more sets of design loading conditions. The minimum value of 1·2 quoted in para. 1 refers to the lowest R.F. on a repaired member arising from consideration of all design loading conditions. The minimum R.F. of an undamaged member should be 1·0 but, in exceptional circumstances, special concessions may be granted for factors to be slightly less than 1·0.

### Alterations to strength

**3.** It is undesirable to repair a member in such a manner that its strength is relatively much below that of the surrounding structure because the stiffness of the member would be reduced and consequently some of the load originally carried by the member would be transferred to the surrounding structure. This would result in decreases in the reserve factors of other members, possibly below the minimum value of 1·0.

**4.** For similar reasons, it is undesirable for the strength and stiffness of a member to be considerably increased by a repair. The repaired member itself may be capable of sustaining increased loading resulting from the increased stiffness, but end attachments and other members to which the load is transmitted may not be sufficiently strong.

### Combinations of repairs

**5.** Restrictions concerning combinations of repairs are usually given in aircraft Vol. 6 by direct statement, for example, "*one repair only per member*", or by quotation of minimum distances or spacing between repairs.

★ ★ ★

# STRUCTURE CLASSIFICATION FOR REPAIRS

### Initial requirement

**1.** To assist Service Users in the determination of strength standards required for repairs, particularly in the case of fly-in repairs and other emergencies, the components on structure illustrations in aircraft Vol. 6 are normally classified into Primary, Secondary or Tertiary Structure. The classifications are denoted by the colours red, yellow and green respectively.▶ ◀ Comparatively rapid assessments of the work involved and materials and equipment required, even in cases of extensive damage, can be made when diagrammatic structure classification is available.

### Other uses of classification

**2.** In some aircraft Vol. 6, the structure classification is used to reduce the number of repair schemes and references required. A typical repair scheme is prepared and the different details such as number of rivets, pitch of rivets, etc., required for its application to different parts of the structure are related, in the scheme, to Primary, Secondary and Tertiary Structure items on the complete aircraft or major component. Thus, one scheme replaces three and, at the same time, repeated references (to the repair schemes) on structure illustrations are unnecessary. References to the different classes of structure are particularly useful in Vol. 6, Part 1, Chapter 8, Fly-in Repairs.

### Definitions of structure classification

**3.** The definitions of structure classification (*for repair purposes only*) are given opposite. The interpretations of definitions for Class 1 parts given in A.P.970, Vol. 2, Leaflet 400/2 should be applied to the definitions for Primary Structure.

**PRIMARY STRUCTURE:** Any part of the structure (except as at (a) for *Secondary Structure*) in which a failure in flight, landing or take-off might be the direct cause of structural collapse, loss of control, failure of motive power, unintentional operation of or inability to operate any services or equipment essential to the safety or operational function of the aeroplane, or injury to any occupant.

**SECONDARY STRUCTURE:** (a) Any part to which the terms of *Primary Structure* would apply but which has such a high reserve factor that appreciable reduction in strength is permissible. (b) Stressed parts not covered by the terms of *Primary Structure*.

**TERTIARY STRUCTURE:** Unstressed or only lightly stressed parts not covered by the terms of *Primary Structure*.

★ ★ ★

# Chapter 1.3 MISCELLANEOUS STANDARD PROCEDURES

## LIST OF CONTENTS

*Scheme*

# FLEXIBLE FUEL TANK BAYS—PREVENTION OF CHAFING

### Cause and effect of chafing

**1.** Slight movements of flexible tanks invariably occur in flight due to the surge of fuel, even when locating studs or ropes are provided. Additionally, tanks may be pushed or dragged, during insertion, over internal surfaces with which they are not normally in contact. On some aircraft, smooth, perforated light alloy or plastic screens are fitted to prevent direct contact between tanks and structure when the tanks are in situ but, in many instances, these screens do not protect the tanks from chafing on the top skin structure during insertion. Leaks would develop rapidly, possibly with fatal consequences, if tanks were allowed to chafe on raw edges, even of thin s.w.g. materials, or on rivets, bolts and similar items.

### Initial precautions

**2.** Repairs to tank bays must always be designed and planned to ensure that no 'sharp' items, such as Chobert rivets complete with sealing pins, project into the bays, since these items cannot be satisfactorily covered. All edges of plates, butt-straps and flanges should be smoothed by formation of a radius equal to the material thickness and allowance should be made for this when marking out minimum rivet landings. All swarf, rivet mandrels and other loose materials must be removed after repairs to, *or in the vicinity of*, tank bays.

### Covering of protrusions

**3.** All edges of sheet materials, castings and forgings and rivet and bolt heads, etc., are normally covered during production and similar covering must be used after repairs. Edges of thin materials can usually be rendered harmless by covering with adhesive tape (*para.* 4); proofed felt may be used to cover more pronounced edges and heads. The materials used must be resistant to water which, if absorbed, would cause corrosion; they must also be resistant to fuel which may be spilled into the bays. Great care must be used when cleaning the surfaces and applying the covering to ensure that full adhesion is obtained. The job is hidden as soon as the tank is replaced and thus the first sign of faulty adhesion may be a fuel leak. This would entail a tank change and replacement of the covering materials or could even result in a fatal accident. A typical procedure is given in para. 4 and 5. This specific procedure and the materials quoted may be used only if referenced in Vol. 6 of the aircraft A.P.

### Typical procedure for covering protrusions

**4.** The materials required for covering edges of flanges, plates, butt-straps and fittings and rivets, bolts, pins and other forms of attachment, to prevent direct chafing are listed below.

| Item | Description and use | S/R No. | Specification |
|---|---|---|---|
| Felt, pressed wool $\frac{1}{16}$ in. thick | Proofed with zinc naphthenate to B.S. Spec. 2087 | 32B/942 | D.T.D.590<br>R.S.7 |
| Adhesive | *Bostik 1775, for attaching felt to structure | 33C/1283 | |
| Tape | Self-adhesive, P.V.C., | | UK/A.I.D./909/1 |
| 1 in. width | 25 yard roll | 32B/764 | |
| 2 in. width | 25 yard roll | 32B/849 | |
| 4 in. width | 25 yard roll | 32B/856 | |
| 6 in. width | 10 yard roll | 32B/989 | |
| Tape | Self-adhesive, waterproof fabric (*alternative to Tape, P.V.C.*) | | C.S.2191E |
| $\frac{3}{4}$ in. width | 25 yard roll | 32B/770 | |
| 2 in. width | 25 yard roll | 32B/793 | |
| 4 in. width | 25 yard roll | 32B/794 | |
| Compound, sealing | Bostik 1752 | 33C/1339 | D.T.D.900/4058 |
| Compound, sealing | Bostik 1754 (*Alternative to Bostik* 1752) | 33C/1332 | D.T.D.900/4058 |

***Note . . .**

*If approved in the aircraft Vol.* 6, *Bostik* 1752 *or* 1754 *may be used as the adhesive instead of Bostik* 1775.

## FLEXIBLE FUEL TANK BAYS—PREVENTION OF CHAFING (*Continued*)

**5.** The general procedure for the covering of protrusions is as follows:—

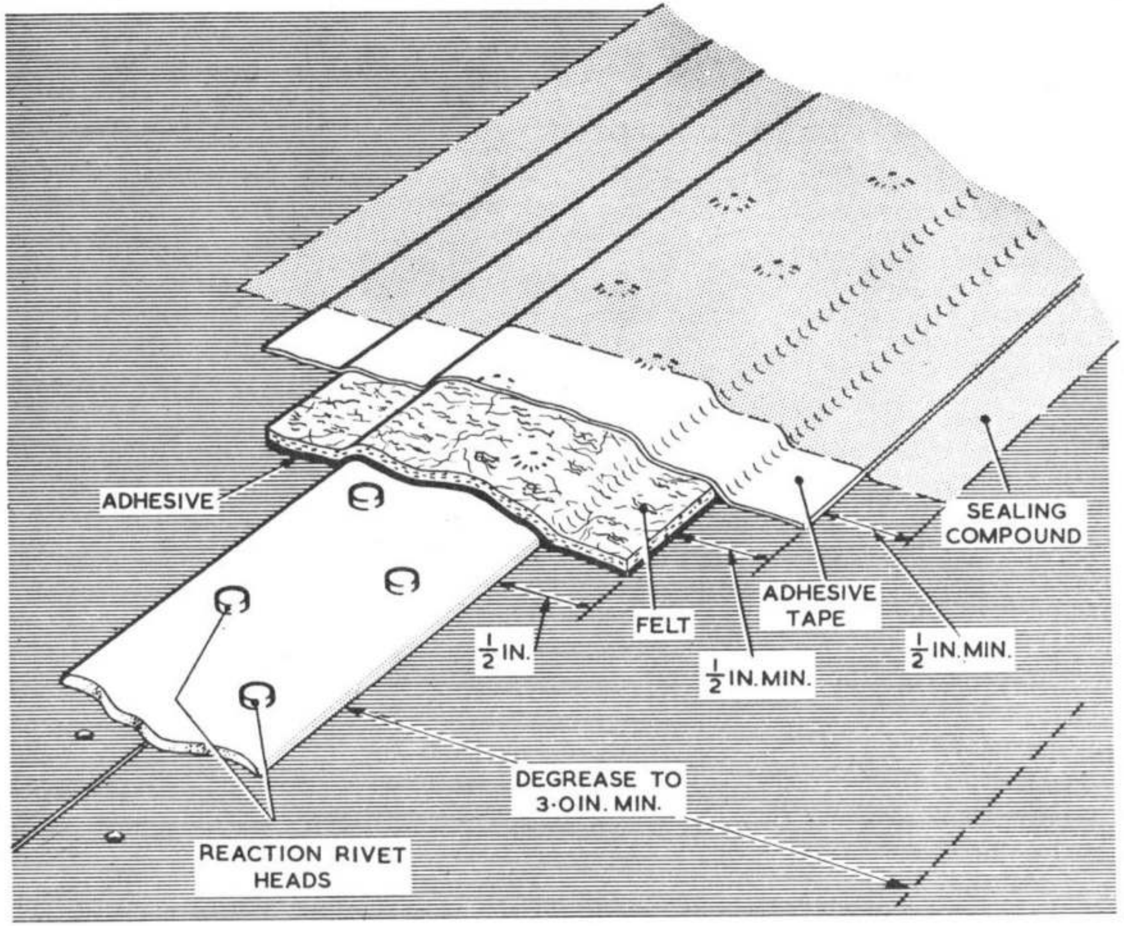
(1) Check that each edge of sheet material etc., has a radius equal to the material, thickness and that edges of new fittings have been smoothed similarly to edges of existing fittings.

(2) Ensure that the appropriate protective finishes have been applied.

(3) Remove all swarf, grit, mandrel heads and other foreign matter. Degrease the metal surface to a distance of at least 3·0 in. from any edge or point to be covered, using any degreasing agent that will not affect protective finishes, metal-to-metal bonding, etc.

(4) When the degreasing agent has completely dried out or evaporated, cover the edges of thin s.w.g. materials with one or two (*but not more*) layers of self-adhesive tape as necessary, ensuring that no wrinkles or air pockets are formed. The tape should be of sufficient width to allow for an overlap of at least ½ in. on each side of the edge being covered.

(5) Working to the dimensions shown in the illustration, cover all bolts and rivets, and also thick edges and other protrusions where tape alone would be inadequate, with one layer of proofed felt cut to the appropriate width. To attach the felt, spread Bostik 1775 adhesive evenly over felt and structure, ensuring that both are completely covered. Locate the felt strip carefully and press into position, first working along the centre of the strip, then outwards to the edges. Apply one or two layers of tape as necessary, over the felt and overlapping on to the structure as shown. Formation of wrinkles or air pockets should be avoided in both tape and felt.



Typical butt-strap covering

## FLEXIBLE FUEL TANK BAYS — PREVENTION OF CHAFING (*Continued*)

(6) Brush a coat of sealing compound evenly over the tape and over the surrounding structure to a distance of at least ½ in. beyond each edge of the tape. This refers to tape applied as in operations (4) and (5). Allow five minutes for the first coat to dry sufficiently and apply a second coat. The sealing compound hardens rapidly and should be thoroughly stirred and applied quickly to prevent the possibility of dragging by successive strokes.

**Note . . .**

*Ensure that no swarf, grit or other foreign matter becomes embedded in the wet Bostik sealing compound.*

(7) Allow a period of at least twenty-four hours for the Bostik to dry and then dust the affected area with french chalk.

**WARNING**

***The materials used in the protective covering scheme are inflammable; the vapours emitted, particularly if concentrated in a confined space, could be injurious to health. Precautions, similar to those applicable to cellulosing operations in confined spaces, should be taken.***

★ ★ ★

# INTEGRAL FUEL TANK LEAK DEFINITIONS

**Leak definitions**

**1.** To provide a common basis for describing a leak from an integral fuel tank, the following definitions, which have been agreed with the Services, will be employed in all future publications dealing with specific aircraft: —

(1) *Stain:*—An area where the paint is discoloured but there is no evidence of wetting.

(2) *Light seep:*—A wet discoloured area not greater than 9 in. in diameter, or an equivalent area.

(3) *Heavy seep:*—A wet discoloured area greater than 9 in. in diameter, or an equivalent area.

(4) *Drip:*—An area where fuel is collecting into droplets and falling.

**Leak rectification**

**2.** Complete repair and test instructions to correct a leak will be given in the appropriate aircraft Vol. 6, Part 1, Chap. 7 (Systems), but in general the following action will be adopted: —

| Class of leak | Action |
|---|---|
| Stain<br>Light seep | Clean, and inspect after next flight. No repair required unless more serious leakage develops. |
| Heavy seep<br>Drip | Repair immediately. |

* * *

# Chapter 1.4 MASS BALANCE OF CONTROLS

## LIST OF CONTENTS

# GENERAL CONDITIONS AFFECTING MASS BALANCE OF CONTROL SURFACES 1.4.1

## Requirement for mass balance

1. Some form of mass balance is necessary with almost all designs of ailerons, elevators and rudders, to prevent flutter. Many types of trim tab also need mass balance. Moving tailplanes and other similar control surfaces are less susceptible to flutter, and may have no provision for adjustment of mass balance. This particularly applies to designs in which the actuating mechanism is attached to the control surface at some distance aft of the hinge line, thus providing a direct restraint against flutter.

## Flutter

2. Control surfaces flutter is a vibration that usually arises from a combination of undamped aerodynamic loading on the control surface itself and flexing or twisting of the mainplane, tailplane, rudder or fuselage, as appropriate. The critical aircraft speeds at which resonant modes would be set up depend upon the aircraft design, but are most likely to exist in the range at which the airflow over the control surface is in the transonic region.

## Effect of flutter

3. Flutter could, in some circumstances, result in immediate loss of control of the aircraft. 'Alternatively, the vibration of the control surface could give rise to sympathetic vibrations in the main aerodynamic surface to which the control surface was attached, or even to the complete airframe. This in turn would probably cause a very rapid major fatigue failure that would result in loss of the aircraft and occupants. At the very least, flutter would cause rapid wear to occur on hinges and control circuit components, due to "chattering" or "hammering".

## Prevention of flutter

4. Flutter is prevented, at least within the operational speed range specified for the aircraft, by arranging that the C.G. (centre of gravity) of the component lies forward of a specified line parallel to the hinge line and that the spanwise distribution of weight of all items comprising the component is also satisfactory (*para.* 9). The tendency of the control surface to pivot rapidly clockwise and anti-clockwise about its hinges when aerodynamic loading is applied at critical speeds is restrained or damped by the reactionary moment exerted by the inertia load at the offset C.G. position and flutter does not occur.

## Location of C.G. limit lines

5. The chordwise position of the C.G. line that is critical from the flutter aspect is represented by the *Aft C.G. limit* in fig. 1, 2 and 3. In general, from the aspect of flutter prevention only, the C.G. of the control surface could lie at any distance forward of this limit. Therefore, the *Forward C.G. limit* shown in the illustrations is not affected by flutter considerations, but its position is governed by control surface handling characteristics and by strength considerations. The most usual range is that shown in fig. 1, with both limits lying forward of the hinge line. The fig. 3 arrangement is less common and the tail-heavy component (*fig.* 2) is rare, but does exist.

### *Maximum values of C.G. range*

6. The permissible C.G. ranges shown in fig. 1, 2 and 3 are greatly exaggerated for clarity. The Design Requirements for Aircraft, S.P.970, recommend that neither C.G. limit should lie at a greater distance than 0·05c from the hinge line, where "c" is the length of the geometric mean chord *aft of the hinge line*. Thus the maximum permissible C.G. range obtainable from application of the recommendations is equivalent to 1 in. for every 10 in. length of mean chord aft of the hinge line, e.g. a maximum range of 3 in. for a mean chord 30 in. in length. This could only apply to a component having the type of range shown in fig. 3, however, for which the flutter characteristics were

satisfactory with an aft C.G. limit lying at 0·05c behind the hinge line. In the more usual case in which both forward and aft C.G. limits are forward of the hinge line (*fig.* 1), the maximum recommended range would be less than 1·5 in. for a 30 in. mean chord. This value also applies to the tail-heavy range shown in fig. 2.

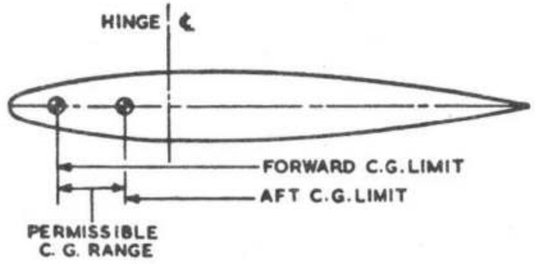


**Fig. 1. C.G. limits, nose-heavy component]**

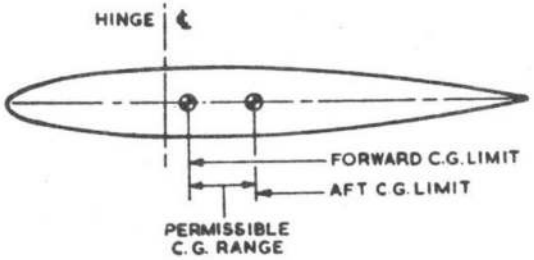


**Fig. 2. C.G. limits, tail-heavy component**

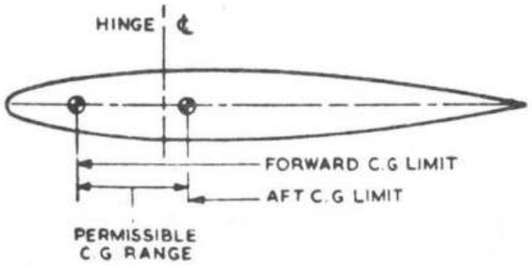


**Fig. 3. C.G. limits, nose- or tail-heavy component**

### Function of permissible C.G. range

**7.** Provision of a permissible C.G. range, instead of a fixed C.G. position, is made firstly for covering production variations in weights of items and protective treatments and secondly to allow for variation in C.G. position due to repairs. Thus certain repairs can be effected without the need for subsequent adjustment of the control surface C.G. position provided that the initial position of the C.G. is known.

**Note . . .**

*In practice, reference is seldom made to the C.G. range and limits, and calculations are usually based on the permissible out-of-balance moment range. This range is not necessarily equivalent to the C.G. range because, for a given out-of-balance moment, the C.G. position will vary according to the total weight of the component.*

### Initial control of C.G. position

**8.** Initial mass balancing of a control surface could be achieved, without the use of balance weights, by very careful control of the detailed design of the structure and of the production of the component to ensure that the C.G. of the finished component was within the required limits. This would involve a considerable amount of additional time and labour, however, and it is customary for manufacturers to design the component initially on the basis of strength and stiffness and to make provision in the design for the attachment of suitable weights, which are subsequently added to effect the necessary balance conditions. Different weights can be used as necessary to make allowance for production variations in the component C.G. position. Almost all control surfaces have a greater length of chord aft of the hinge line than forward and often the weight of the structure aft of the hinge line is greater than that of the forward portion. Consequently most components are basically tail-heavy and need mass balance weights forward of the hinge line to move the C.G. to its correct position. Scheme 1.4.5 provides typical examples of mass balance weights and information on adjustment of mass balance.

### Spanwise C.G. position

**9.** S.P.970 requires the manufacturer to ensure initially that both chordwise and spanwise (or, for rudders, vertical) distributions of weight are satisfactory from both flutter and functioning aspects, but additionally stipulates that, whenever possible, subsequent instructions issued for mass balance calculations and checks, such as those made after repair, should involve only chordwise moments.

**10.** Unless the aircraft Vol. 6 contains specific instructions relating to spanwise distribution of weight, all calculations, checks and adjustments should be made purely on the basis of static balance within the given fore-and-aft C.G. or out-of-balance moment range limits, as appropriate.

### Overall component weight limitations

**11.** Aircraft Vol. 6 sometimes stipulate that the total weight of a control surface must not exceed a specified value. This stipulation may result in return of the component to the manufacturer or even in scrapping, although repairs might appear to be within the capacity of the holding Unit and the necessary mass balance adjustments could be made. The stipulation indicates, however, either that the excessive total weight would overload the hinges or hinge attachments, or that the strength of the structure supporting the mass balance weight is insufficient to cater for the increase in weight that would be needed to satisfy the mass balance requirements. On some aircraft, an automatic limitation on the maximum quantity of mass balance weight that may be fitted is imposed by lack of space or by insufficient clearance between the control surface and the main structure.

★ ★ ★

# PROCEDURE PRIOR TO REPAIR

## Introduction

**1.** The mass balance requirements for a particular control surface should be fully understood before repairs are commenced, to avoid the possibility of wastage of time and effort. Unless it is clearly stated in the Vol. 6 or known from experience that it will be possible to satisfy the mass balance requirements after completion of the proposed repairs, the balance adjustments that will be required should be calculated in advance and checked against the appropriate limitations, as stated in subsequent paragraphs in this Scheme. A considerable amount of effort may be wasted if no initial check is made and it is discovered that the requirements cannot be satisfied when a mass balance check is made after completion of repairs.

## Initial action

**2.** Refer to the aircraft Vol. 6 for details of the appropriate repair scheme and for specific mass balance data and instructions. The information is usually given in Part 1 of the Vol. 6, either in the form of self-contained mass balance instructions in the appropriate structure chapter or, alternatively, by references on the relevant repair illustration to text and tables in the appropriate structure chapter or Chap. 1. When a special jig is required for a mass balance check, however, the instructions for the check itself are given in Vol. 6, Part 2 if the jig is not provisioned at User Unit level.

## Mass balance information in Vol. 6

**3.** Various methods are used for presenting the mass balance information in different Vol. 6, including text, tables, illustrations and graphs. The actual information quoted depends to some extent on the method of presentation and so a standard statement of Vol. 6 contents cannot be made. However, in the majority of cases the numerical values given in Vol. 6 will be based on (1) either the permissible forward and aft out-of-balance moments or the permissible C.G. range (*Scheme* 1.4.1), (2) either the limiting total weight of the component or the maximum permissible mass balance weight (*Scheme* 1.4.1. *para.* 11) and (3) the balance weight moment arm, i.e. the chordwise distance between the centre of the weight and the hinge line. The relationships between these basic values and other forms quoted in Vol. 6 are described in Scheme 1.4.3.

**4.** Mass balance instructions in Vol. 6 include statements concerning the application of A.P.2662B information, the requirements for mass balance calculations or checks, as appropriate, and the required state of completeness of a control surface during a mass balance check. Usually it is stated that a control surface must be complete with trim tabs, access panels, etc. When control circuit connections such as cables or rods are attached to the control surface, particular attention should be paid to Vol. 6 instructions regarding the methods to be used for temporarily positioning these connections. Normally a proportion of the weight of these items is borne by the attachments on the main structure to which the control surface is assembled. Thus the circuit connections should be positioned, during a balance check, in such a manner that the moments exerted by them will be similar to those exerted when the control surface is assembled on the aircraft.

## Satisfactory balance requirements

**5.** If, from a study of the Vol. 6 or from experience it is established, without the need for calculations, that all mass balance requirements can be satisfied after completion of the repair, proceed with the repair as appropriate. Thus when it is known that a bench check is essential, remove the component from the aircraft prior to repair if this will be more advantageous than repair *in situ*.

**6.** If a physical balance check is not mandatory, determine from the nature of the repair and the facilities available whether repair will be more expedient *in situ* or after removal of the component from the aircraft.

**Note . . .**

*When a component is removed from an aircraft to facilitate repair, a bench check is advisable although not required by Vol. 6. It provides the opportunity for adjustment of the mass balance to the most advantageous condition from the aspect of future repairs.*

## Procedure when para. 5 is inapplicable

**7.** When the Vol. 6 does not establish the fact that the mass balance requirements can be met after completion of the repair, determine whether repair is practicable as follows:—

(1) Ascertain from the modification plate on the component, if this is accessible, or from the appropriate servicing or repair documents the existing state of mass balance and total weight of the component (*Scheme* 1.4.4).

**Note . . .**

1. *If the mass balance conditions existing prior to the damage arising are known, removal of the component from the aircraft for a physical mass balance check will not be necessary, unless the Vol. 6 states to the contrary.*

2. *If the mass balance conditions existing prior to the damage arising are not recorded or known, a physical mass balance check* (Scheme 1.4.6) *will be essential, unless the Vol. 6 states to the contrary. A physical check usually involves removal of the component from the aircraft but some Vol. 6 state that the check may, or must, be made* in situ.

3. *In almost all cases in which the old protective treatment is to be completely stripped from a component and new treatment applied over the whole surface, a physical mass balance check will be required whether*

*the mass balance condition is or is not known. This is due to the considerable variations in the weight of paint applied to similar components by different operators.*

If Note 1. applies, continue to the appropriate stage in operations (2) to (9). If Notes 2. or 3. apply, refer to para. 9.

(2) Calculate the additional weight and out-of-balance moment (in *lb. in.* or *oz. in.*) that will be introduced by the repair, assuming no mass balance weight adjustment; use the tables given in Scheme 1.4.10 in conjunction with the details of the repair scheme in the aircraft Vol. 6. Scheme 1.4.9 contains a typical calculation.

(3) Convert the calculated out-of-balance repair moment obtained from operation (2) into the appropriate fraction of the permissible total out-of-balance range quoted in the Vol. 6. Combine this fraction with the existing fractional value as recorded (*Scheme* 1.4.4).

(4) Add the calculated weight increase due to the repair to the existing total weight recorded.

**Note . . .**

*This value is not required if the Vol. 6 does not quote an overall weight limitation.*

(5) Compare the values obtained in operations (3) and (4) with the appropriate limits quoted in Vol. 6. If the combined moment value is safely within the permissible range (*refer to Note below*) and the revised total weight is within the limiting weight, proceed with the repair as appropriate. No further calculations will be required prior to the repair. If the combined moment is outside the permissible range or the weight limitation is exceeded continue with operation (6) *et seq.*

**Note . . .**

*The calculations will not be completely accurate as the manufacturing tolerances on sheet materials, etc. give rise to variations in weight. Also the weight of jointing compounds, etc. cannot be assessed exactly. Therefore when the combined value is near the border-line of a limiting value it is advisable to introduce a safety factor by making allowance for some mass balance adjustment.*

(6) If the repair is *forward* of the hinge line, calculate the amount to be removed from the mass balance weight to produce an out-of-balance moment just within the *forward* limit quoted in the Vol. 6. If the repair is *aft* of the hinge line, calculate the addition to the mass balance weight required to produce out-of-balance moment just within the *aft* limit. To calculate the weight change required, first obtain in *lb. in.* or *oz. in.* the value of the appropriate limiting moment and the combined value of the existing out-of-balance and repair moments. Subtract the larger value from the smaller and divide the resulting value by the distance, in inches, between the C.G. of the balance weight and the component hinge line.

**Note . . .**

*As para. 7 is concerned only with establishing the practicability of repair, operation (6) only refers to essential mass balance weight adjustments, i.e. to the minimum acceptable values. When adjustment is actually made on completion of repair aft of the hinge line, the out-of-balance moment should be returned to the forward limit instead of the aft limit whenever possible.*

(7) If an overall weight limitation is quoted, add the weight increases due to the repair itself and the mass balance adjustment to the recorded total weight and compare with the limiting value.

(8) If a maximum permissible value is quoted for the mass balance weight (*Scheme* 1.4.1), add the calculated mass balance weight increase to the existing recorded value of the mass balance weight and compare with the limiting value. Also check the space available on the component for increase of the mass balance weight and, if appropriate, the clearances between the mass balance weight and the structure to which the component is attached.

**Note . . .**

*Values are often stamped on the mass balance weights.*

(9) If the estimated weights in operations (7) and (8) are within limits and sufficient space and clearance are available, proceed with the repair as appropriate. If the limitations would be exceeded, refer to para. 8.

**8.** If any one of the limitations in para. 7. operations (7) and (8) would be exceeded, there are two possible courses of action. The first course is to dispose of the component through the usual channels and fit a new component. The second course available is to assess the possibility of using a different repair scheme that would produce a smaller weight addition or even result in reduction of weight. An example of this would be the reproduction of original design conditions by renewal of the complete skin panel which contained the damage, instead of making an insertion repair. Since a limitation would be exceeded, it is reasonable to assume that the component is already near the limit, due to the incorporation of previous repairs. If previous repairs were made in the panel now damaged, removal of the complete panel will remove the previous insertions and thus effect a weight reduction. This would ensure compliance with the mass balance requirements.

### Existing balance conditions unknown

**9.** If the mass balance conditions that existed prior to the damage arising cannot be ascertained from the component or from relevant documents, a physical mass balance check and, if applicable, a weight check will be essential, unless the Vol. 6 specifies otherwise (*para.* 5). This also applies when the protective treatment is to be completely renewed.

**Note . . .**

*If the physical check involves removal of the component from the aircraft and the clearances between the balance weights and* *the adjacent fixed structure are small, assess the effect of possible balance weight increases on these clearances before removing the component from the aircraft. Discovery of a foul during replacement of the component after completion of the repair, the restoration of protective treatment and the mass balance check and adjustment can be most disconcerting.*

**10.** The normal mass balance check and adjustments are effected *after* completion of repairs and restoration of protective treatment. However, on many aircraft, limitations are placed on the maximum values of balance weights or total weights of components, and also the space available for additions to the balance weights may be restricted (*Scheme* 1.4.1, *para.* 11). In these circumstances, if a proposed repair aft of the hinge line is comparatively extensive and therefore may be expected to introduce the need for considerable adjustment, a mass balance and weight check is also advisable *before* repairs are started, to ensure that sufficient scope exists for the adjustment The pre-repair check is also advisable when the proposed repair itself is not particularly extensive, if examinations of the component and records reveal that other repairs have been already incorporated aft of the hinge line.

### Procedure for pre-repair balance check

**11.** If it is decided that a pre-repair mass balance check is warranted, the following procedure should be adopted:—

(1) Ascertain from the Vol. 6 whether the balance check should be made *in situ* or on the bench. Succeeding operations are based on the assumption that a bench check is required and the operations should be modified as necessary to suit *in situ* checks.

(2) First compare the existing balance weight clearances (*para.* 9) with any corresponding values given in the Vol. 6 or Vol. 1 to determine the clearance available for increase, then remove the component from the aircraft.

(3) If an overall weight limitation is quoted in the Vol. 6, weigh the component in the required state of completeness (*para.* 4). Make allowance for any material that is missing due to the damage.

(4) Determine from a mass balance check, effected in accordance with the Vol. 6 or a suitable Scheme in this Chapter, the existing out-of-balance moment of the component, but do not adjust the mass balance at this stage.

**Note . . .**

*To avoid errors in out-of-balance moments, make allowance for any material missing due to the damage and dress back to the approximately correct location any displaced material.*

(5) Calculate the repair weight addition and moment as in para. 7 (2).

(6) Combine the repair moment with the out-of-balance moment obtained from operation (4) and compare the "corrected" value with the limits quoted in Vol. 6.

(7) If the out-of-balance moment in (6) is within the aft limit, and an overall weight limitation is quoted in Vol. 6, combine the repair weight addition from operation (5) with the total weight obtained from operation (3). Compare this "corrected" weight with the Vol. 6 limiting value.

(8) If the "corrected" moment and weight are within limits, further calculations are not essential (*refer to Note below*) and repair work may be started.

**Note . . .**

*Up to this point, the operations have established that the repaired component would fulfil the basic requirements and could be replaced on the aircraft as a serviceable item. However, as the out-of-balance moment has been checked against the aft limit only, a subsequent damage arising, aft of the hinge line, would again necessitate a physical check. Whenever possible, therefore, the out-of-balance moment should be adjusted to the forward limit, to allow for the incorporation of future repairs without the need for physical balance checks.*

If the out-of-balance moment is outside the aft limit, continue as in operation (9). If the total weight exceeds the limiting value, refer to para. 8.

(9) Calculate as in para. 7 (6), the addition to be made to the mass balance weight to produce an out-of-balance moment just within the forward or aft limit, as appropriate (*operation* 8, *Note*).

(10) Check that sufficient clearance (*para.* 9) and space (*para.* 10) are available for the increase to the mass balance weight and, if appropriate, that the new value of the balance weight will not exceed the limiting value quoted in the Vol. 6.

(11) Add the increase in mass balance weight from operation (9) to the "corrected" weight from operation (7) and compare with the Vol. 6. limiting value.

(12) If the conditions of operations (10) and (11) are satisfied, proceed with the repair.

### Action if limit is exceeded

**12.** If any one of the limitations would be exceeded, refer to para. 8, but note that when the calculation of balance weight increase in operation (9) has been based on adjustment of the out-of-balance moment to the *forward* limit only, the particular limitation might not be exceeded if the aft limit or an intermediate value within the range is applied.

★ ★ ★

## MASS BALANCE THEORY AND CALCULATIONS

### TYPES OF LIMITS IN VOL. 6

**C.G. range**

**1.** The illustrations in Schemes 1.4.1 and 1.4.3 show, for convenience, the permissible range within which the centre of gravity (*C.G.*) of a component must lie, and the forward and aft limits of the range govern the handling and flutter characteristics respectively (*Scheme* 1.4.1.).

**Calculation of C.G. position**

**2.** When the position of the C.G. of a component is to be calculated, two values must be known. The first value is the out-of-balance moment of the component and the second is its total weight. The out-of-balance moment about the hinge centre-line divided by the total weight of the component gives the distance of the C.G. from the hinge centre-line.

Examples: —

(1) The out-of-balance moment of an aileron is 120 *lb. in. nose-heavy*. The total weight is 100 *lb*. The C.G. of the aileron is therefore $\frac{120}{100} = 1{\cdot}2$ *in. forward* of the hinge centre-line.

(2) The out-of-balance moment of an elevator is 60 *lb. in. tail-heavy* and its total weight is 100 *lb*. The C.G. of the elevator is 0·6 *in. aft* of the hinge centre-line.

**Note . . .**

*The direction of the out-of-balance moment of a component (i.e. nose-heavy or tail-heavy) must not be confused with the direction of the balancing moment that is applied externally during a bench check.*

**Limits quoted in Vol. 6**

**3.** The C.G. range and limits described in para. 1 and 2 must be used by the manufacturer to meet the design requirements in S.P.970, but in subsequent mass balance considerations, e.g. after repair, the *out-of-balance moment* range and limits can be used directly, without conversion to C.G. values. Thus, for mass-balance purposes, the aircraft Vol. 6 often quotes the two limiting out-of-balance moment values, e.g. 120 *lb. in. nose-heavy* and 15 *lb. in. nose-heavy* instead of C.G. limits, although the limiting weights may be quoted from the strength aspect (*Scheme* 1.4.1.).

**4.** The quotation of limits solely in the form of moments does not directly cover the basic C.G. requirements because, for a given moment, the corresponding C.G. position varies according to changes in the total weight of the component. For example, an aft-limit out-of-balance moment of 20 *lb. in.* nose-heavy would give a C.G. position 0·2 *in.* forward of the hinge line if the total weight of the component was 100 *lb.*, but this value would be reduced to 0·182 *in.* approx. if the weight of the component was increased to 110 *lb.* by repair or modification.

**5.** However, out-of-balance moment limits quoted in Vol. 6 take into account possible weight variations. Forward-limit moments that give C.G. positions forward of the hinge line and aft-limit moments that give C.G. positions aft of the hinge-line are based on the lightest possible weights of the components. Conversely, forward-limit moments that give C.G. positions aft of the hinge-line (*i.e. permanently tail-heavy components*) and aft-limit moments that give C.G. positions forward of the hinge line (*i.e. permanently nose-heavy components*) are based on the heaviest possible weights of the components. Thus the C.G. positions corresponding to moment limits quoted in Vol. 6 are within the design C.G. limits at any component weight.

**Alternative Vol. 6 limits**

**6.** As an alternative to quotation of limiting moments or C.G. limits for bench checks, many Vol. 6 state the maximum and minimum weights or loads (*e.g. by spring balance*) to be applied at a specified chordwise position to produce a state of horizontal balance. This appropriate chordwise position may be defined in the Vol. 6 as a point on the trailing or leading edge at a specified spanwise location, *e.g. at Rib* 7, or may be quoted as a distance in inches forward or aft of the hinge line. The product of the maximum or minimum weight or load in *lb.* and the chordwise distance between the applied weight and the hinge line in inches gives the balancing moment, in *lb. in.* which is equal in value but *opposite in direction* to the appropriate limiting out-of-balance moment of the component itself (*para.* 2, *Note*).

**Vol. 6 weight limits**

*Total component weight*

**7.** Limits on the total weights of components (*Scheme* 1.4.1) are usually quoted in Vol. 6 as direct total values. In some cases, however, the Vol. 6 may state the total permissible weight *addition*, due to repairs or modifications and their associated balance weight adjustments. This information may be particularly useful in predetermining whether a repair is possible.

*Numerical balance weight limits*

**8.** The form of the limits quoted in Vol. 6 for mass balance weights depends on the disposition of the weights on a particular component. The mass balance is often distributed along the span or at each end of the component. When a number of equal, known-value weights are fitted, the limit may be given as a maximum number of weights to be fitted.

*Dimensional balance weight limits*

**9.** When the clearances between the balance weights and the shroud on the main structure are critical, dimensional limits for the weights may be quoted in the Vol. 6.

*Weight limits of mass balance*

**10.** As an alternative or an addition to the types of limits in para. 8 and 9, the Vol. 6 may stipulate actual weight limits. These limits may apply to the maximum permissible total weight of the mass balance, or to individual weights to prevent overloading of local structure.

## CALCULATIONS WITHOUT BALANCE CHECKS

### Applicability

**11.** The information in para. 11 to 14 inclusive and Fig. 1 and 2 applies to *pre-repair* calculations made to ensure that the appropriate mass-balance requirements can be satisfied after repair, whether the repair is to be followed by a physical check or not (*Scheme* 1.4.2). It is also applicable, *after repairs,* when the mass balance adjustments can be made or checked without the need for physical mass balance checks. It is therefore based on the assumption that the mass balance conditions that existed prior to the damage arising are known (*Scheme* 1.4.4.).

### Calculation procedure

**12.** The calculation procedures to be used for particular components vary according to the following factors:—

(a) the type of out-of-balance moment or C.G. range, i.e. with both limits forward, or both limits aft, or with one limit forward and the other aft of the hinge line (*Scheme* 1.4.1).

(b) the value of the pre-damage out-of-balance moment, *B lb. in.*

(c) the value and direction of the repair moment, determined by the amount of

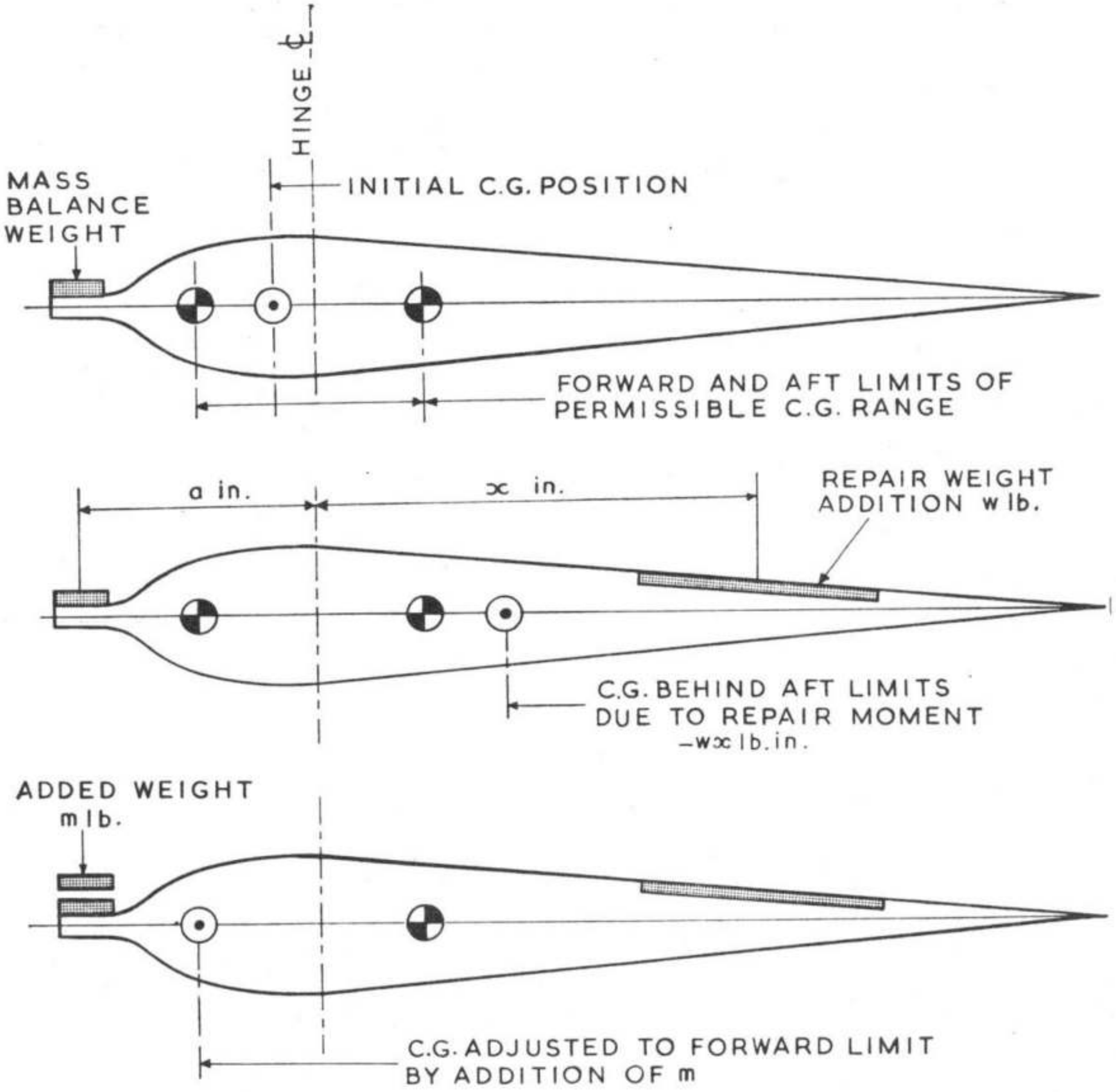


**Fig. 1. Typical case requiring adjustment**

## MASS BALANCE THEORY AND CALCULATIONS—*continued*

added weight and the position of the repair with reference to the hinge line.

(d) the intended degree of mass balance adjustment, as affected by the recording system in use (*Scheme* 1.4.4).

If all of these variables were incorporated in the sequence of operations, all continuity would be destroyed. For this reason, a typical procedure based on the conditions shown in fig. 1 and 2 is given initially in para. 13 and some of the remaining variables are included in the numerical examples given in para. 14.

**13.** Fig. 1 and 2 refer to a component having a forward C.G. limit forward of the hinge and an aft C.G. limit aft of the hinge. The corresponding out-of-balance limiting moments are nose-heavy and tail-heavy respectively and the actual pre-damage out-of-balance moment, as represented by the "initial C.G. position", is nose-heavy. The repairs are aft of the hinge and apply a tail-heavy moment that is numerically greater than the pre-damage moment in both cases. Beak-type mass balance weights are shown for convenience. The calculation procedure is as follows:—

(1) Obtain the out-of-balance moment and, if appropriate, the weight limits from the aircraft Vol. 6.

(2) Ascertain from recordings (Scheme 1.4.4) the nose-heavy out-of-balance moment, $B$ *lb. in.*, and the weight conditions existing prior to the damage arising.

(3) Refer to fig. 1 and 2 and Schemes 1.4.9 and 1.4.10 and calculate the anticipated repair weight addition, $w$ *lb. (or oz. if appropriate)*.

(4) Measure the chordwise distance, $x$ *in.*, between the centre of gravity of the anticipated weight addition and the hinge centre line of the component.

**Note . . .**

*This distance must be measured parallel to the chordline as in fig.* 1, *NOT along the sloping surface of the component.*

(5) Multiply $w$ by the negative value of $x$ to provide the tail-heavy moment $-wx$ *lb. in.*, introduced by the repair.

(6) Find the new value of the out-of-balance moment of the component before adjustment, i.e. $B-wx$ *lb. in.*, from (2) and (5).

**Note . . .**

*If the symbol "*|*" recording system is in use, refer to Scheme* 1.4.4. *To restore the C.G. to its original position, simply add* $\frac{w \times x}{a}$ *lb. to the mass balance weight.*

(7) In both fig. 1 and fig. 2 the numerical value of $wx$ is greater than the value of $B$, so that the resulting out-of-balance moment before adjustment is tail-heavy, i.e. $B-wx$ is a negative value and the corresponding C.G. position is aft of the hinge line. Check whether the value $B-wx$ is less or greater than the aft limiting moment, i.e. whether the C.G. would be within the aft limit (*fig.* 2) or behind the aft limit (*fig.* 1). If $B-wx$ is less than the aft limiting moment, and assuming that the weight considerations in operation (9) are satisfactory, no further action except recording is necessary, but application of the following note is advisable.

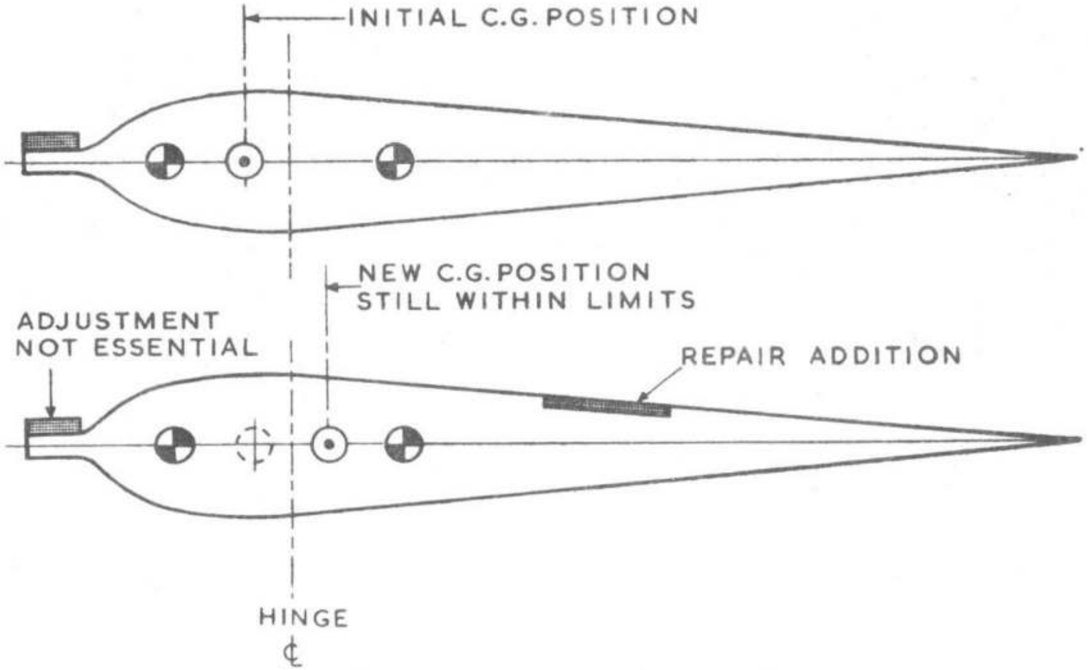


**Fig. 2. Typical case without adjustment**

**Note . . .**

*In practice, most repairs occur aft of the hinge. Therefore, whenever repair-circumstances are favourable, the mass balance should be adjusted as in op.* (8) *to restore the out-of-balance moment to the forward limiting value, i.e. the actual C.G. to the forward limit. This action makes the maximum possible provision for subsequent repairs to be effected without the need for adjustment under emergency conditions.*

If the balance conditions are as in fig. 1, or as fig. 2 but maximum emergency provision is required, continue with operation (8).

(8) Calculate the adjustment required to restore the out-of-balance moment to the forward limiting value. The adjustment required consists of the forward limiting moment value plus the moment required to counteract $B-wx$. The moment required to counteract $B-wx$ (*tail-heavy*) is $wx-B$ (*nose-heavy*). Let the forward limiting moment value be $b_1$ *lb. in.* Then the nose-heavy moment required to restore the component to the forward limit is:—

$$b_1 + (wx - B) = (b_1 - B) + wx \text{ lb. in.}$$

The weight $m$ *lb.* to be added to the mass balance weight, at distance $a$ *in.* forward of the hinge line, to produce the required moment is:—

$$m = \frac{(b_1 - B) + wx}{a} \text{ lb.}$$

(9) Check that the value $m$ *lb.* can be added to the mass balance weight (*Scheme* 1.4.5) and, if applicable, that the pre-damage total weight plus $(w + m)$ *lb.* does not exceed the quoted limit.

(10) If there is insufficient space for the full mass balance addition, or if weight limits would be exceeded by the addition of $m$ *lb.*, calculate the most suitable adjustment possible in the circumstances.

(11) If appropriate, record the altered balance and weight conditions in the relevant documents and on the plates on the component itself (*Scheme* 1.4.4).

**Numerical examples of calculations**

**14.** The following examples are given to indicate procedures applicable to differing sets of conditions. The appropriate assumptions are stated for each example. The symbols used are as given in fig. 1 and 2 and para. 12 and 13, with the addition of $b_2$, the aft-limit out-of-balance moment. It should be noted that when $B$, $b_1$ and $b_2$ are tail-heavy moments their values are given as negative moments and, when nose-heavy, as positive moments. Similarly, when a repair is aft of the hinge, the repair moment $wx$ *lb. in.* is classed as negative and when the repair is forward of the hinge $wx$ is positive.

*Example A*

(1) This is an example of the conditions similar to those in fig. 2:—

$b_1 = +30$ *lb. in.* $b_2 = -20$ *lb. in.*
$B = +10$ *lb. in.* $w = 0{\cdot}5$ *lb.*
$x = 30$ *in.*

From para. 13 (6), the new out-of-balance moment

$$\begin{aligned} &= B - wx = 10 - (0{\cdot}5 \times 30) \\ &= 10 - 15 = -5 \text{ lb. in.} \\ &= 5 \text{ lb. in. tail-heavy} \end{aligned}$$

This is within the limit $b_2$ and adjustment is not essential.

(2) Conditions similar to fig. 1:—

$b_1 = +30$ *lb. in.* $b_2 = -20$ *lb. in.*
$B = +10$ *lb. in.* $w = 0{\cdot}9$ *lb.*
$x = 40$ *in.* $a = 15$ *in.*

$$\begin{aligned} B - wx &= 10 - (0{\cdot}9 \times 40) = 10 - 36 \\ &= -26 \text{ lb. in.} \end{aligned}$$

This is outside the limit $b_2$, therefore adjustment is essential and the following calculations are based on restoration of the out-of-balance moment to the forward-limit value, $b_1$ *lb. in.* From para. 13 (8) the weight to be added to the mass balance is:—

$$\begin{aligned} m &= \frac{(b_1 - B) + wx}{a} = \frac{(30 - 10) + 36}{15} \\ &= \frac{56}{15} = 3{\cdot}7333 \text{ lb. or } 3 \text{ lb. } 11{\cdot}8 \text{ oz.} \end{aligned}$$

*Example B*

This is an example in which both limiting moments are *nose-heavy*, i.e., positive moments, and the repair is *aft* of the hinge line:—

$b_1 = +80$ *lb. in.* $b_2 = +60$ *lb. in.*
$B = +65$ *lb. in.* $w = 0{\cdot}375$ *lb.*
$x = 21$ *in.* $a = 8$ *in.*

Out-of-balance moment before adjustment

$$\begin{aligned} &= (B - wx) = 65 - (0{\cdot}375 \times 21) \\ &= 65 - 7{\cdot}875 = +57{\cdot}125 \text{ lb. in.} \end{aligned}$$

This value is less than that of the aft-limit moment, $b_2$, and therefore adjustment is essential. The following calculations give the adjustments to be made to produce final out-of-balance moments at the forward and aft limits of the permissible range.

(1) The minimum possible adjustment would be by the addition of $(b_2 - 57{\cdot}125)$ *lb. in.* moment to the mass balance, to bring to new out-of-balance moment on to the aft limit. Mass balance weight to be

$$\begin{aligned} \text{added } &= \frac{b_2 - 57{\cdot}125}{a} \\ &= \frac{60 - 57{\cdot}125}{8} \\ &= \frac{2{\cdot}875}{8} \\ &= 0{\cdot}3594 \text{ lb.} \\ &\text{or } 5{\cdot}75 \text{ oz.} \end{aligned}$$

It would be necessary to add slightly more than this value to provide a safety factor, due to the difficulty of assessing weight increases due to paint, etc.

(2) The most satisfactory adjustment would restore the out-of-balance moment

to the forward limit value, $b_1$. From para. 13(8) the weight to be added to achieve this is:—

$$m = \frac{(b_1 - B) + wx}{a} = \frac{(80 - 65) + 7{\cdot}875}{8}$$

$$= 2{\cdot}8594 \ lb.$$

*Example C*

This is an example covering a completely *tail-heavy* moment range, i.e., negative forward and aft-limit moments. The repair is *forward* of the hinge line, e.g., leading edge repair.

| | |
|---|---|
| $b_1 = -5$ *lb. in.* | $b_2 = -40$ *lb. in.* |
| $B = -6$ *lb. in.* | $w = 0{\cdot}22$ *lb.* |
| $x = 9{\cdot}2$ *in.* | $a = 7{\cdot}5$ *in.* |

In this case, $B$ is negative (*tail-heavy*) and $wx$ is positive (*nose-heavy*). Therefore the new moment before adjustment

$$= -6 + (0{\cdot}22 \times 9{\cdot}2) = -6 + 2{\cdot}024$$

$$= -3{\cdot}976 \ lb. \ in.$$

This is outside the permitted range and, since a *tail-heavy* effect is required to bring the value to the forward limit, $b_1$, weight must be *removed from* the mass balance. Minimum weight adjustment to mass balance

$$= \frac{-5 - (-3{\cdot}976)}{7{\cdot}5} = \frac{-5 + 3{\cdot}976}{7{\cdot}5}$$

$$= \frac{-1{\cdot}024}{7{\cdot}5}$$

$$= -0{\cdot}1365 \ lb.$$

$$\text{or } -2{\cdot}184 \ oz.$$

i.e., 2·184 *oz.* must be removed from the existing mass balance weight.

## CALCULATIONS FOR BENCH CHECKS

### Nature of Calculations

**15.** The nature of the calculations required during bench checks depends to a great extent on the form in which the various limits are quoted. In some cases, the use of information from the Vol. 6 in conjunction with the balance-check procedure obviates the need for calculations. The information in subsequent paragraphs provides the general background and also typical examples of the calculations that may be required.

**Note . . .**

(1) *The basic assumption made in the calculations is that a nose-heavy* OUT-OF-BALANCE *moment, b, is* POSITIVE. *For mathematical equality therefore, the* BALANCING *moment, Mc, must be considered* POSITIVE *when it acts in the tail-heavy sense required for equilibrium. Thus, if the distance c is always considered to be a positive quantity, the test weight M, when applied at the* TRAILING *edge as assumed in all following examples, must be considered positive acting* DOWNWARDS *and negative acting* UPWARDS.

(2) *Conversely, when the test weight M is applied at the* LEADING *edge it must be considered positive* UPWARDS *and negative* DOWNWARDS.

### Nose-heavy components

**16.** Fig. 3 shows a case in which the whole of the C.G. range is forward of the hinge-line and thus $b_1$ and $b_2$ *lb. in.*, the forward-limit and aft-limit out-of-balance moments respectively, are both *nose-heavy* and therefore positive. The test weight, $M$ *lb.*, at distance $c$ from the hinge must therefore act vertically downwards at the trailing edge at both limits to provide the positive *tail-heavy* moments required to effect horizontal balance The relationships are:—

$$b_1 = M_1 \times c \qquad \therefore M_1 = \frac{b_1}{c} \ lb.$$

$$b_2 = M_2 \times c \qquad \therefore M_2 = \frac{b_2}{c} \ lb.$$

Thus with the C.G. range shown, $M_1$ *lb.* is the maximum permissible value of the test weight and $M_2$ *lb.* is the minimum permissible value. The test weight required for correct balance after repair but before adjustment is $M_R$ *lb.*

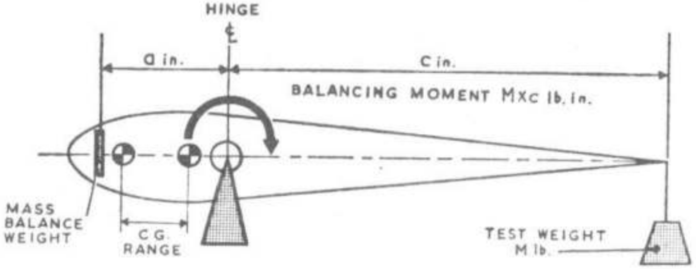


Fig. 3. **Basic balance-check data**

*Repair aft of hinge*

**17.** A repair *aft* of the hinge has the effect of reducing the value of the test weight required for balance and if $M_R$ is less than $M_2$, (i.e., the out-of-balance moment is less than $b_2$), addition to the mass-balance weight will be essential. The minimum possible addition to the mass-balance weight would be $m = \frac{(M_2 - M_R) \times c}{a}$ *lb.*, which would put the C.G. on the *aft* limit. To restore the C.G. to the most advantageous position, i.e., to the *forward* limit, the increase required to the mass-balance weight would be

$$m = \frac{(M_1 - M_R) \times c}{a} \ lb.$$

*Repairs forward of hinge*

**18.** A repair *forward* of the hinge has the effect of increasing the value of the test weight required and if $M_R$ is greater than $M_1$, *reduction* of the mass-balance weight will be essential. The value of the adjustment required is again $\frac{(M_1 - M_R) \times c}{a}$ *lb.* but as $M_R$ is greater than $M_1$ this value will be negative, indicating a reduction, and this reduction would restore the C.G. to the *forward* limit.

**Tail-heavy components**

**19.** The information in para. 20 to 22 refers to components for which both C.G. limits are *aft* of the hinge. For components which have the forward limit forward of the hinge and the aft limit aft of the hinge the relevant items of this information should be used in conjunction with the appropriate information in para. 16 to 18.

**20.** The relationships between $b$ and $M$ are similar to those given in para. 16 but the values are reversed in sense. As $b$ is a tail-heavy moment (negative) the balancing moment, $M \times c$, is nose-heavy (also negative) and therefore $M$ must act vertically upwards (negative) at the trailing edge. As $b_1$, the forward-limit moment, is numerically less than $b_2$ so $M_1$ is less than $M_2$. The most convenient method of applying an upward load at the trailing edge is by the use of a spring balance but, alternatively, a weight may be suspended from the leading edge (*Scheme* 1.4.6.).

*Repairs aft of hinge*

**21.** A repair aft of the hinge will move the C.G. towards or behind the aft limit. If $M_R$ is numerically greater than $M_2$, the minimum possible adjustment to the mass-balance weight would be $\frac{(M_2 - M_R) \times c}{a}$ *lb.* and since both values are initially negative (acting upwards) this gives a positive value, indicating the need for an increase in mass balance which would put the C.G. on the *aft* limit. To restore the C.G. to the *forward* limit, the increase required to the mass-balance weight would be $\frac{(M_1 - M_R) \times c}{a}$ *lb.*

*Repairs forward of hinge*

**22.** A repair forward of the hinge has the effect of *decreasing* the value of test weight required. If $M_R$ is less than $M_1$, *reduction* of the mass-balance weight will be essential. The value of the mass-balance adjustment required is $\frac{(M_1 - M_R) \times c}{a}$ *lb.* and this value will be negative, indicating reduction of the mass balance weight, and this reduction would restore the C.G. to the *forward* limit.

**Numerical examples**

**23.** In the following numerical examples

Example A refers to a nose-heavy component (*para.* 16),

Example B to a tail-heavy component (*para.* 19) and

Example C to a component with a nose-heavy forward limit and tail-heavy aft limit (*para.* 19).

Example A—Nose-heavy component:—

Assume $b_1 = 50$ *lb. in.* $b_2 = 10$ *lb. in.*

$a = 6$ *in.* $c = 20$ *in.*

$$M_1 = \frac{b_1}{c} = \frac{50}{20} = 2{\cdot}5 \ lb. \text{ positive, i.e., acting downwards.}$$

$$M_2 = \frac{b_2}{c} = \frac{10}{20} = 0{\cdot}5 \ lb. \text{ positive.}$$

(1) Repair aft of hinge (*para.* 17),
It is discovered on test that $M_R$, the test weight required to achieve balance, is 0·1 lb.
Addition to mass-balance weight:—

(a) to restore C.G. to *aft* limit

$$= \frac{(M_2 - M_R) \times c}{a}$$
$$= \frac{(0{\cdot}5 - 0{\cdot}1) \times 20}{6}$$
$$= \underline{\underline{1{\cdot}333 \ lb.}}$$

(b) to restore C.G. to *forward* limit

$$= \frac{(M_1 - M_R) \times c}{a}$$
$$= \frac{(2{\cdot}5 - 0{\cdot}1) \times 20}{6}$$
$$= \underline{\underline{8 \ lb.}}$$

(2) Repair forward of hinge (*para.* 18).
It is discovered on test that $M_R$ is 2·65 *lb.*

Adjustment of mass-balance weight to restore C.G. to *forward* limit

$$= \frac{(M_1 - M_R) \times c}{a}$$
$$= \frac{(2{\cdot}5 - 2{\cdot}65) \times 20}{6}$$
$$= -\frac{3}{6} = \underline{\underline{-0{\cdot}5 \ lb.}}$$

Thus 0·5 *lb.* must be removed from the mass-balance weight.

Example B—Tail-heavy component:—

Assume $b_1 = -15$ *lb. in.* $b_2 = -30$ *lb. in.*

$a = 10$ *in.* $c = 25$ *in.*

$$M_1 = \frac{b_1}{c} = -\frac{15}{25} = 0{\cdot}6 \ lb., \text{ i.e., acting upwards}$$

$$M_2 = -\frac{30}{25} = -1{\cdot}2 \ lb., \text{ also acting upwards.}$$

(1) Repair aft of hinge (*para.* 21).
It is discovered on test that $M_R$ is $-1{\cdot}25$ *lb.* (acting upwards).
Adjustment to mass balance weight:—

(a) to restore C.G. to *aft* limit

$$= \frac{[M_2 - M_R] \times c}{a}$$
$$= \frac{[-1{\cdot}2 - (-1{\cdot}25)] \times c}{a}$$
$$= [-1{\cdot}2 + 1{\cdot}25] \times \frac{25}{10}$$
$$= 0{\cdot}05 \times 2{\cdot}5$$
$$= \underline{\underline{+0{\cdot}125 \ lb.}}$$

This is positive and therefore involves addition to the mass balance weight.

(b) to restore C.G. to *forward* limit

$$= \frac{[M_1 - M_R] \times c}{a}$$
$$= [-0{\cdot}6 - (-1{\cdot}25)] \times \frac{25}{10}$$
$$= [-0{\cdot}6 + 1{\cdot}25] \times 2{\cdot}5$$
$$= 0{\cdot}65 \times 2{\cdot}5$$
$$= \underline{\underline{+1{\cdot}625 \ lb.}}$$

This is also positive, indicating addition to mass-balance.

(2) Repair forward of hinge (*para.* 22).

It is discovered on test that $M_R$ is $-0{\cdot}2$ *lb.* Adjustment required to restore C.G. to *forward* limit

$$\begin{aligned} &= \frac{[M_1 - M_R] \times c}{a} \\ &= [-0{\cdot}6 - (-0{\cdot}2)] \times 2{\cdot}5 \\ &= [-0{\cdot}6 + 0{\cdot}2] \times 2{\cdot}5 \\ &= -0{\cdot}4 \times 2{\cdot}5 \\ &= \underline{\underline{-1{\cdot}0\ lb.}} \end{aligned}$$

This is negative, indicating the amount to be removed from the mass balance weight.

Example C — Nose and tail-heavy component:—

Assume $b_1 = 20\ lb.\ in.$ $b_2 = -15\ lb.\ in.$

$a = 10\ in.$ $c = 25\ in.$

$$M_1 = \frac{b_1}{c} = \frac{20}{25} = +0{\cdot}8\ lb. \text{ (acting downwards)}$$

$$M_2 = \frac{b_2}{c} = -\frac{15}{25} = -0{\cdot}6\ lb. \text{ (acting upwards).}$$

(1) Repair aft of hinge (*para.* 21).

It is discovered that $M_R = -1{\cdot}0\ lb.$ Addition to mass-balance weight

(a) to restore C.G. to *aft* limit

$$\begin{aligned} &= \frac{[M_2 - M_R] \times c}{a} \\ &= [-0{\cdot}6 - (-1{\cdot}0)] \times \frac{25}{10} \\ &= [-0{\cdot}6 + 1{\cdot}0] \times 2{\cdot}5 \\ &= 0{\cdot}4 \times 2{\cdot}5 \\ &= \underline{\underline{1{\cdot}0\ lb.}} \end{aligned}$$

(b) to restore C.G. to *forward* limit

$$\begin{aligned} &= \frac{[M_1 - M_R] \times c}{a} \\ &= [0{\cdot}8 - (-1{\cdot}0)] \times 2{\cdot}5 \\ &= [0{\cdot}8 + 1{\cdot}0] \times 2{\cdot}5 \\ &= 1{\cdot}8 \times 2{\cdot}5 \\ &= \underline{\underline{4{\cdot}5\ lb.}} \end{aligned}$$

(2) Repair forward of hinge (*para.* 22).

It is discovered on test that $M_R = +1{\cdot}1\ lb.$ Adjustment to mass-balance weight

$$\begin{aligned} &= \frac{(M_1 - M_R) \times c}{a} \\ &= (0{\cdot}8 - 1{\cdot}1) \times 2{\cdot}5 \\ &= -0{\cdot}3 \times 2{\cdot}5 \\ &= \underline{\underline{-0{\cdot}75\ lb.}} \end{aligned}$$

This value is negative and therefore 0·75 *lb.* must be removed from the mass-balance weight.

★ ★ ★

# RECORDING OF MASS BALANCE CONDITION

## 1.4.4

### Purposes of recording

**1.** The main function of recording is to reduce the amount of work associated with repairs to control surfaces, by obviating the need for physical mass balance checks whenever possible. The recorded information is also required for ensuring, prior to repair, that satisfaction of mass balance requirements can be achieved after comletion of the repair (*Scheme* 1.4.2). The third function of recording is to supply proof that the balance requirements have been satisfied after repair or after incorporation of a modification involving weight and moment changes.

Note . . .

*In subsequent text and in the other Schemes in this Section, references to "repair" should be automatically assumed to include "modifications involving weight changes".*

### Applicability of recording scheme

**2.** The systems quoted in this Scheme for recording of the mass balance condition of a component after repair apply to chordwise moments only. Balance conditions that involve spanwise checks or calculations should be recorded as stated in the appropriate Vol. 6.

### Application of recording

**3.** After any repair, whether a physical balance check has been necessary or not, recording should be made of the revised balance and weight conditions, either by initial insertion of the information or by amendment of existing information. It should be possible to ascertain from recorded information, the number and location of all repairs or modifications incorporated in the balance and weight conditions quoted. Examination of the component after a subsequent damage arising will thus confirm that the recorded information is up-to-date or reveal whether any repairs have been effected without amendment of the recorded values.

**4.** When new values are recorded in documents, the previous values should be cancelled, and cross references to the new values should be substituted.

### Methods of recording

**5.** Recording is made in the relevant servicing and repair documents (*para.* 6) and on the mass balance record plate or the modification plate of the component (*para.* 9). The double recording acts as a safeguard when either the record or modification plate is not visible without removal of the component from the aircraft or, conversely, when new or reconditioned components have been fitted and the relevant balance information has not been transferred into the appropriate servicing documents.

### Documentary recording

**6.** More space is available in documents than on the modification or balance record plate and therefore more comprehensive information can be recorded. Thus the balance condition should be recorded in *lb. in.* or *oz. in.* nose-heavy or tail-heavy as appropriate, not by use of symbols as in the second mod. plate system. Quotation of exact values in figures may allow for a subsequent additional repair without a physical balance check (*para.* 9).

**7.** When weight limitations are applicable, as quoted in the Vol. 6, the amended values of total weight of the component and/or total weight of mass balance must be recorded in the documents.

**8.** Before applying mass balance information recorded in aircraft documents, as distinct from an individual log book for a specific component, ensure that the "aircraft" information refers to the specific component by checking for later entries relating to renewal of the component. When a component is renewed, the balance information for the old component should be deleted but this action may have been overlooked.

## RECORDING ON PLATES

WARNING . . .

**All balance values recorded on plates attached to components must be stamped or scribed into the metal, not merely scratched in the paint or other protective treatment. Paint may flake off or become chipped, resulting in complete loss of the values or, more dangerously, in partial loss.**

**9.** The fitting of mass balance record plates by aircraft manufacturers is not mandatory and no standard pattern exists for the layout of such plates, but some manufacturers have introduced special plates and specific recording systems. If a balance record plate is fitted and specific instructions for the method of recording to be used are not given in the Vol. 6, the general instructions provided in this Scheme for recording on modification plates should be applied. If the Vol. 6 gives specific instructions relating to the information to be recorded, the Vol. 6 instructions should be applied. When the space available on modification plates for the recording of mass balance conditions is limited, the "symbol" recording system described in para. 13 is used. However, if sufficient space is available on the mod. plate it is advisable to record the actual balance condition in figures (*para.* 11) instead of using symbols. If the exact value is recorded, a further repair may be possible without a physical check in circumstances in which the check would be essential if the symbol system was in use. A coat of clear varnish or other suitable transparent protective treatment should be applied over all new markings.

## RECORDING OF MASS BALANCE CONDITION (*Continued*)

**Note . . .**

*If weight limitations apply, these must also be recorded on the mod. plate. If the existing weight value is not known at the time of repair, a physical weight check will be necessary and hence the recording scheme will lose most of its value. The letters "T.W." and "M.B.W." are used as prefixes to the quoted values to represent "Total Weight" and "Mass Balance Weight" respectively, e.g. T.W.* 110 *lb.*

### Use of symbol "C"

**10.** The symbol "C" is stamped or scribed *in the metal*, on one of the two bottom lines of the modification plate to denote that a physical mass balance check has been made and therefore that one of the two mod. plate recording systems may be used. When the symbol "C" is NOT followed by a moment value, either in figures (*para.* 11) or as represented by the symbol "I" (*para.* 12), it indicates that the out-of-balance moment of the component is at its most advantageous value, i.e. at the *forward limit* of the permissible range.

### Mod. plate recording system using figures

**11.** In this system the symbol "C" is followed by the out-of-balance moment of the component scribed or stamped in figures in full, the figures being followed by the letters "N.H." or "T.H." to indicate nose-heaviness or tail-heaviness, e.g. 96·5 lb. in. N.H. The moment value quoted in figures is the ACTUAL value of out-of-balance moment, not a quantity to be deducted from the forward limiting value. Thus when the actual moment value is marked on the mod. plate the symbol "C" only provides proof that a check has been made and does NOT represent the forward limiting moment value.

### Subsequent alterations

**12.** When, after subsequent repairs, new values are substituted on the mod. plate, the previous values must be completely erased or clearly cancelled. Emery cloth or a scraper should be used to erase existing recordings and the abraded area must be given a coat of clear varnish or other suitable transparent protective treatment after the new values have been recorded.

### Cancellation

**13.** If space is available for the new values without erasure of the previous values, the latter must be clearly cancelled by the use of double horizontal lines as in one of the following examples:

82·4 118·2
C. ~~96·5~~ lb. in. N.H. T.W. ~~116·0~~ lb.
or C. ~~96·5 lb. in. N.H. M.B.W. 7·25 lb.~~
82·4 lb. in. N.H. M.B.W. 7·25 lb.

**Note . . .**

*Cancellation MUST NOT be effected solely by the application of paint over the existing values. The paint may flake off, leaving the old values partly or completely exposed. Paint may be used after the old values have been completely erased, to make new values to show up clearly, but the new recording must penetrate through the paint and into the metal so that it will be legible if the paint chips or flakes off.*

### Riveted tab

**14.** If the mod. plate is too thin to allow for the use of emery cloth, a small tab or plate may be securely riveted over the old recording but the old values must first be cancelled by the use of double lines as in para. 13 to avoid the danger of error if the plate is removed after future repairs or balance checks.

### Mod. plate system using symbol "I"

**15.** This system is used when the space for recording is limited and the symbol "I", a single vertical stroke, has been chosen, because it occupies less space than any other possible letter or figure symbol and can be marked easily with a scriber.

**Note . . .**

*When the symbol system is in use, physical adjustment of the mass balance is essential for repairs FORWARD of the hinge line* (para. 22) *for the reason stated in para.* 18(2) *Note* 3.

### Nominal value represented by symbol "I"

**16.** Each symbol "I" or vertical stroke, nominally represents one-tenth of the total permissible out-of-balance moment range (*Scheme* 1.4.3). Thus if the forward and aft limiting values of out-of-balance moment of a component are 85 lb. in. and 20 lb. in. nose-heavy respectively, then the permissible range is 65 lb. and each symbol "I" nominally represents one-tenth of this value, i.e. 6·5 lb. in.

### Combination of symbols "C" and "I"

**17.** In the symbol system, "C" indicates that a check has been made initially (*para.* 10) but also "C" represents the value of the forward limiting moment, which, in the example quoted in para. 16 is 85 lb. in. The number of vertical strokes (*symbol* "I") scribed after the letter "C" indicates the moment value *to be deducted from* the forward limiting moment to provide the existing state of out-of-balance moment of the component.

Example:

Assume values as in para. 16.
The recording on a mod. plate is "C.IIII".
"C" represents 85 lb. in. nose-heavy
"I" represents 6·5 lb. in.
Therefore the nominal existing out-of-balance moment is:
C.IIII = 85 − (4 × 6·5) 85 − 26 =
59 lb. in. nose-heavy.

### Procedure for recording after repair

**18.** The procedure given in this paragraph refers only to the addition of values within the given limits. For repairs aft of the hinge that would take the out-of-balance moment behind the aft limit, i.e. the recording would exceed 10 strokes, refer to para. 19. For any repairs forward of the hinge, refer to para. 22. The recording procedure for values within limits is as follows:—

(1) Obtain the permissible out-of-balance range (*Scheme* 1.4.3) from the Vol. 6 and

divide this range by 10 to obtain the value of "I".

(2) Divide the moment due to the repair by the value of "I", to provide the number of strokes to be added to the existing recorded value.

**Note . . .**

1. *Any moment between zero and one-tenth of the range must be recorded as* "I". *Similarly higher values must be taken to the next complete tenth of the range ABOVE the actual value.*

2. *As a result of the application of Note* 1, *the number of strokes recorded in conjunction with the symbol "C" will represent a value closer to the aft limit than the actual out-of-balance value of the component, in the majority of cases. However, this method allows the "score" to be taken to the full* 10 *strokes before a balance check or mass balance adjustment* (para. 19) *becomes necessary and ensures that the AFT limit of the out-of-balance range will not be exceeded.*

3. *The system MUST NOT be worked in reverse, i.e. by deduction of strokes for repairs forward of the hinge or for mass balance adjustments in excess of the repair effect, because this could result in the actual out-of-balance moment of the component exceeding the forward limit, although the recorded value would appear to be satisfactory.*

(3) Scribe or stamp the appropriate number of additional strokes after the symbol "C" or after the last existing stroke.

(4) If applicable, cancel the recorded total weight value and substitute the revised value.

(5) Apply clear varnish or suitable transparent protective over the newly scored metal.

**Excessive repairs aft of hinge**

**19.** If the moment due to a particular repair aft of the hinge-line is of such magnitude that, when the repair effect is added to the existing recorded value, the number of vertical strokes would exceed 10, the repair moment effect must be completely or partially nullified by addition to the mass balance weight.

**20.** Whenever possible, the increase in mass balance weight should be made to provide a nose-heavy moment that just balances the repair moment and in these circumstances no alteration will be required to the moment recording.

**21.** When space or weight limitations prevent complete balancing of the repair moment, the maximum possible increase should be made to the mass balance weight. The "unbalanced" proportion of the tail-heavy repair moment is then converted into tenths of the range and the appropriate number of strokes is added to the existing recorded value as in para. 18.

**Note . . .**

*When the symbol system is in use, the nose-heavy moment introduced by the increase in mass balance weight must not exceed the moment due to the repair, for the reason given in para.* 18(2), *Note* 3.

**Repairs forward of the hinge**

**22.** As cancellation of existing strokes is not permissible (except after physical balance check), mass balance weight must be removed to compensate for a repair forward of the hinge-line. The reduction in moment due to the removal of balance weight must be at least equal to the repair moment.

**23.** When the reduction in balance weight moment is numerically equal to the repair moment, no moment recording action is required. If over-compensation is necessary due to the physical nature of the balance weights, the appropriate number of strokes, representing the amount of the over-compensation, must be added to the existing recorded value.

## RECORDING SYSTEM IN A.P.2662A

**23.** The recording system quoted in A.P.2662A, Scheme 1203, was similar to the symbol system in this scheme in the use of the symbol "C", but used the symbol "X" to denote one-third of the permissible out-of-balance moment range instead of symbol "I", representing one-tenth. Also cancellation of the symbols was allowed.

**24.** If this system was used as stated, without reference to documentary recording the actual out-of-balance moment could exceed either the forward or the aft limit although the recorded condition would appear to be satisfactory.

**25.** The A.P.2662A system is therefore dangerous if applied to high speed aircraft and therefore any components bearing the "X" symbols on the mod. plate must be given a physical mass balance check at the earliest opportunity. After the check, one of the recording systems quoted in this Scheme must be applied.

★ ★ ★

# 1.4.5 METHODS OF MASS BALANCE WEIGHT ADJUSTMENT

### Types of mass balance weights

**1.** Typical slab-type mass balance weights are illustrated in fig. 1. The most common type of adjustable balance weight other than those shown in fig. 1 consists of a fixed, closed-end metal cylinder containing removable metal discs, with some form of adjustable packing or locking to prevent movement of the discs. An alternative to this type is the removable tube into which molten lead is run.

**2.** The removable-disc type of mass balance weight provides the most convenient method of adjustment and, for many years, was the standard type in use. It is still used on some small aircraft, particularly the slower speed types but, in general, is not suitable for larger and higher speed aircraft due to either the lack of space and suitable attachment structure for the size of container that would be necessary or to the need for spanwise distribution of the mass balance weights (*para*. 4).

### Chordwise location of weights

**3.** Mass balance weights are invariably mounted forward of the hinge-line, to provide a nose-heavy moment. This moment is necessary to prevent flutter on all designs (*Scheme* 1.4.1) because the hinge-line must be close to the leading edge for effective control purposes and thus the C.G. of the structure alone is automatically too far aft of the hinge-line.

### Spanwise location of weights

**4.** Although the majority of mass balance calculations or checks quoted in Vol. 6 require consideration of chordwise balance only, during design of the component the spanwise moments must be checked also (*Scheme* 1.4.1, *para*. 9). During such checks it is often discovered that, to satisfy the balance requirements, the balance weights must be distributed suitably along the span instead of being concentrated in one position.

**5.** The usual result of the balance weight distribution in terms of positions and values of individual weights is that the combined C.G. of all the balance weights lies at the same spanwise distance as the C.G. of the structure, from a given plane such as the root-end rib. Thus for a component that tapers towards the tip, the spanwise C.G. of the structure and that of the weights could be expected to lie approximately on a common chord at a distance between one-third and one-half of the component span from the root-end rib.

**6.** The distribution of the weights may be effected in several ways. Example A on fig. 1 shows a partial distribution method in which the spanwise C.G. would lie midway between the two weights, provided the weights were of equal value. Example B shows a single weight on an inboard rib only, but normally this would be complemented by a smaller weight on the outboard end of the component (*para*. 8). Example C illustrates almost uniform distribution of the balance weights on the beak of a component along the whole span. These weights may diminish in size towards the tip, to compensate for taper on the component itself.

### Spanwise distribution during adjustment

**7.** In many cases, the spanwise tolerance is such that, within the chordwise adjustment limits permitted by the Vol. 6, no further consideration of spanwise distribution is necessary. It is advisable, however, for balance adjustment to be made in, or as near as possible to, the same chordwise plane as that of the repair whenever the provision made for balance weight adjustment allows this to be done. In some cases the Vol. 6 will stipulate that adjustment must be made in this manner.

**8.** When spanwise distribution is critical, the Vol. 6 includes specific instructions, either on the lines indicated in para. 7 or by quotation of a formula to be applied to determine the proportions of the total increase or decrease to be apportioned to each weight. In at least one Vol. 6, the formula is replaced by graphs, which include both chordwise and spanwise adjustments so that no separate calculations are required. This graphical method applies to components, such as Example B, fig. 1, that have only two balance weights, one being at the root and the other at the tip.

## METHODS OF ALTERING BALANCE WEIGHT VALUES

### General

**9.** Adjustment of the mass balance after repair may be made by altering the position of the balance weights or by altering the values of the weights. Balance weight values are varied by fitting either:—

(1) more or fewer weights

(2) shims or strips of sheet materials

(3) different size weights of the same material

(4) similar size weights of a different material.

The fourth method applies particularly to components in which space or clearance is limited. Table 1 gives *average* values of weight in pounds per cubic inch for various balance weight materials. G.E.C. heavy alloy and other similar alloys are expensive and their use is normally confined to components such as trim tabs and rudders in which the space available for balance weights is very limited or the moment arm of the balance weight is relatively short.

### Metal disc weights

**10.** Adjustment of disc weights housed in a cylinder simply entails removal of the sealing cap or plug, removal of the packing material and the addition or removal of discs as appropriate. The packing, now altered in quantity to make allowance for the altered volume of the balance weights, and the sealing cap are replaced and the latter is suitably locked (*para.* 16).

**Table 1**

**Weights of materials**

| Material | Weight in lb./cu. in. |
|---|---|
| Aluminium alloy | 0·105 |
| Brass | 0·298 |
| Cast Iron | 0·261 |
| G.E.C. heavy alloy: | |
| Grade 1 | 0·602 |
| Grade 2 | 0·613 |
| Grade 3 | 0·631 |
| Grade 4 | 0·650 |
| Lead | 0·410 |
| Steel | 0·284 |
| Tungsten | 0·614 |

**11.** The most common material used for disc-type weights is lead. In some cases the discs are drilled and mounted on a bolt or stud, which is fixed within the container to provide positive prevention of movement. Discs of pre-determined weight are often supplied for adjustment purposes and the actual weight or the part number is stamped on the discs. If discs are manufactured locally, the values should be stamped on the discs for future reference.

**12.** The packing, which is used to prevent movement of the weights, may consist of wadding or of discs of very light and partially compressible material, or of wax or resin. Molten wax or resin is run in to the space to be fitted and is checked, after being allowed to harden, to ensure that the correct quantity has been introduced, before the sealing cap or plug is replaced and locked.

**Note . . .**

*Moisture must not be allowed to enter the container and all packing materials used must be completely dry. Drainage or ventilation holes in the container must be kept clear. If washers, sleeves, etc. are incorporated to prevent contact between the discs and cylinder and thus prevent electrolytic corrosion between dissimilar metals, they must be replaced during or after adjustments.*

**Slab-type weights**

*Large adjustments*

**13.** These weights (*Examples A and B, fig.* 1) are usually manufactured from brass or mild steel plate and are stamped with

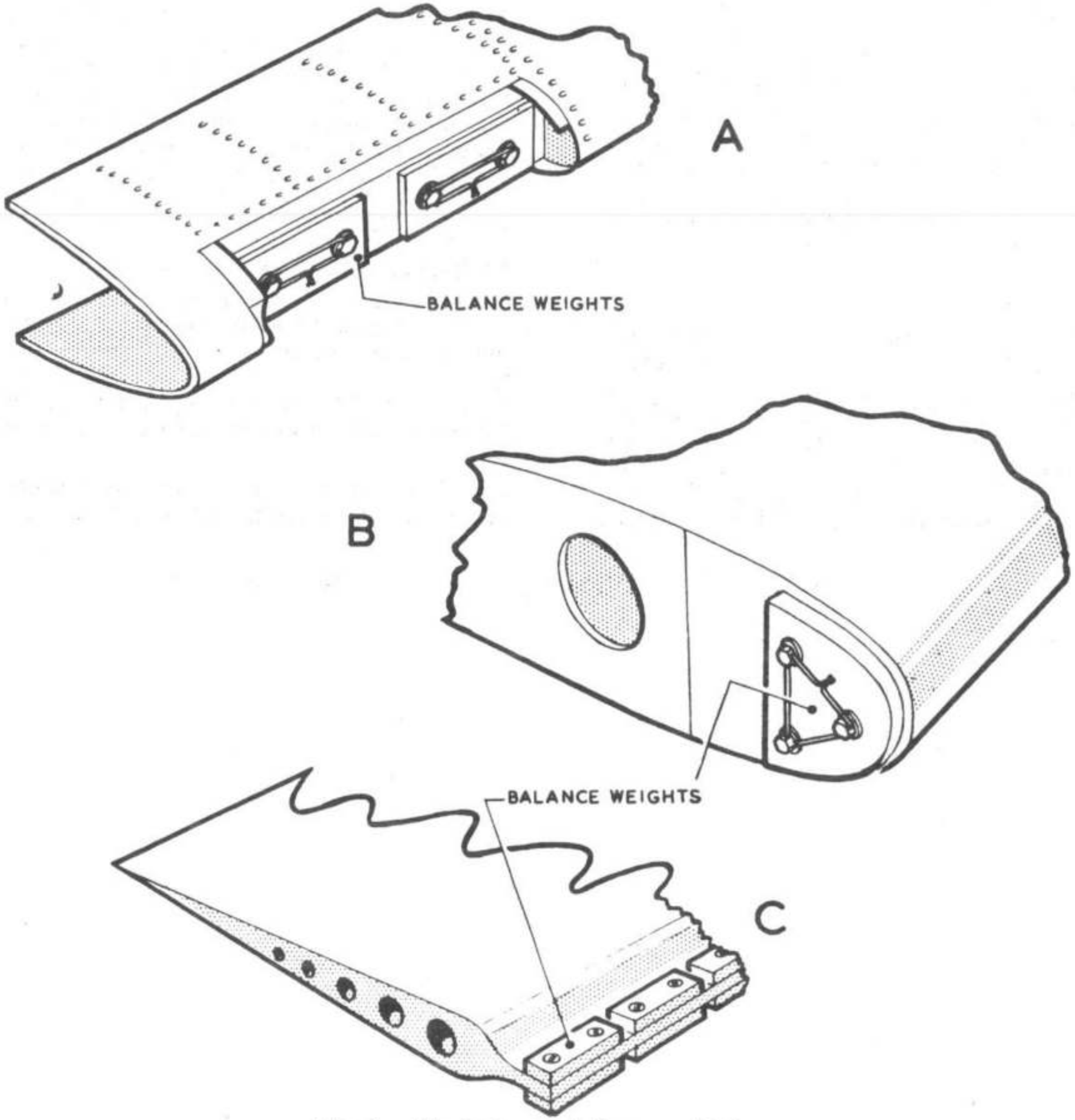


Fig. 1. Typical mass balance weights

part numbers and values. Large adjustments are made by removing existing plates or by fitting additional similar plates. The additional plates, which may be provisioned as repair spares or manufactured locally, are usually fitted on top of existing weights where clearance is available, as in fig. 1, Examples A and B. Beak weights, as illustrated in Example C, seldom have sufficient clearance for superimposition of additional weights and therefore spaces are usually provided at various positions along the span for the addition of weights. The appropriate values must be stamped on all weights that are manufactured locally.

*Small adjustments*

**14.** Small adjustments involving reduction in weight are made either by removing shims if fitted, or by reducing the size of the original weight by sawing or filing off the appropriate quantity. As the weights are subjected to aerodynamic loading, material should be removed symmetrically, e.g. equal amounts from top and bottom edges, and an adequate landing must be maintained round each attachment bolt or stud. If the value of a weight is reduced, the new value must be stamped on the weight and the existing stamped value must be cancelled.

**15.** Small adjustments involving increase in weight are made by fitting shims of sheet material of appropriate s.w.g. value under the existing balance weights. The shims should be manufactured from the same material as the existing weights whenever possible to reduce the possibility of electrolytic corrosion (*para.* 17) and must be stamped with the appropriate values.

### Locking of balance weight attachments

**16.** If balance weight attachments worked loose, controls could become jammed and flutter could occur. Hence Standard A (*positive*) locking must be applied to all balance weight attachments and one of the three following methods of locking must be used:—

(1) Split pins of nickel alloy to B.S. specification S.P.9 in castellated or slotted nuts,

(2) locking wire through the nut *and* bolt, or

(3) peening of the bolt end over the nut.

### Protective treatment

**17.** In almost all cases the material of the balance weight differs from that of the attachment structure, with the consequent possibility of electrolytic corrosion due to contact between dissimilar metals. This possibility is enhanced when the weights are mounted externally and are therefore more exposed to contact with moisture or humid atmospheric conditions. Protective treatment appropriate to the materials in use must be applied between all faying surfaces and external surfaces in accordance with instructions in Scheme 9.1.2 or in the Vol. 6.

**Note . . .**

*The protective treatment should not obscure the part numbers or values stamped on the weights.*

★ ★ ★

# PRACTICAL BENCH CHECK INSTRUCTIONS

### Introduction

**1.** The bench method of mounting a component for a physical mass-balance check (*fig.* 1) was originally standard practice but the increase in size of components has introduced the need for rigs (*Scheme* 1.4.8). A single bench will only accept a comparatively small component but a larger component can be mounted across two similar benches. The choice between this arrangement and manufacture or provision of a rig (*Scheme* 1.4.8) will depend on the size of the component, local accommodation facilities and the frequency of arisings. A rig would occupy less space than two benches but, on the other hand, the benches could be used for other purposes when not in use for balance checks.

### Requirements for test bench

**2.** The bench or benches must be strong enough to bear the weight of the component and must be absolutely rigid. Provision should be made as necessary for the attachment of test equipment, as shown by the examples in the illustrations. The bench top should be level if possible but discrepancies can be overcome as indicated in para. 16. If the floor on which the bench stands is not level, suitable packing must be provided under the legs to prevent rocking. Packing may be used under pairs of legs to assist in levelling the component.

*Dimensions*

**3.** The length of the bench or the distance between two benches will be determined by the distances between hinge supports (*para.* 5). The width of the bench will depend on the method of support, on the nature of the C.G. range of the component and on the method to be adopted for application of the test weights or loads. For example, if a type of component has a nose-heavy forward-limit moment and a tail-heavy aft-limit moment and test weights are to be applied by the chord and hook method shown in fig. 3, the bench should be narrow enough to allow both leading and trailing edges to overhang.

*Padding*

**4.** Felt or foam-rubber padding should be suitably positioned on the bench to prevent damage to the protective treatment or to the actual surface of the component during bench checks. This applies particularly at the trailing-edge position of a tail-heavy component and at the leading-edge position of a nose-heavy component. If the bench is permanently reserved for balance checks, the padding should be fixed to the bench, preferably with a suitable adhesive. If tacks or nails are used, the heads must be driven well down below the surface of the padding.

## REQUIREMENTS FOR HINGE SUPPORTS

### Basic requirements

**5.** The primary requirement for hinge supports is that they must allow the component to pivot about its hinges with complete freedom. The component hinge centre-line must be horizontal and the fore-and-aft centre-line of the hinge fittings or the knife-edges of the supports must lie in the correct plane relative to the component, as on the aircraft. The 'knife-edges' should be slightly rounded to prevent damage to the hinge tubes and their protective treatment.

### Support blocks (*fig.* 1)

**6.** If the bench remains fixed in one position so that levelling (*para.* 16) will not be affected, the hinge support blocks (*fig.* 1) should be bolted to the bench. If different lengths of component are to be tested, however, or the bench is to be used for other purposes, loose supports may be necessary. These should have a sufficiently wide base to ensure that they will not keel over if inadvertently subjected to side loading. The blocks should be made of steel. Shims or packing may be used under the blocks to provide adjustment.

*Hinge-fitting supports*

**7.** The requirements for supports of the hinge-fitting type shown in fig. 2 depend entirely on the design of the hinges and components. The general principles governing this type of support are that it should be similar in basic design to the actual aircraft hinge and mounted at the same angles relative to the component and rig as it would be on the aircraft, and that it must be rigid. Unless there is sufficient side-play between the hinges and hinge fittings, provision should be made for differential expansion (*Scheme* 1.4.8, *para.* 12) by elongation of the hinge fitting bolt holes in the steel T-section uprights. However, humidity variations will have more effect than temperature variations on the expansion and contraction of a wooden bench and provision for this must be made on the basis of experience.

*Bar-type supports*

**8.** The alternative forms of support for "buried" hinges shown on the right of fig. 2 must be rigid and must raise the component above the bench to allow an adequate pivoting movement. The U-shaped type of support need not be bolted to the bench if its base has sufficient lateral spread for stability and extends far enough *aft* of the hinge.

**9.** A flat knife edge may be used instead of the hooked form shown in fig. 2, but greater care will be needed in use to ensure that the component does not slip from the supports, with consequent risk of damage. The hooked knife edge is particularly valuable when the hinges are not readily visible.

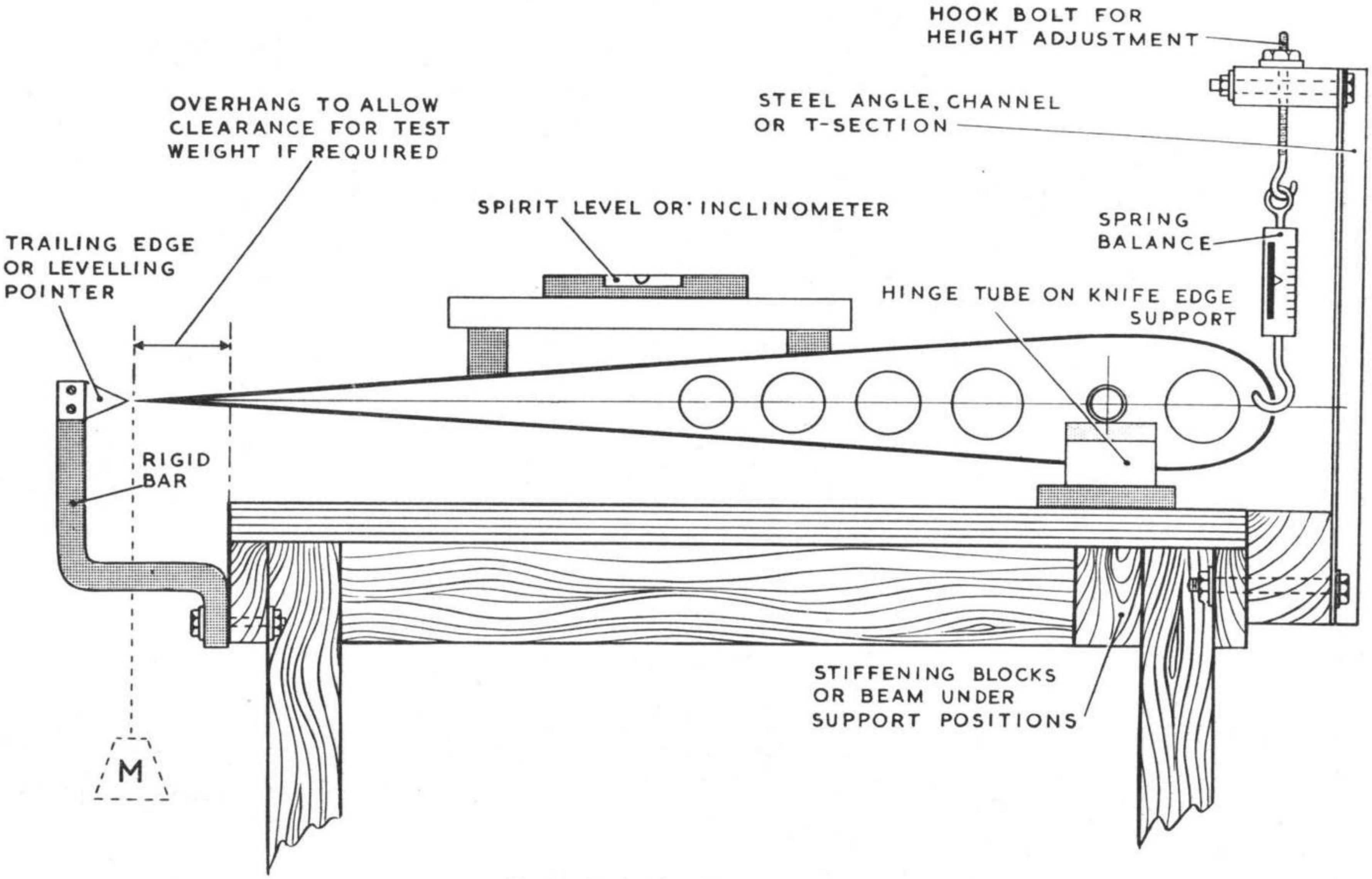


**Fig. 1. Typical bench arrangement**

## PRACTICAL BENCH CHECK INSTRUCTIONS—*continued*

### Bench suspension method

**10.** When a bench can be allocated permanently for balance checks the suspension method may be more suitable for supporting some types of component than the previous methods quoted. Supports similar to that shown in fig. 1 for mounting the spring balance should be used in conjunction with appropriate cable assemblies. This combination would be particularly suitable for components having hinge fittings; for example the type shown in Scheme 1.4.7, fig. 3, with which the use of normal supports would be difficult or impossible.

**11.** The supports must be positioned so that the cables hang vertically but a high degree of accuracy in locating the vertical supports relative to each other is not necessary. Compensation for initial inaccuracy in the distance between the vertical supports and also for expansion and contraction of the bench (*para.* 7) can be provided simply by the introduction of "spanwise" slots instead of holes for the hook bolts in the horizontal arms of the supports. The hook bolts provide convenient spanwise levelling devices (*para.* 16).

### Chordwise level indicator

**12.** The support for the chordwise level indicator or pointer (*fig.* 1) must be attached at the correct spanwise position and should allow adequate handling clearance for initial mounting of the components on the supports. It must be sufficiently strong and rigid to obviate accidental distortion. If the vertical height of the hinge supports is permanently fixed, the vertical position of the pointer may be also permanently fixed although in many cases it will be advisable to provide the pointer with a vertically mounted hinge. A hinged indicator can be swung to one side to allow for handling clearance whilst the component is being mounted on its supports.

**13.** If either the pointer or the supports cannot be permanently fixed, vertical slots or a sliding bar or strip may be incorporated to provide vertical adjustment. This may be essential if different components are tested on the same bench.

### Direct reading indicator

**14.** Some aircraft Vol. 6 quote mass balance limits in terms of direct vertical heights, usually given as distances above or below the position of the trailing edge when the chordline is horizontal. The upper and lower height limits correspond to the forward and aft C.G. limits respectively. Thus when the component is in static balance with its trailing edge at the upper height limit, its C.G. is at the forward limit. An indicator with pointers at the upper and lower height limits, and with a third pointer at the horizontal position for initial checking purposes, will provide a direct check on the balance condition of the component. The height limits may apply without the need for any balancing load or alternatively may be used in conjunction with a fixed-value balancing load applied at a specified position.

### Stand-type indicator

**15.** When the component does not overhang the bench at the trailing edge (*para.* 3) a stand-type indicator may be used. This simply consists of a bar or rod mounted vertically in a suitable base plate or block and marked at the appropriate trailing edge heights. Some marking should be made on the component and on the bench to indicate the spanwise position at which the indicator must be used (*para.* 20 *to* 22).

## SPANWISE LEVELLING

**16.** The spanwise centre line of the hinges must be horizontal during balance tests, unless stated otherwise in Vol. 6. Adjustments may be made by the use of shims or packing under the support blocks or bench legs, or by raising or lowering the hook bolts if the suspension method (*para.* 10) is used. Provision of spanwise adjustment by vertical elongation of hinge-fitting bolt holes (*para.* 7) is inadvisable as this would introduce the risk of distortion of the fittings or components; packing under the bench legs should be used.

**17.** The spanwise level may be checked by the use of a straight-edge and spirit level laid across the hinge supports. When the straight-edge cannot be used on the hinge supports it must be placed vertically above the hinge centre-line but compensation must be made for tapering of the depth of the component from root to tip. Compensation may be made by the attachment to the straight-edge of blocks of appropriate size or by the use of an inclinometer instead of the spirit level.

**Note . . .**

*The spanwise level should be checked before each test unless the bench and the supports are permanently fixed in position.*

## CHORDWISE LEVELLING

**18.** Chordwise levelling is automatically provided by the indicator or pointer (*para.* 12 *to* 15) but this will need adjustment if the height of the supports is altered.

**19.** The correct height for the indicator or pointer is initially obtained and subsequently checked, *after* the spanwise levelling operation, by the use of a straight-edge and inclinometer or a "tapered" straight-edge and spirit level (*fig.* 1). If the standard incidence board provisioned for normal rigging checks is used, allowance must be made for the absence of incidence angle on the component unless the normal rigging check is made with the component chord-line horizontal.

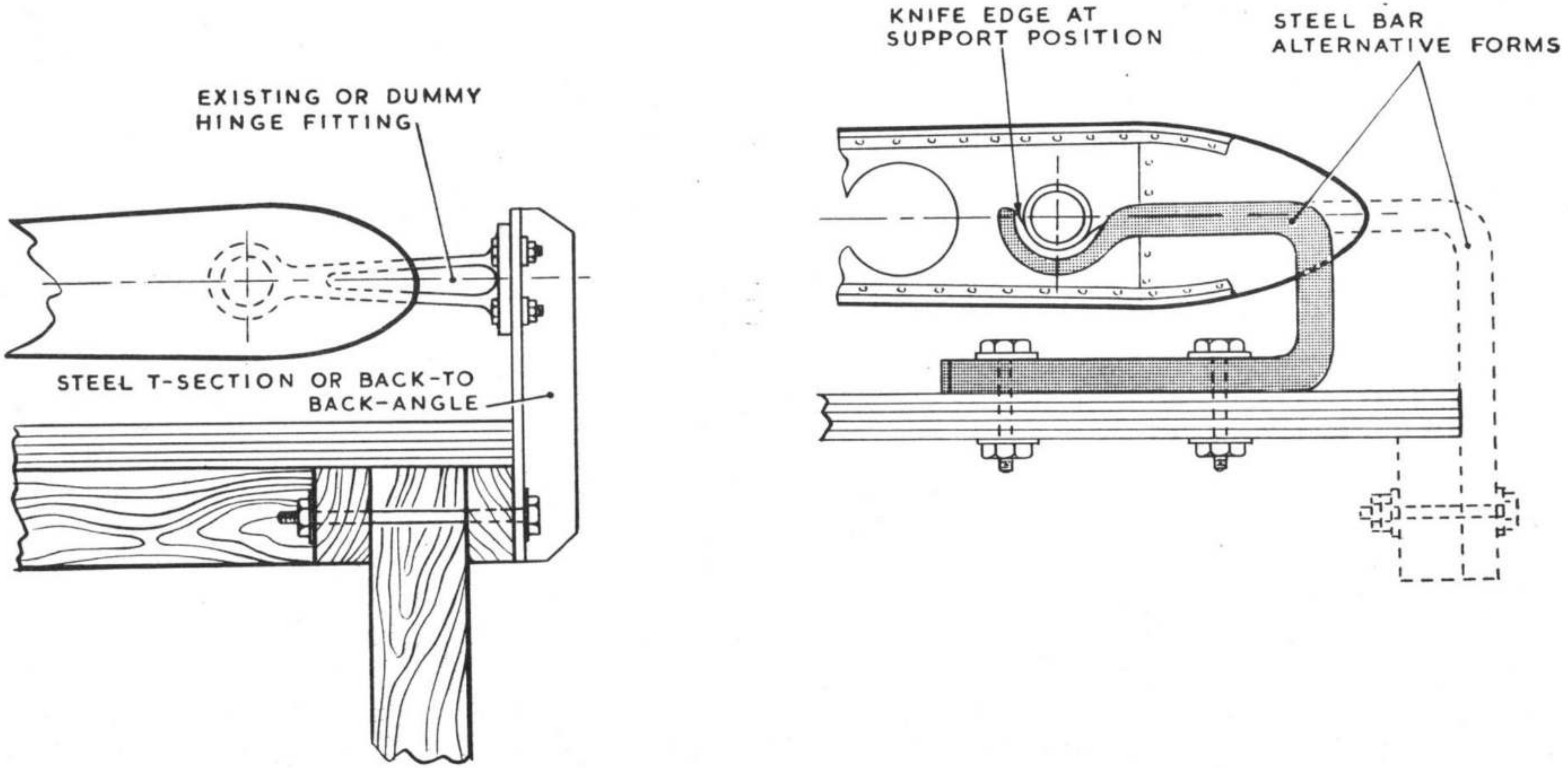


**Fig. 2. Alternative supports for buried hinges**

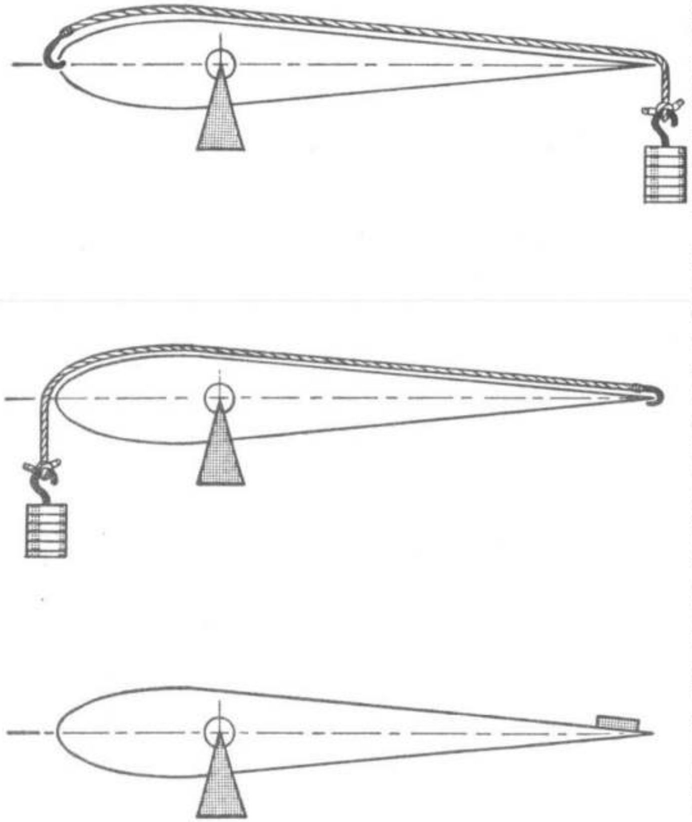


**Fig. 3. Alternative test weight applications**

**Note . . .**

*The straight-edge and spirit level check cannot be used directly in a balance test to obviate the need for an indicator. Considerable difficulty would be experienced in maintaining them in position during the check and accurate calculations would be necessary to determine the value of the compensation to be made for the tail-heavy moment introduced by the check equipment itself.*

**20.** Most components have some degree of wash-in or wash-out and hence the chord can be horizontal at only one spanwise position at any given setting of the component. The correct position will be specified in the Vol. 6 and the indicator must be calibrated and subsequently used at this position only.

**21.** The use of the correct spanwise position is even more critical when a direct-reading indicator (*para.* 14) is used, even if there is no wash-in or wash-out. As an example, consider an aileron (free from wash-in or wash-out) with the length of the chord-line aft of the hinge tapering from 20 inches at the root to 10 inches at the tip. When the root chord-line is horizontal, the tip chord-line will be also horizontal due to the absence of wash-in or wash-out. If the aileron is now pivoted through a given angle until the trailing edge at the *root* end is 1 inch above the common horizontal, the trailing edge at the *tip* will be only ½ inch above the common horizontal. Thus if the Vol. 6 stated that the permissible limits applied at the root, and the indicator was used at the tip instead, the limiting values in terms of height or out-of-balance moments, or C.G. positions could be dangerously exceeded.

**Surface-applied test weights**

**22.** The lower view of fig. 3 shows the simplest method for the application of test weights, that of placing a test weight or weights directly on the surface of the component at a known horizontal distance from the hinge line. The chief disadvantage of this method is that, during a test, the weights may slide aft or forward of their original position and this could result in incorrect adjustment of the mass-balance if the movement was not noticed. A clear locating line should be marked on the component at the appropriate distance from the hinge line and, before mass-balance adjustment is made, the weight should be checked to ensure that it has not moved during the test. Another disadvantage is that the weights may slide completely off the component, with consequent risk of direct damage to the protective treatment and possible damage to the leading or trailing edge due to the sudden pivoting in the opposite direction that would automatically follow the abrupt removal of the balancing moment.

**Suspended test weights**

**23.** The cord and hook system shown in fig. 3 provides the most satisfactory and positive method of attachment for test weights on most components. The case in which the weight is suspended from the trailing edge shows the hook inserted through a hole in the centre of the leading edge, but free edges at hinge positions may be used. If there is no suitable location for attachment of the hook at the leading edge, a longer cord should be used to enable the hook to be fitted at the trailing edge. The cord is passed along the under surface round the leading edge, over the upper surface and finally hangs over the trailing edge.

**24.** The test weight is only shown diagrammatically in fig. 3, but provision should be made for the attachment of either single weights of differing values or for the use of a number of weights.

**25.** The hooks should be made of perspex or similar thermo-plastic if possible, but may be made from metal if necessary. All corners and sharp edges must be removed to prevent damage to the protective treatment and surface of the component.

**Spring balance**

**26.** The spring balance as shown in fig. 1 may be used at either leading or trailing edges, but suitable precautions should be taken to avoid the risk of damage to the protective treatment and component surface. The advantages of the spring balance are that it may be held by hand and that it gives a direct reading irrespective of other adjustments, thus eliminating the need for a range of weights.

**Note . . .**

*The spring balance must be an accurate instrument and the scale should be checked at appropriate intervals against weights of known accuracy suspended from the hook.*

### TEST PROCEDURE

**27.** The basic test procedure is as follows:—

(1) Check that the component to be tested is complete with all tabs, the appropriate portions of control cables or rods, access doors, fairings, etc., and final protective treatment, unless stated otherwise in the aircraft Vol. 6.

(2) Ensure that the hinge supports are correctly positioned.

(3) Perform the appropriate spanwise and chordwise levelling operations and, if applicable (*para.* 15) mark the location of the horizontal level indicator.

Continue the sequence of operations as in para. 28 or 29 as appropriate.

**Test without calculations**

**28.** If temporary additions to or removals from the mass-balance weights can be made easily, continue as follows:—

(1) Apply test weights of the value required to produce a *balancing moment* equal but opposite in direction to the *forward-limit* out-of-balance moment.

**Note . . .**

*If it is known that this value cannot be achieved due to weight or space limitations, apply a balancing moment of arbitrary value within the permissible range.*

(2) Temporarily attach, or remove mass-balance weights as necessary to produce a state of horizontal balance. If applicable, check that the new total value of mass-balance does not exceed Vol. 6 limits. If the Vol. 6 limits are exceeded, reduce as in operation (1), Note.

(3) Remove the component from the bench and weigh it if a maximum total weight value is quoted in the Vol. 6. Record the weight (*Scheme* 1.4.4) if it is within limits. If the total weight exceeds the stated limit, remove the required amount from the mass-balance weight and perform another bench test to ensure that the C.G. is still within the aft limit.

(4) Secure the mass-balance weights to the structure and lock by the approved method (*Scheme* 1.4.5).

(5) Record the new balance conditions on the component and in the relevant documents (*Scheme* 1.4.4.).

**Test incorporating calculations**

**29.** When the mass-balance weight cannot be adjusted readily during the test, the continuation procedure is as follows:—

(1) Apply test weights of the value required to produce horizontal balance.

(2) Calculate the weight adjustment required to the mass-balance (*Scheme* 1.4.3, *para.* 15).

(3) Calculate the size of weight required to be fitted or removed (*Scheme* 1.4.9) and incorporate the necessary alteration.

(4) Check against weight limitations if applicable.

(5) Secure and lock the balance weights.

(6) Record the new balance conditions (*Scheme* 1.4.4).

★ ★ ★

# SUSPENSION METHOD FOR MASS BALANCE CHECK

## Introduction

**1.** The suspension method of mounting a component for mass balance check (*fig.* 1) is very convenient when repair arisings are not frequent enough to justify the provisioning or manufacture of a fixed bench (*Scheme* 1.4.6) or rig (*Scheme* 1.4.8). Only simple equipment is required and this can be stowed away in a comparatively small space when not in use.

## Requirements for trestles

**2.** The trestles must each be strong enough to bear at least two-thirds of the weight of the component and must be absolutely rigid. Fig. 1 shows only one brace across each pair of legs, but it is recommended that a second brace or a triangular-shaped diaphragm of thick plywood should be fitted as close to the top of the legs as possible, to prevent loosening of the leg-to-crossbar joints. The upper crossbar must have sufficient depth of section to prevent bending under load and the lower crossbar, if fitted, must be strong enough to bear the weight of the component.

**3.** The crossbars must be long enough to provide suitable clearances between the leading and trailing edges of the *root-end* of the component and the inner faces of the trestle legs, for both handling and pivoting purposes. Trestles of different lengths may

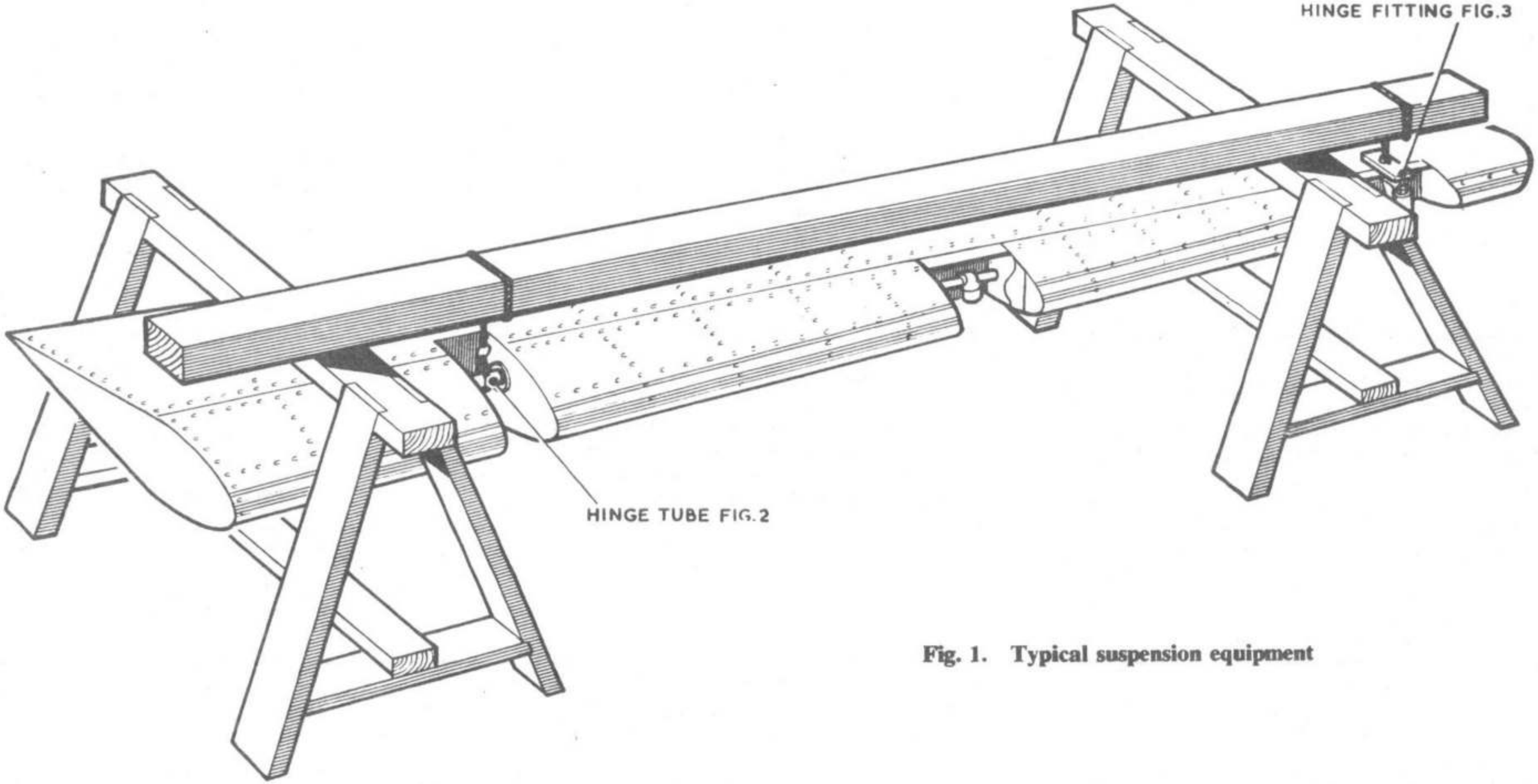


Fig. 1. Typical suspension equipment

be used for root and tip but, in general, it is more convenient to have interchangeable items, i.e. trestles of the same length. The lower crossbars shown in fig. 1 are not essential but their use is advisable because they increase the rigidity of the trestles and provide a support for the component before attachment and after detachment of the suspension wires. The crossbars also act as stops to prevent excessive angular movement of the component during balance operations. Thick felt padding, attached at the leading and trailing edge positions on the underside of the upper crossbars and along the whole of the lower crossbars, will prevent damage to the protective treatment on the components.

### Requirements for support beam

**4.** The support beam must be long enough to overhang the appropriate hinge positions of the component and must be strong enough to bear the weight of the component. The beam may be made from light steel girder or from wood, but the latter must be free from serious defects such as large knot-holes, particularly at the centre of the span.

**5.** The beam must have sufficient depth of section to prevent bending and springing when loaded, as accurate balancing is difficult under these conditions. The actual section of beam required will depend upon the weight of the component and the unsupported span of the beam between the trestles but, as a guide, a 4 × 4 in. timber section would be satisfactory for most components. If this is not available, two 4 × 2 in. sections may be nailed, screwed or strapped together to make a composite beam. Beams of any required depth may be made up by this method, provided that the sections are suitably clamped together. If a very deep beam is required, a hollow box-beam should be manufactured from 1½ in. thick timber. This will provide a stiff beam considerably lighter than a beam of solid section possessing the same degree of stiffness.

### Requirements for suspension wire or cord

**6.** For very light components, braided cord may be used for suspension provided there is, for practical purposes, no frictional resistance to free pivoting of the component. The application of wax to the cord may reduce friction in some cases.

**7.** When a stronger suspension attachment than cord is necessary, 3, 5 or 10 cwt. flexible steel wire or cable should be used, according to the weight of the component. Sound lengths may be taken from discarded aircraft control cables. Alternatively refer to A.P.1086, Book 12, Section 28X, which lists flexible steel wires; other sections in Book 12 deal with eyebolts, rings and similar items that may be useful for making up suspension fittings.

### Requirements for suspension fittings

**8.** Subject to considerations of component weights, any convenient wire or cord assembly may be used (*para.* 10), but the arrangement must be such that the wire or cord hangs freely, vertically and directly over the hinge centre-line. The actual point in the vertical plane about which pivoting occurs during balance operations should be the hinge centre-line itself, but this is only possible, in the suspension method, if the wire can be attached to a hinge fitting or ball race in which the actual hinge can pivot. For example, fig. 3 shows a component which can pivot about its hinge centre-line. If, however, the eyebolt was attached directly to the structure instead of to the hinge via the mild steel bar, the pivoting point would be the point of contact between the cord and the eye of the eyebolt and would therefore be approximately half the depth of the aerofoil section above the hinge line.

**9.** This vertical distance between the actual balance check pivoting point and the hinge centre-line should be kept to a minimum. Although there will be little or no error when, with the component balanced with its chord-line horizontal, the actual pivot point is directly over the hinge centre, false moment values will be given when the trailing edge of the component is above or below the horizontal.

### Wire or cord assemblies

**10.** In the majority of cases an actual component has identical or similar arrangements at all hinge positions but for convenience fig. 1 shows different types of hinge on the same component. The details of the method of attachment to be used depend on the design of the hinges, but fig. 2 and 3 and para. 11 and 12 provide basic ideas.

#### *Assemblies for hinge tubes*

**11.** The most simple assembly for supporting a hinge tube by the suspension method consists of a large, rigid hook permanently attached to the vertical cable. The hook should be slightly greater in diameter than the hinge tube to ensure that, during balancing operations, the tube is only in single-point contact with the hook, to minimise

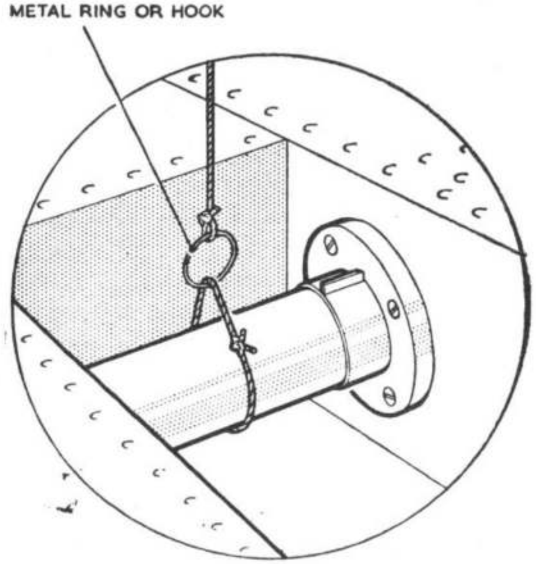


**Fig. 2. Typical open-hinge assembly**

## SUSPENSION METHOD FOR MASS BALANCE CHECK—*continued*

friction. The upper end of the cable should be formed into a fixed loop. When the cable is passed over the support beam (*fig.* 1) and the hook is passed through the fixed loop, the assembly is ready for use.

**12.** The assembly shown in fig. 2 uses cord, knotted as required. Flexible steel wires could be knotted if necessary, but the wires would become kinked and some method of locking the knots to prevent slipping would be required. For regular usage, wires should have thimbles, hooks or rings spliced to the ends.

*Assemblies for buried hinges*

**13.** Fig. 3 shows an assembly in which the actual hinge is buried, and an eyebolt is fitted directly over the hinge centre-line. The knotted cord can be replaced by flexible wire with a small hook attached. The adapter bolt or threaded bar should have sufficient clearance to avoid damage to the bore of the hinge fitting and, although not shown in fig. 3, washers should be fitted as necessary to prevent damage to the end faces of the fitting. The mild steel bar is clamped between the visible top nut (or bolt head) and a second nut against its undersurface. The eyebolt is clamped to the steel bar by means of a nut if there is sufficient clearance between bar and component or, alternatively, the eyebolt is threaded right up to its collar and is screwed direct into a tapped hole in the bar.

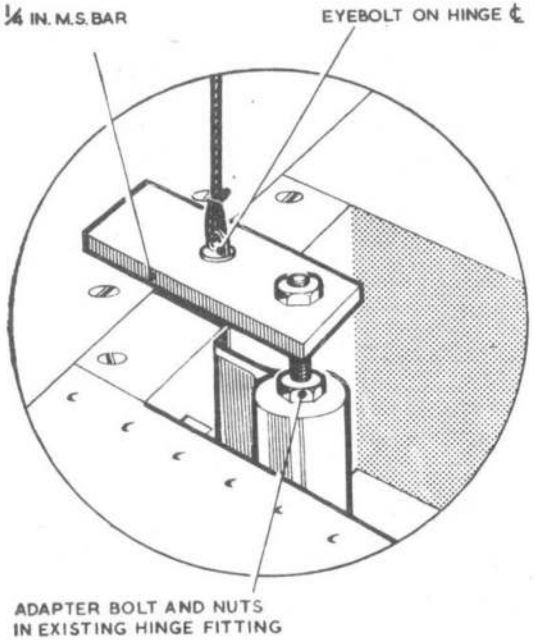


**Fig. 3. Typical buried-hinge assembly**

### Support positions

**14.** The trestles must be positioned as close to the suspension cables as possible without causing interference with the freedom of the cable assemblies; one trestle must be inside a cable and the other outside, as shown in fig. 1.

**Note . . .**

*The relative distances between the cables and trestles shown in fig. 1 should not be used as a guide. These distances are exaggerated to enable the hinge and cable arrangements to be seen clearly.*

The positioning of the trestles close to the cables minimises the basic values of the bending moments exerted on the beam; the alternate positioning causes the bending moments from the two loading positions to act against each other, instead of combining to form a much larger value. The overall effect is that deflection and springing are reduced to a minimum (*para.* 5).

### Methods of adjustment

**15.** In almost all cases, balance checks must be effected with the hinge centre-line of a component horizontal and the balance is actually checked when the chord-line is also horizontal. When a component has a marked degree of wash-in or wash-out, the chord will be horizontal only at one position along the span and the Vol. 6 will define this spanwise position at which the check must be made.

**16.** The component may be set level by the use of an inclinometer or spirit level, but compensation must be made for the degree of taper between the upper surface of the component and the hinge centre-line. If aircraft component rigging boards are used to provide the necessary compensation, allowance must be made for the absence of dihedral on the component being checked.

*Hinge-line adjustment*

**17.** Hinge-line adjustment may be provided for the check by the incorporation of turnbuckles in the cable assemblies or, more simply, by the use of packing between the beam and trestles. The trestles must be firm and, if necessary to prevent rocking, packing should be used under the legs of the trestles.

*Chord-line adjustment*

**18.** An inclinometer or spirit level and incidence board may be used initially to set the chord-line horizontal at the appropriate spanwise position (*para.* 15), but allowance must be made for the absence of actual angle of incidence if a board supplied for normal rigging checks is used.

**19.** Use of the inclinometer or spirit level during actual balancing operations is very difficult, due to the moment effect of the instrument itself and to the difficulty of maintaining the instrument in position. It is therefore advisable to provide, at any convenient trailing edge position along the span, an adjustable pointer or indicator (*Scheme*

1.4.6). The chord is levelled by use of the inclinometer and the pointer is set in line with the trailing edge of the component at the chosen spanwise position. The pointer is then used to indicate the correct level during balancing and the inclinometer is no longer required. The pointer or indicator may be attached to a separate stand or to a board fixed to one of the trestles.

**Attachment of balance-test weights**

**20.** Any of the methods quoted in Scheme 1.4.6 may be used for attachment of the balance-test weights or spring balance but, in general, the use of weights on a cord hooked over the leading edge and hanging over the trailing edge, or vice versa, is the most convenient method for use with the suspension-type rig.

* * *

# RIG FOR MASS BALANCE CHECK

## Application

**1.** The type of rig shown in fig. 1 is used for large and heavy components. It is also used for the mass balancing of smaller components at depots where arisings are sufficiently frequent to justify the manufacture of a rig and the permanent allocation of floor space.

**2.** More complex rigs may be made to accommodate different components from the same type of aircraft or similar components from different aircraft types. When permanent allocation of floor space is impossible, a semi-portable rig may be manufactured from steel angle or channel, etc., but this will take up more floor space than a fixed rig when in use. If possible, a non-fixed rig of this type should be fitted with wheels.

## Requirements for uprights

**3.** The uprights or stanchions must be sufficiently strong and rigid to bear the weight of the largest component for which it is to be used, without vibration. Fig. 1 shows two uprights only, but three or more uprights or, alternatively, fittings attached to the cross piece (*para.* 6), will be necessary if the Vol. 6 states that the component must be supported at more than two hinge positions for balancing purposes.

**4.** The positions for attachment of the hinge fittings must be at the correct relative heights to provide automatic levelling of the hinge centre line. Also the positions must be machined or filed flat and true relative to each other to avoid distortion of the hinge fittings, hinges or component when bolted to the rig. The distortion could cause permanent set or at least could introduce friction that would affect the balance check. Para. 12 also refers to distortion due to temperature changes.

**5.** The hinge fittings for some components may be so short that the leading edge of the components would foul the uprights. Packing will therefore be required between the hinge fittings and the uprights. If possible, this should be permanently attached by welding to the uprights.

## Dummy hinge fittings

**6.** On some aircraft, the hinge fittings are permanently attached to the main plane, tail plane or fin structure and the component is removed by withdrawal of hinge pins. In these cases, dummy hinge fittings or simple brackets similar to that shown in Scheme 1.4.6, fig. 2, must be manufactured and fitted to the rig. Provision must be made for sufficient lateral movement of the component hinges within the dummy hinge brackets to allow for differential expansions (*para.* 10 *et seq*).

## Cross pieces

**7.** Cross pieces are not essential if the uprights have sufficient rigidity and can be correctly aligned during setting in the concrete. The absence of cross pieces would be an advantage where space is limited. However, if cross pieces are bolted or welded to the uprights prior to concreting, alignment is considerably simplified and differential expansion problems are simplified.

**8.** The cross pieces also form a convenient structure for mounting various refinements. Suitable plate or bracket assemblies can be secured to the cross pieces to provide additional hinge attachment positions. Spring balance or pulley assemblies for balance test loading devices may also be attached.

**9.** The cross pieces themselves may be padded, or padded arms may be attached to the cross pieces, to act as stops to prevent damage to the components being tested. A cranked arm, carrying an adjustable or fixed trailing edge pointer (*Scheme* 1.4.6), may be attached at any required spanwise position to provide a chordwise levelling device.

## Location of rig

**10.** The rig should be situated where it will not waste space or cause an obstruction in passage ways, etc. Possible future general requirements for use of the floor space and the effect of possible adaptation of the rig to accommodate larger components should be assessed.

**11.** The location of the rig must be free from draughts that would affect balancing operations. Under normal circumstances, the most suitable location would be adjacent and parallel to a wall and well away from doors, ventilators, etc.

## Allowance for expansion

**12.** However accurately the hinge positions are fixed originally, variations will occur due to the differences between the coefficients of linear expansion of the material of the component and of the steel and concrete forming the rig. There may be sufficient lateral play on the hinges to make allowance for differential expansion; otherwise provision must be made by horizontal elongation of the hinge-fitting holes in one or both end uprights and at all intermediate hinge positions (*para.* 18).

**13.** The degree of relative movement that occurs between the bolt holes in the rig and the holes in the hinge fittings themselves will depend upon the actual constitution of the rig and component materials, the distance between the hinges, and the temperature ranges involved. The following paragraphs indicate the method used for calculation of the approximate allowance to be made.

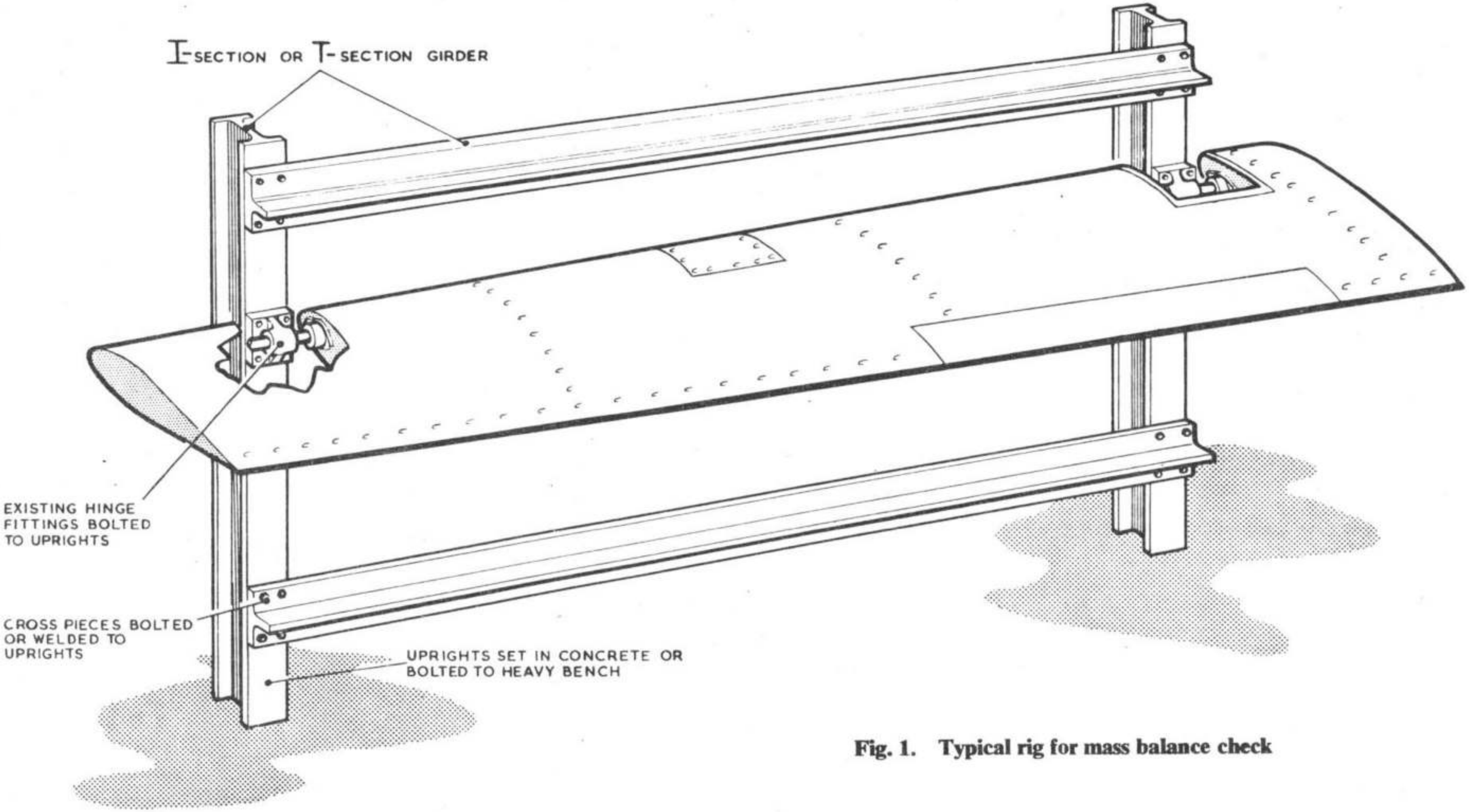


**Fig. 1. Typical rig for mass balance check**

**14.** The average value of the coefficient of linear expansion of aluminium alloys is approximately 0·0000128 per degree Fahrenheit. The average values of steel and concrete are approximately equal at 0·00000665 per deg. F. Thus a *unit* length of a component manufactured from aluminium alloy will expand more than the rig by a value of approximately 0·00000665 = 0·00000615 for each *simultaneous* Fahrenheit degree rise in temperature of rig and component. This value cannot be used directly when the rig and component are at different temperatures (*para.* 16).

**Rig used in hot climate**

**15.** Assume an inter-hinge distance of 20 feet and also assume that, during a balancing operation, the rig and component are at the same temperature, this temperature being 100 deg. F. higher than the corresponding temperature at the time of construction of the rig. Thus the differential movement between the component and the rig is: —

$$0{\cdot}00000615 \times 20 \times 100 = 0{\cdot}0123 \text{ feet}$$
$$= \underline{\underline{0{\cdot}1476 \text{ inches}}}$$

**16.** The assumptions made in para. 15 would apply to a large component in a tropical or semi-tropical country and would result in a mal-alignment of the holes in rig and hinges in excess of $\frac{1}{8}$ in. It should be noted however that para. 15 assumes that the rig and component are both at the same temperature but it is quite common for a concrete floor to have a temperature considerably below the ambient temperature. In these circumstances the differential expansion in a rig consisting only of steel uprights (*i.e. no cross pieces*) would be correspondingly greater than the value calculated in para. 15.

**Rig used in temperate climate**

**17.** As a second example, consider a non-cross piece rig for a Beverley aileron, used in this country. The distance between the inner and outer hinges of the aileron is approximately 30 feet. Intermediate hinge supports would be required and mal-alignment would also occur at these positions, although it would be less than at the end positions. Assume that the rig is made during the winter in a hangar, with the temperatures of both the rig and the component used for initial setting equal at 40 deg. F. The maximum temperature that could be expected in a hangar in this country would be approximately 85 deg. F. and the aileron would be normally at this temperature but the floor temperature could be as low as 60 deg. F. The calculations would therefore be as follows:—

Increase in distance between inner and outer hinges on aileron

$= 0{\cdot}0000128 \times 30 \times (85 - 40)$
$= 0{\cdot}01728 \text{ feet} = 0{\cdot}20736 \text{ inches}$

Increase in distance between rig end uprights

$= 0{\cdot}00000665 \times 30 \times (60 - 40)$
$= 0{\cdot}00399 \text{ feet} = 0{\cdot}04788 \text{ inches}$

Differential movement between component and rig

$= 0{\cdot}20736 - 0{\cdot}04788 = 0{\cdot}15948 \text{ inches}$

**18.** Thus the mal-alignment between the end uprights would again be in excess of $\frac{1}{8}$ in. and the intermediate positions would have lesser values, depending on their distances from the ends. If the bolts in one end hinge fitting had no clearance, and the two intermediate hinges were 10 feet and 20 feet respectively from this end, the degree of mal-alignment at these hinges would be one-third and two-thirds of the total value respectively and provision must be made for this at the intermediate hinge positions.

**Allowance for contraction**

**19.** For convenience, the calculations in para. 15 to 18 inclusive assume that the rig is built when the temperature is at the lowest seasonable value and that all differential movement is therefore due to expansion. In effect, the calculations give an indication of the total range of movement that could be expected. Hence, if a rig is built when the temperature is at the highest expected value, the elongation of the holes must allow for contraction, not expansion. If the rig is built at an intermediate temperature, allowance must be made for expansion and contraction within the overall range.

**Manufacturing tolerances**

**20.** Additional allowance on the rig dimensions must be made to include the basic variations in the distances between hinges given by the manufacturing tolerances.

★ ★ ★

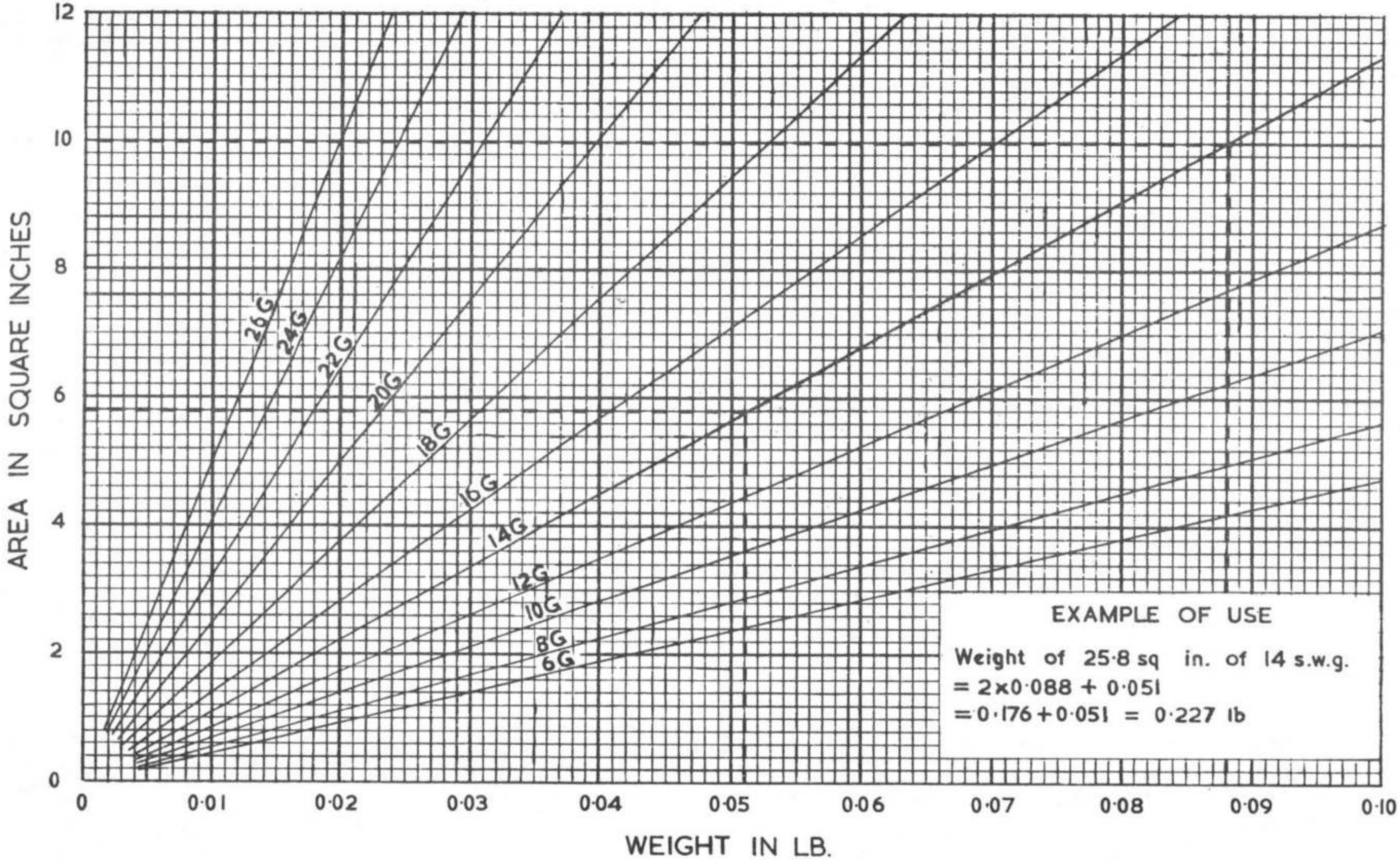
# WEIGHTS OF REPAIR MATERIALS

## 1.4.10

### LIST OF TABLES

**Introduction**

**1.** To calculate the effect of a repair upon the total weight of an aircraft, or upon the weight and balance of a control surface (Scheme 1.4.9) the various weights of the repair components must be calculated before the repair scheme is commenced, unless it is perfectly obvious that the weight effect is negligible. To avoid weighing the raw materials from store, a number of repair materials, such as sheet metal, bolts, rivets, etc., are listed with their weights in the tables which follow. In particular, the weight of rivets and special fasteners which have a different set weight to the weight as issued, are included; this applies to Jo-bolts and pop, Imex, and Avdel rivets.



EXAMPLE OF USE

Weight of 25·8 sq in. of 14 s.w.g.
= 2×0·088 + 0·051
= 0·176 + 0·051 = 0·227 lb

**APPLICABLE SPECIFICATIONS:—**
D.T.D. 687, 710, 746, etc.
L.70, 71, 72, 73, etc.

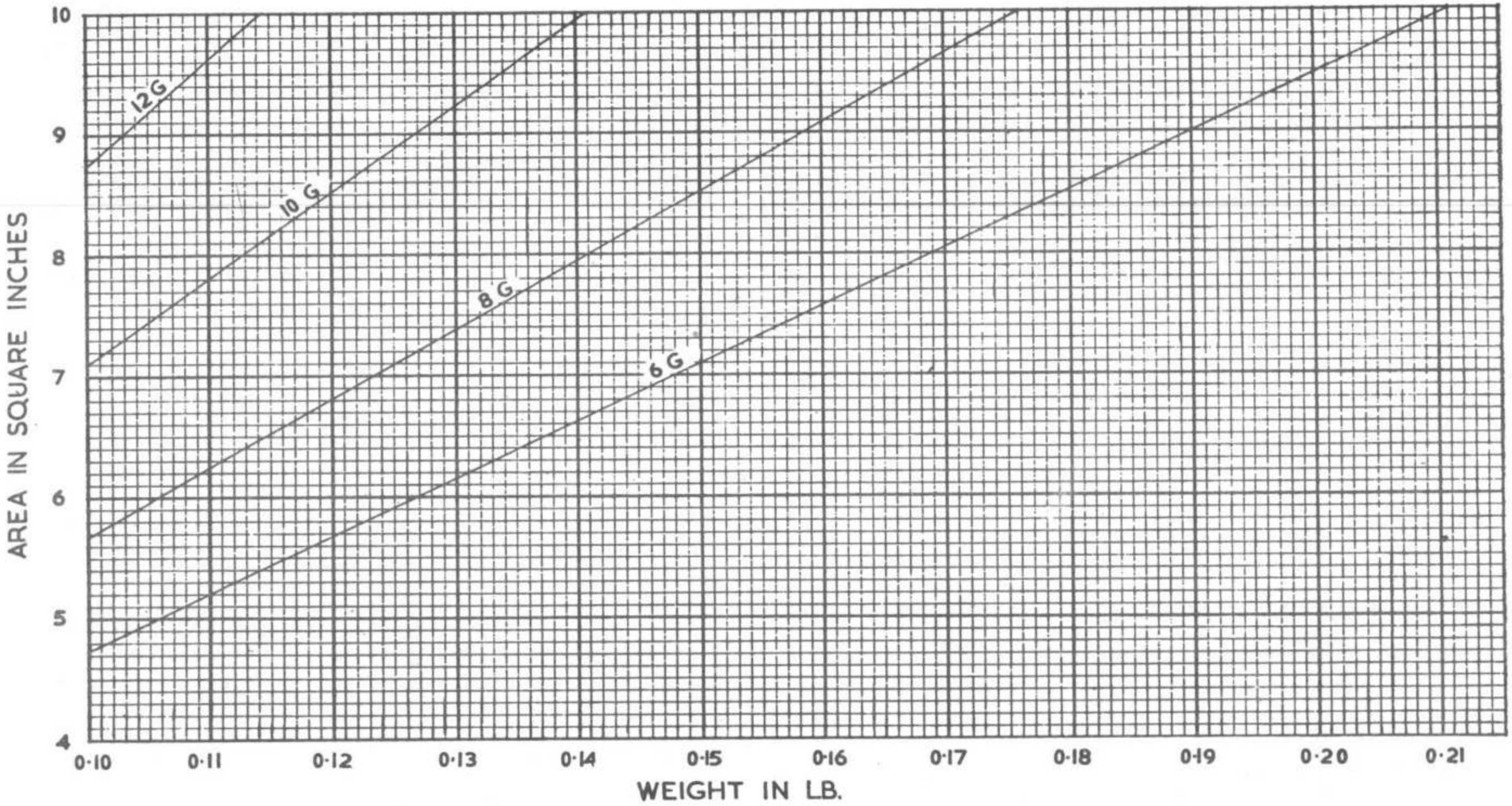
Table 2 gives the continuation values up to 10 square inches, for 6 to 12 s.w.g. aluminium alloy sheet.

Tables 3 and 4 provide values for odd s.w.g. sizes of aluminium alloy sheet.

**Table 1. Weight of even s.w.g. ALUMINIUM ALLOY sheet (1)**

**◄(Example of use amended)►**

## WEIGHTS OF REPAIR MATERIALS—*continued*

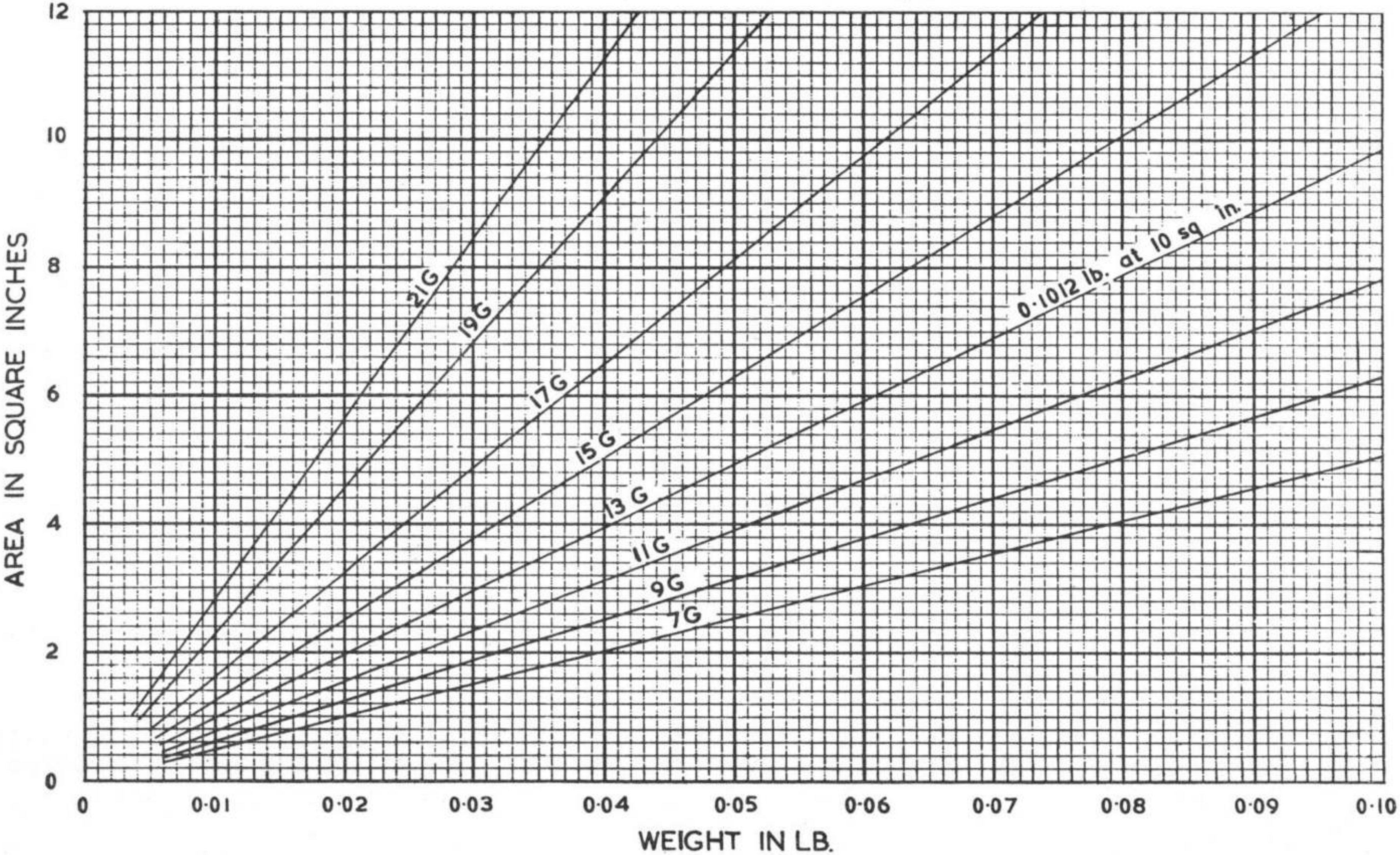


**APPLICABLE SPECIFICATIONS:—**
D.T.D. 687, 710, 746, etc.
L.70, 71, 72, 73, etc.

The values given in Tables 1 to 4 inclusive are based on a unit weight of 0·11 lb. per cubic inch.

For quantities in excess of 10 square inches, refer to the example given in Table 1.

**Table 2. Weight of even s.w.g. ALUMINIUM ALLOY sheet (2)**



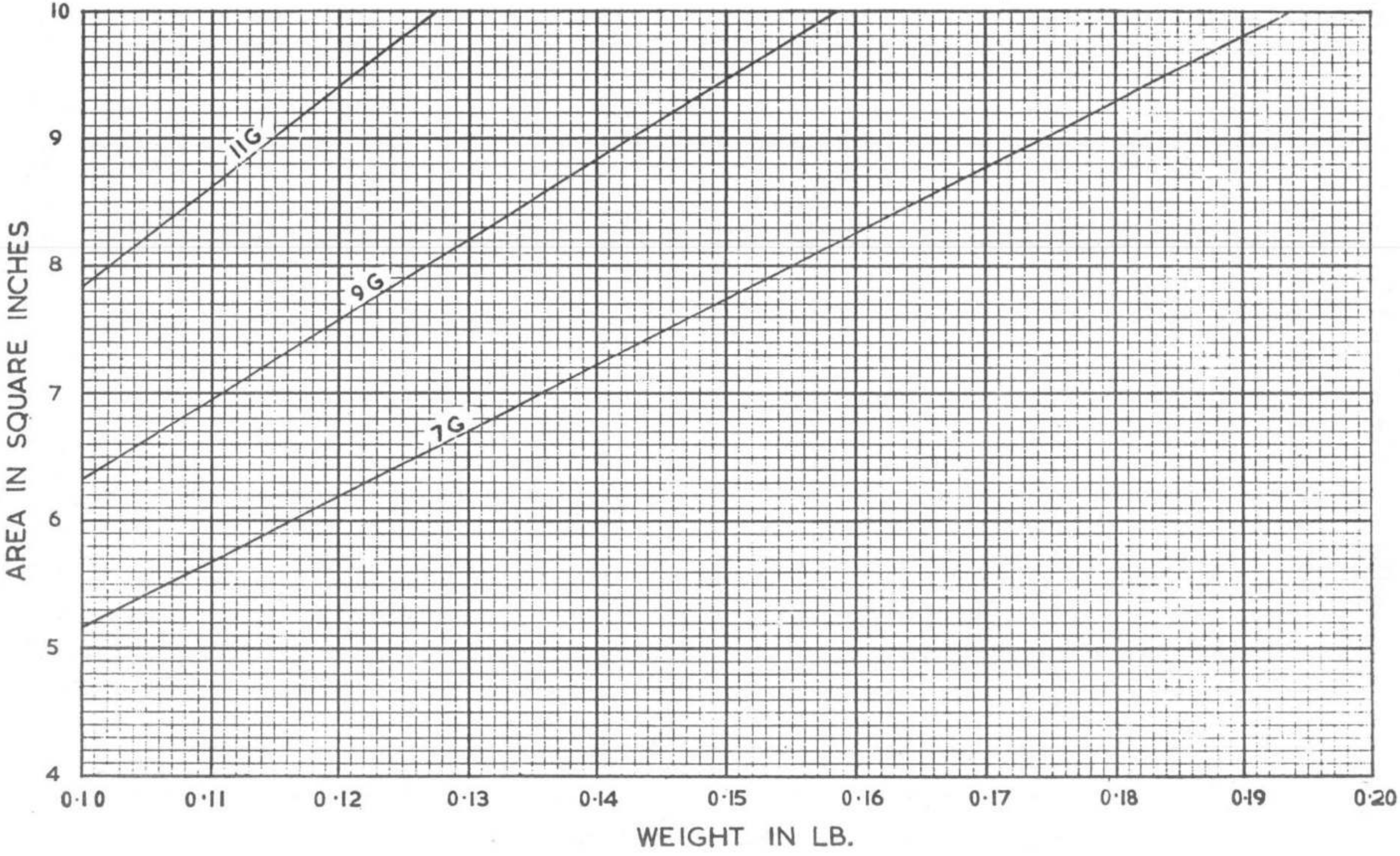
**APPLICABLE SPECIFICATIONS:—**
D.T.D. 687, 710, 746, etc.
L.70, 71, 72, 73, etc.

Table 4 gives the continuation values up to 10 square inches, for 7 to 11 s.w.g. aluminium alloy sheet.

For quantities of sheet materials in excess of 12 square inches, refer to the example given in Table 1.

**Table 3 Weight of odd s.w.g. ALUMINIUM ALLOY sheet (1)**

**WEIGHTS OF REPAIR MATERIALS**—*continued*



**APPLICABLE SPECIFICATIONS:—**
D.T.D. 687, 710, 746, etc.
L.70, 71, 72, 73, etc.

Tables 5 to 8 inclusive contain graphs similar to those in Tables 1 to 4 inclusive, but refer to *aluminium* sheet.

For quantities of sheet materials in excess of 12 square inches, refer to the example given in Table 1.

**Table 4. Weight of odd s.w.g. ALUMINIUM ALLOY sheet (2)**

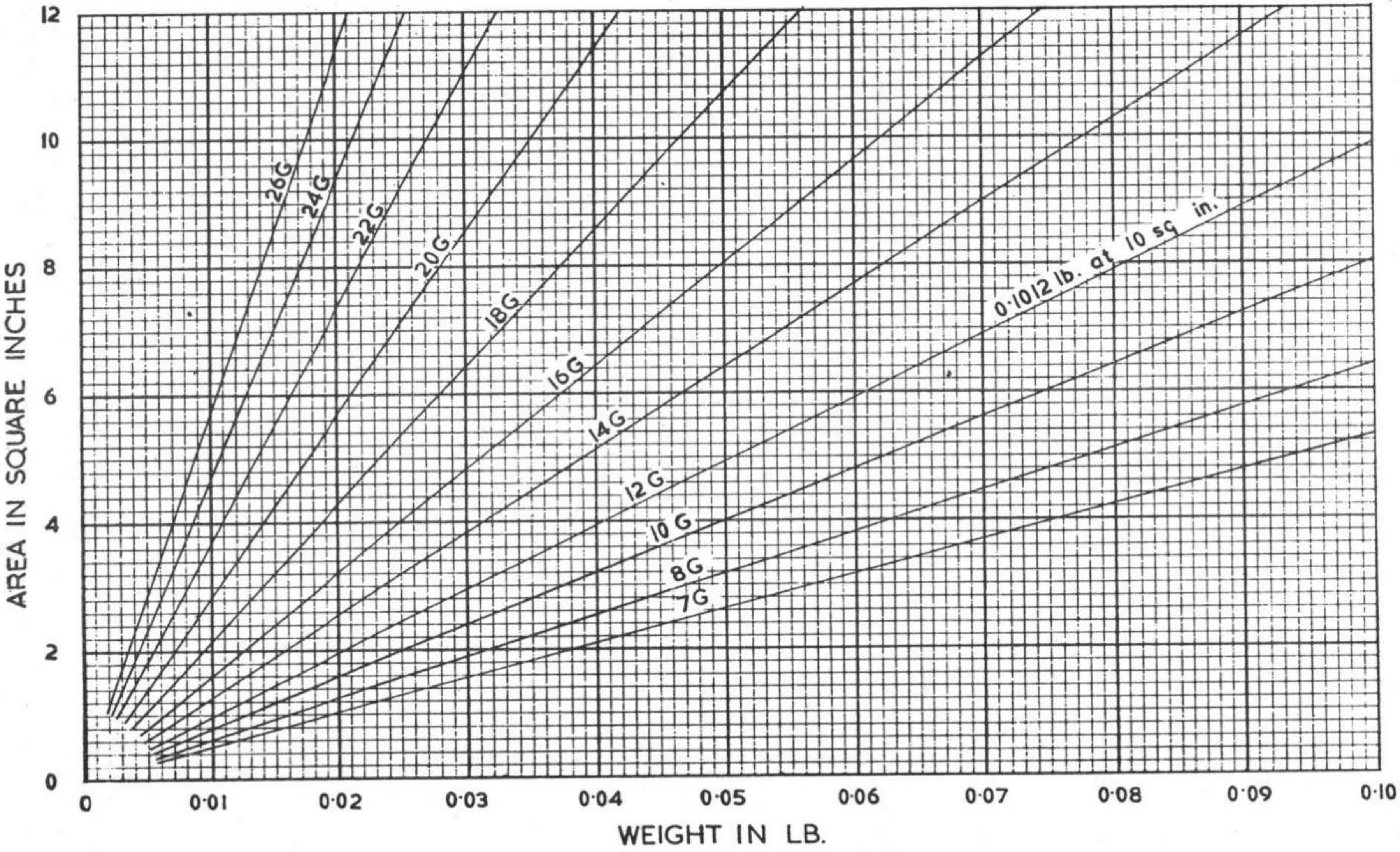


Table 5. Weight of even s.w.g. ALUMINIUM sheet (1)

WEIGHTS OF REPAIR MATERIALS—*continued*

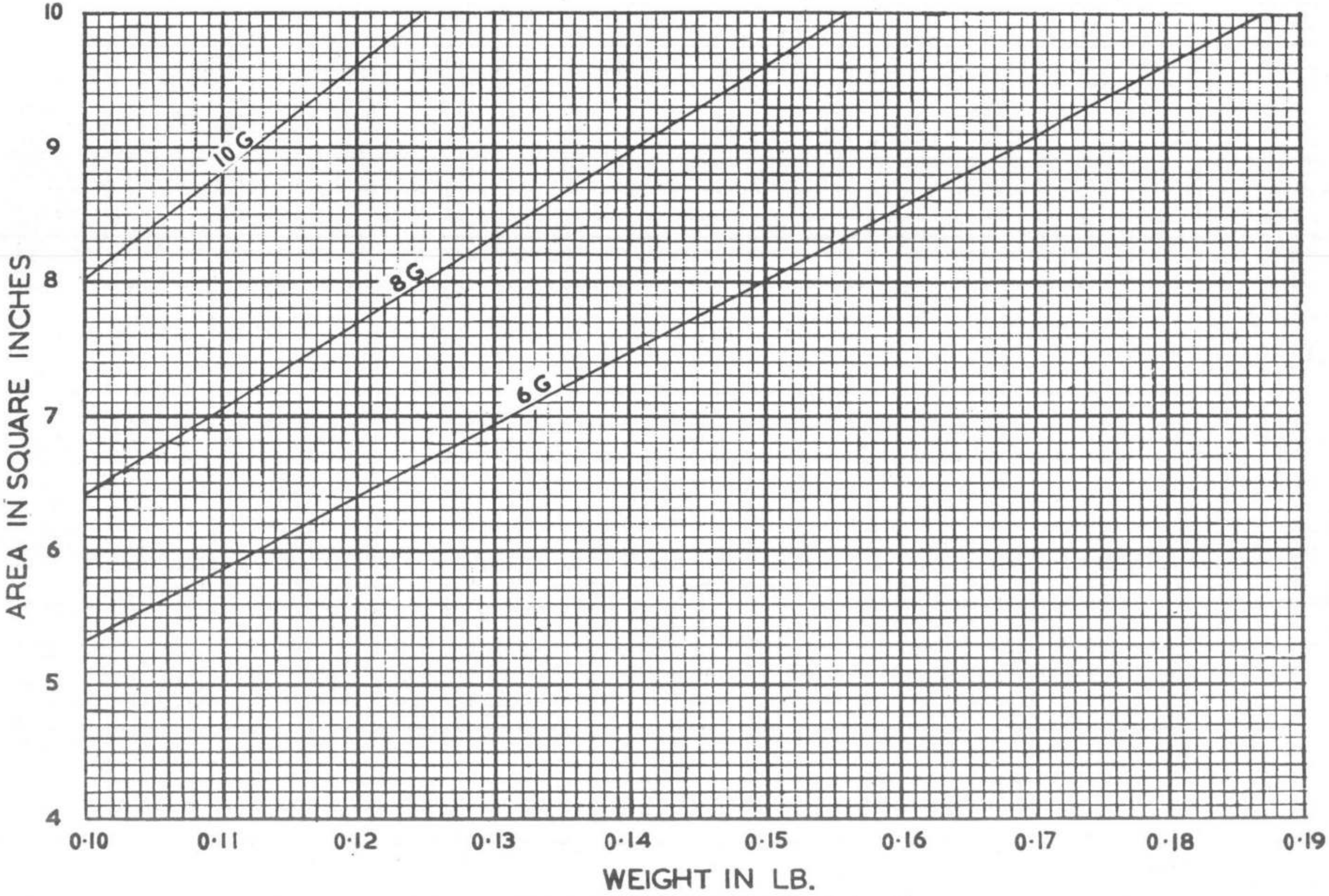


**Table 6. Weight of even s.w.g. ALUMINIUM sheet (2)**

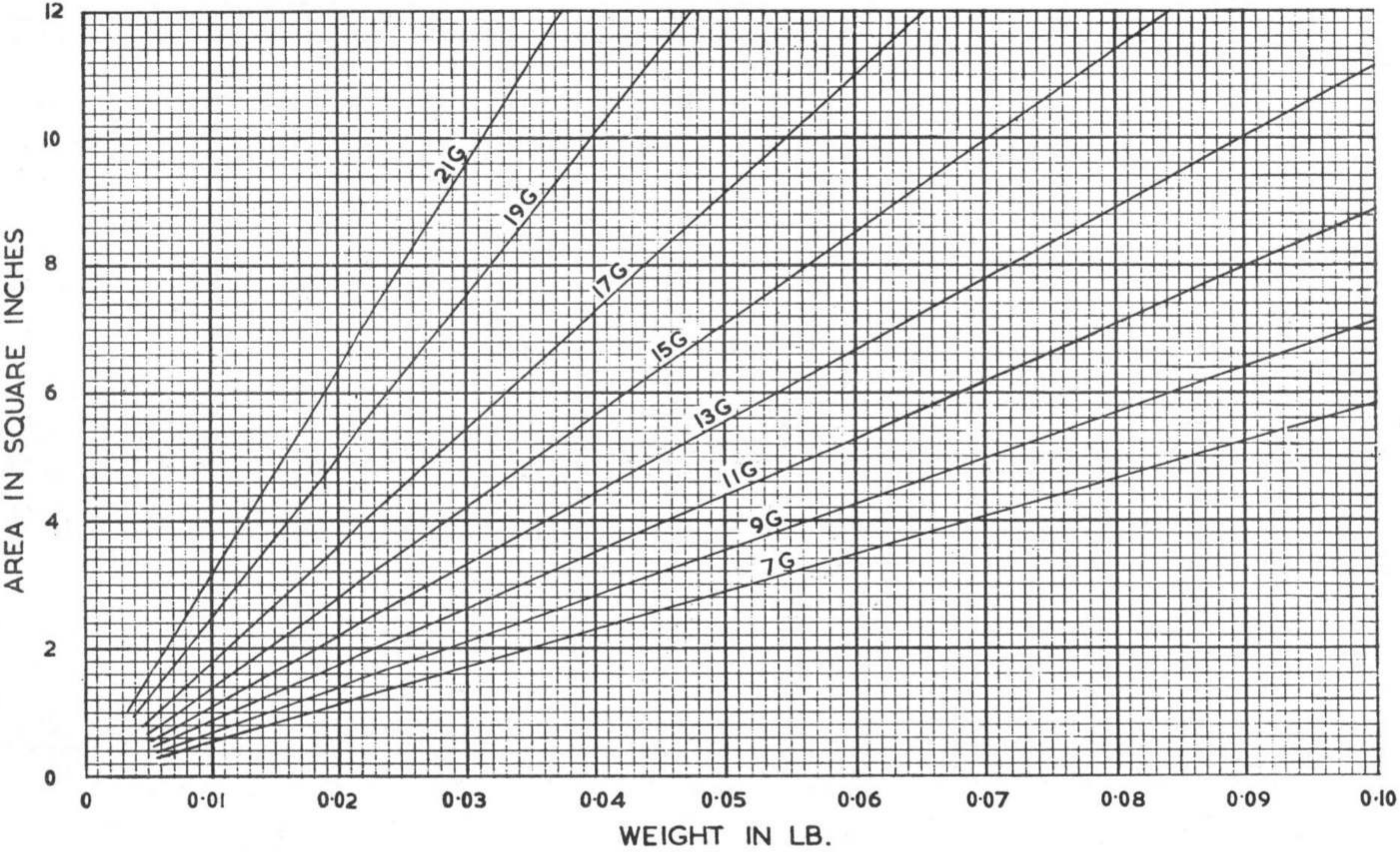


Table 7. Weight of odd s.w.g. ALUMINIUM sheet (1)

## WEIGHTS OF REPAIR MATERIALS—*continued*

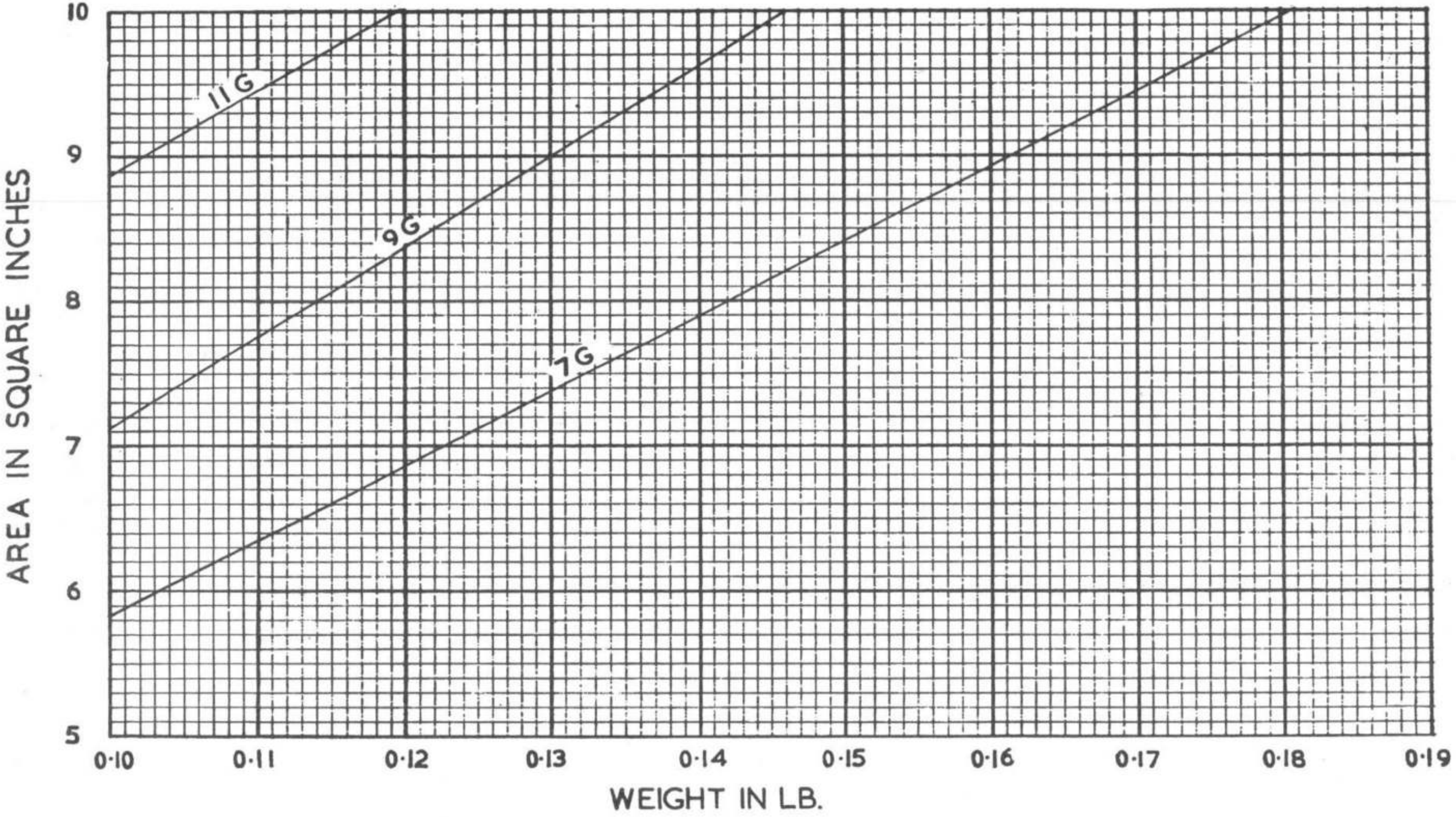


**Table 8. Weight of odd s.w.g. ALUMINIUM sheet (2)**

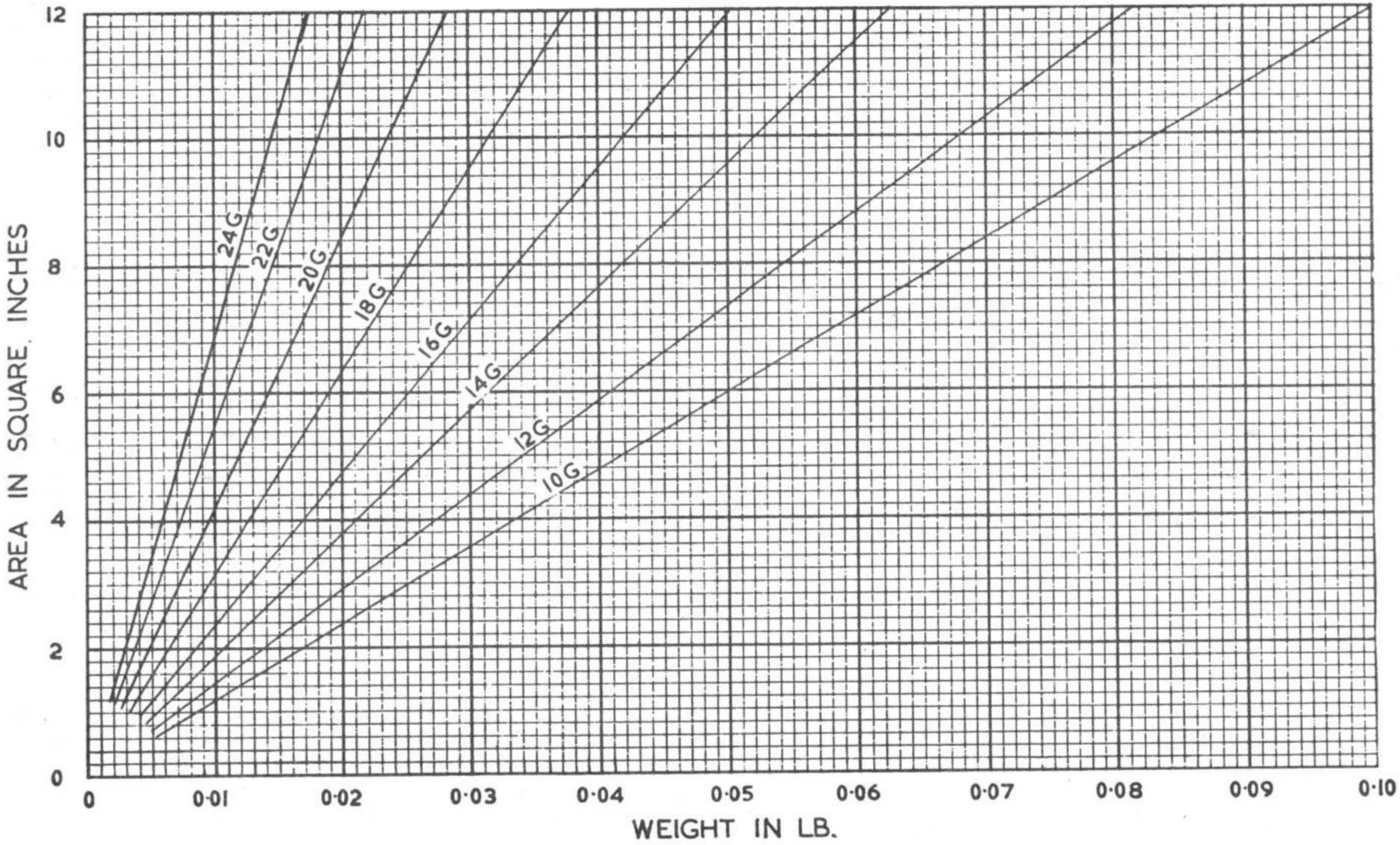


Table 9. Weight of even s.w.g. MAGNESIUM ALLOY sheet

**WEIGHTS OF REPAIR MATERIALS**—*continued*

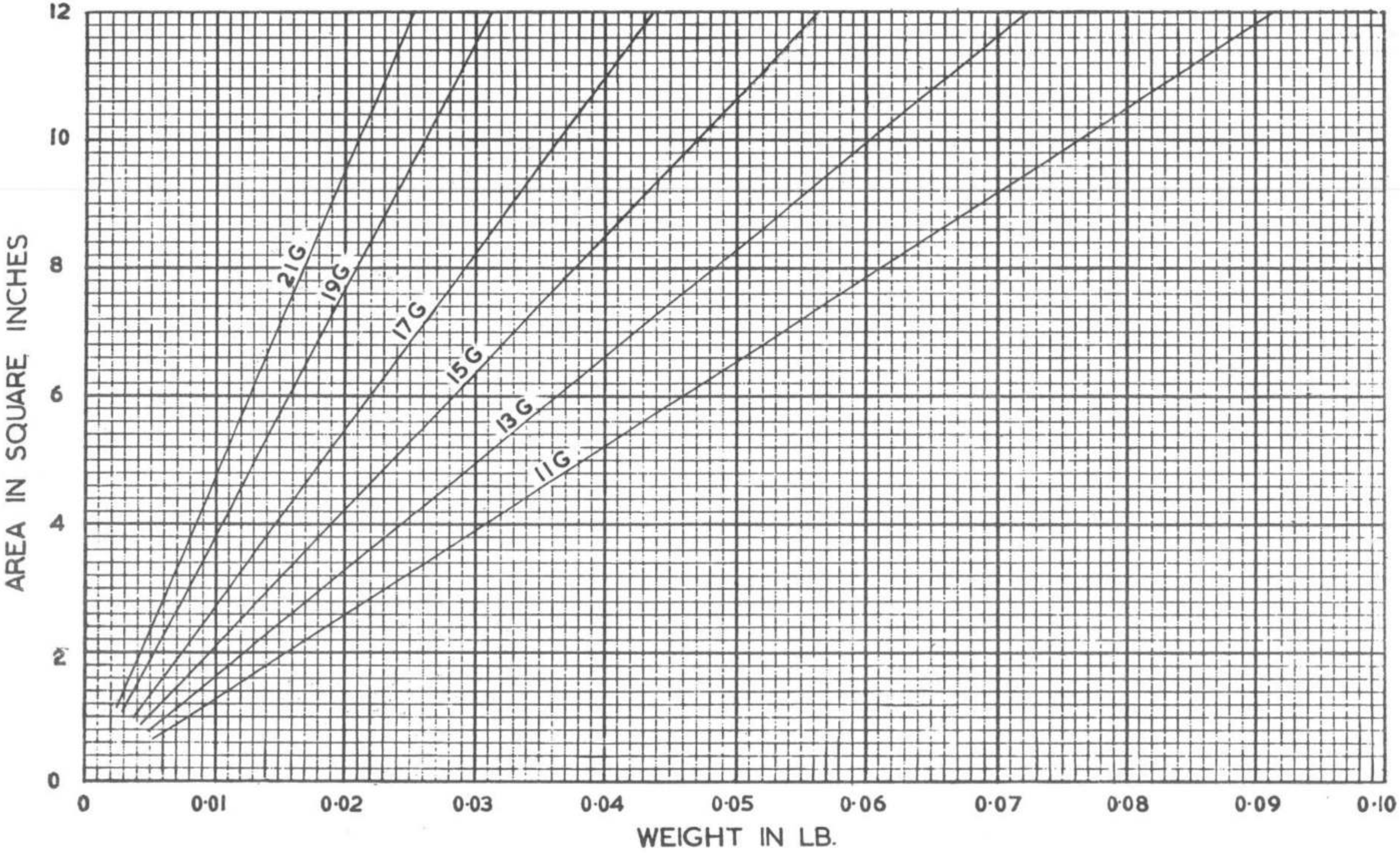
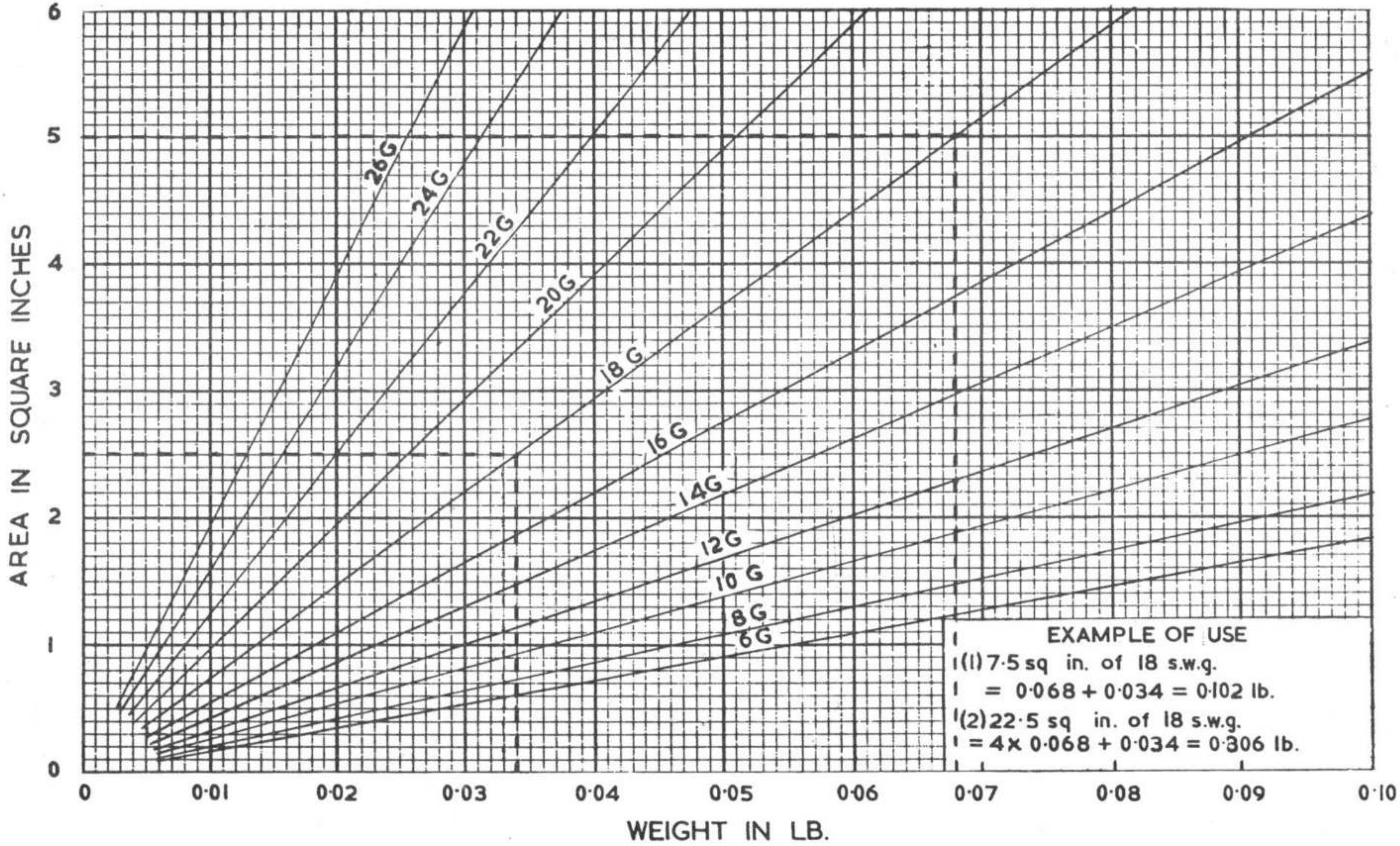


**Table 10. Weight of odd s.w.g. MAGNESIUM ALLOY sheet**



EXAMPLE OF USE

(1) 7·5 sq in. of 18 s.w.g.
= 0·068 + 0·034 = 0·102 lb.

(2) 22·5 sq in. of 18 s.w.g.
= 4× 0·068 + 0·034 = 0·306 lb.

**Table 11. Weight of even s.w.g. STEEL sheet**

WEIGHTS OF REPAIR MATERIALS—*continued*

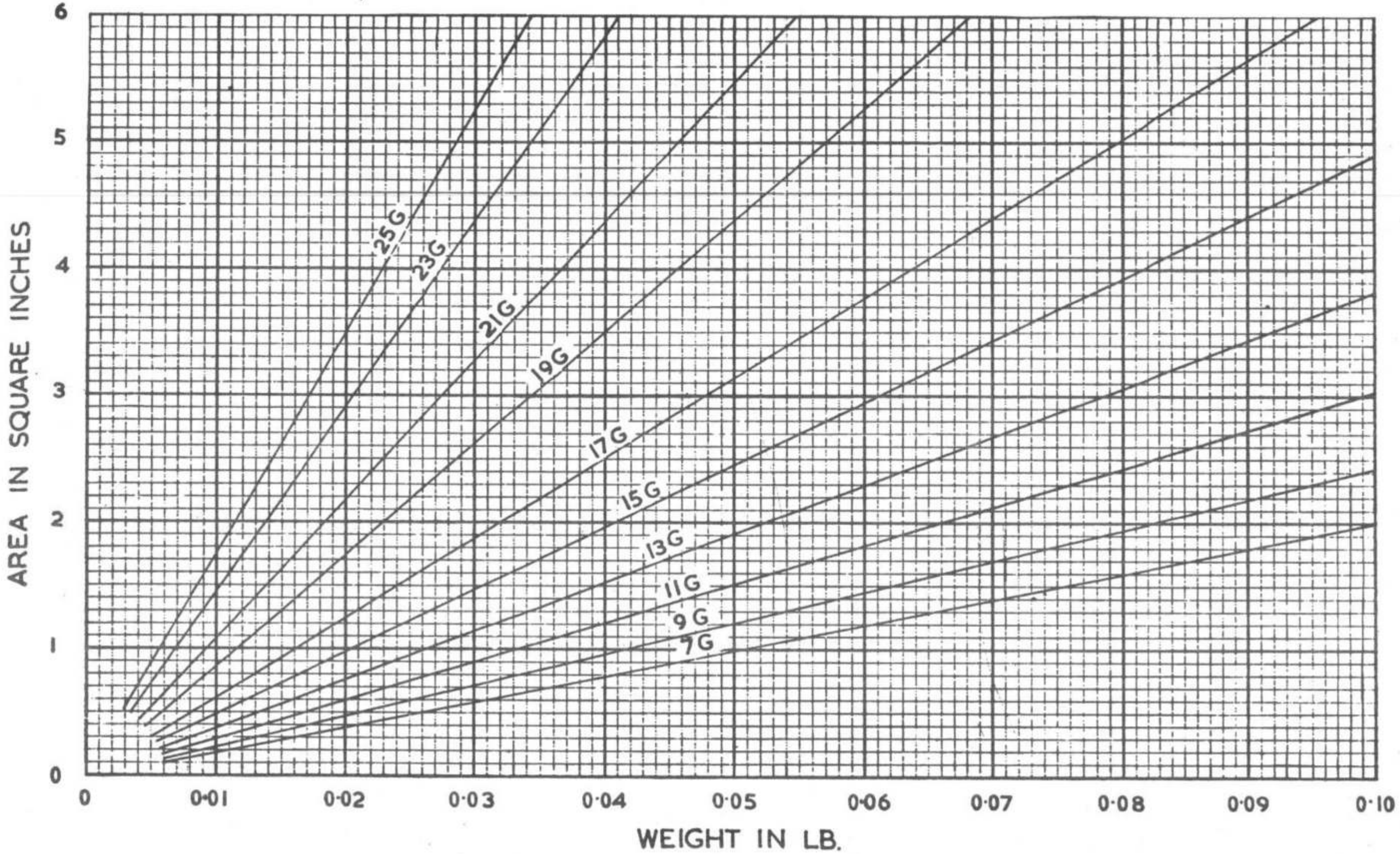


Table 12. Weight of odd s.w.g. STEEL sheet

| Dash No. | Grip range | | Weight (lb/1,000) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Flush head (100 deg) | | | Protruding head | | |
| | Min. | Max. | 100FH190 | 100FH249 | 100FH312 | PH190 | PH249 | PH312 |
| 2 | 0·094 | 0·156 | 3·47 | 6·97 | — | 5·25 | 9·10 | — |
| 3 | 0·156 | 0·219 | 3·82 | 7·89 | — | 5·39 | 9·98 | 16·9 |
| 4 | 0·219 | 0·281 | 4·26 | 8·80 | 14·5 | 5·88 | 10·75 | 18·3 |
| 5 | 0·281 | 0·344 | 4·75 | 9·72 | 16·0 | 6·34 | 11·80 | 20·1 |
| 6 | 0·344 | 0·406 | 5·20 | 10·64 | 17·8 | 6·74 | 12·47 | 21·6 |
| 7 | 0·406 | 0·469 | 5·66 | 11·55 | 19·2 | 7·31 | 13·30 | 22·9 |
| 8 | 0·469 | 0·531 | 6·18 | 12·47 | 21·0 | 7·78 | 14·14 | 25·0 |
| 9 | 0·531 | 0·594 | 6·63 | 13·39 | 23·0 | 8·25 | 14·98 | 26·6 |
| 10 | 0·594 | 0·656 | 7·13 | 14·31 | 24·3 | 8·69 | 15·80 | 28·1 |
| 11 | 0·656 | 0·719 | 7·59 | 15·23 | 25·9 | 9·16 | 16·63 | 29·5 |
| 12 | 0·719 | 0·781 | 8·05 | 16·15 | 27·5 | 9·55 | 17·46 | 31·0 |
| 13 | 0·781 | 0·844 | 8·51 | 17·07 | 29·1 | 10·00 | 18·29 | 32·0 |
| 14 | 0·844 | 0·906 | 8·97 | 17·99 | 30·7 | 10·68 | 19·12 | 33·0 |
| 15 | 0·906 | 0·969 | 9·43 | 18·91 | 32·3 | 11·15 | 19·95 | 34·5 |
| 16 | 0·969 | 1·031 | 9·89 | 19·83 | 33·9 | 11·62 | 20·78 | 36·0 |

**Table 13. Installed weights of steel Jo-bolts**

| Rivet dia (in.) | Rivet Code | Weight of set rivet (lb/1000) | |
|---|---|---|---|
| | | BS mandrel | BH mandrel |
| $\frac{3}{32}$ | TAP/320 | 0·210 | 0·120 |
| | 329 | 0·268 | 0·178 |
| $\frac{1}{8}$ | 414 | 0·380 | 0·203 |
| | 420 | 0·425 | 0·248 |
| | 423 | 0·448 | 0·271 |
| | 429 | 0·493 | 0·316 |
| | 435 | 0·538 | 0·361 |
| | 440 | 0·576 | 0·399 |
| $\frac{5}{32}$ | 518 | 0·721 | 0·328 |
| | 523 | 0·779 | 0·386 |
| | 529 | 0·849 | 0·456 |
| | 537 | 0·943 | 0·550 |
| | 545 | 1·024 | 0·631 |
| | 550 | 1·082 | 0·689 |
| $\frac{3}{16}$ | 625 | 1·323 | 0·820 |
| | 629 | 1·395 | 0·892 |
| | 635 | 1·504 | 1·001 |
| | 640 | 1·594 | 1·091 |
| | 649 | 1·757 | 1·254 |
| | 657 | 1·903 | 1·40 |
| | 665 | 2·047 | 1·544 |

Note . . . No weight difference exists between domed and countersunk heads.

**Table 14. Installed weights of aluminium alloy pop rivets**

| Rivet dia (in.) | Rivet code | Weight of set rivet (lb/1000) | |
|---|---|---|---|
| | | BS mandrel | BH mandrel |
| $\frac{7}{64}$ | TLP/319 | 0·582 | 0·430 |
| | 321 | 0·597 | 0·445 |
| $\frac{1}{8}$ | 413 | 0·722 | 0·487 |
| | 419 | 0·847 | 0·612 |
| | 424 | 0·900 | 0·665 |
| | 429 | 1·155 | 0·920 |
| | 435 | 1·160 | 0·925 |
| | 440 | 1·270 | 1·035 |
| $\frac{5}{32}$ | 519 | 1·275 | 0·858 |
| | 524 | 1·452 | 1·035 |
| | 530 | 1·552 | 1·135 |
| | 537 | 1·912 | 1·495 |
| | 540 | 1·927 | 1·510 |
| | 545 | 2·107 | 1·690 |
| $\frac{3}{16}$ | 624 | 2·534 | 1·680 |
| | 630 | 2·632 | 1·778 |
| | 636 | 2·939 | 2·085 |
| | 639 | 3·114 | 2·260 |
| | 650 | 3·639 | 2·785 |
| | 665 | 4·409 | 3·555 |
| | 675 | 4·784 | 3·930 |
| $\frac{1}{4}$ | 850 | 7·394 | 5·695 |
| | 870 | 9·064 | 7·366 |

Note . . . No weight difference exists between domed and countersunk heads.

**Table 15. Installed weights of monel metal pop rivets**

| Rivet dia (in.) | Rivet code | Weight of set rivet (lb/1000) | |
|---|---|---|---|
| | | BS mandrel | BH mandrel |
| $\frac{1}{8}$ | TSP/424 | 0·935 | 0·70 |
| | 429 | 1·030 | 0·795 |
| $\frac{5}{32}$ | 530 | 1·757 | 1·340 |
| $\frac{3}{16}$ | 636 | 2·899 | 2·130 |
| | 650 | 3·469 | 2·700 |

Note . . . No weight difference exists between domed and countersunk heads.

**Table 16. Installed weights of steel pop rivets**

| Rivet dia (in.) | Rivet code | Weight of set rivets (lb/1000) | |
|---|---|---|---|
| | | Short break mandrel | Long break mandrel |
| $\frac{1}{8}$ | 42 | 0·432 | Not available |
| | 44 | 0·482 | |
| | 46 | 0·533 | |
| | 48 | 0·584 | |
| | 410 | 0·635 | |
| $\frac{5}{32}$ | 54 | 0·857 | |
| | 56 | 0·930 | |
| | 510 | 1·076 | |
| $\frac{3}{16}$ | 64 | 1·322 | |
| | 68 | 1·552 | |
| | 612 | 1·780 | |

Note . . . No weight difference exists between domed and countersunk heads.

**Table 17. Installed weights of Imex aluminium alloy rivets**

## WEIGHTS OF REPAIR MATERIALS—*continued*

| | | Weight (lb/1000 rivets) | | | |
|---|---|---|---|---|---|
| | | Snap | | Countersunk | |
| Dia (in.) | A.G.S. and Avdel suffix | Max sheet thickness | Min sheet thickness | Max sheet thickness | Min sheet thickness |
| $\frac{1}{8}$ | 405 | 0·325 | 0·259 | 0·269 | 0·203 |
| | 407 | 0·400 | 0·334 | 0·344 | 0·278 |
| | 409 | 0·475 | 0·409 | 0·418 | 0·352 |
| | 411 | 0·550 | 0·484 | 0·493 | 0·427 |
| | 413 | 0·625 | 0·559 | 0·568 | 0·502 |
| | 415 | 0·700 | 0·634 | 0·644 | 0·578 |
| $\frac{5}{32}$ | 506 | 0·622 | 0·530 | 0·505 | 0·439 |
| | 508 | 0·743 | 0·651 | 0·628 | 0·532 |
| | 510 | 0·865 | 0·773 | 0·748 | 0·656 |
| | 512 | 0·988 | 0·896 | 0·872 | 0·780 |
| | 514 | 1·100 | 1·018 | 0·973 | 0·881 |
| | 516 | 1·231 | 1·139 | 1·113 | 1·021 |
| | 518 | 1·353 | 1·261 | 1·236 | 1·144 |
| | 520 | 1·474 | 1·382 | 1·359 | 1·267 |
| $\frac{3}{16}$ | 607 | 1·150 | 1·025 | 0·822 | 0·697 |
| | 609 | 1·331 | 1·206 | 1·004 | 0·879 |
| | 611 | 1·515 | 1·390 | 1·185 | 1·060 |
| | 613 | 1·695 | 1·570 | 1·368 | 1·243 |
| | 615 | 1·880 | 1·755 | 1·552 | 1·427 |
| | 617 | 2·062 | 1·937 | 1·735 | 1·610 |
| | 619 | 2·245 | 2·120 | 1·916 | 1·791 |
| | 621 | 2·430 | 2·305 | 2·097 | 1·972 |

Note . . . Weights above are given for rivets with their mandrels milled flush with the rivet heads.

**Table 18. Installed weights of Avdel rivets**

| | | Weight (lb/1000) | |
|---|---|---|---|
| | | BBH.104 | BBH.206<br>BBH.204 |
| Inside dia (in.) | Stroke No. | Aluminium alloy | Stainless iron and mild steel |
| $\frac{1}{8}$ | 04 | 0·23 | 0·638 |
| $\frac{3}{16}$ | 06 | 0·66 | 1·83 |
| $\frac{1}{4}$ | 08 | 1·35 | 3·75 |
| $\frac{5}{16}$ | 10 | 2·46 | 6·83 |
| $\frac{3}{8}$ | 12 | 4·05 | 11·23 |
| $\frac{7}{16}$ | 14 | 6·15 | 17·07 |
| $\frac{1}{2}$ | 16 | 8·94 | 24·80 |
| $\frac{9}{16}$ | 18 | 12·37 | 34·32 |
| $\frac{5}{8}$ | 20 | 16·72 | 46·47 |

**Table 19. Weights of Hi-shear collars**

| Maximum grip length (in.) | Second stroke number | First stroke number (pin diameter) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 06 ($\frac{3}{16}$ in.) | 08 ($\frac{1}{4}$ in.) | 10 ($\frac{5}{16}$ in.) | 12 ($\frac{3}{8}$ in.) | 14 ($\frac{7}{16}$ in.) | 16 ($\frac{1}{2}$ in.) | 18 ($\frac{9}{16}$ in.) | 20 ($\frac{5}{8}$ in.) |
| | | Weight (lb/1,000) | | | | | | | |
| $\frac{1}{8}$ | 02 | — | — | — | — | — | — | — | — |
| $\frac{3}{16}$ | 03 | 2·58 | — | — | — | — | — | — | — |
| $\frac{1}{4}$ | 04 | 3·06 | 6·08 | — | — | — | — | — | — |
| $\frac{5}{16}$ | 05 | 3·55 | 6·93 | 11·33 | — | — | — | — | — |
| $\frac{3}{8}$ | 06 | 4·03 | 7·78 | 12·68 | 21·69 | — | — | — | — |
| $\frac{7}{16}$ | 07 | 4·52 | 8·63 | 14·04 | 23·63 | 32·20 | — | — | — |
| $\frac{1}{2}$ | 08 | 5·00 | 9·48 | 15·39 | 25·56 | 34·80 | 47·20 | — | — |
| $\frac{9}{16}$ | 09 | 5·48 | 10·34 | 16·75 | 27·50 | 37·40 | 50·60 | 67·70 | — |
| $\frac{5}{8}$ | 10 | 5·97 | 11·19 | 18·11 | 29·44 | 40·00 | 54·00 | 72·10 | 92·00 |
| $\frac{11}{16}$ | 11 | 6·45 | 12·04 | 19·46 | 31·38 | 42·60 | 57·40 | 76·50 | 97·40 |
| $\frac{3}{4}$ | 12 | 6·94 | 12·89 | 20·82 | 33·32 | 45·20 | 60·80 | 80·90 | 102·80 |
| $\frac{13}{16}$ | 13 | 7·42 | 13·74 | 22·18 | 35·26 | 47·80 | 64·20 | 85·30 | 108·20 |
| $\frac{7}{8}$ | 14 | 7·91 | 14·59 | 23·53 | 37·20 | 50·40 | 67·60 | 89·70 | 113·60 |
| $\frac{15}{16}$ | 15 | 8·39 | 15·45 | 24·89 | 39·14 | 53·00 | 71·00 | 94·10 | 119·00 |
| 1 | 16 | 8·88 | 16·30 | 26·24 | 41·08 | 55·60 | 74·40 | 98·50 | 124·40 |
| $1\frac{1}{16}$ | 17 | 9·36 | 17·15 | 27·60 | 43·02 | 58·20 | 77·80 | 102·90 | 129·80 |
| $1\frac{1}{8}$ | 18 | 9·84 | 18·00 | 28·96 | 44·96 | 60·80 | 81·20 | 107·30 | 135·20 |
| $1\frac{3}{16}$ | 19 | 10·33 | 18·85 | 30·31 | 46·90 | 63·40 | 84·60 | 111·70 | 140·60 |
| $1\frac{1}{4}$ | 20 | 10·81 | 19·70 | 31·67 | 48·84 | 66·00 | 88·00 | 116·10 | 146·00 |
| $1\frac{5}{16}$ | 21 | 11·30 | 20·55 | 33·03 | 50·78 | 68·60 | 91·40 | 120·50 | 151·40 |
| $1\frac{3}{8}$ | 22 | 11·78 | 21·41 | 34·38 | 52·72 | 71·20 | 94·80 | 124·90 | 156·80 |
| $1\frac{7}{16}$ | 23 | 12·27 | 22·26 | 35·74 | 54·66 | 73·80 | 98·20 | 129·30 | 162·20 |
| $1\frac{1}{2}$ | 24 | 12·75 | 23·11 | 37·09 | 56·60 | 76·40 | 101·60 | 133·70 | 167·60 |
| $1\frac{9}{16}$ | 25 | 13·23 | 23·96 | 38·45 | 58·54 | 79·00 | 105·00 | 138·10 | 173·00 |
| $1\frac{5}{8}$ | 26 | 13·72 | 24·81 | 39·81 | 60·48 | 81·60 | 108·40 | 142·50 | 178·40 |
| $1\frac{11}{16}$ | 27 | 14·20 | 25·66 | 41·16 | 62·42 | 84·20 | 111·80 | 146·90 | 183·80 |
| $1\frac{3}{4}$ | 28 | 14·69 | 26·52 | 42·52 | 64·36 | 86·80 | 115·20 | 151·30 | 189·20 |
| $1\frac{13}{16}$ | 29 | 15·17 | 27·37 | 43·88 | 66·30 | 89·40 | 118·60 | 155·70 | 194·60 |
| $1\frac{7}{8}$ | 30 | 15·66 | 28·22 | 45·23 | 68·24 | 92·00 | 122·00 | 160·10 | 200·00 |

Note . . . Collar weights in Table 19

**Table 20. Weight of Hi-shear steel pins, countersunk heads**

## WEIGHTS OF REPAIR MATERIALS—*continued*

| Maximum grip length (in.) | Second stroke number (length) | First stroke number (pin diameter) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 06 ($\frac{3}{16}$ in.) | 08 ($\frac{1}{4}$ in.) | 10 ($\frac{5}{16}$ in.) | 12 ($\frac{3}{8}$ in.) | 14 ($\frac{7}{16}$ in.) | 16 ($\frac{1}{2}$ in.) | 18 ($\frac{9}{16}$ in.) | 20 ($\frac{5}{8}$ in.) |
| | | Weight (lb/1000) | | | | | | | |
| $1\frac{15}{16}$ | 31 | 16·14 | 29·07 | 46·59 | 70·18 | 94·60 | 125·40 | 164·50 | 205·40 |
| 2 | 32 | 16·63 | 29·92 | 47·94 | 72·12 | 97·20 | 128·80 | 168·90 | 210·10 |
| $2\frac{1}{16}$ | 33 | 17·11 | 30·77 | 49·30 | 74·05 | 99·80 | 132·20 | 173·30 | 216·20 |
| $2\frac{1}{8}$ | 34 | 17·59 | 31·63 | 50·66 | 75·99 | 102·40 | 135·60 | 177·70 | 221·60 |
| $2\frac{3}{16}$ | 35 | 18·08 | 32·48 | 52·01 | 77·93 | 105·00 | 139·00 | 182·10 | 227·00 |
| $2\frac{1}{4}$ | 36 | 18·56 | 33·33 | 53·37 | 79·87 | 107·60 | 142·40 | 186·50 | 232·40 |
| $2\frac{5}{16}$ | 37 | 19·05 | 34·18 | 54·73 | 81·81 | 110·20 | 145·80 | 190·90 | 237·80 |
| $2\frac{3}{8}$ | 38 | 19·53 | 35·03 | 56·08 | 83·75 | 112·80 | 149·20 | 195·30 | 243·20 |
| $2\frac{7}{16}$ | 39 | 20·02 | 35·88 | 57·44 | 85·69 | 115·40 | 152·60 | 199·70 | 248·60 |
| $2\frac{1}{2}$ | 40 | 20·50 | 36·73 | 58·79 | 87·63 | 118·00 | 156·00 | 204·10 | 254·00 |
| $2\frac{9}{16}$ | 41 | 20·99 | 37·58 | 60·15 | 89·57 | 120·60 | 159·40 | 208·50 | 259·40 |
| $2\frac{5}{8}$ | 42 | 21·48 | 38·43 | 61·51 | 91·51 | 123·20 | 162·80 | 212·90 | 264·80 |
| $2\frac{11}{16}$ | 43 | 21·97 | 39·28 | 62·87 | 93·45 | 125·80 | 166·20 | 217·30 | 270·20 |
| $2\frac{3}{4}$ | 44 | 22·46 | 40·13 | 64·23 | 95·39 | 128·40 | 169·60 | 221·70 | 275·60 |
| $2\frac{13}{16}$ | 45 | 22·95 | 40·98 | 65·59 | 97·33 | 131·00 | 173·00 | 226·10 | 281·00 |
| $2\frac{7}{8}$ | 46 | 23·44 | 41·83 | 66·95 | 99·27 | 133·60 | 176·40 | 230·50 | 286·40 |
| $2\frac{15}{16}$ | 47 | 23·93 | 42·68 | 68·31 | 101·21 | 136·20 | 179·80 | 234·90 | 291·80 |
| 3 | 48 | 24·42 | 43·53 | 69·67 | 103·15 | 138·80 | 183·20 | 239·30 | 297·20 |
| $3\frac{1}{16}$ | 49 | 24·91 | 44·38 | 71·03 | 105·09 | 141·40 | 186·60 | 243·70 | 302·60 |
| $3\frac{1}{8}$ | 50 | 25·40 | 45·23 | 72·39 | 107·03 | 144·00 | 190·00 | 248·10 | 308·00 |
| $3\frac{3}{16}$ | 51 | 25·89 | 46·08 | 73·75 | 108·97 | 146·60 | 193·40 | 252·50 | 313·40 |
| $3\frac{1}{4}$ | 52 | 26·38 | 46·93 | 75·11 | 110·91 | 149·20 | 196·80 | 256·90 | 318·80 |
| $3\frac{5}{16}$ | 53 | 26·87 | 47·78 | 76·47 | 112·85 | 151·80 | 200·20 | 261·30 | 324·20 |
| $3\frac{3}{8}$ | 54 | 27·36 | 48·63 | 77·83 | 114·79 | 154·40 | 203·60 | 265·70 | 329·60 |
| $3\frac{7}{16}$ | 55 | 27·85 | 49·48 | 79·19 | 116·73 | 157·00 | 207·00 | 270·10 | 335·00 |
| $3\frac{1}{2}$ | 56 | 28·34 | 50·33 | 80·55 | 118·67 | 159·60 | 210·40 | 274·50 | 340·40 |
| $3\frac{9}{16}$ | 57 | 28·83 | 51·18 | 81·91 | 120·61 | 162·60 | 213·80 | 278·90 | 315·80 |
| $3\frac{5}{8}$ | 58 | 29·32 | 52·03 | 83·27 | 122·55 | 164·80 | 217·20 | 283·30 | 351·20 |
| $3\frac{11}{16}$ | 59 | 29·81 | 52·88 | 84·63 | 124·49 | 167·40 | 220·60 | 287·70 | 356·60 |
| $3\frac{3}{4}$ | 60 | 30·30 | 53·73 | 85·99 | 126·43 | 170·00 | 224·00 | 292·10 | 362·00 |

(Note . . . Collar weights in Table 19)

**Table 20. Weight of Hi-shear steel pins, countersunk heads** (*continued*)

| Maximum grip length (in.) | Second stroke number length | First stroke number (pin diameter) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 06 ($\frac{3}{16}$ in.) | 08 ($\frac{1}{4}$ in.) | 10 ($\frac{5}{16}$ in.) | 12 ($\frac{3}{8}$ in.) | 14 ($\frac{7}{16}$ in.) | 16 ($\frac{1}{2}$ in.) | 18 ($\frac{9}{16}$ in.) | 20 ($\frac{5}{8}$ in.) |
| | | | | | Weight (lb/1000) | | | | |
| $\frac{1}{8}$ | 02 | 2·81 | 5·84 | 10·28 | 15·35 | 26·20 | 37·10 | 50·60 | 66·30 |
| $\frac{3}{16}$ | 03 | 3·30 | 6·70 | 11·64 | 17·29 | 28·80 | 40·50 | 55·00 | 71·70 |
| $\frac{1}{4}$ | 04 | 3·78 | 7·55 | 12·99 | 19·23 | 31·40 | 43·90 | 59·40 | 77·10 |
| $\frac{5}{16}$ | 05 | 4·27 | 8·40 | 14·35 | 21·17 | 34·00 | 47·30 | 63·80 | 82·50 |
| $\frac{3}{8}$ | 06 | 4·75 | 9·25 | 15·71 | 23·11 | 36·60 | 50·70 | 68·20 | 87·90 |
| $\frac{7}{16}$ | 07 | 5·23 | 10·10 | 17·06 | 25·05 | 39·20 | 54·10 | 72·60 | 93·30 |
| $\frac{1}{2}$ | 08 | 5·72 | 10·95 | 18·42 | 26·99 | 41·80 | 57·50 | 77·00 | 98·70 |
| $\frac{9}{16}$ | 09 | 6·20 | 11·80 | 19·78 | 28·93 | 44·40 | 60·90 | 81·40 | 104·10 |
| $\frac{5}{8}$ | 10 | 6·69 | 12·66 | 21·13 | 30·87 | 47·00 | 64·30 | 85·80 | 109·50 |
| $\frac{11}{16}$ | 11 | 7·17 | 13·51 | 22·49 | 32·80 | 49·60 | 67·70 | 90·20 | 114·90 |
| $\frac{3}{4}$ | 12 | 7·66 | 14·36 | 23·84 | 34·74 | 52·20 | 71·10 | 94·60 | 120·30 |
| $\frac{13}{16}$ | 13 | 8·14 | 15·21 | 25·20 | 36·68 | 54·80 | 74·50 | 99·00 | 125·70 |
| $\frac{7}{8}$ | 14 | 8·63 | 16·06 | 26·56 | 38·62 | 57·40 | 77·90 | 103·40 | 131·10 |
| $\frac{15}{16}$ | 15 | 9·11 | 16·91 | 27·91 | 40·56 | 60·00 | 81·30 | 107·80 | 136·50 |
| 1 | 16 | 9·59 | 17·77 | 29·27 | 42·50 | 62·60 | 84·70 | 112·20 | 141·90 |
| $1\frac{1}{16}$ | 17 | 10·08 | 18·62 | 30·63 | 44·44 | 65·20 | 88·10 | 116·60 | 147·30 |
| $1\frac{1}{8}$ | 18 | 10·56 | 19·47 | 31·98 | 46·38 | 67·80 | 91·50 | 121·00 | 152·70 |
| $1\frac{3}{16}$ | 19 | 11·05 | 20·32 | 33·34 | 48·32 | 70·40 | 94·90 | 125·40 | 158·10 |
| $1\frac{1}{4}$ | 20 | 11·53 | 21·17 | 34·69 | 50·26 | 73·00 | 98·30 | 129·80 | 163·50 |
| $1\frac{5}{16}$ | 21 | 12·02 | 22·02 | 36·05 | 52·20 | 75·60 | 101·70 | 134·20 | 168·90 |
| $1\frac{3}{8}$ | 22 | 12·50 | 22·88 | 37·41 | 54·14 | 78·20 | 105·10 | 138·60 | 174·30 |
| $1\frac{7}{16}$ | 23 | 12·98 | 23·73 | 38·76 | 56·08 | 80·80 | 108·50 | 143·00 | 179·70 |
| $1\frac{1}{2}$ | 24 | 13·47 | 24·58 | 40·12 | 58·02 | 83·40 | 111·90 | 147·40 | 185·10 |
| $1\frac{9}{16}$ | 25 | 13·95 | 25·43 | 41·48 | 59·96 | 86·00 | 115·30 | 151·80 | 190·50 |
| $1\frac{5}{8}$ | 26 | 14·44 | 26·28 | 42·83 | 61·90 | 88·60 | 118·70 | 156·20 | 195·90 |
| $1\frac{11}{16}$ | 27 | 14·92 | 27·13 | 44·19 | 63·84 | 91·20 | 122·10 | 160·60 | 201·30 |
| $1\frac{3}{4}$ | 28 | 15·41 | 27·98 | 45·54 | 65·78 | 93·80 | 125·50 | 165·00 | 206·70 |
| $1\frac{13}{16}$ | 29 | 15·89 | 28·84 | 46·90 | 67·72 | 96·40 | 128·90 | 169·40 | 212·10 |
| $1\frac{7}{8}$ | 30 | 16·38 | 29·69 | 48·26 | 69·69 | 99·00 | 132·30 | 173·80 | 217·50 |

Note . . . Collar weights in Table 19

**Table 21. Weight of Hi-shear steel pins, flat heads**

## WEIGHTS OF REPAIR MATERIALS—*continued*

| Maximum grip length (in.) | Second stroke number (length) | First stroke number (pin diameter) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 06 (3/16 in.) | 08 (1/4 in.) | 10 (5/16 in.) | 12 (3/8 in.) | 14 (7/16 in.) | 16 (1/2 in.) | 18 (9/16 in.) | 20 (5/8 in.) |
| | | | | | Weight (lb/1000) | | | | |
| 1 15/16 | 31 | 16·86 | 30·54 | 49·61 | 71·60 | 101·60 | 135·70 | 178·20 | 222·90 |
| 2 | 32 | 17·34 | 31·39 | 50·97 | 73·54 | 104·20 | 139·10 | 182·60 | 228·30 |
| 2 1/16 | 33 | 17·83 | 32·24 | 52·33 | 75·48 | 106·80 | 142·50 | 187·00 | 233·70 |
| 2 1/8 | 34 | 18·31 | 33·09 | 53·68 | 77·42 | 109·40 | 145·90 | 191·40 | 239·10 |
| 2 3/16 | 35 | 18·80 | 33·95 | 55·04 | 79·34 | 112·00 | 149·30 | 195·80 | 244·50 |
| 2 1/4 | 36 | 19·29 | 34·80 | 56·39 | 81·29 | 114·60 | 152·70 | 200·20 | 249·90 |
| 2 5/16 | 37 | 19·77 | 36·65 | 57·75 | 83·23 | 117·20 | 156·10 | 204·60 | 255·30 |
| 2 3/8 | 38 | 20·25 | 36·50 | 59·11 | 85·17 | 119·80 | 159·50 | 209·00 | 260·70 |
| 2 7/16 | 39 | 20·73 | 37·35 | 60·46 | 87·11 | 122·40 | 162·90 | 213·40 | 266·10 |
| 2 1/2 | 40 | 21·22 | 38·20 | 61·82 | 89·05 | 125·00 | 166·30 | 217·80 | 271·50 |
| 2 9/16 | 41 | 21·71 | 39·05 | 63·18 | 90·99 | 127·60 | 169·70 | 222·20 | 276·90 |
| 2 5/8 | 42 | 22·20 | 39·90 | 64·54 | 92·93 | 130·20 | 173·10 | 226·60 | 282·30 |
| 2 11/16 | 43 | 22·69 | 40·75 | 65·90 | 94·87 | 132·80 | 176·50 | 231·00 | 287·70 |
| 2 3/4 | 44 | 23·18 | 41·60 | 67·26 | 96·81 | 135·40 | 179·90 | 235·40 | 293·10 |
| 2 13/16 | 45 | 23·67 | 42·45 | 68·62 | 98·75 | 138·00 | 183·30 | 239·80 | 298·50 |
| 2 7/8 | 46 | 24·16 | 43·30 | 69·98 | 100·69 | 140·60 | 186·70 | 244·20 | 303·90 |
| 2 15/16 | 47 | 24·65 | 44·15 | 71·34 | 102·63 | 143·20 | 190·10 | 248·60 | 309·30 |
| 3 | 48 | 25·14 | 45·00 | 72·70 | 104·57 | 145·80 | 193·50 | 253·00 | 314·70 |
| 3 1/16 | 49 | 25·63 | 45·85 | 74·06 | 106·51 | 148·40 | 196·90 | 257·40 | 370·10 |
| 3 1/8 | 50 | 26·12 | 46·70 | 75·42 | 108·45 | 151·00 | 200·30 | 261·80 | 325·50 |
| 3 3/16 | 51 | 26·61 | 47·55 | 76·78 | 110·39 | 153·60 | 203·70 | 266·20 | 330·90 |
| 3 1/4 | 52 | 27·10 | 48·40 | 78·14 | 112·33 | 156·20 | 207·10 | 270·60 | 336·30 |
| 3 5/16 | 53 | 27·59 | 49·25 | 79·50 | 114·27 | 158·80 | 210·50 | 275·00 | 341·70 |
| 3 3/8 | 54 | 28·08 | 50·10 | 80·86 | 116·21 | 161·40 | 213·90 | 279·40 | 347·10 |
| 3 7/16 | 55 | 28·57 | 50·95 | 82·22 | 118·15 | 164·00 | 217·30 | 283·80 | 352·50 |
| 3 1/2 | 56 | 29·06 | 51·80 | 83·58 | 120·09 | 166·60 | 220·70 | 288·20 | 357·90 |
| 3 9/16 | 57 | 29·55 | 52·65 | 84·94 | 122·03 | 169·20 | 224·10 | 292·60 | 363·30 |
| 3 5/8 | 58 | 30·04 | 53·50 | 86·30 | 123·97 | 171·80 | 227·50 | 297·00 | 368·70 |
| 3 11/16 | 59 | 30·53 | 54·35 | 87·66 | 125·91 | 174·40 | 230·90 | 301·40 | 374·10 |
| 3 3/4 | 60 | 31·02 | 55·20 | 89·02 | 127·85 | 177·00 | 234·30 | 305·80 | 379·50 |

Note . . . Collar weight in Table 19

**Table 21. Weight of Hi-shear steel pins, flat heads** (*continued*)

| Dia. (in.) | A.G.S. Suffix No. | Length (in.) | Weight (lb/1000) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Snap head rivets | | Countersunk head rivets | | Sealing pins | |
| | | | Steel | Light alloy | Steel | Light alloy | Steel | Light alloy |
| $\frac{1}{8}$ | 404 | $\frac{1}{8}$ | 0·46 | 0·165 | 0·40 | 0·145 | 0·36 | 0·13 |
| | 406 | $\frac{3}{16}$ | 0·59 | 0·215 | 0·54 | 0·195 | 0·43 | 0·154 |
| | 408 | $\frac{1}{4}$ | 0·72 | 0·265 | 0·68 | 0·245 | 0·52 | 0·18 |
| | 410 | $\frac{5}{16}$ | 0·84 | 0·305 | 0·82 | 0·285 | 0·61 | 0·21 |
| $\frac{5}{32}$ | 504 | $\frac{1}{8}$ | 1·10 | 0·335 | 0·62 | 0·23 | 0·44 | 0·16 |
| | 506 | $\frac{3}{16}$ | 1·26 | 0·40 | 0·86 | 0·31 | 0·61 | 0·215 |
| | 508 | $\frac{1}{4}$ | 1·40 | 0·49 | 1·09 | 0·39 | 0·77 | 0·27 |
| | 510 | $\frac{5}{16}$ | 1·54 | 0·55 | 1·26 | 0·46 | 0·965 | 0·33 |
| | 512 | $\frac{3}{8}$ | 1·68 | 0·62 | 1·46 | 0·525 | 1·13 | 0·385 |
| | 514 | $\frac{7}{16}$ | 1·87 | 0·69 | 1·64 | 0·595 | 1·295 | 0·436 |
| $\frac{3}{16}$ | 605 | $\frac{5}{32}$ | 1·3 | 0·48 | 1·20 | 0·41 | 0·98 | 0·37 |
| | 607 | $\frac{7}{32}$ | 1·63 | 0·58 | 1·50 | 0·51 | 1·24 | 0·45 |
| | 609 | $\frac{9}{32}$ | 1·93 | 0·68 | 1·83 | 0·62 | 1·53 | 0·55 |
| | 611 | $\frac{11}{32}$ | 2·23 | 0·78 | 2·13 | 0·72 | 1·80 | 0·64 |
| | 613 | $\frac{13}{32}$ | 2·53 | 0·88 | 2·43 | 0·83 | 2·05 | 0·72 |
| | 615 | $\frac{15}{32}$ | 2·85 | 0·98 | 2·70 | 0·93 | 2·30 | 0·80 |
| | 617 | $\frac{17}{32}$ | 3·12 | 1·08 | 3·05 | 1·03 | 2·60 | 0·90 |
| | 619 | $\frac{19}{32}$ | 3·47 | 1·18 | 3·37 | 1·13 | 2·85 | 0·98 |
| | 621 | $\frac{21}{32}$ | 3·75 | 1·28 | 3·67 | 1·23 | 3·10 | 1·05 |
| $\frac{1}{4}$ | 807 | $\frac{7}{32}$ | 2·72 | 0·94 | 2·32 | 0·78 | 2·50 | 1·00 |
| | 809 | $\frac{9}{32}$ | 3·15 | 1·10 | 2·82 | 0·94 | 3·05 | 1·14 |
| | 811 | $\frac{11}{32}$ | 3·63 | 1·25 | 3·32 | 1·10 | 3·52 | 1·25 |
| | 813 | $\frac{13}{32}$ | 4·05 | 1·40 | 3·82 | 1·26 | 3·98 | 1·38 |
| | 815 | $\frac{15}{32}$ | 4·56 | 1·58 | 4·32 | 1·42 | 4·44 | 1·52 |
| | 817 | $\frac{17}{32}$ | 4·98 | 1·73 | 4·82 | 1·58 | 4·98 | 1·65 |
| | 819 | $\frac{19}{32}$ | 5·50 | 1·88 | 5·32 | 1·74 | 5·42 | 1·78 |
| | 821 | $\frac{21}{32}$ | 5·98 | 2·05 | 5·82 | 1·90 | 5·90 | 1·90 |
| | 823 | $\frac{23}{32}$ | 6·38 | 2·20 | 6·32 | 2·06 | 6·35 | 2·04 |
| | 825 | $\frac{25}{32}$ | 6·88 | 2·38 | 6·82 | 2·22 | 6·75 | 2·18 |
| $\frac{5}{16}$ | 1009 | $\frac{9}{32}$ | 5·38 | 1·88 | 4·05 | 1·44 | 4·00 | 1·32 |
| | 1011 | $\frac{11}{32}$ | 6·25 | 2·18 | 4·85 | 1·74 | 4·60 | 1·52 |
| | 1013 | $\frac{13}{32}$ | 6·98 | 2·46 | 5·70 | 2·04 | 5·17 | 1·70 |
| | 1017 | $\frac{17}{32}$ | 8·65 | 3·00 | 7·35 | 2·63 | 6·50 | 2·12 |

**Table 22. Weights of Chobert rivets and sealing pins**

## WEIGHTS OF REPAIR MATERIALS—*continued*

| Length (in.) | Weight (lb/1000 rivets) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\frac{1}{16}$ in. dia | $\frac{3}{32}$ in. dia | $\frac{1}{8}$ in. dia | $\frac{5}{32}$ in. dia | $\frac{3}{16}$ in. dia | $\frac{7}{32}$ in. dia | $\frac{1}{4}$ in. dia | $\frac{5}{16}$ in. dia | $\frac{3}{8}$ in. dia |
| $\frac{1}{8}$ | 0·0608 | — | — | — | — | — | — | — | — |
| $\frac{3}{16}$ | 0·0807 | 0·210 | 0·410 | — | — | — | — | — | — |
| $\frac{1}{4}$ | 0·1010 | 0·250 | 0·490 | 0·810 | 1·243 | — | — | — | — |
| $\frac{5}{16}$ | 0·1208 | 0·300 | 0·570 | 0·930 | 1·450 | 2·050 | — | — | — |
| $\frac{3}{8}$ | 0·1398 | 0·340 | 0·650 | 1·060 | 1·620 | 2·292 | 3·240 | 5·580 | — |
| $\frac{7}{16}$ | 0·1594 | 0·380 | 0·730 | 1·180 | 1·800 | 2·531 | 3·550 | 6·066 | 9·530 |
| $\frac{1}{2}$ | 0·1810 | 0·430 | 0·810 | 1·300 | 1·980 | 2·770 | 3·870 | 6·590 | 10·230 |
| $\frac{9}{16}$ | 0·2002 | 0·470 | 0·890 | 1·430 | 2·160 | 3·009 | 4·180 | 7·080 | 11·000 |
| $\frac{5}{8}$ | 0·2195 | 0·520 | 0·970 | 1·550 | 2·340 | 3·248 | 4·500 | 7·580 | 11·700 |
| $\frac{11}{16}$ | 0·2400 | 0·560 | 1·040 | 1·670 | 2·510 | 3·487 | 4·820 | 8·070 | 12·400 |
| $\frac{3}{4}$ | 0·2590 | 0·610 | 1·120 | 1·800 | 2·690 | 3·726 | 5·130 | 8·560 | 13·100 |
| $\frac{13}{16}$ | 0·2790 | 0·650 | 1·200 | 1·920 | 2·870 | 3·965 | 5·450 | 9·060 | 13·800 |
| $\frac{7}{8}$ | 0·2950 | 0·690 | 1·280 | 2·040 | 3·050 | 4·204 | 5·760 | 9·560 | 14·500 |
| $\frac{15}{16}$ | 0·3210 | 0·740 | 1·360 | 2·170 | 3·220 | 4·443 | 6·080 | 10·050 | 15·300 |
| 1 | 0·3405 | 0·780 | 1·440 | 2·290 | 3·400 | 4·682 | 6·400 | 10·540 | 16·000 |
| $1\frac{1}{8}$ | — | 0·870 | 1·600 | 2·540 | 3·760 | 5·160 | 7·030 | 11·530 | 17·400 |
| $1\frac{1}{4}$ | — | 0·960 | 1·750 | 2·780 | 4·110 | 5·638 | 7·660 | 12·510 | 18·800 |
| $1\frac{3}{8}$ | — | 1·050 | 1·910 | 3·030 | 4·470 | 6·116 | 8·290 | 13·500 | 20·200 |
| $1\frac{1}{2}$ | — | 1·100 | 2·070 | 3·280 | 4·820 | 6·594 | 8·920 | 14·500 | 21·700 |
| $1\frac{3}{4}$ | — | — | 2·363 | — | — | 7·550 | 10·055 | 16·300 | 24·230 |
| 2 | — | — | — | — | — | — | 11·295 | 18·260 | 27·030 |
| Weight of both rivet heads only | 0·050 | 0·160 | 0·370 | 0·710 | 1·240 | 1·740 | 2·670 | 5·320 | 9·260 |

Note . . Weights given above are for rivets to A.S. 156 and A.S. 158. The following conversion factors may be used to find the weights of rivets in other materials.

| | *Conversion factor* |
|---|---|
| Aluminium A.S. 155... ... ... ... ... ... | 0·96 |
| Light alloy A.S. 157, A.S. 159, A.S. 2227, A.S. 2228 ... | 0·936 |
| Mild steel A.S. 455 ... ... ... ... ... ... | 2·790 |

**Table 23. Weights of snap-head and mushroom-head solid rivets**

| Length (in.) | Weight (lb/1000 rivets) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\frac{1}{16}$ in. dia | $\frac{3}{32}$ in. dia | $\frac{1}{8}$ in. dia | $\frac{5}{32}$ in. dia | $\frac{3}{16}$ in. dia | $\frac{7}{32}$ in. dia | $\frac{1}{4}$ in. dia | $\frac{5}{16}$ in. dia | $\frac{3}{8}$ in. dia |
| $\frac{1}{8}$ | 0·0476 | — | — | — | — | — | — | — | — |
| $\frac{3}{16}$ | 0·0668 | 0·160 | 0·280 | — | — | — | — | — | — |
| $\frac{1}{4}$ | 0·8720 | 0·200 | 0·370 | 0·610 | 0·916 | — | — | — | — |
| $\frac{5}{16}$ | 0·1074 | 0·250 | 0·450 | 0·730 | 1·090 | 1·817 | — | — | — |
| $\frac{3}{8}$ | 0·1277 | 0·290 | 0·530 | 0·850 | 1·260 | 2·044 | 2·360 | 3·886 | — |
| $\frac{7}{16}$ | 0·1470 | 0·340 | 0·610 | 0·980 | 1·440 | 2·271 | 2·680 | 4·373 | 6·570 |
| $\frac{1}{2}$ | 0·1570 | 0·380 | 0·690 | 1·100 | 1·620 | 2·498 | 2·990 | 4·860 | 7·270 |
| $\frac{9}{16}$ | 0·1880 | 0·420 | 0·770 | 1·230 | 1·800 | 2·725 | 3·310 | 5·350 | 7·970 |
| $\frac{5}{8}$ | 0·2130 | 0·470 | 0·850 | 1·350 | 1·970 | 2·952 | 3·630 | 5·850 | 8·680 |
| $\frac{11}{16}$ | 0·2172 | 0·510 | 0·930 | 1·470 | 2·150 | 3·179 | 3·940 | 6·340 | 9·390 |
| $\frac{3}{4}$ | 0·2475 | 0·560 | 1·010 | 1·600 | 2·330 | 3·406 | 4·260 | 6·830 | 10·100 |
| $\frac{13}{16}$ | 0·2677 | 0·600 | 1·090 | 1·720 | 2·510 | 3·633 | 4·570 | 7·330 | 10·800 |
| $\frac{7}{8}$ | 0·2880 | 0·650 | 1·160 | 1·840 | 2·690 | 3·860 | 4·900 | 7·820 | 11·500 |
| $\frac{15}{16}$ | 0·3072 | 0·690 | 1·240 | 1·970 | 2·860 | 4·087 | 5·200 | 8·320 | 12·200 |
| 1 | 0·3245 | 0·740 | 1·320 | 2·090 | 2·940 | 4·314 | 5·500 | 8·810 | 13·000 |
| $1\frac{1}{8}$ | — | 0·820 | 1·480 | 2·340 | 3·400 | 4·768 | 6·150 | 9·780 | 14·400 |
| $1\frac{1}{4}$ | — | 0·910 | 1·640 | 2·580 | 3·750 | 5·222 | 6·780 | 10·800 | 15·800 |
| $1\frac{3}{8}$ | — | 1·000 | 1·800 | 2·830 | 4·110 | 5·676 | 7·420 | 11·800 | 17·200 |
| $1\frac{1}{2}$ | — | 1·100 | 1·950 | 3·080 | 4·460 | 6·130 | 8·050 | 12·800 | 18·600 |
| $1\frac{3}{4}$ | — | — | 2·260 | — | — | 7·038 | 9·290 | 14·748 | 21·400 |
| 2 | — | — | — | — | — | — | 10·630 | 16·696 | 24·200 |
| Weight of reaction head only | 0·025 | 0·085 | 0·200 | 0·400 | 0·680 | 0·870 | 1·600 | 3·200 | 5·700 |

Note . . . Weights given above are for rivets to A.S. 161 and A.S. 164. The following conversion factors may be used to find the weights of rivets in other materials.

| | *Conversion factor* |
|---|---|
| Aluminium A.S. 160, A.S. 163 ... ... ... ... | 0·96 |
| Light alloy A.S. 162, A.S. 165, A.S. 2229, A.S. 2230 ... | 0·936 |
| Mild steel A.S. 460, A.S. 463 ... ... ... ... | 2·790 |

**Table 24. Weights of countersunk-head solid rivets**

WEIGHTS OF REPAIR MATERIAL—*continued*

| Length (in.) | Weight (lb/1000 rivets) | | | | | |
|---|---|---|---|---|---|---|
| | $\frac{3}{32}$ in. dia | $\frac{1}{8}$ in. dia | $\frac{5}{32}$ in. dia | $\frac{3}{16}$ in. dia | $\frac{7}{32}$ in. dia | $\frac{1}{4}$ in. dia |
| $\frac{3}{16}$ | 0·142 | — | — | — | — | — |
| $\frac{1}{4}$ | 0·186 | 0·365 | 0·593 | — | — | — |
| $\frac{5}{16}$ | — | 0·442 | — | — | — | — |
| $\frac{11}{32}$ | — | 0·481 | — | — | — | — |
| $\frac{3}{8}$ | — | 0·520 | 0·834 | 1·237 | 1·718 | — |
| $\frac{7}{16}$ | — | 0·598 | 0·954 | — | — | — |
| $\frac{1}{2}$ | 0·362 | 0·676 | 1·074 | 1·585 | 2·186 | 2·827 |
| $\frac{9}{16}$ | — | 0·754 | 1·194 | — | — | — |
| 1 | — | 1·302 | 2·034 | 2·977 | 4·058 | 4·315 |
| Weight of head only | 0·083 | 0·190 | 0·364 | 0·620 | 0·840 | 1·340 |

**Note** . . . **Weights given for aluminium alloy rivets to A.S. 2918 and A.S. 2919.** Conversion factor for rivets to **A.S. 3362 and A.S. 3363** is 0·936

**Table 25. Weights of close tolerance solid rivets**

★ ★ ★

# Chapter 1.5 RECORDING OF REPAIRS

## LIST OF CONTENTS

# INTRODUCTION

**Application**

**1.** The information contained in subsequent schemes in this chapter relates to special cases for which recording of repairs is required on or adjacent to the repairs on the actual aircraft. This is usually due to the imposition of limitations such as minimum permissible distance between repairs in a given component or assembly, or maximum permissible number of repairs in a given component.

**Standard recording on aircraft**

**2.** For R.N. aircraft, a recording procedure exists for certain repairs effected at Aircraft Yards and Store Depot Workshops in the U.K. In this procedure, letters are stamped on repaired components to indicate firstly, the type of approval given to the schemes that have been used and, secondly, to identify the Repair Unit concerned. The instructions for this procedure are contained in A.P. (N) 140.

**Documentary recording**

**3.** The instructions for the recording of repairs in aircraft servicing documents and for the correct maintenance of these documents are given in Vol. 2, Sect. C of A.P.3158, R.A.F. Technical Services Manual for R.A.F. aircraft and in A.P. (N) 140 for R.N. aircraft.

★ ★ ★

# 1.5.2

## RECORDING OF FIBREGLASS REPAIRS

### Limitations on repairs

**1.** In many instances, repairs to fibreglass laminates do not restore the structure to its original strength because of the lack of continuity of the glass cloth, particularly in the outer lamination of a flush repair, and sometimes because cold-curing of the resin does not produce the same strength as the oven-curing usually applied during construction. Therefore, it is often necessary for limitations to be imposed on the maximum size and depth (i.e., the number of laminations) and on the total number of repairs and the minimum spacing in any one component. More stringent limitations may be necessary on radomes due to the need for minimum interference with radar signals.

**2.** The information on limitations is specific to each aircraft and is given in the aircraft Vol. 6. When limitations are imposed on a structure, details of previous repairs must be known before a new repair is attempted. Since, for obvious reasons, determination of the depth and often the location and extent of previous repairs is almost impossible by examination of the wetted surface, recording is required on the inner surface of a component when *spacing* or *total number* limitations apply.

### Recording of repairs

**3.** Repairs are recorded in white paint on the inner surfaces of components which have wetted surfaces. Paint, Stores Ref. 33B/1059, to specification D.T.D.772, is suitable and, in the case of radomes, this or a similar *non-metallic* paint must be used. A line, approximately $\frac{1}{8}$ in. wide, is painted on the inner surface of the component to enclose an area corresponding to that of the largest patch. In the top left quadrant of this area, a large 'R' is painted to indicate 'repair'. The remaining abbreviations should be smaller in size. The letters 'FG' and, if appropriate, 'C' are placed in the top right quadrant, 'E' and/or 'I' in the bottom left, and the number of laminations affected in each, in the bottom right quadrant (*e.g.*, *3 lams.*), opposite to the relevant letter. In the case of structure inside the aircraft, when the terms 'internal' and 'external' are not directly appropriate, 'I' refers to the face on which the record is painted.

The abbreviations are as follows:—

| | |
|---|---|
| R | Repair |
| FG | Fibreglass laminations |
| C | Core (of sandwich-type construction) |
| E | External surface (of aircraft) |
| I | Internal surface |
| X | Complete insert |

The term 'X' is used when the damage completely penetrates the structure and is repaired by the use of a prefabricated insert. The record would only consist of the white line, and the letters R and X unless, due to the chamfer on the insert edges, it should be necessary to indicate the face on which the largest cut-out occurred. In this case, the letter E or I would be needed.

**Note . . .**

*The additional recording required on radomes when the neoprene finish is repaired subsequent to fibreglass repairs, is given in Scheme 9.4.1 of this publication.*

★ ★ ★

# Chapter 1.6 FLY-IN REPAIR SCHEMES

## LIST OF CONTENTS

# FLY-IN REPAIR SCHEME POLICY

### Requirement for schemes

**1.** Fly-in repair schemes are not published automatically in Vol. 6 for all types of aircraft. The size of the aircraft and its major components, transport facilities, anticipated theatres of operation of the aircraft in service, general repair policy and other factors are considered before a decision is reached on the need for a fly-in repair scheme. As examples, there would be an almost automatic requirement for a medium or heavy bomber but, at the other extreme, the fly-in scheme could be unnecessary in the case of a small trainer aircraft intended for use solely on "circuits and bumps" at one or two home stations. When the need for a fly-in repair scheme for a particular type of aircraft is established, the scheme is issued in the relevant aircraft A.P., Vol. 6, Part 1, Chap. 8.

### Purpose

**2.** Fly-in repair schemes are issued to provide guidance and assistance during consideration of damage to aircraft to which the cases of para. 3 apply, in:—

(1) The rapid assessment of the feasibility of repairs to fly-in standards.

(2) The assessment of materials and equipment (including general engineering items) and man hours required if repairs to fly-in standards are possible.

(3) The actual repair of the aircraft to the reduced standards required for a single flight under restricted flight conditions.

### Application to aircraft

**3.** The schemes are applied when damaged aircraft cannot be repaired to normal standards on site and are to be flown, under restricted flight conditions, to bases which either have the necessary facilities for repairs to full normal standards or at which these facilities can be made available. This procedure may be necessary for aircraft on which the damage is only local, in addition to the usual cases of extensive damage due to belly landings and other similar arisings. The circumstances in which fly-in repairs apply are as follows:—

(1) Emergency cases such as those of damaged aircraft on airfields, temporary landing strips or clearings in forward positions open to attack, from which the aircraft must be removed as soon as possible.

(2) Damaged aircraft on airfields to which transport of components or equipment required for repairs to normal standards is impossible due to the size of the items or for geographical reasons.

(3) Damaged aircraft on airfields to which the necessary components and labour could be transported but it is considered to be more economical overall to fly-in to a suitably equipped base.

(4) Cases of small aircraft which could be dismantled for transport to a base, but where fly-in would again be more economical or the transport system is inadequate or overloaded.

### Limitations of use of fly-in schemes

**4.** Repairs to lower standards and other concessions are only permissible because the aerodynamic, inertia and landing loads on the aircraft in the restricted flight and A.U.W. conditions imposed for the fly-in flight are considerably smaller than the loads arising from normal flight conditions. *For this reason, repairs and concessions, either individually or collectively, SPECIFIC to fly-in repair schemes MUST NOT be applied to any aircraft, even as a temporary measure, except for the purpose of a flight under the limited flight and A.U.W. conditions quoted in the fly-in repair scheme, or under satisfactory alternative limited conditions defined by the appropriate specialist officer.*

★ ★ ★

# FLY-IN REPAIR SCHEME CONTENTS

### Location in aircraft Vol. 6

**1.** The fly-in repair scheme is contained in the relevant aircraft A.P., Vol. 6, Part 1, Chap. 8. To emphasise that information in the scheme must not be applied to aircraft for any purpose other than that of a fly-in flight, the marker card (usually blue) is different in colour from the other Vol. 6 chapter markers (orange) and bears the following warning:—

**WARNING . . .**

*The information in this chapter is provided for the sole purpose of preparing an aircraft for a flight to a base or depot where the repair facilities necessary to restore the aircraft to the fully serviceable condition are available.*

*Temporary repairs and extended negligible damage quoted in this chapter MUST NOT be applied to aircraft required to perform normal flights.*

*The fly-in flight must take place in calm weather conditions and the aircraft must be flown in gentle manoeuvres only. The all up weight of the aircraft and its maximum speeds in flight must not exceed those quoted in this chapter under the heading of FLIGHT CONDITIONS.*

### Limitations of use

**2.** The extent to which the published scheme is used for a particular aircraft will be decided by the appropriate specialist officer. Although the scheme is devised to cover a range of contingencies, all cases cannot be covered and, because of this and also because detailed repairs are not usually given, the responsibility for approval of any repairs or negligible damage must devolve upon the officer on the spot. His sources of reference may, in addition to the Vol. 6, Part 1, Chap. 8, be the Loading and C.G. Data and dismantling and assembly instructions in the aircraft A.P., Vol. 1, the Type Record and A.P.970.

## CONTENTS

**3.** The extent and nature of the contents depends upon factors such as the size and operational functions of the aircraft but, in general, the following basic headings are used if applicable:—

**1. FLIGHT CONDITIONS**
**2. OPERATIONAL EQUIPMENT THAT CAN BE REMOVED:**
  **(1) WITHOUT BALLAST ADJUSTMENT**
  **(2) WITH BALLAST ADJUSTMENT**
**3. MINIMUM RUNWAY REQUIREMENTS**
**4. STRENGTH CONCESSIONS**
**5. AREAS OR COMPONENTS TO WHICH NO DAMAGE IS ACCEPTABLE**
**6. EXTENDED NEGLIGIBLE AND REPAIRABLE DAMAGE**

The detailed contents with explanations and precautions are as follows:—

### 1. FLIGHT CONDITIONS

#### (1) All-up weight

##### (a) *Maximum permissible all-up weight*

This is the stressing weight for the published fly-in repair scheme and whenever possible, is chosen to be attainable without the need for C.G. calculations and ballasting (2.(1)). *Unless otherwise stated, the aircraft must be reduced to, or below, this weight prior to flight if ANY relaxed condition sanctioned in the fly-in repair scheme is applied.*

This weight is used whenever possible because the least amount of work is involved.

##### (b) *Reduced maximum A.U.W.*

If applicable, reduced maximum values are quoted for special conditions such as take-off on three engines.

##### (c) *Minimum possible A.U.W.*

This is the weight to which the aircraft is reduced if all normally removable items as quoted in the Loading and C.G. Data in Vol. 1 and also all items listed in 2.(2) are removed. This weight is used when near-maximum range or minimum take-off distance is necessary, or when normal runway length is available, but the required take-off distance is substantially increased due to decreased lift or thrust or to increased drag. It is also used when strength relaxations in excess of those quoted or inferred in the published scheme are essential.

#### (2) Speed

##### (a) *Maximum permissible speed*

This speed is equal to twice the stalling speed, flaps up, at the maximum permissible A.U.W. and *must not be exceeded when the aircraft is at the maximum permissible weight if the relaxations in the published fly-in repair scheme are applied.*

##### (b) *Reduced maximum speeds*

If applicable, maximum permissible speeds lower than the value at (2)(*a*) are quoted for special conditions (for example—*undercarriage locked down*), when higher speeds might introduce the risk of loss of control or of further indirect damage due to lifting of panels, vibration, or other similar causes.

##### (c) *Increased maximum speeds*

If practicable, a table or graph of speed against A.U.W. is given, commencing with the *maximum permissible speed*, (2)(*a*), at the *maximum permissible A.U.W.*, (1)(*a*), and showing the in-

## FLY-IN REPAIR SCHEME CONTENTS (*Continued*)

creased maximum speeds permissible as the A.U.W. is decreased, until the *minimum possible A.U.W.*, (1)(*c*), is reached. The increased speeds corresponding to the decreased weights are only permissible if the strength standards are maintained at the level of the published scheme.

The main uses of the increased speeds are:—

(i) To enable the flight to be made in the minimum possible time in order to take advantage of calm weather conditions or

(ii) to enable a more economical speed to be used—twice stalling speed may be much lower than the most economical speed, particularly for jet engined aircraft.

**Note . . .**

*It must be clearly understood that these increased speeds do not apply when the A.U.W. is reduced below the maximum permissible weight for the purpose of using lower strength standards than those given in Chap. 8.*

**(3) Fuel load and ranges**

The fuel load in gallons or pounds as appropriate, the tanks to be used, and alternative arrangements if damage affects parts of the fuel system (including instructions for isolating damaged parts) are given.

The ranges applicable to the fuel load under different fly-in flight conditions are listed. The ranges include the best and worst combinations of A.U.W. and speed, with the aircraft clean, with undercarriage and flaps locked down, and with and without pressurisation. It is not to be expected that every possible combination of circumstances will be included, but the effect on range of the omission of large items such as bomb doors, or of flight with one or more engines out of action, or of other large aerodynamic or thrust disturbances should be covered.

**(4) Special conditions**

Information is provided on permissible special conditions that may arise from the fly-in case. Examples of the basic arisings are:—

One or more engines out of action (including pre-flight removal of propeller(s) from affected engine(s) )
Undercarriage locked down, jury strutted
Flaps locked at optimum angle

All services not essential for the fly-in flight are quoted. This includes items in 2 (below) and all other items and systems which, although remaining in the aircraft, need not be made serviceable. Any special precautions required due to unserviceability of these services are stated. Examples of these services are:—

Cabin pressurising, cabin conditioning, oxygen, electrics, hydraulics and pneumatics, bomb doors, powered controls if manual is acceptable, radio, radar, armament, instruments, safety equipment.

### 2 OPERATIONAL EQUIPMENT THAT CAN BE REMOVED: (1) WITHOUT BALLAST ADJUSTMENT AND (2) WITH BALLAST ADJUSTMENT

This heading covers items, as in 1 (4), normally regarded as fixed equipment and therefore not included in the Loading and C.G. Data in Vol. 1.

**(1) Equipment removable without adjustment**

Whenever possible, the items quoted are those that, when removed in conjunction with all normal removable items not required for the flight, will cause the A.U.W. to be reduced to that at 1.(1) (*a*), providing a safe C.G. range for the flight without recourse to calculations and ballasting. If possible, sufficient items are given to allow for choice of removal under different circumstances of damage, and essential combinations of the items to be removed or left *in situ* are stated.

If it is impossible to meet this case without ballast adjustment, different headings will be used but every attempt will be made to present a condition for which a single statement of ballast adjustment is satisfactory, again without the need for calculations.

**(2) Equipment removable with ballast adjustment**

This list is as comprehensive as possible and weights and moments are given. The items in 2.(1) are included. Removal of all of these items, in conjunction with all normal removable items will reduce the aircraft to the *minimum possible A.U.W.*

Notes on precautions and restrictions and method of use of the information in conjunction with the Vol. 1 Data or other forms of Loading and C.G. determination are given.

### 3. MINIMUM RUNWAY REQUIREMENTS

These consist of a table of requirements at different weights within the *maximum permissible*, with the aircraft in the clean take-off condition and also for cases when thrust, drag or lift are affected due to take-off on three engines, to increased frontal area due to jury struts, or to omission of bomb doors, locking of flaps or other similar causes. The requirements are given for both grass and hard runways.

### 4. STRENGTH CONCESSIONS

The basic strength requirements are given in A.P.970, Vol. 2, Leaflet 804/2. In the fly-in scheme, Table 1 of Leaflet 804/2 is reproduced with specific values inserted in the third column as appropriate. Two additional columns, the first containing the relevant full normal design strength standards and the second the A.U.W. and speeds corresponding to the normal cases, are included in the table.

### 5. AREAS OR COMPONENTS TO WHICH NO DAMAGE IS ACCEPTABLE

If appropriate, illustrations, with keys, are used to indicate these areas and components, distinction being made between items that must be renewed and those that can be made serviceable if Vol. 6, Part 1 or 2 permanent repairs (or full strength temporary repairs in Chap. 8) are effected.

### 6. EXTENDED NEGLIGIBLE AND REPAIRABLE DAMAGE

#### (1) Extended negligible damage, structure

Tables or statements defining all extended negligible damage to the structure under the relaxed strength conditions are provided. These include extensions of the dimensions of normal negligible damage (dents, nicks, scores, holes, etc.), related to the existing Chap. 1 tables if suitable, plus additional negligible damage such as omission of panels, omission of one or more items in a "group" (ribs, frames, floor struts, stringers, rivets or bolts, etc.), damaged attachments, etc.

#### (2) Temporary repairs to structure

Guidance is provided for temporary repairs to the structure, permissible due to the reduced ultimate and gust factors, A.U.W. and maximum speed. Typical examples are given and tables used if necessary.

#### (3) Extended negligible damage, aerodynamic surfaces

Tables or statements defining extended negligible damage to aerodynamic surfaces, including definitions of acceptable degrees of distortion, are given.

#### (4) Temporary repairs to aerodynamic surfaces

This item includes guidance on temporary repairs, with examples if necessary, and notes on the incorporation of external patch repairs.

#### Notes on Item 6

(a) With regard to item 6, particular attention is paid to temporary repair of damage arising from:—

*Heavy landings*
*One main undercarriage collapsed*
*Both main undercarriages collapsed*
*Nose undercarriage collapsed*
*Belly landings*
*Barrier or obstruction crashes*
*Damage due to freight loading mishaps (air and ground)*

(b) Maximum use is made of the Structure Classification in the normal repair chapters, by direct and general references.

(c) Extended alternative materials are quoted and, where heavy gauge section is concerned, the minimum acceptable gauge for temporary repair is also given. Whenever possible, the use of material requiring heat treatment is avoided. For example, L.72 or D.T.D.610 and close tolerance versions to similar specifications, or steel to specifications such as S.1, is quoted to replace D.T.D.687. The use of general engineering materials and equipment is included if possible. Materials, such as angle iron, rolled steel joists, plywood, wooden frames, fabric and wire, can often be adapted to replace either structural members or fairing.

(d) Where appropriate, the application of a temporary repair may be made conditional upon the completion of an existing approved repair scheme elsewhere in the structure.

★ ★ ★


J-1712