SAAB JA-37 Viggen

Performance Assessment

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Temporal Images

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1. Overview

The SAAB JA-37 Viggen is a Swedish single seat multi-role fighter. The aircraft is a delta wing design with a canard. Viggen is Swedish for "Thunderbolt". The aircraft has been built in several versions, as follows;

AJ-37 single seat all weather attack
JA-37 single seat air defence
SF-37 single seat armed photo reconnaissance
SH-37 single seat armed sea surveillance
SK-37 dual seat conversion trainer

The first flight of the AJ-37 (attack) version was on the 2nd of February, 1967. For the JA-37 (air defence) version, the prototype first flew in June 1974, followed by the first production prototype on the 15th of December 1975, and the first production JA-37 on the 4th of November 1977.

This document is intended to record all the known, freely available weight and dimensional data about the Viggen, then use this information to produce a performance estimate for the aircraft.

2. Dimensions

The following figures represent the best data available for the leading dimensions of the aircraft. Note that most dimensions and weights are provided in metric units, then converted to imperial units.

Wing Span	10.60 metres	34 feet 9.25 inches
Foreplane Span	5.45 metres	17 feet 10.5 inches
Main Wing Aspect Ratio	2.45	

Length	15.45 metres	50 feet 8.25 inches	(AJ, excluding probe)
Length	16.30 metres	53 feet 5.75 inches	(AJ, including probe)
Length	15.58 metres	51 feet 1.5 inches	(JA, excluding probe)
Length	16.40 metres	53 feet 9.75 inches	(JA, including probe)
Height	5.90 metres	19 feet 4.25 inches	
Height	4.00 metres	13 feet 1.5 inches	(fin folded)

Total Lifting Area	52.20 square metres	561.88 sq.ft	(including foreplanes)
Gross Wing Area	46.00 square metres	495.16 sq.ft	(wing alone)
Foreplane Area	6.20 square metres	66.74 sq.ft	(nett)

Note: the gross wing area is the area of the main wing, including that portion which carries across the fuselage. The foreplane area is the area of the lifting surfaces, not including the portion which carries through the fuselage. The "total wing area" defined in some areas is the sum of the gross wing area and nett foreplane area, and can be misleading.

3. Weights

Only limited weight data (in metric units) has been provided for the aircraft. The following is my best estimate for the actual weights of the aircraft and its component parts.

Empty Weight	12,200 kg	26,895 lbs	(approx)
Normal Loaded	16,800 kg	37,040 lbs	(carrying four AAM)
Max Takeoff	22,500 kg	49,600 lbs	

Up to 6,000 kg (13,227 lbs) of ordnance can be carried externally.

Takeoff weight	15,000 kg	33,070 lbs	(clean)
Takeoff weight	17,000 kg	37,478 lbs	(normal armament)

The cannon has 150 rounds, at 0.36 kg (0.79 lbs) per round for a total weight of 54 kg.

Weight of Rb-71 (Skyflash) Missile	193 kg	425 lbs
Weight of Rb-24 (AIM-9L) Missile	85.3 kg	188 lbs
Avionics weight	600 kg	1323 lbs

Pilot weight is assumed to be 100 kg

Internal fuel	5700 litres	1506 US gal	4440 kg	9789 lbs	
External tank	1275 litres	337 US gal	993 kg	2190 lbs	(estimated)

(tank weight without fuel = 100 kg - estimated)

Engine Weight	2100 kg	4630 lbs	RM-8A
	2250 kg	4960 lbs	RM-8B

Weight Breakdown

Assuming the figure of 12,200 kg for a clean, empty aircraft is approximately correct, we can now check one of the other weights to see if it corresponds. An empty aircraft is the condition of the aircraft being fully equipped but with no fuel, pilot or external stores. We have a value for a normal loaded aircraft, which gives us a weight of 17,000 kg when fitted with 4 air-to-air missiles. If we add weights for a pilot and full internal fuel, plus four Rb-24 missiles (AIM-9L), we get the following;

Clean A/C	12,200 kg	(includes 150 rounds for gun)
Pilot	100 kg	
Fuel (100% internal)	4440 kg	(at 6.5 lbs/US gallon)
4 x Aim-9L	342 kg	

Total	17,082 kg	

This corresponds approximately to the weight expected. So we can now propose a weight breakdown for the aircraft and its component parts.

Clean A/C	12,200 kg	(54 kg for 150 rounds for gun) (600 kg for avionics) (2250 kg for engine)
Pilot	100 kg	
Fuel (100% internal)	4440 kg	(at 6.5 lbs/US gallon)
Rb-24 (AIM-9L)	85.3 kg	
Rb-71 (Skyflash)	193 kg	
External Tank	100 kg	(empty)
External Tank	993 kg	(full)

4. Ordnance

The aircraft is typically configured to have up to seven (7) external pylons. These are located as follows (with estimated load limits at each location);

1 x centreline pylon	2000 kg	4410 lbs
2 x fuselage edge pylons	500 kg	1102 lbs
2 x inner wing pylons	1000 kg	2205 lbs
2 x outer wing pylons	500 kg	1102 lbs

A typical air defence loading would include 2 x Rb 72 Skyflash and 2 or 4 x Rb 24 Sidewinder (AIM-9L) missiles. The aircraft is fitted with a single 30 mm Oerlikon KCA cannon. This has 150 rounds available.

5. Engine

The aircraft is fitted with a Volvo Flygmotor RM-8 turbofan engine. This is based on the Pratt & Whitney JT-8D-22 engine, with a Volvo designed afterburner fitted. The engine has two versions. The RM-8A is fitted to all except the JA version of the aircraft. The JA is fitted with the RM-8B engine; a slightly more powerful version of the engine.

Thrust

RM-8A	25,970 lbst	11790 kg	max reheat
	14,750 lbst	6690 kg	max dry
RM-8B	28,110 lbst	12750 kg	max reheat
	16,200 lbst	7350 kg	max dry

Fuel Consumption

RM-8A	2.47 lb/hr/lbst	70.0 mg/Ns	max reheat
	0.63 lb/hr/lbst	17.8 mg/Ns	max dry
	0.61 lb/hr/lbst	17.3 mg/Ns	max continuous
RM-8B	2.52 lb/hr/lbst	71.4 mg/Ns	max reheat
	0.64 lb/hr/lbst	18.1 mg/Ns	max dry
	0.61 lb/hr/lbst	17.3 mg/Ns	max continuous

Dimensions

Length	6.17 metres	RM-8A
	6.24 metres	RM-8B
Max Diameter	1.397 metres	55 inches
Inlet Diameter	1.030 metres	40.55 inches

Max Mass Flowrate	145 kg/sec
Bypass Ratio	1.10
Max Pressure Ratio	16.5

Pratt & Whitney JT-8D-7 Turbofan

For comparison purposes the key performance data for the JT-8 engine are provided here. This is a non-afterburning engine.

6350 kg nett thrust - takeoff - sea level static
1540 kg nett thrust - cruise - Mach 0.80 at 11,000 metres

Cruise sfc	0.81 kg/kg/hour
Bypass Ratio	1.10
Air Flow	141 kg/sec at sea level static conditions
Pressure Ratio	15.8
Internal Diameter	0.108 metres
Length	3.75 metres
Dry Weight	1431 kg
No of Spools	2

6. Performance

The following performance and mission profile data is the best estimate from the various sources of data found.

Max Speed at Seal Level (4 x AAM)	838 mph	1350 kmh	Mach 1.10	
Max Speed at 11,000 metres	1365 mph	2195 kmh	Mach 2.1	(at 36,090 ft)
Approach Speed	119 knots	137 mph	220 kmh	

Service Ceiling	60,000 feet	
Initial Climb	40,000 fpm	(approx)
Time to 32,810 feet (10,000 m)	1.4 minutes	(at max afterburner)

Mission Profiles

Ferry range 2000 km (2250 km with Jet-A fuel)

Tactical Radius

- intercept mission 250 miles 400 km
- hi-lo-hi profile 621 miles (with unspecified external stores)
- lo-lo-lo profile 311 miles (with unspecified external stores)

For external load of 4 x 1000 lbs (454 kg) bombs and fuel

Tactical Radius

- hi-lo-hi profile 782 miles
- lo-lo-lo profile 532 miles

7. Take-Off

The aircraft was initially designed to operate from narrow 500 m long runways (1640 feet). Tha actual take-off run is approximately 400 metres (1310 feet). The key points in the aircraft take-off are as follows;

Afterburner is selected then the wheel brakes are released.

The aircraft accelerates to a rotation speed of 135 knots (250 kmh).

About 600 metres of runway is used to get airborne.

After lift-off the undercarriage is retracted and the aircraft accelerates at a 2 to 3 degree climb angle to 367 knots (680 kmh).

Below 190 knots (350 kmh) the aircraft is very sensitive in roll.

Afterburner is cut out at 270 knots (500 kmh) due primarily to noise abatement requirements.

Exceeding 30 degrees angle of attack results in some loss of yaw stability.

Over 30 degrees AOA the aircraft will enter into a "super stall", but is easily recoverable.

There is little natural pre-stall warning, with low buffet levels.

8. Landing

Landing Run	approx 500 m
Landing Speed	220 kmh

The undercarriage is lowered.

The thrust reverser is pre-selected to activate immediately after landing.

The approach is steep.

The aircraft attitude is 15 degrees nose up.

The speed is controlled by the autopilot.

The aircraft crosses the runway threshold at 130 knots (240 kmh).

Touchdown with a no-flare landing at 97 knots (180 kmh).

Touchdown is about 45 metres (150 feet) beyond the runway threshold.

The undercarriage is designed for a landing sink rate of 16 feet/sec (5 m/s).

9. References

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Frederick Warne & Co 1986

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Attack Aircraft
by Roy Braybrook
Haynes Publishing Group 1990

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Aerospace Publishing Ltd 1998

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Aeronautical Vest Pocket Handbook
Pratt & Whitney June 1978

10. Conversion Factors

The following conversion factors between metric and Imperial units were used at various places in this document.

3.281 feet	=	1.0 metre
10.76 square feet	=	1.0 square metres
2.205 pounds	=	1.0 kilogram
3.785 litres	=	1.0 US gallon
4.545 litres	=	1.0 Imperial Gallon
1 knot	=	6080 feet per second
1 mile per hour	=	5280 feet per second
1.097 feet per second	=	1.0 kilometre per hour

11. Liquid Weights

The following liquid densities were used to determine the fuel weights for the aircraft.

JP-1	6.65 lbs/US gal
JP-3	6.45 lbs/US gal
JP-4	6.55 lbs/US gal
JP-5	6.82 lbs/US gal
Jet-A	6.74 lbs/US gal
Gasoline	5.87 lbs/US gal
Water	8.345 lbs/US gal

Appendix A: Calculated Aircraft Dimensions

The following dimensions and areas have been determined by scanning a 3-view drawing of the Viggen, then importing it into a CAD program, scaling it appropriately and measuring the specific values shown here. Many of these values will be required for a theoretical drag estimation of the aircraft and other aspects of the performance assessment.

No specific wing section data has been found so the values shown are estimates only, based on standard design assumptions.

Wing

Approximately 4% thick, with maximum thickness at 40% of chord.

Root Chord	24.9 feet	Tip Chord	1.8 feet	Taper Ratio	0.07

Sweep of Quarter Chord Line	42 degrees
Wing Semi-Span	17.5 feet
Wing Span	35.0 feet
Gross Wing Area	522 square feet

Foreplane

Approximately 6% thick, with maximum thickness at 40% of chord.

Root Chord	1.0 feet	Tip Chord	2.2 feet	Taper Ratio	0.20

Sweep of Quarter Chord Line	50 degrees
Panel Span	5.3 feet
Panel Area	35.0 square feet
Geometric Aspect Ratio	0.80

Vertical Fin

Approximately 5% thick, with maximum thickness at 40% of chord.

Root Chord	13.6 feet	Tip Chord	1.6 feet	Taper Ratio	0.12

Sweep of Quarter Chord Line	43 degrees
Span	9.0 feet
Area	68.7 square feet
Geometric Aspect Ratio	1.20

Fuselage

Length	50.0 feet	Width	8.25 feet	Height	7.0 feet

Frontal Area 42 square feet
Surface Area 880 square feet

Appendix B: Calculated Aerodynamic Data

Calculation of Maximum Lift Coefficient

It is possible to make an estimate of the maximum lift coefficient for the aircraft. Available data states the aircraft approach speed is 119 knots, which will be a speed just above the stall speed of the aircraft.

Assuming 119 knots is the aircraft stall speed, we know the wing area and air density, and can approximate the aircraft weight, and so find the lift coefficient for this condition.

We will assume the atmospheric conditions are for sea level and standard ISA conditions. This gives an air mass density of 0.002378 slugs per cubic foot. Also, 119 knots is equal to 201 feet per second.

We have a gross wing area of 562 square feet. Because the aircraft is of canard configuration, the foreplanes generate lift as well as the main wing, so both contribute to the total aircraft lift.

We will assume a standard weight condition for the aircraft for all subsequent analysis. Much of the tactical radius data obtained is for an aircraft in an air defence configuration, carrying 4 air to air missiles. We will assume this is for two short range ((AIM-9L) and two long range (SkyFlash) missiles. It is also normal practice to assume a 50% fuel load for performance analysis such as this, so we will assume a 50% internal fuel load and no external fuel.

This then gives a weight of 33,244 pounds (15,077 kilograms).

Clean A/C	12,200 kg	
Pilot	100 kg	
Fuel (50% internal)	2220 kg	
2 x SkyFlash	386 kg	
2 x Aim-9L	171 kg	

Total	15,077 kg	33,244 pounds

CL = (2 x Weight) / (rho x area x velocity x velocity)
CL = (2 x 33,244) / (0.002378 x 562 x 201 x 201)
CL = 1.23

In practice the actual lift coefficient will be probably be somewhere between 1.25 and 1.30 but a value of 1.23 (based on a reference wing area of 562 square feet) is a safe value for controlled flight at a minimum speed.

Appendix C: Performance Analysis

Based on the data presented here, a performance estimate for the Viggen has been prepared. This was generated using the suite of computer programs produced by Mr Sidney A Powers, called "BASIC Aircraft Performance" (Kern International, Inc. Copyright 1984).

This suit of programs includes routines to predict aircraft drag, format engine data and determine various aircraft performance parameters, including mission analysis and flight performance at varying altitudes.

DRAG ESTIMATE

These routines were used to iteratively obtain a likely drag for the Viggen aircraft, then to determine other data, including flight envelopes at various load factors, turning performance and mission performance for varying stores configurations.

In obtaining a drag estimate for the aircraft it is always necessary to define this in relation to the aircraft's engine performance. The engine performance (thrust and fuel flow, and their variation with speed and altitude) was estimated based on the best data available, but cannot be guaranteed to truly represent the Viggen engine. So the drag data presented is that which corresponds to the engine data used here. If another engine computer model is used to generate engine performance then the drag values may need to be adjusted to suit.

Drag is presented in the typical way for computer analysis, as a profile drag coefficient and a wing spanwise efficiency factor. Together these will define the drag polar for the aircraft. These values have been provided at a range of aircraft speeds, to allow for the relative effects of subsonic, transonic and supersonic flow. That is,

CDo = Profile Drag Coefficient
CDi = Induced Drag Coefficient
CD = Total Drag Coefficient
e = Spanwise Efficiency Factor
CL = Lift Coefficient
AR = Wing Aspect Ratio
Pi = 3.14159

CD = CDo + CDi

where CDi = (CL x CL) / (Pi x AR x e)

Initially a set of drag coefficients was obtained using one of the routines provided in the "BASIC Aircraft Performance" suite. Prior use of this program had indicated it provided only a very approximately correct value, and then only at lower speeds. Using this as a starting point these drag data were revised using an iterative procedure. The drag values would be used to generate a flight envelope, then this envelope would be compared with the quoted aircraft performance (stall speed, maximum speed at low level, maximum speed at altitude and service ceiling). The drag data would then be adjusted as required to better match the known performance of the aircraft.

Table 1 shows the geometric data input into the analysis program, and used to obtain the initial drag estimate for the aircraft. Table 2 shows the final drag data obtained after interation, and used for the final performance assessments. Table 3 shows the typical output for one velocity for the "BASIC Aircraft Performance" drag prediction routine, while Table 4 shows the engine data which was used for this analysis.

Figure 1 shows the estimated variation of the aircraft profile drag coefficient with speed, while Figure 2 shows the corresponding wing spanwise efficiency factor and its variation with speed.

Table 1

FILE: (F)VIGGN
IDENTIFIER: SAAB JA-37 VIGGEN

BASIC DATA==	
ZERO FUEL WEIGHT =	27120
FUEL WEIGHT =	9790
NUMBER OF ENGINES =	1
THRUST MULTIPLIER =	1
FUEL FLOW MULTIPLIER =	1
CL(MAX) =	1.25
WING==	
THEORETICAL AREA =	495.16
ASPECT RATIO =	2.45
TAPER RATIO =	0.07
SWEEP OF X/C =	42.0
X/C =	0.25
(T/C)MAX =	0.04
X/C LOC OF (T/C)MAX =	0.4
AIRFOIL RN/C =	1.76304E-03
HORIZONTAL TAIL===FLAPPED=========================	
EXPOSED AREA =	70.0
EXPOSED ASPECT RATIO =	0.8
EXPOSED TAPER RATIO =	0.2
SWEEP OF X/C =	50.0
X/C =	0.25
(T/C)MAX =	0.06
X/C LOC OF (T/C)MAX =	0.4
VERTICAL TAIL===SINGLE/FLAPPED====================	
SINGLE FIN AREA =	68.7
GEOMETRIC ASPECT RATIO =	1.20
EXPOSED TAPER RATIO =	0.12
SWEEP OF X/C =	43.0

```
                X/C =        0.25
           (T/C)MAX =        0.05
   X/C LOC OF (T/C)MAX =     0.4

FUSELAGE==========================================
        WETTED AREA =        880
             LENGTH =        50.0
              WIDTH =        8.25
             HEIGHT =        7.0

MISCELLANEOUS=====================================
        DELTA CD0 =        0.02
          DELTA F =        0.0
      MISC FACTOR =        0.25
```

Table 2

```
              FILE : DG)VIGGN
        IDENTIFIER : SAAB JA-37 VIGGEN

********** REVIEW DRAG TABLE **********
```

MACH NO.	CD0
0.400	0.01770
0.600	0.01770
0.800	0.01770
0.900	0.02150
0.950	0.03140
1.000	0.04130
1.050	0.04420
1.100	0.04500
1.200	0.04450
1.400	0.04290
1.600	0.04290
1.800	0.04290
2.000	0.04290
2.200	0.04290

******** REVIEW WING E TABLE *********

MACH NO.	WING E
0.400	0.764
0.600	0.764
0.800	0.764
0.900	0.764
0.950	0.757
1.000	0.695
1.050	0.642
1.100	0.597
1.200	0.526
1.400	0.450
1.600	0.400
1.800	0.361
2.000	0.329
2.200	0.301

Table 3

FILE: DG)TEST
SAAB JA-37 VIGGEN

SUBSONIC ZERO-LIFT DRAG
M = 0.600
ALT = 0

RN/FT = 4.26E+06
REFERENCE WING AREA = 495.2

COMPONENT	SWET	LENGTH	RN	FORM FACTOR	CF	INTERF FACTOR	CDW	CD0	F
WING	609.2	13.91	5.93E+07	1.048	0.00217	1.143	0.00000	0.00319	1.580
HORIZONTAL	143.2	10.74	4.58E+07	1.073	0.00225	1.351	0.00000	0.00094	0.467
VERTICAL	140.0	9.12	3.89E+07	1.060	0.00231	1.340	0.00000	0.00093	0.459
FUSELAGE	880.0	50.00	2.13E+08	1.227	0.00181	1.015	0.00000	0.00400	1.980
MISC.	0.0	0.00	0.00E+00	0.000	0.00000	0.000	0.00000	0.00866	4.290
TOTAL	1,772.3							0.01772	8.776

CFE = 0.00495

SPAN EFFICIENCY FACTOR = 0.915

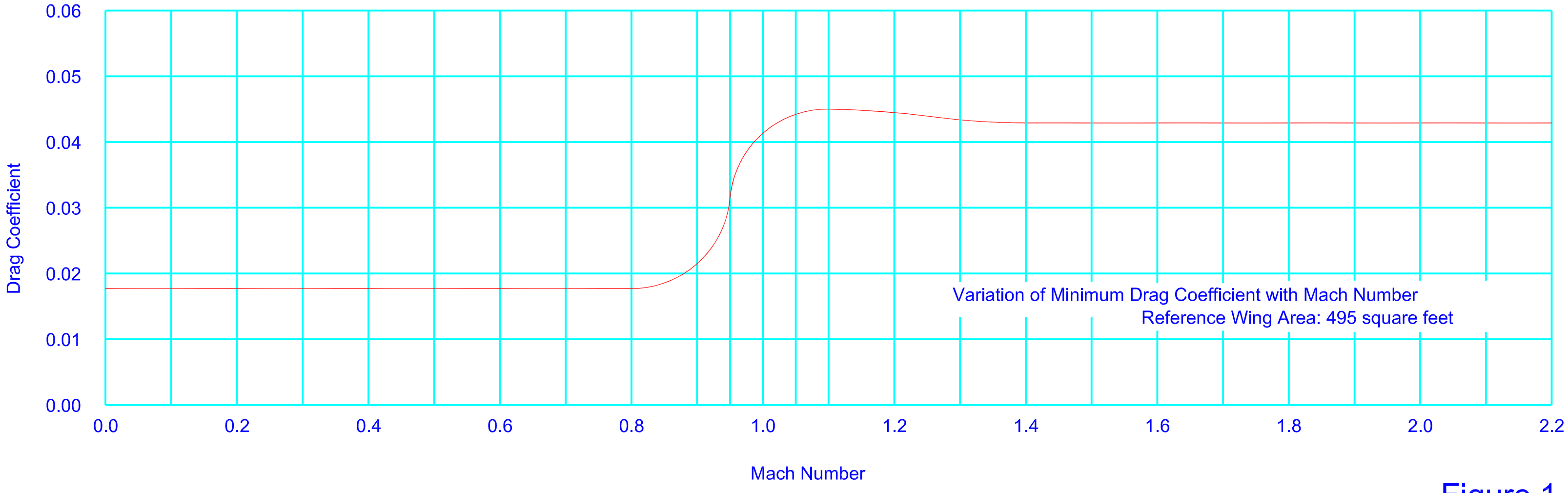


Figure 1

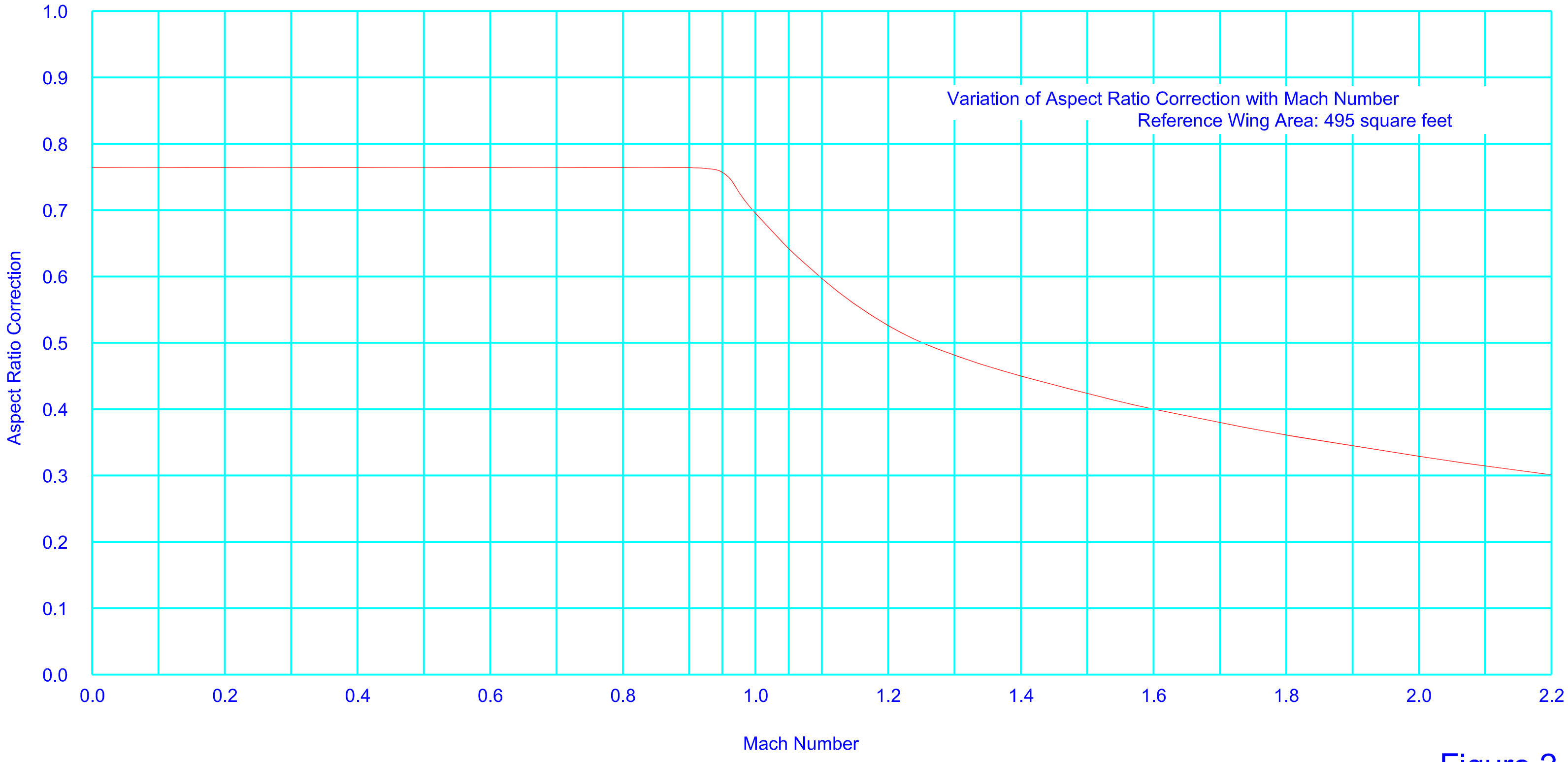


Figure 2

Table 4

FILE :FN)RM8B
IDENTIFIER :VOLVO FLYGMOTOR RM-8B TURBOFAN
NO OF ALTITUDES : 7

ALTITUDE : 0 FEET

MACH	THRUST	FUEL FLOW
0.000	22,650	57,078
	14,164	9,065
	8,758	5,342
0.400	24,414	61,523
	12,657	8,100
	7,474	4,559
0.800	28,836	72,666
	11,311	7,239
	6,174	3,766
0.900	30,827	77,684
	10,988	7,032
	5,676	3,462
1.000	32,421	81,700
	10,090	6,458
	4,125	2,516
1.100	45,740	115,265
	8,456	5,412
	1,435	875
1.200	37,268	93,915
	6,398	4,095
	0	0

ALTITUDE : 10,000 FEET

MACH	THRUST	FUEL FLOW
0.400	19,435	48,976
	8,725	5,584
	5,154	3,144
0.600	21,123	53,230
	8,864	5,673
	5,140	3,135

0.800	23,740	59,825
	9,120	5,837
	5,120	3,123
0.900	25,187	63,471
	9,224	5,903
	4,989	3,043
1.000	26,582	66,987
	9,080	5,811
	4,281	2,611
1.200	28,190	71,039
	7,243	4,636
	458	279
1.600	39,792	100,276
	0	0

ALTITUDE : 20,000 FEET

MACH	THRUST	FUEL FLOW
0.400	14,106	35,547
	5,913	3,784
	3,420	2,086
0.600	15,616	39,352
	6,017	3,851
	3,484	2,125
0.800	18,050	45,486
	6,503	4,162
	3,715	2,266
0.900	19,367	48,805
	6,861	4,391
	3,773	2,302
1.000	20,608	51,932
	6,966	4,458
	3,479	2,122
1.200	23,932	60,308
	6,331	4,052
	1,726	1,053

```
  1.800       41,742      %105,190
                   0             0

        ALTITUDE : 30,000 FEET
   MACH     THRUST      FUEL FLOW
   ----     ------      ---------
  0.400        9,040        22,781
               3,971         2,541
               2,283         1,393

  0.800       12,550        31,626
               4,408         2,821
               2,476         1,510

  0.900       13,709        34,547
               4,651         2,977
               2,562         1,563

  1.000       14,880        37,497
               4,610         2,950
               2,301         1,404

  1.200       18,162        45,768
               5,173         3,311
               1,821         1,111

  1.800       30,458        76,754
                   0             0

  2.200       38,404        96,778
                   0             0

        ALTITUDE : 40,000 FEET
   MACH     THRUST      FUEL FLOW
   ----     ------      ---------
  0.600        6,404        16,138
               2,733         1,749
               1,631           995

  0.800        7,521        18,953
               3,046         1,949
               1,747         1,066

  0.900        8,133        20,495
               3,151         2,017
               1,744         1,064
```

1.000	8,953	22,561
	3,097	1,982
	1,578	963
1.200	12,054	30,376
	3,163	2,024
	1,066	650
2.000	24,957	62,891
	0	0
2.400	31,360	79,027
	0	0

ALTITUDE : 50,000 FEET

MACH	THRUST	FUEL FLOW
0.700	4,570	11,516
	0	0
0.900	5,273	13,288
	0	0
1.000	5,865	14,780
	0	0
1.200	6,990	17,615
	0	0
1.600	11,313	28,508
	0	0
2.000	14,928	37,618
	0	0
2.600	16,968	42,759
	0	0

ALTITUDE : 60,000 FEET

MACH	THRUST	FUEL FLOW
0.800	3,590	9,047
	0	0
1.000	3,890	9,803

	0	0
1.200	4,495 0	11,327 0
1.400	4,818 0	12,141 0
1.600	5,500 0	13,860 0
2.000	7,468 0	18,819 0
2.200	8,820 0	22,226 0

PERFORMANCE ESTIMATE

Once a specific set of drag and thrust data has been defined, for a particular aircraft geometric configuration, it is possible to determine the aircraft's performance. The most useful initial performance data is the aircraft flight envelope. For the Viggen. this has been estimated for a number of load factors. Table 5 shows the flight envelope data generated by the performance analysis program, while Figure 3 presents the flight envelope in a graphical form. The flight envelope approximates to the published performance values for the aircraft in terms of maximum speeds, stall speed and expected service ceiling.

Table 5

FLIGHT ENVELOPE

CONFIGURATION FILE : CF)VIGGN

```
AIRCRAFT        : SAAB JA-37 VIGGEN
ENGINE          :   VOLVO FLYGMOTOR RM-8B TURBOFAN
NO OF ENGINES   :  1
S(REF)          :  495.16
ASPECT RATIO    :  2.45
AIRCRAFT WEIGHT:  32015
PERCENT FUEL    :  50
```

LOAD FACTOR = 1

ALTITUDE	MINIMUM M	MINIMUM KTAS	MINIMUM KEAS	MAXIMUM M	MAXIMUM KTAS	MAXIMUM KEAS
0	0.187	124	124	1.136	752	752
5,000	0.205	133	124	1.123	730	678
10,000	0.225	144	124	1.091	696	599
15,000	0.249	156	124	1.173	735	583
20,000	0.275	169	124	1.485	912	667
25,000	0.306	184	124	1.635	984	660
30,000	0.342	202	124	1.762	%1039	637
35,000	0.396	228	127	1.919	%1106	618
40,000	0.494	283	141	2.099	%1204	599
45,000	0.599	344	152	1.981	%1136	502
50,000	0.729	418	164	1.018	584	229
51,000	0.753	432	165	0.997	572	219
52,000	0.778	446	167	0.983	564	211
53,000	0.807	463	169	0.969	556	203
54,000	0.844	484	172	0.951	545	194
55,000	0.888	509	177	0.915	525	183

LOAD FACTOR = 2

ALTITUDE	MINIMUM M	MINIMUM KTAS	MINIMUM KEAS	MAXIMUM M	MAXIMUM KTAS	MAXIMUM KEAS
0	0.264	175	175	1.131	748	748
5,000	0.290	188	175	1.113	724	672
10,000	0.318	203	175	1.068	682	586
15,000	0.351	220	175	1.123	703	558
20,000	0.397	244	178	1.311	805	589
25,000	0.484	291	195	1.504	906	607
30,000	0.584	344	211	1.594	939	576
35,000	0.726	419	234	1.003	578	323
40,000	0.000	0	0	0.000	0	0

LOAD FACTOR = 3

	<-----MINIMUM----->			<-----MAXIMUM----->		
ALTITUDE	M	KTAS	KEAS	M	KTAS	KEAS
0	0.324	214	214	1.123	743	743
5,000	0.356	232	215	1.058	688	639
10,000	0.415	265	228	1.036	661	568
15,000	0.492	309	245	1.049	657	522
20,000	0.588	361	264	1.051	646	472
25,000	0.700	422	283	1.006	606	406
30,000	0.845	498	305	0.952	561	344
35,000	0.000	0	0	0.000	0	0

LOAD FACTOR = 4

	<-----MINIMUM----->			<-----MAXIMUM----->		
ALTITUDE	M	KTAS	KEAS	M	KTAS	KEAS
0	0.413	273	273	0.989	654	654
5,000	0.476	309	287	1.000	650	603
10,000	0.554	354	304	1.000	638	549
15,000	0.653	409	325	0.990	620	492
20,000	0.765	470	343	0.968	594	434
25,000	0.000	0	0	0.000	0	0

LOAD FACTOR = 5

	<-----MINIMUM----->			<-----MAXIMUM----->		
ALTITUDE	M	KTAS	KEAS	M	KTAS	KEAS
0	0.517	342	342	0.000	0	0
5,000	0.598	389	361	0.976	635	589
10,000	0.692	442	380	0.968	618	531
15,000	0.810	507	403	0.939	589	467
20,000	0.000	0	0	0.000	0	0

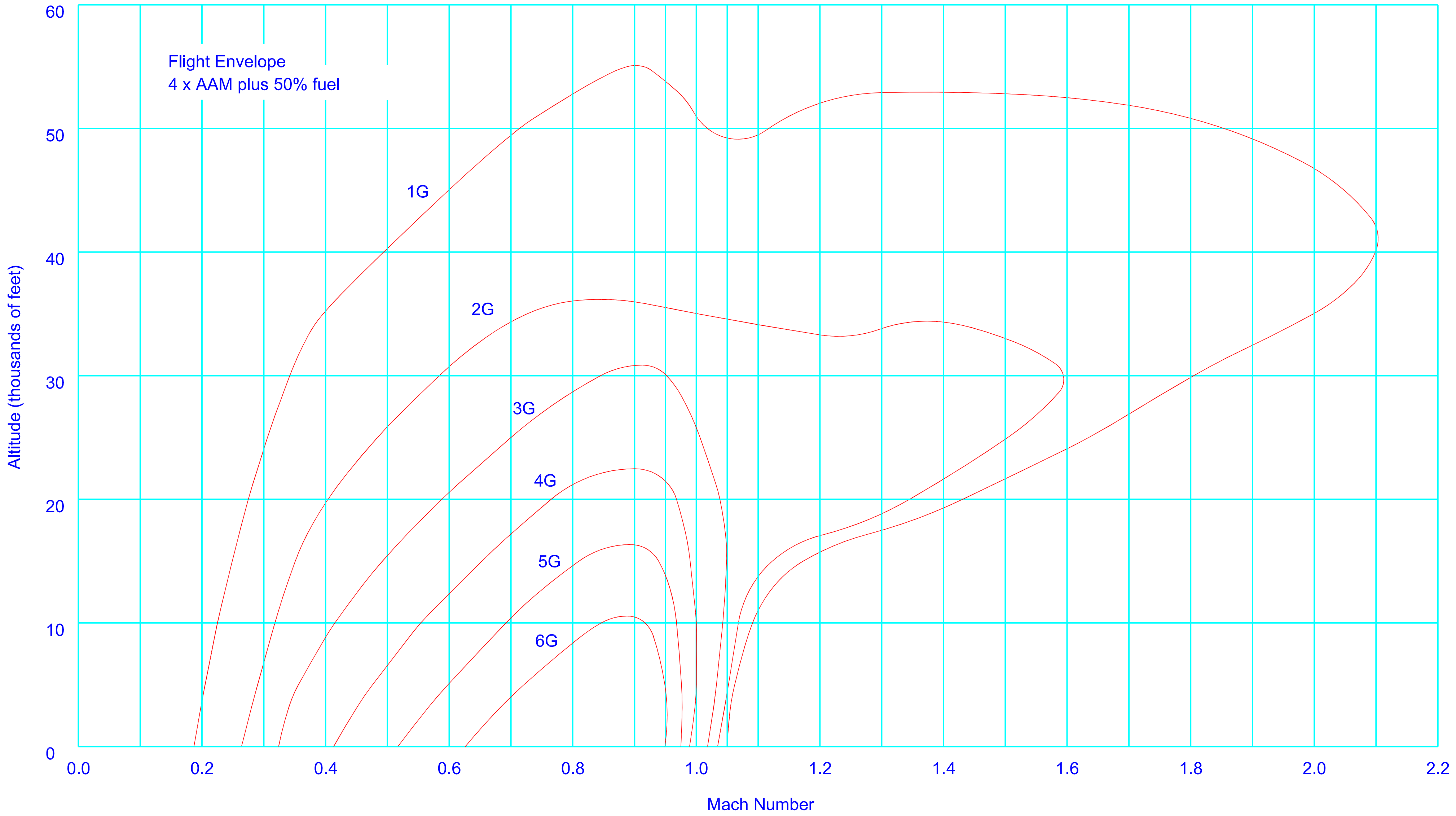

Flight Envelope
4 x AAM plus 50% fuel
1G
2G
3G
4G
5G
6G
Altitude (thousands of feet)
60
50
40
30
20
10
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
Mach Number

Figure 3

LOAD FACTOR = 6

ALTITUDE	MINIMUM M	MINIMUM KTAS	MINIMUM KEAS	MAXIMUM M	MAXIMUM KTAS	MAXIMUM KEAS
0	0.626	414	414	0.000	0	0
5,000	0.721	469	435	0.949	617	573
10,000	0.846	540	464	0.917	586	503
15,000	0.000	0	0	0.000	0	0

LOAD FACTOR = 7

ALTITUDE	MINIMUM M	MINIMUM KTAS	MINIMUM KEAS	MAXIMUM M	MAXIMUM KTAS	MAXIMUM KEAS
0	0.744	492	492	0.933	617	617
5,000	0.898	584	542	0.902	586	545
10,000	0.000	0	0	0.000	0	0

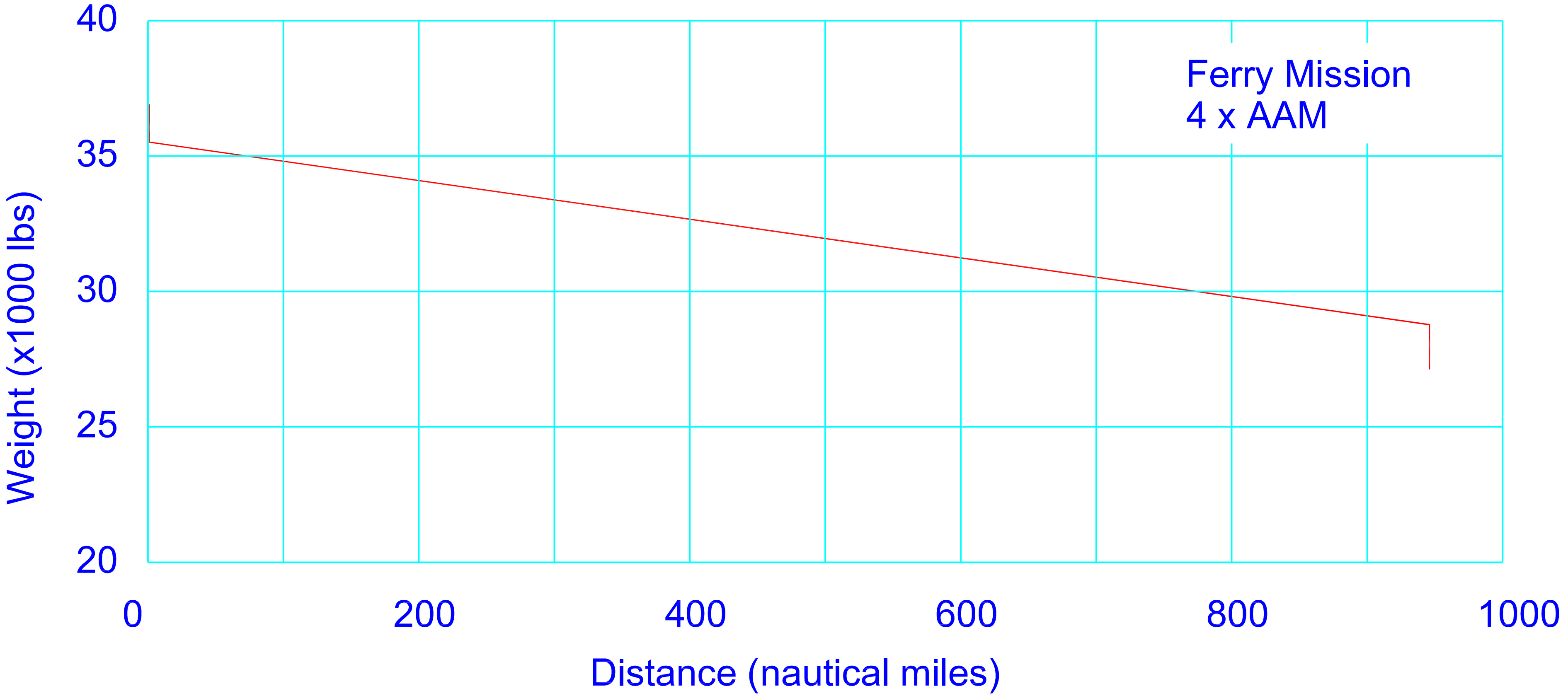
In an attempt to verify the performance data estimated here with the published performance figures a ferry mission was defined. Table 6 shows the specific legs making up this ferry mission, while Figure 4 displays the results obtained from the analysis program. The published figures indicate a ferry range for the aircraft of 1250 miles (2000 kilometres). The computer prediction gives calculated a ferry range of 1088 miles (945 nautical miles).

Table 6

```
                 MISSION DESCRIPTION
                        MI)FERRY

                  VIGGEN FERRY MISSION

            SEG          DESCRIPTION
            ---          -----------
              1  ALLOW FUEL FOR 1 MIN AT FULL THROTTLE
                                5 MIN AT IDLE THRUST
              2  ACCELERATE TO CLIMB SPEED
              3  CLIMB TO 35000 FEET AT MAX R/C
             **** RANGE BALANCE FOLLWING SEGMENT
              4  CRUISE FOR 1200 NM AT BEST NM/LB
              5  DESCEND TO 0 FEET WITH NO CREDIT
              6  ALLOW FUEL FOR 1 MIN AT FULL THROTTLE
                                5 MIN AT IDLE THRUST
```



40
35
30
25
20
Weight (x1000 lbs)
0
200
400
600
800
1000
Distance (nautical miles)
Ferry Mission
4 x AAM

Figure 4

Further checking of the drag data estimated here was carried out by comparing a climb to altitude. This information was provided in the published data for the aircraft, with a climb to 32,810 feet (10,000 metres) quoted as taking 1.4 minutes (84 seconds), for an aircraft loaded with four AAM stores plus 50% internal fuel, and climb performed at maximum afterburner. The analysis program indicated a time to 32,000 feet, for the same aircraft configuration, would take 1.7 minutes (102 seconds). The program output for this climb is presented in Table 7, with Figure 5 showing the actual, and estimated, time to climb in a graphical format.

Table 7

CLIMB VERIFICATION

FILE : CF)VIGGN

AIRCRAFT : SAAB JA-37 VIGGEN
ENGINE : VOLVO FLYGMOTOR RM-8B TURBOFAN
MISSION : CLIMB TO 32810 FEET
S(REF) : 495.16
AR : 2.45
NO OF ENGINES: 1

TIME MIN	ALT FT	RANGE NM	WEIGHT LBS	FUEL LBS	TAS KTS	EAS KTS	MACH	R/C FT/MIN	SR NM/LB	CL	CD0	FUEL FLOW LB/HR	THRUST	E	L/D
0.0	0	0	36,910	9,790	0.0	0.0	0.000	0	0.0000	0.000	0.00000	0	0	0.000	0.0
CLIMB TO 32810 FEET AT BEST R/C															
0.0	0	0	36,910	9,790	555.4	555.4	0.840	29,327	0.0074	0.071	0.01921	74,654	29,625	0.764	3.6
0.1	2,000	1	36,826	9,706	551.3	535.4	0.839	28,660	0.0076	0.077	0.01919	72,181	28,604	0.764	3.8
0.1	4,000	1	36,742	9,622	551.0	519.3	0.845	27,906	0.0079	0.081	0.01940	69,826	27,654	0.764	4.0
0.2	6,000	2	36,659	9,539	551.5	504.4	0.851	27,077	0.0082	0.086	0.01966	67,391	26,691	0.764	4.1
0.3	8,000	3	36,576	9,456	552.5	490.0	0.859	26,182	0.0085	0.091	0.01995	64,872	25,711	0.764	4.3
0.4	10,000	3	36,493	9,373	553.7	476.1	0.867	25,231	0.0089	0.096	0.02026	62,284	24,716	0.764	4.4
0.4	12,000	4	36,411	9,291	555.5	462.8	0.877	24,146	0.0093	0.101	0.02062	59,696	23,660	0.764	4.5
0.5	14,000	5	36,329	9,209	541.5	436.9	0.861	22,869	0.0096	0.114	0.02002	56,196	22,260	0.764	5.1
0.6	16,000	6	36,247	9,127	537.1	419.5	0.861	21,663	0.0101	0.123	0.02001	53,257	21,097	0.764	5.4
0.7	18,000	7	36,165	9,045	536.8	405.7	0.867	20,524	0.0106	0.131	0.02025	50,574	20,046	0.764	5.7
0.8	20,000	7	36,082	8,962	538.1	393.3	0.876	19,419	0.0112	0.139	0.02058	48,005	19,050	0.764	5.8
0.9	22,000	8	35,999	8,879	538.6	380.5	0.884	18,105	0.0119	0.148	0.02088	45,221	17,927	0.764	6.0
1.0	24,000	9	35,916	8,796	528.6	360.8	0.875	16,615	0.0126	0.165	0.02053	41,977	16,633	0.764	6.5
1.2	26,000	11	35,831	8,711	525.0	345.9	0.876	15,295	0.0134	0.179	0.02058	39,178	15,524	0.764	6.9
1.3	28,000	12	35,745	8,625	525.8	334.2	0.884	14,120	0.0143	0.191	0.02091	36,717	14,556	0.764	7.0
1.4	30,000	13	35,657	8,537	524.8	321.7	0.891	12,945	0.0153	0.205	0.02114	34,271	13,599	0.764	7.3
1.6	32,000	14	35,566	8,446	514.4	303.9	0.881	11,104	0.0168	0.230	0.02076	30,600	12,185	0.764	7.7
1.7	32,810	15	35,529	8,409	513.0	298.5	0.881	10,462	0.0175	0.238	0.02079	29,332	11,697	0.764	7.8

1381<---- DELTA FUEL

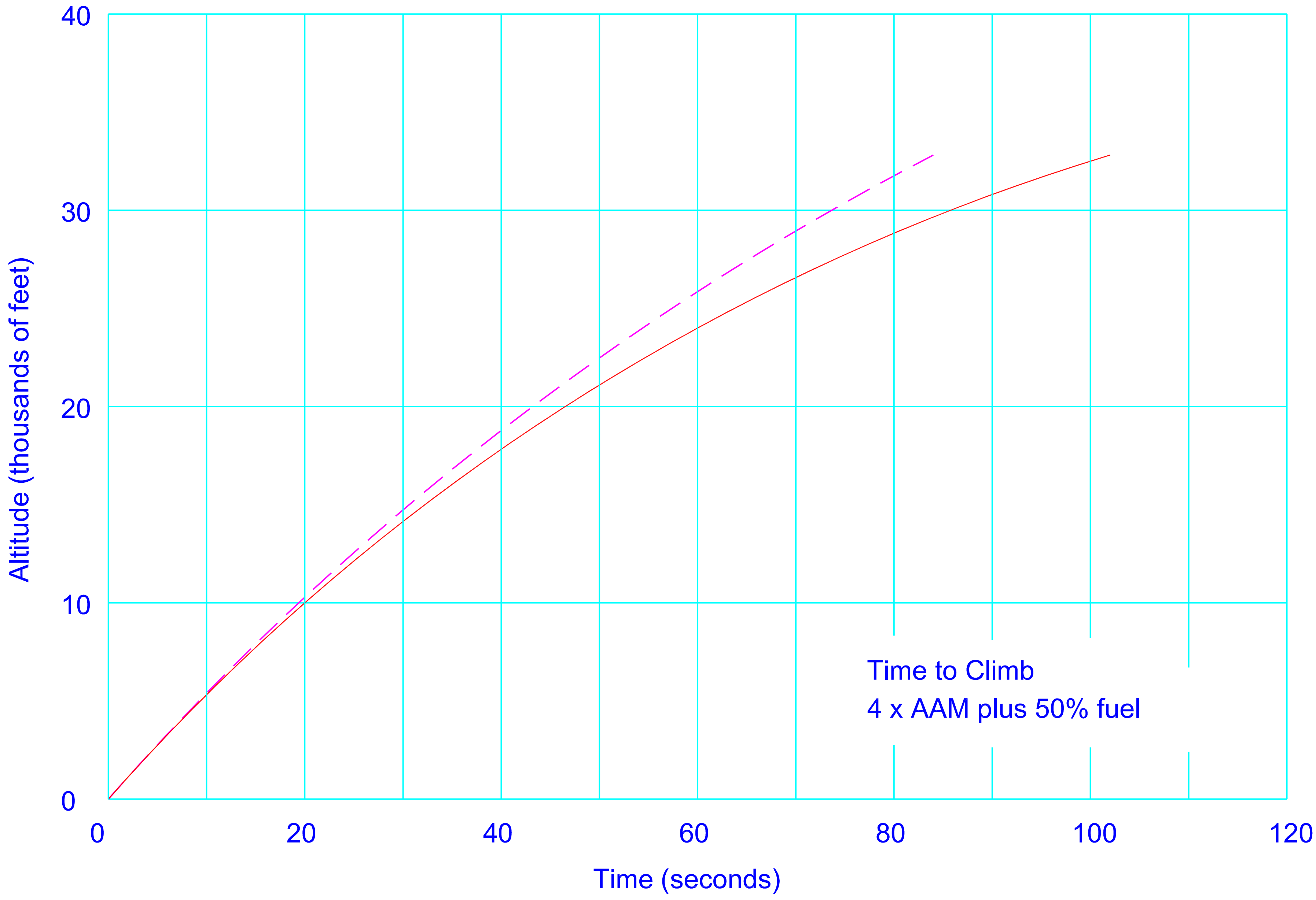
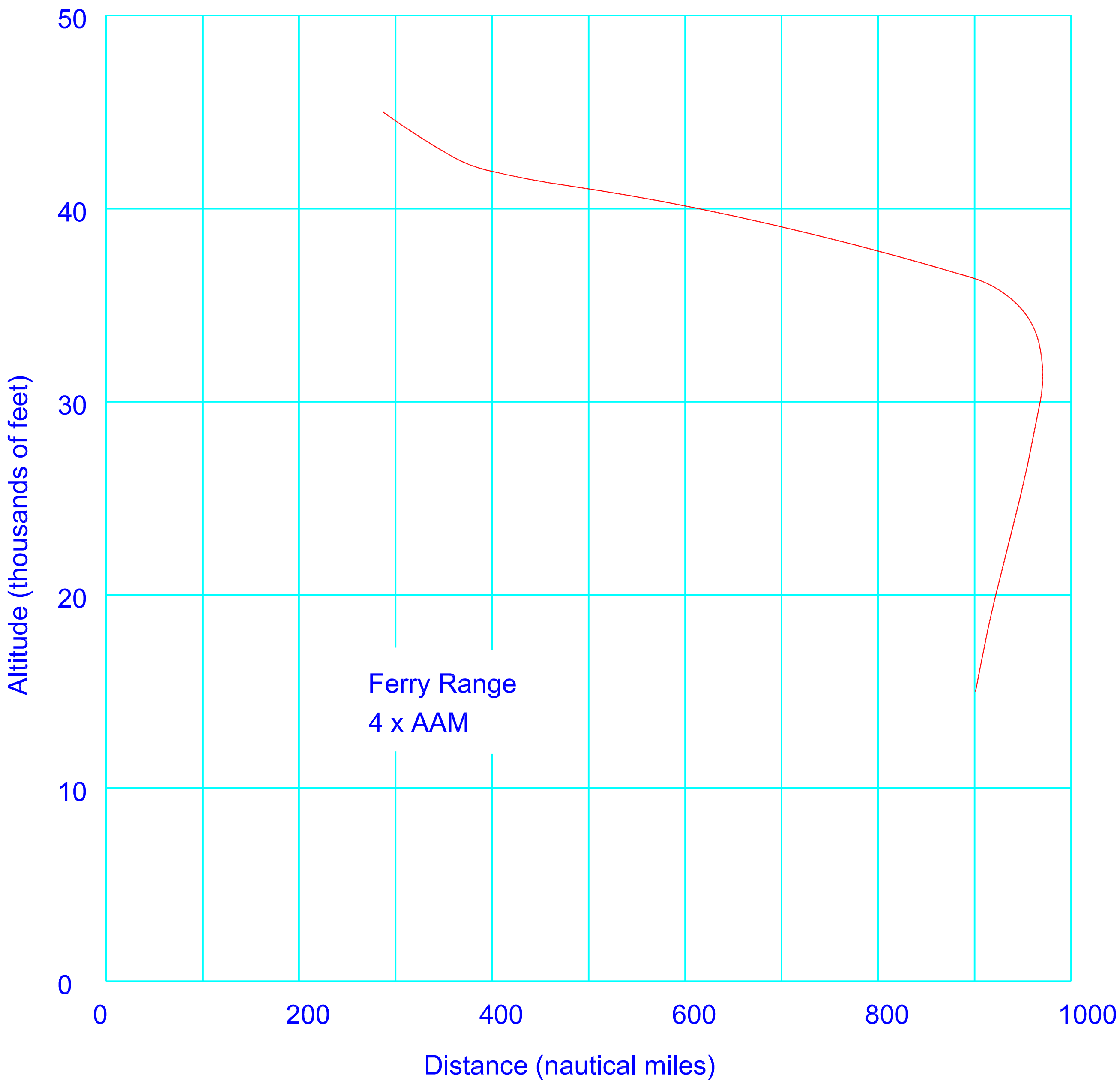

40
30
20
10
0
Altitude (thousands of feet)
0
20
40
60
80
100
120
Time (seconds)
Time to Climb
4 x AAM plus 50% fuel

Figure 5



Altitude (thousands of feet)
50
40
30
20
10
0
0
200
400
600
800
1000
Distance (nautical miles)
Ferry Range
4 x AAM

Figure 6

As there was a discrepancy with the actual and calculated ferry ranges (1250 miles compared with 1088 miles), a little further investigation was carried out. The actual ferry range was at an unspecified cruising altitude, so the ferry mission was run for a range of different cuise altitudes. The results of this analysis are shown in Figure 6. This indicated a maximum achievable range of about 960 nautical miles (1105 miles), which is about 13% less than the published figure for tha actual aircraft.

Overall, the discrepancies in the ferry range and climb performance are most likely due to the use of less than perfect engine performance data. Better engine data would probably give a closer match to the actual aircraft performance. At present, the engine and drag data currently used in the computer analysis program will give conservative performance results.

Finally, a table of data has been provided to define the predicted manoeuvre performance of the aircraft. This data is for a range of velocities and altitudes, and is presented in Table 8. Estimates are given for maximum turnrate, specific excess power, specific range and a few other parameters.

Table 8

MANOEUVRE PERFORMANCE

CONFIGURATION FILE : CF)VIGGN

AIRCRAFT : SAAB JA-37 VIGGEN
ENGINE : VOLVO FLYGMOTOR RM-8B TURBOFAN
NO OF ENGINES : 1
S(REF) : 495.16
ASPECT RATIO : 2.45
AIRCRAFT WEIGHT: 32015
PERCENT FUEL : 50

ALTITUDE = 0

						<------ N = 1	------>		
	<------ MAX POWER				------>	<------ CRUISE POWER		------>	
			T RATE	TR/FF	P-SUB-S	S RNG	F FLOW	THRUST	
MACH	CL-M	N-MAX	DEG/S	DEG/LG	FT/SEC	NM/LB	LB/HR	LB/ENG	CL-C
0.20	1.250	1.15	4.6	0.3	119.1	0.0347	3,813	6,460	1.091*
0.30	1.250	2.58	13.1	0.8	211.0	0.0980	2,025	3,809	0.485*
0.40	1.058	3.88	15.5	0.9	290.9	0.1402	1,887	3,562	0.273
0.50	0.845	4.84	15.6	0.9	371.8	0.1409	2,347	4,196	0.175
0.60	0.699	5.77	15.6	0.8	445.5	0.1261	3,148	5,334	0.121
0.70	0.591	6.64	15.5	0.8	509.8	0.1103	4,198	6,847	0.089
0.80	0.507	7.44	15.2	0.8	562.3	0.0969	5,461	8,681	0.068
0.90	0.423	7.84	14.3	0.7	557.4	0.0412	14,438	13,067	0.054
1.00	0.125	2.85	4.4	0.2	65.1	0.0088	75,413	30,555	0.044
1.10	0.173	4.80	7.1	0.2	212.9	0.0074	98,916	40,191	0.036
1.20	0.000	1.00	0.0	0.0	-417.4	0.0065	122,939	47,243	0.030*

ALTITUDE = 10000

	<-------------	---MAX POWER---	---------->			<--------------	N = 1	CRUISE POWER	---------->
MACH	CL-M	N-MAX	T RATE DEG/S	TR/FF DEG/LG	P-SUB-S FT/SEC	S RNG NM/LB	F FLOW LB/HR	THRUST LB/ENG	CL-C
0.30	1.250	1.77	8.4	0.6	140.9	0.0686	2,792	4,640	0.704*
0.40	1.145	2.89	11.6	0.9	213.3	0.1231	2,074	3,587	0.396
0.50	0.917	3.62	11.9	0.8	280.4	0.1524	2,094	3,615	0.254
0.60	0.761	4.32	12.0	0.8	342.2	0.1545	2,478	4,177	0.176
0.70	0.655	5.06	12.1	0.8	408.6	0.1442	3,098	5,084	0.129
0.80	0.573	5.78	12.2	0.7	470.6	0.1311	3,896	6,260	0.099
0.90	0.485	6.20	11.6	0.7	483.6	0.0974	5,901	9,221	0.078
1.00	0.246	3.88	6.4	0.3	179.9	0.0132	48,299	21,235	0.063
1.10	0.000	1.00	0.0	0.0	-17.6	0.0099	70,729	27,862	0.052

ALTITUDE = 20000

	<-------------	---MAX POWER---	---------->			<--------------	N = 1	CRUISE POWER	---------->
MACH	CL-M	N-MAX	T RATE DEG/S	TR/FF DEG/LG	P-SUB-S FT/SEC	S RNG NM/LB	F FLOW LB/HR	THRUST LB/ENG	CL-C
0.30	1.250	1.19	3.8	0.4	68.8	0.0344	5,355	6,269	1.053*
0.40	1.196	2.02	7.8	0.8	128.6	0.0944	2,604	4,181	0.592
0.50	0.964	2.55	8.3	0.8	183.0	0.1410	2,178	3,558	0.379
0.60	0.807	3.07	8.6	0.8	233.8	0.1680	2,195	3,586	0.263
0.70	0.703	3.63	8.9	0.8	291.3	0.1750	2,457	3,984	0.193
0.80	0.622	4.20	9.1	0.7	347.6	0.1700	2,891	4,634	0.148
0.90	0.538	4.60	8.9	0.7	374.4	0.1329	4,162	6,522	0.117
1.00	0.324	3.42	5.8	0.4	197.0	0.0200	30,761	14,524	0.095
1.10	0.208	2.66	4.0	0.3	118.4	0.0149	45,263	18,947	0.078
1.20	0.138	2.09	2.7	0.2	68.2	0.0135	54,696	22,176	0.066
1.30	0.113	2.02	2.4	0.1	61.6	0.0123	64,947	25,436	0.056
1.40	0.087	1.80	1.9	0.1	45.6	0.0115	74,957	28,863	0.048
1.50	0.031	1.00	0.0	0.0	-9.5	0.0107	86,319	33,033	0.042

ALTITUDE = 30000

						<-------------- N = 1 ------------->			
	<-------------MAX POWER------------->					<--------CRUISE POWER------->			
			T RATE	TR/FF	P-SUB-S	S RNG	F FLOW	THRUST	
MACH	CL-M	N-MAX	DEG/S	DEG/LG	FT/SEC	NM/LB	LB/HR	LB/ENG	CL-C
0.40	1.189	1.30	3.9	0.6	42.8	0.0261	9,040	5,599	0.915*
0.50	0.981	1.68	5.0	0.7	89.5	0.0945	3,118	4,155	0.585*
0.60	0.838	2.06	5.6	0.7	134.0	0.1547	2,285	3,607	0.406
0.70	0.732	2.45	5.9	0.7	177.2	0.1854	2,225	3,523	0.299
0.80	0.650	2.84	6.2	0.7	219.4	0.2001	2,356	3,723	0.229
0.90	0.573	3.17	6.2	0.6	249.3	0.1526	3,475	4,794	0.181
1.00	0.378	2.58	4.4	0.4	154.3	0.0284	20,786	9,912	0.146
1.10	0.283	2.34	3.6	0.3	128.7	0.0222	29,225	12,756	0.121
1.20	0.231	2.27	3.1	0.2	124.4	0.0203	34,858	14,824	0.102
1.30	0.203	2.34	3.0	0.2	133.9	0.0183	41,791	16,897	0.087
1.40	0.177	2.37	2.8	0.2	138.0	0.0170	48,562	19,088	0.075
1.50	0.146	2.24	2.5	0.1	119.0	0.0157	56,170	21,756	0.065
1.60	0.113	1.98	2.0	0.1	86.3	0.0148	63,664	24,624	0.057
1.70	0.077	1.52	1.3	0.1	38.5	0.0141	70,942	27,680	0.051
1.80	0.013	1.00	0.0	0.0	-26.5	0.0136	77,950	30,932	0.045

ALTITUDE = 40000

						<-------------- N = 1 ------------->			
	<-------------MAX POWER------------->					<--------CRUISE POWER------->			
			T RATE	TR/FF	P-SUB-S	S RNG	F FLOW	THRUST	
MACH	CL-M	N-MAX	DEG/S	DEG/LG	FT/SEC	NM/LB	LB/HR	LB/ENG	CL-C
0.50	0.950	1.01	0.6	0.2	2.1	0.0204	14,070	5,705	0.937*
0.60	0.813	1.25	2.4	0.5	36.1	0.0413	8,333	4,413	0.651*
0.70	0.712	1.49	3.0	0.6	67.2	0.0754	5,325	3,788	0.478
0.80	0.634	1.73	3.4	0.6	96.3	0.1198	3,829	3,541	0.366
0.90	0.553	1.91	3.4	0.6	113.7	0.1033	4,998	3,955	0.289
1.00	0.360	1.54	2.2	0.4	57.6	0.0362	15,865	7,048	0.234
1.10	0.292	1.51	2.0	0.3	56.9	0.0301	20,985	8,792	0.194
1.20	0.260	1.60	2.0	0.2	72.9	0.0287	23,974	10,046	0.163
1.30	0.241	1.74	2.1	0.2	93.9	0.0267	27,964	11,277	0.139

1.40	0.221	1.85	2.1	0.2	113.5	0.0251	32,024	12,599	0.119
1.50	0.198	1.91	2.1	0.2	121.5	0.0234	36,723	14,214	0.104
1.60	0.175	1.92	1.9	0.2	122.9	0.0221	41,540	15,965	0.091
1.70	0.153	1.89	1.8	0.1	117.4	0.0210	46,394	17,835	0.081
1.80	0.131	1.81	1.6	0.1	103.2	0.0201	51,284	19,835	0.072
1.90	0.108	1.67	1.3	0.1	79.9	0.0194	56,151	21,954	0.065
2.00	0.083	1.42	1.0	0.1	45.8	0.0188	60,981	24,199	0.059
2.10	0.053	1.00	0.0	0.0	-0.4	0.0180	66,943	26,565	0.053

ALTITUDE = 50000

					N = 1				
	MAX POWER					CRUISE POWER			
			T RATE	TR/FF	P-SUB-S	S RNG	F FLOW	THRUST	
MACH	CL-M	N-MAX	DEG/S	DEG/LG	FT/SEC	NM/LB	LB/HR	LB/ENG	CL-C
0.60	0.842	1.00	0.0	0.0	-36.9	0.0218	15,758	6,253	1.049*
0.70	0.737	1.00	0.0	0.0	-7.7	0.0323	12,430	4,933	0.771*
0.80	0.655	1.11	1.1	0.3	18.1	0.0436	10,518	4,174	0.590
0.90	0.570	1.22	1.5	0.4	34.2	0.0510	10,118	4,015	0.466
1.00	0.386	1.02	0.4	0.1	3.1	0.0395	14,518	5,761	0.378
1.10	0.285	1.00	0.0	0.0	-12.0	0.0369	17,110	6,790	0.312