NASA TM-87582

NASA Technical Memorandum 87582

NASA-TM-87582 19860001722

USER MANUAL FOR 0.3-M TCT WALL-INTERFERENCE ASSESSMENT/CORRECTION PROCEDURE: 8- BY 24-INCH AIRFOIL TEST SECTION

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SEPTEMBER 1985

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N86-11189 #

SUMMARY

A transonic Wall-Interference Assessment/Correction (WIAC) procedure has been developed and verified for the 8- by 24-inch airfoil test section of the Langley 0.3-m Transonic Cryogenic Tunnel. This report is a user manual for the correction procedure. It includes a listing of the computer procedure file as well as input for and results from a step-by-step sample case.

INTRODUCTION

A transonic computational procedure for assessing and correcting the wall interference for airfoils tested in the 8- by 24-inch slotted-wall test section of the Langley 0.3-m TCT has been developed. This procedure is based upon wall interference assessment/correction (WIAC) ideas and codes of Kemp (refs. 1-5). His latest code, TWINTN4 (ref. 5), is the heart of the present procedure. This code includes an accounting for sidewall boundary-layer effects, derived from the work of Barnwell and Sewall (refs. 6-8), and a least-squares velocity matching criterion over the entire airfoil surface as proposed by Murman (ref. 9).

Adaptation of these ideas and codes into a semiautomated WIAC procedure (fig. 1) for the 0.3-m TCT was discussed in reference 10. Validation of the WIAC procedure, using results from several tests in the 0.3-m TCT, was reported in reference 11. The reader should consult these latter two references for details about the WIAC procedure and results from it. Also included as part of this procedure is the GRUMFOIL (refs. 12-13) transonic full-potential equation airfoil analysis code with viscous interaction; this code provides an independent "free-air" check of the wall-interference corrections to Mach number and angle of attack which are determined by the TWINTN4 WIAC code.

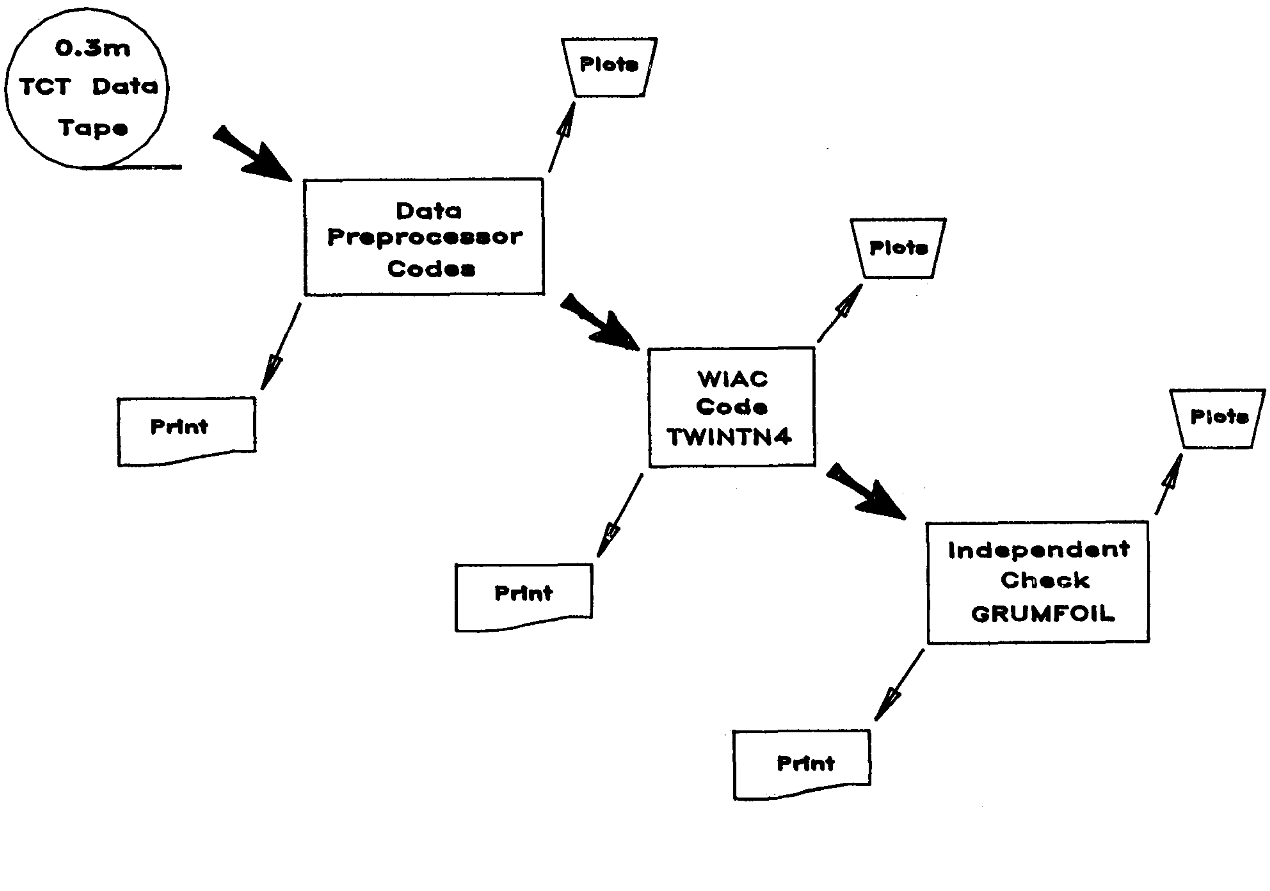

Figure 1. Schematic diagram of WIAC procedure for the 0.3m TCT.

Descriptions of the Langley 0.3-m TCT 8- by 24-inch airfoil test section and the advanced technology airfoil test program are included in references 14 to 19 as well as in the test data references, such as reference 20. The reader is also referred to these works for aspects related to the cryogenic tunnel concept, design, development, and test techniques.

This user manual briefly describes the present WIAC procedure for the 8- by 24-inch airfoil test section of the 0.3-m TCT. A sample case is carried step-by-step through the WIAC procedure in Appendix B.

DESCRIPTION OF PROCEDURE

The WIAC procedure for data taken in the 0.3-m TCT airfoil test section is comprised of five FORTRAN programs: GETTEST, PRECOR, NOCORR, TWINTN4, and GRUMFOIL. These programs begin with the retrieval of coefficient data from tapes made during the 0.3-m TCT tests, then determine Mach number and angle-of-attack corrections, and finally compare corrected data to an independent free-air calculation result. Figure 2 is a flow chart which indicates the normal progression through this procedure. All of the routines are initiated interactively from a file containing a collection of procedures; this file is listed in Appendix A. To illustrate use of the numerous procedures, a sample case (test 169, run 13, point 8) will be followed through step-by-step from beginning to end in Appendix B. This sample case is for results from a test of the CAST 10-2/DOA 2 airfoil model.

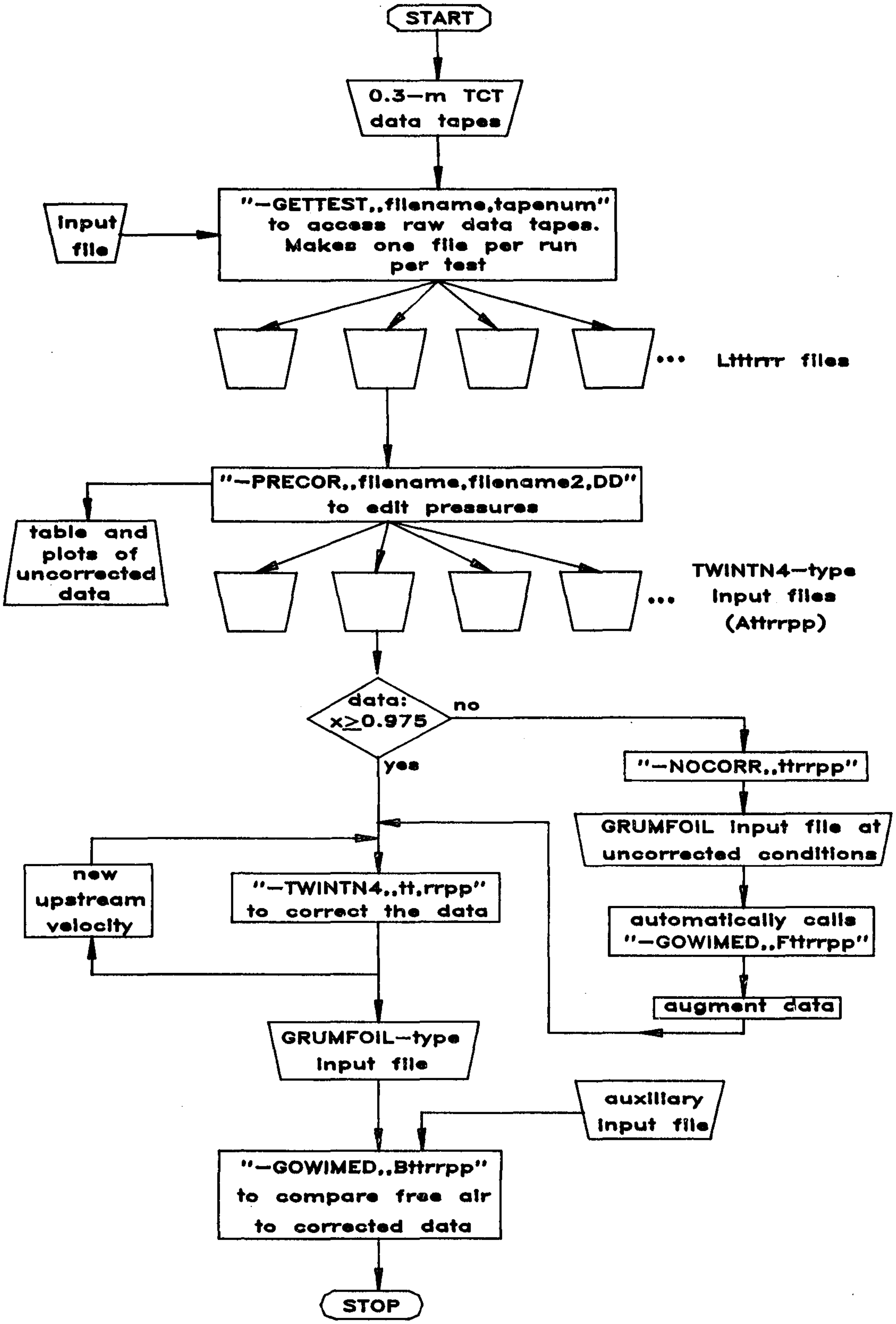

Figure 2. Flowchart of WIAC procedure.

Data to be corrected are retrieved from the coefficient data tapes made subsequent to the airfoil tests in the 0.3-m TCT. The code GETTEST accesses the tape, extracts the data required by the wall-interference assessment/correction code, and creates separate files for each run specified on the input file. This program is submitted by typing "-GETTEST,,filename,tapenum" where 'filename' designates the input file and 'tapenum' designates the name of the coefficient data tape. When GETTEST has completed execution and created the requested files, then PRECOR can be executed as shown in figure 2. The code PRECOR is an interactive routine which uses DI-3000 graphics routines; therefore, it must be run on a graphics terminal. To initiate the program, the user should type "-PRECOR,,filename,filename2,DD" where 'filename' is the name of one of the files created by GETTEST, 'filename2' is a file which describes the wake rake layout for the specific test and 'DD' is the device driver for the computer terminal being used. The file referred to as 'filename2' is a list of the wake rake tube numbers which were used in the drag survey. The naming convention for 'filename2' is PRCDttt where ttt is the three-digit test number. PRECOR writes the input files for each test point onto individual TWINTN4-type input files. The grid parameters for TWINTN4 are set for 20 grid points along the model chord located midway between the upper and lower limits of a grid depicting the 8- by 24-inch airfoil test section of the 0.3-m TCT. According to the file naming convention which has been adopted for this procedure, the files are called 'Attrrpp' where 'A' designates a TWINTN4-type input file and 'ttrrpp' is the concatenation of the last two digits of the test number, the two-digit run number, and the two-digit point number. For instance, for the sample case, the input file to TWINTN4 would be A691308. These files, while they are in the form to be read by TWINTN4, may also be used to run GRUMFOIL for a comparison of the uncorrected test data and the free-air results at the uncorrected test conditions.

A program called NOCORR creates a GRUMFOIL input file from a TWINTN4-type input file. This step may be necessary as well as informative for several tests. The correction code TWINTN4 requires data at the midpoint of each grid cell on the airfoil. For the grid developed for a 6-inch model, data must extend as far back as $x/c = 0.975$; however, several of the models tested in the 0.3-m TCT lacked a pressure orifice in that region. Therefore to run TWINTN4, the test data must be augmented. The free-air code GRUMFOIL, with a few additions, checks for data in the trailing-edge region; and, if necessary, computes a suggested value for the auxiliary data by extrapolating the measured pressures while assuming the same shape as the theoretical pressures at the uncorrected conditions. The suggested values can be added to the 'Attrrpp' file using the line editor. NOCORR is initiated by typing "-NOCORR,,ttrrpp" which creates an input file called "Fttrrpp' and submits the GRUMFOIL job.

The correction code TWINTN4 is submitted by typing "-TWINTN4,,tt,rrpp." The input files created by PRECOR direct TWINTN4 to run a unified four-wall correction and create an input file for GRUMFOIL called 'Bttrrpp.' The TWINTN4 input file can be changed to run the sequential correction as described in reference 5. Also, TWINTN4 creates a second GRUMFOIL input file called 'Ettrrpp' which reflects only the Barnwell-Sewall type Mach number correction due to the sidewall boundary layer. The flow chart (fig. 2) indicates the second pass run of TWINTN4 with an updated upstream boundary condition. Finally, the free-air comparison is made by running GRUMFOIL which is submitted by typing "-GOWIMED,,Bttrrpp."

DESCRIPTION OF INDIVIDUAL CODES

GETTEST.- The code GETTEST calls a program called PF which was developed by the Systems Development Corporation to efficiently handle the data taken during 0.3-m TCT tests. The number of spanwise pressure orifices on the model and on the drag wake rake and the number of streamwise pressure orifices on the top and bottom tunnel walls and the upper and lower model surfaces must be specified on the input file. GETTEST creates a data file for each run of each of the tests which are requested from the coefficient data tape.

PRECOR.- From a series of menu-driven inputs, PRECOR allows the user to preview pressures measured on the upper and lower model surfaces or on the top and bottom tunnel walls and, if necessary, to delete those at bad (leaking or blocked) pressure orifices.

The first user input is namelist TAPE which consists of the following:

NMI(1), NMI(2)	The number of streamwise pressure orifices on the upper and lower model surfaces, respectively: default 29,18; maximum 47,47.
NWI(1), NWI(2)	The number of streamwise pressure orifices on the top and bottom tunnel wall centerlines, respectively: default 26,28; maximum 47,47.
NCOR	The number of spanwise pressure orifices on the wake rake: default 5, maximum 6.
NSPA	The number of spanwise pressure orifices on the model: default 21, maximum 21.
CHORD	The model chord length: default 6.0.
XTSHIFT	The chordwise location of the turntable pivot point with respect to the model leading edge: default 3.0.
DIMEN	The scale factor to convert CHORD and XTSHIFT dimensions to inches; i.e., 1 for inches, 25.4 for millimeters: default 1.

The next user input is namelist IN which consists of:

NTEST	The test number.
NRUN	The run number.
NPOINT	Array of point number(s).
MPOINT	The number of test points selected: default 1, maximum 10.
IPLOT	Plot trigger; 1 for plots, 0 to override plots: default 1.

If IPLOT is set to zero, no plots are generated; the editing capability is temporarily disabled and the TWINTN4 input files are created immediately. Otherwise, the first frame plotted shows the spanwise drag distribution and an oblique plot of the wind-tunnel model with pressure measurements off the model center line. On the following frame, plots of the model surface and tunnel wall pressure signatures are created and the user is given the opportunity (and instructions) to delete any number of points using the crosshair or similar graphics input device associated with the display terminal. The code then returns to the input namelist IN. A simple carriage return response exits the code, sends a table to a predetermined printer, sends the plot metafile to the Varian plotter, saves it as METrr, and writes separate input files for each of the selected test points.

The naming convention used for the WIAC procedure data files is 'Attrrpp' where 'tt' denotes the last two digits of the test number, 'rr' denotes the two-digit run number, and 'pp' denotes the point number. This convention is carried throughout the WIAC procedure data files. The first letter identifies both the code which creates and that which uses the data file. The letter 'A' designates an input file for TWINTN4 created by PRECOR. The letter 'B' designates an input file for GRUMFOIL created by TWINTN4 which contains the Mach number and angle-of-attack corrections. The 'C' and 'D' letters designate plot files from TWINTN4 and GRUMFOIL, respectively. The letters 'E' and 'F' designate input files to GRUMFOIL with Mach corrections only and no corrections, respectively. The 'E' file is created by TWINTN4 and the 'F' file is created by NOCORR.

TWINTN4.- The code in the WIAC procedure which performs the actual wall-interference correction calculations is a version of TWINTN4 (ref. 5). Minor modifications and additions have been made to the input and output; these have no effect on the corrections. The standard input and output for the TWINTN4 WIAC code are described in the user manual, reference 5. The reader should consult reference 5 and earlier references 1-4 for information about this code.

The input to TWINTN4 has been modified to include YM, the ordinate at each model pressure orifice. An input flag, IPRE, has been added which, when set to 1 during a sequential correction (ISEQ=1), creates the input file for GRUMFOIL which takes into account the Barnwell-Sewall sidewall correction alone. Several additions have been made to the standard output. Two plots have been added: a comparison of the input model shape and the effective inviscid shape obtained as the inverse in-tunnel solution (measured pressures as boundary conditions) and a plot of the difference in camber distribution between the effective inviscid shape and the input model shape. These comparisons have also been added to the printed output.

In the present WIAC procedure, TWINTN4 is run twice. The first run of TWINTN4 uses initial values for the upstream flow angles SLA and SLB which are calculated from the most upstream measured pressures. This first estimate neglects any angularity which might be present in the tunnel. A second estimate of values for the upstream angularity inputs (SLA,SLB) is determined from the camber comparison of this first TWINTN4 run and is printed for use in the second run of TWINTN4. After the corrections have been completed, an input file is made for GRUMFOIL.

GRUMFOIL.- The code in this WIAC procedure which compares the corrected data with the independent free-air check is GRUMFOIL. The MCMJ-9 version (with modifications) is being used in the current procedure. The modified version adds another option to the IBL flag. Setting IBL=2 indicates a WIAC run and the difference between the input model shape and the equivalent inviscid shape calculated in TWINTN4 is read from the standard input file. Since the standard small-disturbance style (Cartesian) grid in TWINTN4 is coarse and offers no clustering, the input which controls the mapping which occurs in GRUMFOIL is repeated. This allows a more accurate representation of the model shape to be read from a user-supplied file called ALDATtt where, as before, 'tt' are the last two digits of the test number. The repeated block of input begins with the title card for FSYM, NU, and NL (input line 15) as described in the GRUMFOIL input manual (Appendix C) and continues through the upper and lower surface coordinates.

Upon completion of the computation, a comparison of the thickness and camber distributions is plotted. These are for the effective inviscid shape from TWINTN4 and the airfoil shape plus the boundary layer calculated by GRUMFOIL. This plot is an addition to the standard set of plots generated by GRUMFOIL which includes a comparison of the free-air calculated model pressure coefficient distribution and the corrected tunnel data.

SELECTION OF SAMPLE CASE

The 0.3-m TCT test data sample case to be followed step by step through the WIAC procedure in Appendix B was selected in order to demonstrate not only the semiautomatic nature of the procedure, but also to show deviations which need special attention. For instance, the correction code requires pressure data between the x = 0.975 and x = 1.00 chord stations which were not available for the test case. An erroneous pressure measurement on the top wall needs to be discarded; this utilizes one of the abilities offered by the procedure. Due to severe interactions between the shock and the boundary layer, the equivalent inviscid shape becomes badly distorted; this often adversely affects the determination of the second-pass upstream boundary condition. This sample case is not a typical case in that it shows all of these problems. It should not be misconstrued as a good example of the results obtained from the correction procedure; this case borders on being uncorrectable. This sample case is a point from the second test of the 6-inch-chord CAST 10-2/DOA 2 airfoil model (ref. 20) and is identified as test 169, run 13, point 8. The test data report is in preparation. This case is for the nominal tunnel test conditions $M \sim 0.73$, $\alpha \sim 4.0^{\circ}$, $C_L \sim 0.776$. Additional results from application of the WIAC procedure to several tests of the CAST 10-2/DOA 2 are given in reference 11.

APPENDIX A

Listing Of Procedure File For WIAC Method

Following is a listing of the file which contains each of the procedures called by the user and those called by the other procedures. The user should change the delivery information on each of the JOB statements and supply the appropriate user number, password, and charge number to the VPS computer control statements and assign the appropriate printer designation. The procedures assume they reside on a file called WIPROC. The procedure file was written for the CDC NOS 1.4 operating system on the CYBER computers and the VSOS 2.1.5 operating system on the VPS-32 computer installed at the NASA Langley Research Center.

```
.PROC,PRECOR,J136022,PRCD136,DD4014.
RETURN,EDFIL,SAVFIL,SAVPVF.
GET,TAPE1=J136022.
FILE,TAPE1,BT=I.
GET,TAPE7=PRCD136.
BEGIN,GODI,WIPROC,PRECOR,DD4014.
BEGIN,SND,WIPROC,TTABLE,LO=$B1244CG PREPROCESSOR TABLE$.
REWIND,EDFIL,SAVFIL.
XEDIT,TWININ,NH,I=EDFIL,L=0.
BEGIN,,SAVFIL.
REVERT. DATA PREPROCESSER J136022

.PROC,GODI,FNAME,DD4105,NC=1/0,L=0/LIST,MAP=N/$SB/SB$.
IFE,(NC.EQ.1),COMP.
RETURN,LGO.
GET,FNAME.
FTN5,I=FNAME,#L=L.
ENDIF,COMP.
ATTACH,DI3000,MFNODE,SSNODE,DIERFN,DD4105/UN=LIBRARY.
LDSET,LIB=DI3000,#MAP=MAP.
LOAD,MFNODE,SSNODE,DD4105,LGO.
NOGO,DIGO.
DIGO.
REVERT.COMPILE ANDLOAD DI3000

.PROC,SND,FNAME,EI=$,M=T,EI=101353$/$,M=R,EI=101333$,LO=B1244CG,EX=LP/IN.
DELIVER.LO
SEND,FNAME_EI,DC=EX.
REVERT.SEND_EI

.PROC,TWINTN4,RN=192701,WITWMOD.
BEGIN,SND,WIPROC,SENDEE,,,EX.
REVERT.TWINTN4:TEST,RUN,POINT RN ,MODS
.DATA,SENDEE.
/JOB
TWINTN4,T2800.                          B1244CG   TWINTAN/GRUMFOIL
/USER
/CHARGE
ENQUIRE,OP=B.
GET,UTWINM2.
GET,WITWMOD.
UPDATE,I=WITWMOD,P=UTWINM2,F,C,L=0.
GET,NMACFTN/UN=LIBRARY.
ATTACH,LARCGOS/UN=LIBRARY.
FTN5,I=COMPILE,B=CHANGE,L=LTWIN.
GET,TAPE5=A_RN.
COPYSBF,TAPE5,OUTPUT.
REWIND,TAPE5.
LDSET,LIB=NMACFTN/LARCGOS,PRESETA=NGINDEF,MAP=SB/TWMAP.
LOAD,CHANGE.
```

```
NOGO,TEMP.
TEMP(TAPE5)
REPLACE,TAPE3=B_RN.
REPLACE,TAPE10=E_RN/NA.
PLOT.VARIAN,FF
REPLACE,SAVPLT=C_RN.
EXIT.
REPLACE,TWMAP/NA.
REPLACE,LTWIN/NA.
DAYFILE,DAYT.
REPLACE,DAYT.
/EOF

.PROC,NOCORR,RN=351005,ALDAT35,SET=05,DAT=135.
IFE,FILE(BNOCORR,.NOT.AS),MOVON.
GET,NOCORR.
FTN5,I=NOCORR,L=0,LO=0,B=BNOCORR.
ENDIF,MOVON.
MAP(OFF)
GET,TAPE5=A_RN.
BNOCORR.
REPLACE,TAPE3=F_RN.
BEGIN,GOWIMED,WIPROC,F_RN,ALDAT35,BWIST,SET,DAT.
REVERT.WIAC UNCORRECTED: TEST-RUN-PNT RN ALDAT #SET_SET

.PROC,GOWIMED,B190101,ALDAT19,BWIST,SET=1,DAT=DAT.
SUBMIT,SENDEE,B.
REVERT.WIAC/GRM9:B190101 ALDAT BIN #SET_SET
.DATA,SENDEE.
/JOB
STAR,T300,CM75000,STRHZ.                B1244CG   CLYDE GUMBERT
/USER
/CHARGE
GET,B190101.
GET,TAPE3_SET=ALDAT19.
TOVPS(INPUT,C6UD=B190101,TAPE3_SET,UN=###,PW=,AC=)
EXIT.
DAYFILE,ERRDAY.
REPLACE,ERRDAY.
/EOR
GRUMFL.
USER,U=###,PA=,AC=.
RESOURCE(TL=450,LP=4,WS=800,JCAT=MDBAT)
DELIVER,B1244CG.
ATTACH,BWIST,WAIT=Y,USER=###.
TV,4.
LOAD(BWIST,CN=GO,#800,CDF=#1000,LIST=MAPST,GRLPALL= )
COMMENT. TONOS(Z,C6UD=MAPST,JCS="###N","PWORD","CHNUM")
ATTACH,B190101,TAPE3_SET.
GO(TAPE5=B190101,TAPE7=PLW_SET,TAPE6=OW_SET,TAPE3=TAPE3_SET,TAPE10=T10_SET)
```

```
TONOS(Z,C6UD=T10_SET,JCS="###N","PWORD","CHNUM")
TONOS(Z,C6UD=OW_SET,JCS="###N","PWORD","CHNUM")
TONOS(Z,C6UD=PLW_SET,JCS="###N","PWORD","CHNUM")
PURGE,B190101,TAPE3_SET.
TONOS(INPUT)
DAYFILE,DW_SET.
TONOS(Z,C6UD=DW_SET,JCS="###N","PWORD","CHNUM")
EXIT.
PATTACH,UTILITY.
PURGE,TAPE3_SET,B190101.
DAYFILE,DW_SET.
TONOS(Z,C6UD=DW_SET,JCS="###N","PWORD","CHNUM")
IDUMP(I=GO,L=DUMPST)
TONOS(Z,C6UD=T10_SET,JCS="###N","PWORD","CHNUM")
TONOS(Z,C6UD=DUMPST,JCS="###N","PWORD","CHNUM")
TONOS(Z,C6UD=OW_SET,JCS="###N","PWORD","CHNUM")
TONOS(Z,C6UD=PLW_SET,JCS="###N","PWORD","CHNUM")
TONOS(INPUT)
/EOR
FILES,T200.                                        B1244CG    CLYDE GUMBERT
/USER
/CHARGE
ATTACH,T10_SET/NA.
GET,#DAT_DAT/NA.
IFE,FILE(#DAT_DAT,AS),SKIP.
SKIPEI,#DAT_DAT.
ENDIF,SKIP.
COPYEI,T10_SET,#DAT_DAT.
PACK,#DAT_DAT.
REPLACE,#DAT_DAT/NA.
PURGE,T10_SET/ST=LPF.
GET,WIGRPP.
ATTACH,PLW_SET.
COPY,PLW_SET,TAPE5.
REWIND,TAPE5.
FTN5,I=WIGRPP,L=0.
RETURN,WIGRPP.
ATTACH(LARCGOS/UN=LIBRARY)
MAP(OFF)
LDSET(LIB=LARCGOS,PRESETA=NGINF)
LGO.
REPLACE,SAVPLT=GRW_SET.
ATTACH,OW_SET,DW_SET/NA.
COPY,OW_SET,LIST.
COPY,DW_SET,LIST.
REWIND,LIST.
BEGIN,SND,WIPROC,LIST.
COMMENT. ROUTE,LIST,DC=LP.
PLOT.VARIAN,FF
PURGE,OW_SET,DW_SET/ST=LPF,NA.
```

```
EXIT.
DAYFILE,ERRDAY.
REPLACE,ERRDAY.
REWIND,OUTPUT.
COPY,OUTPUT,OUT.
BEGIN,SND,WIPROC,OUT,EI.
DAYFILE,ERRDAY.
REPLACE,ERRDAY.
REPLACE,SAVPLT=ERRPLT.
/EOF

.PROC,GETTEST,FNAME,TAPNUM.
GET,FNAME.
SUBMIT,SENDE,B.
REVERT. GET TCT TAPE TAPNUM
.DATA,SENDE
/JOB
/NOSEQ
GETTEST,T1000,STRHC.                    B1244CG   TCT TAPE CREATION
/USER
/CHARGE
LABEL(TAPE1,D=PE,LB=KL,F=I,NT,PO=RN,VSN=TAPNUM)
REWIND(TAPE1)
GET,PF/UN=474750C.
PF(TAPE1,PL=10000)
DAYFILE,DAY1.
REPLACE,DAY1.
EXIT.
DAYFILE,ERRDAY.
REPLACE,ERRDAY.
/EOR
/READ,FNAME
/EOR
/EOF

.PROC,GRM9COM,UGRM9ST,BWIST,WIMDMOD,BE.
SUBMIT,SENDE,B.
REVERT.COMP-P=UGRM9ST,B=BWIST,I=WIMDMOD,OPT=BE
.DATA,SENDE.
/JOB
STAR,T100,STRHZ.                        B1244CG   CLYDE GUMBERT
/USER
/CHARGE
GET,OLDPL=UGRM9ST.
GET,WIMDMOD/NA.
UPDATE,I=WIMDMOD,F,C=BWIST_C.
TOVPS(INPUT,C6UD=BWIST_C,UN=###,PW=,AC=)
EXIT.
DAYFILE,ERRDAY.
REPLACE,ERRDAY.
```

```
/EOR
BWIST_C.
USER(U=###,PA=,AC=)
RESOURCE(TL=150,WS=660,LP=4,JCAT=SMBAT)
DELIVER(B1244CG)
TV,8.
ATTACH,BWIST_C.
PURGE,BWIST.
FORTRAN(I=BWIST_C,B=BWIST/#400,L=COMPST,OPT=BE)
TONOS(Z,UUUD=BWIST,C6UD=COMPST,JCS="###N","PWORD","CHNUM")
DEFINE,BWIST.
FILES,PR=*,L=VPSLIST.
SUMMARY.
PURGE,BWIST_C.
DAYFILE,DCOMST.
TONOS(Z,C6UD=DCOMST,VPSLIST,JCS="###N","PWORD","CHNUM")
EXIT.
DAYFILE,DCOMST.
TONOS(Z,C6UD=DCOMST,JCS="###N","PWORD","CHNUM")
/EOF

.PROC,GLOT,DIMETA,CAL=0/1,DI=0/1,EI=/EI.
NOTE,SENDE,NR.\/JOB\GOPLOT,T10.                              B1244CG PLOTS
NOTE,SENDE,NR.\/USER\/CHARGE
IFE,DI.EQ.1,DI3.
IFE,CAL.EQ.1,CALP.
NOTE,SENDE,NR.\GET,DIMETA.\PLOT.#CAL,11    // 0.3MM LEROY PEN  //
ELSE,CALP.
NOTE,SENDE,NR.\GET,DIMETA.\PLOT.VAR,F
ENDIF,CALP.
ELSE,DI3.
IFE,CAL.EQ.1,CALB.
NOTE,SENDE,NR.\GET,SAVPLT=DIMETA.\PLOT.CALPOST,11    //  .3MM LEROY PEN  //
ELSE,CALB.
NOTE,SENDE,NR.\GET,SAVPLT=DIMETA.\PLOT.VARIAN,FF
ENDIF,CALB.
ENDIF,DI3.
NOTE,SENDE,NR.\EXIT.
IFE,DI.EQ.1,DI2.
NOTE,SENDE,NR.\/EOR\S MF 1 DIMETA\D P FROM FIRST TO LAST\Q\/EOF
ELSE,DI2.
NOTE,SENDE,NR.\/EOF
ENDIF,DI2.
PACK,SENDE.
REWIND,SENDE.
BEGIN,SND,WIPROC,SENDE,EI,,EX.
REVERT.SEND PLOTS
```

APPENDIX B

Sample Case

This appendix shows the required user inputs such as input files for batch jobs or specific entries for interactive jobs for the sample case: test 169, run 13, point 8. The input file for procedure GETTEST was called GET169; it is listed in figure B1. The coefficient data for test 169 were written on a tape named NJ0181. There were 26 and 18 chordwise pressure orifices on the model centerline upper and low surfaces, respectively. There were 6 probes on the drag rake and 21 spanwise pressure orifices on the model. There were 26 and 28 pressure orifices on the top and bottom wall, respectively. The 'FACILITY L' command specified the first letter of the created files to be an 'L.' The command to run GETTEST was "-GETTEST,WIPROC,GET169,NJ0181." Of the files created, the one which contains the data for the sample case is 'L169013.' This file can be accessed by the program PRECOR.

The interactive terminal session during which PRECOR was executed is illustrated by prints of the screen, as shown in figures B2-B7. Figure B2 shows the command to initiate PRECOR, the printout of the default values in NAMELIST TAPE, and the updated values that were input. Figure B3 shows the next print which calls for input to NAMELIST IN and user response for this sample case. Since the variable, IPLOT, was let at the default value of 1, the code began to draw the plots. The first frame (fig. B4) shows the spanwise variation of the drag coefficient determined from the wake rake survey, and an oblique projection of the wind-tunnel model above which pressure coefficients are plotted at all locations off the centerline. The experimental pressure distributions on the model and the walls were plotted as shown in figure B5. Instructions were then printed to allow editing of the data.

There are no indications that the model pressures have any "bad" points; therefore, a space was entered for each of the first two prompts. However, the 14th orifice on the upper wall was classified a "leaker" and the value looks inconsistent with the rest; therefore, it was removed as shown in figure B6. PRECOR echoed the point which had been deleted. The first point on the upper wall is also bad; however, this point is expressly needed by the correction code so it must not simply be eliminated. Rather, after PRECOR has been run and the file A691308 has been created the value must be fixed using an editor. Experience gained from other tests in this tunnel indicates that, in general, the C_p variation over the first three orifices of the top wall is nearly linear. Therefore, the value to be used for the first point on the top wall can be linearly extrapolated from points two and three. Since there were no other points to be removed, a space bar was entered for each of the two following prompts. The test, run, and point numbers were echoed as shown in figure B7. A carriage return is then required to continue to the next case. The prompt to input NAMELIST IN was answered by merely a carriage return. This indicated an end-of-file to the program, causing it to exit, to save the TWINTN4-type input file, A691308, and to send a data table (Table B1) and a plot file to their respective output devices. Information on Table B1 includes the identification of the test, run, and point; the test parameters; the spanwise drag and pressure distributions; and the two upstream wall-pressure measurements. Upon completion, the procedure echoes the message "REVERT.DATA PREPROCESSOR L169013" to the screen.

The plots of the model pressure distribution shown in figures B5-B7 indicate that the data do not extend back to the x/c = 0.975 point designated by the cross on the x-axis. Therefore, before TWINTN4--the correction code--can be run, the data must be augmented. A means of extrapolating the experimental data has been added to GRUMFOIL, which can be run at this point by NOCORR using the command "-NOCORR, WIPROC,691308." The extrapolated values of the pressure distribution are shown in figure B8 as they were printed by GRUMFOIL. These values were added to namelist variables YM, XM, and CPM and the values of NMI, the number of points, were increased to 27 and 19 on file A691308 using the line editor.

To submit the correction code, enter the command "-TWINTN4,WIPROC,69,1308." Unless the input file, A691308, is changed, it will run a unified procedure assuming no upstream flow angularity. The comparison of the first-pass free-air model pressure distribution and the renormalized measurements is shown in figure B9. An additional result of the first run is the new suggested input value for SLA and SLB which can be changed on A691308. The suggested new values for SLA and SLB are derived from the comparison of the camberlines of the equivalent inviscid shape and the model shape. One of the plots created by the modified version of TWINTN4 makes such a comparison. The difference between the equivalent inviscid ordinates and the model ordinates is separated into a thickness part and a camber part. The camber part is shown for the sample case in figure B10. For cases exhibiting strong shocks or regions of boundary-layer separation, the effective inviscid shape may become distorted. Figure B11 shows the camber comparison for point three of the same run for which the equivalent shape is not as distorted. For cases which exhibit distorted shapes such as the sample case, the suggested values of SLA and SLB may be wrong. However, the tunnel angularity appears to be (see ref. 10) nearly linearly dependent on the circulation and hence the lift. The second-pass values for SLA and SLB can be determined in such cases by extrapolating with respect to lift coefficient the values from lower lift cases of the same Mach number and Reynolds number as indicated in figure B12. The circles represent the slope of the camberline from the first pass; the diamond is the extrapolated value.

The second run of TWINTN4 is submitted by again typing "-TWINTN4,WIPROC,69,1308." The plots from the second run of TWINTN4 are shown in figures B13-B15. The first two figures are plots of the perturbation velocity at the tunnel centerline caused by all four tunnel walls (fig. B13) and the comparison of the free-air and renormalized model pressure distributions (fig. B14) as described in reference 5. The third figure, figure B15, is a direct comparison of the measured coordinates of the model and the effective inviscid shape determined by the inverse solution for the tunnel flow using the wall and model pressures as boundary conditions. The last figure, figure B16, is a comparison of the camberline increment between the two shapes.

The free-air check code, GRUMFOIL, is submitted to the VPS-32 by the command "-GOWIMED,WIPROC,B691308,ALDAT69." The corrected Mach number and lift coefficient are specified and the drag and angle of attack are returned. The boundary-layer transition location is set close to the leading edge which seems to be appropriate for most cases at moderate Reynolds numbers. (See ref. 11.)

APPENDIX C

Informal User Guide To GRUMFOIL Version MCMJ-9

The methodology used in GRUMFOIL MCMJ-9 is described in reference 13. This appendix is a brief description of the input for the MCMJ-9 version of GRUMFOIL for which a formal users' guide is not available.

Line 1 Title card (in A format)

Line 2 header line

Line 3 FNC,FNR,FMESH (F10 format)

- FNC The number of cells around the airfoil for the crudest mesh.
- FNR The number of cells from the airfoil surface to farfield for the crudest mesh.
- FMESH The number of meshes to be run.
  Typical values are 40.,8.,3.
  Maximum dimensions allow 196 x 34 grid.

Line 4 ICASE,IBL,IWCV,LMODE,IXP,IOPUT (I1,I4,5I5 format)

- ICASE Identifies run number.
- IBL Boundary-layer flag.
  0 for inviscid run.
  1 for viscous interaction.
- IWCV Wake curvature flag.
  0 includes wake curvature; 1 suppresses wake curvature.
- LMODE Kutta condition flag.
  -1 for inverse mode; c_ℓ prescribed, returns α.

0 for direct mode; α prescribed, returns c_ℓ.

+1 for relaxed Kutta condition; both α and c_ℓ prescribed. Kutta condition not enforced. Run LMODE=+1 only in inviscid mode (IBL=0); HMIN must also be specified.

IXP Experimental data flag.

0 no comparison with experimental data.

1 experimental data included for comparison.

IOPUT Output level flag.

0 creates final plots only.

.

.

.

7 draws plot for each grid, prints Mach chart and interacted boundary-layer solution after each update.

Line 5 Namelist &MXF

(Note: VPS computer uses (&) instead of ($) for denoting and enclosing namelists.)

WALO,1,2 Underrelaxation factor applied to α when LMODE=-1 or to c_ℓ when LMODE=0 on the (0,1,2) grid.

defaults .5,.5,.5

ITBLMO,1,2 Maximum number of update cycles on the (0,1,2) grid when IBL=1.

defaults 22,22,30

NHDST	Number of inviscid iterations on the 0th grid before first boundary-layer update. default 2*TOT (from line 7)
NINV	Number of iterations between α updates when LMODE=-1. default 4
LLO,1,2	Number of points upstream of shock over which running average of surface velocity is taken for input to boundary layer. Negative value bypasses smoothing. defaults 1,1,1
LRO,1,2	Number of points downstream of shock over which running average of surface velocity is taken for input to boundary layer. Negative value bypasses smooting. defaults 1,1,1
NSMTH	Number of times smoothing is applied to surface velocity near shock waves. default 4
COVA	Convergence criterion applied to angle of attack in inverse mode. default .005
COVL	Convergence criterion applied to lift coefficient in direct mode. default .005
XPLT,YPLT	Dimensions of experimental-theoretical pressure comparison plot in inches.

defaults 5.,8.

CP1,CP2 Lower and upper limits of pressure comparison plot.

default 1.2,-2.0

.

.

.

Several other parameters are included in NAMELIST MXF; however, under all but the most strenuous conditions their default values will be adequate.

Line 6 header line

Line 7 TOT,COV,P1,P2,P3,P4,P5,NMESH (F10 format)

There will be a line 7 for each mesh (FMESH lines).

TOT Number of multigrid cycles.

COV Convergence criterion applied to max residual.

P1-5 Relaxation factors; P4 is the primary relaxation factor typically ranging from .6 to .8; rarely change the others.

NMESH Number of grids in multigrid cycle. Largest N for which 2^N is a factor of the smaller grid dimension.

Line 8 header line

Line 9 QC,VIS1,VIS2,VIS3 (F10 format)

QC Switch Mach number.

VIS1

VIS2 Artificial viscosity parameters.

VIS3

Suggested values .85,1.2,0.,2., respectively.

Line 10 header line

Line 11 AL1,AL2,STEP,FM1,FM2,DMACH (F10 format)

AL1	Initial angle of attack in degrees.
AL2	Final angle of attack.
STEP	Increment in angle of attack.
FM1	Initial Mach number.
FM2	Final Mach number.
DMACH	Mach number increment.

In inverse mode AL1,AL2 and STEP may be left blank for single case run; if only AL1,FM1 are used, leave others blank.

Line 12 header line

Line 13 CLFT1,CLFT2,DCLFT (F10 format)

CLFT1	Initial lift coefficient.
CLFT2	Final lift coefficient.
DCLFT	Lift-coefficient increment.

For single case run, only CLFT1 is used, leave others blank.

Line 15 FSYM,FNU,FNL (F10 format)

FSYM
- |FSYM|>2 :input airfoil slopes.
- |FSYM|<2:program calculates airfoil slopes.
- FSYM>0:symmetric airfoil, input upper surface only.
- FSYM<0:asymmetric airfoil.

FNU Number of points to define upper surface.

FNL Number of point to define lower surface.

Line 16 header line

Line 17 TRAIL,SLOPT (F10 format)

TRAIL Trailing-edge included angle in degrees. Program computes angle if TRAIL<0 and |FSYM|<2.

SLOPT Meanline slope at trailing edge, computed when |FSYM|<2.

Line 18 header line

Line 19 X,Y,SLOPE (F10 format) FNU lines

Upper surface ordinates and slopes from leading edge to trailing edge.

Include lines 20 and 21 only if FSYM<0.

Line 20 header card

Line 21 X,Y,SLOPE (F10 format) FNL lines

Lower surface ordinates and slopes from leading edge to trailing edge.

Line 22 Namelist &IINP

KT Boundary-layer transition flag.

1 Natural transition

2 modes; KT=1 preferred

3 by Melnik.

4 Assigned transition mode; must input XTRANU,L in &AINP.

default 1

IOUT Boundary-layer output flag.

-1 Least output.

0

1 Most output.

default -1

Line 23 Namelist &AINP

REYNO Free-stream Reynolds number based on chord of 1.0.

XTRANU,L Upper and lower surface assigned transition locations measured in x/c from the L.E.

default .10

QEIT,B Upper and lower surface initial guess for transpiration velocity, order of δ^*/c at trailing edge.

defaults .004,.002

Increase to .006 for REYNO<6 x 10^6.

Following lines (24-26) required if IXP≠0 (on line 4):

Line 24 NXP (I5 format)

Number of experimental data points.

Line 25 AMXP,ALXP,CLXP,CDXP (F10 format)

AMXP Experimental Mach number.

ALXP Experimental angle of attack.

CLXP Experimental lift coefficient.

CDXP Experimental drag coefficient.

Line 26 XXP,CPXP (F10 format)

XXP x-coordinates of experimental data.

CPXP Experimental pressure coefficient.

To stack multiple case, start again at line 1.

To end:

Line 27	Title (END OF CALCULATION)
Line 28	header line
Line 29	0. (FNC=0. stops execution and prints closing banner.)

The files needed to run GRUMFOIL MCMJ-9 are accessed on UN=350607N. For the CYBER VPS-32 version of GRUMFOIL MCMJ-9:

UGRM9ST	Update OLDPL file
BWIST	VPS-32 object file
WIGRPP	Plotting routine

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DATA TAPE FROM .3 M TCT TEST169 , RUN 13 , POINT 8
TUNNEL CONDITIONS : REF MACH NO = .730 , REYNOLDS NO =10.0MILLION , ALPHA = 4.016
CN = .7776 , CC =-.0083 , CMQC =-.0646 , CL = .7763 , CD = .0239 , CDP = .0461
DRAG RAKE SURVEY :

.0239	.0186	.0131	.0099	.0193	.0840

SPANWISE PRESSURE SURVEY :

X	.505	.505	.505	.505	.505	.505	.505
Y	2.953	2.559	2.165	1.772	1.378	.984	.591
Z	.032	.032	.032	.032	.032	.032	.032
CP	-.619	-.640	-.635	-.617	-.652	-.647	-.646

X	.505	.505	.505	.505	.505	.505	.505
Y	.197	-.197	-.591	-.984	-1.378	-1.772	-2.165
Z	.032	.032	.032	.032	.032	.032	.032
CP	-.634	-.613	-.589	-.569	-.566	-.581	-.579

X	.505	.505	.064	.145	.225	.305	.385
Y	-2.559	-2.953	1.795	1.795	1.795	1.795	1.795
Z	.032	.032	.037	.046	.048	.046	.042
CP	-.056	-.568	-1.073	-1.328	-1.419	-1.388	-1.328

TUNNEL WALL PRESSURE :

XT	-26.500	-24.500	-22.500	-20.500	-18.500
X	-3.917	-3.583	-3.250	-2.917	-2.583
CPU	-.1268	-.0111	.0019	.0033	.0032
CPL	-.0350	-.0079	-.0013	.0021	.0115

TABLE BI. - AUXILIARY DATA TABLE

```
FACILITY L
TEST RUN POINT ALPHD M,INF RINF CN CC CMQC
CPUS01 THRU CPUS26 USX01 THRU USX26
USY01 THRU USY26 USZ01 THRU USZ26
CPLS01 THRU CPLS18 LSX01 THRU LSX18
LSY01 THRU LSY18 LSZ01 THRU LSZ18
CPSPAN01 THRU CPSPAN21 SPX01 THRU SPX21 SPY01 THRU SPY21
SPZ01 THRU SPZ21 CDCOR1 THRU CDCOR6 SBX01 THRU SBX28
CPSB01 THRU CPSB28 STX01 THRU STX26 CPST01 THRU CPST26
```

Figure B1. Listing of GET169.

```
-PRECOR,,L169013
-$TAPE
0NMI      = 29, 18,
0NWI      = 26, 28,
0NCOR     = 5,
0NSPA     = 21,
0CHORD    = .6E+01,
0XTSHIFT  = .3E+01,
0DIMEN    = .1E+01,
0$END
?  $TAPE NMI=26,NCOR=6, $
```

Figure B2. Interactive execution of PRECOR - model/tunnel specifications.

```
 INPUT TEST NO ,RUN NO ,NO POINTS AND POINT NOS
 IN NAMELIST IN ... I.E.
  $IN NRUN=   ,NTEST=    ,MPOINT=   ,NPOINT=  ,  ,    $
?  $IN NTEST=169,NRUN=13,NPOINT=8, $
```

Figure B3. Interactive execution of PRECOR - choice of test, run and point number.

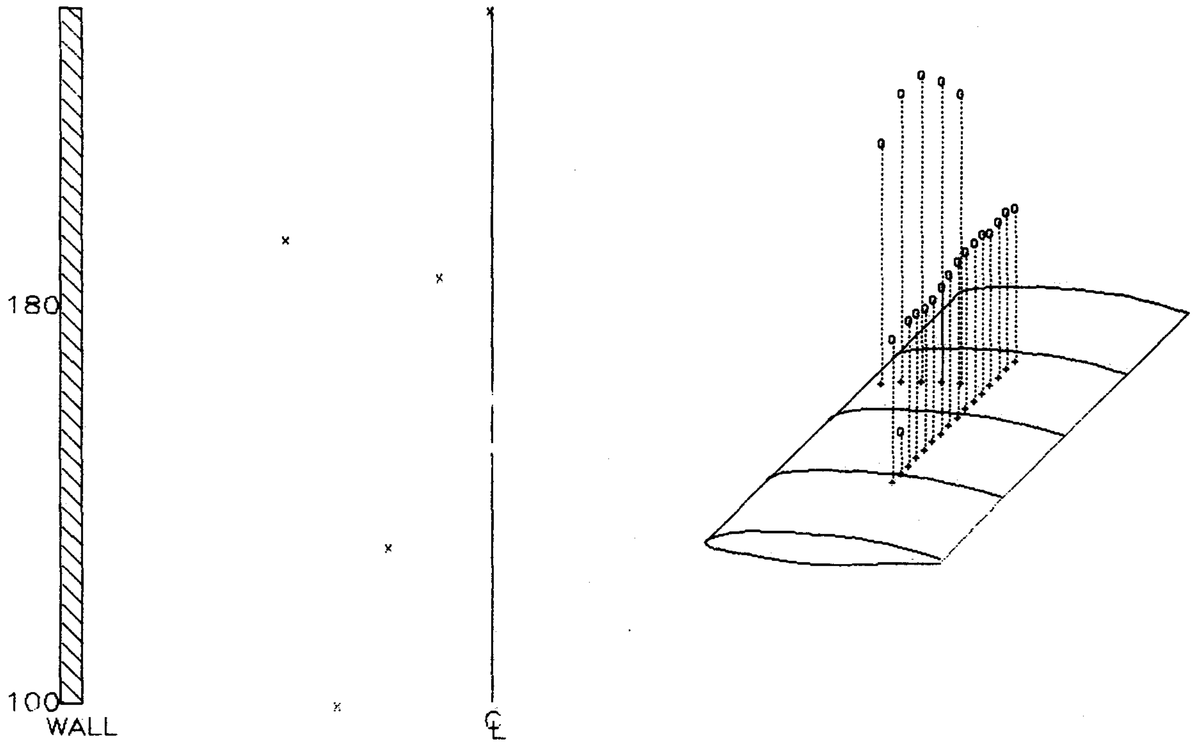

Figure B4. Interactive execution of PRECOR - spanwise drag distribution and upper surface pressure measurements.

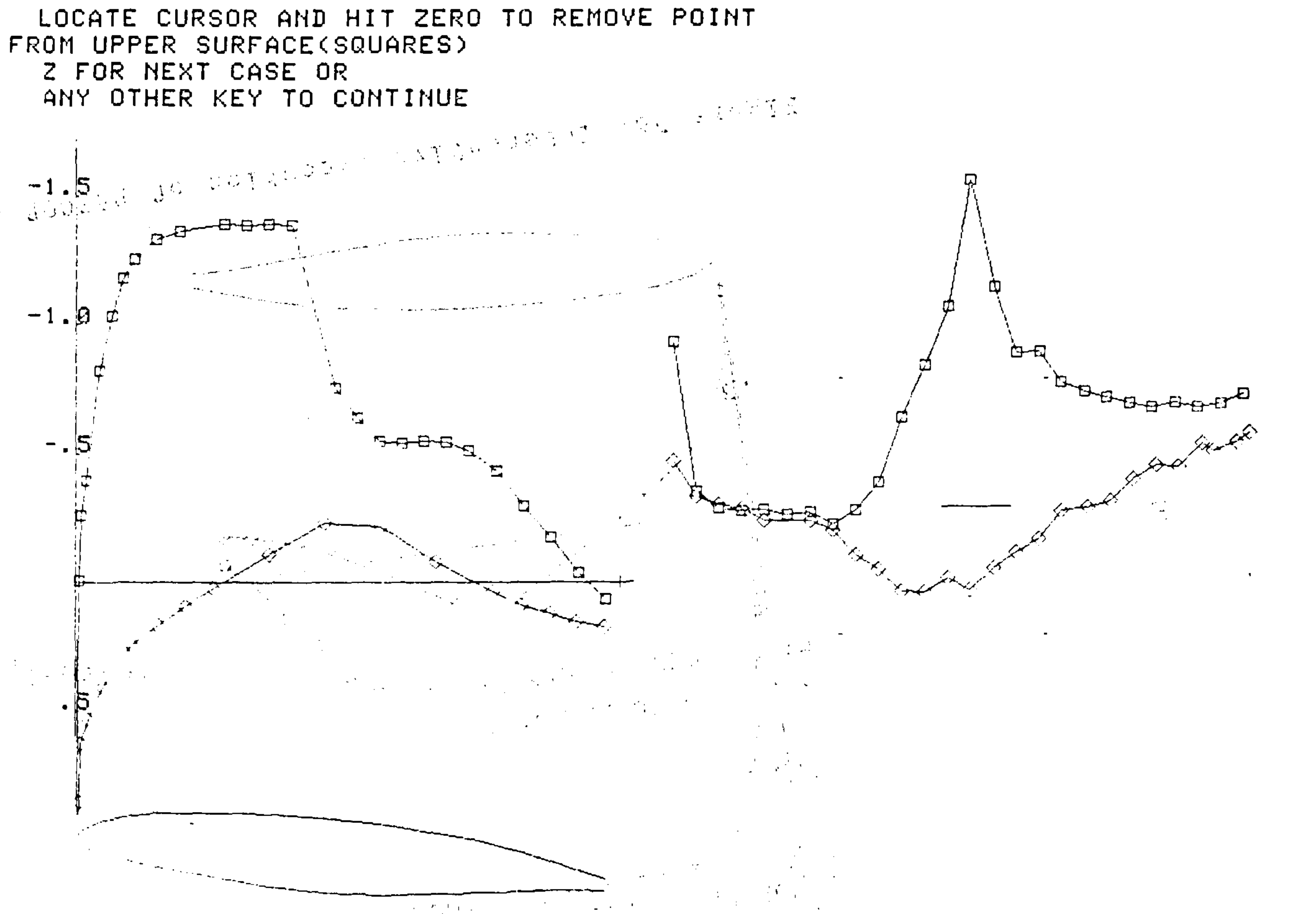

Figure B5. Interactive execution of PRECOR - model and tunnel wall pressure signatures.

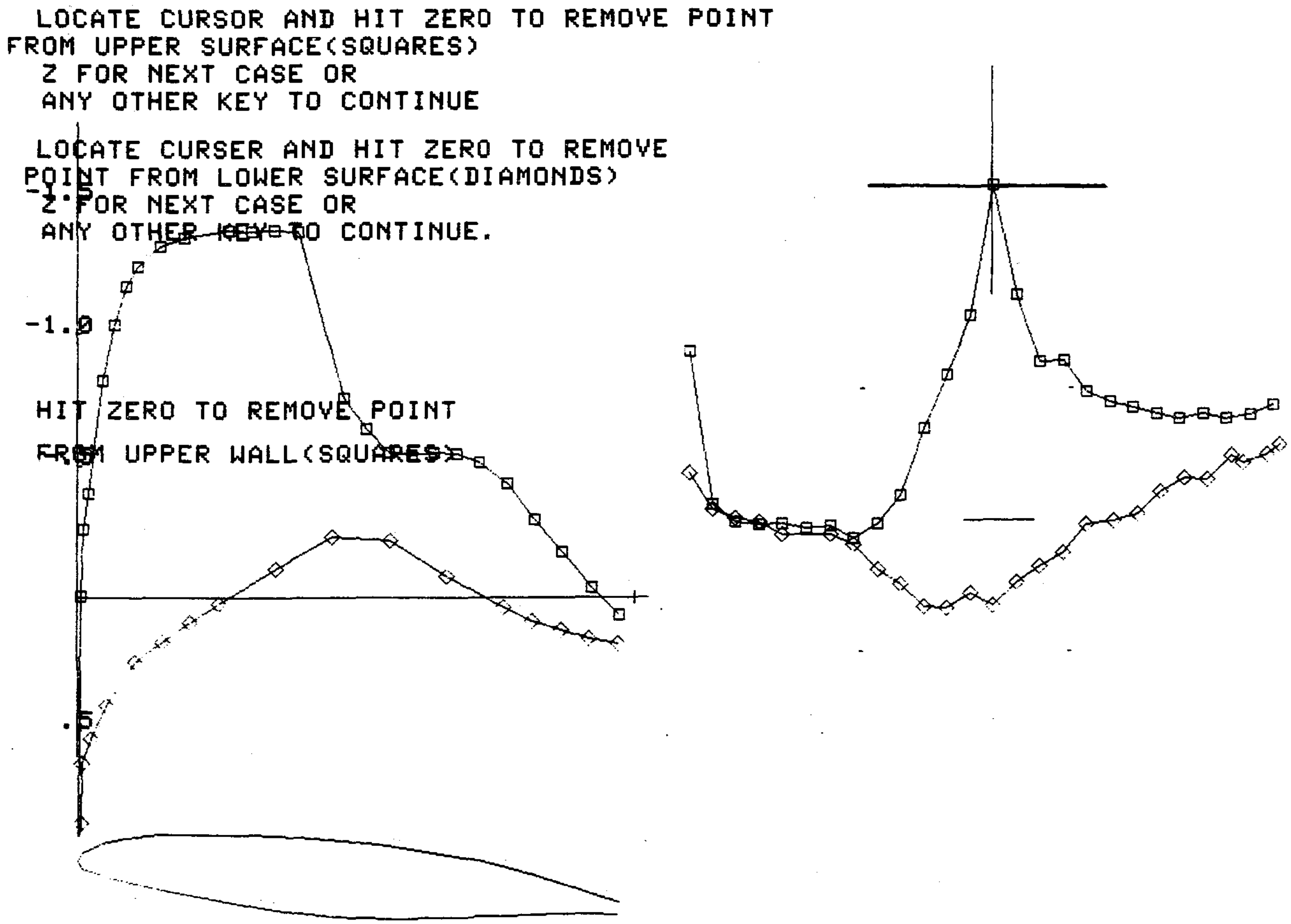

Figure B6. Interactive execution of PRECOR - edit "bad" wall pressure.

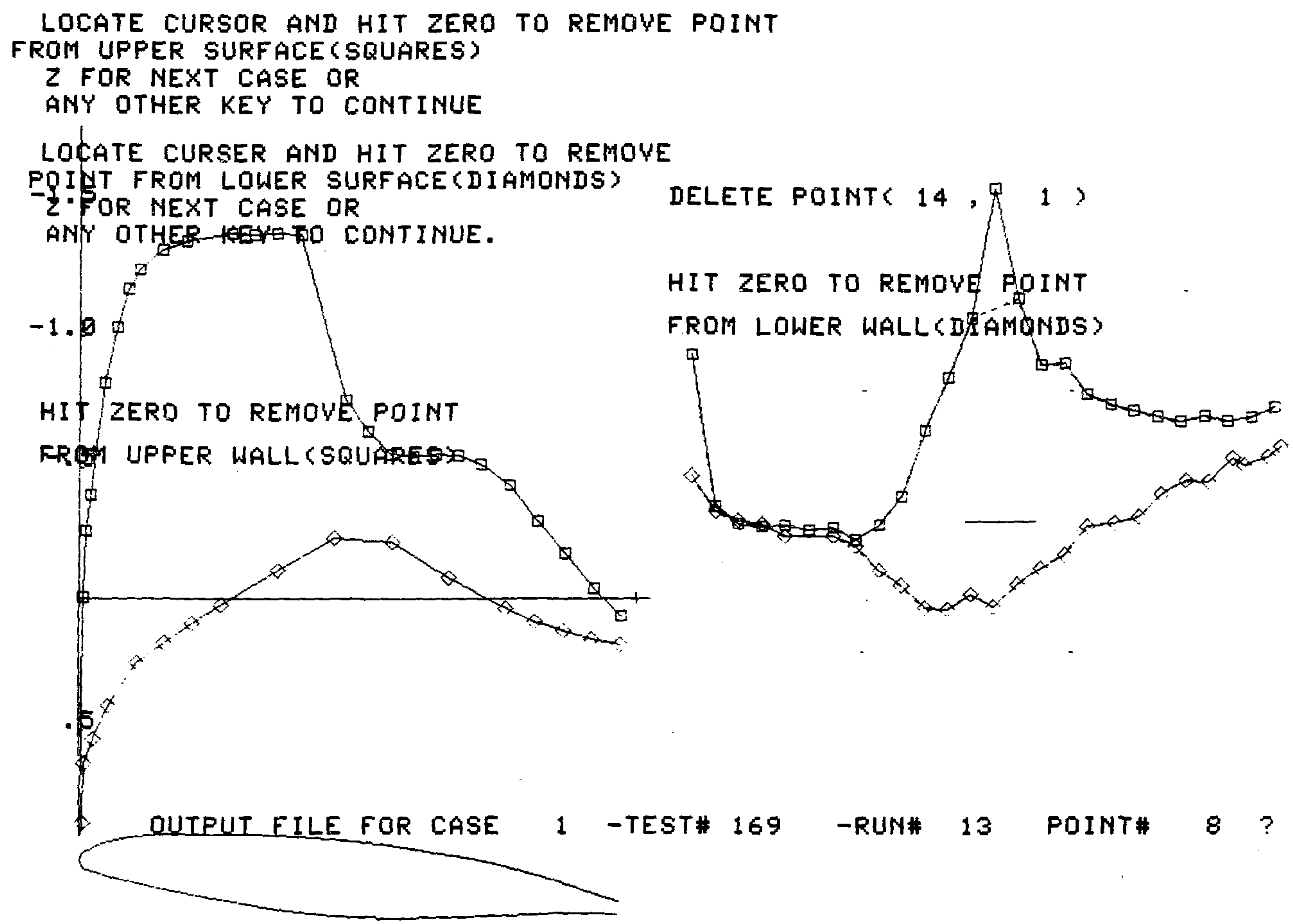

Figure B7. Interactive execution of PRECOR - end of case.

.9614	.946078	.003639	.665481	.920954
.9705	.954849	.001508	.658005	.911652
.9788	.962929	-.000457	.651053	.902992
.9864	.970290	-.002249	.644497	.894801
.9932	.976905	-.003861	.638428	.887212
.9992	.982750	-.005285	.631750	.878681
1.0044	.987798	-.006516	.625411	.870790
1.0087	.992022	-.007546	.617310	.860096
1.0122	.995395	-.008369	.610022	.851392
1.0148	.997882	-.008976	.600323	.837931
1.0164	.999447	-.009357	.590040	.826050
1.0169	1.000000	-.009492	.576647	.804632

```
 X=    .57836 AT THE SHOCK
CP=   -.88559 UPSTREAM
CP=   -.45953 DOWNSTREAM, RANKINE-HUGONIOT
CP=   -.44259 DOWNSTREAM, ISENTROPIC


NXP,NCO2:  44  80
XXP,CPXPI :    4.7388    4.7454    .1718    .0626
X,CP :    1.0000    .9994    .2110    .3313
INPUT POINTS :   7  12  16    NEIGHBOR X :  .9478  .8977
 AUXILIARY POINT ADDED TO LOWER SURFACE
 EXPERIMENTAL DATA
 X,Y,CP        .9795     -.0486      .1792
INPUT POINTS : 155 145 141    NEIGHBOR X : 1.0000   .9001
  AUXILIARY POINT ADDED TO UPPER SURFACE
EXPERIMENTAL DATA
X,Y,CP :      .9812     -.0391      .2527
```

Figure B8. Extrapolation of C_p near the trailing edge - GRUMFOIL output, uncorrected run.

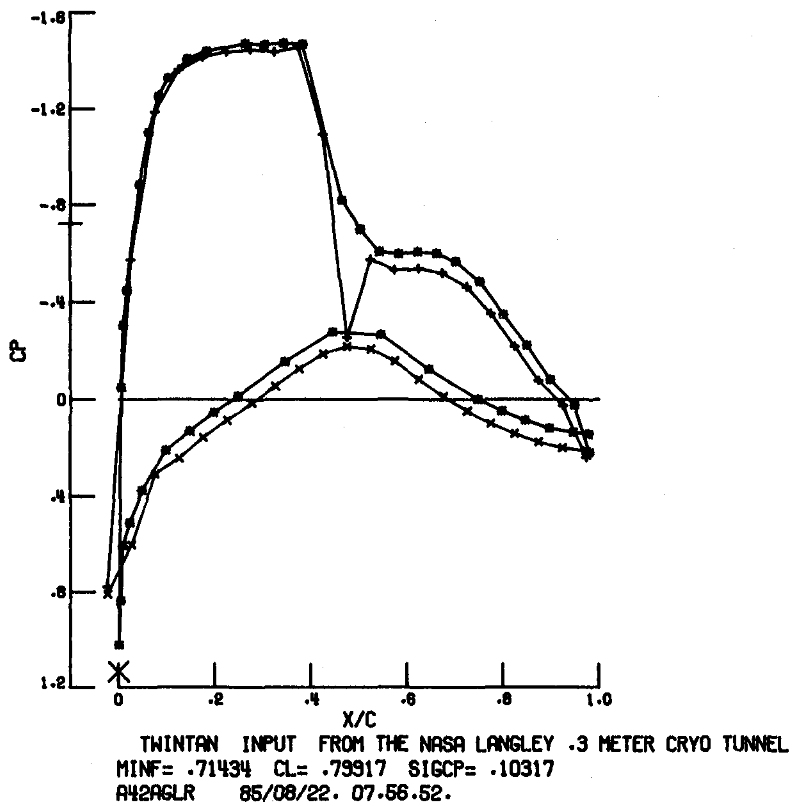

Figure B9. TWINTN4 output, first pass C_p comparison.

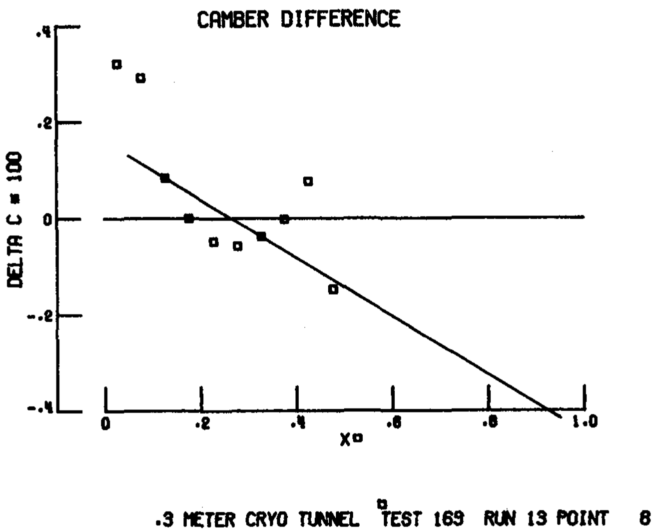

Figure B10. Camber comparison after first pass - sample case.

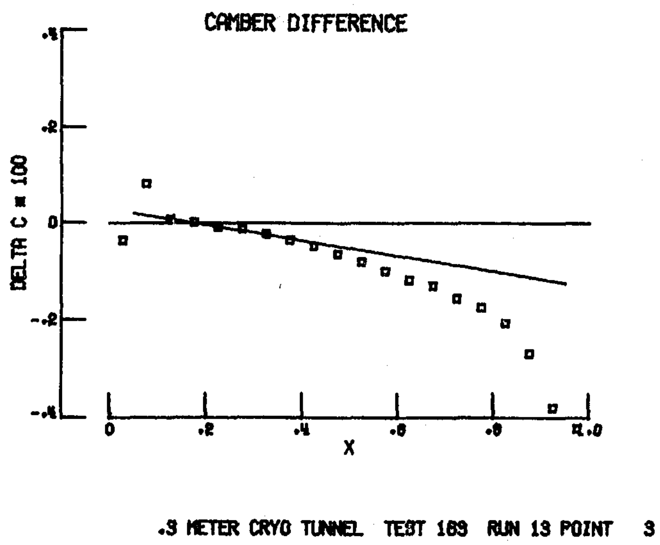

Figure B11. Camber comparison after first pass - point three.

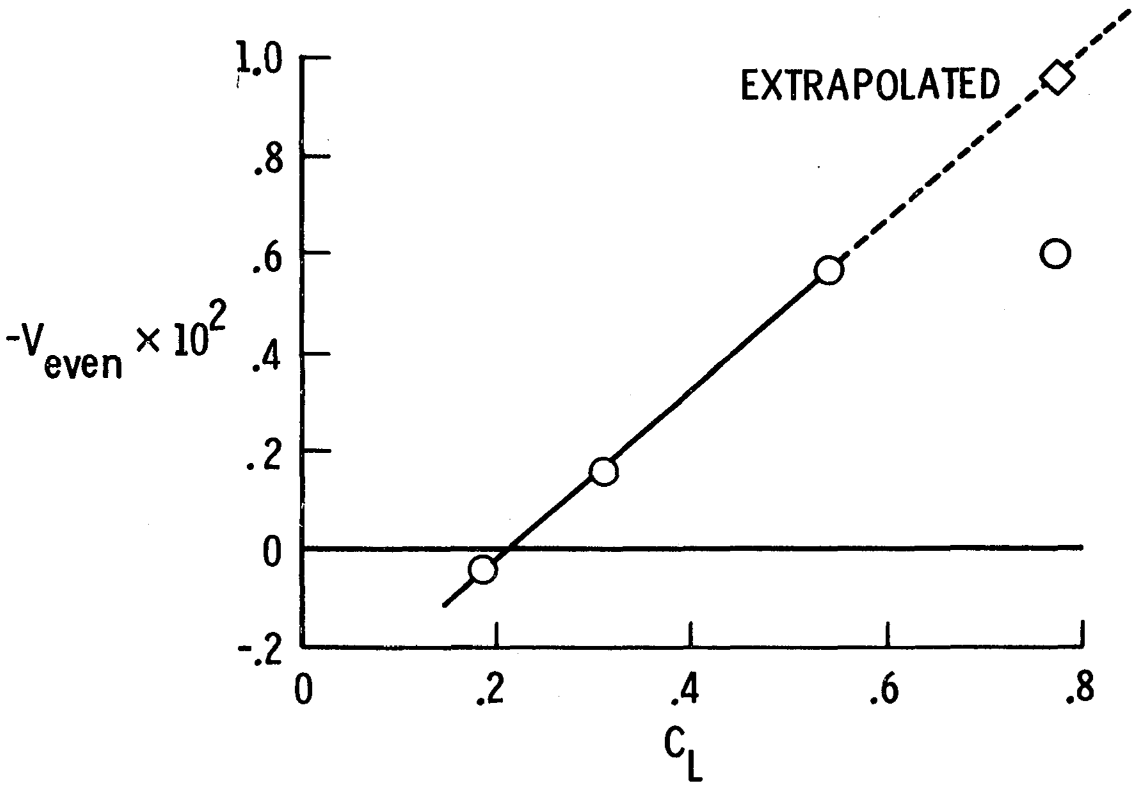

Figure B12. Effect of lift coefficient on upstream angularity.

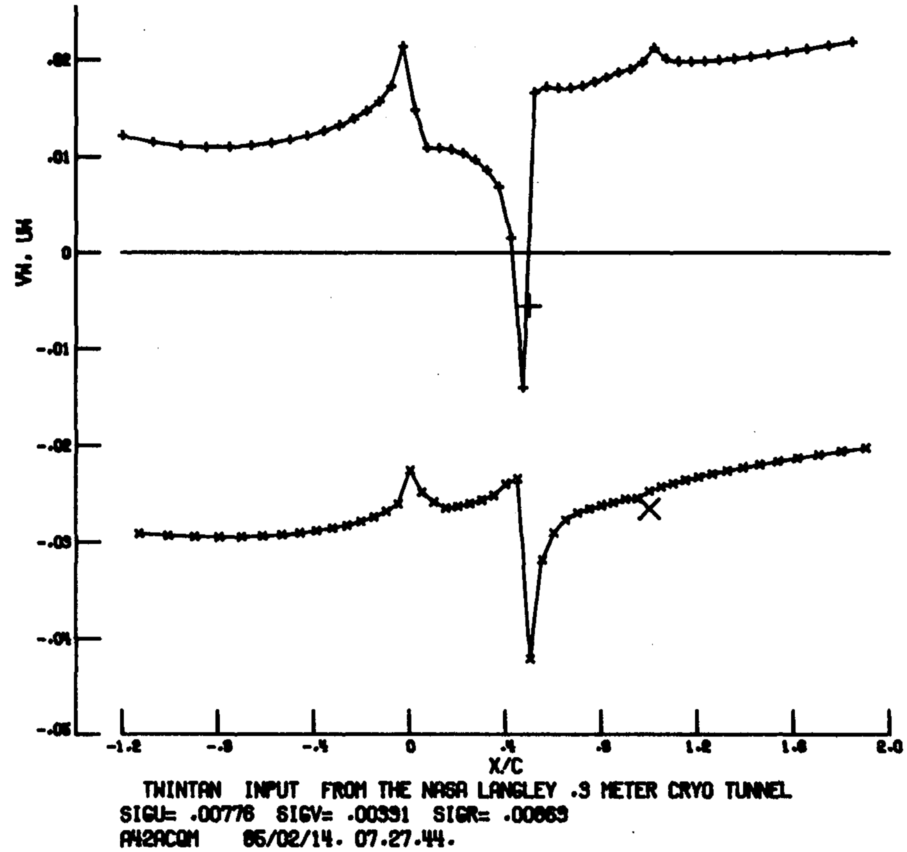

Figure B13. TWINTN4 output, second pass perturbation velocities.

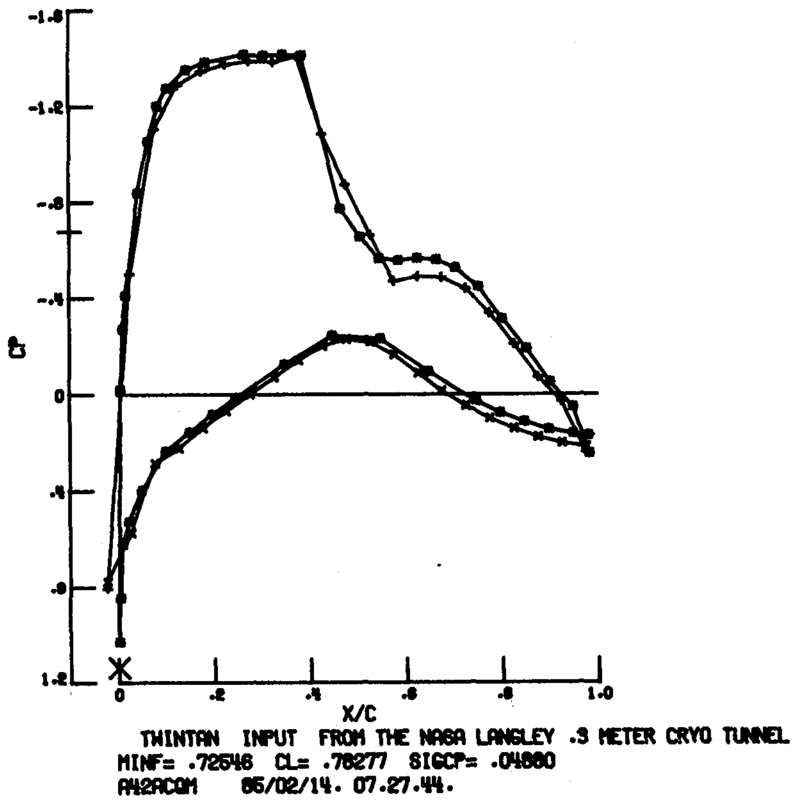

Figure B14. TWINTN4 output, second pass C_p comparison.

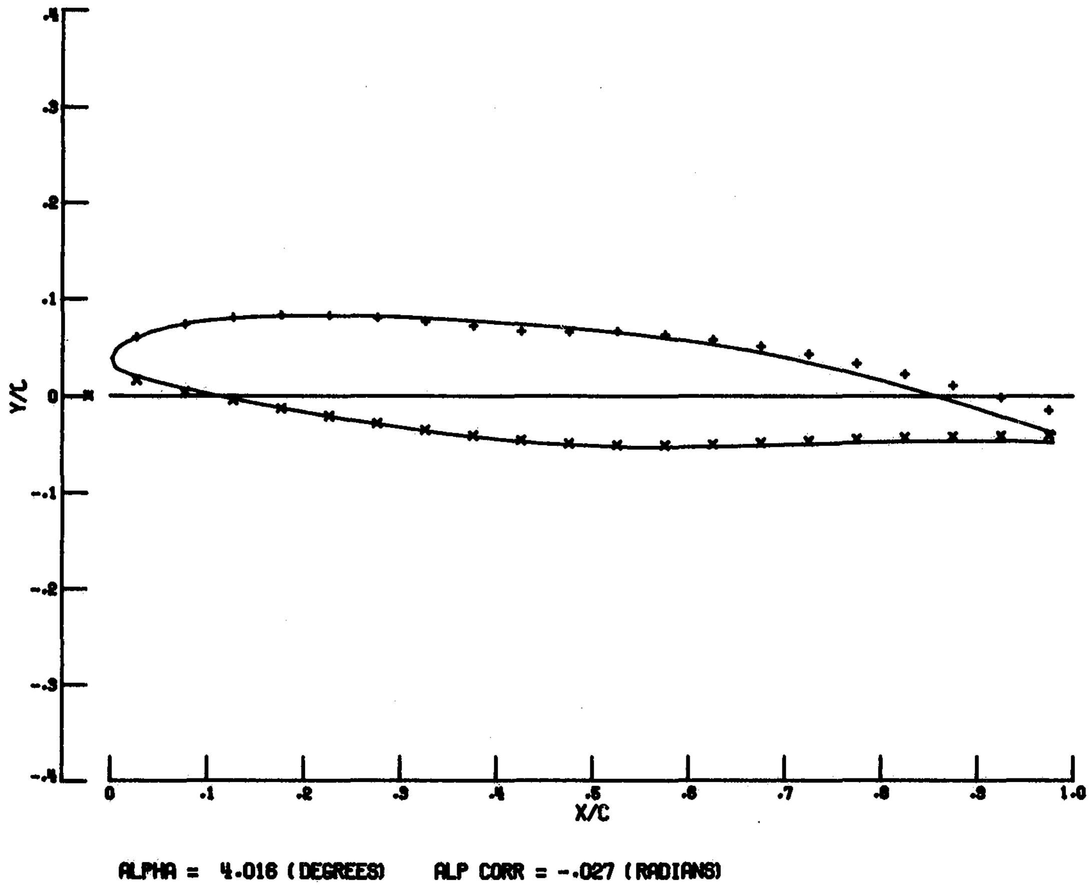

Figure B15. TWINTN4 output, second pass shape comparison.

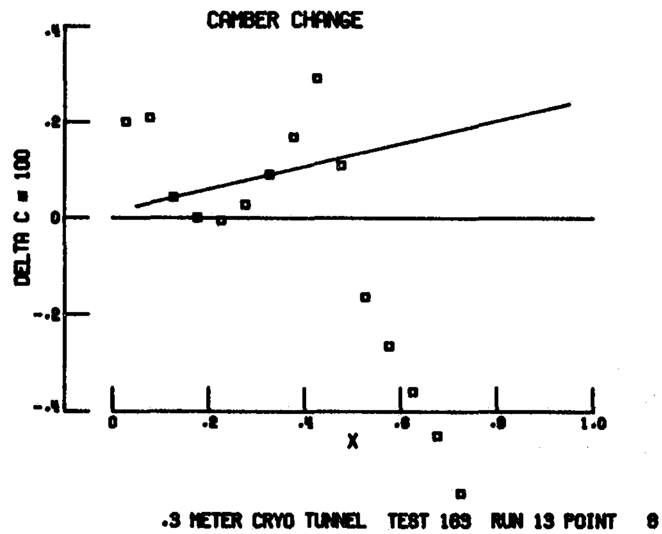

Figure B16. TWINTN4 output, second pass camber comparison.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-87582		

4. Title and Subtitle	5. Report Date
User Manual for 0.3-m TCT Wall Interference Assessment/Correction Procedure: 8- by 24-Inch Airfoil Test Section	September 1985
	6. Performing Organization Code 505-31-53-12
7. Author(s) Clyde R. Gumbert	8. Performing Organization Report No.
	10. Work Unit No.
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665	11. Contract or Grant No.
	13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A transonic Wall-Interference Assessment/Correction (WIAC) procedure has been developed and verified for the 8- by 24-inch airfoil test section of the Langley 0.3-m Transonic Cryogenic Tunnel. This report is a user manual for the correction procedure. It includes a listing of the computer procedure file as well as input for and results from a step-by-step sample case.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Wall Interference Transonic Flow Wind Tunnel Correction	Unclassified - Unlimited Subject Category - 02

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	48	A03

N-305