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Aircraft Performance Program Part 5: Detailed input and output Program APP02



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AIRCRAFT PERFORMANCE PROGRAM PART 5: DETAILED INPUT AND OUTPUT PROGRAM APP02

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AIRCRAFT PERFORMANCE PROGRAM PART 5: DETAILED INPUT AND OUTPUT PROGRAM APP02

1. INTRODUCTION

(Note: In this Data Item, data options and facilities which are not available in the current release of the program are presented in *italic script*.)

The elements of the input and output for the Flight Performance Program (APP02) are described in detail. The main components are as follows.

- The input keywords and symbolic names with their units and conversion factors,
- The table formats and variables,
- The output quantities with additional units for quantities generated by the program,
- The extra debugging output that is produced when the DEBUG keyword is used.

A brief summary of the keywords and symbolic names is given in ESDU 00034 (Reference 9).

2. DATA INPUT

Input data are described by the data Keywords and Symbolic Names listed in full in this Data Item (a summary appears in ESDU 00034 (Reference 9).

The units used for input items are listed in Table 7.1 and the related units conversion factors used in the program are shown in Table 7.4.

The user can specify input data either as a constant value, a range or list of values (to form a data permutation or combination), or as tabular data varying with a range of possible variables. For example, engine power setting could be either constant or vary with time (say) to represent a slam acceleration. Engine thrust and fuel flow can be input for up to five sets of jet engine or propeller-engine combinations having different performance per engine in each set (see examples in Section 2.3.2). It is assumed that the engine data are fully installed (*i.e.* the data have been corrected, for example, for intake spillage, base drag and aerodynamic interferences) but provision is made for additional thrust factors, and incremental aerodynamic effects which can be functions of engine dependent variables.

2.1 Input Formats

All numeric input uses a keyword or symbolic name followed by the data value and units (if the input quantity has units which are known to the program), *e.g.* MASS 23000 kg. These data are supplemented by keywords defining calculation and other options. Keyword input must follow the rules listed here.

- (a) Keywords may be input in any mixture of upper case and lower case (**letters** 'O' or 'o' are always used in keywords not the number zero) and followed by at least one space.
- (b) The value and its units must be separated by at least one space. The values may consist of up to 20 characters; including the sign, leading zero, decimal point and exponent (when required using the FORTRAN format, *e.g.* - 0.1234E-04).

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- (c) All input associated with a particular keyword must be on the same line (maximum line length 100 characters). No continuation character is provided, but additional cases could be input as a follow-on case after the END_CASE keyword.
- (d) Blank lines are permitted (but will be removed during data input).
- (e) Comment lines (starting with '!') or following data input and separated by at least one space or tab from the input, may appear anywhere in the data file.
- (f) The units **must** be input in the correct upper and lower case letters.
- (g) The input units declared with a table input do not have to be the same as those used in the table file.
- (h) Most keywords may be input in any order and may be repeated to change the value of an input.
- (i) For keywords that have units that are not known to the program (*e.g.* RATING12, ENGVAR3, FLAP *etc.*, VARIABLE1 *etc.*), no units name is input. These variables may be given a synonym (introduced by '=') in the data input. This will be used on the output. There should be at least one space before the '=' sign and no spaces after the '=' sign or in the rest of the synonym.

The synonyms given to the miscellaneous variables, VARIABLE and ENGVAR families, may also be used as variable names in tables in place of the keyword (*e.g.* input, VARIABLE3 1.6 =SHP; then use SHP as a table variable which will be given the value 1.6). To be used as a table variable, a synonym must not be the name of any of the standard variable names in Table 5.2. A synonym can be allocated to a different miscellaneous variable when it is used in a new set of input case data; the synonym is not tied to any particular miscellaneous variable; this provides flexibility in the definition and use of the tables.

Input values may be specified in any of the following six formats.

- (1) Single constant value, *e.g.*

SWING	13.45 sqm
CLOWing	-0.78

- (2) A list of values separated by spaces or commas; the calculation is then done at each of these values in turn, *e.g.*

Splay1	1.56 5.67 -0.89, 5.89 deg
VARIABLE1	13476, 35890, 45, -16.76
HP	14000 16000 12000 18000 19000 19500 ft

The three variables will produce a permutation of $4 \times 4 \times 6 = 96$ cases.

- (3) A family of lists for several variables with the same number of values for each variable, and with each list starting with @. This family then forms a combination of cases, *e.g.*

DELTAT	@ 1,	2,	3,	4	C
HP	@ 10,	20,	30,	40	m
Primary1	@ 100	200	300	400	

This is equivalent to the first case input of,
DELTAT 1 C

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HP 10 m
Primary1 100

the second case using the values,

DELTAT 2 C
HP 20 m
Primary1 200

and so on until the last (fourth) case uses,

DELTAT 4 C
HP 40 m
Primary1 400

- (4) A range of values starting from an initial value (X_1), with a constant, signed, increment (DeltaX) and finishing at a final value (X_f). The format is X_1 (DeltaX) X_f . The calculation is then done at each of these values in turn, *e.g.*

DELTAT -15 (5) +25 C
HG 40000 (-5000) 0 ft

The first input is equivalent to the input, DELTAT -15, -10, -5, 0, 5, 10, 15, 20, 25 C
The two variables will produce a permutation of $9 \times 9 = 81$ cases.

- (5) A family of ranges for several variables with the same number of values for each variable, and with each range starting with @. This family then forms a combination of cases, *e.g.*

DELTAT @ 1 (1)4 C
HP @ 10 (10)40 m
Primary1 @ 100 (100) 400

This is equivalent to the first case input of,

DELTAT 1 C
HP 10 m
Primary1 100

the second case using the values,

DELTAT 2 C
HP 20 m
Primary1 200

and so on until the last (fourth) case uses,

DELTAT 4 C
HP 40 m
Primary1 400

(6) As a table, with the additional option to specify a positive factor (Fact) and a signed increment (Delta) to the data on the table. The format is: TAB(table_name)<op1> Fact <op2> Delta (the operators can be as follows. <op1> * or /, <op2> + or -). These factors and increments can be,

- Constants,
- Special factor and increment variables (MODTAB1 to MODTABO, Section 2.3.1.5),
- A mixture of a constant and a MODTAB variable.

For example,

```
XGMAIN1    TAB(XENGINE) lb
XDMAIN1    TAB(XDENGINE)+100 N
CLWING     TAB(CL)*0.99 -0.02
```

! MODTAB1 is a variable factor on fuel flow

```
MODTAB1    TAB(Factor1) #
FEMAIN1    TAB(FuelFlow)*MODTAB1 lb/hr
FEMAIN2    TAB(FuelFlow)*MODTAB1 + 100 lb/hr
```

! MODTAB5 is a variable gross thrust increment, with synonym DelXG

```
MODTAB5    TAB(DeltaXG)N =DelXG
XGMAIN1    TAB(Thrust) +DelXG N
XGMAIN2    TAB(Thrust)*0.95 +MODTAB5 N
```

Notes.

(1) All cases

The input units declared with the table input do not have to be the same as those used in the table file. The case data file units are used to define the units to be used for output. The units on the table file(s) define the units of the dependent variable(s) (Section 3). So if the output of (say) thrust is required in SI units but the engine data are in Imperial Units, the use of Newtons on the case data input will produce the output thrust in Newtons.

(2) Constant increment

The input units declared with the table input are used to define the units of any increment applied.

(3) Using MODTAB variables

- Factors. The dependent data in the MODTAB tables must be non-dimensional.
- Increments. The units of the dependent data in the MODTAB tables must imply the same SI units as those of the table to which the increment is applied.

The MODTAB tables can also be modified by further constant factors and increments, *e.g.*

```
! MODTAB5 is a variable gross thrust increment
MODTAB5    TAB(DeltaXG)*1.05 N
XGMAIN1    TAB(Thrust) +MODTAB5 N
```

Note: MODTAB tables can also be used to modify Special Speeds, see Section 2.3.1.5.

Options (2), (3), (4) and (5) above can be used to define permutations and combinations on two or more variables. The order of input of the variables determines the order in which the permutation is expanded. If a permutation and a combination are used together, the combination is processed first (for the first set of values of the permutation) then repeated for each expansion of the permutation.

2.2 Restricted Use of Tables

Whilst any numeric item may be defined by a table, the initial values of a limited set of items must not change during calculation for a given set of data input (*i.e.* the table variables do not change). These inputs are shown in Table 7.2.

2.3 Keywords for Performance Options

A detail description of the Flight Performance Program keywords and symbolic names is shown in the following tables. The keywords and symbolic names are identified in capital letters, whilst user input and units are in lower case, *e.g.*

SWING value units
this could be input as,

SWING 43 sqm

CALCTYPE type
this could be input as,

CALCTYPE SEP

Where the units are given, a unit name (*e.g.* N, lb, kg/s) should be input: the definition of the units is given in Table 7.1. Where a parameter has no units (*e.g.* Mach number) this is indicated by '-'. A further set of variables may have units depending on the aircraft type (*e.g.* FLAP may be an angle, a fraction or a setting); these items are identified by a footnote. These special unit indicators are not input but the definition must be consistent between the data input and any tables that use these data as variables.

The program minimum and maximum limits, which are used to check for gross error, are shown in internal SI units, the first unit shown in the list. These limits are advisory; a case will run even if the limits are exceeded. When no, general, limiting value can be defined, this is indicated by '-'.

2.3.1 Keywords inputting text only

Keyword or Symbolic Name	Input	Notes	Default
PROGRAM	APP02	Optional keywords used only for reference. The name of the input file and the (optional) output file are taken from DOS command line, and can include optional file types. The default file types are *.IN for the input and *.OUT for the output (results) file. <i>e.g.</i> APPv## Data Results	APP02
INFILE	file_name		*.IN
OUTFILE	file_name file_name PORTrait file_name LANDscape		PORTRAIT *.OUT
		If this parameter is omitted, the name of the output file is created from the input file name with file type/extension of .OUT (<i>e.g.</i> input filename, DATA.IN, gives output file, DATA.OUT). The format qualifier (PORTrait or LANDscape) can also be input using the OUTPUT keyword.	
TABLEDIR	directory_name	Directory where the tables are stored. <i>e.g.</i> C:\ESDU\TABLES ..\TABLES	Local user Directory

Title Lines

TITLE1	text	Main title line of up to 80 characters.	Blank
TITLE2	text	Main title line of up to 80 characters.	Blank
BASICTEXT	text	Basic data title line of up to 80 characters.	Blank
AEROTEXT	text	Aerodynamic data title line of up to 80 characters.	Blank
ENGTEXT1	text	Title line of up to 80 characters for engine set 1.	Blank
ENGTEXT2	text	Title line of up to 80 characters for engine set 2.	Blank
ENGTEXT3	text	Title line of up to 80 characters for engine set 3.	Blank
ENGTEXT4	text	Title line of up to 80 characters for engine set 4.	Blank
ENGTEXT5	text	Title line of up to 80 characters for engine set 5.	Blank

2.3.1.1 Calculation types (keyword followed by a second keyword)

POINT performance

Keyword or Symbolic Name	Second Keyword	Notes
CALCTYPE	SEP	Specific excess power with an option to search for the speed that gives the maximum value at constant height.
CALCTYPE	SET	Specific excess thrust with an option to search for the speed that gives the maximum value at constant height.
CALCTYPE	SUSTAIN	Aircraft normal load factor, rate of turn and radius of a constant speed turn at constant height. An option to search for the speeds that give the maximum value of each parameter at a given height (Reference 15).
CALCTYPE	SUSTAIN+	As SUSTAIN but the instantaneous limits are also checked and the lower result given.
CALCTYPE	INSTANT	Aircraft normal load factor, rate of turn and radius of turn at constant height utilising the maximum lift available (buffet onset, maximum usable or maximum lift as required) on the aircraft. An option to search for the speeds that give the maximum value of each parameter at a given height (Reference 15).
CALCTYPE	MAXSPEED	Maximum speed in level flight, defined as the point at which the “thrust minus drag” margin gives the required longitudinal acceleration or specific excess power.
CALCTYPE	CEILING	The height that gives a specified Specific Excess Power or rate of climb (rate of change of pressure height) with an option to search for the speed that gives the greatest height. For ceiling at a rate of climb, the ‘acceleration factor’ (see Reference 39) is applied. Note: Specific Excess Power is rate of climb at constant airspeed.
CALCTYPE	CEILING+	As CEILING but the lift limits (buffet onset, maximum usable or maximum lift as required) are also checked and the lowest result given.
CALCTYPE	MINDRAG	A search for the speed that gives the minimum drag condition irrespective of how the drag is represented in the input data. This search includes the effects of engine thrust which can be at a given power setting or at the power setting to give “thrust equals drag”.
CALCTYPE	MINSPEED	Aircraft speed when the limiting lift (buffet onset, maximum usable or maximum lift as required) is being used. This speed includes the effects of engine thrust which can be at a given power setting or at the power setting to give “thrust equals drag”. An extra Special Speed option, STALL_PO (‘Stall Power Off’), is available where no credit is given for any contribution of the vertical resolved thrust component to the total lift force (downward thrust is included). All thrust components are included in the power and pitching moment (trim) equations.
CRUISE. Steady cruise fuel consumption for range (air distance covered per unit of fuel). An option to search for the speed that gives the best range at a given height; with a further search for the speed that gives some margin over this optimum (typically 1%) (Reference 28). See also the PATH performance options below.		
CALCTYPE	CRUISE1	The cruise cases where the engine power settings are adjusted to achieve the required cruise speed. If a flight path angle is input, the ‘acceleration factor’ (see Reference 39) is applied.
CALCTYPE	CRUISE2	The cruise cases where the engine power is a given rating and the cruise speed is adjusted to achieve steady conditions.
CALCTYPE	CRUISE3	<i>The cruise case where the engine power is fixed at the rating that gives a cruise at the required speed and constant lift coefficient – Cruise-climb. If a flight path angle is input, the ‘acceleration factor’ (see Reference 39) is applied.</i>

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LOITER: Steady cruise fuel consumption for endurance (fuel flow). An option to search for the speed that gives the best endurance at a given height (Reference 28). See also the PATH performance options below.		
CALCTYPE	LOITER1	The loiter cases where the engine power settings are adjusted to achieve the required speed. If a flight path angle is input, the 'acceleration factor' (see Reference 39) is applied.
CALCTYPE	LOITER2	The loiter cases where the engine power is at a given rating and the cruise speed is adjusted to achieve steady conditions.
CALCTYPE	LOITER3	<i>The loiter case where the engine power is fixed at the rating that gives a cruise at the required speed and constant lift coefficient – Cruise-climb. If a flight path angle is input, the 'acceleration factor' (see Reference 39) is applied.</i>
CALCTYPE	ENVELOPE	<i>Trace a contour line of specific excess power from maximum speed at sea level, through the ceiling and return to sea level.</i>

PATH performance

The initial conditions are specified and the trajectory is terminated by the first end condition limit reached from up to six types of end condition (Sections 2.3.5 to 2.3.9). The Integration Step Length options (Section 2.3.1.4) control the frequency of output of the time history; if no interval is specified, only the initial conditions, points of height or speed discontinuity and the final totals are output.

Note: When a flat Earth is assumed, geometric height is calculated at the input value of latitude. When real Earth corrections are used (e.g. CIRCULAR RHUMB_L), approximate changes in latitude (and longitude) are also found and this allows the true local values of geometric height to be calculated.

Keyword or Symbolic Name	Second Keyword	Notes
CALCTYPE	ACCEL	Time history of aircraft parameters during an acceleration in level flight. The duration of the manoeuvre can be defined in several ways: between two airspeeds, for a given distance, or time to maximum speed.
CALCTYPE	DECEL	Time history of aircraft parameters during a deceleration in level flight. The duration of the manoeuvre can be defined in several ways: between two airspeeds, for a given distance, or time to the stabilised speed.
CLIMB: Time history of aircraft parameters during an en-route climb at constant heading. Several types of climb are available: at a combination of scheduled airspeeds, at constant climb angle, at constant rate of climb, <i>at given cabin pressure rate of change or pressure differential</i> (References 39 and 59).		
CALCTYPE	CLIMB1	The most common type of climb. The speed is defined as the lowest of a set of airspeeds at each calculation step. The engine power settings are known. The calculation produces a history of climb angle and rate of climb achieved in the climb.
CALCTYPE	CLIMB2	The flight path is defined either by climb angle or rate of climb and the engine power settings are known. The initial speed is known and the calculation produces a history of the flight speed achieved in the climb.
CALCTYPE	CLIMB3	The speed is defined as the lowest speed of a set of airspeeds at each calculation step. The flight path is defined either by climb angle or rate of climb. The calculation produces a history of the engine power settings needed to achieve the climb.
CRUISE. Steady cruise fuel consumption for range (air distance covered per unit of fuel) to give a time history of fuel used, distance travelled and time taken in the cruise.		
PATH performance (rather than the POINT performance option above) is used when a STEP (Section 2.3.1.4) and/or a PATH end condition are also input (Sections 2.3.5 to 2.3.9).		

Keyword or Symbolic Name	Second Keyword	Notes
CALCTYPE	CRUISE1	The cruise cases where the engine power settings are adjusted to achieve the required cruise speed. If a climb angle is input, the 'acceleration factor' (see Reference 39) is applied.
CALCTYPE	CRUISE2	The cruise cases where the engine power is a given rating. The initial speed is known and the calculation produces a history of the flight speed achieved in the cruise. (Note: This trajectory is calculated from a known, input, initial speed rather than the speed appropriate to the given power setting that is found in the POINT performance option.)
CALCTYPE	CRUISE3	<i>The cruise case where the engine power is fixed at the rating that gives a cruise at the required constant speed and constant lift coefficient - Cruise-climb. The 'acceleration factor' (see Reference 39) is applied.</i>
LOITER: Steady cruise fuel consumption for endurance (fuel flow) to give a time history of fuel used, distance travelled and time taken in the loiter. PATH performance (rather than the POINT performance option above) is used when a STEP (Section 2.3.1.4) and/or a PATH end condition are also input (Sections 2.3.5 to 2.3.9).		
CALCTYPE	LOITER1	The loiter cases where the engine power settings are adjusted to achieve the required speed. If a climb angle is input, the 'acceleration factor' (see Reference 39) is applied.
CALCTYPE	LOITER2	The loiter cases where the engine power is at a given rating. The initial speed is known and the calculation produces a history of the flight speed achieved in the cruise. (Note: This trajectory is calculated from a known, input, initial speed rather than the speed appropriate to the given power setting that is found in the POINT performance option.)
CALCTYPE	LOITER3	<i>The loiter case where the engine power is fixed at the rating that gives a cruise at the required constant speed and constant lift coefficient - Cruise-climb. If a climb angle is input, the 'acceleration factor' (see Reference 39) is applied.</i>
DESCENT: Time history of aircraft parameters during an en-route descent at constant heading. Several types of descent are available: at a combination of scheduled airspeeds, descent angle, and rate of descent, <i>at given cabin pressure rate of change or pressure differential, or drift down after engine failure.</i> (References 29 & 34).		
CALCTYPE	DESCENT1	The most common type of descent. The speed is defined as the lowest of a set of airspeeds at each calculation step. The engine power settings are known. The calculation produces a history of descent angle and rate of descent achieved in the descent.
CALCTYPE	DESCENT2	The flight path is defined either by descent angle or rate of descent and the engine power settings are known. The initial speed is known and the calculation produces a history of the flight speed achieved in the descent.
CALCTYPE	DESCENT3	The speed is defined as the lowest of a set of airspeeds at each calculation step. The flight path is defined either by descent angle or rate of descent. The calculation produces a history of the engine power settings needed to achieve the descent.
	RADAR_DESC	"Optical Radar Descent". A descent at given speed and following a track tangential to the Earth's surface. The required angle of descent is calculated in the program. The trajectory cannot easily be terminated at sea-level because the flight path angle is zero. A more complex, non-linear, path can be represented by using DESCENT3 with tables to define the required flight path (<i>i.e.</i> GAMMA, ROC_REQD).
	DRIFT_DOWN	<i>Drift down following an engine failure during cruise.</i>

Keyword or Symbolic Name	Second Keyword	Notes
<i>A set of routines for calculating time histories in more complex manoeuvres.</i>		
CALCTYPE	PULLOUT	Time history of aircraft parameters during a pullout from a dive at given normal load factor or rate of pitch. Also time history during "TCAS" manoeuvres.
CALCTYPE	LOOP	Time history of aircraft parameters during a vertical loop at given normal load factor or rate of pitch.
CALCTYPE	TURN	Time history of aircraft parameters during a turn at constant speed or constant height (Reference 15).

Special PATH trajectories when height or speed are not simple constant values.

1. For trajectories (ACCEL, DECEL, CRUISE or LOITER) at constant indicated height or constant geometric height on the real Earth and where no flight path angle (GAMMA) is input,
 - (i) For trajectories at constant geometric height (HGEOM) on a real Earth (Subroutine OBLATE, Section A.3.3), the rate of change of geopotential height (the integration variable) that achieves constant geometric height is a function of latitude and is derived from the equations for motion around the real Earth. The corrections required are relatively small and their size can be found by inspecting of the change of pressure or geopotential height with time (*i.e.* using the input items OUTPUT +H and the STEP TIME parameter).
 - (ii) For trajectories at constant indicated height (HIND), an empirical value for the rate of change of geopotential height is found that keeps the indicated height constant as the pressure error corrections change. To avoid rapid changes in flight path, this correction is limited to a flight path angle of 45 deg or half the available specific excess power.

Note: If a level cruise at constant pressure or geopotential height is required, a zero value of flight path angle should be input (GAMMA 0 deg); the input height (HGEOM or HIND) will then be used as the initial value.

2. For trajectories at given speeds where these speeds are variable. For example,
 - (a) Indicated speeds (IMN or IAS) which result in variable true speeds as the pressure error corrections change,
 - (b) Special speeds (*e.g.* Buffet Onset, Minimum Drag) which vary with weight *etc.*,
 - (c) Variable climb or cruise speeds (*e.g.* speed input as a table varying with height or weight *etc.*)

In these cases an additional acceleration or deceleration is found to achieve the required speed.

These options are available for these trajectories.

Trajectory	To maintained required value		Notes
	dH/dt when γ not input	dV/dt	
ACCEL DECEL	Hind, Hgeom		limit dH/dt to 45° or SEP/2
CRUISE2 LOITER2	Hind, Hgeom		
CRUISE1 LOITER1	Hind, Hgeom	Speed	
CRUISE3 LOITER3		Speed	
CLIMB1 DESCENT1		Speed	
CLIMB3 DESCENT3		Speed	
RADAR_DESC		Speed	
DRIFT_DOWN		Speed	

Utilities

Keyword or Symbolic Name	Second Keyword	Notes
CALCTYPE	ATMOS	Computation of all the atmospheric properties (temperature, pressure, density, speed of sound and kinematic viscosity) for the specified model atmosphere. Different forms of input are provided to allow the user to specify either height or ambient pressure along with either temperature or temperature increment relative to the model (References 31 and 32). Also input ATMOSTYPE, DELTAT TAMB and PAMB HP HG HGEOM.
CALCTYPE	AIRSPEED	Conversion from any of the different airspeed definitions used to all the others for the specified atmosphere (References 22 and 49). Also input ATMOSTYPE, DELTAT TAMB, PAMB HP HG HGEOM and TMN and/or EAS and/or CAS and/or TAS.

2.3.1.2 Calculation options (keyword followed by a second keyword)

Trimming options

The performance options include a range of methods for allowing for the effects of aerodynamic trim correction.

Keyword or Symbolic Name	Second Keyword	Notes	
TRIMTYPE	TRIMMED	The aerodynamic data tables input will have already been corrected for the effects of trimming the aircraft in pitch. This could, for example, be in the form of lift and drag increments due to trim (default). The inputs for CLWING, CDWING etc. are then used for the input of total aircraft trimmed lift and drag.	
	TABLES	<i>The aerodynamic data tables will vary with some trim parameter (e.g. the deflection angle of the trimming device). The required trim setting is known and is input (varying with the flight condition) and the program uses this value to calculate the trimmed condition. A pitching moment balance is not used. This option is a more versatile alternative to TRIMMED.</i>	
	TAILESS	A tailless design, e.g. delta	The aerodynamic data tables will include tables defining the local conditions (downwash and local dynamic pressure) at the tail due to the wing flow. These are combined with tailplane aerodynamic data for the tailplane in isolation to produce the total force and moment balance in pitch. Shown as TRIMTYPE 'TAIL'
	TAILFIX	Fixed tailplane with trim tab or elevator	
	TAILMOVE	All-moving tailplane	
	CANARDFIX	Fixed foreplane with trim tab or elevator	The aerodynamic data tables will include foreplane aerodynamic data and data on the wing-foreplane interaction. These are combined to trim the aircraft in pitch. Shown as TRIMTYPE 'CANARD'
	CANARDMOVE	All-moving foreplane	

Critical limiting lift and/or angle of attack

The lift and/or angle of attack limit that is to be considered critical for SUSTAIN+, MINSPEED, INSTANT and CEILING+ calculations and the value to be used to produce a fatal error, if exceeded in any performance calculation, is specified using LIMITCL. If the keyword is omitted the most severe limit is taken (*i.e.* in increasing order buffet, usable, maximum).

LIMITCL	BUFFET	Buffet onset lift and/or angle of attack (see CLBUFF and ALBUFF).
LIMITCL	USABLE	Maximum usable lift and/or angle of attack (see CLUSE and ALUSE).
LIMITCL	MAXIMUM	Maximum lift and/or angle of attack (see CLMAX and ALMAX).

Corrections for flight around the real Earth

When a trajectory is around the real earth, the aircraft experiences centripetal and Coriolis accelerations due to the curved flight path. These accelerations are expressed as an effective normal load factor (see Reference 28). Approximate time histories of latitude, longitude and heading are also calculated.

When evaluating the derivatives of latitude, longitude and heading, the oblate spheroid model of the real Earth is simplified by assuming the given constant radius for the Earth (see Subroutine Oblate, ESDU 00038, Reference 13). The increments in normal load factor and true ground speed are calculated using the oblate spheroid model. Therefore the changes in latitude and longitude will not correspond exactly with the distance travelled over the Earth: the fuel used per unit distance (and the time taken) are unaffected and the small discrepancy in latitude has a negligible effect on the apparent normal load factor and the true ground speed.

The corrections to normal load factor (*i.e.* DelNg and DelNc) are not applied when the total load factor (N) or data from which load factor can be found (*e.g.* TURNRATE) are input; the increments in normal load factor produced are then provided for information and to enable interpretation of the results. The corrections to normal load factor are only applied when the normal load factor (N) is allowed to take the default value (warning message W0140, see ESDU 00037 (Reference 12))

CIRCULAR	RHUMB_L	Rhumb line track at constant heading		
CIRCULAR	GREAT_C	Great Circle track to give the shortest distance on the Earth's surface		
CIRCULAR	TURN_RT	circular track in a right turn	On the real Earth	For CRUISE or LOITER around a circle (given N, TURNRATE or TURNRAD)
CIRCULAR	TURN_LT	circular track in a left turn		
CIRCULAR	RT_FLAT	circular track in a right turn	For a FLAT Earth	
CIRCULAR	LT_FLAT	circular track in a left turn		

Output options

The units used for output quantities generated by the programs are defined by the keyword OUTPUT. Input quantities are output in the same units as they were input.

OUTPUT	SIUNIT SIUNIT SIUNIT	PORTrait LANDscape	Output in SI units (Default units). [†] Output in SI units in Portrait layout. Output in SI units in Landscape layout.
	AEROUNIT AEROUNIT AEROUNIT	PORTrait LANDscape	Output in SI units but using height in ft, airspeed in kt. [†] Output in SI units using height in ft, airspeed in kt. in Portrait layout. Output in SI units using height in ft, airspeed in kt. in Landscape layout.
	IMPUNIT IMPUNIT IMPUNIT	PORTrait LANDscape	Output in Imperial units. [†] Output in Imperial units in Portrait layout. Output in Imperial units in Landscape layout.
	USERUNIT USERUNIT USERUNIT	PORTrait LANDscape	Output in Imperial units. Output in Imperial units in Portrait layout. Output in Imperial units in Landscape layout.

[†] The layout format will be determined by the last layout keyword, portrait or landscape, used. The layout keyword can be used with the OUTFILE or the OUTPUT keywords.

The OUTPUT keyword may be qualified by the addition of a letter or letters requesting extra output data. These extra lines of output can provide further information on speed, height, engine, MODTAB values, or trimming data. The OUTPUT keyword may be followed by the letters,

	+H	all height and speed definitions.
	+1 to +5	detail engine data for a specific engine set.
OR	+E	detail output for all engine sets.
OR	+X	all engine extra variables (ENGVARij) in use.
OR	+Y	+E and +X.

This page Amendments B and E

- +M all values of the MODTAB variables in use.
- +T trimming surface, tailplane or foreplane, data.
- +P plotting data to a .PLT file.

e.g. OUTPUT SIUNIT +HE
 OUTPUT AEROUNIT landscape +TH2
 OUTPUT AEROUNIT +1 PORT
 OUTPUT SIUNIT +H
 OUTPUT +X

Qualifiers may be cancelled by re-inputting the units keyword, *e.g.* OUTPUT AEROUNIT.

2.3.1.3 Atmosphere definitions

The program allows a choice of ISA, a selection of non-standard and design atmospheres or a user defined atmosphere. Temperature increments about all these atmospheres may be specified.

Keyword or Symbolic Name	Second Keyword	Notes
--------------------------	----------------	-------

International Standard Atmosphere

ATMOSTYPE	ISA	International Standard Atmosphere. (Reference 23) (Default).
-----------	-----	--

Other atmospheres

A set of non-standard atmospheres built-in to the program.

ATMOSTYPE	WWMAX	World Wide Maximum	Reference 3
	WWMIN	World Wide Minimum	
	TROPMEAN	Mean Tropical	
	TROPMAX	Tropical Maximum	Reference 1 & 23
	ARCTMIN	Arctic Minimum	
	N15MEAN	15 Deg North Mean Annual Reference	Reference 24

User atmosphere

When this keyword is used it must be followed immediately by the special set of keywords below.

ATMOSTYPE	USERATMOS	USERATMOs may be followed by a 10 character name	see Special Keywords below
	USERATMOS Name		

Special keywords to follow ATMOSTYPE USERATMOS

These data provide ambient temperature as a function of height. These keywords must be used in the order given below.

Keyword or Symbolic Name	Input	Notes		
ATMOSTEXT	atmos_text	User atmosphere title line of up to 80 characters (Default blank)		
USERALTP	m km ft	Pressure height used in table	Keyword and units only. Specifies what height definition and units are used in the table of temperature against height (below).	
USERALTG	m km ft	Geopotential height used in table		
USERALTZ	m km ft	Geometric height used in table.		
USERTEMP	K C F R	Temperature units	Keyword and units only. Specifies what temperature definition and units are used in the table of temperature against height (below).	
			Normal Limits	
			Min.	Max.
USERLATD	rad deg	The geographic latitude when the user atmosphere is defined as a function of Geometric height (USERALTZ). Positive in the northern hemisphere, negative in the southern hemisphere. (Default 45.5425 deg).	–1.5708	1.5708
USERPSO	Pa lb/sqft	Pressure at zero height, when the temperature profile varies with geopotential or geometric height (default 101 325 Pa).	90 000	110 000
NALTS		Number of pairs of height and temperature. Maximum of 20.		
H1 H_NALTS	TI T_NALTS	Table of pairs of height (as defined by USERALTP G Z) and temperature (as defined by USERTEMP) data to define the user atmosphere. The values of height must be monotonic increasing.		

2.3.1.4 Integration step length options

Control the frequency of output of the time history by defining one of these step lengths; if no interval is specified, only initial conditions, height or speed discontinuities, and the final totals are output.

The first output step is rounded to give a whole number multiple of the step increment given. For example:–

START EAS 260 kt, STEP EAS 40 kt: the speed will be output at 280 (7*40 kt), 320, 360, ... kt.

START EAS 240 kt, STEP EAS 40 kt: the speed will be output at 280 (7*40 kt), 320, 360, ... kt.

WEIGHT 45050 lb, STEP 5000 lb: the weight will be output at 45000 (9*5000 lb), 40000, 35000, ... lb
as fuel is burnt

Keyword or Symbolic Name	Second Keyword	Acceptable Units	Notes
STEP	TIME	s min hr	Output time history in steps of time taken.
STEP	FUEL	kg lbm l gal USgal	Output time history in steps of fuel used.
STEP	DIST_AIR	m km ft n.mile	Output time history in steps of air distance travelled.
STEP	DIST_GRD	m km ft n.mile	Output time history in steps of ground distance travelled.

Keyword or Symbolic Name	Second Keyword	Acceptable Units	Notes
STEP	WEIGHT	N kgf lb lbf	Output time history in steps of change in weight, sum of fuel used and rate of loss of mass (DM/D <i>T</i> _i in engine data).
STEP	MASS	kg kgm lbm slug	Output time history in steps of change of mass, sum of fuel used and rate of loss of mass (DM/D <i>T</i> _i in engine data).
STEP	HP	m km ft	Output time history in steps of Pressure height.
STEP	HG	m km ft	Output time history in steps of Geopotential height.
STEP	HGEOM	m km ft	Output time history in steps of Geometric height.
STEP	HIND	m km ft	Output time history in steps of indicated height.
Not used for ACCEL, DECEL CRUISE1, CRUISE2, LOITER1 or LOITER2 calculations			

STEP	TMN		Output time history in steps of True Mach number.	Not used for CLIMB1, CLIMB3, DESCENT1 or DESCENT3 calculations
STEP	IMN		Output time history in steps of Indicated Mach number.	
STEP	EAS	m/s km/hr ft/s ft/min mph kt	Output time history in steps of Equivalent Airspeed.	
STEP	CAS	m/s km/hr ft/s ft/min mph kt	Output time in history in steps of Calibrated Airspeed.	
STEP	TAS	m/s km/hr ft/s ft/min mph kt	Output time history in steps of True Airspeed.	
STEP	IAS	m/s km/hr ft/s ft/min mph kt	Output time history in steps of Indicated Airspeed.	

2.3.1.5 Factor and increment variables

These special variables (usually defined as tables) are used to factor or increment other tables or Special Speeds (Section 2.3.10). Although they are primarily intended to be used as tables; single value, list and range values can also be input which would allow for example a range of thrust factors to be used in a parametric study. These variables are described as 'MODTAB variables'.

The input format is,

MODTAB_i value units synonym

e.g. MODTAB1 TAB(XG_FACT) #
MODTAB3 TAB(XG_MIN) lb =MinXG
and then using the MODTAB factor (MODTAB1) and increment (MODTAB3 = MinXG),
XGMAIN1 TAB(Xg)*MODTAB1 - MinXG lb

A MODTAB variable must be defined before it is used to modify a table or special speed.

A MODTAB variable may be given a synonym (introduced by '=') in the data input. This synonym can then be used when the table is applied as a factor or increment provided that the table is defined before it is used. There should be at least one space before the '=' sign and no spaces after the '=' sign or in the rest of the synonym. If the synonym is to be used to define a factor or increment it should not include the operators "*" / + -" and it should be defined before it is used to modify another table.

Keyword or Symbolic Name	Acceptable Units	Notes
MODTAB1	Factors. The input definition of the variable must be non-dimensional. A dummy unit name '#' is used. Increments. The units used in the input definition of the variable must imply the same SI unit as those of the table or special speed to which the increment is applied. If the variable has no units (or they are not known to the program) the dummy unit '#' is used.	Examples, ! MODTAB1 is a variable factor on fuel flow MODTAB1 TAB(Factor1) # =Ffact and then, FEMAIN1 TAB(FuelFlow)*ModTab1 lb/hr or, using the synonym, FEMAIN1 TAB(FuelFlow)*FFact lb/hr ! MODTAB5 is a variable gross thrust increment MODTAB5 TAB(DeltaXG) N and then, XGMAIN1 TAB(Thrust) +MODTAB5 N XGMAIN2 TAB(Thrust)*0.95 +MODTAB5 N
MODTAB2		
MODTAB3		
MODTAB4		
MODTAB5		
MODTAB6		
MODTAB7		
MODTAB8		
MODTAB9	Tables. When a MODTAB variable is a table, the units of the dependent data in the table file must be consistent with the SI units implied.	
MODTAB0		

Note: The data input scheme allows an input item to be a constant, a range of values or a table - this also applies to the MODTAB variables. A constant value or a range of values may also be input (this will produce a warning message but the input will be accepted). The input of numeric MODTAB values can be used,

- to change the sign of a table by defining the MODTAB variable input as -1. The use of a negative factor is not normally permitted (*e.g.* D/Q1 tab(store)*-1 sqft).
- to create a permutation or combination by using a range of MODTAB values (*e.g.* a range of thrust factors).

2.3.1.6 Miscellaneous

!	Comment line	A line starting with '!' is a data comment line anywhere in the data file. Comments may also be added to the end of data input lines, separated from the data input by at least one space or tab followed by the '!' character.	
CANCEL	keyword	Cancel a previous keyword assignment so that an alternative keyword in the same set can be used, <i>e.g.</i> cancel TMN so that a different speed type can be used, thus, CANCEL TMN CAS 450 kt	
DEFAULT	-	Toggle the output of messages about default settings OFF or ON	Initially ON
DEBUG	0 1 2 3 4 5 6 7 8	No debugging output Summary of main items 1 + Performance calculations final iteration data 2 + Performance calculations iteration histories 3 + Overall force balance final iteration data 4 + Overall force balance iteration histories 5 + Extra performance data 6 + *.DB1 output file during data input 6 + *.DB2 output file from performance calculations	This keyword can only be used in the first data set.
END_CASE	Optional Text	End of case data, more cases to follow. When there are no more cases use only END_DATA.	Optional for a single data set.
CASE	Optional Text	Alternative to END_CASE.	Optional.
END_DATA	Optional Text	End of the data file.	Optional.
END	Optional Text	Alternative to END_DATA	Optional.

2.3.2 Engine data

Thrust Resolution Marker

Marker to control the resolution of the engine thrust vectors for all engine sets.

Keyword or Symbolic Name	Second Keyword	Notes
RESOLVE	NONE	Thrust forces not resolved. Engine setting angle (ENGANGi) and splay angle (SPLAYi) are not required. The thrust is not resolved through aircraft incidence.
	JET	Jet thrust only.
	ALL	Both jet and propeller thrust (default).

Provide data for up to five sets of engines, for $i = 1$ to 5 in order.

For pairs of engines which are located symmetrically about the aircraft centerline (same values of the X-axis and Z-axis co-ordinates), data are input for the starboard (right) engine that has positive values of the Y-axis co-ordinate. This implies that only even numbers of engines are permitted (except for a single engine).

Up to five engine sets, together with the numbers of 'operating' and 'non-operating' engines (NOPTi and [NENGi – NOPTi], respectively) can be used to simulate many different engine configurations.

- An installation with three different engine types, or significantly different installation corrections, at (say) outboard, inboard and centreline positions.
- An operating condition where each engine is required to be at a different power setting (ECP).
 - One engine windmilling,
 - One engine idling,
 - One engine at a minimum power setting to maintain electrical and hydraulic power supplies,
 - An auxiliary power unit being used to supplement electrical power supplies,
 - The remaining engine power adjusted to maintain a cruise condition.
 - The 'non-operating' engine data will normally be used to represent a windmilling engine. They can also be used to represent an engine at a different power setting (*e.g.* idle) provided that the 'non-operating' engine data tables (XGFAILi, XDFAILi and FEFAILi) **do not** vary with power setting (ECP). Only the main engine performance tables (XGMAINi, XDMAINi & FEMAINi) may vary with ECP. If the same engine tables, varying with ECP, are to be used for 'operating' and 'non-operating' engines, the 'non-operating' engines should be entered as a separate engine set (identical tables are only stored once, so no additional storage space would be used).

FEMAIN and at least one of these engine thrust terms must be input for each engine set used,

Jet thrust terms

XGMAIN and XDMAIN
XGMAIN and MLPMAIN
XNMAIN

Keyword or Symbolic Name	Acceptable Units	Notes	Normal Limits	
			Min.	Max.
ENGTEX <i>i</i>		Title line of up to 80 characters for engine set <i>i</i>	-	-
NENGi		The sum of both the operating and the non-operating engines. A whole number (default 1).	1	10
NOPTi		Number of operating engines at the start of the trajectory. The difference between NENGi and NOPTi are non-operating engines. A whole number (default 1).	0	10
NFAILi		<i>Number of engines that fail during the trajectory (TAKEOFF, DRIFT-DOWN). A whole number (Default 1). After engine failure the number of engines is NOPT NFAIL.</i>	1	10

2.3.2.1 Jet Engine

ENGANGi	rad deg	The angle between projection of gross-thrust vector on to aircraft plane of symmetry and the plane defining zero angle of attack. Positive when gross-thrust contributes to lift. (Default 0 deg)	-3.1416	3.1416
SPLAYi	rad deg	The angle, in plan view, between the gross-thrust vector and the aircraft axis of symmetry. Positive when the lateral component of the gross-thrust vector is towards the plane of symmetry. (Default 0 deg)	-1.5708	1.5708

Point of action of jet engine forces

The sign convention used for intake position and nozzle position is that used by most drawing offices: X is positive aft, Y is positive to the right (starboard) wing, Z is positive upwards. The origin may be at any position chosen by the user but should be consistent for centre of gravity (*e.g.* CGXPOS), aerodynamic centre (*e.g.* ACXPOS), trimming surface (*e.g.* TAILXPOS), gross thrust (*e.g.* XGXPOS_i) and ram drag (*e.g.* XDXPOS_i). The XY plane is the reference plane for angle of attack.

(Note. This is not the axis system that is used in the performance equations, see ESDU 00038 (Reference 13)).

Required when using TRIMTYPE 'TAIL' or 'CANARD'.

Keyword or Symbolic Name	Acceptable Units	Notes	Normal Limits	
			Min.	Max.
XDXPOS _i	m mm ft in	The X-axis co-ordinate point of action of the ram drag on the aircraft.	-	-
XDYPOS _i	m mm ft in	The Y-axis co-ordinate point of action of the ram drag on the aircraft.	-	-
XDZPOS _i	m mm ft in	The Z-axis co-ordinate point of action of the ram drag on the aircraft.	-	-
XGXPOS _i	m mm ft in	The X-axis co-ordinate point of action of the gross thrust on the aircraft.	-	-
XGYPOS _i	m mm ft in	The Y-axis co-ordinate point of action of the gross thrust on the aircraft.	-	-
XGZPOS _i	m mm ft in	The Z-axis co-ordinate point of action of the gross thrust on the aircraft.	-	-
XNXPOS _i	m mm ft in	The X-axis co-ordinate point of action of the net thrust on the aircraft.		
XNYPOS _i	m mm ft in	The Y-axis co-ordinate point of action of the net thrust on the aircraft.		
XNZPOS _i	m mm ft in	The Z-axis co-ordinate point of action of the net thrust on the aircraft.		

Required when XGMAIN_i with XDMAIN_i or MLPMAIN_i

Required when XNMAIN_i input

Engine performance for operating engines

XGMAIN _i	N kgf lb lbf	The total installed jet engine gross thrust for each operating engine. For a turbo-prop this is the gas-turbine residual exhaust gross thrust. An alternative, with XDMAIN _i or MLPMAIN _i , to XNMAIN _i .	0	-
XDMAIN _i	N kgf lb lbf	The total installed jet or turbo-prop installation ram drag (intake momentum drag) for each operating engine. If the installation has significant intake spillage drag, it can be convenient to include this in the ram drag. An alternative to MLPMAIN _i .	0	-
MLPMAIN _i	N/s lbf/s	Engine intake air weight flow rate for each operating engine. If XDMAIN is not input, ram drag is calculated from MLPMAIN _i	0	-
XNMAIN _i	N kgf lb lbf	The total installed jet engine net thrust for each operating engine. For a turbo-prop this is the gas-turbine residual net thrust. An alternative to XGMAIN _i with XDMAIN _i or MLPMAIN _i . For an unpowered aircraft, input zero thrust (e.g. XNMAIN1 0 N).	0	-
FEMAIN _i	kg/s kg/min kg/hr lb/hr lb/min lb/s l/s l/min l/hr gal/s gal/min gal/hr USgal/s USgal/min USgal/hr	The installed fuel flow for each operating engine. Mandatory input item.	0	-

Performance of non-operating engines

Non-operating engines may be windmilling or idling. If these keywords are used to represent an engine at a different power setting (e.g. idle) the data tables (XGFAIL_i, XDFAIL_i and FEFAIL_i) **must not** vary with power setting (ECP).

If the options available in this section are not adequate, the failed engine can be represented by using one of the other engine data sets and treating the engine as if it were operating.

Keyword or Symbolic Name	Acceptable Units	Notes	Normal Limits	
			Min.	Max.
XGWIND _i	N kgf lb lbf	The total installed gross thrust for each non-operating jet engine, use with XDWIND _i . An alternative to CDWIND _i .	0	-
XDWIND _i	N kgf lb lbf	The total installed intake momentum drag (ram drag) for each non-operating jet engine, use with XGWIND _i .	0	-

Keyword or Symbolic Name	Acceptable Units	Notes	Normal Limits	
			Min.	Max.
XNWINDi	N kgf lb lbf	The total installed net thrust for each non-operating jet engine. An alternative to XGWINDi and XDWINDi or to CDWINDi. Must be used for failed jet engines with XNMAINi input.	0	-
CDWINDi		The windmilling drag coefficient, including spillage drag (based on wing reference area, SWING) for each non-operating engine. An alternative to XGWINDi and XDWINDi or XNWINDi for a jet engine.	0	1
FEWINDi	kg/s kg/min kg/hr lb/hr lb/min lb/s	The installed fuel flow for each non-operating engine. The table cannot vary with ECP. Note: When a windmilling drag coefficient (CDWINDi) is used, the fuel flow (FEWINDi) is considered to be optional and will automatically default to zero if no input is provided without warning message W0117 being used.	0	-

2.3.2.2 Jet and propeller power plants

Keyword or Symbolic Name	Acceptable Units	Notes	Normal Limits	
			Min.	Max.
FUEL_SGi		Engine fuel specific gravity. This is required if fuel flow or fuel used are specified in terms of volume. FUEL_SG1 is used for all engines if only FUEL_SG1 is input.	0	1
DM/DTi	kg/s kg/min kg/hr lbm/s lbm/min lbm/hr	Miscellaneous rate of loss of mass for each operating engine (NOPTi) (in addition to, and with the same sign as, engine fuel flow). This can be used for water injection, oil loss from the engine, water loss from the aircraft etc. If input negative it could represent icing, with a corresponding change in the aerodynamic data.	-	-

Engine installation corrections

Aerodynamic interference corrections for the effect of the engine air flows on the airframe. These corrections are for each operating engines (NOPT).

Keyword or Symbolic Name	Acceptable Units	Notes		Normal Limits	
				Min.	Max.
DCDENGi		Incremental drag coefficient for each operating engine.	Based on reference wing area, SWING	-0.2	0.2
DCLENGi		Incremental lift coefficient for each operating engine.		-1	1
DCMENGi		Incremental pitching moment coefficient for each operating engine.		-0.0001	0.0001
D/QENGi	sqm sqft sqin	Incremental drag area for each operating engine.		-50	50

Engine power setting for operating engines

When the engine performance tables (XGMAIN, XDMAIN, FEMAIN, *etc*) are presented against some engine power setting variable (*e.g.* Rotational Speed, Power Code, Jet Pipe Temperature, Propeller Speed, *etc*) this power setting is the Primary ECP. If another engine power setting is required (*e.g.* for display to the aircrew), the Alternate ECP can be used.

Up to five engine rating tables may be defined (*e.g.* Maximum Power, Climb, Cruise, Idle) using RATING_j, in descending thrust levels from RATING1 to RATING5. These define the values of the Primary ECP for each of the ratings.

Keyword or Symbolic Name	Acceptable Units	Notes	Normal Limits	
			Min.	Max.
ALT2ECP _i	†	Table showing Alternate ECP as a function of Primary ECP.	0	-
RATING1 _i	†	Highest engine Primary ECP setting. Must be input when PRIMARY UNKNOWN is used.	0	-
RATING2 _i	†	Engine rating 2	0	-
RATING3 _i	†	Engine rating 3	0	-
RATING4 _i	†	Engine rating 4	0	-
RATING5 _i	†	Engine rating 5	0	-
PRIMARY _i	†	Required power setting defined using Primary ECP, the variable used to describe the variation of gross thrust, ram drag and fuel flow. May also be one of RATING1 to RATING5 Alternative to ALTERNT _i power setting. When the program is required to solve for a power setting (CRUISE1, CRUISE3, LOITER1, LOITER3, CLIMB3, DESCENT3 and optionally MINSPEED, MINDRAG), the input UNKNOWN is used. (RATING1 _i is also required).	0	-
ALTERNT _i	†	Required power setting defined using the Alternate ECP which is linked to the Primary ECP by the table ALT2ECP. Alternative to PRIMARY _i power setting.	0	-

† This item may have units but they are not known to the program. No units name is input. A synonym (introduced by ‘=’) may be input in the place of a unit name.

Extra engine variables

Notes.

- Extra, unallocated, engine data variables. Tables may use these variables to represent parameters that are not explicitly available in the table system, *e.g.*
 - engine bleed or power offtake
 - jet engine intake or final nozzle parameters
 - jet engine final nozzle parameters
 - propeller engine parameters
- These variables may be used to provide information on other aspects of engine performance that do not directly affect the aircraft performance, *e.g.*
 - internal engine settings
 - engine exhaust gas properties
- Since the ENGVAR variables have units that are unknown to the program, a synonym (introduced by '=') may be added to the input. This synonym can then be used when the variable is used in a table. There should be at least one space before the '=' sign and no spaces after the '=' sign or in the rest of the synonym. *e.g.*
 ENGVAR51 27 =Boost
- They may be used to define a miscellaneous variables by assigning using the re-direction symbol (>) the interpolated value to the appropriate VARIABLE_k parameter, *e.g.*
 ENGVAR11 tab(Engine_Data) >VARIABLE3
 or ENGVAR11 tab(Engine_Data) >3
 The miscellaneous variable can then be used to define other table data that is affected by the engines, *e.g.*
 - jet or propellor slipstream affecting the aircraft or trimming surface
 - boundary layer control or jet flap systems
 Since ENGVAR and the miscellaneous variable (VARIABLE) have units that are unknown to the program, a synonym may be added to the input, *e.g.*
 ENGVAR11 tab(Engine_Data) =P7/p0 >VARIABLE3
 The data items must be in the order "Keyword Value =Synonym >Variable !Comment" with no space between the re-direction (>) symbol and the general miscellaneous variable name. The synonym will also be used for the assigned VARIABLE item and can be used when that VARIABLE item is used in a table. There must not be another input for this variable.

Keyword or Symbolic Name	Acceptable Units	Notes	Normal Limits	
			Min.	Max.
ENGVAR1 _i	†	Extra engine data table variables that may be used as required. See above.	-	-
ENGVAR2 _i	†		-	-
ENGVAR3 _i	†		-	-
ENGVAR4 _i	†		-	-
ENGVAR5 _i	†		-	-
ENGVAR6 _i	†		-	-
ENGVAR7 _i	†		-	-
ENGVAR8 _i	†		-	-
ENGVAR9 _i	†		-	-
ENGVARO _i	†		-	-

† This item may have units but they are not known to the program. No units name is input. A synonym (introduced by '=') may be input in the place of a unit name.

2.3.3 Aerodynamic data for wing-body or trimmed aircraft

Keyword or Symbolic Name	Acceptable Units	Notes	Normal Limits	
			Min.	Max.
SWING	sqm sqft sqin	The nominal wing reference area that is used to non-dimensionalise the wing-body aerodynamic coefficients (lift, drag and pitching moment).	0	-
RL	m mm ft in	The length that is used in calculating 'aircraft' Reynolds number, often a parameter in the aircraft drag coefficient table. Although it is common to use the Standard Mean Chord for this, some users prefer to quote 'aircraft' Reynolds per unit length (reference length = 1).	0	-
CBAR	m mm ft in	The length used with wing area to non-dimensionalise the wing-body pitching moment coefficient. Required when using TRIMTYPE 'TAIL' or 'CANARD'	0	-
ALW-ALB	rad deg	Wing setting angle, the angle of the wing datum above the body (X-axis) datum. Used to define the ALPHAW variable. $ALPHAW = ALPHA + (ALW - ALB)$	-0.15	0.15

Point of action of wing-body lift, drag and pitching moment

The sign convention used for aerodynamic centre co-ordinates is that used by most drawing offices: X is positive aft, Y is positive to the right (starboard) wing, Z is positive upwards. The origin may be at any position chosen by the user but should be consistent for centre of gravity (*e.g.* CGXPOS), aerodynamic centre (*e.g.* ACXPOS), trimming surface (*e.g.* TAILXPOS), gross thrust (*e.g.* XGXPOS_i) and ram drag (*e.g.* XDXPOS_i). The XY plane is the reference plane for angle of attack.

Note. This is not the axis system that is used in the performance equations, see ESDU 00038 (Reference 13).

Required when using TRIMTYPE, 'TAIL' or 'CANARD'.

ACXPOS	m mm ft in	The X-axis co-ordinate of the point of action to which the wing-body lift, drag and pitching moment have been referred. This point is often the aircraft aerodynamic centre.	-	-
ACYPOS	m mm ft in	The Y-axis co-ordinate of the point of action to which the wing-body lift, drag and pitching moment have been referred.	-	-
ACZPOS	m mm ft in	The Z-axis co-ordinate of the point of action to which the wing-body lift, drag and pitching moment have been referred.	-	-

Wing-body lift data

The wing-body lift coefficient can either be defined as a single data input (CLWING)

OR

by the components of lift at zero angle of attack (CLOWING) and the lift curve slope (A1WING), giving
 $CLWING = CLOWING + A1WING * \text{Angle of attack}$.

In both cases the wing-body lift increments (DCL-GEAR *etc.*) data can be used.

Keyword or Symbolic Name	Acceptable Units	Notes	Normal Limits	
			Min.	Max.
CLWING		The wing-body lift coefficient defined as a single input.	-10	10
CLOWING		The wing-body lift coefficient at zero angle of attack.	-10	10
A1WING	/rad /deg	Wing-body lift curve slope.	0	12

Incremental wing-body lift coefficients for items not included in the above data input for CLWING. These are added to the main lift data to produce the total lift coefficient.

DCL-GEAR		Incremental wing-body lift coefficient due to undercarriage.	-1	1
DCL-FLAP		Incremental wing-body lift coefficient due to flap, spoiler <i>etc.</i>	-1	1
DCL-SPBRK		Incremental wing-body lift coefficient due to speed brake (air brake).	-1	1
DCL-STORE		Incremental wing-body lift coefficient due to store release.	-1	1
DCLWING1 DCLWING2		Incremental wing-body lift coefficients due to miscellaneous items.	-1	1

Wing-body drag data

The wing-body drag coefficient can either be defined as a single data input (CDWING)

OR

by the components of minimum drag (CDMIN), which occurs at the lift coefficient for minimum drag (CLMIN), the first drag curve slope (KWING) up to a critical lift coefficient (CLCRIT) and an incremental drag curve slope (DELKWING).

Then, for $CLWING < CLCRIT$, $CDWING = CDMIN + KWING * (CL - CLMIN)^2$

and, for $CLWING > CLCRIT$, $CDWING = CDMIN + KWING * (CL - CLMIN)^2 + DELKWING * (CL - CLCRIT)^2$

In both cases the drag increments (DCD-GEAR *etc.*) and the drag areas (D/Q-GEAR *etc.*) are added to the drag.

Keyword or Symbolic Name	Acceptable Units	Notes	Normal Limits	
			Min.	Max.
CDWING		Wing-body drag coefficient as a single input.	0	0.2
CDMIN		Minimum drag coefficient. The lowest value of the drag coefficient as a function of lift; it occurs at a lift coefficient of CLMIN. If CLMIN is zero or is not input, CDMIN is zero lift drag.	0	0.2
CLMIN		Lift coefficient at which the minimum drag coefficient occurs (default zero).	-10	10
CLCRIT		Critical lift coefficient. The lift coefficient at which the drag coefficient starts to rise more rapidly than the first drag slope (KWING).	-10	10
KWING		First drag curve slope. The slope of the curve of drag coefficient as a function of $(CL - CLMIN)^2$ from the region of minimum drag up to the critical lift coefficient.	0	300
DELKWING		Incremental slope of the curve of drag coefficient as a function of $(CL - CLCRIT)^2$ above CLCRIT. (When CLCRIT is not input, DELKWING is not used).	0	1000

Alternative
to
CDWING.