AeroTex UK LLP

TAC2, Issue 2, Revision 2.02

User Guide

Report authors	
Name	Richard Moser
Email	richard.moser@aerotex.co.uk
Signature	
Name	
Email	
Signature	

Authorisation	
Name	Dr. Ian Roberts
Role	Aerospace Consultant
Signature	
Date	23/05/2019

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Executive Summary

This document provides a user guide for the computer programme, Trajectory and Catch, TAC, Issue 2, which can be used to calculate the trajectory of cloud water droplets and resulting water droplet catch (collection) efficiency on a multi-element two-dimensional body/aerofoil. It is a module of the AeroTex UK Aircraft Icing Design, AID, package. This User Guide is for Issue 2, Rev 2.02.

The code uses a Lagrangian particle tracking technique to calculate the trajectory of a cloud water droplet from a starting position upstream of the aerofoil under investigation. The position of the droplet is integrated in small steps until either the droplet impacts the aerofoil or it passes set boundaries (used to signify a 'miss' trajectory). A fourth order Runge-Kutta technique is used to integrate the equations of motion. The integration requires the local velocity components to be known at every position the droplet occupies. In the TAC Issue 2 code, the required velocity data are calculated using a 2D, multi-element, incompressible flow, panel method which is based on linear varying vorticity on each panel. The code calculates the limiting trajectory (i.e. tangential to the aerofoil surface) on each of the upper and lower surfaces of each required aerofoil component (element). A user specified number of 'intermediate' trajectories in-between these limits is then evaluated. A cubic spline fit is made to the initial point ('Y0') and impact point ('s/c'), with a zero gradient end slope condition applied at the limiting trajectory points. The slope of the cubic spline is then evaluated at a series of points about the aerofoil leading edge, which corresponds to the local water droplet catch efficiency, β. The code also calculates the 'overall' catch efficiency, E, which is expressed as the separation between the two limiting trajectories in the free stream relative to the projected height of the aerofoil. Finally, using the panel method calculated surface velocity data, the code conducts an integral boundary layer calculation for a rough surface to predict the local surface convective heat transfer coefficient distribution, which is output, along with pressure coefficient and catch distribution in the format required by AID modules IHB and ET3D.

If required (specified by value of input parameter 'ICE'), the code will also call AID module, 'IHB' (Icing Heat Balance) to predict the resulting ice accretion profile (unheated).

Two additional modules have been implemented in the current TAC2 version to account for the splash and/or bounce phenomena in the Super-cooled Large Droplet (SLD) regime. These modules may be enabled individually or together by introducing the input parameters 'SLD_ACTIVE' and 'SLDTYP'. The user may also specify the droplet size threshold, below which no splash and/or bounce correction will occur. The user is currently advised to use the Splash & Bounce module for all cases when SLD cases are being modelled.

The code requires two input files (TAC2_CRD.DAT and TAC2_INPUT.DAT), plus an optional input file when a droplet spectrum calculation is required (TAC2_SPECTRUM.DAT) and creates two general output files (TAC2_RESULTS.DAT and TAC2_PLOTS.EZ), as well as additional files if required (IHB.DAT and IHB_IP.DAT). It runs under the Windows operating system or from a command prompt.

The main results output file (TAC2_RESULTS.DAT) contains a summary of the input data, the calculated aerodynamic data (panel strengths) and catch efficiency distribution. The aerofoil pressure coefficient, particle paths, collection efficiency distribution, and if specified, ice profile on the aerofoil leading edge, are output in EZDraw plotting file format and may be viewed and printed using this utility routine.

The accuracy of the code has been checked against NASA published experimental data and also against the results from peer programs (e.g. TRAJICE2), and this provides a high confidence in the level of results obtained, at least for the present level of functionality available within the code.

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1 Introduction

This document is the User Guide for a computer program which can be used to calculate the trajectory of cloud water droplets and resultant water droplet catch efficiency distribution on a multi-element 2D body in incompressible flow. The code assumes only the droplet drag force is present when integrating the equations of motion and uses a cubic spline technique to evaluate the local value of catch efficiency on the body surface.

The code is classed as ‘medium’ control software and is to be regarded as ‘design’ software for advising AeroTex, and its clients, on the susceptibility of a surface to impact by cloud water droplets. It can be used to establish the amount and location of water droplet impact on a body, which is a precursor to the calculation of ice accretion shape and size, and in the modelling of ice protection systems.

Section 2 provides an overview of the functionality of the code. Sections 3 to 5 then provide details of the input, execution and output generated by the code.

The document relates specifically to Issue 2, Revision 2.02 of the code. Whilst many parts may be relevant to earlier code revisions, the user should exercise caution if using this document for an earlier revision, and it is recommended that they upgrade to the latest version of the code.

2 Program Overview

The code uses a Lagrangian particle tracking technique [1] to calculate the trajectory of a cloud water droplet from a starting position upstream of the aerofoil under investigation. The position of the droplet is integrated in small steps until either the droplet impacts the aerofoil or it passes defined boundaries (used to signify a 'miss' trajectory). A fourth order Runge-Kutta technique is used to integrate the equations of motion, which assume only aerodynamic drag and droplet inertia affects the droplet motion (the effect of gravity on droplet motion is an optional user selection). The integration requires the local velocity components to be known at every position the droplet occupies. In the TAC2 code, the required velocity data are calculated using a 2D, multi-element, incompressible flow, panel method which is based on linearly varying vorticity on each panel. The code calculates the limiting trajectory (i.e. tangential to the aerofoil surface) on each of the upper and lower surfaces on a user specified number of the aerofoil components. A number of 'intermediate' trajectories in between these limits is then evaluated. A cubic spline fit is made to the initial point ('Y0') and impact point ('s/c'), with a zero gradient end slope condition applied at the limiting trajectory points. The slope of the cubic spline is then evaluated at a series of points about the aerofoil leading edge, which corresponds to the local water droplet catch efficiency, β. The code also calculates the 'overall' catch efficiency, E, which is expressed as the separation between the two limiting trajectories in the free stream relative to the projected height of the aerofoil. Finally, using the panel method calculated surface velocity data, the code conducts an integral boundary layer calculation for a rough surface to predict the local surface convective heat transfer coefficient distribution, which is output, along with pressure coefficient and catch distribution, in the format required by AID modules IHB and ET3D.

The code requires two input files. File TAC2_CRD.DAT contains the ordinates of the 2D body. File TAC2_INPUT contains the specific aerodynamic and cloud droplet run conditions along with the information required to perform the droplet integration, and also to calculate the surface convective heat transfer coefficient distribution. The latter data are not required by the TAC code, but are necessary to create an input file in the format required by the AeroTex icing and ice protection system codes, IHB and ET3D.

The code has a number of options for run types, which are specified in the input file through use of keywords.

3 Program Input

Program TAC requires two input files, called TAC2_CRD.DAT and TAC2_INPUT.DAT. An example content for these two files is shown in Annex B and Annex C respectively, and it will be useful to refer to these appendices when reading the following sections.

The _CRD file contains the ordinates of the body geometry, whereas the _INPUT file contains the required aerodynamic and cloud droplet case details.

3.1 Co-ordinate Input

The ordinate file is effectively not limited in number of input points (panel edges) for any of the aerofoil components (true limit is 9999). The standard method of ordinate input is clock-wise, starting from the body trailing edge and proceeding around the lower surface of the body to the leading edge, then rearward to the aft upper surface trailing edge (i.e. standard format for input to CFD methods). Ordinates can also be input in an anti-clockwise direction, and the code will reverse this direction internally before performing further calculation. The leading edge of the aerofoil must be to the left of the trailing edge (i.e. the code assumes that airflow is from left to right). The orientation of the aerofoil is assumed to be at zero degrees (i.e. any angle of attack specified will be referenced to the input orientation).

The first line in the ordinate input file allows the user to specify a name for the aerofoil, up to 72 characters in length.

The second line stipulates the number of components comprising the aerofoil system (i.e. slat + main element + flap = 3 components). The input is in I3 format.

The next 'n' lines (where 'n' is the number of components) defines the number of ordinates for each component. The input is in I4 format.

A blank line follows.

The ordinates for each component then follow. The ordinates should be formatted as F9.6, 2X, F9.6. After the last point in each component, a flag (icing marker) must be stipulated to define whether a trajectory or ice accretion calculation is required on that particular component. A value of '0' defines that no trajectory/ice accretion calculation is required on the component, whereas a value of '1' defines that the calculation is required. A blank line must follow the icing marker, before the next component ordinate input, except in the case specified in the following paragraph.

There is an additional optional input, used especially (but not exclusively) when the input aerofoil already has an ice shape. The leading edge ordinate is calculated internally within the code as that point the furthest distance from the defined trailing edge point. When an ice shape is present, this method is no longer valid, and therefore the ordinate number of the leading edge is required (e.g. 50th ordinate). It should be noted that this requires the ordinates to be input in a clockwise direction. The ordinate number of the leading edge should be defined on a line after the icing marker input variable, described in the paragraph above. A blank line must follow this ordinate number.

3.2 Flight/Icing Condition Input

The flight and icing conditions are input using keywords. These keywords are summarised in Table 1 with a full description following at the end of this section.

Keyword	Description	Units	Type	Default Value	Possible Values
$TITLE	Run title	N/A	Character	-	Any
$DIMENSIONS	Spatial dimensions	N/A	Integer	2	2
$AERO	Aerodynamic run type	N/A	Integer	0	0 – single incidence 1 – Incidence polar 2 – Cp matching
$TRAJ	Trajectory definition	N/A	Integer	0	0 – mono-disperse droplets 1 – Langmuir-D distribution 2 – User-defined spectrum
$ICE	Ice shape file production / ice shape calculation	N/A	Integer	0	0 – No ice shape calculation files produced 1 – Ice shape calculation files produced
$TAS	True Airspeed	m/s	Real	1.0	0.0 to ∞
$KTAS	True Airspeed	knots	Real	0.0	0.0 to ∞
$EAS	Equivalent Airspeed	m/s	Real	0.0	0.0 to ∞
$KEAS	Equivalent Airspeed	knots	Real	0.0	0.0 to ∞
$CAS	Calibrated Airspeed	m/s	Real	0.0	0.0 to ∞
$KCAS	Calibrated Airspeed	knots	Real	0.0	0.0 to ∞
$ALTM	Altitude	m	Real	0.0	0.0 to 20,000
$ALTF	Altitude	feet	Real	0.0	0.0 to 65,617
$ALTP	Altitude	Pascals	Real	101325.0	5,000 to 105,000
$OATC	Static Temperature	°C	Real	0.0	-∞ to ∞
$OATF	Static Temperature	°F	Real	32.0	-∞ to ∞
$TATC	Total Temperature	°C	Real	0.0	-∞ to ∞
$TATF	Total Temperature	°F	Real	32.0	-∞ to ∞
$SWEEP	Leading edge sweep angle	°	Real	0.0	0.0 (not currently implemented)
$AOAI	Initial angle of incidence	°	Real	0.0	-∞ to ∞
$AOAF	Final angle of incidence	°	Real	0.0	-∞ to ∞
$AOAINC	Incremental angle of incidence	°	Real	1.0	-∞ to ∞
$CHORDM	Aerofoil reference chord	m	Real	1.0	0.0 to ∞
$CHORDI	Aerofoil reference chord	inches	Real	39.37	0.0 to ∞
$RH	Relative humidity	%	Real	100.0	0.0 to 100.0
$VMD	Droplet diameter	microns	Real	20.0	0.0 to ∞
$LWC	Liquid Water Concentration	g/m^3	Real	0.0	0.0 to ∞
$SWEPT	Include sweep effects	N/A	Logical	.FALSE.	.FALSE. or .TRUE.
$WF	Wettedness factor	N/A	Real	1.0	0.0 to 1.0
$TIME	Icing encounter time	minutes	Real	1.0	0.0 to ∞
$COMPRESS	Include compressibility effects	N/A	Logical	.FALSE.	.FALSE. or .TRUE.
$NCOMP	Number of aerofoil	N/A	Integer	1	1 to ∞

	components				
$N_UPP	Number of discretisation nodes on upper surface	N/A	Integer	101	1 to ∞
$N_LOW	Number of discretisation nodes on lower surface	N/A	Integer	101	1 to ∞
$DELS	Non-dimensional discretisation spacing	N/A	Real	0.003	0.0 to ∞
$RUFF	Surface roughness	microns	Integer	8	-1 or 1 to ∞
$NTRAJ	Number of droplet trajectories	N/A	Integer	7	3 to ∞
$GRAVITY	Include gravity effects on droplets	N/A	Logical	.FALSE.	.FALSE. or .TRUE.
$HORIZON	Angle to horizon	°	Real	0.0	-∞ to ∞
$TECPLOT	Include Tecplot format output	N/A	Logical	.FALSE.	.FALSE. or .TRUE.
$SHED	Include water shed from horns	N/A	Logical	.FALSE.	.FALSE. or .TRUE.
$SMOOTHING	Include ice shape smoothing	N/A	Logical	.FALSE.	.FALSE. or .TRUE.
$NSMOOTH	Number of smoothing passes	N/A	Integer	0	0 to ∞
$SCLIMIT	s/c limit for stagnation search	N/A	Real	999.0	-∞ to ∞
$XDROP_MAX	X limit on droplet search	N/A	Real	999.0	-∞ to ∞
$SLD_ACTIVE	Enable SLD regime	N/A	Logical	.FALSE.	.FALSE. Or .TRUE.
$SLDTYP	SLD modules	N/A	Integer	0	0 – no SLD 1 – SLD Splash & Bounce 2 – Bounce
$SLDLIM	Lower limit of SLD model application in microns	Microns	Real	0.0	0.0 to ∞

Table 1: Keywords for flight/icing conditions

Each keyword must start with the '$' sign.

Each variable input line must end with a semi-colon, after which a comment may be added as a reminder of what the variable represents. For example, for the $CHORDM input variable, the input line could look thus:

$CHORDM = 1.50; Aerofoil chord length, in metres

The spaces either side of the '=' sign are not required, so the following input line would be equivalent to that above:

$CHORDM=1.50; Aerofoil chord length, in metres

The added comments are completely optional – any characters after the semi-colon are ignored by the code.

Blank lines can be left in the input file, if the user wishes to group certain inputs together, and will be ignored.

Note that the value of $NCOMP specified in this input file must match the number of components specified in the co-ordinate file (TAC2_CRD.DAT). Note also that this value of $NCOMP must be stipulated before the values of $N_UPP, $N_LOW, $DELS, $RUFF and $NTRAJ. For these 5 variables, the values for each component are listed on a single line, from first to last, separated by a single space. For example, for a case where there are two aerofoil components, with the roughness on the first being 10 microns, and that on the second being 80 microns, the input line would look thus:

$RUFF = 10 80; Surface roughness for each component

Where two or more options for a type of variable exist (e.g. speed), it is feasible (although unnecessary) to input more than one option. The code will perform checks to see if they are equivalent. For example, it is possible to enter a true airspeed in both meters per second and knots. If the code determines that the values are not consistent, it will output an error message (see Section 5.2.2) and stop execution. The same features apply to temperature, altitude and chord length.

A full description of each of the input variables follows:

$TITLE	A descriptive run title to identify the run. Up to 120 characters in length.
$DIMENSIONS	The spatial dimensions of the run (1D, 2D or 3D). Currently, only the 2D option is allowable.
$AERO	The aerodynamic run type. A value of 0 stipulates that a single incidence run is to be performed (at the value of $AOAI), and trajectory calculations will also be performed, together with an icing calculation (dependent on the value of $ICE). A value of 1 indicates that a sequence of incidences will be run (from $AOAI to $AOAF, at intervals of $AOAINC), and no trajectory or icing calculations will be performed (whatever the values of $TRAJ and $ICE input). This option is generally used when trying to match either a C_L value, or a defined pressure distribution. A value of 2 will modify the input AOA value to match a user-defined Cp distribution (in a file named 'CP_REF.DAT')
$TRAJ	Trajectory calculation type (when $AERO = 1). A value of 0 indicates that a mono-disperse droplet diameter will be used (with the value specified by $VMD). A value of 1 stipulates that a 7-bin Langmuir-D droplet distribution (centred around the value specified by $VMD) will be used. A value of 2 indicates that a user-defined droplet spectrum will be used (centred around the value specified by $VMD), which is defined in a separate input file (TAC2_SPECTRUM.DAT), see Section 3.3
$ICE	Icing calculation definition (when $AERO = 1). A value of 0 indicates that the output files for IHB and ET3D will not be produced, and no ice shape calculation will be performed. Conversely, a value of 1 stipulates that output files for both IHB and ET3D will be created, and the IHB programme will be invoked to create an ice shape. In this instance, TAC2 runs a batch file, called 'IHB.BAT' upon completion. This file must be in the same directory as that where TAC2 is being run, and should reference the IHB executable, wherever it is stored on the hard disk. An example IHB.BAT file is shown in Annex D.
$TAS	True airspeed, in metres per second.
$KTAS	True airspeed, in knots.

$EAS	Equivalent airspeed, in metres per second.
$KEAS	Equivalent airspeed, in knots.
$CAS	Calibrated airspeed, in metres per second.
$KCAS	Calibrated airspeed, in knots.
$ALTM	Pressure altitude, in metres.
$ALTF	Pressure altitude, in feet.
$ALTP	Pressure altitude, in Pascals.
$OATC	Static air temperature, in degrees Celsius.
$OATF	Static air temperature, in degrees Fahrenheit.
$TATC	Total air temperature, in degrees Celsius.
$TATF	Total air temperature, in degrees Fahrenheit.
$SWEEP	Leading edge sweep angle, in degrees. The option to account for sweep is currently inhibited. Any value set here will be rest to zero in the code.
$AOAI	Initial incidence value, in degrees. For runs with $AERO = 0, this is the only incidence to be run. For runs with $AERO = 1, this is the first in a sequence of incidences.
$AOAF	Final incidence value, in degrees. For runs with $AERO = 0, this value is set equal to $AOAI. When $AERO = 1, this is the last in a sequence of incidences.
$AOAINC	Incidence increment, in degrees. For runs with $AERO = 0, this is set to 1.0 (and ignored). When $AERO = 1, this value sets the increment between successive incidence values in a sequence.
$CHORDM	Aerofoil reference chord, in metres. For single element aerofoils, this is simply the chord. For multi-element aerofoils, this should be set as the chord value for the stowed (un-deployed) system.
$CHORDI	Aerofoil reference chord, in inches. For single element aerofoils, this is simply the chord. For multi-element aerofoils, this should be set as the chord value for the stowed (un-deployed) system.
$RH	Relative humidity in percent. For natural icing encounters, this should always be set to 100.0. Only when modelling icing wind tunnel cases, when RH is recorded, should the value be lowered.
$VMD	Droplet volumetric median diameter, in microns.
$LWC	Liquid water concentration, grammes of water per cubic metre of air.
$SWEPT	Signifies whether sweep effects should be accounted for. This option is not currently implemented. If a value of .TRUE. (or just TRUE) is entered, it will be reset to .FALSE..

$WF	Surface wettedness factor. This can be used to simulate rivulet formation aft of direct impingement. A value of 1.0 turns the option off (water remains as a thin film everywhere). Experimental evidence suggests a value of 0.2 to 0.3 to be realistic.
$TIME	Icing encounter time, in minutes.
$COMPRESS	Indicates whether compressibility effects are accounted for. At Mach numbers higher than around 0.4, compressibility effects affect the surface speed, and hence C_p and HTC, distributions. A value of .TRUE. (or simply TRUE) corrects for compressibility using the Prandtl-Glauert correction factor. A value of .FALSE. (or simply FALSE) ignores the effect of compressibility.
$NCOMP	Number of aerofoil components. For example, for a wing with a deployed slat, $NCOMP equals 2. This input must match that within the TAC2_CRD.DAT file.
$N_UPP	Number of points defining the nodal discretisation around the upper surface of the leading edge (used when $AERO = 0). $N_UPP multiplied by $DELS gives the non-dimensional surface distance on the upper surface over which a heat balance will be performed. Must be defined for each aerofoil component.
$N_LOW	Number of points defining the nodal discretisation around the lower surface of the leading edge (used when $AERO = 0). $N_LOW multiplied by $DELS gives the non-dimensional surface distance on the lower surface over which a heat balance will be performed. Must be defined for each aerofoil component.
$DELS	Non-dimensional surface spacing of nodes in the discretisation, (used when $AERO = 0). Must be defined for each aerofoil component.
$RUFF	Equivalent sand grain roughness of the ice, in microns. When modelling an ice protection system, the value should be set to the clean surface equivalent sand grain roughness. When modelling an ice shape, the value should be set to -1, whereby the code determines a roughness from an empirical relationship. Must be defined for each aerofoil component.
$NTRAJ	Number of aerofoil trajectories used in impingement calculation. The minimum value to be used is 3 (one tangential trajectory on each of the upper and lower surfaces, and one to capture the maximum local collection efficiency). However, a minimum value of 7 is recommended, in order to ensure that the correct local maximum is obtained, together with a smooth distribution – unless a very small chord aerofoil is being analysed. Must be defined for each aerofoil component. However, if no values are defined (and no keyword specified), the code will automatically calculate a suitable value of NTRAJ, based upon the modified droplet inertia parameter. This is generally most useful when a droplet spectrum run is being performed, as different droplet sizes can require different numbers of trajectories to provide the smoothest, and most accurate, catch efficiency distribution. However, it can also be used for mono-disperse droplet calculations, if desired.

$GRAVITY	Addition of gravity term to the droplet trajectory equations. For CS-25 Appendix C [2] droplets (<50μm), this will have negligible effect on the trajectories, and can be left out of the input file (default value is .FALSE.). For larger droplets, the gravity term can have a significant effect on the trajectory, and the value should be set to .TRUE.
$HORIZON	As standard, the code assumes a line of flight parallel to the ground. When the code assumes no gravity effect, the direction of flight does not matter. However, when gravity effects are taken into account, the direction of the gravitational force must be known, and the line of flight (i.e. in climb or descent) must be included. This angle should be the angle to the horizontal of the line of flight.
$TECPLOT	The code can output all plots in Tecplot format, by setting this value to .TRUE.
$SHED	This value feeds through to the IHB module of the AID code suite. When an ice accretion calculation is performed, water can run over the accretion and freeze aft. If this value is set to .TRUE., and water will be shed from an ice horn.
$SMOOTHING	When performing multi-step ice accretion calculations, small, local accretion shapes can grow extremely quickly, causing spikes in the ice shape. By setting this value to .TRUE., numerical smoothing is performed on the ice shape in order to reduce the small variations. It is recommended that smoothing is never used for single-step ice accretion calculations.
$NSMOOTH	When smoothing is active (see previous item), this parameter determines the number of numerical smoothing passes to be performed on the ice shape. The number should be minimised, and it is recommended that, under most circumstances, no more than 3 smoothing passes should be performed.
$SCLIMIT	In order to determine the stagnation position, the code looks for the smallest value of surface velocity. Where a sharp change in geometry exists (e.g. at the cusp on a slat heel, or at the horn of an ice shape), a stagnation point will exist, which the code may assume to be the main stagnation point (from which the integral boundary layer calculations are started). In order to prevent this, the user can specify a position, in terms of s/c, beyond which the code does not search for stagnation.
$XDROP_MAX	Especially for multi-element aerofoils, it can reduce computational time if miss trajectories can be specified when the droplet passes a certain position in the x-direction (e.g. if calculations are only required on the slat, there is no need to continue a trajectory once it has passed the trailing edge of the slat)
$SLD_ACTIVE	Enables the SLD regime for larger droplet MVDs, by setting this value to .TRUE.
$SLDTYP	SLD regime requires a specification of the SLD module to be used: $SLDTYP=0 – is the default mode in which SLD calculations are not performed; $SLDTYP=1 activates the Splash and Bounce module and is recommended for general use; $SLDTYP=2 – activates only the Bounce module

$SLDLIM	Droplet size threshold, below which no splash and/or bounce correction will occur. However, it should be noted that splashing and bouncing are naturally limiting so the imposition of the threshold is not necessarily required, and is not generally recommended to be used

3.3 Droplet Spectrum File

A droplet spectrum file can be used to provide details of a particular droplet spectrum required for analysis, for example when comparing to an icing tunnel test where the droplet spectrum is known. The file should be titled 'TAC2_SPECTRUM.DAT'. An example is shown in Annex E.

The first line of the file allows a title to be input, specifying where the spectrum originates from. Note that this line is for user reference only, and is not stored or reproduced in the results.

The following line specifies the number of droplet 'bins' within the spectrum (number of discrete droplet sizes to be evaluated), in I3 format. Any number of bins up to 999 can be used.

The following 'n' lines (where 'n' is the number of droplet bins) specify the details of each droplet bin, in free format. On each line, the following numbers must be specified, in order:

- Droplet size for the bin (in microns)
- Fraction of LWC contained within droplet bin (e.g. 5% is specified as 0.05)
- Number of trajectories to analyse for this droplet bin. Not that this will only hold when the $NTRAJ keyword has been specified in the main input file (and will over-write whatever value was specified there). If $NTRAJ was not specified, the code will automatically calculate suitable values for each droplet bin

3.4 Reference Cp distribution input file

A reference Cp distribution file can be used in order to determine the incidence angle required in TAC2 to provide the closest match to this distribution (e.g. to match some wind tunnel data). The file should be titled 'CP_REF.DAT'. An example is shown in Annex F.

The first line of the file allows a title to be input. Note that this line is for user reference only, and is not stored or reproduced in the results.

The second line stipulates the number of components comprising the aerofoil system (i.e. slat + main element + flap = 3 components). The input is in I3 format.

The next 'n' lines (where 'n' is the number of components) defines the number of C_p definition points for each component. The input is in I4 format.

A blank line follows.

The C_p distribution for each component then follows, specified as an s/c value followed by the C_p value, in free format. A blank line must follow the list, before the next component C_p input.

4 Program Execution

The current version of the executable TAC code is called ‘TAC_Iss2_Rev2.02.EXE’. It must be executed through a specific batch file which checks that a current licence exists – the executable itself will not run otherwise. An example of the batch file required is shown in Annex G. The code is multi-processor enabled, and will run on however many processors are available.

The files 'AIDLicence.jar' and 'xLicence.txt' must be situated in the same folder as the TAC2 executable file. It is recommended that they are all stored in a specific code folder, e.g. 'E:\ATX_Codes', although this is not required. They can be stored anywhere on the system, on any drive, as long as these three files are together (and the batch file used to run the code points to the correct place). The batch file should be in the directory where the user wishes to run the case (i.e. where the input files are).

In order to execute the code, a valid licence file ('xLicence.txt') must exist. This file will be checked upon execution to ensure that a licence for that computer exists. The licence is based on a number of parameters, which must be supplied to AeroTex to obtain a valid licence. Details on the installation of the code, including obtaining a licence, are provided in Annex H.

Updates to the source and executable code may be under-taken but this User Guide will only be updated when appropriate to do so, i.e. whenever the input, execution or output files are changed and not for minor changes in output format.

At present only a single run can be performed at a time, for the set of conditions specified in file TAC2_INPUT.DAT. However, batch files can easily be used to run any number of cases, one after the other.

During programme execution error messages may be reported to the screen (and to an errors file, TAC2_ERRORS.DAT). Errors normally cause programme execution to halt. If the code was run from within windows explorer, the output window will automatically close, not giving the user time to view any error message. The user should therefore check for a TAC2_ERRORS.DAT file at the end of every run. When no errors occur, no errors file will be produced. For this reason, it is also suggested to run the batch file from a command prompt, allowing any screen messages to be seen after program execution.

The code also outputs certain warnings (see Section 5.2.1) to the screen, and to a warnings file (TAC2_WARNINGS.DAT). Whilst the warnings do not always indicate a failure in the run, they should always be reviewed at the end of a run. If no warnings occur, no warnings file will be produced.

Output files ‘TAC2_RESULTS.DAT’ and ‘TAC2_PLOTS.EZ’ are created, together with ‘IHB.DAT’ and ‘IHB_IP.DAT’, if required (when input variable $AERO = 1), and also ‘TAC2_ERRORS.DAT’ and ‘TAC2_WARNINGS.DAT’ when either errors or warnings occur. If a version of any of these files already exists, the contents will be over-written when the code is run. If the file does not pre-exist, the file is created.

5 Program Output

5.1 Results Output

An example of the program output is shown in Annex I to Annex L for prediction in a glaze type icing condition.

5.1.1 TAC2_RESULTS.DAT

The initial part of the output file specifies the code version, date, and the time of the run of the analysis case (time is the creation time of the output file). It also lists the CPU time taken, as well as elapsed time. The CPU time is for any processors which the code was run on, and therefore (on multi-processor machines) the CPU time can legitimately be longer than the elapsed time. There then follows a reproduction of the input data, indicating the run type, and the test conditions which have been analysed. The solution parameters are also summarised (nodal spacing on each component, number of upper surface and lower surface nodes, and the surface roughness), followed by a summary table of the number of trajectories used on each component.

The co-ordinate data is reproduced next, in terms of x/c, y/c and s/c.

The next set of data is the aerodynamic data tables. The Reynolds and Mach number are listed, together with a note on whether the compressibility correction has been included. Then, for each component, values are specified at each panel collocation point (not the panel end points); the panel number, x/c, y/c, s/c, surface tangential velocity, and the surface pressure coefficient. After each component, the lift coefficient for that component is output, using two methods (integration of pressures, and direct from the circulation values). Finally, the panel number on which the stagnation point lies is output.

After the aerodynamic data, the catch is summarised. Firstly, the output states for which components catch has been calculated. Then, for each component on which catch is calculated, the trajectories are summarised (start y/c point of trajectory, then x/c, y/c and s/c points of the droplet impact). The total collection efficiency is output, as well as the droplet inertia parameter, and modified droplet inertia parameter. For a spectrum calculation, the trajectories and inertias are listed for each bin in the spectrum, with a total, weighted collection efficiency being output last.

The last section within the file contains the nodal data for each component on which a trajectory calculation has been performed (i.e. data at each user-specified nodal position). The table lists the node number, x/c, y/c and s/c positions of the node, the surface velocity, heat transfer coefficient, pressure coefficient, and beta (collection efficiency). Finally, on the line, there is an ‘L’ or a ‘T’, specifying whether the boundary layer at that point is laminar or turbulent.

5.1.2 TAC2_PLOTS.EZ

The plotting utility, ‘WinEZDraw’ is used to visualise the pressure coefficient, particle paths, catch efficiency and ice shape (ICE=1 option only). The TAC2 code produces a file of .EZ format which can be processed by the EZDraw graphing utility code. The EZDraw code allows the plots to be saved in .wmf or .ps format for inclusion in reports or can be printed on the PCs default printer. Certain versions of the WinEZDraw code allow the user to zoom into specific regions of the plot (e.g. to ensure the TAC2 code has accurately calculated the correct impact point on the body surface). Plots are produced for each aerofoil component, and for each droplet bin size (in a spectrum calculation). Each ‘.EZ’ file can only contain 20 individual plots. Therefore, for multi-element, droplet spectrum cases where the total number of plots exceeds this value, a number of .EZ files are produced. The first of these is always called 'TAC2_PLOTS.EZ', but subsequent files have a number appended, e.g. 'TAC2_PLOTS_2.EZ' and 'TAC2_PLOTS_3.EZ'.

5.1.3 IHB.DAT

The TAC2 code can create an input file in the format required for input to the Icing Heat Balance code (IHB) (when ICE=1). The IHB code can be run without modifying this input file, as a stand-alone operation, but is also called as standard from within the TAC2 code (ICE=1 option). It is possible that the additional functionality of the IHB code to model an electrothermal anti-icing system, and on a conducting surface, may be required, in which case it would be appropriate to edit the IHB.DAT file created by the TAC2 code before running the IHB code (see the IHB User Guide for more details [3]).

5.1.4 IHB_IP.DAT

The TAC2 code creates an input file in the format required for input to the Electrothermal ice protection system modelling code called ET3D.EXE. The data are very similar to that output in file IHB.DAT and differ only in a small number of additional parameters which are specific to the ET3D code input requirements. Unlike IHB, ET3D requires a second input file which specifies the case details including the structure of the heater mat. The file IHB_IP (Icing heat balance Input) specifies only the data required to conduct an icing heat balance on the surface of an electrothermal ice protection system, with the structure and material thermal properties input via a separate input file (ET3D.DAT). Hence, there is no option to run ET3D from within the TAC2 code. The file does, however, speed up the process of establishing the input files necessary to run code ET3D. See the ET3D User Guide for more details [4].

5.2 Warnings and Errors Output

The TAC2 code has been designed to give the user specific and helpful warning and error messages for any code failure. Hence, there are a large number of potential warnings and errors which can occur. However, by following the input formats specified in this user guide, these situations can be avoided.

5.2.1 Code Warnings

Warnings are intended only to make the user aware that they may have provided inputs which are inconsistent, or that specific parts of the results of the calculations should be studied in detail. These warnings should be studied after each run, but there is a high chance that the user will not need to act upon them. Each warning is output both to the screen during the run, and to a 'TAC2_WARNINGS.DAT' file. Each warning is listed with a number (shown in square brackets), to allow easy reference to the table shown in Annex M. Note that a warnings file will not be produced if no warnings occur during code execution.

5.2.2 Code Errors

Code errors will cause execution of the code to stop, and the user will need to change at least one input in order to get it to run successfully. Each error is output both to the screen during the run, and to a 'TAC2_ERRORS.DAT' file. Each error is listed with a number (shown in square brackets), to allow easy reference to the table shown in

Annex N. Note that an errors file will not be produced if no errors occur during code execution.

6 Summary and Conclusions

A computer program has been developed to predict the trajectories of small cloud water droplets about an arbitrary shaped multi-element body in two-dimensional, incompressible flow, conditions. The SLD module has been implemented in a current version to correctly predict the water droplet catch (collection) efficiency distribution, β, for large droplet MVDs. The code also calculates the pressure coefficient and convective heat transfer coefficient.

Distributions of these parameters about the aerofoil/body surface are pre-requisites for the ability to calculate ice accretions (using code IHB) or modelling an electrothermal ice protections system (using code ET3D).

The accuracy of the code has been checked against results from published data and peer group programs, such as the QinetiQ's TRAJICE2 code. A very good level of agreement has been achieved for a range of 2D aerofoils and for droplet MVDs.

7 References

[1] Gent, R.W., Dart, N.P. & Cansdale, J.T., 'Aircraft icing'. Philosophical Transactions of the Royal Society, 15 November 2000, Volume 358, Number 1776 p2873-2912

[2] Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes, CS-25, Appendix C

[3] R Moser, "IHB, Icing Heat Balance – An ice accretion prediction code; User Guide", A19UGR00100074, Issue 2.0G, 21st May 2019

[4] R Moser, "ET3D; Electrothermal Ice Protection System design in 3D; User Guide", A19UGR00100075, Issue 7.0G, 22nd May 2019

[5] W.B. Wright, M.G. Potapczuck, "Semi-Empirical Modeling of SLD physics", AIAA-2004-0412

[6] W.B. Wright, "Further Refinement of the LEWICE SLD Model", AIAA-2006-0464

Annex A – Blank

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Annex B – Example TAC2_CRD.DAT input file

This appendix shows an example of the ordinates input file used by the TAC2 code (from the Demo 1 case supplied with the code). The first line contains the aerofoil name, the second line the number of aerofoil components (I3), the next 'n' lines (where 'n' is the number of components) contain the number of points defining the aerofoil (I4 format), followed by the x and y ordinates (F9.6,2X,F9.6 format) starting at the trailing edge, then proceeding clockwise, around the aerofoil. (Note that the ordinates can also be entered in an anti-clockwise direction, but these are then reversed in the code).

```
NACA 0012
1
101

 1.000000   0.000000
 0.999013   0.000143
 0.996058   0.000572
 0.991144   0.001280
 0.984292   0.002260
 0.975529   0.003501
 0.964889   0.004990
 0.952414   0.006710
 0.938154   0.008643
 0.922165   0.010770
 0.904509   0.013071
 0.885257   0.015523
 0.864485   0.018106
 0.842274   0.020795
 0.818713   0.023569
 0.793893   0.026405
 0.767914   0.029279
 0.740878   0.032168
 0.712890   0.035048
 0.684063   0.037896
 0.654509   0.040686
 0.624346   0.043394
 0.593691   0.045992
 0.562667   0.048455
 0.531396   0.050754
 0.500001   0.052862
 0.468606   0.054749
 0.437334   0.056390
 0.406310   0.057755
 0.375656   0.058819
 0.345492   0.059557
 0.315938   0.059947
 0.287111   0.059972
 0.259124   0.059614
 0.232087   0.058863
 0.206108   0.057712
 0.181289   0.056159
 0.157727   0.054207
 0.135516   0.051862
 0.114744   0.049138
 0.095492   0.046049
 0.077836   0.042615
 0.061847   0.038859
 0.047587   0.034803
 0.035112   0.030473
 0.024472   0.025893
 0.015709   0.021088
 0.008857   0.016079
 0.003943   0.010884
 0.000987   0.005521
 0.000000   0.000000
 0.000987  -0.005521
 0.003943  -0.010884
 0.008857  -0.016079
 0.015709  -0.021088
 0.024472  -0.025893
```

```
 0.035112  -0.030473
 0.047587  -0.034803
 0.061847  -0.038859
 0.077836  -0.042615
 0.095492  -0.046049
 0.114744  -0.049138
 0.135516  -0.051862
 0.157727  -0.054207
 0.181289  -0.056159
 0.206108  -0.057712
 0.232087  -0.058863
 0.259124  -0.059614
 0.287111  -0.059972
 0.315938  -0.059947
 0.345492  -0.059557
 0.375656  -0.058819
 0.406310  -0.057755
 0.437334  -0.056390
 0.468606  -0.054749
 0.500001  -0.052862
 0.531396  -0.050754
 0.562667  -0.048455
 0.593691  -0.045992
 0.624346  -0.043394
 0.654509  -0.040686
 0.684063  -0.037896
 0.712890  -0.035048
 0.740878  -0.032168
 0.767914  -0.029279
 0.793893  -0.026405
 0.818713  -0.023569
 0.842274  -0.020795
 0.864485  -0.018106
 0.885257  -0.015523
 0.904509  -0.013071
 0.922165  -0.010770
 0.938154  -0.008643
 0.952414  -0.006710
 0.964889  -0.004990
 0.975529  -0.003501
 0.984292  -0.002260
 0.991144  -0.001280
 0.996058  -0.000572
 0.999013  -0.000143
 1.000000   0.000000
1
```

Annex C – Example TAC2_INPUT.DAT input file

This appendix shows an example of the case input file, TAC2_INPUT.DAT (from the Demo 1 case supplied with the code).

Note that the highlighted lines are wrapped here onto more than one line only due to page width restriction. In the input file, they should all be on a single line.

```
$TITLE = Demo case: Water catch on a 2m chord, NACA0012 wing, AoA=4, 250KTAS, 5000ft,
-12C;

$AERO = 0; Icing analysis (0 for icing, 1 for aerodynamic only)
$TRAJ = 0; Mono-disperse droplets (0 for mono-disperse, 1 for Langmuir-D spectrum, 2
for user-defined spectrum)
$ICE = 0; No ice shape output (0 for no ice shape, 1 for creation of IHB and ET3D
input files)

$TAS = 128.7; Airspeed, true (m/s)
$AOAI = 4.0; Initial angle of attack (degrees)
$CHORDM = 2.0; Aerofoil chord (m)
$ALTF = 5000.0; Altitude (feet)
$OATC = -12.0; Static temperature (deg. C)
$VMD = 20.0; Droplet median diameter (microns)
$LWC = 0.54; Liquid water concentration (g/m3)
$TIME = 15.0; Encounter time (minutes)

$NCOMP = 1; Number of aerofoil components
$DELS = 0.003; Non-dimensional surface spacing
$N_UPP = 120; Number of nodes on upper surface
$N_LOW = 120; Number of nodes on lower surface
$RUFF = 8; Equivalent sand-grain surface roughness (microns)
$NTRAJ = 5; Number of trajectories
```

Annex D – Example IHB.BAT file

The following shows an example of the command which should be placed into the 'IHB.BAT' file to call the IHB executable. This assumes that the user wishes to run Issue 1, revision 1.002F (IHB_Iss1_Rev1.002F.EXE), stored in the "E:\ATX_Codes" folder.

```
"E:\ATX_Codes\IHB_Iss1_Rev1.002F.EXE"
```

Annex E – Example TAC2_SPECTRUM.DAT input file

The following shows an example of a spectrum input file. Note that, in this case, there are notes written after the data block to aid as a reminder for what each column represents. This can be put on any line after the data block.

```
NASA/WSU Experimental Catch measurement; NACA65-415,AoA=4, MVD=11um, 10 bin
10
  3.5 0.05447  4
  6.5 0.09494  4
  9.5 0.22265  5
 12.5 0.26695  5
 15.5 0.19893  5
 18.5 0.11554  5
 21.5 0.03624  5
 24.5 0.00893  5
 27.5 0.00109  7
 30.5 0.00025  7


 Dia.  %LWC  NTRJ
```

Annex F – Example CP_REF.DAT input file

This appendix shows an example of the reference Cp input file used by the TAC2 code. The first line contains a title, the second line the number of aerofoil components (I3), the next ‘n’ lines (where ‘n’ is the number of components) contain the number of points defining the aerofoil (I4 format), followed by the s/c and Cp values (free format) starting at the trailing edge, then proceeding clockwise, around the aerofoil.

Note that some values are excluded, for brevity.

```
"Slat5, Case 1"
1
269

-1.016095881   0.111623
-1.015142718   0.129685
-1.014189608   0.135439
-1.013235191   0.032716
-1.011890646   0.200662
-1.008815129   0.186988
-1.000027901   0.196479
-0.98214594    0.211785
-0.970848554   0.220673
-0.946173626   0.236785
-0.920630748   0.245526
-0.899803023   0.245555
-0.894682804   0.245011
...
...
...
0.846739918    -0.271470
0.872586266    -0.199241
0.896129087    -0.126647
0.91115036     -0.081875
0.936820998    -0.012746
0.962100201    0.044227
0.986495525    0.088767
1.006832663    0.124932
1.013780602    0.137405
1.018270615    0.145504
1.022447927    0.155053
1.024080984    0.111623
```

Annex G – Example batch file for execution

The following shows an example of the command which should be placed into the 'TAC2.BAT' file to call the TAC2 executable. Note that the name of this batch file is not important (e.g. if the user wishes they can specify the version of TAC2 in the batch filename, 'TAC2_Iss2_Rev2.02.BAT'). This assumes that the executable is stored in the "E:\ATX_Codes" folder. The 'AIDLicence.jar' and 'xLicence.txt' files must also be stored in this folder. The batch file can then be placed in every folder in which the code needs to be run, so as not to have multiple copies of the executable on the disk.

```
"E:\ATX_Codes\TAC2_Iss2_Rev2.02.EXE"
```

Annex H – Code installation guide

All files on the installation media should be copied into a specific directory on the user's hard drive. It is recommended that these files are placed into a directory which is specific to the AeroTex codes (e.g. E:\ATX_Codes), but this is not a requirement.

In order to obtain a valid software licence (which is required to run the code), the user must supply their computer MAC address to AeroTex. To simplify this, AeroTex supply a code to obtain the MAC address. If the user runs the GetMAC.jar file, and selects the 'Get MAC address' button, the computer MAC address will be displayed. This can be copied and emailed to AeroTex (richard.moser@aerotex.co.uk), for a valid licence file to be provided. This will be named 'xLicence.txt', and must be placed in the same directory as the AIDLicence.jar and TAC2_Iss2_Rev2.02.exe files.

Once a valid licence file has been supplied, the user can create a batch file to run TAC2, as defined in Annex G. This batch file must be used to execute the TAC2 code.

Annex I – Example TAC2_RESULTS.DAT output file

This appendix shows an example of a main results output file created for the input case listed in Annex B and Annex C.

```
================================================================================
2D WATER DROPLET TRAJECTORY AND CATCH EFFICIENCY CODE (MULTI-ELEMENT VERSION)
================================================================================

                    TAC Issue 2, Revision2.02  09/01/2017

                       Copyright AeroTex UK LLP, 2009-2017


Code run on 01-05-2017 at 15:51:37
CPU time was    0.967 seconds
Elapsed time was    0.961 seconds

Run: Demo case: Water catch on a 2m chord, NACA0012 wing, AoA=4, 250KTAS, 5000ft, -12C


Summary of input data

Run type:

     2D aerodynamic calculation
     Single incidence evaluated
     Trajectory and catch calculated
     Mono-disperse droplets
     Unheated ice shape calculated
     No SLD model implemented

Test run conditions:

          Airspeed (true)       =     128.70 m/s      250.17 knots
          Airspeed (equivalent) =     123.32 m/s      239.71 knots
          Airspeed (calibrated) =     123.71 m/s      240.47 knots
          Incidence             =       4.00 °
          Chord (reference)     =      2.000 m         78.74 inches
          Altitude              =    5000.00 feet    1524.00 metres
          OAT                   =     -12.00 °C        10.40 °F
          TAT                   =      -3.76 °C        25.23 °F
          RH                    =     100.00 %
          VMD                   =      20.00 microns
          LWC                   =      0.540 g/m3

          Barometric pressure   =   84308.04 Pa
          Air density           =      1.124 kg/m3
          Dynamic viscosity     =   1.674E-5 N.m-2.s-1


Solution parameters:

Component number: 1

          Nodal spacing         =     0.0030 (non-dimensional)
          Number of u/s nodes   =        100
          Number of l/s nodes   =        100
          Surface roughness     =          8 microns


Trajectory details:

     Component no.     No. of trajectories
          1                     5


Co-ordinate Data Table

Aerofoil name:  NACA 0012

Component number: 1

    Ord No.  X ordinate     Y ordinate        S/C
       1      1.000000       0.000000      -1.019682
       2      0.999013      -0.000143      -1.018685
       3      0.996058      -0.000572      -1.015699
       4      0.991144      -0.001280      -1.010734
       5      0.984292      -0.002260      -1.003813
       6      0.975529      -0.003501      -0.994962
       7      0.964889      -0.004990      -0.984218
       8      0.952414      -0.006710      -0.971625
```

9	0.938154	-0.008643	-0.957235
10	0.922165	-0.010770	-0.941105
11	0.904509	-0.013071	-0.923300
12	0.885257	-0.015523	-0.903892
13	0.864485	-0.018106	-0.882960
14	0.842274	-0.020795	-0.860587
15	0.818713	-0.023569	-0.836863
16	0.793893	-0.026405	-0.811882
17	0.767914	-0.029279	-0.785744
18	0.740878	-0.032168	-0.758555
19	0.712890	-0.035048	-0.730419
20	0.684063	-0.037896	-0.701451
21	0.654509	-0.040686	-0.671766
22	0.624346	-0.043394	-0.641482
23	0.593691	-0.045992	-0.610717
24	0.562667	-0.048455	-0.579595
25	0.531396	-0.050754	-0.548240
26	0.500001	-0.052862	-0.516774
27	0.468606	-0.054749	-0.485322
28	0.437334	-0.056390	-0.454007
29	0.406310	-0.057755	-0.422953
30	0.375656	-0.058819	-0.392281
31	0.345492	-0.059557	-0.362108
32	0.315938	-0.059947	-0.332551
33	0.287111	-0.059972	-0.303724
34	0.259124	-0.059614	-0.275735
35	0.232087	-0.058863	-0.248688
36	0.206108	-0.057712	-0.222683
37	0.181289	-0.056159	-0.197816
38	0.157727	-0.054207	-0.174173
39	0.135516	-0.051862	-0.151838
40	0.114744	-0.049138	-0.130889
41	0.095492	-0.046049	-0.111390
42	0.077836	-0.042615	-0.093403
43	0.061847	-0.038859	-0.076979
44	0.047587	-0.034803	-0.062154
45	0.035112	-0.030473	-0.048949
46	0.024472	-0.025893	-0.037365
47	0.015709	-0.021088	-0.027371
48	0.008857	-0.016079	-0.018883
49	0.003943	-0.010884	-0.011732
50	0.000987	-0.005521	-0.005609
51	0.000000	0.000000	0.000000
52	0.000987	0.005521	0.005609
53	0.003943	0.010884	0.011732
54	0.008857	0.016079	0.018883
55	0.015709	0.021088	0.027371
56	0.024472	0.025893	0.037365
57	0.035112	0.030473	0.048949
58	0.047587	0.034803	0.062154
59	0.061847	0.038859	0.076979
60	0.077836	0.042615	0.093403
61	0.095492	0.046049	0.111390
62	0.114744	0.049138	0.130889
63	0.135516	0.051862	0.151838
64	0.157727	0.054207	0.174173
65	0.181289	0.056159	0.197816
66	0.206108	0.057712	0.222683
67	0.232087	0.058863	0.248688
68	0.259124	0.059614	0.275735
69	0.287111	0.059972	0.303724
70	0.315938	0.059947	0.332551
71	0.345492	0.059557	0.362108
72	0.375656	0.058819	0.392281
73	0.406310	0.057755	0.422953
74	0.437334	0.056390	0.454007
75	0.468606	0.054749	0.485322
76	0.500001	0.052862	0.516774
77	0.531396	0.050754	0.548240
78	0.562667	0.048455	0.579595
79	0.593691	0.045992	0.610717
80	0.624346	0.043394	0.641482
81	0.654509	0.040686	0.671766
82	0.684063	0.037896	0.701451
83	0.712890	0.035048	0.730419
84	0.740878	0.032168	0.758555
85	0.767914	0.029279	0.785744
86	0.793893	0.026405	0.811882
87	0.818713	0.023569	0.836863
88	0.842274	0.020795	0.860587
89	0.864485	0.018106	0.882960
90	0.885257	0.015523	0.903892
91	0.904509	0.013071	0.923300
92	0.922165	0.010770	0.941105
93	0.938154	0.008643	0.957235
94	0.952414	0.006710	0.971625
95	0.964889	0.004990	0.984218
96	0.975529	0.003501	0.994962

97	0.984292	0.002260	1.003813
98	0.991144	0.001280	1.010734
99	0.996058	0.000572	1.015699
100	0.999013	0.000143	1.018685
101	1.000000	0.000000	1.019682

Aerodynamic Data Tables

Reynold's number = 1.728E+7
Mach number = 0.397
Compressibility correction has not been included

Component number: 1

Ord No.	X ordinate	Y ordinate	S/C	Tang. Vel (m/s)	Cp
1	0.999507	-0.000072	-1.019184	63.79	0.754
2	0.997536	-0.000358	-1.017192	102.65	0.364
3	0.993601	-0.000926	-1.013217	107.91	0.297
4	0.987718	-0.001770	-1.007273	111.38	0.251
5	0.979910	-0.002881	-0.999387	114.03	0.215
6	0.970209	-0.004246	-0.989590	116.20	0.185
7	0.958651	-0.005850	-0.977922	118.03	0.159
8	0.945284	-0.007676	-0.964430	119.61	0.136
9	0.930160	-0.009706	-0.949170	120.99	0.116
10	0.913337	-0.011921	-0.932203	122.23	0.098
11	0.894883	-0.014297	-0.913596	123.34	0.082
12	0.874871	-0.016814	-0.893426	124.34	0.067
13	0.853379	-0.019451	-0.871774	125.26	0.053
14	0.830493	-0.022182	-0.848725	126.09	0.040
15	0.806303	-0.024987	-0.824373	126.87	0.028
16	0.780903	-0.027842	-0.798813	127.58	0.017
17	0.754396	-0.030724	-0.772150	128.25	0.007
18	0.726884	-0.033608	-0.744487	128.88	-0.003
19	0.698476	-0.036472	-0.715935	129.47	-0.012
20	0.669286	-0.039291	-0.686609	130.02	-0.021
21	0.639428	-0.042040	-0.656624	130.55	-0.029
22	0.609018	-0.044693	-0.626099	131.06	-0.037
23	0.578179	-0.047224	-0.595156	131.53	-0.044
24	0.547032	-0.049604	-0.563917	131.97	-0.052
25	0.515699	-0.051808	-0.532507	132.38	-0.058
26	0.484303	-0.053805	-0.501048	132.75	-0.064
27	0.452970	-0.055570	-0.469665	133.07	-0.069
28	0.421822	-0.057072	-0.438480	133.32	-0.073
29	0.390983	-0.058287	-0.407617	133.50	-0.076
30	0.360574	-0.059188	-0.377194	133.60	-0.078
31	0.330715	-0.059752	-0.347330	133.57	-0.077
32	0.301524	-0.059959	-0.318138	133.42	-0.075
33	0.273118	-0.059793	-0.289730	133.11	-0.070
34	0.245606	-0.059238	-0.262211	132.61	-0.062
35	0.219098	-0.058287	-0.235685	131.87	-0.050
36	0.193698	-0.056935	-0.210249	130.87	-0.034
37	0.169508	-0.055183	-0.185994	129.54	-0.013
38	0.146622	-0.053034	-0.163006	127.82	0.014
39	0.125130	-0.050500	-0.141364	125.61	0.047
40	0.105118	-0.047593	-0.121139	122.79	0.090
41	0.086664	-0.044332	-0.102397	119.18	0.143
42	0.069842	-0.040737	-0.085191	114.53	0.208
43	0.054717	-0.036831	-0.069566	108.47	0.290
44	0.041349	-0.032638	-0.055551	100.40	0.391
45	0.029792	-0.028183	-0.043157	89.37	0.518
46	0.020091	-0.023490	-0.032368	73.83	0.671
47	0.012283	-0.018583	-0.023127	51.27	0.841
48	0.006400	-0.013482	-0.015308	18.03	0.980
49	0.002465	-0.008202	-0.008670	29.02	0.949
50	0.000494	-0.002760	-0.002804	86.83	0.545
51	0.000494	0.002760	0.002804	141.97	-0.217
52	0.002465	0.008202	0.008670	179.57	-0.947
53	0.006400	0.013482	0.015308	196.78	-1.338
54	0.012283	0.018583	0.023127	201.39	-1.449
55	0.020091	0.023490	0.032368	200.44	-1.426
56	0.029792	0.028183	0.043157	197.49	-1.355
57	0.041349	0.032638	0.055551	194.01	-1.272
58	0.054717	0.036831	0.069566	190.54	-1.192
59	0.069842	0.040737	0.085191	187.27	-1.117
60	0.086664	0.044332	0.102397	184.22	-1.049
61	0.105118	0.047593	0.121139	181.40	-0.987
62	0.125130	0.050500	0.141364	178.75	-0.929
63	0.146622	0.053034	0.163006	176.25	-0.876
64	0.169508	0.055183	0.185994	173.88	-0.825
65	0.193698	0.056935	0.210249	171.60	-0.778
66	0.219098	0.058287	0.235685	169.40	-0.733
67	0.245606	0.059238	0.262211	167.27	-0.689
68	0.273118	0.059793	0.289730	165.20	-0.648
69	0.301524	0.059959	0.318138	163.17	-0.607
70	0.330715	0.059752	0.347330	161.20	-0.569
71	0.360574	0.059188	0.377194	159.28	-0.532
72	0.390983	0.058287	0.407617	157.40	-0.496

73	0.421822	0.057072	0.438480	155.58	-0.461
74	0.452970	0.055570	0.469665	153.79	-0.428
75	0.484303	0.053805	0.501048	152.06	-0.396
76	0.515699	0.051808	0.532507	150.38	-0.365
77	0.547032	0.049604	0.563917	148.73	-0.336
78	0.578179	0.047224	0.595156	147.13	-0.307
79	0.609018	0.044693	0.626099	145.57	-0.279
80	0.639428	0.042040	0.656624	144.05	-0.253
81	0.669286	0.039291	0.686609	142.55	-0.227
82	0.698476	0.036472	0.715935	141.07	-0.201
83	0.726884	0.033608	0.744487	139.60	-0.177
84	0.754396	0.030724	0.772150	138.14	-0.152
85	0.780903	0.027842	0.798813	136.67	-0.128
86	0.806303	0.024987	0.824373	135.19	-0.103
87	0.830493	0.022182	0.848725	133.68	-0.079
88	0.853379	0.019451	0.871774	132.14	-0.054
89	0.874871	0.016814	0.893426	130.54	-0.029
90	0.894883	0.014297	0.913596	128.87	-0.003
91	0.913337	0.011921	0.932203	127.13	0.024
92	0.930160	0.009706	0.949170	125.27	0.053
93	0.945284	0.007676	0.964430	123.29	0.082
94	0.958651	0.005850	0.977922	121.14	0.114
95	0.970209	0.004246	0.989590	118.76	0.149
96	0.979910	0.002881	0.999387	116.06	0.187
97	0.987718	0.001770	1.007273	112.90	0.230
98	0.993601	0.000926	1.013217	108.96	0.283
99	0.997536	0.000357	1.017192	103.42	0.354
100	0.999507	0.000072	1.019184	108.56	0.289

Cl = 0.477 (from integration of Cp's)
Cl = 0.482 (from circulation)

Stagnation point for component 1 lies on panel no. 48

Total Catch Tables

Catch calculated on component 1

Component number: 1
Trajectory start point (X): -7.000833

Y0	X/C Impact	Y/C Impact	S/C Impact
-0.646	0.04759	-0.03480	-0.06215
-0.642	0.01351	-0.01948	-0.02464
-0.638	0.00494	-0.01194	-0.01318
-0.634	0.00082	-0.00461	-0.00469
-0.630	0.00099	0.00551	0.00560

Total collection efficiency: 0.1233
Projected height (m): 0.2659
Droplet inertia parameter: 0.08541
Droplet modified inertia parameter: 0.02392

Nodal Data Tables

Component number: 1

Node No.	X	Y	S/C	Velocity	HTC	Cp	Beta	BL state
1	0.280387	-0.059886	-0.2970	133.19	201.03	-0.071	0.0000	T
2	0.277387	-0.059848	-0.2940	133.16	201.03	-0.070	0.0000	T
3	0.274388	-0.059809	-0.2910	133.12	201.38	-0.070	0.0000	T
4	0.271388	-0.059771	-0.2880	133.08	201.71	-0.069	0.0000	T
5	0.268388	-0.059733	-0.2850	133.02	202.03	-0.068	0.0000	T
6	0.265388	-0.059694	-0.2820	132.97	202.35	-0.067	0.0000	T
7	0.262389	-0.059656	-0.2790	132.91	202.68	-0.067	0.0000	T
8	0.259389	-0.059617	-0.2760	132.86	203.02	-0.066	0.0000	T
9	0.256390	-0.059538	-0.2730	132.80	203.37	-0.065	0.0000	T
10	0.253391	-0.059455	-0.2700	132.75	203.72	-0.064	0.0000	T
11	0.250392	-0.059371	-0.2670	132.69	204.08	-0.063	0.0000	T
12	0.247393	-0.059288	-0.2640	132.64	204.45	-0.062	0.0000	T
13	0.244395	-0.059205	-0.2610	132.57	204.81	-0.061	0.0000	T
14	0.241396	-0.059122	-0.2580	132.49	205.14	-0.060	0.0000	T
15	0.238397	-0.059038	-0.2550	132.41	205.48	-0.058	0.0000	T
16	0.235398	-0.058955	-0.2520	132.32	205.83	-0.057	0.0000	T
17	0.232399	-0.058872	-0.2490	132.24	206.19	-0.056	0.0000	T
18	0.229402	-0.058744	-0.2460	132.16	206.56	-0.054	0.0000	T
19	0.226405	-0.058611	-0.2430	132.08	206.94	-0.053	0.0000	T
20	0.223408	-0.058478	-0.2400	131.99	207.32	-0.052	0.0000	T
21	0.220411	-0.058346	-0.2370	131.91	207.72	-0.051	0.0000	T
22	0.217414	-0.058213	-0.2340	131.81	208.09	-0.049	0.0000	T
23	0.214417	-0.058080	-0.2310	131.69	208.44	-0.047	0.0000	T
24	0.211420	-0.057947	-0.2280	131.57	208.80	-0.045	0.0000	T
25	0.208423	-0.057815	-0.2250	131.45	209.17	-0.043	0.0000	T
26	0.205426	-0.057669	-0.2220	131.33	209.56	-0.041	0.0000	T
27	0.202432	-0.057482	-0.2190	131.22	209.95	-0.040	0.0000	T
28	0.199438	-0.057295	-0.2160	131.10	210.36	-0.038	0.0000	T

29	0.196444	-0.057107	-0.2130	130.98	210.78	-0.036	0.0000	T
30	0.193450	-0.056920	-0.2100	130.86	211.21	-0.034	0.0000	T
31	0.190455	-0.056733	-0.2070	130.69	211.57	-0.031	0.0000	T
32	0.187461	-0.056545	-0.2040	130.53	211.94	-0.029	0.0000	T
33	0.184467	-0.056358	-0.2010	130.37	212.32	-0.026	0.0000	T
34	0.181473	-0.056171	-0.1980	130.20	212.72	-0.023	0.0000	T
35	0.178483	-0.055927	-0.1950	130.04	213.14	-0.021	0.0000	T
36	0.175493	-0.055679	-0.1920	129.87	213.57	-0.018	0.0000	T
37	0.172504	-0.055431	-0.1890	129.71	214.03	-0.016	0.0000	T
38	0.169514	-0.055183	-0.1860	129.54	214.50	-0.013	0.0000	T
39	0.166524	-0.054936	-0.1830	129.32	214.86	-0.010	0.0000	T
40	0.163534	-0.054688	-0.1800	129.09	215.24	-0.006	0.0000	T
41	0.160544	-0.054440	-0.1770	128.87	215.64	-0.003	0.0000	T
42	0.157555	-0.054189	-0.1740	128.64	216.06	0.001	0.0000	T
43	0.154572	-0.053874	-0.1710	128.42	216.50	0.004	0.0000	T
44	0.151588	-0.053559	-0.1680	128.19	216.96	0.008	0.0000	T
45	0.148605	-0.053244	-0.1650	127.97	217.45	0.011	0.0000	T
46	0.145621	-0.052929	-0.1620	127.72	217.91	0.015	0.0000	T
47	0.142638	-0.052614	-0.1590	127.41	218.28	0.020	0.0000	T
48	0.139655	-0.052299	-0.1560	127.10	218.67	0.025	0.0000	T
49	0.136671	-0.051984	-0.1530	126.80	219.08	0.029	0.0000	T
50	0.133693	-0.051623	-0.1500	126.49	219.53	0.034	0.0000	T
51	0.130719	-0.051233	-0.1470	126.18	220.01	0.039	0.0000	T
52	0.127744	-0.050843	-0.1440	125.88	220.52	0.043	0.0000	T
53	0.124770	-0.050453	-0.1410	125.56	221.04	0.048	0.0000	T
54	0.121795	-0.050063	-0.1380	125.14	221.38	0.055	0.0000	T
55	0.118821	-0.049673	-0.1350	124.72	221.75	0.061	0.0000	T
56	0.115846	-0.049283	-0.1320	124.30	222.16	0.067	0.0000	T
57	0.112879	-0.048839	-0.1290	123.88	222.61	0.073	0.0000	T
58	0.109917	-0.048364	-0.1260	123.46	223.10	0.080	0.0000	T
59	0.106955	-0.047888	-0.1230	123.05	223.65	0.086	0.0000	T
60	0.103993	-0.047413	-0.1200	122.57	224.11	0.093	0.0000	T
61	0.101031	-0.046938	-0.1170	121.99	224.39	0.101	0.0000	T
62	0.098069	-0.046462	-0.1140	121.41	224.72	0.110	0.0000	T
63	0.095109	-0.045974	-0.1110	120.83	225.11	0.118	0.0000	T
64	0.092164	-0.045402	-0.1080	120.26	225.56	0.127	0.0000	T
65	0.089219	-0.044829	-0.1050	119.68	226.09	0.135	0.0000	T
66	0.086274	-0.044256	-0.1020	119.07	226.62	0.144	0.0000	T
67	0.083330	-0.043683	-0.0990	118.26	226.74	0.155	0.0000	T
68	0.080385	-0.043111	-0.0960	117.45	226.93	0.167	0.0000	T
69	0.077443	-0.042523	-0.0930	116.64	227.21	0.178	0.0000	T
70	0.074523	-0.041837	-0.0900	115.83	227.59	0.190	0.0000	T
71	0.071602	-0.041151	-0.0870	115.02	228.09	0.201	0.0000	T
72	0.068682	-0.040465	-0.0840	114.07	228.36	0.214	0.0000	T
73	0.065761	-0.039778	-0.0810	112.91	228.18	0.230	0.0000	T
74	0.062841	-0.039092	-0.0780	111.74	228.14	0.246	0.0000	T
75	0.059943	-0.038318	-0.0750	110.58	228.25	0.261	0.0000	T
76	0.057058	-0.037497	-0.0720	109.42	228.55	0.277	0.0000	T
77	0.054172	-0.036676	-0.0690	108.15	228.77	0.294	0.0000	T
78	0.051287	-0.035855	-0.0660	106.42	227.93	0.316	0.0000	T
79	0.048401	-0.035035	-0.0630	104.69	227.31	0.337	0.0000	T
80	0.045552	-0.034097	-0.0600	102.97	226.97	0.359	0.0054	T
81	0.042718	-0.033113	-0.0570	101.24	227.01	0.381	0.0152	T
82	0.039884	-0.032129	-0.0540	99.02	226.03	0.407	0.0276	T
83	0.037050	-0.031146	-0.0510	96.35	224.12	0.438	0.0426	T
84	0.034241	-0.030098	-0.0480	93.68	222.78	0.468	0.0602	T
85	0.031485	-0.028912	-0.0450	91.01	222.32	0.499	0.0804	T
86	0.028730	-0.027726	-0.0420	87.71	221.15	0.534	0.1032	T
87	0.025974	-0.026540	-0.0390	83.39	218.56	0.577	0.1286	T
88	0.023275	-0.025237	-0.0360	79.06	219.89	0.619	0.1566	T
89	0.020645	-0.023794	-0.0330	74.74	113.16	0.662	0.1873	L
90	0.018014	-0.022352	-0.0300	68.05	118.18	0.715	0.2205	L
91	0.015410	-0.020869	-0.0270	60.73	124.75	0.770	0.2564	L
92	0.012988	-0.019099	-0.0240	53.40	138.03	0.825	0.2947	L
93	0.010566	-0.017328	-0.0210	42.23	148.24	0.879	0.3328	L
94	0.008250	-0.015437	-0.0180	29.48	139.12	0.932	0.3694	L
95	0.006189	-0.013258	-0.0150	0.00	130.01	0.979	0.4044	L
96	0.004127	-0.011079	-0.0120	23.51	120.89	0.965	0.4386	L
97	0.002624	-0.008491	-0.0090	28.48	111.77	0.951	0.4788	L
98	0.001176	-0.005864	-0.0060	55.34	171.41	0.765	0.5267	L
99	0.000528	-0.002953	-0.0030	84.90	195.40	0.558	0.5613	L
100	0.000000	0.000000	0.0000	114.40	203.29	0.164	0.4829	L
101	0.000528	0.002953	0.0030	143.23	205.44	-0.241	0.2789	L
102	0.001176	0.005864	0.0060	162.46	418.49	-0.615	0.0000	T
103	0.002624	0.008491	0.0090	180.43	417.21	-0.966	0.0000	T
104	0.004127	0.011079	0.0120	188.21	403.96	-1.143	0.0000	T
105	0.006189	0.013258	0.0150	195.99	397.17	-1.320	0.0000	T
106	0.008250	0.015437	0.0180	198.37	384.64	-1.376	0.0000	T
107	0.010566	0.017328	0.0210	200.14	374.59	-1.419	0.0000	T
108	0.012988	0.019099	0.0240	201.30	365.90	-1.447	0.0000	T
109	0.015410	0.020869	0.0270	200.99	356.60	-1.439	0.0000	T
110	0.018014	0.022352	0.0300	200.68	348.77	-1.431	0.0000	T
111	0.020645	0.023794	0.0330	200.27	341.85	-1.421	0.0000	T
112	0.023275	0.025237	0.0360	199.45	335.16	-1.402	0.0000	T
113	0.025974	0.026540	0.0390	198.63	329.17	-1.382	0.0000	T
114	0.028730	0.027726	0.0420	197.81	323.75	-1.362	0.0000	T
115	0.031485	0.028912	0.0450	196.97	318.76	-1.342	0.0000	T
116	0.034241	0.030098	0.0480	196.13	314.15	-1.323	0.0000	T

117	0.037050	0.031146	0.0510	195.29	309.86	-1.303	0.0000	T
118	0.039884	0.032129	0.0540	194.45	305.85	-1.283	0.0000	T
119	0.042718	0.033113	0.0570	193.65	302.15	-1.264	0.0000	T
120	0.045552	0.034097	0.0600	192.91	298.73	-1.247	0.0000	T
121	0.048401	0.035035	0.0630	192.17	295.50	-1.230	0.0000	T
122	0.051287	0.035855	0.0660	191.43	292.41	-1.212	0.0000	T
123	0.054172	0.036676	0.0690	190.68	289.47	-1.195	0.0000	T
124	0.057058	0.037497	0.0720	190.03	286.79	-1.180	0.0000	T
125	0.059943	0.038318	0.0750	189.40	284.25	-1.166	0.0000	T
126	0.062841	0.039092	0.0780	188.78	281.81	-1.152	0.0000	T
127	0.065761	0.039778	0.0810	188.15	279.46	-1.137	0.0000	T
128	0.068682	0.040465	0.0840	187.52	277.18	-1.123	0.0000	T
129	0.071602	0.041151	0.0870	186.95	275.07	-1.110	0.0000	T
130	0.074523	0.041837	0.0900	186.42	273.09	-1.098	0.0000	T
131	0.077443	0.042523	0.0930	185.89	271.16	-1.086	0.0000	T
132	0.080385	0.043111	0.0960	185.35	269.29	-1.074	0.0000	T
133	0.083330	0.043683	0.0990	184.82	267.47	-1.062	0.0000	T
134	0.086274	0.044256	0.1020	184.29	265.70	-1.050	0.0000	T
135	0.089219	0.044829	0.1050	183.83	264.07	-1.040	0.0000	T
136	0.092164	0.045402	0.1080	183.38	262.50	-1.030	0.0000	T
137	0.095109	0.045974	0.1110	182.92	260.97	-1.020	0.0000	T
138	0.098069	0.046462	0.1140	182.47	259.47	-1.010	0.0000	T
139	0.101031	0.046938	0.1170	182.02	258.01	-1.000	0.0000	T
140	0.103993	0.047413	0.1200	181.57	256.58	-0.990	0.0000	T
141	0.106955	0.047888	0.1230	181.15	255.23	-0.981	0.0000	T
142	0.109917	0.048364	0.1260	180.76	253.94	-0.973	0.0000	T
143	0.112879	0.048839	0.1290	180.37	252.67	-0.964	0.0000	T
144	0.115846	0.049283	0.1320	179.97	251.43	-0.956	0.0000	T
145	0.118821	0.049673	0.1350	179.58	250.22	-0.947	0.0000	T
146	0.121795	0.050063	0.1380	179.19	249.02	-0.939	0.0000	T
147	0.124770	0.050453	0.1410	178.80	247.85	-0.930	0.0000	T
148	0.127744	0.050843	0.1440	178.44	246.75	-0.922	0.0000	T
149	0.130719	0.051233	0.1470	178.10	245.68	-0.915	0.0000	T
150	0.133693	0.051623	0.1500	177.75	244.63	-0.908	0.0000	T
151	0.136671	0.051984	0.1530	177.41	243.59	-0.900	0.0000	T
152	0.139655	0.052299	0.1560	177.06	242.57	-0.893	0.0000	T
153	0.142638	0.052614	0.1590	176.72	241.57	-0.885	0.0000	T
154	0.145621	0.052929	0.1620	176.37	240.58	-0.878	0.0000	T
155	0.148605	0.053244	0.1650	176.05	239.64	-0.871	0.0000	T
156	0.151588	0.053559	0.1680	175.74	238.73	-0.865	0.0000	T
157	0.154572	0.053874	0.1710	175.43	237.83	-0.858	0.0000	T
158	0.157555	0.054189	0.1740	175.12	236.94	-0.852	0.0000	T
159	0.160544	0.054440	0.1770	174.81	236.06	-0.845	0.0000	T
160	0.163534	0.054688	0.1800	174.50	235.20	-0.838	0.0000	T
161	0.166524	0.054936	0.1830	174.19	234.35	-0.832	0.0000	T
162	0.169514	0.055183	0.1860	173.88	233.50	-0.825	0.0000	T
163	0.172504	0.055431	0.1890	173.60	232.71	-0.819	0.0000	T
164	0.175493	0.055679	0.1920	173.32	231.92	-0.814	0.0000	T
165	0.178483	0.055927	0.1950	173.03	231.15	-0.808	0.0000	T
166	0.181473	0.056171	0.1980	172.75	230.38	-0.802	0.0000	T
167	0.184467	0.056358	0.2010	172.47	229.62	-0.796	0.0000	T
168	0.187461	0.056545	0.2040	172.19	228.87	-0.790	0.0000	T
169	0.190455	0.056733	0.2070	171.91	228.13	-0.784	0.0000	T
170	0.193450	0.056920	0.2100	171.62	227.39	-0.778	0.0000	T
171	0.196444	0.057107	0.2130	171.36	226.69	-0.773	0.0000	T
172	0.199438	0.057295	0.2160	171.10	226.00	-0.768	0.0000	T
173	0.202432	0.057482	0.2190	170.84	225.32	-0.762	0.0000	T
174	0.205426	0.057669	0.2220	170.58	224.65	-0.757	0.0000	T
175	0.208423	0.057815	0.2250	170.33	223.98	-0.752	0.0000	T
176	0.211420	0.057947	0.2280	170.07	223.31	-0.746	0.0000	T
177	0.214417	0.058080	0.2310	169.81	222.66	-0.741	0.0000	T
178	0.217414	0.058213	0.2340	169.55	222.01	-0.736	0.0000	T
179	0.220411	0.058346	0.2370	169.30	221.37	-0.730	0.0000	T
180	0.223408	0.058478	0.2400	169.06	220.76	-0.725	0.0000	T
181	0.226405	0.058611	0.2430	168.81	220.15	-0.721	0.0000	T
182	0.229402	0.058744	0.2460	168.57	219.54	-0.716	0.0000	T
183	0.232399	0.058872	0.2490	168.33	218.94	-0.711	0.0000	T
184	0.235398	0.058955	0.2520	168.09	218.35	-0.706	0.0000	T
185	0.238397	0.059038	0.2550	167.85	217.76	-0.701	0.0000	T
186	0.241396	0.059122	0.2580	167.61	217.17	-0.696	0.0000	T
187	0.244395	0.059205	0.2610	167.37	216.59	-0.691	0.0000	T
188	0.247393	0.059288	0.2640	167.14	216.03	-0.686	0.0000	T
189	0.250392	0.059371	0.2670	166.91	215.48	-0.682	0.0000	T
190	0.253391	0.059455	0.2700	166.68	214.93	-0.677	0.0000	T
191	0.256390	0.059538	0.2730	166.46	214.39	-0.673	0.0000	T
192	0.259389	0.059617	0.2760	166.23	213.85	-0.668	0.0000	T
193	0.262389	0.059656	0.2790	166.01	213.31	-0.664	0.0000	T
194	0.265388	0.059694	0.2820	165.78	212.78	-0.659	0.0000	T
195	0.268388	0.059733	0.2850	165.55	212.25	-0.655	0.0000	T
196	0.271388	0.059771	0.2880	165.33	211.73	-0.650	0.0000	T
197	0.274388	0.059809	0.2910	165.11	211.21	-0.646	0.0000	T
198	0.277387	0.059848	0.2940	164.89	210.71	-0.642	0.0000	T
199	0.280387	0.059886	0.2970	164.68	210.71	-0.637	0.0000	T

Annex J – Example TAC2_PLOTS.EZ output file

This appendix shows an example TAC_PLOTS.EZ graphics file taken from the input case shown in Annex B and Annex C.

```
! Pressure coefficient plot created by code TAC
DRAW 5
0.0 0.0 25.0 0.0 25.0 15.00 0.0 15.00 0.0 0.0
OPTIONS TEXT/JUS=CEN
FONT TIM
TSIZE 0.27
TEXT  12.50 0.3
Demo case: Water catch on a 2m chord, NACA0012 wing, AoA=4, 250KTAS, 5000ft, -12C
TSIZE 0.15
TEXT 23.0 14.5
               Issue 2, Revision2.02
TSIZE 0.27
FONT TIM
TSIZE 0.2
SIZEL 0.20
SIZEN 0.2
SIZES 0.15
OPTIONS GRAPH/FRA=LIN
OPTIONS GRAPH/XMIN = -0.10000
OPTIONS GRAPH/XMAX =   1.10000
OPTIONS GRAPH/YMIN =-1.000
OPTIONS GRAPH/YMAX =  2.000
OPTIONS GRAPH/YNUM=PER
FACTOR  1.0
GRID       3.0000    2.0000   23.0000   14.0000 1.0 2 2
GRAPH     3.0   2.0  20.0  12.0   1.0   1.0  2  2  1
X/C
-Cp
1  100 1 1

   0.999507 -0.754360  0.997536 -0.363899  0.993601 -0.297028  0.987718 -0.251069
   0.979910 -0.214937  0.970209 -0.184847  0.958651 -0.158972  0.945284 -0.136333
   0.930160 -0.116200  0.913337 -0.098038  0.894883 -0.081601  0.874871 -0.066572
   0.853379 -0.052771  0.830493 -0.040095  0.806303 -0.028279  0.780903 -0.017267
   0.754396 -0.006954  0.726884  0.002740  0.698476  0.011938  0.669286  0.020684
   0.639428  0.029025  0.609018  0.036950  0.578179  0.044449  0.547032  0.051514
   0.515699  0.058049  0.484303  0.063902  0.452970  0.068986  0.421822  0.073139
   0.390983  0.076059  0.360574  0.077524  0.330715  0.077156  0.301524  0.074703
   0.273118  0.069704  0.245606  0.061609  0.219098  0.049940  0.193698  0.034031
   0.169508  0.013169  0.146622 -0.013643  0.125130 -0.047489  0.105118 -0.089794
   0.086664 -0.142523  0.069842 -0.208021  0.054717 -0.289616  0.041349 -0.391392
   0.029792 -0.517757  0.020091 -0.670891  0.012283 -0.841318  0.006400 -0.980363
   0.002465 -0.949142  0.000494 -0.544817  0.000494  0.216930  0.002465  0.946815
   0.006400  1.337903  0.012283  1.448705  0.020091  1.425516  0.029792  1.354733
   0.041349  1.272450  0.054717  1.191949  0.069842  1.117238  0.086664  1.048910
   0.105118  0.986558  0.125130  0.928990  0.146622  0.875513  0.169508  0.825335
   0.193698  0.777775  0.219098  0.732533  0.245606  0.689203  0.273118  0.647605
   0.301524  0.607477  0.330715  0.568832  0.360574  0.531671  0.390983  0.495790
   0.421822  0.461248  0.452970  0.427952  0.484303  0.395968  0.515699  0.365217
   0.547032  0.335559  0.578179  0.306979  0.609018  0.279409  0.639428  0.252703
   0.669286  0.226739  0.698476  0.201414  0.726884  0.176574  0.754396  0.152087
   0.780903  0.127742  0.806303  0.103394  0.830493  0.078878  0.853379  0.054101
   0.874871  0.028743  0.894883  0.002676  0.913337 -0.024299  0.930160 -0.052522
   0.945284 -0.082242  0.958651 -0.113998  0.970209 -0.148515  0.979910 -0.186739
   0.987718 -0.230442  0.993601 -0.283209  0.997536 -0.354243  0.999507 -0.288508
ENDPLOT
! Droplet trajectory plot created by code TAC2
DRAW 5
0.0 0.0  28.0 0.0  28.0  16.0 0.0  16.0 0.0 0.0
OPTIONS TEXT/JUS=CEN
FONT TIM
TSIZE 0.27
TEXT   14.0 0.3
Demo case: Water catch on a 2m chord, NACA0012 wing, AoA=4, 250KTAS, 5000ft, -12C
TSIZE 0.15
TEXT  26.0  15.5
               Issue 2, Revision2.02
```

```
TSIZE 0.27
TEXT  14.0 2.0
Droplet diameter =   20.000 microns
FONT TIM
TSIZE 0.2
SIZEL 0.20
SIZEN 0.2
SIZES 0.15
OPTIONS GRAPH/FRA=LIN
OPTIONS GRAPH/XMIN = -0.30000
OPTIONS GRAPH/XMAX =   1.20000
OPTIONS GRAPH/YMIN =-0.200
OPTIONS GRAPH/YMAX =  0.300
OPTIONS GRAPH/YNUM=PER
FACTOR  0.8
GRID       3.0000    6.0000   33.0000   16.0000 1.0 2 2
GRAPH      3.0000    6.0000   30.0000   10.0000    1.0000    1.0000  2  2  8
X/C
Y/C
1  101 1 1

   1.00000  0.00000  0.99901 -0.00014  0.99606 -0.00057  0.99114 -0.00128
   0.98429 -0.00226  0.97553 -0.00350  0.96489 -0.00499  0.95241 -0.00671
   0.93815 -0.00864  0.92217 -0.01077  0.90451 -0.01307  0.88526 -0.01552
   0.86448 -0.01811  0.84227 -0.02080  0.81871 -0.02357  0.79389 -0.02641
   0.76791 -0.02928  0.74088 -0.03217  0.71289 -0.03505  0.68406 -0.03790
   0.65451 -0.04069  0.62435 -0.04339  0.59369 -0.04599  0.56267 -0.04845
   0.53140 -0.05075  0.50000 -0.05286  0.46861 -0.05475  0.43733 -0.05639
   0.40631 -0.05776  0.37566 -0.05882  0.34549 -0.05956  0.31594 -0.05995
   0.28711 -0.05997  0.25912 -0.05961  0.23209 -0.05886  0.20611 -0.05771
   0.18129 -0.05616  0.15773 -0.05421  0.13552 -0.05186  0.11474 -0.04914
   0.09549 -0.04605  0.07784 -0.04262  0.06185 -0.03886  0.04759 -0.03480
   0.03511 -0.03047  0.02447 -0.02589  0.01571 -0.02109  0.00886 -0.01608
   0.00394 -0.01088  0.00099 -0.00552  0.00000  0.00000  0.00099  0.00552
   0.00394  0.01088  0.00886  0.01608  0.01571  0.02109  0.02447  0.02589
   0.03511  0.03047  0.04759  0.03480  0.06185  0.03886  0.07784  0.04262
   0.09549  0.04605  0.11474  0.04914  0.13552  0.05186  0.15773  0.05421
   0.18129  0.05616  0.20611  0.05771  0.23209  0.05886  0.25912  0.05961
   0.28711  0.05997  0.31594  0.05995  0.34549  0.05956  0.37566  0.05882
   0.40631  0.05776  0.43733  0.05639  0.46861  0.05475  0.50000  0.05286
   0.53140  0.05075  0.56267  0.04845  0.59369  0.04599  0.62435  0.04339
   0.65451  0.04069  0.68406  0.03790  0.71289  0.03505  0.74088  0.03217
   0.76791  0.02928  0.79389  0.02641  0.81871  0.02357  0.84227  0.02080
   0.86448  0.01811  0.88526  0.01552  0.90451  0.01307  0.92217  0.01077
   0.93815  0.00864  0.95241  0.00671  0.96489  0.00499  0.97553  0.00350
   0.98429  0.00226  0.99114  0.00128  0.99606  0.00057  0.99901  0.00014
   1.00000  0.00000
1    89 1 1

  -0.27579 -0.07862 -0.25310 -0.07538 -0.23232 -0.07233 -0.21327 -0.06945
  -0.19581 -0.06675 -0.17981 -0.06421 -0.16513 -0.06182 -0.15166 -0.05957
  -0.13931 -0.05745 -0.12798 -0.05546 -0.11758 -0.05359 -0.10803 -0.05182
  -0.09927 -0.05017 -0.09122 -0.04861 -0.08383 -0.04715 -0.07703 -0.04577
  -0.07078 -0.04448 -0.06502 -0.04326 -0.05973 -0.04212 -0.05484 -0.04105
  -0.05034 -0.04005 -0.04618 -0.03910 -0.04234 -0.03822 -0.03879 -0.03738
  -0.03551 -0.03660 -0.03246 -0.03587 -0.02963 -0.03519 -0.02701 -0.03454
  -0.02457 -0.03394 -0.02230 -0.03338 -0.02020 -0.03285 -0.01824 -0.03236
  -0.01642 -0.03190 -0.01472 -0.03148 -0.01314 -0.03108 -0.01165 -0.03071
  -0.01026 -0.03036 -0.00895 -0.03004 -0.00765 -0.02972 -0.00637 -0.02941
  -0.00510 -0.02911 -0.00385 -0.02882 -0.00262 -0.02854 -0.00141 -0.02827
  -0.00022 -0.02802  0.00096 -0.02778  0.00212 -0.02755  0.00326 -0.02734
   0.00439 -0.02714  0.00550 -0.02697  0.00659 -0.02681  0.00768 -0.02668
   0.00874 -0.02656  0.00980 -0.02647  0.01085 -0.02640  0.01188 -0.02635
   0.01291 -0.02633  0.01394 -0.02633  0.01495 -0.02635  0.01597 -0.02640
   0.01698 -0.02647  0.01799 -0.02656  0.01901 -0.02668  0.02002 -0.02682
   0.02104 -0.02698  0.02207 -0.02716  0.02310 -0.02736  0.02414 -0.02758
   0.02518 -0.02782  0.02624 -0.02808  0.02731 -0.02835  0.02838 -0.02864
   0.02947 -0.02895  0.03057 -0.02926  0.03168 -0.02959  0.03281 -0.02994
   0.03394 -0.03029  0.03509 -0.03066  0.03626 -0.03104  0.03744 -0.03143
   0.03864 -0.03182  0.03986 -0.03222  0.04108 -0.03263  0.04232 -0.03304
   0.04358 -0.03346  0.04484 -0.03389  0.04613 -0.03431  0.04743 -0.03475
   0.04759 -0.03480
1    55 1 1

  -0.27759 -0.06164 -0.25504 -0.05835 -0.23438 -0.05525 -0.21546 -0.05233
  -0.19813 -0.04957 -0.18225 -0.04696 -0.16771 -0.04450 -0.15438 -0.04218
  -0.14217 -0.03999 -0.13097 -0.03792 -0.12071 -0.03596 -0.11131 -0.03412
```

```
   -0.10268 -0.03237 -0.09477 -0.03071 -0.08752 -0.02915 -0.08086 -0.02767
   -0.07475 -0.02627 -0.06914 -0.02494 -0.06399 -0.02368 -0.05926 -0.02249
   -0.05492 -0.02136 -0.05092 -0.02029 -0.04725 -0.01927 -0.04388 -0.01831
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   -0.03062 -0.01417 -0.02856 -0.01346 -0.02666 -0.01279 -0.02490 -0.01215
   -0.02328 -0.01154 -0.02179 -0.01096 -0.02040 -0.01040 -0.01902 -0.00983
   -0.01767 -0.00925 -0.01634 -0.00866 -0.01504 -0.00805 -0.01376 -0.00743
   -0.01250 -0.00680 -0.01128 -0.00615 -0.01009 -0.00548 -0.00893 -0.00479
   -0.00780 -0.00408 -0.00672 -0.00333 -0.00568 -0.00256 -0.00468 -0.00175
   -0.00372 -0.00089 -0.00282  0.00002 -0.00196  0.00100 -0.00115  0.00205
   -0.00037  0.00318  0.00039  0.00442  0.00099  0.00551
1     63 1 1

   -0.27628 -0.07438 -0.25363 -0.07112 -0.23289 -0.06806 -0.21388 -0.06518
   -0.19645 -0.06246 -0.18049 -0.05990 -0.16585 -0.05750 -0.15243 -0.05523
   -0.14012 -0.05309 -0.12882 -0.05108 -0.11846 -0.04919 -0.10895 -0.04740
   -0.10023 -0.04572 -0.09222 -0.04414 -0.08487 -0.04265 -0.07812 -0.04125
   -0.07191 -0.03993 -0.06621 -0.03869 -0.06096 -0.03752 -0.05613 -0.03642
   -0.05169 -0.03538 -0.04760 -0.03441 -0.04382 -0.03350 -0.04034 -0.03263
   -0.03713 -0.03182 -0.03416 -0.03106 -0.03142 -0.03035 -0.02888 -0.02967
   -0.02652 -0.02904 -0.02434 -0.02844 -0.02232 -0.02788 -0.02044 -0.02736
   -0.01869 -0.02686 -0.01706 -0.02639 -0.01553 -0.02595 -0.01412 -0.02554
   -0.01279 -0.02515 -0.01148 -0.02477 -0.01020 -0.02439 -0.00893 -0.02401
   -0.00769 -0.02364 -0.00646 -0.02327 -0.00526 -0.02292 -0.00409 -0.02257
   -0.00294 -0.02223 -0.00181 -0.02190 -0.00071 -0.02159  0.00037 -0.02129
    0.00142 -0.02100  0.00244 -0.02074  0.00344 -0.02049  0.00442 -0.02026
    0.00537 -0.02005  0.00630 -0.01987  0.00720 -0.01972  0.00808 -0.01959
    0.00895 -0.01949  0.00980 -0.01942  0.01063 -0.01938  0.01145 -0.01936
    0.01226 -0.01938  0.01306 -0.01943  0.01351 -0.01948
1     57 1 1

   -0.27674 -0.07014 -0.25413 -0.06687 -0.23342 -0.06379 -0.21444 -0.06089
   -0.19705 -0.05816 -0.18112 -0.05559 -0.16652 -0.05317 -0.15313 -0.05088
   -0.14086 -0.04873 -0.12961 -0.04670 -0.11929 -0.04478 -0.10982 -0.04298
   -0.10113 -0.04127 -0.09316 -0.03967 -0.08583 -0.03815 -0.07911 -0.03672
   -0.07294 -0.03537 -0.06727 -0.03410 -0.06207 -0.03291 -0.05728 -0.03178
   -0.05288 -0.03071 -0.04883 -0.02970 -0.04511 -0.02876 -0.04167 -0.02786
   -0.03851 -0.02702 -0.03560 -0.02623 -0.03292 -0.02548 -0.03044 -0.02477
   -0.02815 -0.02410 -0.02603 -0.02347 -0.02408 -0.02288 -0.02227 -0.02232
   -0.02060 -0.02179 -0.01904 -0.02129 -0.01761 -0.02082 -0.01626 -0.02037
   -0.01493 -0.01992 -0.01363 -0.01947 -0.01234 -0.01902 -0.01108 -0.01857
   -0.00985 -0.01812 -0.00864 -0.01767 -0.00746 -0.01722 -0.00631 -0.01677
   -0.00519 -0.01633 -0.00411 -0.01589 -0.00306 -0.01546 -0.00204 -0.01504
   -0.00107 -0.01462 -0.00013 -0.01421  0.00076 -0.01382  0.00161 -0.01344
    0.00242 -0.01307  0.00318 -0.01273  0.00389 -0.01240  0.00455 -0.01211
    0.00494 -0.01194
1     54 1 1

   -0.27718 -0.06589 -0.25460 -0.06261 -0.23392 -0.05952 -0.21497 -0.05661
   -0.19761 -0.05387 -0.18171 -0.05128 -0.16714 -0.04884 -0.15378 -0.04654
   -0.14154 -0.04436 -0.13032 -0.04231 -0.12004 -0.04038 -0.11060 -0.03855
   -0.10195 -0.03682 -0.09401 -0.03519 -0.08673 -0.03365 -0.08004 -0.03220
   -0.07390 -0.03082 -0.06826 -0.02952 -0.06308 -0.02829 -0.05832 -0.02713
   -0.05394 -0.02603 -0.04992 -0.02499 -0.04622 -0.02401 -0.04282 -0.02308
   -0.03969 -0.02220 -0.03681 -0.02137 -0.03415 -0.02058 -0.03171 -0.01983
   -0.02945 -0.01913 -0.02737 -0.01846 -0.02546 -0.01783 -0.02368 -0.01723
   -0.02205 -0.01666 -0.02054 -0.01612 -0.01914 -0.01560 -0.01778 -0.01510
   -0.01645 -0.01458 -0.01514 -0.01406 -0.01385 -0.01353 -0.01259 -0.01300
   -0.01136 -0.01246 -0.01015 -0.01192 -0.00898 -0.01136 -0.00785 -0.01080
   -0.00674 -0.01023 -0.00568 -0.00965 -0.00467 -0.00906 -0.00370 -0.00846
   -0.00278 -0.00785 -0.00191 -0.00723 -0.00111 -0.00659 -0.00037 -0.00594
    0.00029 -0.00526  0.00082 -0.00461
10 1 1 4

   0.00099  0.00551
10 1 1 4

   0.04759 -0.03480
ENDPLOT
! Catch efficiency plot created by code TAC
DRAW 5
0.0 0.0 17.0 0.0 17.0 25.00 0.0 25.00 0.0 0.0
OPTIONS TEXT/JUS=CEN
FONT TIM
TSIZE 0.27
TEXT  8.50 0.3
Demo case: Water catch on a 2m chord, NACA0012 wing, AoA=4, 250KTAS, 5000ft, -12C
```
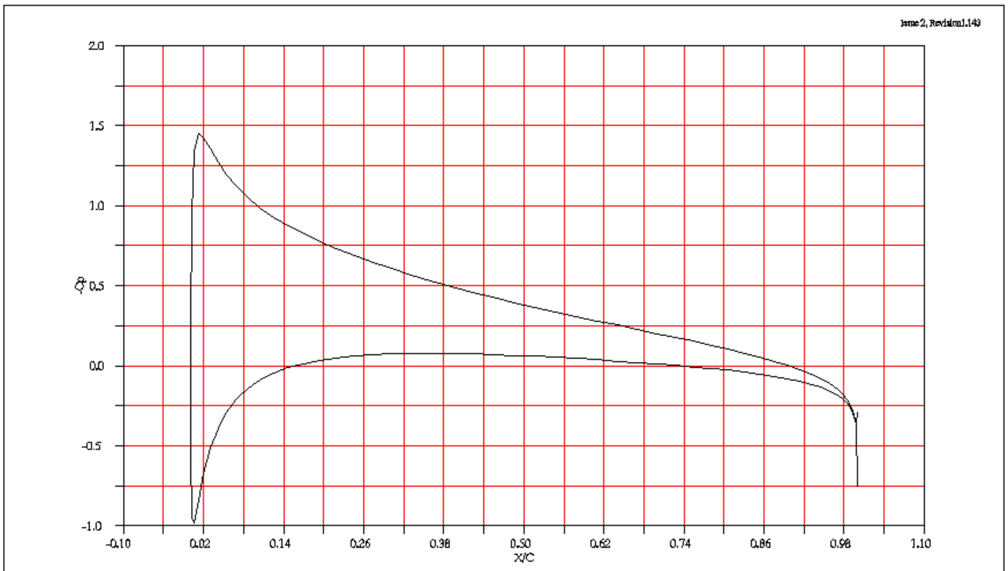
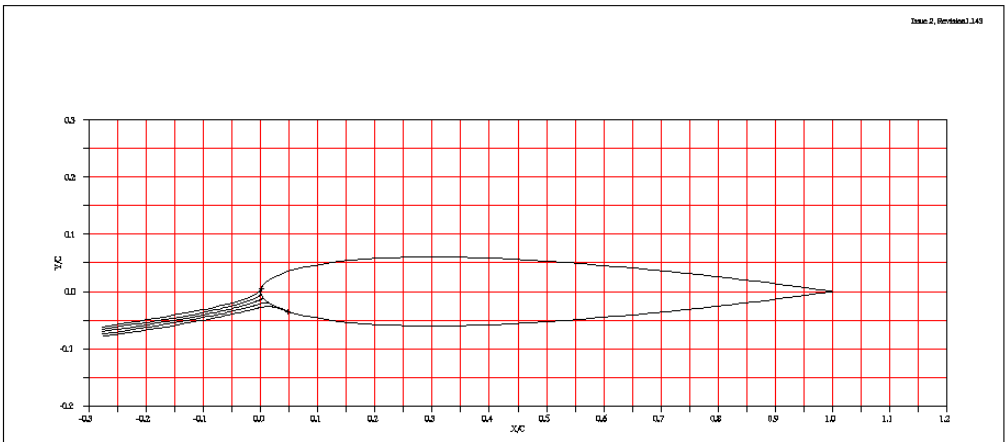

```
TSIZE 0.15
TEXT 15.0 24.5
               Issue 2, Revision2.02
TSIZE 0.27
TEXT  8.50 2.0
Droplet diameter =   20.000 microns
FONT TIM
TSIZE 0.2
SIZEL 0.20
SIZEN 0.2
SIZES 0.15
OPTIONS GRAPH/FRA=LIN
OPTIONS GRAPH/XMIN = -0.10000
OPTIONS GRAPH/XMAX =   0.10000
OPTIONS GRAPH/YMIN = 0.000
OPTIONS GRAPH/YMAX =  1.000
OPTIONS GRAPH/YNUM=PER
FACTOR  1.0
GRID       4.0000    4.0000   14.0000   24.0000 1.0 2 2
GRAPH     4.0   4.0  10.0  20.0   1.0   1.0  2  2  2
S/C
Catch efficiency, Beta
1   24 1 1

  -0.06300  0.00000 -0.06000  0.00542 -0.05700  0.01520 -0.05400  0.02759
  -0.05100  0.04258 -0.04800  0.06018 -0.04500  0.08039 -0.04200  0.10320
  -0.03900  0.12862 -0.03600  0.15665 -0.03300  0.18728 -0.03000  0.22052
  -0.02700  0.25636 -0.02400  0.29472 -0.02100  0.33281 -0.01800  0.36936
  -0.01500  0.40437 -0.01200  0.43855 -0.00900  0.47875 -0.00600  0.52667
  -0.00300  0.56126  0.00000  0.48292  0.00300  0.27885  0.00600  0.00000
1   55 4 1

  -0.06215  0.00000 -0.06080  0.00325 -0.05944  0.00703 -0.05809  0.01135
  -0.05673  0.01619 -0.05538  0.02157 -0.05402  0.02748 -0.05267  0.03392
  -0.05131  0.04089 -0.04996  0.04840 -0.04860  0.05644 -0.04725  0.06500
  -0.04589  0.07410 -0.04454  0.08374 -0.04318  0.09390 -0.04183  0.10460
  -0.04047  0.11582 -0.03912  0.12758 -0.03776  0.13987 -0.03641  0.15270
  -0.03505  0.16605 -0.03370  0.17994 -0.03234  0.19435 -0.03099  0.20930
  -0.02963  0.22479 -0.02828  0.24080 -0.02692  0.25734 -0.02557  0.27442
  -0.02421  0.29199 -0.02286  0.30944 -0.02150  0.32657 -0.02015  0.34339
  -0.01879  0.35989 -0.01743  0.37608 -0.01608  0.39195 -0.01472  0.40751
  -0.01337  0.42275 -0.01201  0.43838 -0.01066  0.45556 -0.00930  0.47433
  -0.00795  0.49466 -0.00659  0.51658 -0.00524  0.54006 -0.00479  0.54824
  -0.00434  0.55569 -0.00388  0.56036 -0.00343  0.56218 -0.00298  0.56115
  -0.00253  0.55727 -0.00117  0.52853  0.00018  0.47413  0.00154  0.39408
   0.00289  0.28837  0.00425  0.15701  0.00560  0.00000
LEGEND 13.5 2.0 2 1 0
1 1 0 'Nodal data'
1 4 0 'Smoothed'
```

Using the WinEZDraw.exe graphics utility, the above .ez file produces three plots, as shown in the following three figures.

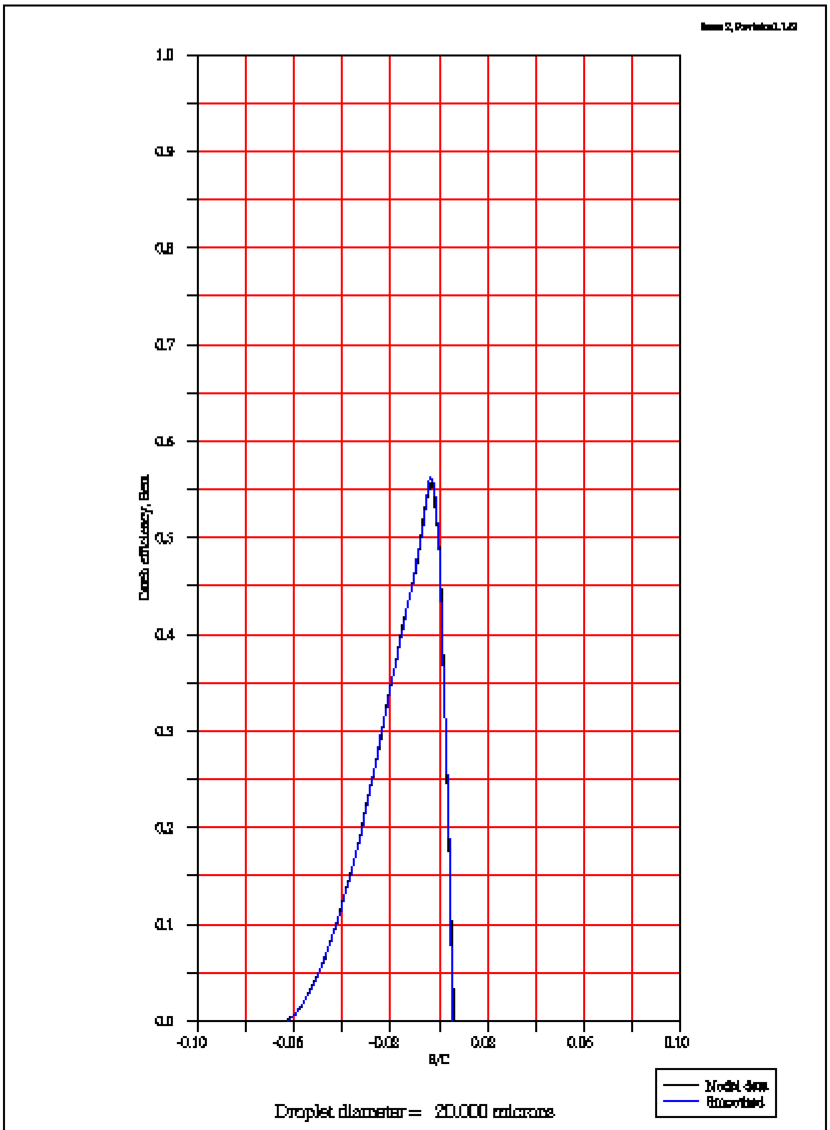


Demo case: Water catch on a 2m chord, NACA0012 wing, AoA=4, 250KTAS, 5000ft, -12C



Droplet diameter = 20.000 microns

Demo case: Water catch on a 2m chord, NACA0012 wing, AoA=4, 250KTAS, 5000ft, -12C



Demo case: Water catch on a 2m chord, NACA0012 wing, AoA=4, 250KTAS, 5000ft, -12C

Annex K – Example IHB.DAT output file

This appendix shows an example IHB.DAT file which is an input file required by code IHB, created by the TAC2 code for the case specified by Annex B and Annex C (Demo 1).

Note that the highlighted lines are wrapped here onto more than one line only due to page width restriction. In the input file, they should all be on a single line.

In the SLD regime an additional column 'Beta_orig' showing the original Beta values before SLD application was added into the file.

```
Demo case: Water catch on a 2m chord, NACA0012 wing, AoA=4, 250KTAS, 5000ft, -12C
   0          ! Run type 0=unheated, 1=minimum (ideal) AI power, 2=Electrothermal AI,3=Hot-Air
AI, I4 FORMAT
NACA 0012     ! Aerofoil name, max 12 characters.
    128.70    ! Freestream velocity / flight speed in m/s. F10.0
      4.00    ! Angle of attack, in degrees, F10.0
    2.0000    ! Aerofoil chord length in metres, F10.0
0   84.31 0.0     ! Input pressure altitude =0 use input PINF in KPa, =1 calculate PINF from
pressure alt, ft [*]
    -12.00    ! Freestream static temperature / OAT, C, F10.0
     20.00    ! Cloud VMD / droplet diameter in mircons, F10.0
     0.540    ! Cloud liquid water concentration, g/m3, F10.0
     15.00    ! Icing encounter time in minutes
       0.3     ! Surface wettedness factor. Can be used to simulate rivulet formation aft of
direct impingement. Typically 0.2-0.3. Set=1.0 to disable.
    100.00    ! Cloud relative humidity in %, F10.0
 0.0000080    ! Surface equivalent sand grain roughness, m, F10.0
0.001000      ! Surface material thickness, m, F10.0
 0.001        ! Surface thermal conductivity in W.m-1.K-1, F10.0
 0.0001       ! Convergence tolerance on nodal temperature in degrees C, F10.0
 0.0001       ! Convergence tolerance on nodal freezing fraction, F10.0
 0.4000       ! Solution relaxation factor, typically 0.1
9000           ! Maximum number of iterations allowed for a converged solution to be achieved,
I4
  0.000000     ! s/c limit on lower surface of ice from a previous icing step, set to zero if
not multi-step
  0.000000     ! s/c limit on upper surface of ice from a previous icing step, set to zero if
not multi-step
   0          ! Control for runback water shed from tip of glaze horns, 1=true, 0=false. I4
   0   0     ! Control for ice shape smoothing 1=true, followed by number of levels of smoothing
(typially 1-3),I4
 199          ! Total number of surface nodes Lower and upper surface of aerofoil, I4.
   0          ! Indicator for local pressure input as Cp (=0) or P/H0 (<>0), I4
   x/c      y/c      s/c     Cp/Ph0    htc   beta
 0.28039 -0.05989 -0.29700  -0.07098  201.0 0.0000
 0.27739 -0.05985 -0.29400  -0.07046  201.0 0.0000
 0.27439 -0.05981 -0.29100  -0.06993  201.4 0.0000
 0.27139 -0.05977 -0.28800  -0.06920  201.7 0.0000
 0.26839 -0.05973 -0.28500  -0.06831  202.0 0.0000
 0.26539 -0.05969 -0.28200  -0.06743  202.4 0.0000
 0.26239 -0.05966 -0.27900  -0.06655  202.7 0.0000
 0.25939 -0.05962 -0.27600  -0.06567  203.0 0.0000
 0.25639 -0.05954 -0.27300  -0.06478  203.4 0.0000
 0.25339 -0.05945 -0.27000  -0.06390  203.7 0.0000
 0.25039 -0.05937 -0.26700  -0.06302  204.1 0.0000
 0.24739 -0.05929 -0.26400  -0.06213  204.5 0.0000
 0.24439 -0.05920 -0.26100  -0.06108  204.8 0.0000
 0.24140 -0.05912 -0.25800  -0.05976  205.1 0.0000
 0.23840 -0.05904 -0.25500  -0.05844  205.5 0.0000
 0.23540 -0.05895 -0.25200  -0.05712  205.8 0.0000
 0.23240 -0.05887 -0.24900  -0.05580  206.2 0.0000
 0.22940 -0.05874 -0.24600  -0.05448  206.6 0.0000
 0.22640 -0.05861 -0.24300  -0.05316  206.9 0.0000
 0.22341 -0.05848 -0.24000  -0.05184  207.3 0.0000
 0.22041 -0.05835 -0.23700  -0.05052  207.7 0.0000
 0.21741 -0.05821 -0.23400  -0.04889  208.1 0.0000
 0.21442 -0.05808 -0.23100  -0.04701  208.4 0.0000
 0.21142 -0.05795 -0.22800  -0.04513  208.8 0.0000
 0.20842 -0.05781 -0.22500  -0.04326  209.2 0.0000
 0.20543 -0.05767 -0.22200  -0.04138  209.6 0.0000
```

0.20243	-0.05748	-0.21900	-0.03950	210.0	0.0000
0.19944	-0.05729	-0.21600	-0.03763	210.4	0.0000
0.19644	-0.05711	-0.21300	-0.03575	210.8	0.0000
0.19345	-0.05692	-0.21000	-0.03382	211.2	0.0000
0.19046	-0.05673	-0.20700	-0.03124	211.6	0.0000
0.18746	-0.05655	-0.20400	-0.02866	211.9	0.0000
0.18447	-0.05636	-0.20100	-0.02608	212.3	0.0000
0.18147	-0.05617	-0.19800	-0.02350	212.7	0.0000
0.17848	-0.05593	-0.19500	-0.02091	213.1	0.0000
0.17549	-0.05568	-0.19200	-0.01833	213.6	0.0000
0.17250	-0.05543	-0.18900	-0.01575	214.0	0.0000
0.16951	-0.05518	-0.18600	-0.01317	214.5	0.0000
0.16652	-0.05494	-0.18300	-0.00968	214.9	0.0000
0.16353	-0.05469	-0.18000	-0.00618	215.2	0.0000
0.16054	-0.05444	-0.17700	-0.00268	215.6	0.0000
0.15756	-0.05419	-0.17400	0.00082	216.1	0.0000
0.15457	-0.05387	-0.17100	0.00432	216.5	0.0000
0.15159	-0.05356	-0.16800	0.00782	217.0	0.0000
0.14860	-0.05324	-0.16500	0.01132	217.5	0.0000
0.14562	-0.05293	-0.16200	0.01522	217.9	0.0000
0.14264	-0.05261	-0.15900	0.01991	218.3	0.0000
0.13965	-0.05230	-0.15600	0.02460	218.7	0.0000
0.13667	-0.05198	-0.15300	0.02929	219.1	0.0000
0.13369	-0.05162	-0.15000	0.03398	219.5	0.0000
0.13072	-0.05123	-0.14700	0.03867	220.0	0.0000
0.12774	-0.05084	-0.14400	0.04337	220.5	0.0000
0.12477	-0.05045	-0.14100	0.04825	221.0	0.0000
0.12180	-0.05006	-0.13800	0.05453	221.4	0.0000
0.11882	-0.04967	-0.13500	0.06080	221.7	0.0000
0.11585	-0.04928	-0.13200	0.06708	222.2	0.0000
0.11288	-0.04884	-0.12900	0.07335	222.6	0.0000
0.10992	-0.04836	-0.12600	0.07963	223.1	0.0000
0.10696	-0.04789	-0.12300	0.08590	223.7	0.0000
0.10399	-0.04741	-0.12000	0.09300	224.1	0.0000
0.10103	-0.04694	-0.11700	0.10144	224.4	0.0000
0.09807	-0.04646	-0.11400	0.10988	224.7	0.0000
0.09511	-0.04597	-0.11100	0.11832	225.1	0.0000
0.09216	-0.04540	-0.10800	0.12676	225.6	0.0000
0.08922	-0.04483	-0.10500	0.13520	226.1	0.0000
0.08627	-0.04426	-0.10200	0.14403	226.6	0.0000
0.08333	-0.04368	-0.09900	0.15545	226.7	0.0000
0.08038	-0.04311	-0.09600	0.16688	226.9	0.0000
0.07744	-0.04252	-0.09300	0.17830	227.2	0.0000
0.07452	-0.04184	-0.09000	0.18972	227.6	0.0000
0.07160	-0.04115	-0.08700	0.20114	228.1	0.0000
0.06868	-0.04046	-0.08400	0.21424	228.4	0.0000
0.06576	-0.03978	-0.08100	0.22991	228.2	0.0000
0.06284	-0.03909	-0.07800	0.24558	228.1	0.0000
0.05994	-0.03832	-0.07500	0.26124	228.2	0.0000
0.05706	-0.03750	-0.07200	0.27691	228.5	0.0000
0.05417	-0.03668	-0.06900	0.29373	228.8	0.0000
0.05129	-0.03586	-0.06600	0.31551	227.9	0.0000
0.04840	-0.03503	-0.06300	0.33730	227.3	0.0000
0.04555	-0.03410	-0.06000	0.35908	227.0	0.0054
0.04272	-0.03311	-0.05700	0.38087	227.0	0.0152
0.03988	-0.03213	-0.05400	0.40721	226.0	0.0276
0.03705	-0.03115	-0.05100	0.43779	224.1	0.0426
0.03424	-0.03010	-0.04800	0.46838	222.8	0.0602
0.03149	-0.02891	-0.04500	0.49896	222.3	0.0804
0.02873	-0.02773	-0.04200	0.53417	221.2	0.1032
0.02597	-0.02654	-0.03900	0.57675	218.6	0.1286
0.02328	-0.02524	-0.03600	0.61934	219.9	0.1566
0.02064	-0.02379	-0.03300	0.66192	113.2	0.1873
0.01801	-0.02235	-0.03000	0.71456	118.2	0.2205
0.01541	-0.02087	-0.02700	0.76989	124.7	0.2564
0.01299	-0.01910	-0.02400	0.82522	138.0	0.2947
0.01057	-0.01733	-0.02100	0.87914	148.2	0.3328
0.00825	-0.01544	-0.01800	0.93249	139.1	0.3694
0.00619	-0.01326	-0.01500	0.97892	130.0	0.4044
0.00413	-0.01108	-0.01200	0.96480	120.9	0.4386
0.00262	-0.00849	-0.00900	0.95069	111.8	0.4788
0.00118	-0.00586	-0.00600	0.76508	171.4	0.5267
0.00053	-0.00295	-0.00300	0.55831	195.4	0.5613
0.00000	0.00000	0.00000	0.16394	203.3	0.4829
0.00053	0.00295	0.00300	-0.24128	205.4	0.2789
0.00118	0.00586	0.00600	-0.61456	418.5	0.0000
0.00262	0.00849	0.00900	-0.96624	417.2	0.0000

0.00413	0.01108	0.01200	-1.14301	404.0	0.0000
0.00619	0.01326	0.01500	-1.31977	397.2	0.0000
0.00825	0.01544	0.01800	-1.37605	384.6	0.0000
0.01057	0.01733	0.02100	-1.41857	374.6	0.0000
0.01299	0.01910	0.02400	-1.44651	365.9	0.0000
0.01541	0.02087	0.02700	-1.43899	356.6	0.0000
0.01801	0.02235	0.03000	-1.43146	348.8	0.0000
0.02064	0.02379	0.03300	-1.42137	341.9	0.0000
0.02328	0.02524	0.03600	-1.40169	335.2	0.0000
0.02597	0.02654	0.03900	-1.38200	329.2	0.0000
0.02873	0.02773	0.04200	-1.36232	323.7	0.0000
0.03149	0.02891	0.04500	-1.34250	318.8	0.0000
0.03424	0.03010	0.04800	-1.32258	314.2	0.0000
0.03705	0.03115	0.05100	-1.30266	309.9	0.0000
0.03988	0.03213	0.05400	-1.28275	305.9	0.0000
0.04272	0.03311	0.05700	-1.26413	302.2	0.0000
0.04555	0.03410	0.06000	-1.24690	298.7	0.0000
0.04840	0.03503	0.06300	-1.22967	295.5	0.0000
0.05129	0.03586	0.06600	-1.21243	292.4	0.0000
0.05417	0.03668	0.06900	-1.19520	289.5	0.0000
0.05706	0.03750	0.07200	-1.18031	286.8	0.0000
0.05994	0.03832	0.07500	-1.16597	284.3	0.0000
0.06284	0.03909	0.07800	-1.15162	281.8	0.0000
0.06576	0.03978	0.08100	-1.13728	279.5	0.0000
0.06868	0.04046	0.08400	-1.12293	277.2	0.0000
0.07160	0.04115	0.08700	-1.11006	275.1	0.0000
0.07452	0.04184	0.09000	-1.09814	273.1	0.0000
0.07744	0.04252	0.09300	-1.08623	271.2	0.0000
0.08038	0.04311	0.09600	-1.07431	269.3	0.0000
0.08333	0.04368	0.09900	-1.06240	267.5	0.0000
0.08627	0.04426	0.10200	-1.05049	265.7	0.0000
0.08922	0.04483	0.10500	-1.04025	264.1	0.0000
0.09216	0.04540	0.10800	-1.03027	262.5	0.0000
0.09511	0.04597	0.11100	-1.02029	261.0	0.0000
0.09807	0.04646	0.11400	-1.01031	259.5	0.0000
0.10103	0.04694	0.11700	-1.00033	258.0	0.0000
0.10399	0.04741	0.12000	-0.99035	256.6	0.0000
0.10696	0.04789	0.12300	-0.98126	255.2	0.0000
0.10992	0.04836	0.12600	-0.97272	253.9	0.0000
0.11288	0.04884	0.12900	-0.96418	252.7	0.0000
0.11585	0.04928	0.13200	-0.95564	251.4	0.0000
0.11882	0.04967	0.13500	-0.94710	250.2	0.0000
0.12180	0.05006	0.13800	-0.93856	249.0	0.0000
0.12477	0.05045	0.14100	-0.93002	247.8	0.0000
0.12774	0.05084	0.14400	-0.92247	246.8	0.0000
0.13072	0.05123	0.14700	-0.91506	245.7	0.0000
0.13369	0.05162	0.15000	-0.90765	244.6	0.0000
0.13667	0.05198	0.15300	-0.90024	243.6	0.0000
0.13965	0.05230	0.15600	-0.89282	242.6	0.0000
0.14264	0.05261	0.15900	-0.88541	241.6	0.0000
0.14562	0.05293	0.16200	-0.87800	240.6	0.0000
0.14860	0.05324	0.16500	-0.87116	239.6	0.0000
0.15159	0.05356	0.16800	-0.86461	238.7	0.0000
0.15457	0.05387	0.17100	-0.85806	237.8	0.0000
0.15756	0.05419	0.17400	-0.85152	236.9	0.0000
0.16054	0.05444	0.17700	-0.84497	236.1	0.0000
0.16353	0.05469	0.18000	-0.83842	235.2	0.0000
0.16652	0.05494	0.18300	-0.83187	234.3	0.0000
0.16951	0.05518	0.18600	-0.82532	233.5	0.0000
0.17250	0.05543	0.18900	-0.81944	232.7	0.0000
0.17549	0.05568	0.19200	-0.81356	231.9	0.0000
0.17848	0.05593	0.19500	-0.80768	231.1	0.0000
0.18147	0.05617	0.19800	-0.80179	230.4	0.0000
0.18447	0.05636	0.20100	-0.79591	229.6	0.0000
0.18746	0.05655	0.20400	-0.79003	228.9	0.0000
0.19046	0.05673	0.20700	-0.78415	228.1	0.0000
0.19345	0.05692	0.21000	-0.77826	227.4	0.0000
0.19644	0.05711	0.21300	-0.77288	226.7	0.0000
0.19944	0.05729	0.21600	-0.76755	226.0	0.0000
0.20243	0.05748	0.21900	-0.76221	225.3	0.0000
0.20543	0.05767	0.22200	-0.75687	224.6	0.0000
0.20842	0.05781	0.22500	-0.75154	224.0	0.0000
0.21142	0.05795	0.22800	-0.74620	223.3	0.0000
0.21442	0.05808	0.23100	-0.74087	222.7	0.0000
0.21741	0.05821	0.23400	-0.73553	222.0	0.0000
0.22041	0.05835	0.23700	-0.73039	221.4	0.0000
0.22341	0.05848	0.24000	-0.72549	220.8	0.0000

```
 0.22640  0.05861  0.24300  -0.72058  220.1 0.0000
 0.22940  0.05874  0.24600  -0.71568  219.5 0.0000
 0.23240  0.05887  0.24900  -0.71078  218.9 0.0000
 0.23540  0.05895  0.25200  -0.70588  218.3 0.0000
 0.23840  0.05904  0.25500  -0.70098  217.8 0.0000
 0.24140  0.05912  0.25800  -0.69608  217.2 0.0000
 0.24439  0.05920  0.26100  -0.69118  216.6 0.0000
 0.24739  0.05929  0.26400  -0.68650  216.0 0.0000
 0.25039  0.05937  0.26700  -0.68196  215.5 0.0000
 0.25339  0.05945  0.27000  -0.67743  214.9 0.0000
 0.25639  0.05954  0.27300  -0.67289  214.4 0.0000
 0.25939  0.05962  0.27600  -0.66836  213.8 0.0000
 0.26239  0.05966  0.27900  -0.66382  213.3 0.0000
 0.26539  0.05969  0.28200  -0.65929  212.8 0.0000
 0.26839  0.05973  0.28500  -0.65475  212.3 0.0000
 0.27139  0.05977  0.28800  -0.65022  211.7 0.0000
 0.27439  0.05981  0.29100  -0.64581  211.2 0.0000
 0.27739  0.05985  0.29400  -0.64157  210.7 0.0000
 0.28039  0.05989  0.29700  -0.63734  210.7 0.0000
   2          ! Number of zones to be used in heat balance calculation, maximum 50, I4
 -0.588000    ! Start distance, metre ** NOT S/C ** (-ve = lower surface, aft)
 zone width (m)  no.nodes (spaces),  heat input (W/m2) 1 line of data for each zone
0.58800  98 0.0
0.58800  98 0.0
```

Annex L – Example IHB_IP.DAT output file

This appendix shows an example IHB_IP.DAT file which is an input file required by code ET3D, created by the TAC2 code for the case specified by Annex B and Annex C (Demo 1).

Note that the highlighted lines are wrapped here onto more than one line only due to page width restriction. In the input file, they should all be on a single line.

```
NACA 0012     ! Aerofoil name, max 12 characters.
    128.70    ! Freestream velocity / flight speed in m/s. F10.0
      4.00    ! Angle of attack, in degrees, F10.0
    2.0000    ! Aerofoil chord length in metres, F10.0
0  84.31 0.0     ! Input pressure altitude =0 use input PINF in KPa, =1 calculate PINF from
pressure alt, ft [*]
    -12.00    ! Freestream static temperature / OAT, C, F10.0
     20.00    ! Cloud VMD / droplet diameter in mircons, F10.0
     0.540    ! Cloud liquid water concentration, g/m3, F10.0
       0.3     ! Surface wettedness factor. Can be used to simulate rivulet formation aft of
direct impingement. Typically 0.2-0.3. Set=1.0 to disable.
    100.00    ! Cloud relative humidity in %, F10.0
 0.0010000    ! Maximum surface equivalent sand grain roughess, in metres, used when calculating
heat transfer coeff. metres, F10.0
 0.0000080    ! Minimum surface equivalent sand grain roughness, m, F10.0
 199          ! Total number of surface nodes Lower and upper surface of aerofoil, I4.
   0          ! Marker for variable (time dependent) htc (=0), or use constant values read in
from this file (=1)
   0          ! Indicator for local pressure input as Cp (=0) or P/H0 (<>0), I4
   x/c      y/c      s/c     Cp/Ph0    htc  beta
 0.28039 -0.05989 -0.29700  -0.07098  201.0 0.0000
 0.27739 -0.05985 -0.29400  -0.07046  201.0 0.0000
 0.27439 -0.05981 -0.29100  -0.06993  201.4 0.0000
 0.27139 -0.05977 -0.28800  -0.06920  201.7 0.0000
 0.26839 -0.05973 -0.28500  -0.06831  202.0 0.0000
 0.26539 -0.05969 -0.28200  -0.06743  202.4 0.0000
 0.26239 -0.05966 -0.27900  -0.06655  202.7 0.0000
 0.25939 -0.05962 -0.27600  -0.06567  203.0 0.0000
 0.25639 -0.05954 -0.27300  -0.06478  203.4 0.0000
 0.25339 -0.05945 -0.27000  -0.06390  203.7 0.0000
 0.25039 -0.05937 -0.26700  -0.06302  204.1 0.0000
 0.24739 -0.05929 -0.26400  -0.06213  204.5 0.0000
 0.24439 -0.05920 -0.26100  -0.06108  204.8 0.0000
 0.24140 -0.05912 -0.25800  -0.05976  205.1 0.0000
 0.23840 -0.05904 -0.25500  -0.05844  205.5 0.0000
 0.23540 -0.05895 -0.25200  -0.05712  205.8 0.0000
 0.23240 -0.05887 -0.24900  -0.05580  206.2 0.0000
 0.22940 -0.05874 -0.24600  -0.05448  206.6 0.0000
 0.22640 -0.05861 -0.24300  -0.05316  206.9 0.0000
 0.22341 -0.05848 -0.24000  -0.05184  207.3 0.0000
 0.22041 -0.05835 -0.23700  -0.05052  207.7 0.0000
 0.21741 -0.05821 -0.23400  -0.04889  208.1 0.0000
 0.21442 -0.05808 -0.23100  -0.04701  208.4 0.0000
 0.21142 -0.05795 -0.22800  -0.04513  208.8 0.0000
 0.20842 -0.05781 -0.22500  -0.04326  209.2 0.0000
 0.20543 -0.05767 -0.22200  -0.04138  209.6 0.0000
 0.20243 -0.05748 -0.21900  -0.03950  210.0 0.0000
 0.19944 -0.05729 -0.21600  -0.03763  210.4 0.0000
 0.19644 -0.05711 -0.21300  -0.03575  210.8 0.0000
 0.19345 -0.05692 -0.21000  -0.03382  211.2 0.0000
 0.19046 -0.05673 -0.20700  -0.03124  211.6 0.0000
 0.18746 -0.05655 -0.20400  -0.02866  211.9 0.0000
 0.18447 -0.05636 -0.20100  -0.02608  212.3 0.0000
 0.18147 -0.05617 -0.19800  -0.02350  212.7 0.0000
 0.17848 -0.05593 -0.19500  -0.02091  213.1 0.0000
 0.17549 -0.05568 -0.19200  -0.01833  213.6 0.0000
 0.17250 -0.05543 -0.18900  -0.01575  214.0 0.0000
 0.16951 -0.05518 -0.18600  -0.01317  214.5 0.0000
 0.16652 -0.05494 -0.18300  -0.00968  214.9 0.0000
 0.16353 -0.05469 -0.18000  -0.00618  215.2 0.0000
 0.16054 -0.05444 -0.17700  -0.00268  215.6 0.0000
 0.15756 -0.05419 -0.17400   0.00082  216.1 0.0000
 0.15457 -0.05387 -0.17100   0.00432  216.5 0.0000
 0.15159 -0.05356 -0.16800   0.00782  217.0 0.0000
```

0.14860	-0.05324	-0.16500	0.01132	217.5	0.0000
0.14562	-0.05293	-0.16200	0.01522	217.9	0.0000
0.14264	-0.05261	-0.15900	0.01991	218.3	0.0000
0.13965	-0.05230	-0.15600	0.02460	218.7	0.0000
0.13667	-0.05198	-0.15300	0.02929	219.1	0.0000
0.13369	-0.05162	-0.15000	0.03398	219.5	0.0000
0.13072	-0.05123	-0.14700	0.03867	220.0	0.0000
0.12774	-0.05084	-0.14400	0.04337	220.5	0.0000
0.12477	-0.05045	-0.14100	0.04825	221.0	0.0000
0.12180	-0.05006	-0.13800	0.05453	221.4	0.0000
0.11882	-0.04967	-0.13500	0.06080	221.7	0.0000
0.11585	-0.04928	-0.13200	0.06708	222.2	0.0000
0.11288	-0.04884	-0.12900	0.07335	222.6	0.0000
0.10992	-0.04836	-0.12600	0.07963	223.1	0.0000
0.10696	-0.04789	-0.12300	0.08590	223.7	0.0000
0.10399	-0.04741	-0.12000	0.09300	224.1	0.0000
0.10103	-0.04694	-0.11700	0.10144	224.4	0.0000
0.09807	-0.04646	-0.11400	0.10988	224.7	0.0000
0.09511	-0.04597	-0.11100	0.11832	225.1	0.0000
0.09216	-0.04540	-0.10800	0.12676	225.6	0.0000
0.08922	-0.04483	-0.10500	0.13520	226.1	0.0000
0.08627	-0.04426	-0.10200	0.14403	226.6	0.0000
0.08333	-0.04368	-0.09900	0.15545	226.7	0.0000
0.08038	-0.04311	-0.09600	0.16688	226.9	0.0000
0.07744	-0.04252	-0.09300	0.17830	227.2	0.0000
0.07452	-0.04184	-0.09000	0.18972	227.6	0.0000
0.07160	-0.04115	-0.08700	0.20114	228.1	0.0000
0.06868	-0.04046	-0.08400	0.21424	228.4	0.0000
0.06576	-0.03978	-0.08100	0.22991	228.2	0.0000
0.06284	-0.03909	-0.07800	0.24558	228.1	0.0000
0.05994	-0.03832	-0.07500	0.26124	228.2	0.0000
0.05706	-0.03750	-0.07200	0.27691	228.5	0.0000
0.05417	-0.03668	-0.06900	0.29373	228.8	0.0000
0.05129	-0.03586	-0.06600	0.31551	227.9	0.0000
0.04840	-0.03503	-0.06300	0.33730	227.3	0.0000
0.04555	-0.03410	-0.06000	0.35908	227.0	0.0054
0.04272	-0.03311	-0.05700	0.38087	227.0	0.0152
0.03988	-0.03213	-0.05400	0.40721	226.0	0.0276
0.03705	-0.03115	-0.05100	0.43779	224.1	0.0426
0.03424	-0.03010	-0.04800	0.46838	222.8	0.0602
0.03149	-0.02891	-0.04500	0.49896	222.3	0.0804
0.02873	-0.02773	-0.04200	0.53417	221.2	0.1032
0.02597	-0.02654	-0.03900	0.57675	218.6	0.1286
0.02328	-0.02524	-0.03600	0.61934	219.9	0.1566
0.02064	-0.02379	-0.03300	0.66192	113.2	0.1873
0.01801	-0.02235	-0.03000	0.71456	118.2	0.2205
0.01541	-0.02087	-0.02700	0.76989	124.7	0.2564
0.01299	-0.01910	-0.02400	0.82522	138.0	0.2947
0.01057	-0.01733	-0.02100	0.87914	148.2	0.3328
0.00825	-0.01544	-0.01800	0.93249	139.1	0.3694
0.00619	-0.01326	-0.01500	0.97892	130.0	0.4044
0.00413	-0.01108	-0.01200	0.96480	120.9	0.4386
0.00262	-0.00849	-0.00900	0.95069	111.8	0.4788
0.00118	-0.00586	-0.00600	0.76508	171.4	0.5267
0.00053	-0.00295	-0.00300	0.55831	195.4	0.5613
0.00000	0.00000	0.00000	0.16394	203.3	0.4829
0.00053	0.00295	0.00300	-0.24128	205.4	0.2789
0.00118	0.00586	0.00600	-0.61456	418.5	0.0000
0.00262	0.00849	0.00900	-0.96624	417.2	0.0000
0.00413	0.01108	0.01200	-1.14301	404.0	0.0000
0.00619	0.01326	0.01500	-1.31977	397.2	0.0000
0.00825	0.01544	0.01800	-1.37605	384.6	0.0000
0.01057	0.01733	0.02100	-1.41857	374.6	0.0000
0.01299	0.01910	0.02400	-1.44651	365.9	0.0000
0.01541	0.02087	0.02700	-1.43899	356.6	0.0000
0.01801	0.02235	0.03000	-1.43146	348.8	0.0000
0.02064	0.02379	0.03300	-1.42137	341.9	0.0000
0.02328	0.02524	0.03600	-1.40169	335.2	0.0000
0.02597	0.02654	0.03900	-1.38200	329.2	0.0000
0.02873	0.02773	0.04200	-1.36232	323.7	0.0000
0.03149	0.02891	0.04500	-1.34250	318.8	0.0000
0.03424	0.03010	0.04800	-1.32258	314.2	0.0000
0.03705	0.03115	0.05100	-1.30266	309.9	0.0000
0.03988	0.03213	0.05400	-1.28275	305.9	0.0000
0.04272	0.03311	0.05700	-1.26413	302.2	0.0000
0.04555	0.03410	0.06000	-1.24690	298.7	0.0000
0.04840	0.03503	0.06300	-1.22967	295.5	0.0000

0.05129	0.03586	0.06600	-1.21243	292.4	0.0000
0.05417	0.03668	0.06900	-1.19520	289.5	0.0000
0.05706	0.03750	0.07200	-1.18031	286.8	0.0000
0.05994	0.03832	0.07500	-1.16597	284.3	0.0000
0.06284	0.03909	0.07800	-1.15162	281.8	0.0000
0.06576	0.03978	0.08100	-1.13728	279.5	0.0000
0.06868	0.04046	0.08400	-1.12293	277.2	0.0000
0.07160	0.04115	0.08700	-1.11006	275.1	0.0000
0.07452	0.04184	0.09000	-1.09814	273.1	0.0000
0.07744	0.04252	0.09300	-1.08623	271.2	0.0000
0.08038	0.04311	0.09600	-1.07431	269.3	0.0000
0.08333	0.04368	0.09900	-1.06240	267.5	0.0000
0.08627	0.04426	0.10200	-1.05049	265.7	0.0000
0.08922	0.04483	0.10500	-1.04025	264.1	0.0000
0.09216	0.04540	0.10800	-1.03027	262.5	0.0000
0.09511	0.04597	0.11100	-1.02029	261.0	0.0000
0.09807	0.04646	0.11400	-1.01031	259.5	0.0000
0.10103	0.04694	0.11700	-1.00033	258.0	0.0000
0.10399	0.04741	0.12000	-0.99035	256.6	0.0000
0.10696	0.04789	0.12300	-0.98126	255.2	0.0000
0.10992	0.04836	0.12600	-0.97272	253.9	0.0000
0.11288	0.04884	0.12900	-0.96418	252.7	0.0000
0.11585	0.04928	0.13200	-0.95564	251.4	0.0000
0.11882	0.04967	0.13500	-0.94710	250.2	0.0000
0.12180	0.05006	0.13800	-0.93856	249.0	0.0000
0.12477	0.05045	0.14100	-0.93002	247.8	0.0000
0.12774	0.05084	0.14400	-0.92247	246.8	0.0000
0.13072	0.05123	0.14700	-0.91506	245.7	0.0000
0.13369	0.05162	0.15000	-0.90765	244.6	0.0000
0.13667	0.05198	0.15300	-0.90024	243.6	0.0000
0.13965	0.05230	0.15600	-0.89282	242.6	0.0000
0.14264	0.05261	0.15900	-0.88541	241.6	0.0000
0.14562	0.05293	0.16200	-0.87800	240.6	0.0000
0.14860	0.05324	0.16500	-0.87116	239.6	0.0000
0.15159	0.05356	0.16800	-0.86461	238.7	0.0000
0.15457	0.05387	0.17100	-0.85806	237.8	0.0000
0.15756	0.05419	0.17400	-0.85152	236.9	0.0000
0.16054	0.05444	0.17700	-0.84497	236.1	0.0000
0.16353	0.05469	0.18000	-0.83842	235.2	0.0000
0.16652	0.05494	0.18300	-0.83187	234.3	0.0000
0.16951	0.05518	0.18600	-0.82532	233.5	0.0000
0.17250	0.05543	0.18900	-0.81944	232.7	0.0000
0.17549	0.05568	0.19200	-0.81356	231.9	0.0000
0.17848	0.05593	0.19500	-0.80768	231.1	0.0000
0.18147	0.05617	0.19800	-0.80179	230.4	0.0000
0.18447	0.05636	0.20100	-0.79591	229.6	0.0000
0.18746	0.05655	0.20400	-0.79003	228.9	0.0000
0.19046	0.05673	0.20700	-0.78415	228.1	0.0000
0.19345	0.05692	0.21000	-0.77826	227.4	0.0000
0.19644	0.05711	0.21300	-0.77288	226.7	0.0000
0.19944	0.05729	0.21600	-0.76755	226.0	0.0000
0.20243	0.05748	0.21900	-0.76221	225.3	0.0000
0.20543	0.05767	0.22200	-0.75687	224.6	0.0000
0.20842	0.05781	0.22500	-0.75154	224.0	0.0000
0.21142	0.05795	0.22800	-0.74620	223.3	0.0000
0.21442	0.05808	0.23100	-0.74087	222.7	0.0000
0.21741	0.05821	0.23400	-0.73553	222.0	0.0000
0.22041	0.05835	0.23700	-0.73039	221.4	0.0000
0.22341	0.05848	0.24000	-0.72549	220.8	0.0000
0.22640	0.05861	0.24300	-0.72058	220.1	0.0000
0.22940	0.05874	0.24600	-0.71568	219.5	0.0000
0.23240	0.05887	0.24900	-0.71078	218.9	0.0000
0.23540	0.05895	0.25200	-0.70588	218.3	0.0000
0.23840	0.05904	0.25500	-0.70098	217.8	0.0000
0.24140	0.05912	0.25800	-0.69608	217.2	0.0000
0.24439	0.05920	0.26100	-0.69118	216.6	0.0000
0.24739	0.05929	0.26400	-0.68650	216.0	0.0000
0.25039	0.05937	0.26700	-0.68196	215.5	0.0000
0.25339	0.05945	0.27000	-0.67743	214.9	0.0000
0.25639	0.05954	0.27300	-0.67289	214.4	0.0000
0.25939	0.05962	0.27600	-0.66836	213.8	0.0000
0.26239	0.05966	0.27900	-0.66382	213.3	0.0000
0.26539	0.05969	0.28200	-0.65929	212.8	0.0000
0.26839	0.05973	0.28500	-0.65475	212.3	0.0000
0.27139	0.05977	0.28800	-0.65022	211.7	0.0000
0.27439	0.05981	0.29100	-0.64581	211.2	0.0000
0.27739	0.05985	0.29400	-0.64157	210.7	0.0000

```
0.28039  0.05989  0.29700  -0.63734  210.7 0.0000
```

Annex M – Code Warnings

The following table provides a list of possible warning messages which can be output by the code, together with reasons for the message, and potential actions to be taken.

Warning No.	Output	Meaning	Action
1	No altitude input value detected. Default value of 0 feet will be used in calculations	No user-defined value of altitude was read in, so the default value of sea-level will be used	Check that sea-level calculation is required
2	No chord input value detected. Default value of 1.0 metres will be used in calculations	No user-defined value of chord was read in, so the default value of 1.0 metres will be used	Check that a chord of 1m is required
3	Cannot currently account for sweep. Sweep angle reset to 0.0	The code cannot currently account for a leading edge sweep, so the sweep will be set to 0 (i.e. no sweep) and calculations will continue	Note that all calculations/results are for a non-swept aerofoil
4	Cannot currently account for sweep. SWEPT variable reset to .FALSE.	The code cannot currently account for a leading edge sweep, so the sweep will be set to 0 (i.e. no sweep) and calculations will continue	Note that all calculations/results are for a non-swept aerofoil
5	No value of VMD input. Using default value 0f 20.0 microns	No user-defined value of droplet size was read in, so the default value of 20.0 microns will be used	Check that a droplet VMD of 20.0 microns is required
6	No value(s) of NTRAJ input. Using automatic calculation of NTRAJ value(s) based on K0	No values of NTRAJ were read in, so the code will automatically generate suitable values based on the droplet modified inertia parameter	Check that specific values of NTRAJ were not required
7	Automatic definition of NTRAJ is recommended for droplet spectrum calculations (i.e. leave NTRAJ undefined)	The automatic method of trajectory number calculation is recommended for spectrum calculations	Check that specific numbers of trajectories are really required, and give sensible catch distributions
8	No value(s) of DELS input. Using default value(s) of 0.003 s/c	No user-defined value(s) of nodal spacing were read in, so the default value(s) of 0.003 s/c will be used	Check that the default nodal spacing is suitable

9	No value(s) of N_UPP input. Using default value(s) of 101	No user-defined value(s) of upper surface nodes were read in, so the default value(s) of 101 will be used	Check that the default number of upper surface nodes is suitable
10	No value(s) of N_LOW input. Using default value(s) of 101	No user-defined value(s) of lower surface nodes were read in, so the default value(s) of 101 will be used	Check that the default number of lower surface nodes is suitable
11	No value of TIME input. Using default value of 1 minute	No user-defined value of icing encounter time was read in, so the default value of 1 minute will be used	Check that the icing encounter time should be 1 minute
12	No value of LWC input. Using default value of 0.0 g/m3	No user-defined value of LWC read in, so the default value of 0.0g/m3 will be used (i.e. no water)	Check that no water is required in the calculations
13	Only single incidence can be evaluated for icing run. AOAF set to AOAI, and AOAINC set to 1.0	For an icing run, a series of incidences cannot be evaluated. Only the incidence specified as AOAI will be evaluated	Check that an icing run was required rather than an alpha sweep, and that the correct incidence was specified for AOAI
14	No value of initial incidence input. Using default value of 0.0 degrees	No user-defined value for the initial incidence was read in, so the default value of 0 degrees will be used	Check that an incidence of 0 degrees was required
15	No value of final incidence input. Value has been set to initial incidence	No user-defined value for the final incidence (in an alpha sweep run) has been read in, so the final incidence has been set to the initial incidence (i.e. only one incidence will be analysed)	Check that only one incidence is required to be analysed
16	No value of incidence increment input. Using default value of 1.0 degrees	No user-defined value for the incidence increment (in an alpha sweep run) has been read in, so an increment of 1 degree will be used	Check that an incidence increment of 1 degree is suitable. For runs where only a single incidence is required, this is also correct
17	A sweep angle has been defined, but the SWEPT variable has not been set to TRUE. Check that a sweep angle is really desired	Although a sweep angle has been defined, no sweep correction will be made unless SWEPT is also set to TRUE	Ensure that SWEPT is set to TRUE if a sweep correction is required (BUT note that sweep cannot currently be accounted for)
18	The SWEPT variable has been set to TRUE, but no sweep angle has been input	A sweep correction will be performed, but the sweep angle is 0 degrees, hence it will have no effect	Ensure that the correct sweep angle is set, or that SWEPT really should be set to TRUE (BUT note that sweep cannot currently be accounted for)

19	Impingement limit on lower surface (component X) for droplet bin Y is beyond nodal discretisation	The impingement limit on the lower surface of the specified component is further aft than the N_LOW x DELS value, and hence the true ice shape limit will not be found	Increase N_LOW or DELS for the specified component, if finding the true limit is important
20	Impingement limit on upper surface (component X) for droplet bin Y is beyond nodal discretisation	The impingement limit on the upper surface of the specified component is further aft than the N_UPP x DELS value, and hence the true ice shape limit will not be found	Increase N_UPP or DELS for the specified component, if finding the true limit is important
21	No temperature input value detected. Default value of 0 deg. C OAT will be used in calculations	No user-defined value of temperature was read in, so the default value of 0 deg. C (OAT) will be used	Check that an OAT of 0 deg. C is correct
22	No velocity input value detected. Default value of 1 m/s (TAS) will be used in calculations	No user-defined value of speed was read in, so the default value of 1m/s (TAS) will be used	Check that a TAS of 1m/s is correct
23	Upper surface nodal discretisation which has been specified is greater than the chord for component X. Value of N_UPP has been reset	The value of DELS x N_UPP for component X exceeds the physical dimensions of the component	No action necessary – code automatically modifies values of N_UPP for component X
24	Lower surface nodal discretisation which has been specified is greater than the chord for component X. Value of N_LOW has been reset	The value of DELS x N_LOW for component X exceeds the physical dimensions of the component	No action necessary – code automatically modifies values of N_LOW for component X
25	Chord value specified is greater than 10.0m	The chord values specified by the user is greater than 10.0m, indicating a possible error in input	Check that the chord value specified in TAC2_INPUT.DAT is correct
26	Chord value specified is greater than 393.7 inches (10.0m)	The chord values specified by the user is greater than 10.0m, indicating a possible error in input	Check that the chord value specified in TAC2_INPUT.DAT is correct
27	The GRAVITY variable has been set to TRUE, but no flight path angle has been input	When gravity is active, the correct direction for the gravitational force must be used.	Check that the flight path angle is zero, or use the HORIZON variable to set the correct flight path angle
28	A value for the flight path angle has been input, but gravity is	A flight path angle is irrelevant if gravity is not	Check that the droplets are below 50μm in diameter. If

	not accounted for. Flight path angle (HORIZON) has been reset to 0.0	being used in the trajectory equations.	not, set the GRAVITY variable to TRUE
29	Smoothing is being applied to the ice shape, but the number of smoothing passes has been set to zero	For smoothing to be actually be applied to the ice shape, the number of smoothing passes ($NSMOOTH) must be set greater than zero	Set the $NSMOOTH variable > 0, if smoothing is actually required on the ice shape
30	Smoothing is not being applied to the ice shape, but the number of smoothing passes is greater than zero. This value (NSMOOTH) has been reset to 0.	Smoothing can only be applied if SMOOTHING is set to TRUE, and NSMOOTH is greater than zero	Set SMOOTHING to TRUE if smoothing is required on the ice shape
31	No solution can be found on component XX for droplet bin number YY	No droplet impacts (for droplets in spectrum bin YY) can be found on aerofoil component XX	Check the results for other droplet bins to ensure that this result is consistent
32	Mach no. is greater than 0.4, but compressibility correction has not been set. It is recommended to use compressibility correction ($COMPRESS = .TRUE.) when M>0.4	For high speed flows a correction to the pressure coefficient should be included to account for compressibility	Set $COMPRESS = .TRUE., or use incompressible results with caution
33	Altitude is above Appendix C limits	Appendix C specifies icing up to 22,000ft (CM) or 31,000ft (IM)	Check that the case should really be run at the current altitude

Annex N – Code Errors

The following table provides a list of possible error messages which can be output by the code, together with reasons for the message, and actions to be taken.

Error No.	Output	Meaning	Remedy
1	File TAC2_INPUT.DAT must exist. Create file and re-run code.	No TAC2_INPUT.DAT file exists in the directory where the executable (or batch file) is being run	Create a TAC2_INPUT.DAT file in the correct directory
2	File TAC2_CRD.DAT must exist. Create file and re-run code.	No TAC2_CRD.DAT file exists in the directory where the executable (or batch file) is being run	Create a TAC2_CRD.DAT file in the correct directory
3	Error in co-ordinate input. Check correct number of co-ordinate points is specified. Also check flag to designate whether trajectory analysis is conducted on component is present.	The end of the co-ordinate file has been reached during a read process, when not all of the expected data has been read	Check formatting of TAC2_CRD.DAT, ensuring that the correct number of points has been specified, and that the icing flag for each component is present. Also, check that each component is separated from the next by a blank line
4	Trailing edge of component X not closed	The aerofoil definition does not have a closed trailing edge, for component X	Manually change the aerofoil definition to close the trailing edge of the specified component
5	An icing calculation has been specified (ICE > 0), but no aerofoil component has been designated in TAC2_CRD.DAT	If an icing calculation is required, at least one component must have the icing marker in TAC2_CRD.DAT set to 1	Ensure that at least one aerofoil component has the icing marker set to 1 in TAC2_CRD.DAT, or set ICE to 0 if no icing calculation is required
6	Error running IHB code	The IHB code has not executed properly	Check that an 'IHB.BAT' file exists in the current folder, referring to the IHB executable (if IHB is wanted to be run)
7	Altitude values have been specified in feet and metres, and values are not consistent	More than one value of altitude has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
8	Altitude values have been specified in feet and pascals, and values are not consistent	More than one value of altitude has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input

9	Altitude values have been specified in metres and pascals, and values are not consistent	More than one value of altitude has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
10	Chord values have been specified in metres and inches, and values are not consistent	More than one value of chord has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
11	Error merging iced and clean ordinates on component X	The code cannot find where the ice shape starts on the aerofoil surface for component number X	Ensure that the specified N_LOW x DELS is less than the component chord length for the specified component
12	Error merging iced and clean ordinates on component X	The code cannot find where the ice shape ends on the aerofoil surface for component number X	Ensure that the specified N_UPP x DELS is less than the component chord length for the specified component
13	Too many iced ordinates on component X: Y, max = Z	An iced aerofoil can contain only up to 3x as many points as the original aerofoil	Reduce N_UPP and/or N_LOW on the specified component
14	Keyword must start with a $	An input value has been read from TAC2_INPUT.DAT, which does not start with $	Check TAC2_INPUT.DAT and ensure that all variable inputs start with a $ (and no space after)
15	Zero length descriptor detected	An input variable in TAC2_INPUT.DAT has only a $ sign, and no name	Check TAC2_INPUT.DAT and ensure that all variable inputs start with a $ (and no space after)
16	Either ‘;’ missing in input statement, or variable input goes beyond column 120 in input file	No end of variable input has been detected	Check TAC2_INPUT.DAT and ensure all variable inputs end with a ‘;’
17	Number of components stated in input file does not match number of components specified in co-ordinate file	Miss-match in number of components specified in the input files	Ensure same number of components is specified in TAC2_INPUT.DAT and TAC2_CRD.DAT files
18	$NCOMP keyword must be specified before $DELS keyword	Number of components must be defined before values for each component are read in	Ensure that $N_COMP is specified before any of $DELS, $N_UPP, $N_LOW, $RUFF or $NTRAJ
19	$NCOMP keyword must be specified before $N_UPP keyword	Number of components must be defined before values for each component are read in	Ensure that $N_COMP is specified before any of $DELS, $N_UPP, $N_LOW, $RUFF or $NTRAJ

20	$NCOMP keyword must be specified before $N_LOW keyword	Number of components must be defined before values for each component are read in	Ensure that $N_COMP is specified before any of $DELS, $N_UPP, $N_LOW, $RUFF or $NTRAJ
21	$NCOMP keyword must be specified before $RUFF keyword	Number of components must be defined before values for each component are read in	Ensure that $N_COMP is specified before any of $DELS, $N_UPP, $N_LOW, $RUFF or $NTRAJ
22	$NCOMP keyword must be specified before $NTRAJ keyword	Number of components must be defined before values for each component are read in	Ensure that $N_COMP is specified before any of $DELS, $N_UPP, $N_LOW, $RUFF or $NTRAJ
23	Unknown input for SWEPT variable. Value must be TRUE (or .TRUE.) or FALSE (or .FALSE.)	The SWEPT variable is logical, hence can be only true or false	Ensure that the SWEPT variable is defined only in the stated way in TAC2_INPUT.DAT
24	Unknown input for COMPRESS variable. Value must be TRUE (or .TRUE.) or FALSE (or .FALSE.)	The COMPRESS variable is logical, hence can be only true or false	Ensure that the COMPRESS variable is defined only in the stated way in TAC2_INPUT.DAT
25	Keyword not recognised	An input keyword has not been recognised	Check the spelling of all keywords in TAC2_INPUT.DAT
26	Value of ICE must be 0 (no icing output) or 1 (produce IHB and ET3D input files)	A value of ICE outside of the allowable range has been input	Ensure that ICE is either 0 or 1 in TAC2_INPUT.DAT
27	File CP_REF.DAT must exist. Create file and re-run code.	No CP_REF.DAT file exists in the directory where the executable (or batch file) is being run	Create a CP_REF.DAT file in the correct directory
28	OAT values have been specified in deg. C and deg. F, and values are not consistent	More than one value of temperature has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
29	Temperature values have been specified as OAT in deg. C and TAT in deg. C, and values are not consistent	More than one value of temperature has been specified, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
30	Temperature values have been specified as OAT in deg. C and TAT in deg. F, and values are not consistent	More than one value of temperature has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input

31	Temperature values have been specified as OAT in deg. F and TAT in deg. C, and values are not consistent	More than one value of temperature has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
32	Temperature values have been specified as OAT in deg. F and TAT in deg. F, and values are not consistent	More than one value of temperature has been specified, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
33	Temperature values have been specified as TAT in deg. C and TAT in deg. F, and values are not consistent	More than one value of temperature has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
34	Repeat point detected in component X	A co-ordinate point has been repeated in the specified component	Remove the repeated point in TAC2_CRD.DAT, and update number of points
35	Speed values have been specified in KCAS and KEAS, and values are not consistent	More than one value of speed has been specified, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
36	Speed values have been specified in KCAS and EAS, and values are not consistent	More than one value of speed has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
37	Speed values have been specified in KCAS and CAS, and values are not consistent	More than one value of speed has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
38	Speed values have been specified in KEAS and EAS, and values are not consistent	More than one value of speed has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
39	Speed values have been specified in KEAS and CAS, and values are not consistent	More than one value of speed has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
40	Speed values have been specified in KTAS and TAS, and values are not consistent	More than one value of speed has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input

41	Speed values have been specified in KTAS and KCAS, and values are not consistent	More than one value of speed has been specified, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
42	Speed values have been specified in KTAS and KEAS, and values are not consistent	More than one value of speed has been specified, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
43	Speed values have been specified in KTAS and EAS, and values are not consistent	More than one value of speed has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
44	Speed values have been specified in KTAS and CAS, and values are not consistent	More than one value of speed has been specified, in different units, and the values are not equivalent	Ensure that the specified values are equivalent, or remove to have only one input
45	LWC percentages in TAC2_SPECTRUM.DAT must add to 1.0	The LWC fractions given for each droplet size bin must add to 1.0	Ensure that the fractions in the spectrum input file add to 1.0
46	Spectrum input: number of bins = X, maximum allowed = Y	Too many droplets bins have been entered. The maximum allowed is 999	Reduce the number of droplet size bins to 999 or less
47	Not enough data points in spectrum	There is not enough data listed in the file to match with the number of droplet size bins specified	Ensure that there are the same number of input lines as number of droplet bins specified
48	Altitude value specified as below 0ft	Altitude value specified by user in input file is below 0ft	Ensure value of ALTF in TAC2_INPUT.DAT is above 0
49	Altitude value specified as over 31,000ft	Altitude value specified by user in input file is above 31,000ft (limit of Appendix C icing)	Ensure value of ALTF in TAC2_INPUT.DAT is below 31000
50	Altitude value specified as below 0m	Altitude value specified by user in input file is below 0m	Ensure value of ALTM in TAC2_INPUT.DAT is above 0
51	Altitude value specified as over 9448.8m (31,000ft)	Altitude value specified by user in input file is above 9448.8m (31,000ft) (limit of Appendix C icing)	Ensure value of ALTM in TAC2_INPUT.DAT is below 9448.8
52	Altitude value specified as below 105,000Pa	Altitude value specified by user in input file is below 105,000Pa	Ensure value of ALTP in TAC2_INPUT.DAT is below 105000

53	Altitude value specified as over 28,000Pa	Altitude value specified by user in input file is above 28,000Pa	Ensure value of ALTP in TAC2_INPUT.DAT is above 28000
54	Chord value specified as less than 0.0m	A negative value for the chord length has been entered	Ensure the correct (positive) chord length has been entered in TAC2_INPUT.DAT
55	Chord value specified as less than 0 inches	A negative value for the chord length has been entered	Ensure the correct (positive) chord length has been entered in TAC2_INPUT.DAT
56	Spline data is not monotonic on component X	The data of Y0 (droplet start position) against s/c (droplet impact position) is not monotonic, i.e. the trajectories must cross on component X	Re-run the code with a different number of trajectories for component X
57	File TAC2_SPECTRUM.DAT must exist. Create file and re-run code.	No TAC2_SPECTRUM.DAT file exists in the directory where the executable (or batch file) is being run	Create a TAC2_SPECTRUM.DAT file in the correct directory
58	Unknown input for GRAVITY variable. Value must be TRUE (or .TRUE.) or FALSE (or .FALSE.)	The GRAVITY variable is logical, hence can be only true or false	Ensure that the GRAVITY variable is defined only in the stated way in TAC2_INPUT.DAT
59	Terminal velocity iteration has gone unstable. Velocity has gone negative, so drag coefficient cannot be calculated. Suggestion : turn GRAVITY option off	If the GRAVITY option is used for very small droplets, the numerical iteration can go unstable, and cause negative velocities	Turn off the GRAVITY option in the TAC2_INPUT.DAT file
60	Terminal velocity iteration is not converging. Droplet terminal velocity cannot be evaluated. Suggestion: turn GRAVITY option off	If the GRAVITY option is used for very small droplets, the numerical iteration may not converge to allow calculation of the droplet drag coefficient	Turn off the GRAVITY option in the TAC2_INPUT.DAT file
61	Unknown input for TECPLOT variable. Value must be TRUE (or .TRUE.) or FALSE (or .FALSE.)	The TECPLOT variable is logical, hence can be only true or false	Ensure that the TECPLOT variable is defined only in the stated way in TAC2_INPUT.DAT
62	Unknown input for SHED variable. Value must be TRUE (or .TRUE.) or FALSE (or .FALSE.)	The SHED variable is logical, hence can be only true or false	Ensure that the SHED variable is defined only in the stated way in TAC2_INPUT.DAT

63	Unknown input for SMOOTHING variable. Value must be TRUE (or .TRUE.) or FALSE (or .FALSE.)	The SMOOTHING variable is logical, hence can be only true or false	Ensure that the SMOOTHING variable is defined only in the stated way in TAC2_INPUT.DAT
64	Number of smoothing passes (NSMOOTH) must be positive	The NSMOOTH parameter defines the number of numerical smoothing passes made to the ice growth rates, and must be positive	Ensure that the NSMOOTH variable is set to a positive (integer) value
65	$NCOMP keyword must be specified before $SCLIMIT keyword	The code needs to know how many components to allow an s/c limit to on stagnation search	Ensure that the SCLIMIT input line comes after the NCOMP input line in TAC2_INPUT.DAT
66	Unknown input for PLOT_ALL variable. Value must be TRUE (or .TRUE.) or FALSE (or .FALSE.)	The PLOT_ALL variable is logical, hence can be only true or false	Ensure that the PLOT_ALL variable is defined only in the stated way in TAC2_INPUT.DAT
67	Speed value is set to zero. Define a non-zero value and re-start analysis	A zero flow speed cannot be analysed	Change the speed input value to something higher than zero
68	$NCOMP keyword must be specified before $XDROP_MAX keyword	The code needs to know how many components to allow a limit on trajectory position on	Ensure that the XDROP_MAX input line comes after the NCOMP input line in TAC2_INPUT.DAT
69	Cannot match Cp data if more than one incidence is set	Cp matching can only be performed for a single incidence value	Change AOAF to match AOAI
70	Mach No. calculation only valid for M < 1	Mach number can only be calculated correctly for sub-sonic flows	Change the speed input to ensure that M < 1
71	Pressure calculation only valid below 20,000m (65,617ft)	Pressure cannot be calculated above a value of 20,000m	Reduce the altitude below 20,000m
72	Unknown input for SLD_ACTIVE variable. Value must be TRUE (or .TRUE.) or FALSE (or .FALSE.)'	The SLD_ACTIVE variable is logical, hence can be only true or false	Ensure that the SLD_ACTIVE variable is defined only in the stated way in TAC2_INPUT.DAT
73	$SLDTYP keyword must be 0 = no SLD, 1 = SLD with Splash and Bounce, 2 = SLD with Bounce Only	If SLD module is activated SLD type needs to be specified in the TAC2_INPUT.DAT.	Ensure that SLD type SLDTYP is specified by choosing one of the three given options: 0 – no SLD, 1 – Splash and Bounce or 2 – Bounce.