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Cranfield Institute of Technology

Aeroplane Design Study

STOL Airliner (A71)

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Part 1 — Configuration description and data

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by D. HOWE and R. E. WARD

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Part 1 - Configuration description and data

by D. Howe and R.E. Ward

Summary

The interest in STOL airliners was reflected in the choice of a 100-118 passenger short range aircraft of this type as the 1971 design project. In addition to the use of the study for detailed investigation by the students of Aircraft Design it also served as the basis for an investigation of the low speed lift and control problems of STOL aircraft.

This report is concerned with a description of the configuration adopted and specification of geometric and aerodynamic data. As such it is the first part of the complete reporting of the investigation, subsequent parts being concerned with the more detailed work.

The aircraft was designed to operate from 2000 ft long single runways and have a cruising speed of up to M = 0.83 at 30,000 ft altitude. The estimated gross weight is 115,000 lb and when landing at 100,000 lb weight the approach speed is 79 knots. The high lift coefficients necessitated by this are obtained either by externally blown jet flaps or an augmenter wing arrangement.

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Notation

a_1, a_{1T}, a_{1F}, a_{1BT}	Lift curve slopes, per radian for wing, tailplane net fin and fin with body and tile effects respectively.
a_{2T}, a_{2F}	Lift curve slopes, per radian, due to elevator and rudder deflection, respectively.
b_1, b_{1T}, b_{1F}	Hinge moment coefficient slopes, per radian, due to wing, tail and fin incidence respectively.
b_2, b_{2T}, b_{2F}	Hinge moment coefficient slopes, per radian, due to aileron, elevator and rudder deflections, respectively.
$\bar{c}$	Mean wing chord (standard)
C_D	Drag coefficient
$(C_D)_{\mu=0}$	Low speed drag coefficient with $C_\mu = 0$
C_{FA}	low speed axial force coefficient
C_L	Lift coefficient
C_{M_o}	Pitching moment coefficient at zero lift
C_M	Increment to pitching moment coefficient due to lift at low speed with flaps deployed.
C_μ	Engine exhaust mass flow coefficient
M	Mach number
α	Fuselage datum angle of attack, degrees
	Non-dimensional stability and control derivatives:-
l_i, n_i, y_i,	rolling moment, yawing moment and sideforce derivatives due to i given by:
	rolling p
	yawing r
	sideforce v
	rudder deflection ζ
	aileron deflection ξ

1. Introduction

The widespread interest in short take off and landing airliners is reflected in the choice of subject for the A71 design project. This study is concerned with an STOL short range jet airliner. For the purpose of the investigation STOL is defined as the ability to operate from single 2000 ft long runways. Whilst in some respects this choice of runway length is arbitrary it does coincide with the tentative requirements of certain operators. A greater runway length may be acceptable and could result in a more straightforward design but this is irrelevant in the present context as the aim of the study is to investigate the problems associated with a true STOL airliner.

There are two distinct aspects of the investigation. Firstly the A71 is the subject of the annual design exercise undertaken by the students of Aircraft Design and therefore the structural and mechanical features of the design are being examined in depth. Secondly it is a convenient vehicle on which to base a study of the low speed lift and control problems of STOL jet transports.

The payload-range and cruise speed performance have been chosen to be similar to that of the present generation of twin-jet airliners and also to that of the A70 lift fan VTOL airliner study.(1) This similarity of performance enables direct comparisons to be made between the various concepts.

For convenience the report of the investigation has been divided into separate parts. Part one is concerned with a description of the basic configuration and the overall data applicable to the aircraft. Subsequent parts will cover the detailed investigations.

2. High lift systems and powerplants

Two alternative means of developing the high lift coefficients required for low speed flight are being considered. Typically the approach lift coefficient must exceed 3 corresponding to a wing loading of approximately 70 lb/sq ft.

2.1 External flap blowing

The major study is based on the use of external flap blowing. The exhaust from four wing mounted Rolls Royce RB 410 fan engines is directed on to the lower surface of the double slotted trailing edge flaps. Each powerplant has a nominal static thrust rating of 14500 lb, and a bypass ratio of rather more than ten. The high bypass ratio has been chosen primarily to reduce the overall noise level, but the reduction of average efflux velocity and temperature also facilitates flap structural design. The downward turning of the exhaust by the trailing edge flaps is assisted by thrust deflectors which are located along the lower edges of the fan duct exits. These deflections enable the bypass flow to be directed upwards towards the knee of the flaps and this has the effect of increasing the angle through which the exhaust is turned. Full span leading edge flaps are used in conjunction with the deflectors and trailing edge devices.

The fans of the RB410 have variable pitch blades and are driven through gearboxes.

With this type of high lift system the failure of a powerplant has unusually serious consequences. Apart from the normal loss of thrust and the directional control problem there is also a significant loss of lift and an associated induced rolling moment. This introduces severe control problems which it is desirable to minimise. One possible way of doing this is to mechanically connect the adjacent fans on each side of the aircraft through the existing gearboxes. Providing a freewheel is incorporated in the drive the effect of a gas generator failure is considerably reduced. There is, of course, a substantial weight penalty and the effect of fan failure is not overcome. The possibility of fan failure due to foreign object ingestion or pitch control system faults is a matter of design requirements, but the mechanical aspects of such an engine interconnection are considered to be worthy of investigation.

2.2 Augmenter wing

The alternative lift system is the use of an internally blown augmenter wing arrangement. In this case the powerplants are four Rolls Royce RB419 units. These are generally similar in concept to the RB410 engines but have been designed specifically to enable large masses of air to be tapped off the compressors. The offtake air is passed through ducts located within the engine mounting pylons and wing before being expelled through a long spanwise nozzle formed by the separated upper and lower surfaces of the trailing edge flap system.

The augmenter wing has one major advantage relative to the externally blown flap system. As the four engines can feed into a single spanwise duct system the effect of a single powerplant failure is much less severe. It may also be possible to produce a quieter aircraft as it is conceivably possible to apply sound treatment to the augmenter system and thereby reduce scrubbing noise which may be a serious difficulty with the externally blown arrangement. Against these advantages must be placed the demands made upon internal volume by the duct system and the mechanical complexity of the flaps.

3. Design conditions

The aircraft is designed to operate from 2000 ft long runways and have a comfort limited cruise speed of 300 knots equivalent airspeed, or M = 0.83 which ever is the least. Taken together the runway length and cruise speed limitations are the dominant influences in the design.

In order to achieve a still air landing on a 2000 ft long runway with the usual margins the aircraft is designed to descend along a 7.5 degree glideslope with a 0.25g incomplete flare and a final touchdown vertical velocity of 4 ft/sec. The mean longitudinal deceleration after touchdown is limited to 0.33g by passenger comfort considerations. The requirement to operate from single runway STOL ports implies a need to be able to cope with 20 degrees of sideslip if an acceptably high reliability of operation is to be achieved.

The aircraft is designed to meet the B.C.A.R. requirements in as far as they are applicable to this type of design. Design life for the airframe is 40,000 hours with an average flight duration of 40 minutes. A cabin differential pressure of 8 lb/sq in enables the cabin altitude to be maintained at 6000 ft for all normal operations but during a long range fast cruise it may reach 8000 ft.

The steep approach and difficult flare set the vertical descent velocity at 18 ft/sec, and the cross wind landing implies a need for the main undercarriage wheels to be steered up to 20 degrees in either direction. The main undercarriage can absorb the vertical energy in a landing when the aircraft fails to carry out the flare manoeuvre.

4. Description of aircraft

The configuration of the A71 design is shown in Figure 1. This and the following description applies primarily to the externally blown flap version but the augmenter wing alternative is similar in most respects.

The design take off weight is 115,000 lbs and the installed static thrust/weight ratio in this condition is approximately 0.5. Design landing weight is 100,000 lbs. Details of the weight of individual components are given in Table 1 and geometric data for the aircraft in Appendix A. Inertia characteristics appear in Table 2.

Sweepback is used in the wing configuration for the following reasons:-

a) The spanwise flow outwards towards the tips assists in increasing the effectiveness of the thrust deflection system.

b) The lower lift curve slope is beneficial in reducing gust sensitivity in the cruise. This is of special importance as it places a lower bound on wing area which is best made as high as possible to reduce the magnitude of the required low speed lift coefficient. The relatively low aspect ratio of 5.9 was chosen for the same reason.

c) The swept wing enables the long range high speed cruise to be flown at rather more than M = 0.8. Thus the aircraft is potentially as fast as existing short range types although it must be accepted that the cruise equivalent airspeed limitation implies flight at approximately 30,000 ft altitude for this to be so.

d) Passengers are now used to flying in swept wing aircraft and will expect new designs to possess this characteristic.

The high mounting of the wing is inevitable because of the need to provide adequate ground clearance for the relatively large diameter powerplants. The considerable downwash effects from the high lift system require the tailplane to be located well away from the wing plane in the vertical sense and the only possible position for it is at the top of the tail fin. Cross wind landing at low approach speed necessitates flight at unusually high sideslip angles and the extensive dorsal fin has been incorporated in the layout to ensure a high fin stall angle.

The fuselage layout is shown in Figure 2. The passenger accommodation is based on the use of six abreast tourist class seating with a single central aisle. Overall fuselage diameter required for this with the high wing configuration is 12.5 ft. When a seat pitch of 33 inches is employed it is possible to carry 120 tourist class passengers. Access is through a forward side door and a rear ventral door. Baggage holds are incorporated in the layout below the passenger floor and an auxiliary power unit is mounted in the tail cone.

Undercarriage design and layout present serious difficulties. The large design vertical descent velocity implies the need for a very long stroke undercarriage to minimise structural fatigue and passenger discomfort. The large cross wind components at landing suggest the necessity for a wide track. Thus the use of fuselage mounted main undercarriage units is not possible and the A71 employs long, inevitably heavy, wing mounted main undercarriage units. As shown in Figure 3 they retract forwards into wing fairings

which do not interfere with the trailing edge flaps but do interrupt the leading edge devices. Four wheel bogie units capable of being preset at steering angles of up to 20 degrees are used for compactness. The nose undercarriage has normal steering capability and is retracted forwards into the fuselage below the crew compartment.

The use of a variable incidence wing was considered in the initial design phase, but it was found to be impracticable. Apart from introducing difficulties with the wing mounted undercarriage the relative rotation of the fuselage brought the tailplane into an unacceptably high downwash field. In any case calculations on the low speed configuration of the aircraft showed that it was possible to arrange for the fuselage to remain in a substantially horizontal position during the approach and thus variable incidence is not required.

5. Control considerations

During cruising and climbing flight the aircraft is controlled by conventional ailerons, rudder and tailplane/elevator combination. The tailplane incidence is adjustable for trim purposes. Airbrakes are located above the wing trailing edge flap for speed control although with variable pitch fans it is likely that the main use of these will be as spoiler/lift dumpers at low speed.

Control of the aircraft at low speed is complicated by the nature of the high lift system and the severe cross wind requirement. The externally blown flaps give a substantial measure of direct lift control which interacts with speed control. Initial calculations suggested that the conventional controls are of insufficient power to deal with the low speed problem and this aspect of the design is the subject of a special investigation.

6. Aerodynamic characteristics

The estimated aerodynamic characteristics of the aircraft are stated in Appendix B and Figures 4 to 7. Aerofoil section ordinates are quoted in Table 3. A study of the low speed stability characteristics is included in the special control investigation.

The data applicable to low speed flight with the flaps deployed has been derived from an interpretation of the N.A.S.A. wind tunnel work on models of aircraft of similar configuration.(2) to (7)

7. Performance

7.1 Take off.

The take off wing loading is 74 lb/sq ft and the nominal thrust/weight ratio 0.5. Take off procedure is for the leading edge flaps to be deployed and the trailing edge flaps set at 10 degrees plus an additional 10 degrees on the aft segment. The engine thrust deflectors are in the cruise position. During the ground roll the aircraft reaches 1.2 times the flaps out stalling speed at which point the engine thrust deflectors are repositioned and rotation takes place. Initial normal acceleration is 0.25g but forward acceleration is small which explains the necessity for rotation to occur at the take off safety speed. In the event of an engine failure before rotation the aircraft can be brought to rest before the end of the 2000 ft runway. Engine failure after rotation necessitates an unaccelerated climb out. The take off safety speed is about 96 knots, and the lift coefficient at rotation just over 3. Further work has shown the need to increase thrust.

7.2 Cruise

Maximum cruise Mach number is 0.83 at 30,000 ft altitude. This condition is thrust as well as Mach limited and can only be achieved at a relatively low flight weight. The normal cruise Mach number at 30,000 ft is 0.8. As the cruise speed is limited to 300 knots equivalent air speed for comfort reasons the useful Mach number is restricted below 30,000 ft, as is shown in Figure 8. Flight at M = 0.67 and 20,000 ft is a more usual cruise condition for short stage length operations. The still air, no reserve, payload-range characteristics for both 20,000 ft and 30,000 ft cruise are shown in Figure 9.

The high installed thrust/weight ratio results in an unusually high value of the maximum continuous engine operating speed, V_{M_O}, at low levels. On this basis the design value of the cruising speed, V_c, is approximately 435 knots equivalent air speed and the corresponding design diving speed,

V_D is 485 knots equivalent air speed. The variation of these with altitude is shown in Figure 8. There is no operational requirement to fly at these high air speeds at low level and it would appear to be reasonable to introduce a performance restriction limiting V_{M_O} to approximately 390 knots equivalent air speed and V_D would be correspondingly reduced to 435 knots equivalent air speed or M = 0.9 at higher altitudes.

7.3 Landing

At the maximum landing weight the wing loading is 64 lb/sq ft. The approach speed has to be restricted to 79 knots to achieve a landing from 35 ft altitude in 2000 ft with the normal margins. The corresponding approach lift coefficient is 3.4. This is achieved by deploying the leading edge flaps, using the engine thrust deflectors and setting the trailing edge flaps at the 20 degrees plus 20 degrees position. Use of greater trailing edge flap settings introduces speed control difficulties due to the combination of high effective induced drag and low effective forward thrust. It also implies a fuselage attitude which is nose down. relative to the ground during approach and this could introduce nose undercarriage design problems in the event of a late flare out.

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TABLE 1

Component Weights

Component	Weight lb	A.U.W. %
Wing, including fairings	11000	9.6
Fuselage	10400	8.9
Tailplane	2140	1.9
Fin	1800	1.6
Main undercarriage	4600	4.0
Nose undercarriage	800	0.7
Structure	30740	26.7
Propulsion engines, complete pods	16000	13.9
Pylons	400	0.3
Engine controls and systems	900	0.8
Powerplant	17300	15.0
Fuel system	1200	1.0
Power supplies	4000	3.5
Auxiliary power unit	530	0.5
Flying control systems	3000	2.6
Deicing and miscellaneous systems	830	0.7
Air conditioning	1500	1.3
Systems	11060	9.6
Radio and radar	1500	1.3
Instruments and automatic units	600	0.5
Fixed equipment	2100	1.8
Sound proofing	800	0.7
Flight crew furnishing	400	0.3
Cabin furnishing	1880	1.6
Cabin seats	2500	2.2
Cabin services, etc	1870	1.6
Furnishings	7450	6.5

... continued

TABLE 1 continued

Component	Weight lb	A.U.W. %
Basic operating empty weight	68650	59.7
Passenger service items, supplies	1250	
Crew	1100	
As prepared for service weight	71000	61.7
Passengers, 120 maximum	24000	20.9
Fuel	20000	17.4
All up weight	115000	100
Passengers, 80	16000	13.9
Fuel, maximum	28000	24.4
All up weight	115000	100

TABLE 2

Moments of Inertia

(Relative to As prepared for service centre of gravity position)

GENERAL

Configuration	Moment of Inertia 10^6 lb ft^2		
	Pitch	Roll	Yaw
As prepared for service, 71,000 lb	33.5	24	52.5
Increment due to 120 passengers, 24,000 lb	10.5	1	10.5
Increment due to 20,000 lb fuel	1	12.5	12.0
Increment due to 28,000 lb fuel	1	17.0	16.5

APPROACH CONDITION - 100,000 lbs

	Speed kts	Trimmed Attitude to flight path	Moment of Inertia 10^6 lb ft^2
Roll-Yaw Product	60	12.55°	-4.15
	70	10.5°	-3.20
	80	8.55°	-1.34
	90	6.20°	-0.48
	100	4.80°	+0.88
Pitch			44.4
Roll			28.1
Yaw			66.0

TABLE 3

Aerofoil Section Coordinates

10% Thickness Chord Ratio

	2% Camber		Symmetrical
% Chord	Upper Surface	Lower Surface	Half Depth
Nose radians	0.56		0.56
0.75	1.10	0.96	1.03
1.25	1.59	1.37	1.48
2.5	2.22	1.84	2.03
5.0	2.96	2.32	2.64
7.5	3.59	2.73	3.16
10	4.05	3.01	3.53
15	4.78	3.42	4.10
20	5.30	3.70	4.50
25	5.61	3.81	4.71
30	5.87	3.91	4.89
35	6.02	3.96	4.99
40	6.06	3.92	4.99
45	5.94	3.74	4.84
50	5.66	3.46	4.56
55	5.30	3.20	4.20
60	4.86	2.72	3.79
65	4.33	2.30	3.33
70	3.81	1.87	2.84
75	3.33	1.53	2.43
80	2.70	1.20	1.90
85	2.10	0.76	1.43
90	1.45	0.51	0.98
95	0.82	0.18	0.50
100	0	0	0

Appendix A. Geometry and Weights - Externally blown flap aircraft.

1 Wing

Gross area	1560 sq ft.
Span	96 ft.
Aspect ratio	5.9
Leading edge sweepback	28°
Root chord (centreline nominal)	24.1 ft
Tip chord (nominal)	8.5 ft.
Standard mean chord, $\bar{c}$	16.3 ft

Aerofoil sections;

Root: 13% thickness at 37.5%c, 2% camber

Tip: 10% thickness at 37.5%c, 2% camber

See Table 3. Linear Spanwise variation.

Wing-body angle (chord datum to fuselage datum)	0°
Anhedral	3°
Location of $0.25\bar{c}$ aft of fuselage nose	49.0 ft
Location of chord datum above fuselage datum	5.62 ft
Location of $0.25\bar{c}$ aft of nominal centreline leading edge	14.7 ft

2 Ailerons

Type:- Round nose

Aileron chord/wing chord	0.3
Movement	$\pm 20^{\circ}$
Inboard end relative to aircraft centreline	37.6 ft
Outboard end relative to aircraft centreline	47.6 ft

3 Trailing edge flaps

Type: Externally blown, double slotted

Total flap chord/wing chord, retracted	0.365
Subsidiary rear flap chord/total flap chord	0.56
Take off flap setting	$10^{\circ} + 10^{\circ}$
Landing flap setting	$20^{\circ} + 20^{\circ}$
Inboard end of flap from aircraft centreline	6.25 ft.
Outboard end of flap from aircraft centreline	37.5 ft.

4 Leading edge flaps, inboard

Type: Variable camber, Kruger.	
Flap chord/wing chord	0.15
Take off flap setting	60°
Landing flap setting	60°
Inboard end of flap from aircraft centreline	6.25 ft.
Outboard end of flap from aircraft centreline, approx.	29 ft

5 Leading edge flaps, outboard

Type: Variable camber, Kruger	
Flap chord/wing chord	0.30
Take off flap setting	45°
Landing flap setting	45°
Inboard end of flap from aircraft centreline, approx.	31 ft
Outboard end of flap from aircraft centreline, approx.	47 ft

6 Spoilers

Spoiler chord/wing chord	0.10
Maximum movement	30°
Leading edge of spoiler aft of wing leading edge	0.62c
Inboard end of leading edge relative to aircraft centreline	6.25 ft
Outboard end of leading edge relative to aircraft centreline	37.5 ft

7 Tailplane

Gross area	525 sq ft
Span	45.8 ft
Aspect ratio	4.0
Sweepback of leading edge	28°
Root chord (centreline)	14.3 ft
Tip chord (nominal)	8.6 ft
Aerofoil section: 12% thickness at 37.5% c, symmetrical (see Table 3)	
Dihedral	$+3^{\circ}$ nose up
Movement	-12° nose down

Tailplane continued

Vertical location of tailplane chord datum above fuselage datum	26.0 ft
Distance of tail 0.25$\bar{c}$ aft of wing 0.25$\bar{c}$	49.2 ft
Location of tail 0.25$\bar{c}$ aft of nominal centreline leading edge	8.8 ft

8 Elevator

Type:- Round nose	
Elevator chord/tailplane chord	0.30
Movement	+ 10° down - 30° up

9 Fin

Nominal area above datum root chord, reference	274 sq ft
Height above datum root chord	19.75 ft
Aspect ratio based on above	1.43
Location of datum root chord above fuselage datum	6.25 ft
Datum root chord	17.0 ft
Tip chord(nominal)	10.7 ft
Sweepback of leading edge	35°
Aerofoil section:	
13% thickness at 37.5%c, symmetrical (see Table 3)	
Distance of leading edge intersection with fuselage datum aft of nose	75.0 ft

10 Rudder

Type: Round nose	
Rudder chord/fin chord	0.40
Height of rudder root leading edge above fin root chord	0 ft
Height of rudder tip leading edge above fin root chord	18.5 ft
Movement	± 20°

11 Fuselage

Overall length	96.6 ft
Maximum diameter	12.5 ft
Maximum cabin internal width	11.65 ft
Cabin height	6.5 ft
Cabin length, overall	70.3 ft

12 Undercarriage (See Fig.A71-2 for geometry)

Type: Nosewheel

Wheelbase (to centre of main unit bogie)	41.9 ft
Track (to centre of mainwheels	25.1 ft

Main undercarriage units (See Fig.A71-5)

4 wheel bogie arrangement, forward retracting.

Tyres: 34 in dia x 9.25 in width - 16 in rim.

Pressure	150 p.s.i.
Bogie wheelbase	3.35 ft
Bogie track	2.1 ft
Static tyre closure, approx.	0.25 ft
Maximum tyre closure, approx.	0.5 ft
Nominal shock absorber stroke	3.5 ft
Location of leg aft of fuselage nose	53.2 ft
Overall length of retraction fairing	27.5 ft
Depth of fairing, maximum	4.2 ft
Width of fairing	3.35 ft

Nose undercarriage unit

Twin wheels, forward retracting

Tyres: 34 in dia. x 9.25 in width - 16 in rim

Pressure	180 p.s.i.
Wheel track	1.7 ft
Static tyre closure	0.25 ft
Maximum tyre closure	0.5 ft
Nominal shock absorber stroke	3.1 ft
Location of leg aft of fuselage nose	11.9 ft

13 Propulsion engines

Type: Rolls-Royce RB 410

Installation: 4 pods below wing

Bypass ratio, approx.	10
Sea level rated thrust	14,500 lb
Overall length of complete pod	16.0 ft
Overall diameter of pod	6.3 ft
Intake diameter, nominal	4.6 ft
Location of engine centreline below wing chord datum, approx	5.0 ft
Location of pod front face forward of leading edge, approx.	9.0 ft
Location of inboard engine from aircraft centreline	18.5 ft
Location of outboard engine from aircraft centreline	30.0 ft
Sweepback of mounting pylon leading edge approx.	72°
Thickness/chord ratio of mounting pylon	0.12

Auxiliary power unit

Type: Airesearch GTCP 85C

Location of A.P.U. above fuselage datum	42 ft
Location of A.P.U. front face aft of fuselage nose, approx.	85.5 ft

14 WEIGHTS, CENTRES OF GRAVITY AND MOMENTS OF INERTIA

Design normal weight at take off	115,000 lb
Maximum landing weight	100,000 lb
Minimum flying weight	72,000 lb
As prepared for service weight	71,000 lb
Maximum payload	24,000 lb
Maximum fuel load	28,000 lb

Weight breakdown - see Table 1

Centre of Gravity at APS weight relative to $0.25\bar{c}$ and fuselage datum:

Undercarriage retracted: $\bar{x} = 0.3$ ft aft

$\bar{z} = 2.15$ ft above

Undercarriage extended: $\bar{x} = 0.97$ ft aft

$\bar{z} = 1.57$ ft above

Appendix B. Aerodynamic Data - Externally blown flap aircraft

1 Inertia characteristics

Allowable centre of gravity range $0.20\bar{c}$ to $0.36\bar{c}$

Moments of inertia - see Table 2

2. Lift characteristics

Maximum lift coefficient, basic aerofoil 1.2

Maximum lift coefficient, take off condition, flaps $10^\circ + 10^\circ$ and full thrust 3.2

Maximum lift coefficient, approach condition, flaps $20^\circ + 20^\circ$ and 80% thrust 5.2

Slope of wing body lift curve, a_1, clean See Fig. 5

Slope of wing body lift curve, flaps deployed See Fig. 4

(N.B. Over the range of blowing coefficient, C_μ, considered the effect on lift curve slope is negligible)

Lift coefficient, flaps $10^\circ + 10^\circ$ $C_L = 0.456+0.0914C_\mu+0.0955\alpha$

(where α is the fuselage angle of attack in degrees)

Lift coefficient, flaps $20^\circ + 20^\circ$ $C_L = 0.912+1.82C_\mu+0.0955\alpha$

Wing no lift angle, clean, relative to wing centreline chord -2.5°

3. Drag characteristics

Drag polars:-

Cruise: M = 0.80 and 30,000 ft. $C_D = 0.0266+0.081C_L^2$

M = 0.67 and 20,000 ft. $C_D = 0.020+0.072C_L^2$

Zero lift drag coefficient increment due to undercarriage 0.021

Take off, flaps $10^\circ + 10^\circ$, $C_\mu=0$ $(C_D)_{C_\mu=0} = 0.13+0.117C_L^2$

$= 0.154+0.0102\alpha+0.00107\alpha^2$

Approach, flaps $20^\circ + 20^\circ$, $C_\mu=0$ $(C_D)_{C_\mu=0} = 0.151+0.091C_L^2$

$= 0.227+0.01585\alpha+0.00083\alpha^2$

4. Axial force characteristics

Take off, flaps $10^\circ + 10^\circ$

$$C_{FA} = C_\mu(0.81-0.0295\alpha+0.0045C_\mu\alpha-0.06C_\mu)$$

where C_{FA} is the coefficient of axial force excluding the zero below drag coefficient

Approach, flaps $20^\circ + 20^\circ$

$$C_{FA} = C_\mu(0.423-0.0466\alpha+0.00762C_\mu\alpha-0.0381C_\mu)$$

5. Pitching moment characteristics

Pitching moment coefficient at zero lift, clean aircraft, C_{M_0} -0.07

Location of low speed overall wing-body aero. centre, clean aircraft, from fuselage nose 48.7 ft

Location of overall wing-body aero.centre, M = 0.9 49.0 ft

Pitching moment coefficient at zero lift, take off condition flaps $10^\circ + 10^\circ$ $C_{M_0} = -(0.2050+0.77C_\mu -0.07C_\mu^2)$

Increment at fwd c.g. due to lift

$$\Delta C_M = \left[0.047+0.042C_\mu - \frac{0.0314}{(C_\mu+0.2)}\right]C_L - 0.006C_L^2$$

Increment at aft c.g. due to lift

$$\Delta C_M = \left[0.468-0.0115C_\mu - \frac{0.514}{(C_\mu+1.21)}\right]C_L - 0.0112C_L^2$$

Pitching moment coefficient at zero lift, approach condition flaps at $20^\circ + 20^\circ$ $C_{M_0} = -(0.35+1.44C_\mu-0.11C_\mu^2)$

Increment at fwd c.g.

$$\Delta C_M = \left[0.06+0.0775C_\mu - \frac{0.0185}{(C_\mu+0.142)}\right]C_L-0.000832C_L^2(13.48+C_\mu)$$

Increment at aft c.g.

$$\Delta C_M = \left[0.22+0.068C_\mu - \frac{0.0196}{(C_\mu+0.153)}\right]C_L-0.00396C_L^2(4.67-C_\mu)$$

6. Control and stabiliser characteristics, basic surfaces

(per radian)

Location of mean tailplane aero.centre aft of fuselage nose, cruise 98.6 ft

Location of mean fin aero.centre aft of fuselage nose, cruise 89.0 ft

Slope of tailplane lift curve, a_{1T} see Fig.5

Ratio of elevator lift curve slope, a_{2T}/a_{1T} 0.68

Slope of elevator hinge moment curve due to tailplane incidence, b_{1T} -0.26

Slope of elevator hinge moment curve due to elevator angle, b_{2T} -0.59

Slope of fin life curve, a_{1F}(net area and a_{1BT} (including body and tail effect) See Fig. 5

Ratio of rudder lift curve slope, a_{2F}/a_{1F} 0.83

Slope of rudder hinge moment curve due to fin incidence, b_{1F} -0.13

Slope of rudder hinge moment curve due to rudder angle, b_{2F} -0.43

Rolling moment coefficient due to aileron,

cruise, l_ξ $-(0.045+0.1M)$

approach $-0.125+0.000167\alpha^2-0.0174C_\mu$

Slope of aileron hinge moment due to wing incidence, b_1, $C_\mu=0$ -0.31

Slope of aileron hinge moment due to aileron angle b_2, $C_\mu=0$ -0.63

Rolling moment coefficient due to rudder, l_ζ, approach $0.0625-0.00261\alpha$

Yawing moment coefficient due to aileron, n_ξ, approach $0.016+0.013C_\mu$

Yawing moment coefficient due to rudder, n_ζ, approach -0.152

Side force coefficient due to aileron, y_ξ, approach 0

Downwash at tailplane, cruise See Fig. 6

approach See Fig.7

7. <u>Lateral stability derivatives</u> (per radian)

Rolling moment derivatives due to:-

Roll, l_p, cruise, $0.6 < M < 0.83$ $-(0.27+0.09M)$

approach $-0.00088(481+4.09\alpha-\alpha^2)-0.0025\left\{C_\mu(50.3-5\alpha+\alpha^2)-0.34C_\mu{}^2(35.7-5\alpha+\alpha^2)\right\}$

Sideslip, l_v, cruise $-\left[0.01+0.14C_L+a_{1BT}(0.023-0.035C_L)\right]$

approach $-0.14-0.009\alpha-C_\mu\left[0.071-0.0073\alpha+0.00145C_\mu\alpha-0.01C_\mu\right]$

Yaw, l_r, cruise $0.21C_L+a_{1BT}(0.02-0.03C_L)$

approach $0.26+0.013\alpha$

Yawing moment derivatives due to:-

Roll, n_p, approach $-0.135-0.0025\alpha-C_\mu(0.00235\alpha+0.0365-0.0121C_\mu)$

Sideslip, n_v, cruise $0.073a_{1BT}-0.07$

approach $0.166+0.00258\alpha+0.117C_\mu-0.025C_\mu{}^2$

Yaw, n_r, cruise	$-(0.07+0.18C_L^2+0.061a_{1_{BT}})$	
approach		-0.188

Sideforce derivatives due to:-

Roll, y_p, approach	$-0.035+0.317C_\mu-0.171C_\mu^2$
Sideslip, y_v, cruise	$-(0.15+0.176a_{1_{BT}})$
approach	$-0.24+0.00052\alpha-0.000478\alpha^2$ $-0.078C_\mu+0.00825C_\mu^2$
Yaw, y_r, approach	$0.035-0.0025\alpha$

Tailplane rolling moment coefficient due to sideslip, K_β, cruise	0.15

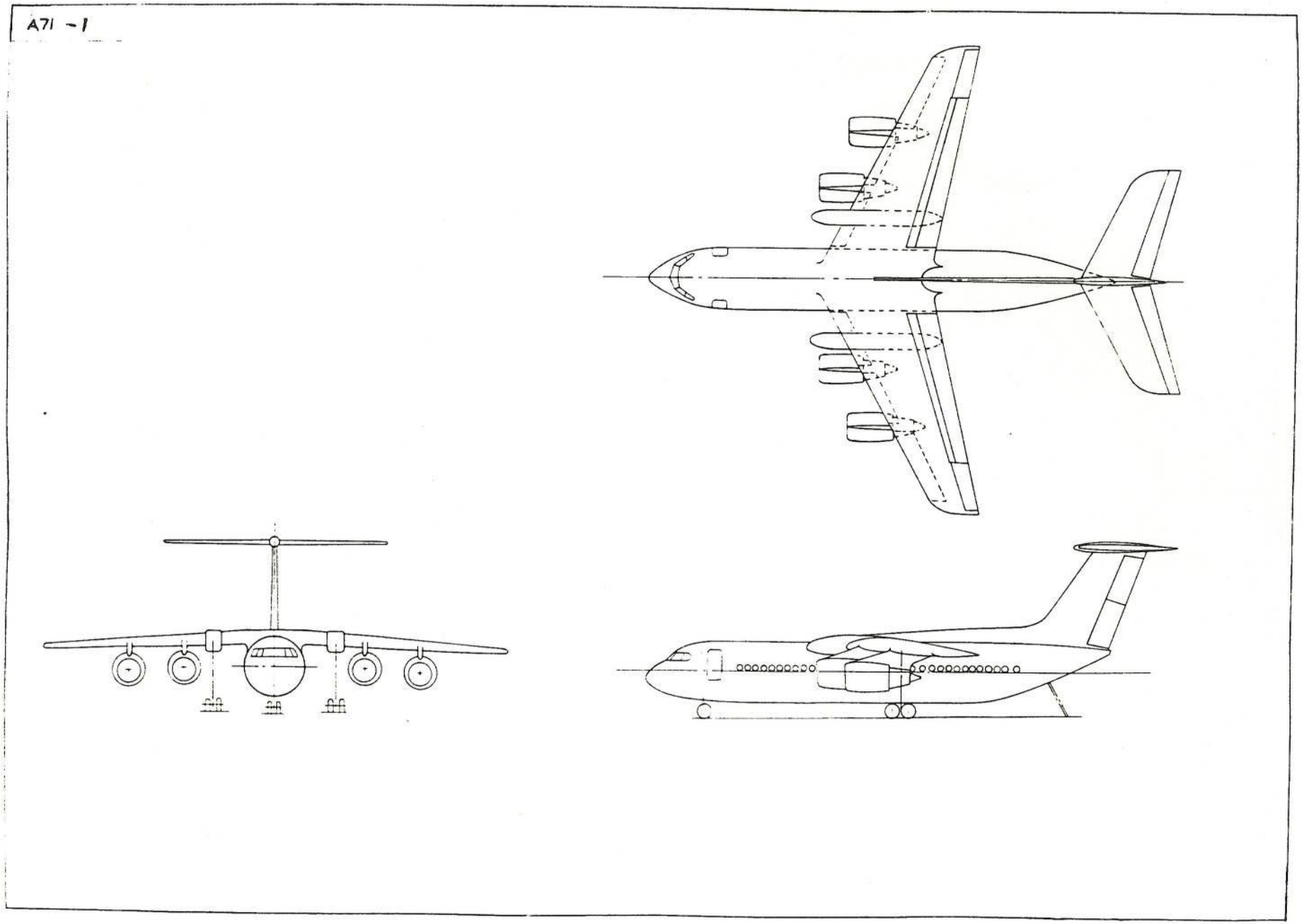

FIGURE 1. GENERAL ARRANGEMENT OF A71 AIRCRAFT

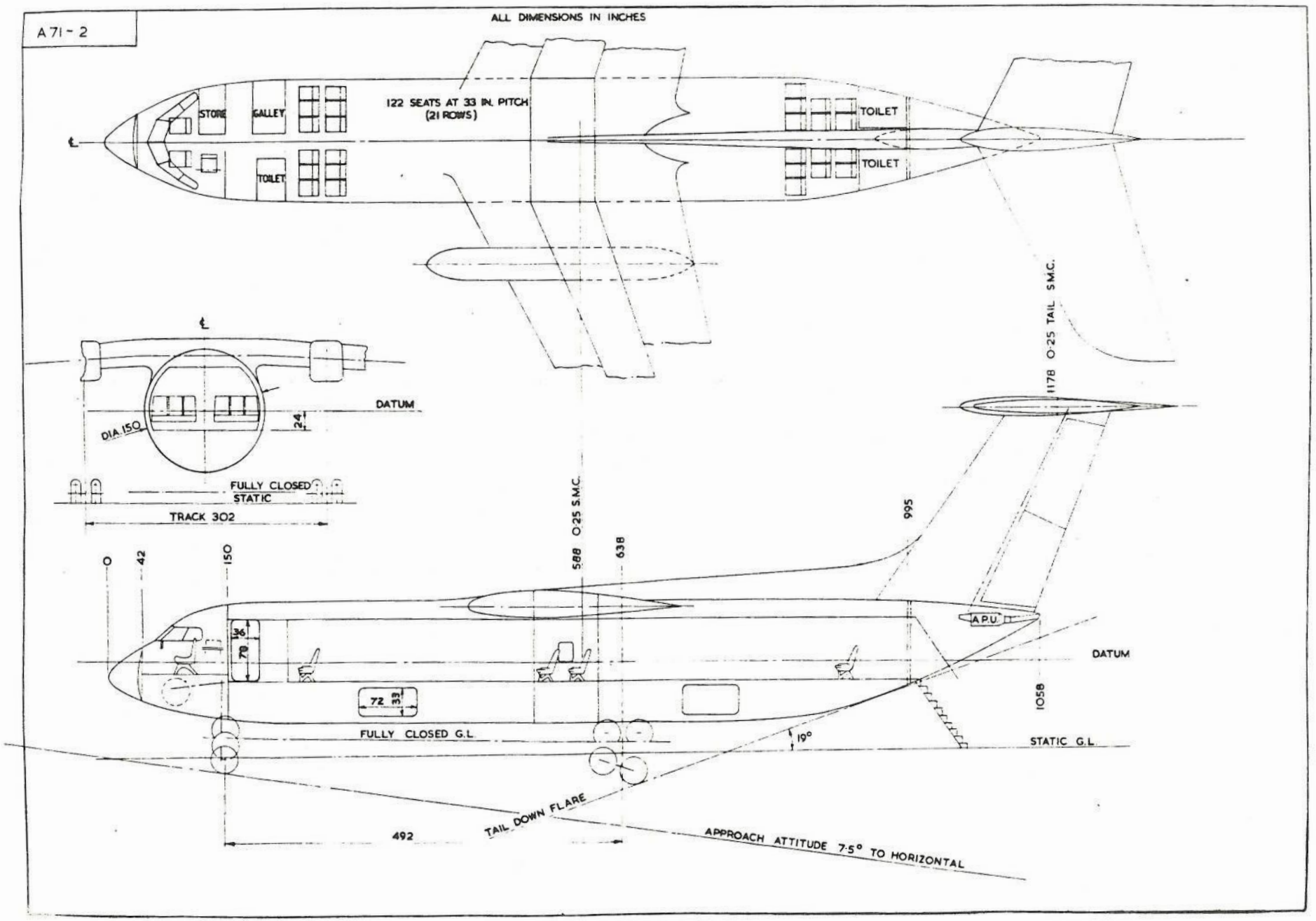

FIGURE 2. FUSELAGE LAYOUT

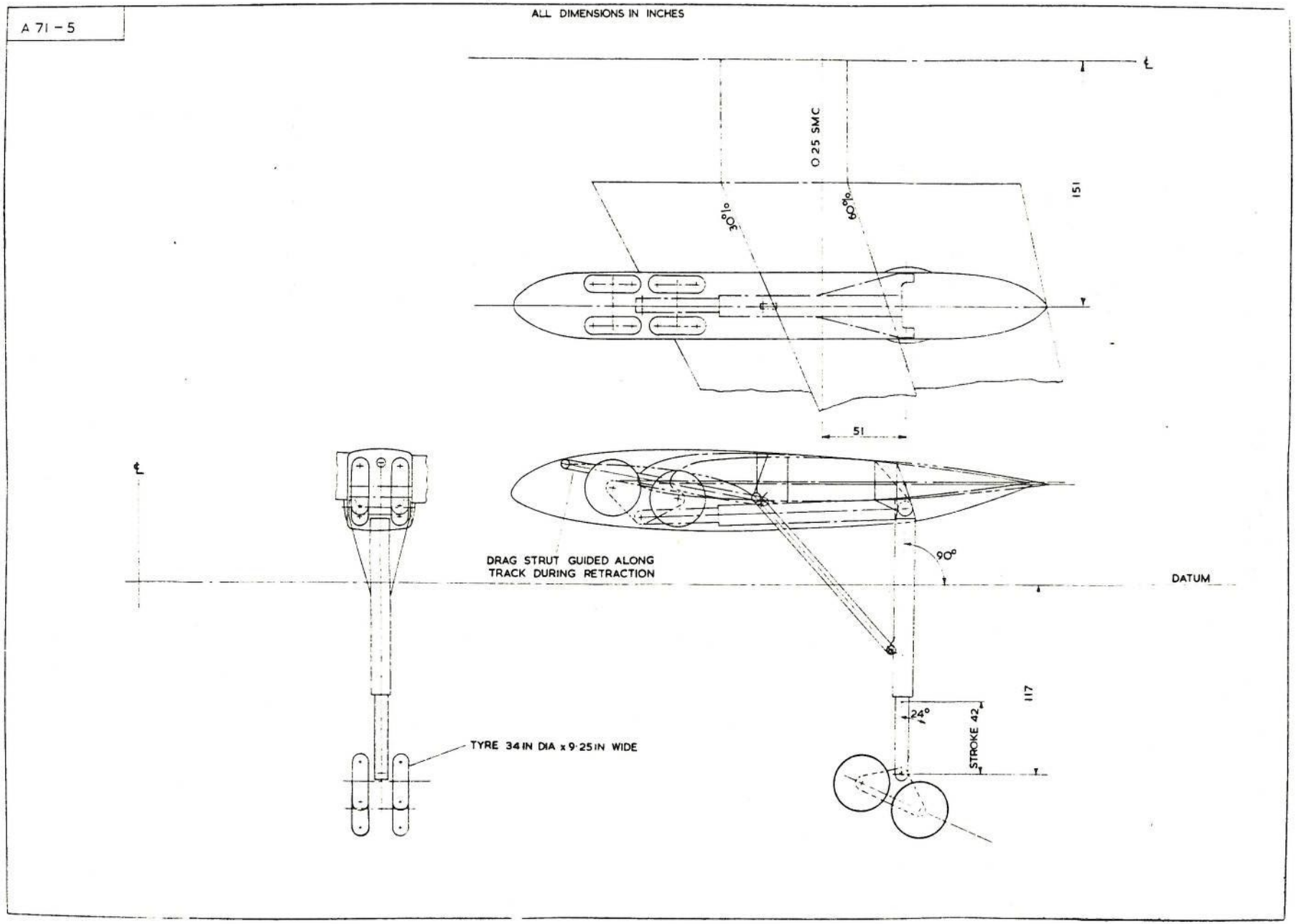

FIGURE 3. UNDERCARRIAGE LAYOUT

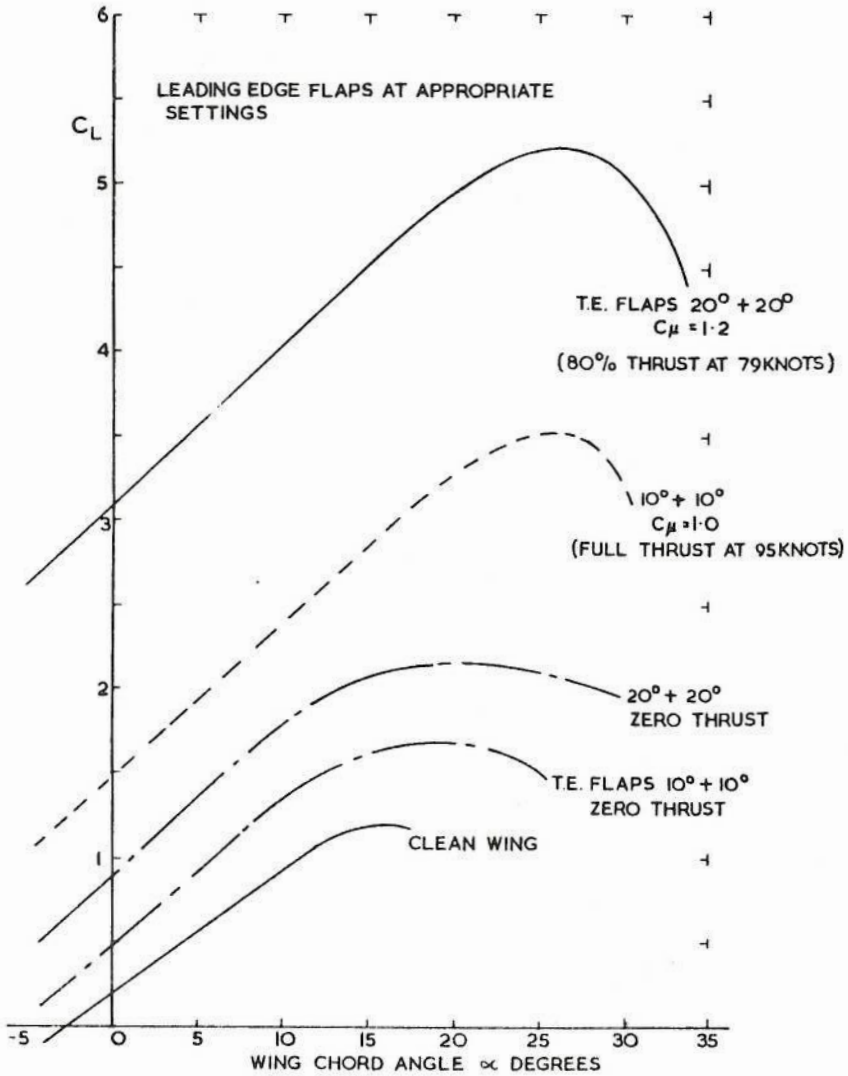

FIGURE 4. LOW SPEED LIFT CHARACTERISTIC

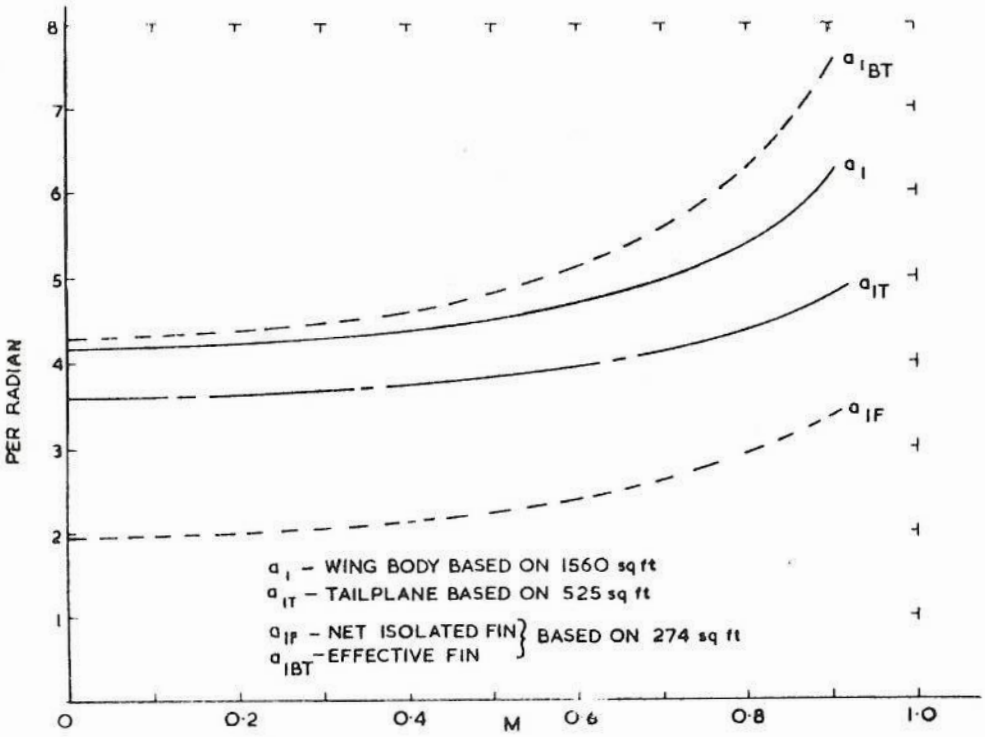

FIGURE 5. CRUISE LIFT CURVE SLOPES

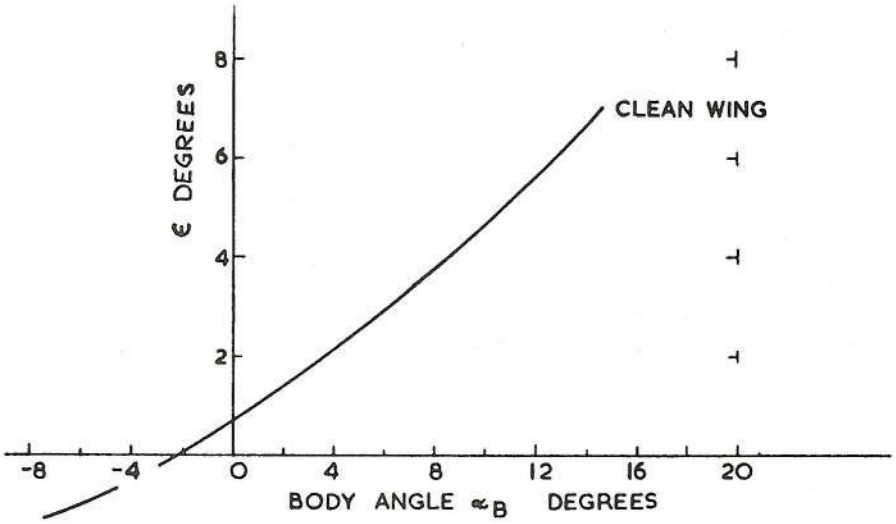

FIGURE 6. DOWNWASH AT TAILPLANE–CRUISE

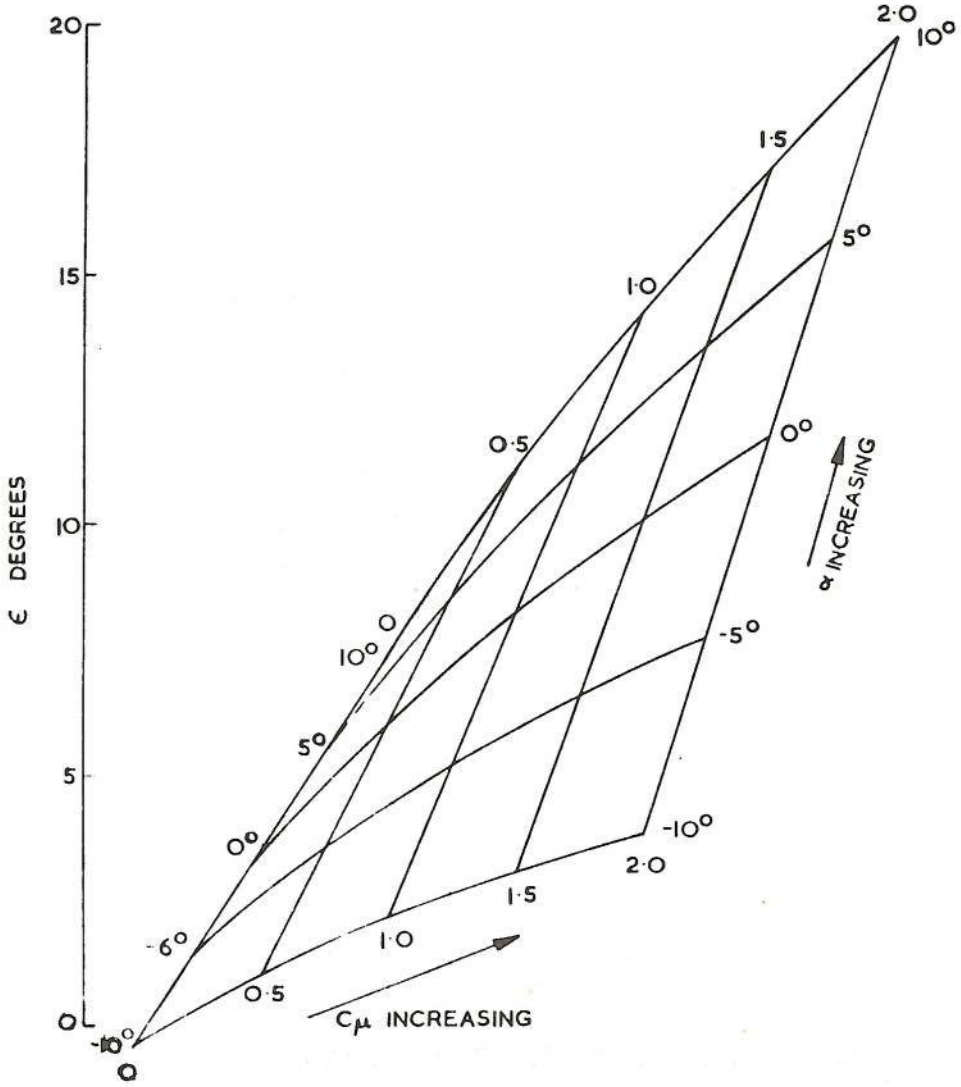

FIGURE 7. DOWNWASH AT TAIL – LOW SPEED

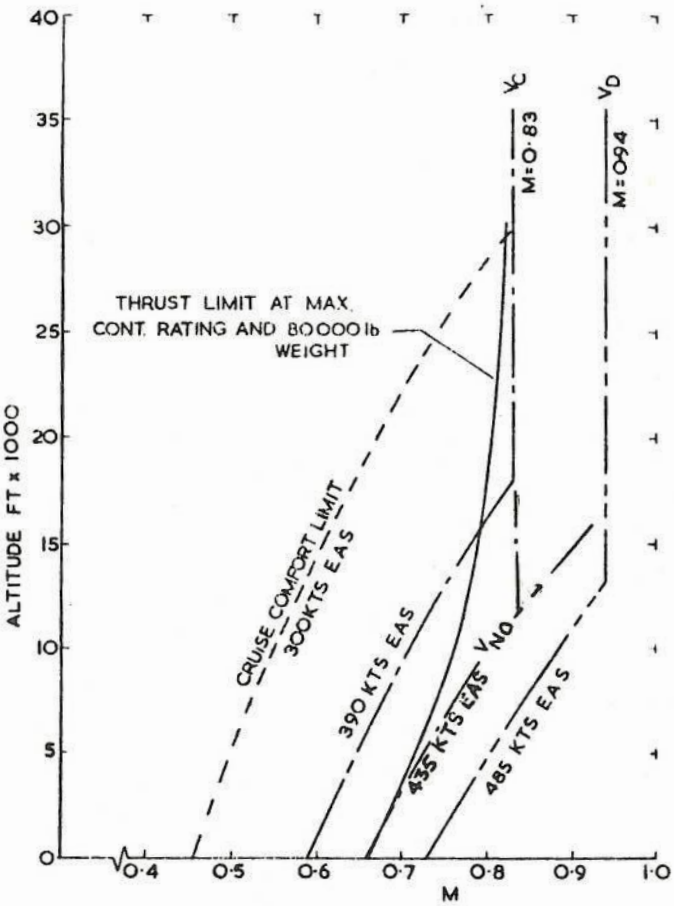

FIGURE 8 LEVEL SPEED PERFORMANCE AND LIMITATIONS

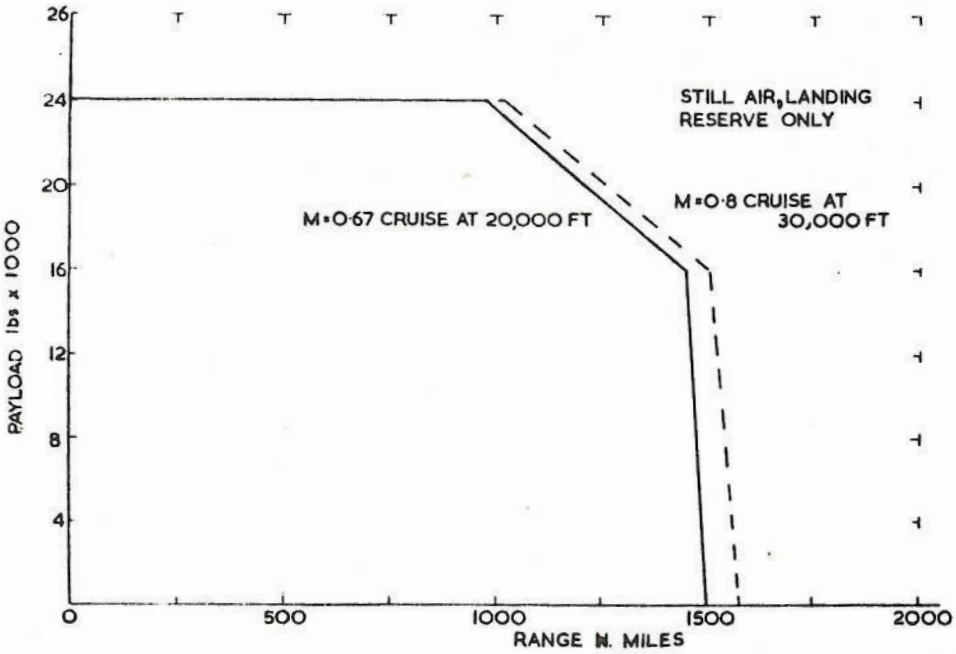

FIGURE 9 PAYLOAD– RANGE PERFORMANCE