



ESDU 90034

Issued December 1990
With Amendments A to C
September 2004

Computer program for the calculation of normal force and pitching moment of forebody-cylinder combinations at angles of attack up to 90 degrees and Mach numbers up to 5, including effects of conical boat-tailing

Associated software: ESDUpac A9034

Endorsed by
The Royal Aeronautical Society

AVA Documents
Document Sharing Hub

ESDU DATA ITEMS

Data Items provide validated information in engineering design and analysis for use by, or under the supervision of, professionally qualified engineers. The data are founded on an evaluation of all the relevant information, both published and unpublished, and are invariably supported by original work of ESDU staff engineers or consultants. The whole process is subject to independent review for which crucial support is provided by industrial companies, government research laboratories, universities and others from around the world through the participation of some of their leading experts on ESDU Technical Committees. This process ensures that the results of much valuable work (theoretical, experimental and operational), which may not be widely available or in a readily usable form, can be communicated concisely and accurately to the engineering community.

We are constantly striving to develop new work and review data already issued. Any comments arising out of your use of our data, or any suggestions for new topics or information that might lead to improvements, will help us to provide a better service.

THE PREPARATION OF THIS DATA ITEM

The work on this particular Data Item was monitored and guided by the Aerodynamics Committee. This Committee first met in 1942 and now has the following membership:

Chairman	
Mr H.C. Garner	— Independent
Vice Chairman	
Mr P.K. Jones	— British Aerospace (Commercial Aircraft) Ltd, Woodford
Members	
Mr G.E. Bean*	— Boeing Aerospace Company, Seattle, Wash., USA
Dr N.T. Birch	— Rolls-Royce plc, Derby
Mr K. Burgin	— Southampton University
Mr D. Choo*	— Northrop Corporation, Pico Rivera, Calif., USA
Dr T.J. Cummings	— Short Brother plc
Mr J.R.J. Dovey	— Independent
Mr L. Elmeland*	— Saab-Scania, Linköping, Sweden
Dr J.W. Flower	— Independent
Dr K.P. Garry	— Cranfield Institute of Technology
Mr P.G.C. Herring	— Sowerby Research Centre, Bristol
Mr R. Jordan	— Aircraft Research Association
Mr J.R.C. Pedersen	— Independent
Mr R. Sanderson	— Deutsche Airbus, Bremen, Germany
Mr A.E. Sewell*	— McDonnell Douglas Corp., Long Beach, Calif., USA
Mr M.R. Smith	— British Aerospace (Commercial Aircraft) Ltd, Bristol
Miss J. Willaume	— Aérospatiale, Toulouse, France.

* Corresponding Member

The technical work in the assessment of the available information and the construction and subsequent development of the Data Item was carried out by

Mr A.J. Clarke	— Consultant to ESDU
Mr C. King	— Consultant to ESDU
Mr M.C. Liu	— Engineer, Computer Products Group.

The person with overall responsibility for the work in this subject area is Mr P.D. Chappell, Head of Aircraft Aerodynamics Group.

COMPUTER PROGRAM FOR THE CALCULATION OF NORMAL FORCE AND PITCHING MOMENT OF FOREBODY-CYLINDER COMBINATIONS AT ANGLES OF ATTACK UP TO 90 DEGREES AND MACH NUMBERS UP TO 5, INCLUDING EFFECTS OF CONICAL BOAT-TAILING

CONTENTS

	Page
1. INTRODUCTION	1
2. SUMMARY OF PROGRAM	2
3. DESCRIPTION OF INPUT AND OUTPUT DATA	3
3.1 Input Data	3
3.2 Output Data	5
4. DERIVATION	6
5. EXAMPLES OF INPUT AND OUTPUT	6
5.1 Input for Examples 1, 2, 3 and 4	6
5.2 Output for Examples 1, 2, 3 and 4	8

COMPUTER PROGRAM FOR THE CALCULATION OF NORMAL FORCE AND PITCHING MOMENT OF FOREBODY-CYLINDER COMBINATIONS AT ANGLES OF ATTACK UP TO 90 DEGREES AND MACH NUMBERS UP TO 5, INCLUDING EFFECTS OF CONICAL BOAT-TAILING

1. INTRODUCTION

This Item provides details of a computer program, called ESDUpac A9034, for the calculation of normal force and pitching moment of axisymmetric bodies, both with and without conical boat-tailing, for angles of attack up to 90 degrees and Mach numbers up to 5. The methods employed are those given in Item No. 89008 (Derivation 3) for normal-force-curve and pitching-moment-curve slopes, Item No. 89014 (Derivation 4) for normal force and pitching moment at angle of attack, Item No. 87033 (Derivation 2) for the effects of conical boat-tailing and Item No. 77028 (Derivation 1) for calculation of geometric parameters.

The program has been written in "STRICT" Microsoft FORTRAN 77 for use on machines using PC/MS DOS.

A summary of the program is given in Section 2 and Section 3 describes the required input data and the output. Four examples are given in Section 5 to illustrate both program input and output. All notation used in this Item is identical to that given in Item Nos 77028, 87033, 89008 and 89014, which should be used for reference concerning notation, applicability and limitations.

2. SUMMARY OF PROGRAM

The program reads in the geometric and flow data from the input file, which is described in Section 3.1, and checks that they are within the scope of the Items. If any parameters are outside the ranges of applicability, they are listed in error messages and the program stops. If all the input data are acceptable, the program then calculates the required geometric coefficients using the equations of Item No. 77028 which, in the case of the secant ogive forebody, involves a numerical integration using Simpson's rule. The normal-force-curve and pitching-moment-curve slopes are then calculated using the equations and Figures of Item No. 89008. The Figures themselves are stored within the program in digital form, and data are extracted using the method of cubic splines and/or linear interpolation as appropriate. Similarly, the program then uses the equations and Figures of Item No. 89014 to calculate normal force and pitching moment coefficients at angle of attack. If the input data indicate that the body has a conical boat-tail, the normal force and pitching moment coefficients are modified using the equations of Item No. 87033. The output is then produced which includes the input data, geometric coefficients, the normal-force-curve and pitching-moment-curve slopes and, in tabular form, the results at angle of attack for normal force coefficient, pitching moment coefficient about the nose, centre of pressure position and pitching moment coefficient about a chosen reference point, see Section 3.2.

It should be noted that if any of the flow conditions at angle of attack fail to meet the applicability criteria discussed in Section 8.1 of Item No. 89014, the program continues to produce results but marks the value for angle of attack with an 'x' and provides a footnote referring to the relevant section of the Item (see Example 3 in Section 5). This is done because there are circumstances under which the results may still be valid.

3. DESCRIPTION OF INPUT AND OUTPUT DATA

3.1 Input Data

Table 3.1 gives a generalised list of the input parameters required for the program, including their name and, where appropriate, their corresponding notation in the relevant Data Items.

TABLE 3.1 Generalised Input Data

Variable Name in Program	Notation in Items	Comments
CHAR1 CHAR2 CHAR3	–	The first three lines of the input data are read as text and written on the output file. Each line may contain 75 characters and must end with a carriage return. A blank line must be entered if text is not required.
BODY	–	Forebody identification number* 3 = tangent ogive 4 = secant ogive 5 = cone 6 = ellipsoid 10 = spherically-blunted cone 11 = spherically-blunted tangent ogive 12 = spherically-blunted secant ogive
LFD	l_f/D	Forebody fineness ratio, $1.5 \leq l_f/D \leq 7.0$
RO1RO	ρ'/ρ	Radius ratio; only required for secant ogive forebody (see Item No. 77028), $0 \leq \rho'/\rho \leq 1$
RO0R	ρ_0/R	Blunting ratio; only required for spherically-blunted forebodies (see Item No. 77028), $0 \leq \rho_0/R \leq 0.8$
LD	L/D	Overall body fineness ratio, $1.5 \leq (L/D - l_f/D) \leq 20.0$
BOAT	–	Boat-tail indicator 1 or 0 for with or without boat-tailing, respectively
LAD	l_a/D	Boat-tail fineness ratio; only required if BOAT = 1, $0 \leq l_a/D \leq 2$
BETA	β	Boat-tail angle; only required if BOAT = 1, $0 \leq \beta \leq 10^\circ$
MFREE	M_∞	Free-stream Mach number, $0 \leq M_\infty \leq 5$
RL	R_L	Reynolds number based on body length, $10^5 \leq R_L \leq 10^9$
XMD	x_m/D	Dimensionless distance from nose to moment reference point
ANGMAX, ASTEP	–	Maximum required angle of attack, α_{max} , ($0 \leq \alpha_{max} \leq 90^\circ$) and interval in α at which results are required, $\Delta\alpha$, both in degrees

* The forebody identification numbers are the same as those given in Item No. 77028. This program only caters for those forebody shapes that are of practical interest. It should be noted, however, that the forebody identification numbers 5 and 6 in Item No. 77028 refer to two families of shapes described as 'power law' and 'modified ellipsoid', respectively. The program assumes in both of these cases that the user requires the most common type of shape in each family, namely the cone and ellipsoid.

Table 3.2 gives a complete summary of input data for bodies using any of the forebody shapes and with and without conical boat-tailing.