Section 4

LOADING, C.G. AND FATIGUE INDEX DATA

CONTENTS

WEIGHING THE AIRCRAFT

ILLUSTRATION

LOADING AND C.G. DATA

1. This Section deals with the effect of different loads upon the fore-and-aft positions of the aircraft centre of gravity. The C.G. position is determined with the aircraft in the rigging position (fuselage datum line horizontal) and is found by taking moments about a fixed point known as the 'C.G. datum point'. For general information on aircraft weighing, C.G. determination and loading refer to AP 119W Series.

Datum point

2. The position of the datum point is arbitrarily selected by the manufacturer and is marked on the port side of the fuselage.

Positive and negative moments

3. The distance of each load from the datum point is known as its 'moment arm'. The loads are measured in pounds and the moment arms in inches. If a load lies forward of the datum point, its moment arm is negative and, therefore, the resultant moment is negative. Conversely, the moments of loads and moment arms aft of the datum are positive.

Method of calculating the C.G. position

4. The C.G. is determined from the following expression :-

$$\frac{\text{(Basic Wt. x basic moment arm) + (Wt. of loads x respective moment arms)}}{\text{Basic wt. + Total Wt. of loads}}$$

$$= \frac{\text{Basic moment + Load moments}}{\text{Total Wt.}}$$

The C.G. range

5. The approved limits of travel of the C.G. are shown in Table 3 and Fig.1. The C.G. must always be kept within this range, even when the fuel and oil are wholly or partially expended.

Basic weight items

6. The weights, moment arms and moments of the items included in the Basic Weight are given in Fig.1.

TABLE 1

	Weight (lb.)	Arm (in.)	Moment (lb. in.)
TYPICAL BASIC WEIGHT, ARM AND MOMENT	1,532	-4.602	- 7,050
Variable load (with one pilot)			
Pilot and Parachute (front cockpit)	235	0	0
Luggage (maximum available locker capacity)	40	50.0	2,000
OPERATING WEIGHT WITH ONE PILOT	1,807	-2.795	- 5,050
Variable load (with two pilots)			
Pilot and Parachute (front cockpit)	235	0	0
Pilot and Parachute (rear cockpit)	235	33.6	7,896
Luggage (maximum available locker capacity)	0	50.0	0
OPERATING WEIGHT WITH TWO PILOTS	2,002	0.423	846
Expendable load			
Full fuel, 20 gal. at 7.2 lb./gal.	144	-12.0	- 1,728
Full oil , 2 gal. at 9.0 lb./gal.	18	-45.6	- 821

TABLE 2

Typical basic weight includes:-

Map cases
Control locks
First aid kit
* U.H.F. transmitter receiver PTR.170
Or V.H.F.transmitter receiver TR.1998
* U.H.F. control unit (front)
Or V.H.F. control unit (front)
* U.H.F. control unit (rear)
** Batteries (2)
Or Battery
Starter cartridges
Fire Extinguisher
Pilot's harness
All instruments including blind flying panels and compasses
Radio mountings connector sets and aerial

* U.H.F. PTR.170 system is included in the typical Basic Weight, arm and moment shown in Table 1.

** Two batteries are included in the typical Basic Weight, arm and moment shown in Table 1.

TABLE 3

Weight and C.G. limits

Maximum permissible weight for:-
Take-off, landing and aerobatics (post mod H-319) 2,200 lb.
Take-off, landing and aerobatics (pre mod H-319) 2,100 lb.
Forward C.G. limit 6.48 in. forward of C.G.datum
Aft C.G. limit 0.257 in. aft of C.G.datum

Luggage Locker load

With 1 pilot maximum load 40 lb. *
With 2 pilots (at 235 lb.) no luggage may be carried in the locker (See Loading example Para.9).
Luggage locker moment arm 50.0 in. aft of C.G.datum
* Control locks (1.5 lb.), if carried, comprise part of the maximum locker load.

BASIC WEIGHT

7. The basic weight and moment includes all items of equipment listed in Table 2 and takes account of modifications H:-

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	19	21	22
23	24	25	26	27	28	29	31	36	37
40	41	42	43	44	45	46	47 pt.	49	52
53	54	55	56	57	58	59	61	63	64
65	66	67	69	70	71	72	73	74	75
76	77	78	80	81	82B	83	84	86	92
93	96	97	98	99	100	104	106	108	109
111	113	116	117	118	119	120	121	122	123
125	126	129	132	133	135	136	139	141	142
146	147	148	156	157	158	159	167	168	169
170	172	173	177	179	180	181	182	184	185
186	188	189	190	191	192	193	194	195 pt.	198
199	206	207	208	212	218RH	221	223	225	229
231	233	237	240	242	244	248	251	252	255
258	259	261	262	263	264	269	273	275	277
278	280	282	283	284	286	288	289	297	319
Com.Mod.		2	3	6	9	10	11	13	15
	17	19	21	22	23	24	25	27	28
SRIM	1102	2260	3465						

TYPICAL LOADING EXAMPLES

8. In the following paragraphs, calculations are given for the Weight and C.G. position under possible conditions of variations of loading.

9. With 2 pilots and no luggage in the locker

	Weight (lb.)	Moment (lb.in.)
Operating Weight (Table 1)	2002	846
Add		
Fuel	144	-1728
Oil	18	- 821
Total Weight and Moment at Take Off	2164	-1703

C.G. position at Take Off $\frac{-1703}{2164}$ = -0.787 ins. (i.e. 0.787 ins. forward of C.G. datum)

The consumption of all fuel and part oil modifies the C.G. as follows:-

	2164	-1703
Deduct		
Fuel	- 144	1728
Consumed oil	- 9	410
	2011	435

C.G. position with all fuel and part oil consumed $\frac{435}{2011}$ = +0.216 ins. (i.e. 0.216 ins. aft of C.G. datum)

Note ... The consumption of fuel and oil moves the C.G. rearwards.

10. With 1 pilot and no luggage in the locker

	Weight (lb.)	Moment (lb.in.)
Operating Weight (Table 1)	1807	-5050
Deduct		
Luggage	- 40	-2000
Add		
Fuel	144	-1728
Oil	18	- 821
Total Weight and Moment at Take Off	1929	-9599

C.G. position at Take Off $\frac{-9599}{1929}$ = -4.976 ins. (i.e. 4.976 ins. forward of C.G. datum)

The consumption of all fuel and part oil modifies the C.G. as follows:-

	1929	-9599
Deduct		
Fuel	- 144	1728
Consumed Oil	- 9	410
	1776	-7461

C.G. position with all fuel and part oil consumed $\frac{-7461}{1776}$ = -4.201 ins. (i.e. 4.201 ins. forward of C.G. datum)

11. With 1 pilot and luggage locker full

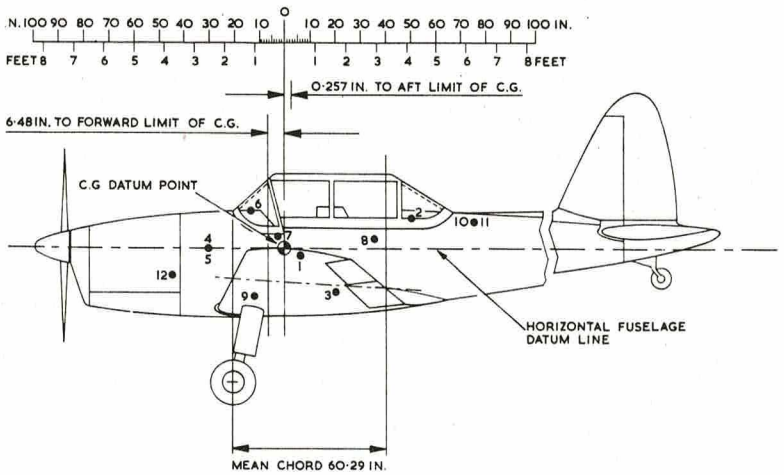
	Weight (lb.)	Moment (lb.ins.)
Operating Weight (Table 1)	1807	-5050
Add		
Fuel	144	-1728
Oil	18	- 821
Total Weight and Moment at Take Off	1969	-7599

C.G. position at Take Off $\frac{-7599}{1969}$ = -3.859 ins. (i.e. 3.859 ins. forward of C.G. datum)

The consumption of all the fuel and part oil modifies the C.G. as follows:-

	1969	-7599
Deduct		
Fuel	- 144	1728
Consumed oil	- 9	410
	1816	-5461

C.G. position with all fuel and part oil consumed $\frac{-5461}{1816}$ = -3.007 ins. (i.e. 3.007 ins. forward of C.G. datum)



Item No.	Item	Weight (lb)	Arm (in)	Moment (lb. in)
1	Map cases	2.0	3.0	6
2	Control locks (if carried)	1.5	50.0	75
3	First aid kit	1.0	20.0	20
4	U.H.F. T.R. PTR.170	23.0	-30.7	-707
5	(or V.H.F. T.R. 1998)	(26.4	-31.8	-840)
6	U.H.F. Control unit (front)	1.3	-16.0	- 20
7	(or V.H.F. Control unit (front)	(0.6	- 3.0	- 2)
8	U.H.F. Control unit (rear)	1.3	36.0	45
9	Fire extinguisher 27N-299	5.4	-11.2	- 60
10	Batteries (2 Monobloc insert)	41.5	78.0	3237
11	(or Battery type J)	(40.65	78.0	3171)
12	Starter cartridges (6)	0.5	-45.6	- 23

Fig.1 Equipment weights, arms and moments

FATIGUE INDEX DATA

INTRODUCTION

General

12. Every aircraft suffers fatigue damage and because of this each type of aircraft is given a safe fatigue life at which it must either be retired from service or modified to permit further flying. The consumption of fatigue life must be monitored as each aircraft is flown to ensure that the declared safe fatigue life is not exceeded.

Fatigue index (RAF aircraft only)

13. Fatigue life consumption is measured in terms of the consumption of 'Fatigue index' (FI) which is a non-dimensional number, calculated either from fatigue meter readings or by assessment of the sortie flown; the methods of calculation are described in the following paragraphs.

Units of fatigue life measurement (RN aircraft only)

14. Prior to the fitment of a fatigue meter, the units of fatigue consumption for this aircraft was stated in basic hours which were assessed by factoring the flying hours according to the sortie pattern flown. This produced a result in units called 'basic hours'. The fatigue formula devised for processing fatigue meter readings produces results in units called 'fatigue hours' which are directly compatible with basic hours so that the total fatigue life consumed is both obtained by adding basic hours to fatigue hours. The resultant measure of total fatigue life consumed is, for convenience, considered to be in units of fatigue hours.

Assessing fatigue life consumption

15. The fatigue life consumed is calculated by reading the fatigue meter counters at periodic intervals, subtracting the 'before' and 'after' readings to determine the counts recorded during the interval, and substituting these values in the fatigue formula. One type of aircraft may have several formulae to cover different all-up weights or operating patterns, or the fitment of different types of fatigue meter.

Unmetered flying

16. If the aircraft does not have a fatigue meter fitted, or an installed meter is unserviceable, fatigue consumption is assessed from the details of the sortie flown and is dependent upon the types of aircraft manoeuvres and the theatre of operations. Fatigue consumption assessed in this way is always greater than the more accurate consumption figures calculated from fatigue meter readings.

Recording of fatigue data

17. Instructions for the recording of fatigue data and references to the forms to be used are given in AP 3158 Vol 2 Leaflet C6 (for the RAF and Army Air Corp) and in AP (N) 140 ART 0502 (for the RN). The following general instructions and precautions apply to all recording of fatigue data :

(1) The aircraft captain is responsible for completing the sortie details, while servicing personnel are responsible for reading fatigue meters (where fitted) and for recording the information. All personnel responsible for the collection and compilation of fatigue data must appreciate the need for accuracy and legibility of the entries. Careless or incomplete recording is dangerous if it causes a less damaging sortie to be assumed: it is wasteful if, in the interests of safety, the worst case has to be assumed. In extreme cases, continued careless or incomplete recording can result in the expensive premature retirement of an aircraft from service because of doubt regarding the true situation.

(2) All personnel responsible for reading fatigue meters are to be familiar with, and are to apply, the serviceability checks described in AP 112G-0203-1, Chapter 2, 'Fatigue Meters', and the associated AD 112G-0203-D1. In particular, the validity of fatigue meter readings is to be checked either before any fatigue life calculations are taken at the unit or before the appropriate forms are despatched from the unit for fatigue life calculations to be performed elsewhere. The replacement of unserviceable meters is to be regarded as a high priority task.

(3) The unit engineering record section is to retain or dispose of completed forms in accordance with the appropriate single-service instructions.

Refining of fatigue index

18. When the fatigue records for an aircraft show that it has consumed 80% of its fatigue life action is to be taken in accordance with AP 3158 Vol 2 Leaflet C6 or AP (N) 140 ART 0502 as appropriate.

Action on fitment of a new fatigue meter

19. When a fatigue meter is fitted or replaced, a new form is to be started and the readings from the counters of the meter to be fitted are to be recorded in the 'B/F' line of the fatigue calculation sheet. The checks specified in AP 112G-0203-1- Chap 2 are to be applied after three flights have been completed with a new or replacement meter installed.

APPLICATION

Extent of fatigue damage

20. A complete re-assessement of the Chipmunk fatigue life has been made and the resultant analysis has shown that fatigue damage is more severe than previously estimated, especially during supposedly non-aerobatic flying.

Calculation of fatigue life

21. Fatigue lives of all components are given in fatigue hours. These are obtained by multiplying the hours flown in a given role by the appropriate role factor. When calculating or re-assessing fatigue life, information must be obtained from aircraft record cards and appropriate role factors applied for the periods spent at each type of unit. In the absence of such information, fatigue consumption rate of 1000 fatigue hours per year is to be used.

Role factors

22. Role factors have been allocated as follows for all flying :-

Employment	Factor
Central Flying School	4.0
University Air Squadrons	3.0
Flying Training Schools	2.0
Air experience flights	1.6

...continued

Employment	Factor
R.A.F. College	1.6
Apprentice Training Schools	1.6
Gatow, Chivenor and other STC Units with flying pattern similar to Chivenor	1.6
Army Aviation Centre	1.2
Preliminary Flying Schools	1.0
Glider tug role	1.0

Critical components

23. Critical fatigue lives apply to the components listed in Table 4 and the action indicated is to be taken when these lives are achieved.

Monitoring fatigue consumption

24. Commands should monitor fatigue consumption by means of periodic returns, to ensure that appropriate action is taken and forward provisioning information obtained.

25. In addition to the Airframe Record Card (Form 4801), an assembly Record Card (Form 4805) is to be maintained for each individual main plane. The fatigue life of the items listed in Table 4 is to be recorded on the relevant Form 4801 or 4805.

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TABLE 4 - CRITICAL COMPONENTS

ITEM	FATIGUE LIFE	REMARKS	ACTION
(a) Fuselage centre section lower tie bar			
(i) Light alloy	10,000 fatigue hours	Original fit	Embody Mod.288
(ii) Steel	30,000 fatigue hours (from embodiment)	Introduced by Mod.288 (previously, repair scheme RC1-FS-191 and RD-C1-FS-106)	Fuselage life expired
(b) Mainplane attachment links			
(i) Steel	17,000 fatigue hours	26AE/75 (C1-W493)	Replace with new items
(c) Wing main spar root end lower lug insert			
(i) Light alloy	8,000 fatigue hours	Original fit	Embody Mod.289
(ii) Steel*	22,000 fatigue hours (from embodiment)	Introduced by Mod.289 (previously,repair scheme RD-C1-W102), and renewed by Mod.290	Mainplane life expired
(d) Wing main spar boom			
(i) Light alloy * (pre Mod.290)	30,000 fatigue hours	Original fit	Mainplane life expired
(ii) Light alloy * (post Mod.290)	30,000 fatigue hours (mainplane total life)	Renewed component	Mainplane life expired

*Note...
The mainplane total life is limited to 30,000 fatigue hours regardless of modification state.

WEIGHING THE AIRCRAFT

Introduction

26. The weight and centre of gravity of the aircraft as equipped to a given standard, known as the Basic Condition, must be determined before any correct loading data can be calculated. The condition of the aircraft must be checked prior to weighing and every possible effort made to bring it to a true Basic Condition.

27. For general information and the principles of aircraft weighing refer to AP 119W-0001-1.

Preparation

28. Before weighing the aircraft :-

(1) Drain fuel tanks; final draining should be carried out by removing sump drain plug (Part 2, Sect.2, Chap.1).

(2) Check engine oil tank and ensure full (Part 2, Sect.1, Chap.3). Record usable oil (18.0 lb, - 821 lb in.) as surplus (MOD. F756D).

(3) Check aircraft condition against list of equipment included in Basic Weight (Part 1, Sect.4, Fig.1). Record all items not fitted as deficient (MOD.F756D).

(4) Remove all loose items of equipment, i.e. crew's personal gear, protective covers etc.

(5) Ensure aircraft is clean and dry.

(6) Position aircraft on a level site in a closed hangar under a gantry, ensuring gantry can be moved along longitudinal axis of aircraft.

Equipment Required

29.

Ref.No.	Description	Qty
4GB/11718	Craneweigher, 2 ton	1
4Q/2617	Jack, 5 ton	2
26AE/95006	Ring, slinging	1
1A/9106532	Tape, steel	1

Equipment required - continued

Ref.No.	Description	Qty
1A/1203563	Clinometer	1
1A/NIV	Spring balance, 0-400 lbf	1
NIV	Plumb line	1
NIV	Bar, tail lifting	1
NIV (Pt.No.IAC-S.1103)	Sling, webbing LM	1
NIV	Straight edge	1
NIV	Cantry	1

Procedure

30. (1) Weigh slinging ring and record its weight (MOD.F756A).

(2) Fit slinging ring to aircraft (Part 2, Sect.1, Chap.2).

(3) Move gantry clear of aircraft and hook to craneweigher.

(4) Raise gantry and move along aircraft axis until craneweigher hook is above slinging ring.

(5) Slowly lower gantry and hook craneweigher to slinging ring.

(6) Slowly raise aircraft clear of floor.

(7) Record craneweigher reading (MOD.F756A).

(8) Slowly lower aircraft to floor.

(9) Remove slinging ring from aircraft.

(10) Remove wing fillets to gain access to jacking points.

(11) Weigh tail lifting bar and webbing sling.

(12) Fit tail lifting bar through tail lifting tube (Part 2, Sect.1, Chap.1).

(13) Secure webbing sling to tail lifting bar.

(14) Attach safety anchor weight to aircraft tail.

(15) Position gantry above tail lifting point and attach spring balance to gantry and sling webbing.

Procedure continued

(16) Raise aircraft tail until aircraft longitudinal axis is approximately level.

(17) Position jacks under main jacking points and raise aircraft until wheels are clear of floor.

(18) Level aircraft longitudinally (Pt.2,Sect.3,Chap.1) ensuring anchor weight has not been lifted and wheels are clear of floor.

(19) Use plumb line to ensure spring balance is vertical.

(20) Deduct weight of tail lifting bar and webbing sling (obtained in operation 11) from spring balance reading. Record answer as Wt (MOD F756A).

(21) Physically measure distance from CG datum point to main jacking point and from CG datum point to tail lifting point, record (MOD.F756A).

(22) Lower aircraft, keeping longitudinal axis level, until mainwheels are on floor.

(23) Move jacks clear of aircraft.

(24) Lower tail to floor and disconnect spring balance from webbing sling.

(25) Remove sling, tail lifting bar and anchor weight.

(26) Refit wing fillets.

Calculations

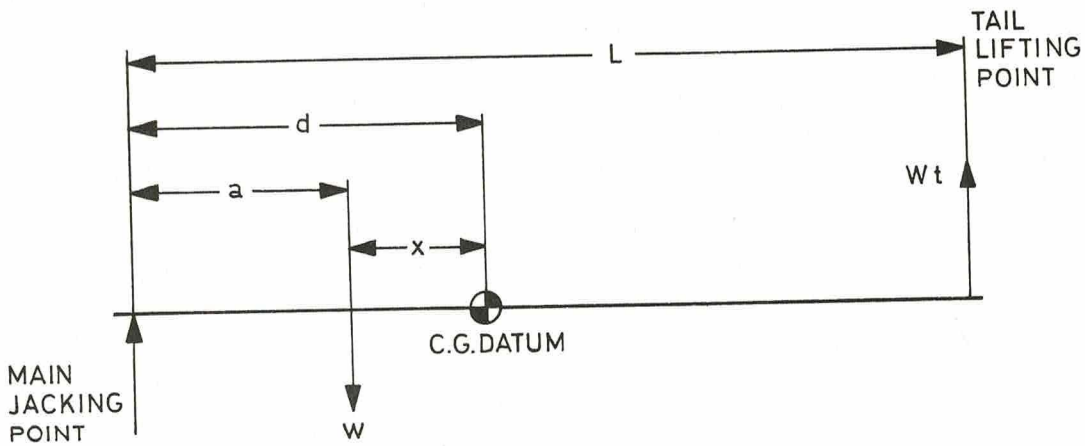
31. Complete MOD.F756A

W = Weight of aircraft as weighed
Wt = Reaction at tail (obtained in operation (20) of procedure).
L = Distance from centre line of main jacking point to centre line of tail lifting point.
d = Distance from centre line of main jacking point to CG datum point.
a = Distance from centre line of main jacking point to aircraft CG
x = Distance from aircraft CG to CG datum point
M = Aircraft moment as weighed

$$a = \frac{Wt \times L}{W}$$

$$x = d - a$$

$$M = W \times x$$



32. The as weighed weight and moment must now be corrected to Basic Weight and Basic Moment by adding weight and moment of deficiencies and subtracting weight and moment of surpluses.

Recording

33. Check the last recorded entry on aircraft MOD.F751/RAF F4908 and ensure that results obtained from physical weighing are within these limits :-

(1) Weight 10 lb.

(2) CG position 0.3 in.

Results which are not within these limits are unacceptable unless a satisfactory reason for the deviation can be determined.