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AST Critical Propulsion and Noise Reduction Technologies for Future Commercial Subsonic Engines

Aeroacoustic Prediction Codes—Supplement: Code Descriptions and Users Guides

Philip Gliebe, Ramani Mani, Stuart Connell, Samir Salamah, Janet Sober, and Ronald Coffin
General Electric Aircraft Engines, Cincinnati, Ohio

April 2022

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Level of Review: This material has been technically reviewed by NASA expert reviewer(s).

This report is available in electronic form at http://www.sti.nasa.gov/ and http://ntrs.nasa.gov/

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1.0 Introduction

This document is a supplement to the final Contract Report prepared by GEAE for the NASA AST (Advanced Subsonic Transport) Technology Noise Reduction Program, NAS3–27720, Area of Interest 13, “Aeroacoustic Prediction Codes.”

The NASA AST Technology Noise Reduction Program has a goal of demonstrating a 10-decibel reduction in EPNL (effective perceived noise level), for aircraft community noise, for several classes of civil aircraft, relative to 1992 technology levels. Of this 10-dB reduction in EPNL, a 6-dB reduction in engine or propulsion system noise is targeted. The remaining reduction is targeted to be demonstrated from reductions in airframe noise, from improvements in aircraft performance, and from defining improved operational (takeoff and landing) procedures. A key ingredient to achieving the 6-dB propulsion system noise reduction goal is having accurate design and analysis tools and codes available that capture the important physics of engine noise generation, propagation, and radiation for each of the significant component noise sources in an aircraft engine. These tools should be capable of carrying out design studies, investigating new concepts for noise reduction, explaining observed results from tests and experiments, and guiding the design of features that will provide the required noise reduction.

The efforts documented herein focused on new and improved models for the various sources of fan “broadband” noise and combustor-related core noise. It was also judged that improvements were needed in the analytic descriptions of the three-dimensional turbulence velocity correlation functions that make up the noise source descriptions for turbulence-generated broadband noise, for both fans and jets. Hence, a task was included to quantify these turbulence correlations for fan broadband noise source model application.

The objective was to establish validated prediction and design analysis tools — methods and codes — applicable to high-bypass commercial turbofans, for: (1) fan broadband noise, (2) fan multiple-pure-tone (MPT) noise, and (3) low-emissions-combustor noise.

The program consisted of four major subtasks:

- Subtask 1 – Improved Aeroacoustic Turbulence Model
- Subtask 2 – Fan Broadband Noise Model
- Subtask 3 – Fan MPT Noise Model
- Subtask 4 – Core Noise Model

Subtask 1 provides improvements in turbulence descriptions and guidance for modeling, feeding into the fan broadband noise model development of subtask 2. Subtasks 1 and 2 combined focus on the eventual objective of reducing broadband noise from high-bypass engines. The third subtask addresses MPT fan noise generated by rotor-bound, shock-wave formations produced when fan rotors operate at supersonic tip speeds. The last subtask addresses possible sources of core noise from new, low-emissions, combustor designs.

The GEAE Program manager was Philip R. Gliebe, and the NASA Contract Technical Manager was Dennis Huff. The fan broadband noise code development was carried out by Dr. Ramani Mani, Dr. Brian Mitchell, Dr. Gregory Ashford, and Ms. Janet Sober of GE Corporate Research and Development (GE–CRD). The Combustor code development was carried out by Dr. Ramani Mani, Dr. Samir Salamah, and Ms. Janet Sober of GE– CRD. The MPT code development work was carried out by

Dr. Stuart Connell of GE–CRD. The directivity model codes were developed by Dr. Edward J. Rice under subcontract to Hersh Acoustical Engineering, Inc. The empirical correlation combustor code was developed by Dr. Jay Mehta and Mr. David Hoskins under subcontract to Diversitec, Inc., and was subsequently streamlined and simplified by Mr. Ronald Coffin of GEAE.

Technical descriptions of the code-development work carried out in subtasks 1 through 4 are documented in a final Contract Report. The resulting computer code descriptions and code users guides are documented in this supplement. These codes include the following:

Section 2.0 – Fan Broadband Noise Code Descriptions and Users Guides

BBNINPUT Input preprocessor code for running fan broadband noise codes.

ROTOR Fan rotor-turbulence interaction broadband noise prediction code.

STATOR Fan stator-turbulence interaction broadband noise prediction code.

BBNPLOTS Produces plots of output results from ROTOR and STATOR.

Section 3.0 – Fan MPT Superposition Code Descriptions and Users Guides

ROTBLD Generates a multiple-passage CFD (computational fluid dynamics) mesh system for producing baseline blade geometry perturbation CFD solutions.

SUPERPOSE Generates complete 360° full-annulus circumferential pressure distribution upstream of a rotor operating at supersonic tip speeds, through superposition of baseline solutions generated by ROTBLD and user-supplied, blade-to-blade distribution of blade geometric variations from the nominal blade shape.

Section 4.0 – Core Noise Code Description and Users Guide

CNOISE Predicts “indirect” noise produced by combustor temperature fluctuations propagating through downstream turbine stages — using CFD for evaluation of combustor temperature fluctuation parameters and actuator disk theory for propagation through the turbine stages.

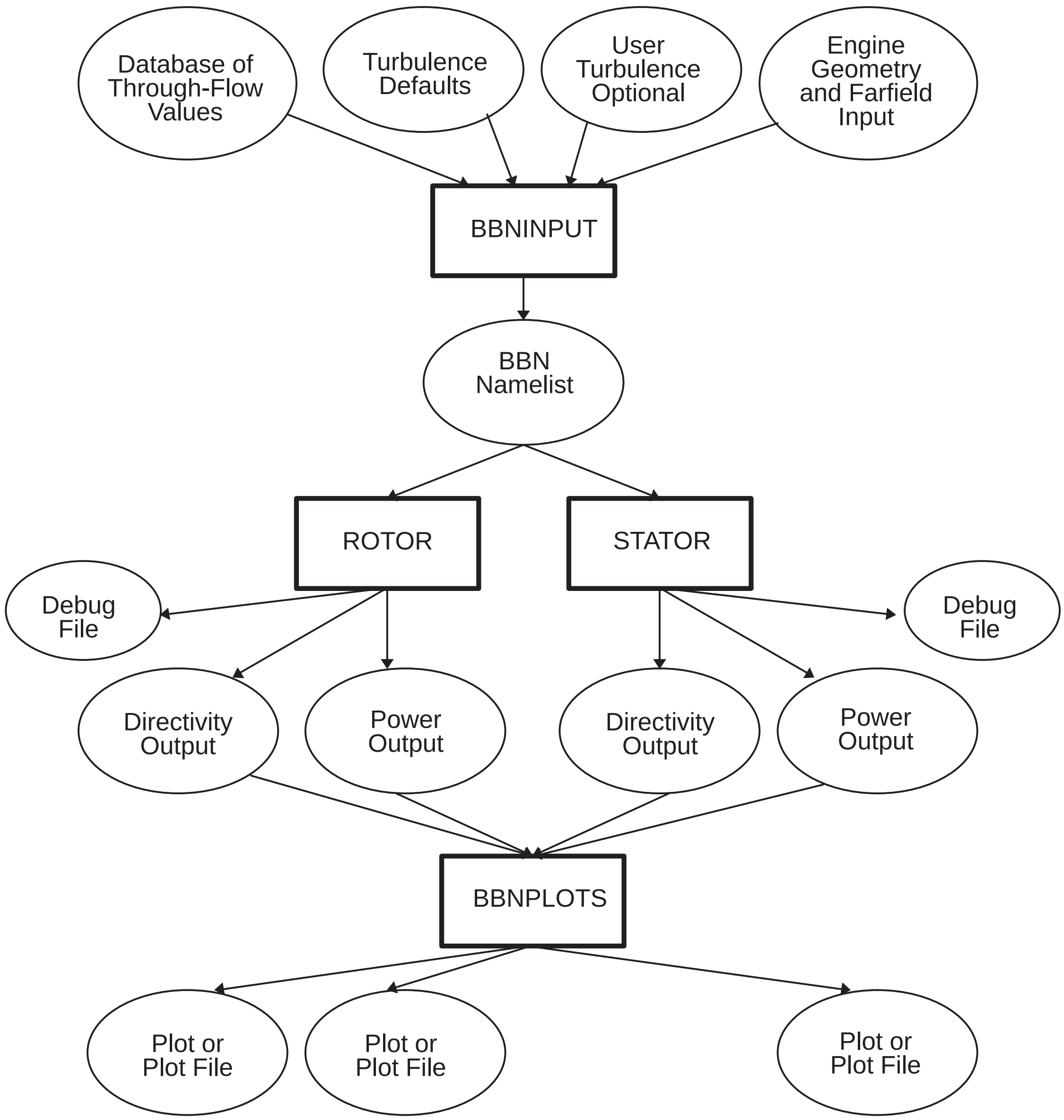
Section 5.0 – Empirical Combustor Noise Correlation

COMBUSTOR Empirical correlation model prediction of core noise based on GEAE and CFMI engine acoustic data.

2.0 Fan Broadband Noise Code Descriptions and Users Guides

This section describes software written to support Contract NAS3–27720, Sub AoI 13.2, Fan Broadband Noise Model.

The broadband noise prediction system consists of the broadband noise prediction programs ROTOR and STATOR along with programs BBNINPUT and BBNPLOTS that provide pre- and postprocessing capabilities. The programs are run independently with interaction only through input and output files as shown below.



Broadband Noise Prediction System

2.1 Software Requirements

All programs of the broadband noise prediction system are written in standard Fortran 77.

Programs ROTOR and STATOR must be linked with the IMSL math library from IMSL, Inc. The two routines referenced from that library are QDVAL and SVRGP.

BBNPLOTS (a suggested postprocessor implementation) uses Unix utility XMGR to produce plots. XMGR, an XY plotting tool for workstations or X-terminals using X-windows, may be obtained from website:

http://plasma–gate.weizmann.ac.il/Xmgr/

2.2 Program Descriptions

2.2.1 BBNINPUT – Preprocessor

A preprocessor helps to reduce the time and the possibility of manual error when combining through-flow values and turbulence data to create input for programs ROTOR and STATOR. Through-flow values may be obtained from a suitable 3D axisymmetric code and turbulence data may come from test results or from a turbulence model.

BBNINPUT (a suggested preprocessor implementation) gets through-flow values from an in-house (GEAE) code and turbulence values from a previously defined default file. Calculations are performed to produce additional values needed as input for the ROTOR and STATOR programs. The default turbulence data may be overridden by the user. The output file produced is a Fortran namelist format file suitable for input to programs ROTOR and STATOR.

2.2.1.1 Description of Input Files

Input values for through-flow variables are obtained from an in-house code. The default turbulence data input file is a subset of the ROTOR and STATOR input file.

2.2.1.2 Description of Output File

The output file is written as a Fortran namelist file. All variables are listed under the group name INPUT. The complete file description is given with the description of program ROTOR, Section 2.2.2.

2.2.2 ROTOR – Rotor/Turbulence Interaction Noise Program

2.2.2.1 Description of Prediction Code

A listing of the code that yields prediction of broadband noise due to inlet turbulence with the rotor may be found in Section 2.2.2.6, and the line numbers in it will be used to sketch out a description of the code. Salient differences (which are quite minor) of the code used to predict noise due to interaction of inlet turbulence with a rotor and noise due to interaction of inlet turbulence with the outlet guide vane row are indicated.

2.2.2.2 Description of Main Routine

Lines 1 – 156 are preliminary operations. Since the noise from each strip is considered uncorrelated from the other strips, each strip is calculated separately.

In the loop starting at line 162, the process of calculating each strip is started. The acoustic power is normalized initially by the flux of incoming turbulent kinetic energy. Also references will be found to variables with the characters MUG. These arise from the fact that the semiempirical method of Mugridge is also included in the present prediction code.

In lines 270 – 296, the various possibilities of calculating the steady lift coefficient are indicated.

The loop from lines 498 to 533 accomplishes the following. For a given frequency and radial mode order, only a range of tangential wave numbers corresponds to cut-on modes. In this loop, for this range of cut-on modes, several useful modal properties such as the acoustic power of the modes, the degree to which the mode couples to dipoles of a particular orientation, etc., are evaluated.

Starting with line 350, for each frequency band, the 1/3-octave power level contributions (fore and aft) from each strip are calculated.

In the loop beginning at line 418, scattering of an incident shear wave over $2n/d$ where $n = 0, 1, 30$ is considered. The source noncompactness effect as it affects the flowfield associated with steady loading is calculated. Incidentally, lines 210 – 216 calculate the equivalent exponential attenuation factor in case of supersonic inlet relative Mach number. The steps in lines 344 – 354 relate to the idea that if a harmonic of the blade passing frequency (BPF) falls within the band of integration, the power level is calculated by using three points in the band: the two end points and the harmonic of BPF of interest. Otherwise, only the two end points are used. In the loop beginning at 370, the range of tangential wake numbers of incoming shear waves that yield sound waves above cut-off is employed to determine the dipole and quadrupole noise contributions .

2.2.2.3 Description of Subroutines

Subroutine FKCAL – This subroutine calculates the gust response of an isolated airfoil allowing for both compressibility and aspect ratio effects. In the compressible case, separate formulas for low and high frequencies are used.

Subroutine PHICAL – This subroutine calculates the turbulence spectrum function for specified axial and tangential wave numbers. The spectrum function is integrated over the wave number component in the spanwise direction. The subroutine, in principle, allows for specification of a “sudden contraction” following the location at which the turbulence properties are known, although this feature is not used in the present study.

Subroutine EXINT – This subroutine estimates the integral of a monotonically varying function based on its end point values. It is adapted to a situation where the variation of the function could be rapid between the end points.

Subroutine SGN – This subroutine yields “Sgn(x)” where “Sgn = 1” if “x” is greater than or less than zero and “Sgn = 0” if “x = 0.”

Subroutine FRESNL – As indicated, this subroutine computes Fresnel integrals.

Subroutine MUGRIDGE – This subroutine has not been used in the present study. A semiempirical approach has been proposed by Mugridge for broadband noise. The subroutine MUGRIDGE relates to prediction of noise by Mugridge’s suggested formulas.

Subroutine TRANSOGV – This subroutine calculates the transmission loss, in the actuator disk approximation, of a sound wave incident from upstream on an array of unstaggered flat plates. A uniform, purely axial, subsonic flow is assumed for the mean flow.

Subroutine NEWSUB – Sets up tangential and radial mode orders for calculation of the 3D factor.

Subroutine SUB3D – Calculates the 3D factor.

Subroutine SIMP – Calculates term in numerator of the 3D factor.

Subroutine SIMP1 – Calculates normalizing factor for Fourier Bessel analysis.

Subroutine PHIJ – Bessel functions (J) of order "ORD," argument "ARG."

Subroutine PHIY – Similar to PHIJ except Y's.

Subroutine PHIJD – Derivative of Bessel function (J).

Subroutine PHIRYD – Derivative of Y type Bessel function.

Subroutine RJBESL – Program for calculation of Bessel functions (J).

Subroutine RYBESL – Program for calculation of Bessel functions (Y).

Function GAMMA – Function to calculate the gamma function.

Subroutines ABESJ, ABESY, ABESJD, ARBESYD – Routines for calculation of the Bessel functions J, Y and their derivatives for large arguments and arguments less than order.

Subroutine BBRDCFIN – Inlet radiation (directivity) program from E.J. Rice and associated subprograms.

Subroutine BBRDCFEX – Exit radiation (directivity) program from E.J. Rice and associated subprograms.

In the case of noise due to turbulence intercepting the outlet guide vane (OGV) blade row, the computer program is very similar. As far as the main program is concerned, by and large, the minor differences that may be noticed can be easily understood by consideration that the OGV case differs from the rotor case. The difference is that the OGV may be considered to be an unstaggered rotor traveling at zero wheel tip Mach number. Subroutine TRANSROT is used in place of TRANSOGV and calculates the transmission of upstream traveling sound waves impinging on a rotor from the downstream side. The rotor is modeled as a cascade of flat plates that are staggered at an angle $\tan^{-1}(M_t/M_a)$ with respect to the machine axis and carrying uniform flow at a Mach number of $\sqrt{M_a^2 + M_t^2}$ where M_a, M_t are axial and wheel tip Mach numbers. Actuator disk methods are used.

2.2.2.4 Description of Input File

The input file is a Fortran namelist format file with one group named INPUT. The variables within group INPUT are described below:

ANOZRAT	Fan nozzle exit area divided by fan duct area.
ALIP	Major and minor axes of fan inlet lip approximated by an ellipse (inches). For
BLIP	sharp edged lip, make minor axis less than or equal to 0.01 * DTIP.
BW	Bandwidth. This must be set equal to zero to obtain third octave PWL's.
DELANG	Angular separation in degrees between two successive far field microphones must be such that both 180 and 120. Are divisible by DELANG.

DTIP	Tip diameter of blade row in inches.
ETAFAN	Fan adiabatic efficiency.
GAM	Specific heat ratio.
HTR	Hub to tip ratio of blade row.
IABSOR	If equal to 0, hard walls are assumed. Not equal to 0 is treated wall case.
ISIDELN	Set this equal to 0 for far field microphones on an arc and equal to 1 for farfield microphones on a sideline.
ITL	If equal to 0 means inlet and exhaust termination losses are included. Not equal to 0 means that such losses are neglected.
KASE	Number of cases to be run: I recommend KASE=1 (have not tested other cases).
LEXIT	(Real) exhaust duct length divided by DTIP.
LINLET	Ratio of inlet length (from leading edge of rotor to inlet) to rotor tip diameter.
MACHS	Mach number of surrounding medium (flight Mach number).
NBLADE	Number of rotor blades.
NBSTD	Number of rotor blades for the case for which the turbulence scales are known.
NCOF	Number of cut-off ratio bins to be used in directivity calculations: should not exceed 200.
NF	Number of 1/3-octave bands to be calculated.
NHM	(Ignore) in case of inlet distortion rotor interaction, number of harmonics of BPF to be calculated.
NSTR	Number of streamlines to be computed.
NTOBNI	Ranges from 1 to NF. Information in the NTOBNI'th frequency band is printed for debug purposes.
NVANE	Number of stators (outlet guide vanes).
RADMIC	Radius or sideline distance in feet of far field microphones from center of inlet.
RHO	Inlet density, lbm/ft^3
RPM	Rotor rpm.
SATIR	Rms turbulence of axial component of inlet turbulence incident on rotor normalized by mean axial velocity (for each streamline).
SATIS	Same as above except for turbulence incident on stator (for each streamline), not used in BR or BS programs
SATIW	Similar to above except that here the component parallel to rotor wake (normalized by steady velocity parallel to rotor wake) is referred to (for each streamline). No longer used — superseded by an internal calculation based on rotor drag coefficient.
SAXSP	Axial spacing between rotor trailing edge and stator leading edge normalized by rotor chord (for each streamline).

SCHDR	Rotor chords in inches (for each streamline).
SCHDS	Stator chords in inches (for each streamline).
SCLOPTR	Lift coefficient calculation options for rotor and stator respectively; integer inputs.
SCLOPTS	1 – prescribed CL, 2 – based on work coefficient, 3 – based on pressure ratio, 4 – based on incidence angle. If rotor inlet relative Mach number exceeds unity, regardless of input, SCLOPTR is assumed to be 3.
SCLR	Rotor steady lift coefficient on each streamline. Used only if SCLOPTR is 1 and inlet relative Mach number to rotor is subsonic.
SCLS	Stator steady lift coefficient on each streamline. Used only if SCLOPTS is 1.
SCO	(For each streamline) static speed of sound.
SCONTR SCONTS	(For each streamline) contraction ratios from where turbulence is measured or specified to blade row leading edge for three cases of rotor, stator and wake
SCPNTW	Turbulence incident on stator.
SDIA	(For each streamline) streamline diameter in inches.
SELINR	Inlet length scale of incident turbulence normalized by rotor blade pitch for rotor,
SELINS	Stator and wake turbulence incident on stator (for each streamline).
SELINW	SELINW is no longer used as it is superseded by an internal calculation based on rotor drag coefficient. These length scales are integral scales in the axial direction for SELINR, SELINS.
SEMA	Axial Mach number (for each streamline).
SEMT	Tip Mach number (for each streamline).
SINCDR SINCDS	(For each streamline) incidence angle in degrees (i.e. angle between inflow direction and stagger line of blade row) for rotor, stator. Note that reference direction is stagger line of blade row.
SPERC	(For each streamline) height or width of stream annulus normalized by annulus outer radius and expressed as a percentage.
SPIMPI	Imaginary part of inlet outer wall specific impedance for various frequencies (used only if IABSOR is not equal to 0).
SPIMPIE	Imaginary part of exhaust outer wall specific impedance for various frequencies (used only if IABSOR is not equal to 0).
SPIMPR	Real part of inlet outer wall specific impedance for various frequencies (used only if IABSOR is not equal to 0).
SPIMPRE	Real part of exhaust outer wall specific impedance for various frequencies (used only if IABSOR is not equal to 0).

SROTCD	(For each streamline) drag coefficient of rotor.
SSADIN	Stagger angle of stator in degrees. (For each streamline).
SSCLR	(For each streamline) ratio of turbulence length scales axial/tangential or
SSCLS	Streamwise to cross stream for rotor, stator, rotor wake turbulence on stator
SSCLW	mechanisms.
SSTATCD	(For each streamline) drag coefficient on stator.
STHETA	(For each streamline) ratio of tangential (absolute) velocity downstream of rotor to rotor speed.
STPRIN	(For each streamline) total pressure ratio across rotor.
STVELR STVELS STVELW	(For each streamline) ratio of tangential turbulent velocity to axial turbulent velocity.
TOBN	One-third-octave band numbers at which NF calculations are desired. Thus if "n" denotes a 1/3-octave band number, the center frequency of the associated band is 10**(0.1 n).

Variable names IDIST, IPRINT, NDSTLB, SALD, SDELP, SDELU, SPHD, SSIGS, and STHD are still listed in the namelist group in programs ROTOR and STATOR, but these variables are no longer used.

2.2.2.5 Description of Output Files

This section briefly explains some of the outputs the broadband noise codes yield. The following remarks apply to the power and SPL directivity output files.

Practically all outputs in the ROTOR and STATOR power output files are self explanatory. TI stands for turbulence intensity, specifically SATIR for the relevant streamline. CONTR is SCONTR for the relevant streamline. EMR is the tangential length scale (product of RSCAL and the axial length scale). TIT is the tangential turbulence intensity (product of RVEL and TI). AR is the calculated aspect ratio of the blade. The part of the output shown as MUGRIDGE is based on the correlation for total (inlet + exhaust) broadband noise power output suggested by Mugridge.

Concerning STHI, STHUSED, for the subsonic inlet relative Mach numbers, these two outputs are the same and denote the input STHETA. In the supersonic inlet relative Mach number case, STHI is still STHETA but STHUSED is the calculated STHETA consistent with input STPRIN and is the one used to calculate the discharge relative Mach number.

The ROTOR and STATOR SPL directivity output files contain the SPL directivity for each frequency given in the namelist input file. ANGLE is angle from the inlet axis in degrees. SPL is the sound pressure level per header of first output re: $2*10^{-5}$ N/m^2. The first set is forward radiated, the second set is aft radiated and the third is the total.

2.2.2.6 ROTOR Source Code Listing

```
C     PROGRAM RDIRNEW1.FOR
C*#RUN *=;16130ER/PG/ROTIN2C(BCD,NOGO,CORE=2)
C  ROTIN       ROTOR/TURBULENCE INTERACTION NOISE PREDICTION
C
      DIMENSION AEV(46),AED(46),ZMM(46),ZPP(46),DCV1(91),DCD1(91),
     &           F(200),DCV2(91),DCD2(91),STHOSR(91),AEVETC(2,91),
     &           AEDETC(2,91),TOBN(200),SAXSP(21),SCHDS(21),
     &           TROGV(91),F3D(4,200,91),CTFRAT(200,91),
     &           CTFRATN(20000),IPERM(20000),CTFRATO(20000),
     &           POWTOT(20000),SPIMPR(200),SPIMPI(200),
     &           SPIMPRE(200),SPIMPIE(200),FINT(200),SPIMPZ2(200),
     &           SPIMPZ2E(200),RICEV(4,200,91),RICED(4,200,91)
C
      DIMENSION SAREA(21),SCLR(21),SEMA(21),SEMT(21),SSIGR(21),
     &          SSADIN(21),FOB(200),PVT(200),PDT(200),
     &          SCONTR(21),SCONTS(21),STVELR(21),SSCLR(21),
     &          STPRIN(21),SCO(21),SROTCD(21),SDIA(21),SNCD(2,91),
     &          SPERC(21),SINCDR(21),SCHDR(21),SCLS(21),SCONTW(21),
     &          SINCDS(21),SSCLS(21),SSCLW(21),STVELS(21),STVELW(21)
C
      DIMENSION DVP(21),DDP(21),QVP(21),QDP(21),CVP(21),CDP(21),
     &          SSIGS(21),SDELU(21),NDSTLB(21),SALD(21),STHD(21),
     &          SPHD(21),SDELP(21),TVP(21),TDP(21),FJJ(21)
C
      DIMENSION SATIR(21),SATIS(21),SATIW(21),SELINR(21),SELINS(21),
     &          SELINW(21),SNCU(2,91),SSTATCD(21),STHETA(21)
C
      DIMENSION FDVTH(3,200,91),FDDTH(3,200,91),FQVTH(3,200,91),
     &          FQDTH(3,200,91),ANGLEO(100)
      DIMENSION SDVTH(200,91),SDDTH(200,91),SQVTH(200,91),
     &          SQDTH(200,91),STVTH(200,91),STDTH(200,91)
      DIMENSION WSUMDV(3,200),WSUMDD(3,200),WSUMQV(3,200),
     &          WSUMQD(3,200),WSNDV(3,200),WSNDD(3,200),WSNQV(3,200),
     &          WSNQD(3,200),WSDV(200),WSDD(200),WSQV(200),
     &          WSTV(200),WSTD(200),ANGLE(100),WSUMIN(200),
     &          WSQD(200),WSNDV1(200),WSNDD1(200),WSNQV1(200),
     &          WSNQD1(200),SPLVDB(100),SPLDDB(100),SPLOUT(100),
     &          SPLVDBT(100,200),SPLDDBT(100,200),SPLDB(100),
     &          SPLDBT(100),WUP(200,200),WDN(200,200),SPLTL(100)
      REAL      NDVTH(200,91),NDDTH(200,91),NQVTH(200,91),
     &          NQDTH(200,91),MACHS
      REAL LEXIT,IXP,IXM,NBNP,NBNM,KYS,KTOTP,KTOTM,KR,LEXLOC
      REAL MDB(200),ID,LINLET,LSHOCK,LINLOC,LINOVD,LEXOVD
      COMPLEX CTU,CTV,CTRM,CTEXP,CGX,CGY,CSYM,CASYM,CDEN,CDEN1,CPART,
     &        IM
      REAL FREQNCY
      INTEGER FHZ,HSTRIG
      INTEGER SCLOPTS,SCLOPTR,SCLOPST
      LOGICAL CHECK
C
      CHARACTER *60 INFILE,OUTFILE,OUTFILE1,PLOTFILE
C
C
      NAMELIST/INPUT/
     &         BW, DTIP, GAM, HTR, IDIST, IPRINT, KASE, NBLADE,
     &         NBSTD, NDSTLB, NF, NHM, NSTR, NVANE, RHO, RPM, SALD,
     &         SCHDR,SCLOPTS,SCLOPTR,SCO, SCONTR, SDELP, SDELU,
     &         SDIA, SELINR, SEMA, SEMT, SINCDR, SPERC, SPHD, SROTCD,
```

```
     &         SSCLR, SSIGS, STHD, STHETA, STPRIN, STVELR, TOBN,
     &         SATIR,SATIW,SATIS,SCLR,SCLS,SCONTS,SCONTW,SELINS,
     &         SELINW,SINCDS,SSCLS,SSCLW,STVELS,STVELW,SCHDS,SAXSP,
     &         SSADIN,SSTATCD,LEXIT,LINLET,SPIMPR,SPIMPI,
     &         SPIMPRE,SPIMPIE,IABSOR,NTOBNI,NCOF,RADMIC,ISIDELN,
     &         ALIP,BLIP,MACHS,ANOZRAT,ETAFAN,DELANG,ITL
C      OPEN INPUT FILE
C
      WRITE(*,41)
   41 FORMAT(' Enter input file name  : ',$)
      READ(*,42) INFILE
   42 FORMAT(A60)
C
      OPEN (UNIT=11,STATUS='OLD',FORM='FORMATTED',FILE=INFILE,
     & ERR=45)
      GO TO 46
   45     PRINT *,'INPUT FILE NOT FOUND'
          GO TO 10001
C
C      OPEN OUTPUT FILES
C
   46 WRITE(*,47)
   47 FORMAT(' Enter output file name : ',$)
      READ(*,42) OUTFILE
C
      OPEN (UNIT=12,STATUS='NEW',FORM='FORMATTED',FILE=OUTFILE,
     & CARRIAGECONTROL='LIST')
C
      WRITE(*,48)
   48 FORMAT(' Enter 2nd output file name : ',$)
      READ(*,42) OUTFILE1
C
      OPEN (UNIT=13,STATUS='NEW',FORM='FORMATTED',FILE=OUTFILE1,
     & CARRIAGECONTROL='LIST')
C
      WRITE(*,49)
   49 FORMAT(' Enter spl plot output file name : ',$)
      READ(*,42) PLOTFILE
C
      OPEN (UNIT=14,STATUS='NEW',FORM='FORMATTED',FILE=PLOTFILE,
     & CARRIAGECONTROL='LIST')
C
C      WRITE TO SPL PLOT OUTPUT FILE TO INDICATE ROTOR INFO
C
      WRITE(14,'(''ROTOR SPL PLOT OUTPUT FILE'')')
C
C      READ INPUT DATA
C
C..       CALL FXOPT(12,1,1,0)
      KASE=1
      NCASE=0
      BW=0.0
      IM = CMPLX(0.0,1.0)
C      print *,'input J of interest'
C      READ *,NTOBNI
C
C****     LOOP TO PROCESS ALL CASES
C
      DO WHILE (NCASE .LT. KASE)
 1      NCASE=NCASE+1
```

```
         READ(11,INPUT,ERR=1000,END=9999)
      IF(IABSOR.EQ.0) WRITE(12,*)'       HARD WALL ASSUMED'
      IF(IABSOR.NE.0) WRITE(12,*)'    TREATED WALL ASSUMED'
      FCOF = NCOF
      IF(ISIDELN.EQ.0)WRITE(12,*)'MICROPHONE IS ON AN ARC'
      IF(ISIDELN.EQ.1)WRITE(12,*)'MICROPHONE IS ON A SIDELINE'
      WRITE(12,*)' MICROPHONE DISTANCE IN FEET IS = ',RADMIC
      WRITE(12,*)' MACH NUMBER OF SURROUNDING MEDIUM = ',MACHS
      WRITE(13,*)'NOZZLE EXIT AREA/DUCT AREA = ',ANOZRAT
      WRITE(12,*)'ESTIMATED FAN ADIABATIC EFFICIENCY = ',ETAFAN
      IF ( ITL.NE.0 ) WRITE(13,*)' NO DUCT TRANS LOSS ASSUMED'
      IF ( ITL.NE.0 ) WRITE(13,*)' '
      WRITE(12,*)'  '
         WRITE(12,108)
         WRITE(12,106) NCASE,KASE
         NJJ=10
C
      CHECK = .TRUE.
      PI=3.1415926
      BPF=RPM*NBLADE/60.
      DO 20 J=1,NF
        DO 18 I = 1,NCOF
          WUP(I,J) = 0.00
          WDN(I,J) = 0.00
 18        CONTINUE
        DO 19 I = 1,100
          SPLVDBT(I,J) = -150.
          SPLDDBT(I,J) = -150.
          IF ( J.EQ.1 ) SPLDBT(I)  = -150.
 19        CONTINUE
        PDT(J)=-150.
        PVT(J)=-150.
        MDB(J)=-150.
        FOB(J)=10.**(TOBN(J)*0.1)
        FINT(J)=FOB(J)/BPF
        SPIMPZ2(J) = SPIMPR(J)**2+SPIMPI(J)**2
        SPIMPZ2E(J)= SPIMPRE(J)**2+SPIMPIE(J)**2
 20      END DO
C
C      INDEX OVER STRIP NUMBER - KJI
C
      IF ( NSTR.EQ.1 ) MIDSTR = 1
      IF ( NSTR.GT.1 ) MIDSTR = NSTR/2
         DO 1949 KJI=1,NSTR
        LINLOC = LINLET*DTIP/SDIA(KJI)
        LINOVD = FLOAT(NBLADE)*LINLOC/PI
        LEXLOC = LEXIT*DTIP/SDIA(KJI)
        LEXOVD = FLOAT(NBLADE)*LEXLOC/PI
        AR  = 0.5*DTIP*(1.-HTR)/SCHDR(KJI)
        RAR = AR
        PER = SPERC(KJI)
        OD  = SDIA(KJI)
        ID  = (1.-0.01*PER)*OD
        RUPP = OD/DTIP
        IF ( RUPP.GT.1.00 ) RUPP = 1.00
        RLOW = RUPP*(1.-0.01*PER)
        IF ( RLOW.LT.HTR ) RLOW = HTR
        IF ( RLOW.LE.HTR ) RUPP = RLOW/(1.-0.01*PER)
        BNEW = DTIP*FLOAT(NBLADE)/(2.*PI*SDIA(KJI))
        ANEW = BNEW*HTR
```

```
C         PRINT *,'BNEW,ANEW ',BNEW,ANEW
       A   = PI*(OD**2-ID**2)/576.
       CDR=SROTCD(KJI)
       TI=SATIR(KJI)
          CONTR=SCONTR(KJI)
       SIGR=SCHDR(KJI)*FLOAT(NBLADE)/(PI*SDIA(KJI))
          EMA=SEMA(KJI)
       EMT=SEMT(KJI)*(1.-0.005*PER)
          EMR=SQRT(EMA**2+EMT**2)
       SSAD=ATAND(EMT/EMA)-SINCDR(KJI)
C Does this (the following line) make all that much sense ? Who knows!
       EL=SELINR(KJI)*FLOAT(NBLADE)/FLOAT(NBSTD)
          RSCAL=SSCLR(KJI)
          RVEL=STVELR(KJI)
          TPR=STPRIN(KJI)
          ELT=EL/RSCAL
          TIT=TI*RVEL
          AAA=A
          C=SCO(KJI)
       TABS = (C/49.0422)**2
       PABS = 53.3*TABS*RHO/144.
       IF (KJI.EQ.1) PTOT = PABS*TPR
C
C
C      WRITE INPUT DATA
C
          WRITE(12,118) KJI
          WRITE(12,120)
       WRITE(12,122) EMA,SEMT(KJI),TI,SINCDR(KJI),CONTR,
     &                  SELINR(KJI)
          WRITE(12,124)
       WRITE(12,126) GAM,RHO,C,SDIA(KJI),SPERC(KJI),TPR
       WRITE(12,125)
       WRITE(12,127) RPM,NBLADE,NBSTD,HTR,DTIP,SCHDR(KJI)
          WRITE(12,136)
          WRITE(12,138) EMR,RSCAL,RVEL,ELT,TIT,AR
       WRITE(12,*)'  '
       WRITE(12,*)'  '
       WRITE(12,*)'  CDROTOR = ',CDR
       WRITE(12,*)' INLET LENGTH/TIP DIAMETER = ',LINLET
C
C
C      PRELIMINARY CONSTANTS AND COEFFICIENTS
C
          DBL=130.+4.342945*ALOG(.105*RHO*(C*EMA)**3*TI**2*A)
       DBLSPL = 4.342945*ALOG(.105*RHO*(C*EMA)**3*TI**2*A)
       WATCON = .105*RHO*(C*EMA)**3*TI**2*A
          PI=3.1415926
          TPI=2.*PI
          G1OV2=(GAM-1.)/2.
          G1OVG=(GAM-1.)/GAM
       TDGP1=2./(GAM+1.)
       GEXP = (GAM+1.)/(2.*(GAM-1.))
          T11=TPR**G1OVG-1.
       IF (KJI.EQ.1) TTOT = TABS*(1.+T11/ETAFAN)
          T12=1.+1./(G1OV2*EMA**2)
          CR=EMA/EMR
          CR2=CR*CR
          SR=EMT/EMR
          SR2=SR*SR
```

```
       IF (EMR.LT.1.) STHETAR= STHETA(KJI)
       IF (EMR.GT.1.) STHETAR= 0.625*(CR2/SR2)*T12*T11
       WRITE(12,*)'STHI,STHUSED ',STHETA(KJI),STHETAR
       OMM2 = 1.-EMA**2
          SR1MM2=SQRT(1.-EMA**2)
       T1 = EMA**2
       T2 = (EMT*(1.-STHETAR))**2
       EMRE = SQRT(T1+T2)
       IF ((EMR.GT.1.).AND.(EMRE.GT.1.))PRINT *,
     &       ' INLET & EXIT MREL ARE .GT. 1'
       IF ((EMR.GT.1.).AND.(EMRE.GT.1.))PRINT *,
     &       'MINLET = ',EMR,' MEXIT = ',EMRE
       IF ((EMR.GT.1.).AND.(EMRE.LT.1.))PRINT *,
     &       ' INLET & EXIT MREL ARE ',EMR,EMRE
       IF ((EMR.GT.1.).AND.(EMRE.LT.1.))WRITE(12,*)
     &       ' MRINLET = ',EMR,' MREXIT = ',EMRE
       IF ( EMR.LT.1. ) SR1MR2=SQRT(1.-EMR**2)
       IF ( EMR.GT.1. ) SR1MR2=SQRT(1.-EMRE**2)
          SRCR=SR*CR
          TR=EMT/EMA
          EMRC=EMR/(5.*CR)
       F0MUG=1./(SR*SIGR*20.*CDR)
       RMUG=4.*(10.0**(-6))*(RHO/32.17)*(C**3)*SIGR*A*CDR*
     &         (EMR**6)
       DBMUG=130.+4.342945*ALOG(RMUG)
       SCLOPST = SCLOPTR
       IF ((EMR.GT.1.).AND.(EMRE.LT.1.))SCLOPST=3
C
C
C     STEADY STATE LIFT COEFFICIENT CALCULATION
C
       IF (SCLOPST .EQ. 1) THEN
C
C CL BASED ON INPUT LIFT COEFFICIENTS
C
         CL=SCLR(KJI)
       ELSE IF (SCLOPST .EQ. 2) THEN
C
C CL BASED ON WORK COEFFICIENT
C
         CL=2.0*EMT*STHETAR/(EMR*SIGR)
       ELSE IF (SCLOPST .EQ. 3) THEN
C
C CL BASED ON TOTAL PRESSURE RATIO
C
            CL=1.25*(CR2*T12*T11/(SIGR*SR))
          ELSE
C
C CL BASED ON STAGGER ANGLE
C
            SSAR=SSAD*PI/180.
            AINC=ABS(ATAN(TR)-SSAR)
            CLF1=5.65/(1.0+1.8/AR)
            CLF2=1.8+AR
            CLF3=1.8+AR*SR1MR2
            CLPR=CLF1*CLF2/CLF3
            CL=CLPR*AINC
          END IF
       GP1OV2 = (GAM+1.)/2.
       SSAR=SSAD*PI/180.
```

```
       AINC=ABS(ATAN(TR)-SSAR)
       IF ( EMR.GT.1. ) THEN
          EMU  = ASIN(1./EMR)
          T1   = EMR**2/(EMR**2-1.)
          DEL  = AINC*T1*GP1OV2
          LSHOCK = COS(EMU+SSAR)**2/(2.*DEL)
          ALU  = LOG(LINOVD/LSHOCK)/LINOVD
       ENDIF
C
 500      AA=1.0-EMA**2
       WRITE(12,140)SCLOPST
C
C     MORE CONSTANTS AND COEFFICIENTS
C
          A=CL*SIGR*EMA*EMT/(4.*AA)
          B=CL*SIGR*SR1MR2/(4.*AA)
          C=CL*SIGR/4.
          ALC=TPI*SR1MR2
          BETC=TPI
          CHIC=BETC*EMT
       CHINC = BNEW*(1.-HTR)/(PI*SR1MM2)
          DELC=TPI*EMA*EMT
          CDP2=(PI*SIGR/2.0)**2
          CAE=1./(EMA*SR1MM2)
          NINCO2=6
       NINCO2P1=NINCO2+1
          NINC=2*NINCO2
          FNINC=NINC
          DELTH=PI/FNINC
          THETA=-PI/2.
          IMAX=NINC+1
       DSNCT=0.5*SIGR/(1.-EMA**2)
C
C
C     CALCULATION OF WAVE PROPAGATION FACTORS
C
C
          WRITE(12,110)
          IF (BW .LE. 0.0) THEN
             WRITE(12,111)
          IBW=0
          ELSE
             WRITE(12,113) BW
          IBW=1
          END IF
          WRITE(12,112)
          WRITE(12,114)
C
C
C     INDEX OVER FREQUENCY  -  J
C
          DO 3000 J=1,NF
            F(J)=FOB(J)/BPF
            ISKIP=0
         IF(BW.GT.0.0.OR.F(J).LT.0.5) ISKIP=1
C
            IF (ISKIP .NE. 1) THEN
              FHI=1.122462*F(J)
              FLO=0.890899*F(J)
              FJJ(1)=FLO
```

```
           FJJ(2)=F(J)
           FJJ(3)=FHI
           JJMAX=3
            ELSE
              FJJ(1)=F(J)
              JJMAX=1
            END IF
         CHI=F(J)*CHIC
         CHI2=CHI*CHI
         NMAXC = CHI*CHINC-0.000001
         NMP1C = NMAXC+1
         DO IRAD = 1,NMP1C
            IRADM1 = IRAD-1
            ENR    = FLOAT(IRAD-1)
            ENRC   = ENR/CHINC
            ENRC2  = ENRC**2
            THETA  = -PI/2.
            DO I = 1,IMAX
              CTH   = COS(THETA)
              STH   = SIN(THETA)
              CTH2  = CTH**2
              STH2  = STH**2
              IF ((IRAD.GT.1).OR.(I.NE.NINCO2P1)) THEN
                   CTF   = SQRT (CHI2*STH2+ENRC2*CTH2)
                   CTFRAT(IRAD,I) = CHI/CTF
                 ELSE
                   CTFRAT(IRAD,I) = 1.E+06
              ENDIF
              THETA = THETA+DELTH
            ENDDO
         ENDDO
C           IF (J.EQ.NTOBNI) WRITE(13,*)’  ’
C
            SDV=0.
            SDD=0.
            SQV=0.
            SQD=0.
         DO IJR = 1,NCOF
            WSDV(IJR) = 0.00
            WSDD(IJR) = 0.00
            WSQV(IJR) = 0.00
            WSQD(IJR) = 0.00
         ENDDO
         DO IRAD = 1,NMP1C
          DO I = 1,IMAX
           SDVTH(IRAD,I)=0.00
           SDDTH(IRAD,I)=0.00
           SQVTH(IRAD,I)=0.00
           SQDTH(IRAD,I)=0.00
          ENDDO
         ENDDO
            NVAL=30
            NVALP1=NVAL+1
C
C
C     INDEX OVER BPF HARMONIC NUMBER  -  N
C
         NNCNT     = 0
         JJCNT     = 0
            DO 2800 NN=1,NVALP1
```

```
              N=NN-1
              FLTN=N
 1580         EN=N
C             IF (ABS(F(J)-EN) .LE. 8.0) THEN
            NNCNT = NNCNT+1
            ALD1=ALC
            ALDN=ABS(EN)*ALC
            AL = ALDN
                AL2=AL*AL
                ALSGNB=AL*SGN(FLTN)*B
                BET=EN*BETC
                DEL=DELC*EN
            RZQ=0.5*TPI*SIGR*ABS(EN)*SR/(1.-EMA**2)
            ZQI=0.5*ABS(AL)*CR*SIGR/(1.-EMA**2)
            ZQ=SQRT(RZQ**2+ZQI**2)
            SNQA=SQRT(PI*ZQ*0.5)
            SNQDEN=(1.+SNQA)**2
C
C
C       INITIATE BANDWIDTH SUBDIVISION AND NUMERICAL INTEGRATION
C       FOR 1/3-OCTAVE SPECTRUM CALCULATION
C
                IF (ISKIP .NE. 1) THEN
              HSTRIG  = 0
                  IF (EN .GT. FLO .AND. EN .LT. FHI) THEN
                    FJJ(2)=EN
                HSTRIG = 1
              ELSE
                JJCNT = JJCNT+1
                  END IF
C
            END IF
C
            FM=FJJ(2)
                JJ=1
                DO WHILE (JJ .LE. JJMAX)
              DO JR = 1,NCOF
                 WSUMDV(JJ,JR)=0.00
                 WSUMDD(JJ,JR)=0.00
                 WSUMQV(JJ,JR)=0.00
                 WSUMQD(JJ,JR)=0.00
              ENDDO
              ETARICE = FJJ(JJ)*BPF*DTIP/(12.*SCO(KJI))
                  CHI=FJJ(JJ)*CHIC
                  CHI2=CHI*CHI
              FVAL=FJJ(JJ)
              THE = QDVAL(FVAL,NF,FINT,SPIMPRE,CHECK)
              THI = QDVAL(FVAL,NF,FINT,SPIMPR,CHECK)
              Z2E = QDVAL(FVAL,NF,FINT,SPIMPZ2E,CHECK)
              Z2I = QDVAL(FVAL,NF,FINT,SPIMPZ2,CHECK)
              IF ((NNCNT.EQ.1)) THEN
                 IF((J.EQ.1).OR.(J.EQ.NF)) THEN
                   TRME  = SQRT(Z2E-THE**2)
                   TRMI  = SQRT(Z2I-THI**2)
                   TFREQ = FVAL*BPF
                 ENDIF
              ENDIF
                  SUMDV=0.
                  SUMDD=0.
                  SUMQV=0.
```

```
                  SUMQD=0.
                  THETA=-PI/2.
              NMAX = CHI*CHINC-0.000001
              NMP1 = NMAX+1
              IF ( JJ.EQ.1 ) NMP1L = NMP1
 2345             CONTINUE
C     INDEX OVER RADIAL MODE ORDERS
              DO 2700 IRAD = 1,NMP1
                 ENR = FLOAT(IRAD-1)
                 ENRC = ENR/CHINC
                 ENRC2 = ENRC**2
                 NRAD = IRAD-1
                 CHIN = SQRT ( CHI2-(ENR/CHINC)**2 )
                 RCHI = CHI/CHIN
                 KR    = (ENR*PI)/(BNEW*(1.-HTR)*CHIN)
                 SUMDVR=0.
                 SUMDDR=0.
                 SUMQVR=0.
                 SUMQDR=0.
          THETA=-PI/2.
          DO 1230 I=1,IMAX
            CTH=COS(THETA)
         EMAMC=EMA*RCHI-CTH
         EMAPC=EMA*RCHI+CTH
            IF (I .LE. (NINCO2+1)) THEN
              ZMM(I)=EMAMC
              ZPP(I)=EMAPC
              AEV(I)=CAE/(1.+EMA*CTH)**2
              AED(I)=CAE/(1.-EMA*CTH)**2
            END IF
C
         STH=SIN(THETA)
            TERM=SR1MM2*STH*CR
         TRM =-SR1MM2*STH*SR
            DCV1(I)=(EMAPC*SR-TERM)**2
         SNCU(1,I)=ABS(EMAPC*CR-TRM)*DSNCT
            DCV2(I)=(EMAPC*SR+TERM)**2
         SNCU(2,I)=ABS(EMAPC*CR+TRM)*DSNCT
            DCD1(I)=(EMAMC*SR-TERM)**2
         SNCD(1,I)=ABS(EMAMC*CR-TRM)*DSNCT
            DCD2(I)=(EMAMC*SR+TERM)**2
         SNCD(2,I)=ABS(EMAMC*CR+TRM)*DSNCT
            STHOSR(I)=STH/SR1MM2
         TANANG   =ABS(STH*SR1MM2/(CTH-EMA*RCHI))
         THETOGV  =ATAN(TANANG)
         CALL TRANSOGV ( THETOGV,EMA,TR2 )
         TROGV(I) = TR2
            INDEX=I
            IF (I .GT. (NINCO2+1)) INDEX=IMAX+1-I
            AEVETC(1,I)=AEV(INDEX)*CDP2*DCV1(I)
            AEVETC(2,I)=AEV(INDEX)*CDP2*DCV2(I)
            AEDETC(1,I)=AED(INDEX)*CDP2*DCD1(I)
            AEDETC(2,I)=AED(INDEX)*CDP2*DCD2(I)
            THETA=THETA+DELTH
 1230     END DO
C
C
C     INDEX OVER (I) FOR INTEGRATION OVER KY
C
              THETA=-PI/2.
```

```
                  DO 2600 I=1,IMAX
                CTH   = COS(THETA)
                STH   = SIN(THETA)
                CTH2  = CTH**2
                STH2  = STH**2
                IF ((IRAD.GT.1).OR.(I.NE.NINCO2P1)) THEN
                   CTF   = SQRT (CHI2*STH2+ENRC2*CTH2)
                   CTFR = CHI/CTF
                ELSE
                   CTFR = 1.E+09
                ENDIF
                CTFR2 = CTFR**2
                IKY = I-(NINCO2+1)
                    AKX=BET*TR-CHI/EMA
                AKY=-BET+CHIN*STHOSR(I)
                    INDEX=I
                    IF (I .GT. (NINCO2+1)) INDEX=IMAX+1-I
                ZM=ZMM(INDEX)*CHIN
                ZP=ZPP(INDEX)*CHIN
                    DO 2310 L1=1,2
C
C        INLET TURBULENCE SPECTRUM CALCULATION
C
                      CALL PHICAL(AKX,AKY,CONTR,EL,RSCAL,RVEL,
     &                        PHIXX,PHIXY,PHIYY)
                      TPHIXY=2.*PHIXY
C
C        DIPOLE CONTRIBUTION
C
                      OMR=SIGR*(AKX*CR+AKY*SR)/2.
                      OM=ABS(OMR)
                      CALL FKCAL(OM,AR,SIGR,ELT,EMR,FK)
                      SRF=FK*FK
                      SRF2=2.0*FK
                      OMR=ABS(OMR)
                      PHIT=PHIXX*SR2-TPHIXY*SRCR+PHIYY*CR2
                  PHITS=ABS(PHIT*SRF)
C
                      IF (L1 .EQ. 2) THEN
                   SNZ  =CHIN*SNCU(2,I)
                   SNA  =SQRT(PI*SNZ*0.5)
                   SNDEN=(1.+SNA)**2
                   FNDVM=AEVETC(2,I)*PHITS/SNDEN
                   SNZ  =CHIN*SNCD(2,I)
                   SNA  =SQRT(PI*SNZ*0.5)
                   SNDEN=(1.+SNA)**2
                   FNDDM=AEDETC(2,I)*PHITS*TROGV(I)/SNDEN
                      ELSE
                   SNZ  =CHIN*SNCU(1,I)
                   SNA  =SQRT(PI*SNZ*0.5)
                   SNDEN=(1.+SNA)**2
                   FNDVP=AEVETC(1,I)*PHITS/SNDEN
                   SNZ  =CHIN*SNCD(1,I)
                   SNA  =SQRT(PI*SNZ*0.5)
                   SNDEN=(1.+SNA)**2
                   FNDDP=AEDETC(1,I)*PHITS*TROGV(I)/SNDEN
                      END IF
C
C        QUADRUPOLE CONTRIBUTION
C
```

```
 2060                 ZTERM=ZP
                      AKXA=AKX*AA
                      DO 2200 L2=1,2
                        ZDELAK=ZTERM-DEL-AKXA
                        DEN=(AL2+ZDELAK**2)**2
                        PART=ZTERM*(ZDELAK*A-ALSGNB)+C*ZDELAK*
     &                    CHIN*STHOSR(I)*AA
                        GX=ZTERM*PART
                   GY=CHIN*STHOSR(I)*PART*AA
             TQ=ABS((GX**2*PHIXX+GY**2*PHIYY+GX*GY*TPHIXY)/DEN)
                        IF (L2 .EQ. 2) THEN
                     FNQD=TQ*AED(INDEX)*TROGV(I)
                        ELSE
                          FNQV=TQ*AEV(INDEX)
                        END IF
C
                        ZTERM=ZM
 2200                 END DO
C
                      IF (L1 .EQ. 2) THEN
                        FNQVM=FNQV
                        FNQDM=FNQD
                      ELSE
                        FNQVP=FNQV
                        FNQDP=FNQD
                        AKX=BET*TR+CHI/EMA
                        ZP=-ZP
                        ZM=-ZM
                      END IF
C
 2310               END DO
C
                    FDV=FNDVP+FNDVM
                    FDD=FNDDP+FNDDM
                    FQV=FNQVP+FNQVM
                    FQD=FNQDP+FNQDM
C
                    IF ((I .EQ. 1) .OR. (I .EQ. IMAX)) THEN
                      FDV=FDV/2.
                      FDD=FDD/2.
                      FQV=FQV/2.
                      FQD=FQD/2.
                    END IF
C
                AKYN = CHIN*STHOSR(I)*BNEW
                IF ((NNCNT.EQ.1).AND.(JJ.NE.2)) THEN
                 IF(IABSOR.EQ.0)RICEV(JJ,IRAD,I)=1.00
                 IF(IABSOR.EQ.0)RICED(JJ,IRAD,I)=1.00
                 IF(IABSOR.NE.0)THEN
                  CTH    = COS(THETA)
                  STH    = SIN(THETA)
                  ALP    = ( CTH-RCHI*EMA)/OMM2
                  ALM    = (-CTH-RCHI*EMA)/OMM2
                  KYS    = STH/SR1MM2
                  KTOTP  = (RCHI-EMA*ALP)
                  KTOTM  = (RCHI-EMA*ALM)
                  CPHXP  = ALP/KTOTP
                  CPHXM  = ALM/KTOTM
                  CPHRP  = KR/KTOTP
                  CPHRM  = KR/KTOTM
```

```
                  DENP   = SQRT(CPHXP**2+CPHRP**2)
                  DENM   = SQRT(CPHXM**2+CPHRM**2)
                  CPHYP  = CPHRP/DENP
                  CPHYP2 = CPHYP**2
                  SPHYP  = CPHXP/DENP
                  CPHYM  = CPHRM/DENM
                  CPHYM2 = CPHYM**2
                  SPHYM  = CPHXM/DENM
                  OMSYP  = 1.+EMA*SPHYP
                  TOMSYP = 2.*OMSYP
                  OMSYM  = 1.+EMA*SPHYM
                  TOMSYM = 2.*OMSYM
                  OMSYP2 = OMSYP**2
                  OMSYM2 = OMSYM**2
                  IF ((I.GT.1).AND.(I.LT.IMAX)) THEN
                   TPSIXP = CPHRP/(CPHXP+EMA)
                   TPSIXM = CPHRM/(CPHXM+EMA)
                   NBNP   =  LEXOVD*TPSIXP/(1.-HTR)
                   NBNM   = -LINOVD*TPSIXM/(1.-HTR)
                   RIXP=(Z2E*CPHYP2*OMSYP2-THE*TOMSYP*CPHYP+1.)/
     &                            (Z2E*CPHYP2*OMSYP2+THE*TOMSYP*CPHYP+1.)
                   RIXM=(Z2I*CPHYM2*OMSYM2-THI*TOMSYM*CPHYM+1.)/
     &                           (Z2I*CPHYM2*OMSYM2+THI*TOMSYM*CPHYM+1.)
                   IXP = RIXP**NBNP
                   IXM = RIXM**NBNM
                  ELSE
                   IXP    = 0.00
                   IXM    = 0.00
                  ENDIF
                  RICEV(JJ,IRAD,I) = IXM
                  RICED(JJ,IRAD,I) = IXP
                 ENDIF
                 CALL NEWSUB(RLOW,RUPP,HTR,AKYN,IKY,IRAD,FC)
                 F3D ( JJ,IRAD,I ) = FC
                ENDIF
                IF ((JJCNT.EQ.1).AND.(JJ.EQ.2)) THEN
                 IF(IABSOR.EQ.0)RICEV(JJ,IRAD,I)=1.00
                 IF(IABSOR.EQ.0)RICED(JJ,IRAD,I)=1.00
                 IF(IABSOR.NE.0)THEN
                  CTH    = COS(THETA)
                  STH    = SIN(THETA)
                  ALP    = ( CTH-RCHI*EMA)/OMM2
                  ALM    = (-CTH-RCHI*EMA)/OMM2
                  KYS    = STH/SR1MM2
                  KTOTP  = (RCHI-EMA*ALP)
                  KTOTM  = (RCHI-EMA*ALM)
                  CPHXP  = ALP/KTOTP
                  CPHXM  = ALM/KTOTM
                  CPHRP  = KR/KTOTP
                  CPHRM  = KR/KTOTM
                  DENP   = SQRT(CPHXP**2+CPHRP**2)
                  DENM   = SQRT(CPHXM**2+CPHRM**2)
                  CPHYP  = CPHRP/DENP
                  CPHYP2 = CPHYP**2
                  SPHYP  = CPHXP/DENP
                  CPHYM  = CPHRM/DENM
                  CPHYM2 = CPHYM**2
                  SPHYM  = CPHXM/DENM
                  OMSYP  = 1.+EMA*SPHYP
                  TOMSYP = 2.*OMSYP
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```
                  OMSYM  = 1.+EMA*SPHYM
                  TOMSYM = 2.*OMSYM
                  OMSYP2 = OMSYP**2
                  OMSYM2 = OMSYM**2
                  IF ((I.GT.1).AND.(I.LT.IMAX)) THEN
                   TPSIXP = CPHRP/(CPHXP+EMA)
                   TPSIXM = CPHRM/(CPHXM+EMA)
                   NBNP   =  LEXOVD*TPSIXP/(1.-HTR)
                   NBNM   = -LINOVD*TPSIXM/(1.-HTR)
                   RIXP=(Z2E*CPHYP2*OMSYP2-THE*TOMSYP*CPHYP+1.)/
     &                      (Z2E*CPHYP2*OMSYP2+THE*TOMSYP*CPHYP+1.)
                   RIXM=(Z2I*CPHYM2*OMSYM2-THI*TOMSYM*CPHYM+1.)/
     &                     (Z2I*CPHYM2*OMSYM2+THI*TOMSYM*CPHYM+1.)
                   IXP = RIXP**NBNP
                   IXM = RIXM**NBNM
                  ELSE
                   IXP    = 0.00
                   IXM    = 0.00
                  ENDIF
                  RICEV(JJ,IRAD,I) = IXM
                  RICED(JJ,IRAD,I) = IXP
                 ENDIF
                 CALL NEWSUB(RLOW,RUPP,HTR,AKYN,IKY,IRAD,FC)
                 F3D ( JJ,IRAD,I ) = FC
                ENDIF
                IF ((HSTRIG.EQ.1).AND.(JJ.EQ.2)) THEN
                 IF(IABSOR.EQ.0)RICECV=1.00
                 IF(IABSOR.EQ.0)RICECD=1.00
                 IF(IABSOR.NE.0)THEN
                  CTH    = COS(THETA)
                  STH    = SIN(THETA)
                  ALP    = ( CTH-RCHI*EMA)/OMM2
                  ALM    = (-CTH-RCHI*EMA)/OMM2
                  KYS    = STH/SR1MM2
                  KTOTP  = (RCHI-EMA*ALP)
                  KTOTM  = (RCHI-EMA*ALM)
                  CPHXP  = ALP/KTOTP
                  CPHXM  = ALM/KTOTM
                  CPHRP  = KR/KTOTP
                  CPHRM  = KR/KTOTM
                  DENP   = SQRT(CPHXP**2+CPHRP**2)
                  DENM   = SQRT(CPHXM**2+CPHRM**2)
                  CPHYP  = CPHRP/DENP
                  CPHYP2 = CPHYP**2
                  SPHYP  = CPHXP/DENP
                  CPHYM  = CPHRM/DENM
                  CPHYM2 = CPHYM**2
                  SPHYM  = CPHXM/DENM
                  OMSYP  = 1.+EMA*SPHYP
                  TOMSYP = 2.*OMSYP
                  OMSYM  = 1.+EMA*SPHYM
                  TOMSYM = 2.*OMSYM
                  OMSYP2 = OMSYP**2
                  OMSYM2 = OMSYM**2
                  IF ((I.GT.1).AND.(I.LT.IMAX)) THEN
                   TPSIXP = CPHRP/(CPHXP+EMA)
                   TPSIXM = CPHRM/(CPHXM+EMA)
                   NBNP   =  LEXOVD*TPSIXP/(1.-HTR)
                   NBNM   = -LINOVD*TPSIXM/(1.-HTR)
                   RIXP=(Z2E*CPHYP2*OMSYP2-THE*TOMSYP*CPHYP+1.)/
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```
     &                      (Z2E*CPHYP2*OMSYP2+THE*TOMSYP*CPHYP+1.)
                   RIXM=(Z2I*CPHYM2*OMSYM2-THI*TOMSYM*CPHYM+1.)/
     &                     (Z2I*CPHYM2*OMSYM2+THI*TOMSYM*CPHYM+1.)
                   IXP = RIXP**NBNP
                   IXM = RIXM**NBNM
                  ELSE
                   IXP    = 0.00
                   IXM    = 0.00
                  ENDIF
                  RICECV = IXM
                  RICECD = IXP
                ENDIF
                CALL NEWSUB(RLOW,RUPP,HTR,AKYN,IKY,IRAD,FC)
                F3DF = FC
              ENDIF
              IF ((HSTRIG.NE.1).OR.(JJ.NE.2)) THEN
                 RICECV = RICEV(JJ,IRAD,I)
                 RICECD = RICED(JJ,IRAD,I)
                 F3DF  = F3D ( JJ,IRAD,I )
              ENDIF
              SUMDVR=SUMDVR+FDV*F3DF*RICECV
              SUMDDR=SUMDDR+FDD*F3DF*RICECD
              SUMQVR=SUMQVR+(FQV/SNQDEN)*F3DF*RICECV
              SUMQDR=SUMQDR+(FQD/SNQDEN)*F3DF*RICECD
              FDVTH(JJ,IRAD,I) = FDV*F3DF*RICECV
              FDDTH(JJ,IRAD,I) = FDD*F3DF*RICECD
              FQVTH(JJ,IRAD,I) = FQV*F3DF*RICECV/SNQDEN
              FQDTH(JJ,IRAD,I) = FQD*F3DF*RICECD/SNQDEN
              TJR1  = (1.-1./CTFR2)
              TJR   = FCOF*TJR1
              JR    = 1+INT(TJR)
              IF ( JR.GT.NCOF ) JR = NCOF
              WSUMDV(JJ,JR)=WSUMDV(JJ,JR)+FDVTH(JJ,IRAD,I)
              WSUMDD(JJ,JR)=WSUMDD(JJ,JR)+FDDTH(JJ,IRAD,I)
              WSUMQV(JJ,JR)=WSUMQV(JJ,JR)+FQVTH(JJ,IRAD,I)
              WSUMQD(JJ,JR)=WSUMQD(JJ,JR)+FQDTH(JJ,IRAD,I)
                  THETA=THETA+DELTH
 2600           END DO
              SUMDV=SUMDV+SUMDVR
              SUMDD=SUMDD+SUMDDR
              SUMQV=SUMQV+SUMQVR
              SUMQD=SUMQD+SUMQDR
 2700           CONTINUE

            PROD = CHI2*DELTH
            SNDV=PROD*SUMDV
            SNDD=PROD*SUMDD
                SNQV=SUMQV*DELTH
                SNQD=SUMQD*DELTH
            DO IJR = 1,NCOF
               WSNDV(JJ,IJR)=PROD*WSUMDV(JJ,IJR)
               WSNDD(JJ,IJR)=PROD*WSUMDD(JJ,IJR)
               WSNQV(JJ,IJR)=DELTH*WSUMQV(JJ,IJR)
               WSNQD(JJ,IJR)=DELTH*WSUMQD(JJ,IJR)
            ENDDO
            DO IRAD = 1,NMP1
               DO I = 1,IMAX
                 FDVTH(JJ,IRAD,I) = PROD*FDVTH(JJ,IRAD,I)
                 FDDTH(JJ,IRAD,I) = PROD*FDDTH(JJ,IRAD,I)
                 FQVTH(JJ,IRAD,I) = FQVTH(JJ,IRAD,I)*DELTH
```

```
                   FQDTH(JJ,IRAD,I) = FQDTH(JJ,IRAD,I)*DELTH
                 ENDDO
              ENDDO
              DVP(JJ)=SNDV
                  DDP(JJ)=SNDD
                  QVP(JJ)=SNQV
                  QDP(JJ)=SNQD
              DO IRAD = 1,NMP1
                DO I = 1,IMAX
                  NDVTH(IRAD,I)=FDVTH(JJ,IRAD,I)
                  NDDTH(IRAD,I)=FDDTH(JJ,IRAD,I)
                  NQVTH(IRAD,I)=FQVTH(JJ,IRAD,I)
                  NQDTH(IRAD,I)=FQDTH(JJ,IRAD,I)
                ENDDO
              ENDDO
              DO IJR = 1,NCOF
                 WSNDV1(IJR) = WSNDV(JJ,IJR)
                 WSNDD1(IJR) = WSNDD(JJ,IJR)
                 WSNQV1(IJR) = WSNQV(JJ,IJR)
                 WSNQD1(IJR) = WSNQD(JJ,IJR)
              ENDDO
C
                  IF (ISKIP .NE. 1) THEN
                    DVP(JJ)=DVP(JJ)/FJJ(JJ)
                    DDP(JJ)=DDP(JJ)/FJJ(JJ)
                    QVP(JJ)=QVP(JJ)/FJJ(JJ)
                    QDP(JJ)=QDP(JJ)/FJJ(JJ)
                DO IJR = 1,NCOF
                   WSNDV(JJ,IJR) = WSNDV(JJ,IJR)/FJJ(JJ)
                   WSNDD(JJ,IJR) = WSNDD(JJ,IJR)/FJJ(JJ)
                   WSNQV(JJ,IJR) = WSNQV(JJ,IJR)/FJJ(JJ)
                   WSNQD(JJ,IJR) = WSNQD(JJ,IJR)/FJJ(JJ)
                ENDDO
                  END IF
                  IF (ISKIP .NE. 1) THEN
                DO IRAD = 1,NMP1
                 DO I = 1,IMAX
                  FDVTH(JJ,IRAD,I) = FDVTH(JJ,IRAD,I)/FJJ(JJ)
                  FDDTH(JJ,IRAD,I) = FDDTH(JJ,IRAD,I)/FJJ(JJ)
                  FQVTH(JJ,IRAD,I) = FQVTH(JJ,IRAD,I)/FJJ(JJ)
                  FQDTH(JJ,IRAD,I) = FQDTH(JJ,IRAD,I)/FJJ(JJ)
                 ENDDO
                ENDDO
                  END IF
C
                  JJ=JJ+1
                END DO
C                    IF (JJMAX.EQ.3) NNCNT = 0
C
                IF (ISKIP .NE. 1) THEN
                  IF (JJMAX .EQ. 3) THEN
                CALL EXINT(DVP(1),DVP(2),FLO,FM,SNDV1)
                CALL EXINT(DVP(2),DVP(3),FM,FHI,SNDV2)
                    SNDV=SNDV1+SNDV2
                DO IJR = 1,NCOF
                   W1 = WSNDV(1,IJR)
                   W2 = WSNDV(2,IJR)
                   W3 = WSNDV(3,IJR)
                   CALL EXINT(W1,W2,FLO,FM,R1)
                   CALL EXINT(W2,W3,FM,FHI,R2)
```

```
   WSNDV1(IJR) = R1+R2
ENDDO
CALL EXINT(DDP(1),DDP(2),FLO,FM,SNDD1)
CALL EXINT(DDP(2),DDP(3),FM,FHI,SNDD2)
    SNDD=SNDD1+SNDD2
DO IJR = 1,NCOF
   W1 = WSNDD(1,IJR)
   W2 = WSNDD(2,IJR)
   W3 = WSNDD(3,IJR)
   CALL EXINT(W1,W2,FLO,FM,R1)
   CALL EXINT(W2,W3,FM,FHI,R2)
   WSNDD1(IJR) = R1+R2
ENDDO
CALL EXINT(QVP(1),QVP(2),FLO,FM,SNQV1)
CALL EXINT(QVP(2),QVP(3),FM,FHI,SNQV2)
    SNQV=SNQV1+SNQV2
DO IJR = 1,NCOF
   W1 = WSNQV(1,IJR)
   W2 = WSNQV(2,IJR)
   W3 = WSNQV(3,IJR)
   CALL EXINT(W1,W2,FLO,FM,R1)
   CALL EXINT(W2,W3,FM,FHI,R2)
   WSNQV1(IJR) = R1+R2
ENDDO
CALL EXINT(QDP(1),QDP(2),FLO,FM,SNQD1)
CALL EXINT(QDP(2),QDP(3),FM,FHI,SNQD2)
    SNQD=SNQD1+SNQD2
DO IJR = 1,NCOF
   W1 = WSNQD(1,IJR)
   W2 = WSNQD(2,IJR)
   W3 = WSNQD(3,IJR)
   CALL EXINT(W1,W2,FLO,FM,R1)
   CALL EXINT(W2,W3,FM,FHI,R2)
   WSNQD1(IJR) = R1+R2
ENDDO
  ELSE
    CALL EXINT(DVP(1),DVP(2),FLO,FHI,SNDV)
DO IJR = 1,NCOF
   W1 = WSNDV(1,IJR)
   W2 = WSNDV(2,IJR)
   CALL EXINT(W1,W2,FLO,FHI,R1)
   WSNDV1(IJR) = R1
ENDDO
    CALL EXINT(DDP(1),DDP(2),FLO,FHI,SNDD)
DO IJR = 1,NCOF
   W1 = WSNDD(1,IJR)
   W2 = WSNDD(2,IJR)
   CALL EXINT(W1,W2,FLO,FHI,R1)
   WSNDD1(IJR) = R1
ENDDO
    CALL EXINT(QVP(1),QVP(2),FLO,FHI,SNQV)
DO IJR = 1,NCOF
   W1 = WSNQV(1,IJR)
   W2 = WSNQV(2,IJR)
   CALL EXINT(W1,W2,FLO,FHI,R1)
   WSNQV1(IJR) = R1
ENDDO
    CALL EXINT(QDP(1),QDP(2),FLO,FHI,SNQD)
DO IJR = 1,NCOF
   W1 = WSNQD(1,IJR)
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                   W2 = WSNQD(2,IJR)
                   CALL EXINT(W1,W2,FLO,FHI,R1)
                   WSNQD1(IJR) = R1
                ENDDO
                  END IF
C
                END IF
C
                IF (ISKIP .NE. 1) THEN
                  IF (JJMAX .EQ. 3) THEN
                DO IRAD = 1,NMP1
                 DO I = 1,IMAX
                  DVP(1) = FDVTH(1,IRAD,I)
                  DDP(1) = FDDTH(1,IRAD,I)
                  QVP(1) = FQVTH(1,IRAD,I)
                  QDP(1) = FQDTH(1,IRAD,I)
                  DVP(2) = FDVTH(2,IRAD,I)
                  DDP(2) = FDDTH(2,IRAD,I)
                  QVP(2) = FQVTH(2,IRAD,I)
                  QDP(2) = FQDTH(2,IRAD,I)
                  DVP(3) = FDVTH(3,IRAD,I)
                  DDP(3) = FDDTH(3,IRAD,I)
                  QVP(3) = FQVTH(3,IRAD,I)
                  QDP(3) = FQDTH(3,IRAD,I)
                  CALL EXINT(DVP(1),DVP(2),FLO,FM,SNDV1)
                  CALL EXINT(DVP(2),DVP(3),FM,FHI,SNDV2)
                  NDVTH(IRAD,I)    = SNDV1+SNDV2
                  CALL EXINT(DDP(1),DDP(2),FLO,FM,SNDD1)
                  CALL EXINT(DDP(2),DDP(3),FM,FHI,SNDD2)
                  NDDTH(IRAD,I)    = SNDD1+SNDD2
                  CALL EXINT(QVP(1),QVP(2),FLO,FM,SNQV1)
                  CALL EXINT(QVP(2),QVP(3),FM,FHI,SNQV2)
                  NQVTH(IRAD,I)    = SNQV1+SNQV2
                  CALL EXINT(QDP(1),QDP(2),FLO,FM,SNQD1)
                  CALL EXINT(QDP(2),QDP(3),FM,FHI,SNQD2)
                  NQDTH(IRAD,I)    = SNQD1+SNQD2
                 ENDDO
                ENDDO
               ELSE
                DO IRAD = 1,NMP1
                 DO I = 1,IMAX
                  DVP(1) = FDVTH(1,IRAD,I)
                  DDP(1) = FDDTH(1,IRAD,I)
                  QVP(1) = FQVTH(1,IRAD,I)
                  QDP(1) = FQDTH(1,IRAD,I)
                  DVP(2) = FDVTH(2,IRAD,I)
                  DDP(2) = FDDTH(2,IRAD,I)
                  QVP(2) = FQVTH(2,IRAD,I)
                  QDP(2) = FQDTH(2,IRAD,I)
                  CALL EXINT(DVP(1),DVP(2),FLO,FHI,DUM)
                  NDVTH(IRAD,I)    = DUM
                  CALL EXINT(DDP(1),DDP(2),FLO,FHI,DUM)
                  NDDTH(IRAD,I)    = DUM
                  CALL EXINT(QVP(1),QVP(2),FLO,FHI,DUM)
                  NQVTH(IRAD,I)    = DUM
                  CALL EXINT(QDP(1),QDP(2),FLO,FHI,DUM)
                  NQDTH(IRAD,I)    = DUM
                 ENDDO
                ENDDO
               END IF
```

```
C
                END IF
C
                IF (N .GT. 0) THEN
                  SDV=SDV+4.*SNDV
                  SDD=SDD+4.*SNDD
                  SQV=SQV+4.*SNQV
                  SQD=SQD+4.*SNQD
              DO IJR = 1,NCOF
                 WSDV(IJR)=WSDV(IJR)+4.*WSNDV1(IJR)
                 WSDD(IJR)=WSDD(IJR)+4.*WSNDD1(IJR)
                 WSQV(IJR)=WSQV(IJR)+4.*WSNQV1(IJR)
                 WSQD(IJR)=WSQD(IJR)+4.*WSNQD1(IJR)
              ENDDO
                ELSE
                  SDV=SDV+SNDV
                  SDD=SDD+SNDD
                  SQV=SQV+SNQV
                  SQD=SQD+SNQD
              DO IJR = 1,NCOF
                 WSDV(IJR)=WSDV(IJR)+WSNDV1(IJR)
                 WSDD(IJR)=WSDD(IJR)+WSNDD1(IJR)
                 WSQV(IJR)=WSQV(IJR)+WSNQV1(IJR)
                 WSQD(IJR)=WSQD(IJR)+WSNQD1(IJR)
              ENDDO
                END IF
                IF (N .GT. 0) THEN
C                DO IRAD = 1,NMP1L
             DO IRAD = 1,NMP1
              DO I = 1,IMAX
               SDVTH(IRAD,I)=SDVTH(IRAD,I)+4.*NDVTH(IRAD,I)
               SDDTH(IRAD,I)=SDDTH(IRAD,I)+4.*NDDTH(IRAD,I)
               SQVTH(IRAD,I)=SQVTH(IRAD,I)+4.*NQVTH(IRAD,I)
               SQDTH(IRAD,I)=SQDTH(IRAD,I)+4.*NQDTH(IRAD,I)
              ENDDO
             ENDDO
                ELSE
C                DO IRAD = 1,NMP1L
             DO IRAD = 1,NMP1
              DO I = 1,IMAX
               SDVTH(IRAD,I)=SDVTH(IRAD,I)+NDVTH(IRAD,I)
               SDDTH(IRAD,I)=SDDTH(IRAD,I)+NDDTH(IRAD,I)
               SQVTH(IRAD,I)=SQVTH(IRAD,I)+NQVTH(IRAD,I)
               SQDTH(IRAD,I)=SQDTH(IRAD,I)+NQDTH(IRAD,I)
              ENDDO
             ENDDO
                END IF
C
C             END IF
C
 2800       END DO
C
            SDV=SDV*EMRC
            SDD=SDD*EMRC
            SQV=SQV*EMRC
            SQD=SQD*EMRC
            STV=SDV+SQV
            STD=SDD+SQD
         DO IJR = 1,NCOF
            WSDV(IJR)=WSDV(IJR)*EMRC
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```
            WSDD(IJR)=WSDD(IJR)*EMRC
            WSQV(IJR)=WSQV(IJR)*EMRC
            WSQD(IJR)=WSQD(IJR)*EMRC
            WSTV(IJR)=WSDV(IJR)+WSQV(IJR)
            WSTD(IJR)=WSDD(IJR)+WSQD(IJR)
         ENDDO
         TRMDV1= 0.00
         TRMDD1= 0.00
         TRMQV1= 0.00
         TRMQD1= 0.00
         TRMV1 = 0.00
         TRMD1 = 0.00
         DO I = 1,NCOF
            TRMDV1= WSDV(I)+TRMDV1
            TRMDD1= WSDD(I)+TRMDD1
            TRMQV1= WSQV(I)+TRMQV1
            TRMQD1= WSQD(I)+TRMQD1
            TRMV1 = WSTV(I)+TRMV1
            TRMD1 = WSTD(I)+TRMD1
         ENDDO
C           DO IRAD = 1,NMP1L
         DO IRAD = 1,NMP1
          DO I = 1,IMAX
           SDVTH(IRAD,I)=SDVTH(IRAD,I)*EMRC
           SDDTH(IRAD,I)=SDDTH(IRAD,I)*EMRC
           SQVTH(IRAD,I)=SQVTH(IRAD,I)*EMRC
           SQDTH(IRAD,I)=SQDTH(IRAD,I)*EMRC
           STVTH(IRAD,I)=SDVTH(IRAD,I)+SQVTH(IRAD,I)
           STDTH(IRAD,I)=SDDTH(IRAD,I)+SQDTH(IRAD,I)
          ENDDO
         ENDDO
            FHZ=FOB(J)
         FHZZ=FOB(J)
            DBNB=0.0
         IF (J.EQ.NTOBNI) THEN
            WRITE(13,*) '    '
            POWMAX  = STVTH(1,1)+SDVTH(1,1)
            ICOUNT = 0
C              DO IRAD = 1,NMP1L
            DO IRAD = 1,NMP1
             DO I = 1,IMAX
               ICOUNT = ICOUNT+1
               CTFRATN ( ICOUNT ) = CTFRAT ( IRAD,I )
               POWTOT  ( ICOUNT ) = STVTH ( IRAD,I ) +
     &                                  STDTH ( IRAD,I )
               IF(POWTOT(ICOUNT).GT.POWMAX)
     &               POWMAX = POWTOT( ICOUNT )
             ENDDO
            ENDDO
            DO ISP = 1,ICOUNT
              IPERM ( ISP ) = ISP
            ENDDO
            CALL SVRGP ( ICOUNT,CTFRATN,CTFRATO,IPERM )
            DO IRAD = 1,NMP1
             DO I = 1,IMAX
               CTFINT  = CTFRAT ( IRAD,I )
               POWINT  = STVTH ( IRAD,I ) + STDTH ( IRAD,I )
               IF (POWINT.GT.0.00) THEN
                 POWDB   = 10.00*ALOG10(POWINT/POWMAX)
               ELSE
```

```
                 POWDB   = -1.00E+06
               ENDIF
C                  WRITE(13,*) CTFINT,POWDB
             ENDDO
            ENDDO
            DO ISP = 1,ICOUNT
              CTFINT = CTFRATO ( ISP )
              IREL   = IPERM ( ISP )
              POWRAT = POWTOT ( IREL )/ POWMAX
              IF (POWRAT.GT.0.00) THEN
                 POWDB   = 10.00*ALOG10(POWRAT)
               ELSE
                 POWDB   = -1.00E+06
               ENDIF
C                 WRITE(13,* ) CTFINT , POWDB
            ENDDO
            SUMCHKDV = 0.00
            SUMCHKDD = 0.00
            SUMCHKQV = 0.00
            SUMCHKQD = 0.00
            SUMCHKV  = 0.00
            SUMCHKD  = 0.00
C              DO IRAD = 1,NMP1L
            DO IRAD = 1,NMP1
             DO I = 1,IMAX
               SUMCHKDV = SUMCHKDV+SDVTH(IRAD,I)
               SUMCHKDD = SUMCHKDD+SDDTH(IRAD,I)
               SUMCHKQV = SUMCHKQV+SQVTH(IRAD,I)
               SUMCHKQD = SUMCHKQD+SQDTH(IRAD,I)
               SUMCHKV  = SUMCHKV+STVTH(IRAD,I)
               SUMCHKD  = SUMCHKD+STDTH(IRAD,I)
             ENDDO
            ENDDO
            WRITE(13,*) '                       SUMCHK   ',
     &                    '     SUM'
            WRITE(13,*)'  '
            WRITE(13,*) 'UPSTR DIPOLE CHECKS ',SUMCHKDV,SDV,TRMDV1
            WRITE(13,*) 'DNSTR DIPOLE CHECKS ',SUMCHKDD,SDD,TRMDD1
            WRITE(13,*) 'UPSTR QUADRU CHECKS ',SUMCHKQV,SQV,TRMQV1
            WRITE(13,*) 'DNSTR QUADRU CHECKS ',SUMCHKQD,SQD,TRMQD1
            WRITE(13,*) 'UPSTR TOTAL  CHECKS ',SUMCHKV,STV,TRMV1
            WRITE(13,*) 'DNSTR TOTAL  CHECKS ',SUMCHKD,STD,TRMD1
         ENDIF
C
            IF (BW .LE. 0.0) THEN
              IF (F(J) .LT. 0.5) DBNB= -6.35
            ELSE
              DBNB=10.0*ALOG10(BW/FOB(J))
            END IF
         DBNBT = 10.**(0.1*DBNB)
C
            SDVDB=10.0*ALOG10(SDV) + DBL + DBNB
            SDDDB=10.0*ALOG10(SDD) + DBL + DBNB
            SQVDB=10.0*ALOG10(SQV) + DBL + DBNB
            SQDDB=10.0*ALOG10(SQD) + DBL + DBNB
            STVDB=10.0*ALOG10(STV) + DBL + DBNB
            STDDB=10.0*ALOG10(STD) + DBL + DBNB
         IF ( J.EQ.NTOBNI ) WRITE(13,* ) ' OBN = ',TOBN(J)
         IF ( J.EQ.NTOBNI ) WRITE(13,* ) '  '
         DO IJR = 1,NCOF
```

```
                WUP(IJR,J) = WUP(IJR,J)+ DBNBT*WSTV(IJR)*WATCON
                WDN(IJR,J) = WDN(IJR,J)+ DBNBT*WSTD(IJR)*WATCON
             ENDDO
               PVT(J)=10.0*ALOG10(10.0**(PVT(J)/10.0)+
     &                  10.0**(STVDB/10.0))
               PDT(J)=10.0*ALOG10(10.0**(PDT(J)/10.0)+
     &                  10.0**(STDDB/10.0))
C
             FMUG=F(J)/F0MUG
             CALL MUGRIDGE(FMUG,DBMUG,IBW,BW,FHZZ,TBLDB)
             MDB(J)=10.0*ALOG10(10.0**(MDB(J)/10.0)+
     &                  10.0**(TBLDB/10.0))
C
               WRITE(12,116) FHZ,F(J),SDVDB,SDDDB,SQVDB,
     &                       SQDDB,STVDB,STDDB,TBLDB
C
 3000     END DO
C
 1949   END DO
C
C
C     FAN TOTAL POWER SPECTRUM
C
            WRITE(12,132)
         TPR    =  STPRIN(MIDSTR)
         TABS   =  (SCO(MIDSTR)/49.0422)**2
         PABS   =  53.3*TABS*RHO/144.
         PTOT   =  PABS*TPR
         T11    =  TPR**G1OVG-1.
         TTOT   =  TABS*(1.+T11/ETAFAN)
         FMACH  = -ABS(SEMA(MIDSTR))
         FMACHS = -ABS(MACHS)
         FMACHD =  ABS(SEMA(MIDSTR))
         XM     =  FMACHD
         XM2    =  XM**2
         AOAST  =  (TDGP1*(1.+G1OV2*XM2))**GEXP/XM
         ANOZRATC = 1./AOAST
         IF ( ANOZRATC.GT.ANOZRAT ) ANOZRAT = 1.02*ANOZRATC
         FMACH2 =  ABS(MACHS)
            DO 101 J=1,NF
C             FHZ=FOB(J)
           ETARICE = FOB(J)*DTIP/(12.*SCO(MIDSTR))
              PVDBT=PVT(J)
              PDDBT=PDT(J)
           PTDB=10.0*ALOG10(10.0**(PVDBT/10.0)+
     &             10.0**(PDDBT/10.0))
           PTDBM=MDB(J)+3.0103
           WRITE(12,134) NINT(TOBN(J)), F(J) ,PVDBT,PDDBT,PTDB,PTDBM
           DO IJR = 1,NCOF
              WSUMIN(IJR) = WUP (IJR,J)
           END DO
          CALL BBRDCFIN(TABS,PABS,RADMIC,ISIDELN,DTIP,ALIP,BLIP,FMACH,
     &FMACHS,NCOF,WSUMIN,ETARICE,DELANG,NANGLE,ANGLE,
     &SPLOUT,SPLTL,WATTS,WATTRAN)
           WATTDB = 130.00 + 10.00*ALOG10(WATTS)
           WRITE(13,*)' INPOWER CHECK IN DB',WATTDB,TOBN(J),PVDBT
           NANGI   = NANGLE
           DO IANG = 1,NANGI
              SPLVDB(IANG) = SPLOUT(IANG)
           ENDDO
```

```
          DO IJR = 1,NCOF
             WSUMIN(IJR) = WDN (IJR,J)
          END DO
         CALL BBRDCFEX(TTOT,PTOT,TABS,PABS,HTR,ANOZRAT,RADMIC,
        & ISIDELN,DTIP,DJET,FMACHD,FMACH1,FMACH2,NCOF,WSUMIN,DELANG,
        & ETARICE,NANGLE,ANGLE,SPLOUT,SPLTL,WATTS,WATTRAN,FMACHN,
        & COFMIN)
          WATTDB = 130.00 + 10.00*ALOG10(WATTS)
          WRITE(13,*)' EXPOWER CHECK IN DB',WATTDB,TOBN(J),PDDBT
          NANG    = NANGLE
          DO IANG = 1,NANG
             II           = NANGLE+1-IANG
             SPLDDB(IANG) = SPLOUT(II)
             ANGLEO(IANG) = ANGLE(II)
             IF ( IANG.GT.NANGI ) SPLVDB (IANG ) = -150.00
             P2IN         = 10.**(0.1*SPLVDB(IANG))
             P2EX         = 10.**(0.1*SPLDDB(IANG))
             SPLDBT(IANG) = 10.*ALOG10(P2IN+P2EX)
          ENDDO
          IF ( J.EQ.NTOBNI ) THEN
             DO IANG = 1,NANG
               IF ( IANG.EQ.1 ) WRITE(13,*)' TOTAL OVER ALL STRIPS'
               IF ( IANG.EQ.1 ) WRITE(13,*)
               IF ( IANG.EQ.1 ) WRITE(13,150)
               IF ( IANG.EQ.1 ) WRITE(13,*)
               WRITE(13,160)ANGLEO(IANG),SPLVDB(IANG),
        &                    SPLDDB(IANG),SPLDBT(IANG)
             ENDDO
          ENDIF
C
C          .. Write data to spl plot file
C
             FREQNCY  = 10.00**(0.1*TOBN(J))
             DO IANG = 1,NANG
            IF ( IANG.EQ.1 ) WRITE(14,148)INT(FREQNCY),INT(TOBN(J))
            IF ( IANG.EQ.1 ) WRITE(14,*)
            IF ( IANG.EQ.1 ) WRITE(14,150)
            IF ( IANG.EQ.1 ) WRITE(14,*)
            WRITE(14,160)ANGLEO(IANG),SPLVDB(IANG),
        &                    SPLDDB(IANG),SPLDBT(IANG)
          ENDDO
C
 101    END DO
C
         END DO
         GO TO 9999
C
C****    ERROR DURING READ
C
 1000 WRITE(12,1002)
C
C     FORMAT SECTION
C
106   FORMAT(/,27H                CASE NUMBER,I4,5H   OF,I4)
108   FORMAT(//16X,23HPROGRAM *** ROTIN2M ***//
     &13X,29HRESPONSE OF AN ISOLATED ROTOR
     &//12X,32HTO INGESTION OF INLET TURBULENCE)
110   FORMAT(/,'   *** COMPONENT PWL CONTRIBUTIONS  -  DB RE 10**(-13)',
    & ' WATTS ***')
111   FORMAT(/,'                         ONE THIRD OCTAVE')
```

```
112   FORMAT(/,'     FREQUENCY        DIPOLE        QUADRUPOLE',
     & '         TOTAL')
113   FORMAT(/,'                    BANDWIDTH = ',F6.1,' Hz')
114   FORMAT('   HERTZ   F/BPF   INLET EXHAUST   INLET EXHAUST   INLET',
     & ' EXHAUST MUGRIDGE')
116   FORMAT(I8,F8.4,7F8.1)
118   FORMAT(//24H***** STRIP AREA NUMBER ,I4)
120   FORMAT(//52H     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD)
122   FORMAT(2F9.3,F9.4,F9.2,F8.3,F7.2)
124   FORMAT(//53H     GAM     RHO        C      SDIA    SPERC      TPR)
125   FORMAT(//53H     RPM        NB     NBSTD    HTR    DTIP      CHDR)
126   FORMAT(F9.3,F9.4,F9.0,F9.3,F8.3,F9.3)
127   FORMAT(F9.1,I9,I9,F9.3,F8.3,F9.3)
128   FORMAT(//3X,6H  CLW=F08.4,4X,6HCLINC=F08.4,4X,6HCLINP=F08.4)
132   FORMAT(///12X,24HFAN TOTAL POWER SPECTRUM//
     &7X,4HTOBN,8X,5HF/BPF,6X,6HPWL-UP,6X,6HPWL-DN,5X,7HPWL-TOT,4X,
     &8HMUGR-TOT//)
134   FORMAT(I11,F13.4,4F12.2)
136   FORMAT(//53H     EMR     RSCAL    RVEL      ELT      TIT      AR )
138   FORMAT(F9.3,F9.2,F9.4,F9.3,F9.4,F9.3)
140   FORMAT(/,' STREAMLINE LIFT COEFFICIENT CALCULATED U
     &SING SCLOPT= ',I2)
148   FORMAT(/,1x,'FREQUENCY =',I6,',  OBN =',I3)
150   FORMAT(1X,'ANGLE',1X,'INL SPL',1X,'EXH SPL',1X,'TOT SPL')
160   FORMAT(1X,F5.1,1X,3(1X,F7.1))
1002  FORMAT(//6X,41H** INPUT ERROR ** PROCEEDING TO NEXT CASE//)
C
 9999 CLOSE (UNIT=5)
      CLOSE (UNIT=6)
10001 CONTINUE
C
      STOP
      END
```

```
C
C        FKCAL        CALCULATION OF FK
C
      SUBROUTINE FKCAL(OM,AR,SIGR,ELT,EMR,FK)
C
      PI=3.1415926
C
      IF(EMR.GT.0.8) GOTO 15
      BETASQ=1.0-EMR*EMR
      OMS=OM/BETASQ
      AMU=EMR*OMS
      IF(AMU.GT.1.0) GOTO 15
      BETA=SQRT(BETASQ)
      OMK=OMS*EMR*EMR
      SEARS=SQRT(1.0/(2.0*PI*OMS+1.0/(1.0+2.4*OMS)))
      SEARS=SEARS/BETA
      SEARS=SEARS*SQRT(1.0-(0.5*OMK)**2)
      GOTO 25
   15 CONTINUE
      EX=2.0*EMR*OM/(1.0+EMR)
      Z =SQRT(2.0*EX/PI)
      CALL FRESNL(Z,C2X,S2X)
      SEARS=1.0/(PI*OM)
      SEARS=SEARS*SQRT(2.0*(C2X**2+S2X**2)/EMR)
   25 CONTINUE
      ELTOH=ELT/(AR*SIGR)
```

```
      A=1.0/(2.0*ELTOH)
      ASQ=A*A
      BSQ=(AR**2)*(OM**2+2.0/PI**2)
      B=SQRT(BSQ)
      DEN=BSQ-ASQ
      ANUM=0.0
C
      IF (A .LE. 25.0) ANUM=EXP(-2.0*A) -1.0
      ACON=ANUM/DEN
      BNUM=0.0
C
      IF (B .LE. 25.0) BNUM=EXP(-2.0*B) -1.0
      BCON=BNUM/DEN
      FKSQ=1.0/A + 0.5*(BSQ/ASQ)*ACON - 0.5*(A/B)*BCON
      AFKSQ=ABS(FKSQ)
      FK=SEARS*SQRT(AFKSQ)
C
      RETURN
      END
```

```
C
C        PHICAL     CALCULATION OF PHIXX, PHIXY, AND PHIYY
C
      SUBROUTINE PHICAL(AKX,AKY,CONTR,EL,RSCAL,RVEL,PHIXX,PHIXY,PHIYY)
C
      PI=3.1415926
      RVEL2=RVEL**2
      RSCAL2=RSCAL**2
      C=CONTR
      IF(C.LE.0.0) C=1.0
      EPS=1.0/C**3
      OMEPS=1.0-EPS
      OMEPS2=OMEPS**2
C
      ELA=EL
      ELT=EL/RSCAL
      AK1=AKX*C
      AK2=AKY/SQRT(C)
      AKNX=AK1*ELA
      AKNY=AK2*ELT
      AKNX2=AKNX**2
      AKNY2=AKNY**2
C
      ALT2=1.0+AKNX2+AKNY2
      ALT=SQRT(ALT2)
      RA5=1.0/ALT**5
      A=ALT/ELT
C
      FPHIYY=2.0*RVEL2-1.0/RSCAL2
      IF (C .LE. 1.01 .AND. C .GE. 0.99) THEN
C
C     ANALYTIC TWO-DIMENSIONAL SPECTRA FOR CONTRACTION RATIO = 1.0
C
        CPHIXX=ELT*ELA*RA5/(4.0*PI)
        CPHIXY=-3.0*CPHIXX/RSCAL
        CPHIYY=CPHIXX
C
        PHIXX=CPHIXX*(3.0*AKNY2+ALT2)
        PHIXY=CPHIXY*(AKNX*AKNY)
        PHIYY=CPHIYY*(3.0*AKNX2/RSCAL2+ALT2*FPHIYY)
```

```
          RETURN
        END IF
C
C     NUMERICAL INTEGRATION OVER K3 FOR CONTRACTION RATIO .NE. 1.0
C
      RC2 =1.0/C**2
      RSQC=1.0/SQRT(C)
      CPHI=4.0*SQRT(C)*ELA*ELT/PI**2
      PHI11=0.0
      PHI12=0.0
      PHI22=0.0
      DELTH=PI/36.
      CPHI=CPHI*RA5*DELTH
C
      DO 30 I=1,18
        FI=I-1
        TH=FI*DELTH
        CTH4=COS(TH)**4
        AK3=A*SIN(TH)/COS(TH)
        AKNZ=AK3*ELT
        AKNZ2=AKNZ**2
        AKNT2=AKNY2+AKNZ2
        GAM11=AKNT2
        GAM12=-AKNX*AKNY/RSCAL
        GAM22=AKNX2/RSCAL2+AKNZ2*FPHIYY
        B2=EPS*AK1**2+AK2**2+AK3**2
C
        IF (B2 .LT. 1.0E-05) THEN
          TERM11=CTH4*GAM11
          TERM12=CTH4*GAM12
          TERM22=CTH4*GAM22
        ELSE
          RB2=1.0/B2
          B4=B2**2
          RB4=1.0/B4
          TERM11=CTH4*RC2*GAM11*(1.0+AK1**2*OMEPS*RB2)**2
          TERM12=CTH4*RSQC*(GAM12+RB2*OMEPS*AK1*(GAM11*AK2+GAM12*AK1)
     &      +RB4*OMEPS2*AK1**3*AK2*GAM11)
          TERM22=CTH4*C*(GAM22+2.0*RB2*OMEPS*AK1*AK2*GAM12
     &      +RB4*OMEPS2*((AK1*AK2)**2)*GAM11)
        END IF
C
        IF (I .LE. 1) THEN
          TERM11=0.5*TERM11
          TERM12=0.5*TERM12
          TERM22=0.5*TERM22
        END IF
C
        PHI11=PHI11+TERM11
        PHI12=PHI12+TERM12
        PHI22=PHI22+TERM22
   30 END DO
C
      PHIXX=PHI11*CPHI
      PHIXY=PHI12*CPHI
      PHIYY=PHI22*CPHI
C
      RETURN
      END
```

```
C
C       EXINT      SUBROUTINE EXINT  -  EXPONENTIAL CURVE INTEGRATION
C
      SUBROUTINE EXINT(Y1,Y2,X1,X2,YINT)
C
C
      YMAX=AMAX1(Y1,Y2)
      YMIN=AMIN1(Y1,Y2)
      DELX=ABS(X1-X2)
      YINT=YMAX*DELX
      IF (YMIN.EQ.00) YINT =  0.5*YINT
      IF (YMIN.EQ.00) GO TO 100
C
      DELY=ALOG(YMAX/YMIN)
      IF (DELY .GE. 0.01) THEN
        COR1=(1.0-YMIN/YMAX)/DELY
        X   =SQRT(YMAX/YMIN-1.0)
        COR2=(ATAN(X))/X
        COR =SQRT(COR1*COR2)
        YINT=YINT*COR
      END IF
C
  100 CONTINUE
      RETURN
      END
```

```
C
C        SGN         SIGN OF A FUNCTION OR PARAMETER
C
      FUNCTION SGN(X)
C
      IF (X .EQ. 0.) THEN
        SGN=0.
      ELSE
        SGN=X/ABS(X)
      END IF
C
      RETURN
      END
```

```
C
C        FRESNL      FRESNEL INTEGRAL FUNCTIONS C(Z) AND S(Z)
C
      SUBROUTINE FRESNL(Z,C,S)
C
      PI=3.1415926
      X =0.5*PI*Z*Z
      COSX=COS(X)
      SINX=SIN(X)
C
      TOP=1.0+0.926*Z
      BOT=2.0+Z*(1.792+3.104*Z)
      F  =TOP/BOT
C
      TOP=1.0
      BOT=2.0+Z*(4.142+Z*(3.492+6.670*Z))
      G  =TOP/BOT
```

```
C
      C  =  0.5 + F*SINX - G*COSX
      S  =  0.5 - F*COSX - G*SINX
C
      RETURN
      END


C
      SUBROUTINE MUGRIDGE ( FMUG,DBMUG,IBW,BW,FHZZ,TBLDB )
      RAL2=1./ALOG(2.)
      IF(FMUG.LE.1.)TBLDB=DBMUG+3.0*ALOG(FMUG)*RAL2
      IF((FMUG.GE.1.).AND.(FMUG.LE.2.))TBLDB=DBMUG
      IF((FMUG.GE.2.).AND.(FMUG.LE.4.))TBLDB=DBMUG-3.0*ALOG(.5*FMUG)
     &                                      *RAL2
      IF(FMUG.GE.4.)TBLDB=DBMUG-3.-8.*ALOG(.25*FMUG)*RAL2
      IF(IBW.EQ.1)TBLDB=TBLDB+6.3533+4.342945*ALOG(BW/FHZZ)
      RETURN
      END


      SUBROUTINE TRANSOGV ( THETA,M,TR2 )
      REAL M
      CTH    = COS(THETA)
      STH    = SIN(THETA)
      DENTH  = 1.+M**2+2.*M*CTH
      CPHI   = (-CTH*(1.+M**2)-2.*M)/DENTH
      SPHI   = (1.-M**2)*STH/DENTH
      DENPHI = (1.-M**2)*(1.+M*CTH)/DENTH
      TR     = (CTH-CPHI)*(1.+M*CTH)/(CTH-CPHI+M*(1.-CTH*CPHI))
      TR2    = TR**2
      RETURN
      END


C
      SUBROUTINE NEWSUB ( RLOW,RUPP,HTR,AKYN,IKY,NR,F3DB )
C
      ord     = abs(akyn)*(1.+htr)/2.
C
      N         = NR-1
      CALL SUB3D ( AKYN,IKY,HTR,RLOW,RUPP,N,F3DB )
      RETURN
      END


C
      SUBROUTINE SUB3D ( KY,IKY,SIG,RL,RU,N,f3d1 )
      REAL KY,KMN,kmn2,kmns
      if ( (iky.eq.0).and.(n.eq.0) ) then
       f3d1 = (ru**2-rl**2)/(1.-sig**2)
       go to 100
      endif
      pi      = 3.14159265
      enc     = pi*float(n)
      kmn     = sqrt ( ky**2+(enc/(1.-sig))**2 )
      kmns    = kmn*sig
      kmn2    = kmn**2
      sig2    = sig**2
      ord     = abs(ky)*(1.+sig)/2.
```

```
      call simp ( rl,ru,kmn,sig,ord,cnn )
      call simp1 ( kmn,sig,ord,dencn1 )
      f3d1    = ( 2.*cnn**2/dencn1 )/(ru**2-rl**2)
  100 continue
      return
      end
```

```
c
      SUBROUTINE SIMP ( RL,RU,KMN,SIG,ORD,RES )
      REAL KMN
c     # of points for Simpson’s rule (minimum value 7:also needs to be odd)
c     # of points determined assuming period of ”2*pi.”This must be
c     reflected in rescaling of argument as below
      a       = kmn*rl
      b       = kmn*ru
      args    = kmn*sig
      factor  = 1./kmn**2
c     # of points for Simpson’s rule (minimum value 7:also needs to be odd)
pi      = 3.14159265
      rint    = (b-a)
      npm1    = 5.*(rint/pi)
      np      = 2*(npm1/2)+1
      if (np.lt.7) np = 7
      npm1    = np-1
c     evaluation by Simpson’s rule with np points
      delx    = (b-a)/float(npm1)
c     multipliers for end,even and odd terms
      mulend  = 1.00
      muleven = 4.00
      mulodd  = 2.00
      sum     = 0.00
      rargs   = args/ord
      if ((ord.le.30).or.(rargs.gt.0.9)) then
       call  phijd ( args,ord,bjd  )
       call phiryd ( args,ord,rbyd )
      endif
      if ((ord.gt.30).and.(rargs.le.0.9)) then
       call  abesjd ( args,ord,bjd  )
       call arbesyd ( args,ord,rbyd )
      endif
      do 200 i = 1,np
       x     = a+float(i-1)*delx
       rx    = x/ord
       if ((ord.le.30).or.(rx.gt.0.9)) then
          call  phij ( x,ord,bj )
          call  phiy ( x,ord,by )
          trm= by*rbyd
       endif
       if ((ord.gt.30).and.(rx.le.0.9)) then
          call  abesj  ( x,ord,bj )
          call  abesyr ( x,args,ord,trm )
       endif
       y     = (bj-trm*bjd)*x
       if ((i.eq.1).or.(i.eq.np)) sum    = sum+y*mulend
       if ((i.ne.1).and.(i.ne.np)) then
          idisc   = 2*(i/2)-i
          if (idisc.ne.0) sum     = sum+y*mulodd
          if (idisc.eq.0) sum     = sum+y*muleven
        endif
```

```
  200 continue
      aints   = delx*sum/3.
      res     = aints*factor
      return
      end


c
      SUBROUTINE SIMP1 ( KMN,SIG,ORD,RES )
      REAL KMN
c     # of points for Simpson's rule (minimum value 7:also needs to be odd)
c     # of points determined assuming period of "2*pi."This must be
c     reflected in rescaling of argument as below
      a       = kmn*sig
      b       = kmn
      args    = a
      factor  = 1./kmn**2
c     # of points for Simpson's rule (minimum value 7:also needs to be odd)
      pi      = 3.14159265
      rint    = (b-a)
      npm1    = 5.*(rint/pi)
      np      = 2*(npm1/2)+1
      if (np.lt.7) np = 7
      npm1    = np-1
c     evaluation by Simpson's rule with np points
      delx    = (b-a)/float(npm1)
c     multipliers for end,even and odd terms
      mulend  = 1.00
      muleven = 4.00
      mulodd  = 2.00
      sum     = 0.00
      rargs   = args/ord
      if ((ord.le.30).or.(rargs.gt.0.9)) then
       call  phijd ( args,ord,bjd  )
       call phiryd ( args,ord,rbyd )
      endif
      if ((ord.gt.30).and.(rargs.le.0.9)) then
       call  abesjd ( args,ord,bjd  )
       call arbesyd ( args,ord,rbyd )
      endif
      do 200 i = 1,np
       x     = a+float(i-1)*delx
       rx    = x/ord
       if ((ord.le.30).or.(rx.gt.0.9)) then
          call  phij ( x,ord,bj )
          call  phiy ( x,ord,by )
          trm= by*rbyd
       endif
       if ((ord.gt.30).and.(rx.le.0.9)) then
          call  abesj  ( x,ord,bj )
          call  abesyr ( x,args,ord,trm )
       endif
       y     = (bj-trm*bjd)**2*x
       if ((i.eq.1).or.(i.eq.np)) sum    = sum+y*mulend
       if ((i.ne.1).and.(i.ne.np)) then
          idisc   = 2*(i/2)-i
          if (idisc.ne.0) sum     = sum+y*mulodd
          if (idisc.eq.0) sum     = sum+y*muleven
         endif
  200 continue
      aints   = delx*sum/3.
```

```
      res     = aints*factor
      return
      end
```

```
c
      SUBROUTINE PHIJ ( ARG,ORD,BJARG )
      DIMENSION BJ(1000)
C     CALCULATES ″ JORD(ARG) ″
      NORD   = ORD
      NB     = NORD+1
      AL     = ORD-FLOAT(NORD)
      IF ( NB.GT.1000 ) PRINT *,'NEED TO INCREASE DIMENSIONS OF',
     1                 ' BJ IN SUBROUTINE PHIJ BEYOND 1000'
      IF ( NB.GT.1000 ) GO TO 200
C     WRITE(12,*)'RJBESL,ARG,ORD ',ARG,ORD
      CALL RJBESL ( ARG,AL,NB,BJ,NCALC )
      IF ( NCALC.LT.NB ) PRINT *,' ERROR IN BJ CALCULATION !-PHIJ'
      IF ( NCALC.LT.NB ) PRINT *,'ORD,ARG = ',ORD,ARG
      IF ( NCALC.LT.NB ) GO TO 100
      BJARG  = BJ(NB)
C     WRITE(12,*)'RJBESL,RES ',BJARG
  100 CONTINUE
  200 CONTINUE
      return
      END
```

```
C
      SUBROUTINE PHIY ( ARG,ORD,BYARG )
      DIMENSION BY(1000)
C     CALCULATES ″ YORD(ARG) ″
      NORD   = ORD
      NB     = NORD+1
      AL     = ORD-FLOAT(NORD)
C     WRITE(12,*)'RYBESL,ARG,ORD ',ARG,ORD
      CALL RYBESL ( ARG,AL,NB,BY,NCALC )
      IF ( NCALC.LT.NB ) PRINT *,' ERROR IN BY CALCULATION !-PHIY'
      IF ( NCALC.LT.NB ) PRINT *,'ORD,ARG = ',ORD,ARG
      IF ( NCALC.LT.NB ) GO TO 100
      BYARG  = BY(NB)
C     WRITE(12,*)'RYBESL,RES ',BYARG
  100 CONTINUE
  200 CONTINUE
      return
      END
```

```
C
      SUBROUTINE PHIJD ( ARG,ORD,BJDER )
      DIMENSION BJ(1000)
C     CALCULATES ″ JORD'(ARG) ″
      NORD   = ORD
      NB     = NORD+1
      NBP1   = NB+1
      IF ( NBP1.GT.1000 ) PRINT *,'NEED TO INCREASE DIMENSIONS OF',
     1                 ' BJ IN SUBROUTINE PHIJD BEYOND 1000'
      IF ( NBP1.GT.1000 ) GO TO 200
      AL     = ORD-FLOAT(NORD)
C     WRITE(12,*)'RJBESL,ARG,ORD ',ARG,(ORD+1.)
      CALL RJBESL ( ARG,AL,NBP1,BJ,NCALC )
```

```
      IF ( NCALC.LT.NBP1 ) PRINT *,’ ERROR IN BJDER CALCULATION !’
      IF ( NCALC.LT.NBP1 ) PRINT *,’ ERROR IN PHIJD!’
      IF ( NCALC.LT.NBP1 ) PRINT *,’ORD,ARG= ’,ORD,ARG
      IF ( NCALC.LT.NBP1 ) GO TO 100
      BJDER = –BJ(NBP1)+ORD*BJ(NB)/ARG
C     WRITE(12,*)’RJBESL,RES ’,BJ(NBP1)
  100 CONTINUE
  200 CONTINUE
      return
      END
```

```
C
      SUBROUTINE PHIRYD ( ARG,ORD,RBYDER )
      DIMENSION BY(1000)
C     CALCULATES ” JORD’(ARG) AND YORD’(ARG) ”
      NORD   = ORD
      NB     = NORD+1
      NBP1   = NB+1
      IF ( NBP1.GT.1000 ) PRINT *,’NEED TO INCREASE DIMENSIONS OF’,
     1                  ’ BY IN SUBROUTINE PHIYD BEYOND 1000’
      IF ( NBP1.GT.1000 ) GO TO 200
      AL     = ORD–FLOAT(NORD)
C     WRITE(12,*)’RYBESL,ARG,ORD ’,ARG,(ORD+1.)
      CALL RYBESL ( ARG,AL,NBP1,BY,NCALC )
      IF ( NCALC.LT.NBP1 ) PRINT *,’ ERROR IN BYDER CALCULATION !’
      IF ( NCALC.LT.NBP1 ) PRINT *,’ ERROR IN PHIYD!’
      IF ( NCALC.LT.NBP1 ) PRINT *,’ORD,ARG = ’,ORD,ARG
      IF ( NCALC.LT.NBP1 ) GO TO 100
      BYDER = –BY(NBP1)+ORD*BY(NB)/ARG
      RBYDER = 1./BYDER
C     WRITE(12,*)’RYBESL,RES ’,BY(NBP1)
  100 CONTINUE
  200 CONTINUE
      return
      END
```

```
C
      SUBROUTINE RJBESL(X, ALPHA, NB, B, NCALC)
C–––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––
C This routine calculates Bessel functions J sub(N+ALPHA) (X)
C   for non–negative argument X, and non–negative order N+ALPHA.
C
C
C  Explanation of variables in the calling sequence.
C
C   X     – working precision non–negative real argument for which
C           J’s are to be calculated.
C   ALPHA – working precision fractional part of order for which
C           J’s or exponentially scaled J’r (J*exp(X)) are
C           to be calculated.  0 <= ALPHA < 1.0.
C   NB  – integer number of functions to be calculated, NB > 0.
C           The first function calculated is of order ALPHA, and the
C           last is of order (NB – 1 + ALPHA).
C   B  – working precision output vector of length NB.  If RJBESL
C           terminates normally (NCALC=NB), the vector B contains the
C           functions J/ALPHA/(X) through J/NB–1+ALPHA/(X), or the
C           corresponding exponentially scaled functions.
C   NCALC – integer output variable indicating possible errors.
C           Before using the vector B, the user should check that
```

```
C           NCALC=NB, i.e., all orders have been calculated to
C           the desired accuracy.  See Error Returns below.
C
C
C*******************************************************************
C*******************************************************************
C
C  Explanation of machine-dependent constants
C
C   it     = Number of bits in the mantissa of a working precision
C            variable
C   NSIG   = Decimal significance desired.  Should be set to
C            INT(LOG10(2)*it+1).  Setting NSIG lower will result
C            in decreased accuracy while setting NSIG higher will
C            increase CPU time without increasing accuracy.  The
C            truncation error is limited to a relative error of
C            T=.5*10**(-NSIG).
C   ENTEN  = 10.0 ** K, where K is the largest integer such that
C            ENTEN is machine-representable in working precision
C   ENSIG  = 10.0 ** NSIG
C   RTNSIG = 10.0 ** (-K) for the smallest integer K such that
C            K .GE. NSIG/4
C   ENMTEN = Smallest ABS(X) such that X/4 does not underflow
C   XLARGE = Upper limit on the magnitude of X.  If ABS(X)=N,
C            then at least N iterations of the backward recursion
C            will be executed.  The value of 10.0 ** 4 is used on
C            every machine.
C
C
C     Approximate values for some important machines are:
C
C
C                           it    NSIG    ENTEN       ENSIG
C
C   CRAY-1        (S.P.)     48     15    1.0E+2465   1.0E+15
C   Cyber 180/855
C     under NOS   (S.P.)     48     15    1.0E+322    1.0E+15
C   IEEE (IBM/XT,
C     SUN, etc.)  (S.P.)     24      8    1.0E+38     1.0E+8
C   IEEE (IBM/XT,
C     SUN, etc.)  (D.P.)     53     16    1.0D+308    1.0D+16
C   IBM 3033      (D.P.)     14      5    1.0D+75     1.0D+5
C   VAX           (S.P.)     24      8    1.0E+38     1.0E+8
C   VAX D-Format  (D.P.)     56     17    1.0D+38     1.0D+17
C   VAX G-Format  (D.P.)     53     16    1.0D+307    1.0D+16
C
C
C                          RTNSIG      ENMTEN      XLARGE
C
C   CRAY-1        (S.P.)    1.0E-4    1.84E-2466   1.0E+4
C   Cyber 180/855
C     under NOS   (S.P.)    1.0E-4    1.25E-293    1.0E+4
C   IEEE (IBM/XT,
C     SUN, etc.)  (S.P.)    1.0E-2    4.70E-38     1.0E+4
C   IEEE (IBM/XT,
C     SUN, etc.)  (D.P.)    1.0E-4    8.90D-308    1.0D+4
C   IBM 3033      (D.P.)    1.0E-2    2.16D-78     1.0D+4
C   VAX           (S.P.)    1.0E-2    1.17E-38     1.0E+4
C   VAX D-Format  (D.P.)    1.0E-5    1.17D-38     1.0D+4
C   VAX G-Format  (D.P.)    1.0E-4    2.22D-308    1.0D+4
```

```
C
C*******************************************************************
C*******************************************************************
C
C  Error returns
C
C    In case of an error,  NCALC .NE. NB, and not all J’s are
C    calculated to the desired accuracy.
C
C    NCALC .LT. 0:  An argument is out of range. For example,
C       NBES .LE. 0, ALPHA .LT. 0 or .GT. 1, or X is too large.
C       In this case, B(1) is set to zero, the remainder of the
C       B–vector is not calculated, and NCALC is set to
C       MIN(NB,0)–1 so that NCALC .NE. NB.
C
C    NB .GT. NCALC .GT. 0: Not all requested function values could
C       be calculated accurately.  This usually occurs because NB is
C       much larger than ABS(X).  In this case, B(N) is calculated
C       to the desired accuracy for N .LE. NCALC, but precision
C       is lost for NCALC .LT. N .LE. NB.  If B(N) does not vanish
C       for N .GT. NCALC (because it is too small to be represented),
C       and B(N)/B(NCALC) = 10**(–K), then only the first NSIG–K
C       significant figures of B(N) can be trusted.
C
C
C  Intrinsic and other functions required are:
C
C     ABS, AINT, COS, DBLE, GAMMA (or DGAMMA), INT, MAX, MIN,
C
C     REAL, SIN, SQRT
C
C
C  Acknowledgement
C
C   This program is based on a program written by David J. Sookne
C   (2) that computes values of the Bessel functions J or I of real
C   argument and integer order.  Modifications include the restriction
C   of the computation to the J Bessel function of non–negative real
C   argument, the extension of the computation to arbitrary positive
C   order, and the elimination of most underflow.
C
C  References: ”A Note on Backward Recurrence Algorithms,” Olver,
C               F. W. J., and Sookne, D. J., Math. Comp. 26, 1972,
C               pp 941–947.
C
C              ”Bessel Functions of Real Argument and Integer Order,”
C               Sookne, D. J., NBS Jour. of Res. B. 77B, 1973, pp
C               125–132.
C
C  Latest modification: March 19, 1990
C
C  Author: W. J. Cody
C          Applied Mathematics Division
C          Argonne National Laboratory
C          Argonne, IL  60439
C
C----------------------------------------------------------------------
      INTEGER I,J,K,L,M,MAGX,N,NB,NBMX,NCALC,NEND,NSTART
      REAL               GAMMA,
CD    DOUBLE PRECISION  DGAMMA,
```

```
     1 ALPHA,ALPEM,ALP2EM,B,CAPP,CAPQ,CONV,EIGHTH,EM,EN,ENMTEN,ENSIG,
     2 ENTEN,FACT,FOUR,FUNC,GNU,HALF,HALFX,ONE,ONE30,P,PI2,PLAST,
     3 POLD,PSAVE,PSAVEL,RTNSIG,S,SUM,T,T1,TEMPA,TEMPB,TEMPC,TEST,
     4 THREE,THREE5,TOVER,TWO,TWOFIV,TWOPI1,TWOPI2,X,XC,XIN,XK,XLARGE,
     5 XM,VCOS,VSIN,Z,ZERO
      DIMENSION B(NB), FACT(25)
C----------------------------------------------------------------------
C  Mathematical constants
C
C   PI2    - 2 / PI
C   TWOPI1 - first few significant digits of 2 * PI
C   TWOPI2 - (2*PI - TWOPI) to working precision, i.e.,
C            TWOPI1 + TWOPI2 = 2 * PI to extra precision.
C----------------------------------------------------------------------
 DATA PI2, TWOPI1, TWOPI2 /0.636619772367581343075535E0,6.28125E0,
1 1.935307179586476925286767E-3/
      DATA ZERO, EIGHTH, HALF, ONE /0.0E0,0.125E0,0.5E0,1.0E0/
      DATA TWO, THREE, FOUR, TWOFIV /2.0E0,3.0E0,4.0E0,25.0E0/
      DATA ONE30, THREE5 /130.0E0,35.0E0/
CD    DATA PI2, TWOPI1, TWOPI2 /0.636619772367581343075535D0,6.28125D0,
CD   1 1.935307179586476925286767D-3/
CD    DATA ZERO, EIGHTH, HALF, ONE /0.0D0,0.125D0,0.5D0,1.0D0/
CD    DATA TWO, THREE, FOUR, TWOFIV /2.0D0,3.0D0,4.0D0,25.0D0/
CD    DATA ONE30, THREE5 /130.0D0,35.0D0/
C----------------------------------------------------------------------
C  Machine-dependent parameters
C----------------------------------------------------------------------
      DATA ENTEN, ENSIG, RTNSIG /1.0E38,1.0E8,1.0E-2/
      DATA ENMTEN, XLARGE /1.2E-37,1.0E4/
CD    DATA ENTEN, ENSIG, RTNSIG /1.0D38,1.0D17,1.0D-4/
CD    DATA ENMTEN, XLARGE /1.2D-37,1.0D4/
C----------------------------------------------------------------------
C     Factorial(N)
C----------------------------------------------------------------------
      DATA FACT /1.0E0,1.0E0,2.0E0,6.0E0,24.0E0,1.2E2,7.2E2,5.04E3,
     1 4.032E4,3.6288E5,3.6288E6,3.99168E7,4.790016E8,6.2270208E9,
     2 8.71782912E10,1.307674368E12,2.0922789888E13,3.55687428096E14,
     3 6.402373705728E15,1.21645100408832E17,2.43290200817664E18,
     4 5.109094217170944E19,1.12400072777760768E21,
     5 2.585201673888497664E22,6.2044840173323943936E23/
CD    DATA FACT /1.0D0,1.0D0,2.0D0,6.0D0,24.0D0,1.2D2,7.2D2,5.04D3,
CD   1 4.032D4,3.6288D5,3.6288D6,3.99168D7,4.790016D8,6.2270208D9,
CD   2 8.71782912D10,1.307674368D12,2.0922789888D13,3.55687428096D14,
CD   3 6.402373705728D15,1.21645100408832D17,2.43290200817664D18,
CD   4 5.109094217170944D19,1.12400072777760768D21,
CD   5 2.585201673888497664D22,6.2044840173323943936D23/
C----------------------------------------------------------------------
C Statement functions for conversion and the gamma function.
C----------------------------------------------------------------------
      CONV(I) = REAL(I)
      FUNC(X) = GAMMA(X)
CD    CONV(I) = DBLE(I)
CD    FUNC(X) = DGAMMA(X)
C----------------------------------------------------------------------
C Check for out of range arguments.
C----------------------------------------------------------------------
      MAGX = INT(X)
      IF ((NB.GT.0) .AND. (X.GE.ZERO) .AND. (X.LE.XLARGE)
     1       .AND. (ALPHA.GE.ZERO) .AND. (ALPHA.LT.ONE))
     2   THEN
```

```
C-----------------------------------------------------------------------
C Initialize result array to zero.
C-----------------------------------------------------------------------
            NCALC = NB
            DO 20 I=1,NB
              B(I) = ZERO
   20       CONTINUE
C-----------------------------------------------------------------------
C Branch to use 2-term ascending series for small X and asymptotic
C form for large X when NB is not too large.
C-----------------------------------------------------------------------
            IF (X.LT.RTNSIG) THEN
C-----------------------------------------------------------------------
C Two-term ascending series for small X.
C-----------------------------------------------------------------------
               TEMPA = ONE
               ALPEM = ONE + ALPHA
               HALFX = ZERO
               IF (X.GT.ENMTEN) HALFX = HALF*X
               IF (ALPHA.NE.ZERO)
     1            TEMPA = HALFX**ALPHA/(ALPHA*FUNC(ALPHA))
               TEMPB = ZERO
               IF ((X+ONE).GT.ONE) TEMPB = -HALFX*HALFX
               B(1) = TEMPA + TEMPA*TEMPB/ALPEM
               IF ((X.NE.ZERO) .AND. (B(1).EQ.ZERO)) NCALC = 0
               IF (NB .NE. 1) THEN
                  IF (X .LE. ZERO) THEN
                        DO 30 N=2,NB
                          B(N) = ZERO
   30                   CONTINUE
                     ELSE
C-----------------------------------------------------------------------
C Calculate higher order functions.
C-----------------------------------------------------------------------
                        TEMPC = HALFX
                        TOVER = (ENMTEN+ENMTEN)/X
                        IF (TEMPB.NE.ZERO) TOVER = ENMTEN/TEMPB
                        DO 50 N=2,NB
                          TEMPA = TEMPA/ALPEM
                          ALPEM = ALPEM + ONE
                          TEMPA = TEMPA*TEMPC
                          IF (TEMPA.LE.TOVER*ALPEM) TEMPA = ZERO
                          B(N) = TEMPA + TEMPA*TEMPB/ALPEM
                          IF ((B(N).EQ.ZERO) .AND. (NCALC.GT.N))
     1                       NCALC = N-1
   50                   CONTINUE
                  END IF
               END IF
            ELSE IF ((X.GT.TWOFIV) .AND. (NB.LE.MAGX+1)) THEN
C-----------------------------------------------------------------------
C Asymptotic series for X .GT. 21.0.
C-----------------------------------------------------------------------
               XC = SQRT(PI2/X)
               XIN = (EIGHTH/X)**2
               M = 11
               IF (X.GE.THREE5) M = 8
               IF (X.GE.ONE30) M = 4
               XM = FOUR*CONV(M)
C-----------------------------------------------------------------------
C Argument reduction for SIN and COS routines.
```

```
C---------------------------------------------------------------------
               T = AINT(X/(TWOPI1+TWOPI2)+HALF)
               Z = ((X-T*TWOPI1)-T*TWOPI2) - (ALPHA+HALF)/PI2
               VSIN = SIN(Z)
               VCOS = COS(Z)
               GNU = ALPHA + ALPHA
               DO 80 I=1,2
                 S = ((XM-ONE)-GNU)*((XM-ONE)+GNU)*XIN*HALF
                 T = (GNU-(XM-THREE))*(GNU+(XM-THREE))
                 CAPP = S*T/FACT(2*M+1)
                 T1 = (GNU-(XM+ONE))*(GNU+(XM+ONE))
                 CAPQ = S*T1/FACT(2*M+2)
                 XK = XM
                 K = M + M
                 T1 = T
                 DO 70 J=2,M
                   XK = XK - FOUR
                   S = ((XK-ONE)-GNU)*((XK-ONE)+GNU)
                   T = (GNU-(XK-THREE))*(GNU+(XK-THREE))
                   CAPP = (CAPP+ONE/FACT(K-1))*S*T*XIN
                   CAPQ = (CAPQ+ONE/FACT(K))*S*T1*XIN
                   K = K - 2
                   T1 = T
   70            CONTINUE
                 CAPP = CAPP + ONE
                 CAPQ = (CAPQ+ONE)*(GNU*GNU-ONE)*(EIGHTH/X)
                 B(I) = XC*(CAPP*VCOS-CAPQ*VSIN)
                 IF (NB.EQ.1) GO TO 300
                 T = VSIN
                 VSIN = -VCOS
                 VCOS = T
                 GNU = GNU + TWO
   80         CONTINUE
C---------------------------------------------------------------------
C If  NB .GT. 2, compute J(X,ORDER+I)  I = 2, NB-1
C---------------------------------------------------------------------
               IF (NB .GT. 2) THEN
                  GNU = ALPHA + ALPHA + TWO
                  DO 90 J=3,NB
                    B(J) = GNU*B(J-1)/X - B(J-2)
                    GNU = GNU + TWO
   90             CONTINUE
               END IF
C---------------------------------------------------------------------
C Use recurrence to generate results.  First initialize the
C calculation of P*S.
C---------------------------------------------------------------------
            ELSE
               NBMX = NB - MAGX
               N = MAGX + 1
               EN = CONV(N+N) + (ALPHA+ALPHA)
               PLAST = ONE
               P = EN/X
C---------------------------------------------------------------------
C Calculate general significance test.
C---------------------------------------------------------------------
               TEST = ENSIG + ENSIG
               IF (NBMX .GE. 3) THEN
C---------------------------------------------------------------------
C Calculate P*S until N = NB-1.  Check for possible overflow.
```

```
C---------------------------------------------------------------------
                  TOVER = ENTEN/ENSIG
                  NSTART = MAGX + 2
                  NEND = NB - 1
                  EN = CONV(NSTART+NSTART) - TWO + (ALPHA+ALPHA)
                  DO 130 K=NSTART,NEND
                     N = K
                     EN = EN + TWO
                     POLD = PLAST
                     PLAST = P
                     P = EN*PLAST/X - POLD
                     IF (P.GT.TOVER) THEN
C---------------------------------------------------------------------
C To avoid overflow, divide P*S by TOVER.  Calculate P*S until
C ABS(P) .GT. 1.
C---------------------------------------------------------------------
                        TOVER = ENTEN
                        P = P/TOVER
                        PLAST = PLAST/TOVER
                        PSAVE = P
                        PSAVEL = PLAST
                        NSTART = N + 1
  100                   N = N + 1
                           EN = EN + TWO
                           POLD = PLAST
                           PLAST = P
                           P = EN*PLAST/X - POLD
                        IF (P.LE.ONE) GO TO 100
                        TEMPB = EN/X
C---------------------------------------------------------------------
C Calculate backward test and find NCALC, the highest N such that
C the test is passed.
C---------------------------------------------------------------------
                        TEST = POLD*PLAST*(HALF-HALF/(TEMPB*TEMPB))
                        TEST = TEST/ENSIG
                        P = PLAST*TOVER
                        N = N - 1
                        EN = EN - TWO
                        NEND = MIN(NB,N)
                        DO 110 L=NSTART,NEND
                           POLD = PSAVEL
                           PSAVEL = PSAVE
                           PSAVE = EN*PSAVEL/X - POLD
                           IF (PSAVE*PSAVEL.GT.TEST) THEN
                              NCALC = L - 1
                              GO TO 190
                           END IF
  110                   CONTINUE
                        NCALC = NEND
                        GO TO 190
                     END IF
  130             CONTINUE
                  N = NEND
                  EN = CONV(N+N) + (ALPHA+ALPHA)
C---------------------------------------------------------------------
C Calculate special significance test for NBMX .GT. 2.
C---------------------------------------------------------------------
                  TEST = MAX(TEST,SQRT(PLAST*ENSIG)*SQRT(P+P))
               END IF
C---------------------------------------------------------------------
```

```
C Calculate P*S until significance test passes.
C----------------------------------------------------------------------
  140         N = N + 1
                 EN = EN + TWO
                 POLD = PLAST
                 PLAST = P
                 P = EN*PLAST/X - POLD
              IF (P.LT.TEST) GO TO 140
C----------------------------------------------------------------------
C Initialize the backward recursion and the normalization sum.
C----------------------------------------------------------------------
  190         N = N + 1
              EN = EN + TWO
              TEMPB = ZERO
              TEMPA = ONE/P
              M = 2*N - 4*(N/2)
              SUM = ZERO
              EM = CONV(N/2)
              ALPEM = (EM-ONE) + ALPHA
              ALP2EM = (EM+EM) + ALPHA
              IF (M .NE. 0) SUM = TEMPA*ALPEM*ALP2EM/EM
              NEND = N - NB
              IF (NEND .GT. 0) THEN
C----------------------------------------------------------------------
C Recur backward via difference equation, calculating (but not
C storing) B(N), until N = NB.
C----------------------------------------------------------------------
                 DO 200 L=1,NEND
                    N = N - 1
                    EN = EN - TWO
                    TEMPC = TEMPB
                    TEMPB = TEMPA
                    TEMPA = (EN*TEMPB)/X - TEMPC
                    M = 2 - M
                    IF (M .NE. 0) THEN
                       EM = EM - ONE
                       ALP2EM = (EM+EM) + ALPHA
                       IF (N.EQ.1) GO TO 210
                       ALPEM = (EM-ONE) + ALPHA
                       IF (ALPEM.EQ.ZERO) ALPEM = ONE
                       SUM = (SUM+TEMPA*ALP2EM)*ALPEM/EM
                    END IF
  200            CONTINUE
              END IF
C----------------------------------------------------------------------
C Store B(NB).
C----------------------------------------------------------------------
  210         B(N) = TEMPA
              IF (NEND .GE. 0) THEN
                 IF (NB .LE. 1) THEN
                       ALP2EM = ALPHA
                       IF ((ALPHA+ONE).EQ.ONE) ALP2EM = ONE
                       SUM = SUM + B(1)*ALP2EM
                       GO TO 250
                    ELSE
C----------------------------------------------------------------------
C Calculate and store B(NB-1).
C----------------------------------------------------------------------
                       N = N - 1
                       EN = EN - TWO
```

```
                        B(N) = (EN*TEMPA)/X - TEMPB
                        IF (N.EQ.1) GO TO 240
                        M = 2 - M
                        IF (M .NE. 0) THEN
                           EM = EM - ONE
                           ALP2EM = (EM+EM) + ALPHA
                           ALPEM = (EM-ONE) + ALPHA
                           IF (ALPEM.EQ.ZERO) ALPEM = ONE
                           SUM = (SUM+B(N)*ALP2EM)*ALPEM/EM
                        END IF
                  END IF
               END IF
               NEND = N - 2
               IF (NEND .NE. 0) THEN
C---------------------------------------------------------------------
C Calculate via difference equation and store B(N), until N = 2.
C---------------------------------------------------------------------
                  DO 230 L=1,NEND
                     N = N - 1
                     EN = EN - TWO
                     B(N) = (EN*B(N+1))/X - B(N+2)
                     M = 2 - M
                     IF (M .NE. 0) THEN
                        EM = EM - ONE
                        ALP2EM = (EM+EM) + ALPHA
                        ALPEM = (EM-ONE) + ALPHA
                        IF (ALPEM.EQ.ZERO) ALPEM = ONE
                        SUM = (SUM+B(N)*ALP2EM)*ALPEM/EM
                     END IF
  230             CONTINUE
               END IF
C---------------------------------------------------------------------
C Calculate B(1).
C---------------------------------------------------------------------
               B(1) = TWO*(ALPHA+ONE)*B(2)/X - B(3)
  240          EM = EM - ONE
               ALP2EM = (EM+EM) + ALPHA
               IF (ALP2EM.EQ.ZERO) ALP2EM = ONE
               SUM = SUM + B(1)*ALP2EM
C---------------------------------------------------------------------
C Normalize.  Divide all B(N) by sum.
C---------------------------------------------------------------------
  250          IF ((ALPHA+ONE).NE.ONE)
     1              SUM = SUM*FUNC(ALPHA)*(X*HALF)**(-ALPHA)
               TEMPA = ENMTEN
               IF (SUM.GT.ONE) TEMPA = TEMPA*SUM
               DO 260 N=1,NB
                 IF (ABS(B(N)).LT.TEMPA) B(N) = ZERO
                 B(N) = B(N)/SUM
  260          CONTINUE
            END IF
C---------------------------------------------------------------------
C Error return -- X, NB, or ALPHA is out of range.
C---------------------------------------------------------------------
         ELSE
            B(1) = ZERO
            NCALC = MIN(NB,0) - 1
      END IF
C---------------------------------------------------------------------
C Exit
```

```
C---------------------------------------------------------------------
  300 RETURN
C ---------- Last line of RJBESL ----------
      END
```

```





      SUBROUTINE RYBESL(X,ALPHA,NB,BY,NCALC)
C---------------------------------------------------------------------
C
C  This routine calculates Bessel functions Y SUB(N+ALPHA) (X)
C  for non-negative argument X, and non-negative order N+ALPHA.
C
C
C Explanation of variables in the calling sequence
C
C X     - Working precision non-negative real argument for which
C         Y's are to be calculated.
C ALPHA - Working precision fractional part of order for which
C         Y's are to be calculated.  0 .LE. ALPHA .LT. 1.0.
C NB    - Integer number of functions to be calculated, NB .GT. 0.
C         The first function calculated is of order ALPHA, and the
C         last is of order (NB - 1 + ALPHA).
C BY    - Working precision output vector of length NB.  If the
C         routine terminates normally (NCALC=NB), the vector BY
C         contains the functions Y(ALPHA,X), ... , Y(NB-1+ALPHA,X),
C         If (0 .LT. NCALC .LT. NB), BY(I) contains correct function
C         values for I .LE. NCALC, and contains the ratios
C         Y(ALPHA+I-1,X)/Y(ALPHA+I-2,X) for the rest of the array.
C NCALC - Integer output variable indicating possible errors.
C         Before using the vector BY, the user should check that
C         NCALC=NB, i.e., all orders have been calculated to
C         the desired accuracy.  See error returns below.
C
C
C*******************************************************************
C*******************************************************************
C
C Explanation of machine-dependent constants
C
C   beta   = Radix for the floating-point system
C   p      = Number of significant base-beta digits in the
C            significand of a floating-point number
C   minexp = Smallest representable power of beta
C   maxexp = Smallest power of beta that overflows
C   EPS    = beta ** (-p)
C   DEL    = Machine number below which sin(x)/x = 1; approximately
C            SQRT(EPS).
C   XMIN   = Smallest acceptable argument for RBESY; approximately
C            max(2*beta**minexp,2/XINF), rounded up
C   XINF   = Largest positive machine number; approximately
C            beta**maxexp
C   THRESH = Lower bound for use of the asymptotic form; approximately
C            AINT(-LOG10(EPS/2.0))+1.0
C   XLARGE = Upper bound on X; approximately 1/DEL, because the sine
C            and cosine functions have lost about half of their
C            precision at that point.
```

```
C
C
C     Approximate values for some important machines are:
C
C                          beta    p     minexp      maxexp      EPS
C
C  CRAY–1        (S.P.)    2    48     –8193        8191    3.55E–15
C  Cyber 180/185
C    under NOS   (S.P.)    2    48      –975        1070    3.55E–15
C  IEEE (IBM/XT,
C    SUN, etc.)  (S.P.)    2    24      –126         128    5.96E–8
C  IEEE (IBM/XT,
C    SUN, etc.)  (D.P.)    2    53     –1022        1024    1.11D–16
C  IBM 3033      (D.P.)   16    14       –65          63    1.39D–17
C  VAX           (S.P.)    2    24      –128         127    5.96E–8
C  VAX D–Format  (D.P.)    2    56      –128         127    1.39D–17
C  VAX G–Format  (D.P.)    2    53     –1024        1023    1.11D–16
C
C
C                           DEL      XMIN      XINF     THRESH  XLARGE
C
C CRAY–1        (S.P.)  5.0E–8  3.67E–2466 5.45E+2465  15.0E0  2.0E7
C Cyber 180/855
C   under NOS   (S.P.)  5.0E–8  6.28E–294  1.26E+322   15.0E0  2.0E7
C IEEE (IBM/XT,
C   SUN, etc.)  (S.P.)  1.0E–4  2.36E–38   3.40E+38     8.0E0  1.0E4
C IEEE (IBM/XT,
C   SUN, etc.)  (D.P.)  1.0D–8  4.46D–308  1.79D+308   16.0D0  1.0D8
C IBM 3033      (D.P.)  1.0D–8  2.77D–76   7.23D+75    17.0D0  1.0D8
C VAX           (S.P.)  1.0E–4  1.18E–38   1.70E+38     8.0E0  1.0E4
C VAX D–Format  (D.P.)  1.0D–9  1.18D–38   1.70D+38    17.0D0  1.0D9
C VAX G–Format  (D.P.)  1.0D–8  2.23D–308  8.98D+307   16.0D0  1.0D8
C
C*******************************************************************
C*******************************************************************
C
C Error returns
C
C  In case of an error, NCALC .NE. NB, and not all Y’s are
C  calculated to the desired accuracy.
C
C  NCALC .LT. –1:  An argument is out of range. For example,
C       NB .LE. 0, IZE is not 1 or 2, or IZE=1 and ABS(X) .GE.
C       XMAX.  In this case, BY(1) = 0.0, the remainder of the
C       BY–vector is not calculated, and NCALC is set to
C       MIN0(NB,0)–2  so that NCALC .NE. NB.
C  NCALC = –1:  Y(ALPHA,X) .GE. XINF.  The requested function
C       values are set to 0.0.
C  1 .LT. NCALC .LT. NB: Not all requested function values could
C       be calculated accurately.  BY(I) contains correct function
C       values for I .LE. NCALC, and and the remaining NB–NCALC
C       array elements contain 0.0.
C
C
C Intrinsic functions required are:
C
C     DBLE, EXP, INT, MAX, MIN, REAL, SQRT
C
C
C Acknowledgement
```

```
C
C  This program draws heavily on Temme’s Algol program for Y(a,x)
C  and Y(a+1,x) and on Campbell’s programs for Y_nu(x).  Temme’s
C  scheme is used for  x < THRESH, and Campbell’s scheme is used
C  in the asymptotic region.  Segments of code from both sources
C  have been translated into Fortran 77, merged, and heavily modified.
C  Modifications include parameterization of machine dependencies,
C  use of a new approximation for ln(gamma(x)), and built-in
C  protection against over/underflow.
C
C References: ”Bessel functions J_nu(x) and Y_nu(x) of real
C              order and real argument,” Campbell, J. B.,
C              Comp. Phy. Comm. 18, 1979, pp. 133-142.
C
C             ”On the numerical evaluation of the ordinary
C              Bessel function of the second kind,” Temme,
C              N. M., J. Comput. Phys. 21, 1976, pp. 343-350.
C
C  Latest modification: March 19, 1990
C
C  Modified by: W. J. Cody
C               Applied Mathematics Division
C               Argonne National Laboratory
C               Argonne, IL  60439
C
C----------------------------------------------------------------------
      INTEGER I,K,NA,NB,NCALC
      REAL
CD    DOUBLE PRECISION
     1  ALFA,ALPHA,AYE,B,BY,C,CH,COSMU,D,DEL,DEN,DDIV,DIV,DMU,D1,D2,
     2  E,EIGHT,EN,ENU,EN1,EPS,EVEN,EX,F,FIVPI,G,GAMMA,H,HALF,ODD,
     3  ONBPI,ONE,ONE5,P,PA,PA1,PI,PIBY2,PIM5,Q,QA,QA1,Q0,R,S,SINMU,
     4  SQ2BPI,TEN9,TERM,THREE,THRESH,TWO,TWOBYX,X,XINF,XLARGE,XMIN,
     5  XNA,X2,YA,YA1,ZERO
      DIMENSION BY(NB),CH(21)
C----------------------------------------------------------------------
C  Mathematical constants
C    FIVPI = 5*PI
C    PIM5 = 5*PI - 15
C    ONBPI = 1/PI
C    PIBY2 = PI/2
C    SQ2BPI = SQUARE ROOT OF 2/PI
C----------------------------------------------------------------------
      DATA ZERO,HALF,ONE,TWO,THREE/0.0E0,0.5E0,1.0E0,2.0E0,3.0E0/
      DATA EIGHT,ONE5,TEN9/8.0E0,15.0E0,1.9E1/
DATA FIVPI,PIBY2/1.5707963267948966192E1,1.5707963267948966192E0/
DATA PI,SQ2BPI/3.1415926535897932385E0,7.9788456080286535588E-1/
DATA PIM5,ONBPI/7.0796326794896619231E-1,3.1830988618379067154E-1/
CD    DATA ZERO,HALF,ONE,TWO,THREE/0.0D0,0.5D0,1.0D0,2.0D0,3.0D0/
CD    DATA EIGHT,ONE5,TEN9/8.0D0,15.0D0,1.9D1/
CD    DATA FIVPI,PIBY2/1.5707963267948966192D1,1.5707963267948966192D0/
CD    DATA PI,SQ2BPI/3.1415926535897932385D0,7.9788456080286535588D-1/
CD    DATA PIM5,ONBPI/7.0796326794896619231D-1,3.1830988618379067154D-1/
C----------------------------------------------------------------------
C  Machine-dependent constants
C----------------------------------------------------------------------
      DATA DEL,XMIN,XINF,EPS/1.0E-4,2.36E-38,1.70E38,5.96E-8/
      DATA THRESH,XLARGE/8.0E0,1.0E4/
CD    DATA DEL,XMIN,XINF,EPS/1.0D-8,4.46D-308,1.79D308,1.11D-16/
CD    DATA THRESH,XLARGE/16.0D0,1.0D8/
```

```
C-----------------------------------------------------------------------
C  Coefficients for Chebyshev polynomial expansion of
C         1/gamma(1-x), abs(x) .le. .5
C-----------------------------------------------------------------------
      DATA CH/-0.67735241822398840964E-23,-0.61455180116049879894E-22,
     1         0.29017595056104745456E-20, 0.13639417919073099464E-18,
     2         0.23826220476859635824E-17,-0.90642907957550702534E-17,
     3        -0.14943667065169001769E-14,-0.33919078305362211264E-13,
     4        -0.17023776642512729175E-12, 0.91609750938768647911E-11,
     5         0.24230957900482704055E-09, 0.17451364971382984243E-08,
     6        -0.33126119768180852711E-07,-0.86592079961391259661E-06,
     7        -0.49717367041957398581E-05, 0.76309597585908126618E-04,
     8         0.12719271366545622927E-02, 0.17063050710955562222E-02,
     9        -0.76852840844786673690E-01,-0.28387654227602353814E+00,
     A         0.92187029365045265648E+00/
CD    DATA CH/-0.67735241822398840964D-23,-0.61455180116049879894D-22,
CD   1         0.29017595056104745456D-20, 0.13639417919073099464D-18,
CD   2         0.23826220476859635824D-17,-0.90642907957550702534D-17,
CD   3        -0.14943667065169001769D-14,-0.33919078305362211264D-13,
CD   4        -0.17023776642512729175D-12, 0.91609750938768647911D-11,
CD   5         0.24230957900482704055D-09, 0.17451364971382984243D-08,
CD   6        -0.33126119768180852711D-07,-0.86592079961391259661D-06,
CD   7        -0.49717367041957398581D-05, 0.76309597585908126618D-04,
CD   8         0.12719271366545622927D-02, 0.17063050710955562222D-02,
CD   9        -0.76852840844786673690D-01,-0.28387654227602353814D+00,
CD   A         0.92187029365045265648D+00/
C-----------------------------------------------------------------------
      EX = X
      ENU = ALPHA
      IF ((NB .GT. 0) .AND. (X .GE. XMIN) .AND. (EX .LT. XLARGE)
     1       .AND. (ENU .GE. ZERO) .AND. (ENU .LT. ONE))  THEN
            XNA = AINT(ENU+HALF)
            NA = INT(XNA)
            IF (NA .EQ. 1) ENU = ENU - XNA
            IF (ENU .EQ. -HALF) THEN
                  P = SQ2BPI/SQRT(EX)
                  YA = P * SIN(EX)
                  YA1 = -P * COS(EX)
               ELSE IF (EX .LT. THREE) THEN
C-----------------------------------------------------------------------
C  Use Temme's scheme for small X
C-----------------------------------------------------------------------
                  B = EX * HALF
                  D = -LOG(B)
                  F = ENU * D
                  E = B**(-ENU)
                  IF (ABS(ENU) .LT. DEL) THEN
                        C = ONBPI
                     ELSE
                        C = ENU / SIN(ENU*PI)
                  END IF
C-----------------------------------------------------------------------
C  Computation of sinh(f)/f
C-----------------------------------------------------------------------
                  IF (ABS(F) .LT. ONE) THEN
                        X2 = F*F
                        EN = TEN9
                        S = ONE
                        DO 80 I = 1, 9
                           S = S*X2/EN/(EN-ONE)+ONE
```

```
                           EN = EN - TWO
   80                   CONTINUE
                     ELSE
                        S = (E - ONE/E) * HALF / F
                  END IF
C---------------------------------------------------------------------
C  Computation of 1/gamma(1-a) using Chebyshev polynomials
C---------------------------------------------------------------------
                  X2 = ENU*ENU*EIGHT
                  AYE = CH(1)
                  EVEN = ZERO
                  ALFA = CH(2)
                  ODD = ZERO
                  DO 40 I = 3, 19, 2
                     EVEN = -(AYE+AYE+EVEN)
                     AYE = -EVEN*X2 - AYE + CH(I)
                     ODD = -(ALFA+ALFA+ODD)
                     ALFA = -ODD*X2 - ALFA + CH(I+1)
   40             CONTINUE
                  EVEN = (EVEN*HALF+AYE)*X2 - AYE + CH(21)
                  ODD = (ODD+ALFA)*TWO
                  GAMMA = ODD*ENU + EVEN
C---------------------------------------------------------------------
C  End of computation of 1/gamma(1-a)
C---------------------------------------------------------------------
                  G = E * GAMMA
                  E = (E + ONE/E) * HALF
                  F = TWO*C*(ODD*E+EVEN*S*D)
                  E = ENU*ENU
                  P = G*C
                  Q = ONBPI / G
                  C = ENU*PIBY2
                  IF (ABS(C) .LT. DEL) THEN
                        R = ONE
                     ELSE
                        R = SIN(C)/C
                  END IF
                  R = PI*C*R*R
                  C = ONE
                  D = - B*B
                  H = ZERO
                  YA = F + R*Q
                  YA1 = P
                  EN = ZERO
  100             EN = EN + ONE
                  IF (ABS(G/(ONE+ABS(YA)))
     1                      + ABS(H/(ONE+ABS(YA1))) .GT. EPS) THEN
                        F = (F*EN+P+Q)/(EN*EN-E)
                        C = C * D/EN
                        P = P/(EN-ENU)
                        Q = Q/(EN+ENU)
                        G = C*(F+R*Q)
                        H = C*P - EN*G
                        YA = YA + G
                        YA1 = YA1+H
                        GO TO 100
                  END IF
                  YA = -YA
                  YA1 = -YA1/B
               ELSE IF (EX .LT. THRESH) THEN
```

```
C-------------------------------------------------------------------
C  Use Temme's scheme for moderate X
C-------------------------------------------------------------------
                  C = (HALF-ENU)*(HALF+ENU)
                  B = EX + EX
                  E = (EX*ONBPI*COS(ENU*PI)/EPS)
                  E = E*E
                  P = ONE
                  Q = -EX
                  R = ONE + EX*EX
                  S = R
                  EN = TWO
  200             IF (R*EN*EN .LT. E) THEN
                        EN1 = EN+ONE
                        D = (EN-ONE+C/EN)/S
                        P = (EN+EN-P*D)/EN1
                        Q = (-B+Q*D)/EN1
                        S = P*P + Q*Q
                        R = R*S
                        EN = EN1
                        GO TO 200
                  END IF
                  F = P/S
                  P = F
                  G = -Q/S
                  Q = G
  220             EN = EN - ONE
                  IF (EN .GT. ZERO) THEN
                        R = EN1*(TWO-P)-TWO
                        S = B + EN1*Q
                        D = (EN-ONE+C/EN)/(R*R+S*S)
                        P = D*R
                        Q = D*S
                        E = F + ONE
                        F = P*E - G*Q
                        G = Q*E + P*G
                        EN1 = EN
                        GO TO 220
                  END IF
                  F = ONE + F
                  D = F*F + G*G
                  PA = F/D
                  QA = -G/D
                  D = ENU + HALF -P
                  Q = Q + EX
                  PA1 = (PA*Q-QA*D)/EX
                  QA1 = (QA*Q+PA*D)/EX
                  B = EX - PIBY2*(ENU+HALF)
                  C = COS(B)
                  S = SIN(B)
                  D = SQ2BPI/SQRT(EX)
                  YA = D*(PA*S+QA*C)
                  YA1 = D*(QA1*S-PA1*C)
               ELSE
C-------------------------------------------------------------------
C  Use Campbell's asymptotic scheme.
C-------------------------------------------------------------------
                  NA = 0
                  D1 = AINT(EX/FIVPI)
                  I = INT(D1)
```

```
                  DMU = ((EX-ONE5*D1)-D1*PIM5)-(ALPHA+HALF)*PIBY2
                  IF (I-2*(I/2) .EQ. 0) THEN
                        COSMU = COS(DMU)
                        SINMU = SIN(DMU)
                     ELSE
                        COSMU = -COS(DMU)
                        SINMU = -SIN(DMU)
                  END IF
                  DDIV = EIGHT * EX
                  DMU = ALPHA
                  DEN = SQRT(EX)
                  DO 350 K = 1, 2
                     P = COSMU
                     COSMU = SINMU
                     SINMU = -P
                     D1 = (TWO*DMU-ONE)*(TWO*DMU+ONE)
                     D2 = ZERO
                     DIV = DDIV
                     P = ZERO
                     Q = ZERO
                     Q0 = D1/DIV
                     TERM = Q0
                     DO 310 I = 2, 20
                        D2 = D2 + EIGHT
                        D1 = D1 - D2
                        DIV = DIV + DDIV
                        TERM = -TERM*D1/DIV
                        P = P + TERM
                        D2 = D2 + EIGHT
                        D1 = D1 - D2
                        DIV = DIV + DDIV
                        TERM = TERM*D1/DIV
                        Q = Q + TERM
                        IF (ABS(TERM) .LE. EPS) GO TO 320
  310                CONTINUE
  320                P = P + ONE
                     Q = Q + Q0
                     IF (K .EQ. 1) THEN
                           YA = SQ2BPI * (P*COSMU-Q*SINMU) / DEN
                        ELSE
                           YA1 = SQ2BPI * (P*COSMU-Q*SINMU) / DEN
                     END IF
                     DMU = DMU + ONE
  350             CONTINUE
            END IF
            IF (NA .EQ. 1) THEN
               H = TWO*(ENU+ONE)/EX
               IF (H .GT. ONE) THEN
                  IF (ABS(YA1) .GT. XINF/H) THEN
                     H = ZERO
                     YA = ZERO
                  END IF
               END IF
               H = H*YA1 - YA
               YA = YA1
               YA1 = H
            END IF
C----------------------------------------------------------------------
C  Now have first one or two Y's
C----------------------------------------------------------------------
```

```
            BY(1) = YA
            BY(2) = YA1
            IF (YA1 .EQ. ZERO) THEN
                  NCALC = 1
               ELSE
                  AYE = ONE + ALPHA
                  TWOBYX = TWO/EX
                  NCALC = 2
                  DO 400 I = 3, NB
                     IF (TWOBYX .LT. ONE) THEN
                           IF (ABS(BY(I-1))*TWOBYX .GE. XINF/AYE)
     1                                                     GO TO 450
                        ELSE
                           IF (ABS(BY(I-1)) .GE. XINF/AYE/TWOBYX )
     1                                                     GO TO 450
                     END IF
                     BY(I) = TWOBYX*AYE*BY(I-1) - BY(I-2)
                     AYE = AYE + ONE
                     NCALC = NCALC + 1
  400             CONTINUE
            END IF
  450       DO 460 I = NCALC+1, NB
               BY(I) = ZERO
  460       CONTINUE
         ELSE
            BY(1) = ZERO
            NCALC = MIN(NB,0) - 1
      END IF
  900 RETURN
C---------- Last line of RYBESL ----------
      END
```

```
      REAL FUNCTION GAMMA(X)
CD    DOUBLE PRECISION FUNCTION DGAMMA(X)
C----------------------------------------------------------------------
C
C This routine calculates the GAMMA function for a real argument X.
C   Computation is based on an algorithm outlined in reference 1.
C   The program uses rational functions that approximate the GAMMA
C   function to at least 20 significant decimal digits.  Coefficients
C   for the approximation over the interval (1,2) are unpublished.
C   Those for the approximation for X .GE. 12 are from reference 2.
C   The accuracy achieved depends on the arithmetic system, the
C   compiler, the intrinsic functions, and proper selection of the
C   machine-dependent constants.
C
C
C*********************************************************************
C*********************************************************************
C
C Explanation of machine-dependent constants
C
C beta   - radix for the floating-point representation
C maxexp - the smallest positive power of beta that overflows
C XBIG   - the largest argument for which GAMMA(X) is representable
C          in the machine, i.e., the solution to the equation
C                  GAMMA(XBIG) = beta**maxexp
C XINF   - the largest machine representable floating-point number;
C          approximately beta**maxexp
C EPS    - the smallest positive floating-point number such that
```

```
C          1.0+EPS .GT. 1.0
C XMININ - the smallest positive floating-point number such that
C          1/XMININ is machine representable
C
C     Approximate values for some important machines are:
C
C                            beta       maxexp        XBIG
C
C CRAY-1         (S.P.)        2         8191        966.961
C Cyber 180/855
C   under NOS    (S.P.)        2         1070        177.803
C IEEE (IBM/XT,
C   SUN, etc.)   (S.P.)        2          128        35.040
C IEEE (IBM/XT,
C   SUN, etc.)   (D.P.)        2         1024        171.624
C IBM 3033       (D.P.)       16           63        57.574
C VAX D-Format   (D.P.)        2          127        34.844
C VAX G-Format   (D.P.)        2         1023        171.489
C
C                            XINF         EPS        XMININ
C
C CRAY-1         (S.P.)   5.45E+2465   7.11E-15    1.84E-2466
C Cyber 180/855
C   under NOS    (S.P.)   1.26E+322    3.55E-15    3.14E-294
C IEEE (IBM/XT,
C   SUN, etc.)   (S.P.)   3.40E+38     1.19E-7     1.18E-38
C IEEE (IBM/XT,
C   SUN, etc.)   (D.P.)   1.79D+308    2.22D-16    2.23D-308
C IBM 3033       (D.P.)   7.23D+75     2.22D-16    1.39D-76
C VAX D-Format   (D.P.)   1.70D+38     1.39D-17    5.88D-39
C VAX G-Format   (D.P.)   8.98D+307    1.11D-16    1.12D-308
C
C********************************************************************
C********************************************************************
C
C Error returns
C
C  The program returns the value XINF for singularities or
C     when overflow would occur.  The computation is believed
C     to be free of underflow and overflow.
C
C
C  Intrinsic functions required are:
C
C     INT, DBLE, EXP, LOG, REAL, SIN
C
C
C References: "An Overview of Software Development for Special
C              Functions," W. J. Cody, Lecture Notes in Mathematics,
C              506, Numerical Analysis Dundee, 1975, G. A. Watson
C              (ed.), Springer Verlag, Berlin, 1976.
C
C              Computer Approximations, Hart, Et. Al., Wiley and
C              sons, New York, 1968.
C
C  Latest modification: October 12, 1989
C
C  Authors: W. J. Cody and L. Stoltz
C           Applied Mathematics Division
C           Argonne National Laboratory
```

```
C           Argonne, IL 60439
C
C----------------------------------------------------------------------
      INTEGER I,N
      LOGICAL PARITY
      REAL
CD    DOUBLE PRECISION
     1    C,CONV,EPS,FACT,HALF,ONE,P,PI,Q,RES,SQRTPI,SUM,TWELVE,
     2    TWO,X,XBIG,XDEN,XINF,XMININ,XNUM,Y,Y1,YSQ,Z,ZERO
      DIMENSION C(7),P(8),Q(8)
C----------------------------------------------------------------------
C  Mathematical constants
C----------------------------------------------------------------------
      DATA ONE,HALF,TWELVE,TWO,ZERO/1.0E0,0.5E0,12.0E0,2.0E0,0.0E0/,
     1     SQRTPI/0.9189385332046727417803297E0/,
     2     PI/3.1415926535897932384626434E0/
CD    DATA ONE,HALF,TWELVE,TWO,ZERO/1.0D0,0.5D0,12.0D0,2.0D0,0.0D0/,
CD   1     SQRTPI/0.9189385332046727417803297D0/,
CD   2     PI/3.1415926535897932384626434D0/
C----------------------------------------------------------------------
C  Machine dependent parameters
C----------------------------------------------------------------------
      DATA XBIG,XMININ,EPS/35.040E0,1.18E-38,1.19E-7/,
     1     XINF/1.7E38/
CD    DATA XBIG,XMININ,EPS/171.624D0,2.23D-308,2.22D-16/,
CD   1     XINF/1.79D308/
C----------------------------------------------------------------------
C  Numerator and denominator coefficients for rational minimax
C     approximation over (1,2).
C----------------------------------------------------------------------
DATA P/-1.71618513886549492533811E+0,2.47656508055759199108314E+1,
     1       -3.79804256470945635097577E+2,6.29331155312818442661052E+2,
     2       8.66966202790413211295064E+2,-3.14512729688483675254357E+4,
     3       -3.61444134186911729807069E+4,6.64561438202405440627855E+4/
      DATA Q/-3.08402300119738975254353E+1,3.15350626979604161529144E+2,
     1      -1.01515636749021914166146E+3,-3.10777167157231109440444E+3,
     2        2.25381184209801510330112E+4,4.75584627752788110767815E+3,
     3      -1.34659959864969306392456E+5,-1.15132259675553483497211E+5/
CD    DATA P/-1.71618513886549492533811D+0,2.47656508055759199108314D+1,
CD   1       -3.79804256470945635097577D+2,6.29331155312818442661052D+2,
CD   2       8.66966202790413211295064D+2,-3.14512729688483675254357D+4,
CD   3       -3.61444134186911729807069D+4,6.64561438202405440627855D+4/
CD    DATA Q/-3.08402300119738975254353D+1,3.15350626979604161529144D+2,
CD   1      -1.01515636749021914166146D+3,-3.10777167157231109440444D+3,
CD   2        2.25381184209801510330112D+4,4.75584627752788110767815D+3,
CD   3      -1.34659959864969306392456D+5,-1.15132259675553483497211D+5/
C----------------------------------------------------------------------
C  Coefficients for minimax approximation over (12, INF).
C----------------------------------------------------------------------
      DATA C/-1.910444077728E-03,8.4171387781295E-04,
     1     -5.952379913043012E-04,7.93650793500350248E-04,
2     -2.777777777777681622553E-03,8.333333333333333331554247E-02,
3      5.7083835261E-03/
CD    DATA C/-1.910444077728D-03,8.4171387781295D-04,
CD   1     -5.952379913043012D-04,7.93650793500350248D-04,
CD   2     -2.777777777777681622553D-03,8.333333333333333331554247D-02,
CD   3      5.7083835261D-03/
C----------------------------------------------------------------------
C  Statement functions for conversion between integer and float
C----------------------------------------------------------------------
```

```
      CONV(I) = REAL(I)
CD    CONV(I) = DBLE(I)
      PARITY = .FALSE.
      FACT = ONE
      N = 0
      Y = X
      IF (Y .LE. ZERO) THEN
C---------------------------------------------------------------------
C  Argument is negative
C---------------------------------------------------------------------
            Y = -X
            Y1 = AINT(Y)
            RES = Y - Y1
            IF (RES .NE. ZERO) THEN
                  IF (Y1 .NE. AINT(Y1*HALF)*TWO) PARITY = .TRUE.
                  FACT = -PI / SIN(PI*RES)
                  Y = Y + ONE
               ELSE
                  RES = XINF
                  GO TO 900
            END IF
      END IF
C---------------------------------------------------------------------
C  Argument is positive
C---------------------------------------------------------------------
      IF (Y .LT. EPS) THEN
C---------------------------------------------------------------------
C  Argument .LT. EPS
C---------------------------------------------------------------------
            IF (Y .GE. XMININ) THEN
                  RES = ONE / Y
               ELSE
                  RES = XINF
                  GO TO 900
            END IF
         ELSE IF (Y .LT. TWELVE) THEN
            Y1 = Y
            IF (Y .LT. ONE) THEN
C---------------------------------------------------------------------
C  0.0 .LT. argument .LT. 1.0
C---------------------------------------------------------------------
                  Z = Y
                  Y = Y + ONE
               ELSE
C---------------------------------------------------------------------
C  1.0 .LT. argument .LT. 12.0, reduce argument if necessary
C---------------------------------------------------------------------
                  N = INT(Y) - 1
                  Y = Y - CONV(N)
                  Z = Y - ONE
            END IF
C---------------------------------------------------------------------
C  Evaluate approximation for 1.0 .LT. argument .LT. 2.0
C---------------------------------------------------------------------
            XNUM = ZERO
            XDEN = ONE
            DO 260 I = 1, 8
               XNUM = (XNUM + P(I)) * Z
               XDEN = XDEN * Z + Q(I)
  260       CONTINUE
```

```
            RES = XNUM / XDEN + ONE
            IF (Y1 .LT. Y) THEN
C----------------------------------------------------------------------
C  Adjust result for case  0.0 .LT. argument .LT. 1.0
C---------------------------------------------------------------------
                  RES = RES / Y1
               ELSE IF (Y1 .GT. Y) THEN
C----------------------------------------------------------------------
C  Adjust result for case  2.0 .LT. argument .LT. 12.0
C----------------------------------------------------------------------
                  DO 290 I = 1, N
                     RES = RES * Y
                     Y = Y + ONE
  290             CONTINUE
            END IF
         ELSE
C----------------------------------------------------------------------
C  Evaluate for argument .GE. 12.0,
C----------------------------------------------------------------------
            IF (Y .LE. XBIG) THEN
                  YSQ = Y * Y
                  SUM = C(7)
                  DO 350 I = 1, 6
                     SUM = SUM / YSQ + C(I)
  350             CONTINUE
                  SUM = SUM/Y - Y + SQRTPI
                  SUM = SUM + (Y-HALF)*LOG(Y)
                  RES = EXP(SUM)
               ELSE
                  RES = XINF
                  GO TO 900
            END IF
      END IF
C----------------------------------------------------------------------
C  Final adjustments and return
C----------------------------------------------------------------------
      IF (PARITY) RES = -RES
      IF (FACT .NE. ONE) RES = FACT / RES
  900 GAMMA = RES
CD900 DGAMMA = RES
      RETURN
      END
```

```
C ---------- Last line of GAMMA ----------

     FUNCTION SINH(X)
     SINH    = (EXP(X)-EXP(-X))/2.
     RETURN
     END
```

```
     FUNCTION TANH(X)
     TX      = 2.*X
     ETX     = EXP(-TX)
     TANH    = (1.-ETX)/(1.+ETX)
     RETURN
     END
```

```
     FUNCTION ARCSECH(X)
```

```
      RX      =1./X
      TRM     = SQRT(RX**2-1.)
      ARCSECH = ALOG(RX+TRM)
      RETURN
      END
```

```
      FUNCTION COTH(X)
      COTH    = 1./TANH(X)
      RETURN
      END
```

```
      FUNCTION U1(X)
      X3      = X**3
      U1      = (3.*X-5.*X3)/24.
      RETURN
      END
```

```
      FUNCTION U2(X)
      X2      = X**2
      X4      = X2**2
      X6      = X2*X4
      U2      = (81.*X2-462.*X4+385.*X6)/1152.
      RETURN
      END
```

```
      FUNCTION V1(X)
      X3      = X**3
      V1      = (-9.*X+7.*X3)/24.
      RETURN
      END
```

```
      FUNCTION V2(X)
      X2      = X**2
      X4      = X2**2
      X6      = X2*X4
      V2      = (-135.*X2+594.*X4-455.*X6)/1152.
      RETURN
      END
```

```
      SUBROUTINE ABESJ ( ARG,ORD,BESJ )
      IF ( ARG.GE.ORD ) PRINT *,'ARG.GE.ORD-ABESJ NOT APPLICABLE'
      IF ( ARG.GE.ORD ) GO TO 100
      PI      = 3.14159265
      ORD2    = ORD**2
      SECHAL  = ARG/ORD
      AL      = ARCSECH(SECHAL)
      TANHAL  = TANH(AL)
      COTHAL  = 1./TANHAL
      RNUMJ   = EXP(ORD*(TANHAL-AL))
      DENJ    = SQRT(2.*PI*ORD*TANHAL)
      BESJ    = (RNUMJ/DENJ)*(1.+U1(COTHAL)/ORD+U2(COTHAL)/ORD2)
  100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ABESY ( ARG,ORD,BESY,RBESY )
      IF ( ARG.GE.ORD ) PRINT *,'ARG.GE.ORD-ABESY NOT APPLICABLE'
      IF ( ARG.GE.ORD ) GO TO 100
      PI      = 3.14159265
      ORD2    = ORD**2
      SECHAL  = ARG/ORD
      AL      = ARCSECH(SECHAL)
      TANHAL  = TANH(AL)
      COTHAL  = 1./TANHAL
      RNUMJ   = EXP(ORD*(TANHAL-AL))
      DENJ    = SQRT(2.*PI*ORD*TANHAL)
      BESJ    = (RNUMJ/DENJ)*(1.+U1(COTHAL)/ORD+U2(COTHAL)/ORD2)
      ABESJ   = ABS(BESJ)
      IF ( ABESJ.LE.1.E-36 ) GO TO 90
      RNUMY   = -1./RNUMJ
      DENY    = 0.5*DENJ
      BESY    = (RNUMY/DENY)*(1.-U1(COTHAL)/ORD+U2(COTHAL)/ORD2)
      RBESY   = 1./BESY
      GO TO 100
   90   BESY    = -1.E+36
      RBESY   = 0.00
  100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ABESJD ( ARG,ORD,BESJD )
      IF ( ARG.GE.ORD ) PRINT *,'ARG.GE.ORD-ABESJD NOT APPLICABLE'
      IF ( ARG.GE.ORD ) GO TO 100
      PI      = 3.14159265
      ORD2    = ORD**2
      SECHAL  = ARG/ORD
      AL      = ARCSECH(SECHAL)
      TANHAL  = TANH(AL)
      COTHAL  = 1./TANHAL
      RNUMJ   = SQRT(SINH(2.*AL))*EXP(ORD*(TANHAL-AL))
      DENJ    = SQRT(4.*PI*ORD)
      BESJD   = (RNUMJ/DENJ)*(1.+V1(COTHAL)/ORD+V2(COTHAL)/ORD2)
  100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ARBESYD ( ARG,ORD,RBESYD )
      IF ( ARG.GE.ORD ) PRINT *,'ARG.GE.ORD-ABESJY NOT APPLICABLE'
      IF ( ARG.GE.ORD ) GO TO 100
      PI      = 3.14159265
      ORD2    = ORD**2
      SECHAL  = ARG/ORD
      AL      = ARCSECH(SECHAL)
      TANHAL  = TANH(AL)
      COTHAL  = 1./TANHAL
      RNUMJ   = SQRT(SINH(2.*AL))*EXP(ORD*(TANHAL-AL))
      DENJ    = SQRT(4.*PI*ORD)
      BESJD   = (RNUMJ/DENJ)*(1.+V1(COTHAL)/ORD+V2(COTHAL)/ORD2)
      ABESJD  = ABS(BESJD)
      IF ( ABESJD.LE.1.E-36 ) GO TO 90
      RNUMY   = SQRT(SINH(2.*AL))*EXP(ORD*(AL-TANHAL))
      DENY    = 0.5*DENJ
      BESYD   = (RNUMY/DENY)*(1.-V1(COTHAL)/ORD+V2(COTHAL)/ORD2)
      RBESYD  = 1./BESYD
```

```
      GO TO 100
   90   BESYD   = 1.E+36
      RBESYD  = 0.00
  100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ABESYR ( A1,A2,ORD,RES )
      IF ( A1.GE.ORD ) PRINT *,'1ST ARG.GE.ORD-ABESYR ',
     &                           'NOT APPLICABLE'
      IF ( A1.GE.ORD ) GO TO 100
      IF ( A2.GE.ORD ) PRINT *,'2ND ARG.GE.ORD-ABESYR ',
     &                           'NOT APPLICABLE'
      IF ( A2.GE.ORD ) GO TO 100
      PI      = 3.14159265
      ORD2    = ORD**2
      SECHAL1 = A1/ORD
      AL1     = ARCSECH(SECHAL1)
      TANHAL1 = TANH(AL1)
      COTHAL1 = 1./TANHAL1
      SECHAL2 = A2/ORD
      AL2     = ARCSECH(SECHAL2)
      TANHAL2 = TANH(AL2)
      COTHAL2 = 1./TANHAL2
      SINH2AL2= SINH(2.*AL2)
      EXPON   = -ORD*((AL2-TANHAL2)-(AL1-TANHAL1))
      DEN     = -SQRT(TANHAL1*SINH2AL2/2.)
      SRAT    = (1.-U1(COTHAL1)/ORD+U2(COTHAL1)/ORD2)/
     &              (1.-V1(COTHAL2)/ORD+V2(COTHAL2)/ORD2)
      RES     = EXP(EXPON)*SRAT/DEN
  100   CONTINUE
      RETURN
      END
```

```
C  **** INLET FAN RADIATION SUBROUTINE, E. J. RICE, REVISED 02/21/1998
C  ** CONTAINS PLANE WAVE RADIATION AND IMPROVED TERMINATION LOSS
C  ** THE FOLLOWING "BBRDCFIN" IS THE MAIN SUBROUTINE.  ALL ARGUMENTS
C     ARE INPUTS EXCEPT "NANGLE," "ANGLE," "SPL," "SPLTL" AND WATTS
C     RETURNED TO THE MAIN PROGRAM FOR PRINTING, FILE STORAGE ETC.
C
C  ** THIS VERSION REMOVES THE P**2 OSCILLATIONS BEYOND THE PEAK.  FOUR
C     REGIONS (ETA AND CUT-OFF RATIO) DETERMINE PROPER APPROXIMATION FOR
C     HIGH ANGLE RADIATION. DEVELOPED 01/30/98.

      SUBROUTINE BBRDCFIN(TTOT,PTOT,DISTANCE,
     1ISIDELN,DIAM,ALIP,BLIP,FMACHI,FMACHS,NCOF,WATTSCOF,ETAI,
     2DELANG,NANGLE,ANGLE,SPL,SPLTL,WATTS,WATTRAN)
C
      DIMENSION ANGLE(200),SPL(200),SPLTL(200),WATTSCOF(200),
     1COFRAT(200),PSQTOT(200),PSQTLOS(200),PSQRADT(200)

      COMMON FMSQ,FM1,BETA,COFBETIN,CFBTINSQ,GDEN,HDEN,
     1PSQPK,PSIC,AC,BC,CC,IREG

C
C  ** SUBROUTINES REQUIRED "LIPEF3" AND "PSQGCOF"
C
C  ***************** DEFINITION OF SUBROUTINE ARGUMENTS *************
C
C TTOT    ABSOLUTE TEMPERATURE, (DEGREES RANKINE)
```

```
C PTOT    ABSOLUTE PRESSURE, (PSIA)
C DISTANCE  RADIUS OR SIDELINE DISTANCE OF MICROPHONE ARRAY, (FT.)
C ISIDELN = 0 FOR CONSTANT RADIUS, = 1 FOR CONSTANT SIDELINE CALCULATION
C DIAM    INLET DUCT DIAMETER, (INCHES)
C ALIP    MAJOR OR AXIAL RUNNING DIMENSION OF ELLIPTIC INLET LIP (INCHES)
C BLIP    MINOR OR TRANSVERSE DIMENSION OF ELLIPTIC INLET LIP (INCHES)
C FMACH   INLET MACH NUMBER, NEGATIVE FOR INLET
C FMACHS  SURROUNDING MACH NUMBER, ALSO NEGATIVE FOR INLET
C NCOF    NUMBER OF CUT-OFF RATIO BINS TO SORT ACOUSTIC POWER
C WATTSCOF VECTOR WITH ACOUSTIC POWER FOR EACH BIN, (WATTS)
C ETA     FREQUENCY PARAMETER, (DUCT DIAMETER)/(SOUND WAVELENGTH)
C DELANG  ANGLE INCREMENT DESIRED ON FAR-FIELD RADIAL TRAVERSE, (DEGREES)
C NANGLE  NUMBER OF ANGLES USED IN CALCULATION, DETERMINED BY DELANG AND
C         THE MAXIMUM ANGLE OF 90 DEGREES
C ANGLE   VECTOR OF ANGLES ON THE FAR-FIELD TRAVERSE, (DEGREES)
C SPL     THE SOUND PRESSURE LEVEL VECTOR ON THE FAR-FIELD TRAVERSE
C         "IGNORING" THE EXIT TRANSMISSION LOSS (DECIBELS) RELATIVE TO
C         2*10**(-5) NEWTONS/METER**2
C SPLTL   THE SOUND PRESSURE LEVEL VECTOR ON THE FAR-FIELD TRAVERSE
C         "INCLUDING" THE EXIT TRANSMISSION LOSS (DECIBELS) RELATIVE TO
C         2*10**(-5) NEWTONS/METER**2
C WATTS   SUM OF ACOUSTIC POWER IN ALL THE CUT-OFF RATIO BINS, (WATTS)
C WATTRAN SUM OF TRANSMITTED ACOUSTIC POWER, ALL BINS, (WATTS)

      FMACH = FMACHI
      ETA = ETAI
      DRAD = 0.5*DIAM
      PI = 3.1415927
      AREAD = PI*DRAD**2
      ABELEX = AREAD+2.0*PI*BLIP*(BLIP+0.5*PI*DRAD)
      FMBELEX =FMACH*AREAD/ABELEX
      ETABELEX = ETA*(DIAM+2.0*BLIP)/DIAM

C  CALCULATE COEF. (PLANE WAVE) INTEGRATION OF RAD. DIRECTIVITY, MACH=0
      IF(ETABELEX.LT.1.0) THEN
      ACOEFPW = 0.741697+3.190822*ETABELEX**2.650078
      GO TO 14
      END IF
      ACOEFPW = 3.932518*ETABELEX**1.96285
   14 CONTINUE
C

      PSQCOEFP = ACOEFPW


      QM = 1.0+0.2*FMACHS**2
      TSUR = TTOT/QM
      PSUR = PTOT/QM**3.5

      SONIC = 49.0422*SQRT(TSUR)
      RHO = 144.*PSUR/(53.3*TSUR)
      POWCON = 8.36424*RHO*SONIC

      ETAEXP = ETA**1.08156
      WATINFIX = (1.0+1.9036*ETAEXP)/(PI*0.71385*ETAEXP)

C  ****************** DIMENSIONS, SONIC (FT/SEC), RHO (LBm/FT**3) ****

C  ******* NOTE!! THIS VERSION CALCULATES TO 178 DEGREES FROM INLET AXIS
```

```
      NANGLE = 178.0/DELANG
      DO 5 I=1,NANGLE
      FI = I
      ANGLE(I) = FI*DELANG
    5 CONTINUE

      FMSQ = FMACH**2
      FM1 = 1.0-FMSQ
      BETA = SQRT(FM1)

      ACOEF = 0.7/ETA

      FCOF = NCOF
      FCOFINV = 1./FCOF
      FCOFIND2 = 0.5/FCOF
C    *********************** SET UP CUT-OFF RATIOS IN THE DUCT *******
      COFSQPR = 1.0
      DO 20 I=1,NCOF
      COFRAT(I) = SQRT(1.0/(COFSQPR-FCOFIND2))
      COFSQPR = COFSQPR-FCOFINV
   20 CONTINUE

C    ****************** INITIALIZE P**2 AT EACH FAR-FIELD ANGLE *******
C
      DO 10 I=1,NANGLE
      PSQRADT(I) = 0.0
      PSQTLOS(I) = 0.0
      PSQTOT(I) = 0.0
   10 CONTINUE
C
C    ****************************** START LOOP ON CUT-OFF RATIO ********
C
      WATTS = 0.0
      WATTRAN = 0.0

      DO 70 J=1,NCOF
      WATTS = WATTS+WATTSCOF(J)
      POWCOEF = POWCON*WATTSCOF(J)

C    *******************************************************************
C    !!!!!!!! VERY IMPORTANT! FOLLOWING DEFINES PLANE WAVE REGIME !!!!!!
C    *******************************************************************

C ********** DETERMINE IF PLANE WAVE RADIATION ALGORITHM SHOULD BE USED
C ********** IF PLANE WAVE IPW = 1 (YES) FOR COFRATD>=3 OR LAST BIN
      IPW = 0
      IF(COFRAT(J).GE.3.0.OR.J.EQ.NCOF) IPW=1
C
C    ********** PROGRAM SPITS HERE.  IT WILL CONTINUE ON FOR NON-PLANE
C    ********** WAVES AND WILL JUMP FOR THE PLANE WAVE

      IF(IPW.EQ.1) GO TO 45

C    ******** NOW IN "NON-PLANE" WAVE, RADIAL OR SPINNING MODE REGIME !!



      XID = COFRAT(J)
      FRAC = 0.85
      IF(XID.LE.2.5) FRAC=1.0-0.1*(XID-1.0)
```

```
C
C  ** FOLLOWING ALLOWS SHARP EDGE OR UNFLANGED DUCT APPROXIMATION
      BTHK = BLIP/DIAM
      IF(BTHK.LT.0.01.OR.XID.GT.10.0) THEN
      XIBEL = XID
      FMBEL = FMACH
      DIAMBEL = DIAM
      XDARAD = 1.0
      GO TO 23
      END IF
C
      CALL LIPEF3(XID,XIBEL,FMACH,FMBEL,DIAMBEL,DIAM,ALIP,BLIP,XDARAD,FR
     1AC)
      IF(FMACH.NE.0.0) THEN
      FMBEL = FMACH*ABS(FMBEL/FMACH)
      GO TO 23
      END IF
      FMBEL = 0.0
C
C
   23 CONTINUE
      ETABEL = ETA*DIAMBEL/DIAM
      FMSQ = FMBEL**2
      FM1 = 1.0-FMSQ
      BETA = SQRT(FM1)

      COF = XIBEL
      COFINV = 1.0/XIBEL
      COFINVSQ = COFINV**2
      COFBETIN = 1.0/(XIBEL*BETA)
      CFBTINSQ = COFBETIN**2
      COFM1 = 1.0-COFINVSQ
      COFSQRT = SQRT(COFM1)

      A90 = 2.0*(ACOEF+COFSQRT)/(ACOEF+1.0)
      PSQCOEF = A90*(1.0-FMSQ*COFM1)**1.5/BETA
      PSQCOEF = PSQCOEF*WATINFIX

      GDEN = (1.0+COFSQRT)**2
      COSPK = BETA*COFSQRT/SQRT(1.0-FMSQ*COFM1)
      PSIPK = ACOS(COSPK)*180.0/PI
      HDEN = 1.0-FMBEL*COSPK


C  ********* CALCULATE TRANSMISSION LOSS IN NON-PLANE WAVE REGION ****

      QF = PI*ETABEL*(1.0-1.0/XIBEL)
      QF15SQ = (QF-1.5)**2
      RADREC = 1.135*EXP(-0.29*(QF+0.18)**2)

      IF(QF.LE.1.5) THEN
      RADRES = 1.5*EXP(-0.2124*QF15SQ)
      GO TO 53
      END IF

      RADRES = 1.0+0.5*EXP(-0.5338*QF15SQ)
   53 CONTINUE

      TAU = SQRT(1.0-1.0/XIBEL**2)
      TPM = TAU+FMBEL
```

```
      TTM = TAU*FMBEL
      QDEN = (RADRES*TPM+TTM+1.0)**2+(RADREC*TPM)**2
      QNUM = (RADRES+FMBEL)*(RADRES*FMBEL+1.0)+FMBEL*RADREC**2
      TLCF = 4.0*TAU*QNUM/QDEN

      IF(TLCF.GT.1.0) TLCF=1.0
      IF(TLCF.LT.0.0) TLCF=0.0001

C  ******* FINISHED WITH TRANSMISSION LOSS AT CURRENT CUT-OFF RATIO **

C  ****************************** CALCULATE TRANSMITTED POWER ********
C
      WATTRAN = WATTRAN+TLCF*WATTSCOF(J)
C
C  ********** CALCULATE P**2 COEF. TO ACCOUNT FOR WATTS.
C      TO ACCOUNT FOR MIC. RADIUS, DIVIDE BY DISTANCE**2 AT PSQ BELOW.
C

      PSQPK = PSQCOEF*ETABEL*XIBEL/(2.0*BETA)
C
C  ********** START SORTING INTO REGIMES TO HANDLE LARGE ANGLES ******
C
      IREG = 0
      ETAC1 = 0.6*BETA/(1.0-COFINV)
      IF(ETABEL.GT.ETAC1) THEN
      IREG = 1

C ********** REGION 1, SLOPE AT ARG=PI/2 USED TO PROJECT BEYOND PEAK

      EPS = 1.0/(BETA*COF)+0.5/ETABEL
      EPSQ = EPS**2
      QNUM = 1.0+FMSQ*EPSQ
      DEPDPSI = QNUM*SQRT(1.0-FM1*EPSQ)
      PSQRATC1 = (4.0/PI)**2*EPS*COFBETIN/(COFBETIN+EPS)**2
      FDEN = CFBTINSQ-EPSQ
      DPSQDPSI = (FDEN+4.0*EPSQ)*PSQRATC1*DEPDPSI/(EPS*FDEN)
      SINPSIC1 = EPS/SQRT(QNUM)
      PSIC = ASIN(SINPSIC1)*180.0/PI
      AC = ALOG(PSQRATC1)
      BC = 0.8889*DPSQDPSI/PSQRATC1
      BC = BC*PI/180.0
      CC = -0.1781*BC
      GO TO 50
      END IF

      ETAC2 = 0.6*BETA*COF
      IF(ETABEL.GT.ETAC2) THEN
      IREG = 2

C ********** REGION 2, PSQratio AT ARG=-PI/2 USED TO FIT EXPONENTIAL FOR
C             USE BEYOND PEAK

      EPS = 1.0/(BETA*COF)-0.5/ETABEL
      PSQRATC2 = (4.0/PI)**2*EPS*COFBETIN/(COFBETIN+EPS)**2
      EPSQ = EPS**2
      QDEN = 1.0+FMSQ*EPSQ
      SINPSIC2 = EPS/SQRT(QDEN)
      PSIC2 = ASIN(SINPSIC2)*180.0/PI
      AC = ALOG(PSQRATC2)/(PSIPK-PSIC2)**2
      GO TO 50
```

```
      END IF



C ********** REGION 3, LOW ETA REGION, PSIPK>60 DEG. FIT EXPONENTIAL AT
C    0.5*PSIPK FOR USE BEYOND PEAK.  CODE IREG=3.  EXPONENTIAL EQUATION
C    USED IN PSQ SUBROUTINE FOR PSI > PSIPK.

      IF(PSIPK.GT.60.0) THEN

      IREG = 3

      ANGF = 0.5*PSIPK
      ANGRAD = ANGF*PI/180.0
      SINF = SIN(ANGRAD)
      EPS = SINF/SQRT(1.0-FMSQ*SINF**2)
      ARG = PI*ETABEL*(COFBETIN-EPS)
      SINARG = SIN(ARG)
      PSQRATC3 = 4.0*EPS*COFBETIN/(COFBETIN+EPS)**2
      PSQRATC3 = PSQRATC3*(SINARG/ARG)**2
      AC = ALOG(PSQRATC3)/(PSIPK-ANGF)**2
      GO TO 50
      END IF

C ********** REGION 4, LOW ETA REGION, PSIPK<60 DEG. FIT EXPONENTIAL AT
C    80 deg. FOR USE BEYOND PEAK.  CODE IREG=4.  EXPONENTIAL EQUATION
C    USED IN PSQ SUBROUTINE FOR PSI>80 deg.

      IREG = 4

      ANGF = 80.0
      ANGRAD = ANGF*PI/180.0
      SINF = SIN(ANGRAD)
      EPS = SINF/SQRT(1.0-FMSQ*SINF**2)
      ARG = PI*ETABEL*(COFBETIN-EPS)
      SINARG = SIN(ARG)
      PSQRATC3 = 4.0*EPS*COFBETIN/(COFBETIN+EPS)**2
      PSQRATC3 = PSQRATC3*(SINARG/ARG)**2
      AC = ALOG(PSQRATC3)/(PSIPK-ANGF)**2

   50 CONTINUE

C
      DO 25 I=1,NANGLE
      ANG = ANGLE(I)
      IF(ANG.EQ.0.0.AND.ISIDELN.EQ.1) THEN
      PSQRADT(I) = 0.0
      PSQTOT(I) = 0.0
      PSQTLOS(I) = 0.0
      GO TO 25
      END IF
C
      CALL PSQGCOF(ANG,PSQ,FMBEL,ETABEL,XIBEL,PSIPK)

      PSQRAD = PSQ
      RAD = DISTANCE
      IF(ISIDELN.EQ.1) THEN
      RAD = DISTANCE/SIN(ANG*PI/180.0)
      END IF
      PSQ = PSQ/RAD**2
```

```
      PSQRADT(I) = PSQRADT(I)+POWCOEF*PSQRAD
      PSQTOT(I) = PSQTOT(I)+POWCOEF*PSQ
      PSQTLOS(I) = PSQTLOS(I)+POWCOEF*PSQ*TLCF
C  ******* NOTE THAT AN INLET TRANMISSION LOSS (TLCF) HAS BEEN USED ****
   25 CONTINUE
      GO TO 70
   45 CONTINUE
C  ********** IN PLANE-WAVE CALCULATION PROCEDURE !!!!!!!!!!!!!!!!!!!
C  ********** P**2 PRINCIPAL LOBE PEAK FOR 1 WATT POWER INPUT ********
      PSQPK = 2.0*PSQCOEFP
C  ******************************************************************
      GDEN = 4.0
      FMSQEX = FMBELEX**2
C  ********* LOW ETA REGION. FIT EXPONENTIAL AT PSICRPL FOR BEYOND PEAK.
C  ********* IF PSICRPL < 90 CAN'T BE OBTAINED, USE PSICRPL = 90.
      ANGF = 90.0
      ETACRPL = 0.5*SQRT(1.0-FMSQEX)
      SINCRPL = 1.0/SQRT(4.0*ETABELEX**2+FMSQEX)
      IF(ETABELEX.GT.ETACRPL) ANGF=ASIN(SINCRPL)*180./PI
      PSICRPL = ANGF
      ANGFRAD = ANGF*PI/180.0
      SINF = SIN(ANGFRAD)
      ARG = PI*ETABELEX*SINF/SQRT(1.0-FMSQEX*SINF**2)
      SINARG = SIN(ARG)
      PSQRATPL = (SINARG/ARG)**2
      ACPL = ALOG(PSQRATPL)/ANGF**2
C ********** ACPL IS THE AMPLITUDE OF THE EXPONENTIAL AT PSICRPL *****
C ********** END LOW ETA REGION EXPONENTIAL FIT AT PSICRPL. **********
C  ** CALCULATE TRANSMISSION LOSS AT BELMOUTH EXIT CUT-OFF RATIO AND
C  ** FREQUENCY PARAMETER.
      X = 0.5*(PI*ETABELEX)**2
      RADRES = 1.0+X*EXP(-0.325226*X)-
     1                  EXP(-0.101669*ETABELEX**5.7848)
      A = 0.023567
      Y = 0.5*PI**2*ETABELEX
      RADREC=EXP(-3.574331*ETABELEX**1.957292)*8.*ETABELEX/
     13.+A*Y**2/(1.+A*Y**3)
      QDEN = (1.0+FMBELEX)**2*((RADRES+1.0)**2+RADREC**2)
      TLCF=4.*(RADRES*(1.+FMSQEX)+FMBELEX*(RADRES**2+
     1       RADREC**2+1.))/QDEN
      IF(TLCF.GT.1.0) TLCF=1.0
      IF(TLCF.LT.0.0) TLCF=0.0001
C  ** END TRANSMISSION LOSS CALCULATION FOR PLANE WAVE AT BELLMOUTH EXIT
C  ****************************** CALCULATE TRANSMITTED POWER ********
C
      WATTRAN = WATTRAN+TLCF*WATTSCOF(J)
C
```

```

      DO 40 I=1,NANGLE
      FI = I
      ANGDEG = ANGLE(I)
      IF(ANGDEG.EQ.0.0.AND.ISIDELN.EQ.1) THEN
      PSQRADT(I) = 0.0
      PSQTOT(I) = 0.0
      PSQTLOS(I) = 0.0
      GO TO 40
      END IF
C
      ANGRAD = ANGDEG*PI/180.0

      SINANG = SIN(ANGRAD)
      COSANG = COS(ANGRAD)

      Q1DEN = SQRT(1.0-FMSQEX*SINANG**2)
      Q1 = SINANG/Q1DEN
      ARG = PI*ETABELEX*Q1
      SINSQNUM = (SIN(ARG))**2
      GG = (1.0+COSANG/Q1DEN)**2/GDEN
      PSQRAT = 1.0

      PSQDEN = ARG**2
      IF(PSQDEN.LT.1.E-06.AND.ANGDEG.LE.90.0) GO TO 49


C  ** LOW FREQUENCY REGION.  FOLLOWING ALLOWS REASONABLE
C  ** EXTRAPOLATION BEYOND 90 deg, STARTING AT ARG = PI/2 IF ETA>ETAcrit
C  ** OR AT 90 deg. OTHERWISE.  USES EXPONENTIAL FIT AT PSI = 0
C  ** AND PSI = PSIFIT.

      IF(ANGDEG.LT.PSICRPL) GO TO 48

      QEXP = ACPL*(ANGDEG)**2
      IF(QEXP.LT.-20.) QEXP=-20.

      PSQRAT = EXP(QEXP)
      GO TO 49


   48 PSQRAT = PSQRAT*SINSQNUM/PSQDEN
   49 CONTINUE

      PSQ = PSQRAT*PSQPK*GG

      PSQRAD = PSQ
C
      RAD = DISTANCE
      IF(ISIDELN.EQ.1) THEN
      RAD = DISTANCE/SIN(ANGDEG*PI/180.0)
      END IF

      PSQ = PSQ/RAD**2

C
      PSQRADT(I) = PSQRADT(I)+POWCOEF*PSQRAD
      PSQTOT(I) = PSQTOT(I)+POWCOEF*PSQ
      PSQTLOS(I) = PSQTLOS(I)+POWCOEF*PSQ*TLCF

```

```
C  ************ NOTE THAT A TRANMISSION LOSS (TLCF) HAS BEEN USED ***

   40 CONTINUE
   41 CONTINUE


   70 CONTINUE

      FNANGLE = NANGLE
      SUMWATT = 0.0
      DO 75 I=1,NANGLE
      ANGRAD = ANGLE(I)*PI/180.0
      SUMWATT = SUMWATT+PSQRADT(I)*SIN(ANGRAD)

      IF(PSQTOT(I).LT.4.E-08) THEN
      SPLTL(I) = 20.0
      SPL(I) = 20.0
      GO TO 75
      END IF
      SPLTL(I) = 10.0*ALOG10(PSQTLOS(I))+93.9794
      SPL(I) = 10.0*ALOG10(PSQTOT(I))+93.9794
   75 CONTINUE

      WATTINT = SUMWATT*PI/(POWCON*FNANGLE)
      SPLDIF = 10.0*ALOG10(WATTS/WATTINT)

      DO 80 I=1,NANGLE
      SPLTL(I) = SPLTL(I)+SPLDIF
      SPL(I) = SPL(I)+SPLDIF
   80 CONTINUE


      RETURN
      END


C
C  ********************************************************************
C  ********** END OF MAIN SUBROUTINE "BBRDCFIN" **********************
C  ********** MODIFIED 02/21/1998, E. J. RICE ************************
C  ********************************************************************
C
C  ********************************************************************
C  ** SUBROUTINE FOR CALC PSQ FOR EQUAL ENERGY PER MODE AT AN ANGLE
C  ** CUT-OFF RATIO APPROXIMATE EQUATIONS USED, BLOCK BUILD-UP AS IN
C     AIAA PAPER 96-1774, EMPIRICAL NORMALIZATION REPLACES FACTOR
C     SQRT(1.-1/XI**2).  FOUR REGIONS (ETA AND CUT-OFF RATIO) DETERMINE
C     PROPER APPROXIMATION FOR HIGH ANGLE RADIATION. DEVELOPED 01/30/98.
C
      SUBROUTINE PSQGCOF(ANG,PSQ,FMACH,ETA,XI,PSIPK)
C
      COMMON FMSQ,FM1,BETA,COFBETIN,CFBTINSQ,GDEN,HDEN,
     1PSQPK,PSIC,AC,BC,CC,IREG

      PI = 3.1415927

      ANGRAD = ANG*PI/180.0
      SINANG = SIN(ANGRAD)
      COSANG = COS(ANGRAD)

```

```
      Q1DEN = SQRT(1.0-FMSQ*SINANG**2)
      Q1 = SINANG/Q1DEN
      ARG = PI*ETA*(Q1-COFBETIN)
      SINSQNUM = (SIN(ARG))**2
      GG = (1.0+COSANG/Q1DEN)**2/GDEN
      HH = (1.0-FMACH*COSANG)/HDEN
      PSQRAT = 4.0*Q1/(BETA*XI*(Q1+COFBETIN)**2)
      PSQDEN = ARG**2
      ANGCK = PSIPK+1.0
      IF(ANG.GT.ANGCK) GO TO 5
C  ********** CHECK FOR 0/0, USE LIMITING CASE IF INDETERMINATE ******
C  ********** DON'T CHECK IF ANGLE ABOVE PEAK ANGLE ******************
      IF(PSQDEN.LT.1.E-06) GO TO 39
    5 CONTINUE
      IF(ANG.LT.PSIPK) GO TO 38
      IF(ANG.GE.PSIC.AND.IREG.EQ.1) THEN
C  ** FOLLOWING TO REMOVE THE P**2 OSCILLATIONS BEYOND THE PEAK ******
C  ** USES SLOPE AT ARG = PI/2 TO EXTRAPOLATE TO HIGH ANGLES *********
      DANG = ANG-PSIC
      QEXP = AC+BC*DANG/(1.0+CC*DANG)
      IF(QEXP.LT.-20.) QEXP=-20.
      PSQRAT = EXP(QEXP)
      GO TO 39
      END IF
      IF(ANG.GE.PSIPK.AND.IREG.EQ.2) THEN
C  ** FOLLOWING TO REMOVE THE P**2 OSCILLATIONS BEYOND THE PEAK ******
C  ** USES EXPONENTIAL FIT AT ARG = -PI/2 TO EXTRAPOLATE TO HIGH ANGLES
C  ** ALSO HANDLES LOW FREQUENCY REGIMES 3 AND 4 FOR ANGLES BEYOND PEAK.
      QEXP = AC*(ANG-PSIPK)**2
      IF(QEXP.LT.-20.) QEXP=-20.
      PSQRAT = EXP(QEXP)
      GO TO 39
      END IF
      IF(ANG.GE.PSIPK.AND.IREG.EQ.3) THEN
C  ** ONE OF THE LOW FREQUENCY REGIONS, REGION 3.  FOLLOWING ALLOWS
C  ** REASONABLE EXTRAPOLATION BEYOND 90 deg, STARTING AT PEAK.
C  ** USES EXPONENTIAL FIT AT PSI = PSIPK AND 0.5*PSIPK. PSIPK>60 deg.
      QEXP = AC*(ANG-PSIPK)**2
      IF(QEXP.LT.-20.) QEXP=-20.
      PSQRAT = EXP(QEXP)
      GO TO 39
      END IF
C  ** ONLY REGION LEFT, REGION 4, WITH PSIPK<60 deg.
C  ** ONE OF THE LOW FREQUENCY REGIONS.  FOLLOWING ALLOWS REASONABLE
C  ** EXTRAPOLATION BEYOND 90 deg, STARTING THIS TIME AT 80 deg.
C  ** USES EXPONENTIAL FIT AT PSI = PSIPK AND 80 deg. PSIPK<60 deg.
```

```
      IF(ANG.LT.80.0) GO TO 38

      QEXP = AC*(ANG-PSIPK)**2
      IF(QEXP.LT.-20.) QEXP=-20.

      PSQRAT = EXP(QEXP)
      GO TO 39

   38 PSQRAT = PSQRAT*SINSQNUM/PSQDEN
   39 CONTINUE

      PSQ = PSQRAT*PSQPK*GG*HH
C

      RETURN
      END


C  *******************************************************
C  ** END OF PSQGCOF.FOR ********************************
C  ********************************************************************




C
C  ********************************************************************
C  ********** ALLOWS CUT OFF MODES TO PROPAGATE IN BELLMOUTH IF THEY CAN
C  ********** BE CUT ON OR PROPAGATING BEFORE THE BELLMOUTH EXIT *****
C  ********************************************************************
C  ** SUBROUTINE "LIPEF3" CALCULATES THE EFFECT OF THE INLET LIP OR
C     BELLMOUTH ON THE INLET FAR-FIELD RADIATION, SECOND MODEL
C  ********************************************************************
C  ********************************************************************
C
      SUBROUTINE LIPEF3(XID,XIBEL,FMACK,FMBEL,DBEL,DIAM,ALIP,BLIP,XDARAD
     1,FRAC)
C
C  ********** DEFINITION OF VARIABLES ********************************
C
C     ALIP =  MINOR AXIS OF THE ELLIPTICAL INLET LIP, INCHES
C     BLIP =  MAJOR AXIS OF THE ELLIPTICAL INLET LIP, INCHES
C             FOR CIRCULAR ARC, ALIP = BLIP
C     DIAM =  DIAMETER OF INLET DUCT, INCHES
C     FMACH=  MACH NUMBER OF UNIFORM FLOW IN THE STRAIGHT DUCT SECTION
C     XID =   CUT-OFF RATIO OF MODE IN THE STRAIGHT DUCT SECTION
C     XIBEL = CUT-OFF RATIO OF MODE IN THE ELLIPTIC BELLMOUTH AS THE
C               MODE RELEASES AND RADIATES.  USE THIS VALUE FOR RADIATION.
C     XDARAD=VALUE OF X/A WHERE RADIATION RELEASES FROKM BELLMOUTH
C
C  **  AN ITERATION IS REQUIRED TO DETERMINE XIRAD, START THE ITERATION
C
      FMACH = FMACK
      IF(FMACK.LT.0.0) FMACH=-FMACK
      PI = 3.1415927
      N = 100
      FN = N
      RAD = DIAM/2.0
      BDA = BLIP/ALIP
      ADUCT = PI*DIAM**2/4.0
```

```
      FM1 = SQRT(1.0-FMACH**2)
      IF(XID.LE.1.0) GO TO 40
C  ** IF THE MODE DOES NOT PROPAGATE IN THE DUCT, THE BELLMOUTH MAY
C     STILL CUT THE MODE ON AND ALLOW PROPAGATION. SKIP DUCT
C     CALCULATIONS BELOW IF DUCT CUT-OFF RATIO LESS THAN UNITY.
      QXI = 1.0-1.0/XID**2
      QNT = QXI/(1.0-QXI*FMACH**2)
      QNT = FM1*SQRT(QNT)
C  ** ANGDUCT IS THE PROPAGATION ANGLE OF THE MODE IN THE STRAIGHT DUCT
      ANGDUCT = ACOS(QNT)
      TANANG = TAN(ANGDUCT)
      TANANG2 = TANANG**2
      XDATSQ = TANANG2/(TANANG2+BDA**2)
      XDAT = SQRT(XDATSQ)
      QNT = 1.0-XDATSQ
      RT = RAD+BLIP*(1.0-SQRT(QNT))
      XT = XDAT*ALIP
      DELX = (RT-FRAC*RAD)/TANANG
      XRAD = XT-DELX
      IF(DELX.GE.XT) THEN
      XIBEL = XID
      ANGDUCT = ANGDUCT*180.0/PI
      FMBEL = FMACH
      DBEL = DIAM

C
C  ** THE BELLMOUTH DOES NOT EFFECT THE RADIATION AT THIS CUTOFF RATIO
      GO TO 501
      END IF
   40 CONTINUE
      XDAPR = 0.0
      XDIFPR = XRAD
      ICALC = 0
      DO 50 I=1,N
      FI = I
      XDA = SQRT(FI/FN)
      IF(XDA.GE.1.0) XDA=0.9999
      SQXA = SQRT(1.0-XDA**2)
      QNT = BDA*XDA/SQXA
C  ******** ANGWAL IS THE SLOPE OF THE BELLMOUTH WALL AT THIS X/A (XDA)
      ANGWAL = ATAN(QNT)
C
C  ** CALCULATE THE INCREASED FLOW AREA DUE TO THE BELLMOUTH AT THIS XDA
C
      QRB = BLIP*(1.0-SQXA)
      RC = QRB/SIN(ANGWAL)
      AEX = 2.0*PI*RC*(RAD*ANGWAL+RC*(1.0-COS(ANGWAL)))
C
C  ** AEX IS THE EXTRA FLOW AREA DUE TO THE BELLMOUTH AT THIS XDA
      ATOT = AEX+ADUCT
      FMBEL = FMACH*ADUCT/ATOT
      RADBEL = RAD+QRB
      FM1B = SQRT(1.0-FMBEL**2)
      XIBEL= XID*RADBEL*FM1/(RAD*FM1B)
      QXI = 1.0-1.0/XIBEL**2
      QNT = QXI/(1.0-QXI*FMBEL**2)
C  ********** CHECK IF MODE HAS STARTED PROPAGATING IN BELLMOUTH *****
      IF(QXI.LT.0.0) GO TO 50
      ICALC = ICALC+1
      QNT = FM1B*SQRT(QNT)
```

```
C  ******** ANGPROP IS THE ANGLE OF PROPAGATION OF THE MODE AT THIS XDA
      ANGPROP = ACOS(QNT)
      TANANG = TAN(ANGPROP)
      TANANG2 = TANANG**2
      XDATSQ = TANANG2/(TANANG2+BDA**2)
      XDAT = SQRT(XDATSQ)
      QNT = 1.0-XDATSQ
      RT = RAD+BLIP*(1.0-SQRT(QNT))
      XT = XDAT*ALIP
      DELX = (RT-FRAC*RADBEL)/TANANG
      XRAD = XT-DELX
      XDIF = XRAD-XDA*ALIP
      IF(XDIF.LE.0.0) GO TO 55
      XDIFPR = XDIF
      XDAPR = XDA
   50 CONTINUE
      IF(ICALC.EQ.0) THEN
      WRITE(12,100)
      WRITE(*,100)
  100 FORMAT(' ******** ALERT ******** ALERT ******** ALERT ******')
      WRITE(12,101)
      WRITE(*,101)
  101 FORMAT(' ** THIS MODE CAN NOT ESCAPE THE BELLMOUTH EXIT.  PLEASE M
     1AKE MODIFICATIONS ** ')
      WRITE(12,100)
      WRITE(*,100)
      XIBEL = .1
      GO TO 500
      END IF
      IF(ICALC.EQ.1) THEN
C  *************** MODE CUT-ON ACHIEVED AT BELLMOUTH EXIT ************
      XIBEL = 1.0001
      GO TO 500
      END IF
   55 CONTINUE
      IF(ICALC.EQ.1) THEN
      XDARAD = XDA
      GO TO 60
      END IF
      X2 = XDA
      X1 = XDAPR
      Y2 = XDIF
      Y1 = XDIFPR
      DY21 = ABS(Y2-Y1)
      IF(DY21.EQ.0.0) THEN
      XDARAD = XDAPR
      GO TO 60
      END IF
      XDARAD = (X1*Y2-X2*Y1)/(Y2-Y1)
C
C  ** ITERATION DONE, CALCULATE OUTPUTS AT X/A = XDARAD
C
   60 CONTINUE
      SQXA = SQRT(1.0-XDARAD**2)
      QNT = BDA*XDARAD/SQXA
C  ******** ANGWAL IS THE SLOPE OF THE BELLMOUTH WALL AT MODE RADIATION
      ANGWAL = ATAN(QNT)
C
C  ** CALCULATE THE FINAL FLOW AREA INCREASE DUE TO THE BELLMOUTH
C
```

```
      QRB = BLIP*(1.0-SQXA)
      RC = QRB/SIN(ANGWAL)
      AEX = 2.0*PI*RC*(RAD*ANGWAL+RC*(1.0-COS(ANGWAL)))
C
C  ** AEX IS THE EXTRA FLOW AREA DUE TO THE BELLMOUTH AT THIS XDA
      ATOT = AEX+ADUCT
      FMBEL = FMACH*ADUCT/ATOT
      RADBEL = RAD+QRB
      FM1B = SQRT(1.0-FMBEL**2)
      XIBEL= XID*RADBEL*FM1/(RAD*FM1B)
      QXI = 1.0-1.0/XIBEL**2
      QNT = QXI/(1.0-QXI*FMBEL**2)
      QNT = FM1B*SQRT(QNT)
      IF(XID.GE.1.0) THEN
      QXI = 1.0-1.0/XID**2
      QNT = QXI/(1.0-QXI*FMACH**2)
      QNT = FM1*SQRT(QNT)
C  ** "ANGDUCT" IS THE PROPAGATION ANGLE OF THE MODE FROM THE DUCT IF
C     BELLMOUTH IS "NOT" CONSIDERED *********************************
      ANGDUCT = ACOS(QNT)*180.0/PI
      ELSE
      ANGDUCT = 90.0
      END IF
  500 CONTINUE
      DBEL = 2.0*RADBEL
  501 CONTINUE
      RETURN
      END


C
C  *****************************************************************
C  ********** END OF SUBROUTINE "LIPEF3" *****************************
C  *****************************************************************

C
C  **** AFT FAN RADIATION SUBROUTINE, E. J. RICE, REVISED 02/19/1998
C  **** NORMALIZED PLANE WAVE RADIATION INCLUDED HERE.
C  ** THE FOLLOWING "BBRDCFEX" IS THE MAIN SUBROUTINE.  ALL ARGUMENTS
C     ARE INPUTS EXCEPT "DJET," "FMACH1," "NANGLE," "ANGLE," "SPL,"
C     "SPLTL," "WATTS," "FMACHN," AND "COFMIN" AND WATTS
C     RETURNED TO THE MAIN PROGRAM FOR PRINTING, FILE STORAGE ETC.
C
C  ** THIS VERSION REMOVES THE P**2 OSCILLATIONS BEYOND THE PEAK.  FOUR
C     REGIONS (ETA AND CUT-OFF RATIO) DETERMINE PROPER APPROXIMATION FOR
C     HIGH ANGLE RADIATION. DEVELOPED 01/30/98.

      SUBROUTINE BBRDCFEX(TTOT,PTOT,TSUR,PSUR,HTRAT,
     1ANOZRAT,DISTANCE,ISIDELN,DDUCT,DJET,FMACHD,FMACH1,FMACH2,
     2NCOF,WATTSCOF,DELANG,ETAD,
     3NANGLE,ANGLE,SPL,SPLTL,WATTS,WATTRAN,FMACHN,COFMIN)

C
      DIMENSION ANGLE(200),SPL(200),SPLTL(200),WATTSCOF(200),
     1COFRAT(200),COFRATD(200),COFRATN(200),PSQTOT(200),
     2PSQTLOS(200),PSQRADT(200)

C
C  ** SUBROUTINE REQUIRED "CONOZ"
C
```

```
C  ***************** DEFINITION OF SUBROUTINE ARGUMENTS **************
C
C TTOT    TOTAL TEMPERATURE IN AFT FAN DUCT, (DEGREES RANKINE)
C PTOT    TOTAL PRESSURE IN AFT FAN DUCT, (PSIA)
C TSUR    TOTAL TEMPERATURE IN SURROUNDING MEDIUM, (DEGREES RANKINE)
C PSUR    TOTAL PRESURE IN SURROUNDING MEDIUM, (PSIA)
C HTRAT   AFT FAN DUCT HUB-TIP RATIO
C ANOZRAT (NOZZLE THROAT AREA)/(FAN DUCT AREA)
C DISTANCE  RADIUS OF MICROPHONE ARRAY OR TRAVERSE, (FT.)
C ISIDELN = 0 FOR CONSTANT RADIUS, = 1 FOR CONSTANT SIDELINE CALCULATION
C DDUCT   AFT FAN DUCT OUTSIDE DIAMETER, (INCHES)
C DJET    FINAL JET DIAMETER, (INCHES)
C FMACHD  AFT FAN DUCT MACH NUMBER, POSITIVE FOR EXHAUST
C FMACH1  FINAL JET MACH NUMBER
C FMACH2  MACH NUMBER OF SURROUNDING MEDIUM
C FMACHN  NOZZLE EXIT (THROAT) MACH NUMBER
C NCOF    NUMBER OF CUT-OFF RATIO BINS TO SORT ACOUSTIC POWER
C WATTSCOF VECTOR WITH ACOUSTIC POWER FOR EACH BIN, (WATTS)
C FREQ    FREQUENCY OF SOUND, (HERTZ)
C DELANG  ANGLE INCREMENT DESIRED ON FAR-FIELD RADIAL TRAVERSE, (DEGREES)
C NANGLE  NUMBER OF ANGLES USED IN CALCULATION, DETERMINED BY DELANG AND
C         THE MAXIMUM ANGLE OF 180 DEGREES
C ANGLE   VECTOR OF ANGLES ON THE FAR-FIELD TRAVERSE, CONVERTED TO
C         THAT MEASURED FROM THE ENGINE ”INLET” AXIS, (DEGREES)
C SPL     THE SOUND PRESSURE LEVEL VECTOR ON THE FAR-FIELD TRAVERSE
C         ”IGNORING” THE EXIT TRANSMISSION LOSS (DECIBELS) RELATIVE TO
C         2*10**(-5) NEWTONS/METER**2
C SPLTL   THE SOUND PRESSURE LEVEL VECTOR ON THE FAR-FIELD TRAVERSE
C         ”INCLUDING” THE EXIT TRANSMISSION LOSS (DECIBELS) RELATIVE TO
C         2*10**(-5) NEWTONS/METER**2
C WATTS   SUM OF ACOUSTIC POWER IN ALL THE CUT-OFF RATIO BINS, (WATTS)
C WATTRAN SUM OF TRANSMITTED ACOUSTIC POWER IN ALL BINS, (WATTS)
C COFMIN  THE MINIMUM CUT-OFF RATIO BELOW WHICH COMPLETE REFLECTION
C         OCCURS DUE TO REFRACTION THROUGH THE SLIP LAYER
C
      PI = 3.1415927
      QAFP = 1.0+0.328766*ETAD**1.702882
      AFPOWFAC = 1.741*(QAFP+1.274989*ETAD**2)/(PI*ETAD*QAFP)

C  CALCULATE COEF. (PLANE WAVE) INTEGRATION OF RAD. DIRECTIVITY, MACH=0
      IF(ETAD.LT.1.0) THEN
      ACOEFPW = 1.733303+5.30259*ETAD**2.28937
      GO TO 14
      END IF
      ACOEFPW = 7.035893*ETAD**1.773669
   14 CONTINUE
C
C  CALC. COEF. FOR INTEGRATION WITH AFT SHEAR LAYERS, PLANE WAVE
C
      AFPOWFPW = (1.0+0.127683*ETAD)/(3.0+0.137590*ETAD)
      PSQCOEFP = ACOEFPW*AFPOWFPW*(1.0+2.6557*ETAD)/(1.0515+3.8508*ETAD)
      PSQCOEFP = 1.3704*PSQCOEFP
C  *******************************************************************

      FCOF = NCOF
      FCOFINV = 1./FCOF
      FCOFIND2 = 0.5/FCOF
C  *********************** SET UP CUT-OFF RATIOS IN THE DUCT ********
      COFSQPR = 1.0
      DO 20 I=1,NCOF
```

```
      COFRATD(I) = SQRT(1.0/(COFSQPR-FCOFIND2))
      COFSQPR = COFSQPR-FCOFINV
   20 CONTINUE

      TDUCT = TTOT/(1.0+0.2*FMACHD**2)
      CDUCT = 49.0421*SQRT(TDUCT)

      QSUR = 1.0+0.2*FMACH2**2
      TSTS = TSUR/QSUR
      PSTS = PSUR/QSUR**3.5
      CSUR = 49.0421*SQRT(TSTS)
      RHOSUR = 144.0*PSTS/(53.3*TSTS)

C
C  ************************* DETERMINE NOZZLE FLOW PROPERTIES ********

      CALL CONOZ(TTOT,PTOT,PSTS,HTRAT,ANOZRAT,DDUCT,FMACHD,FMACH1,CJET,D
     1JET,TJET,PNOZ,DNOZ,CNOZ,FMACHN)

      CRAT = CJET/CSUR

      ETA = ETAD*DJET*CDUCT/(DDUCT*CJET)
      ETAN= ETAD*DNOZ*CDUCT/(DDUCT*CNOZ)

      RATCFNOZ = DNOZ*CDUCT*SQRT(1.0-FMACHD**2)/(DDUCT*CNOZ*
     1SQRT(1.0-FMACHN**2))

      RATCFJET = DJET*CDUCT*SQRT(1.0-FMACHD**2)/(DDUCT*CJET*
     1SQRT(1.0-FMACH1**2))


      FMSQ1 = FMACH1**2
      FM11 = 1.0-FMSQ1
      BETA1 = SQRT(FM11)
      FMSQ2 = FMACH2**2
C
C  ********** ESTABLISH CUT-OFF LIMITS FOR COMPLETE REFLECTION
      COFMIN = 1.0
      IF(FMACH1.EQ.0.0) GO TO 15

      CKM2 = 1.0-CRAT*FM11/FMACH1
      IF(FMACH2.LT.CKM2) THEN
      COSPHIL = -CRAT/(1.0+CRAT*FMACH1-FMACH2)
      PHIL = ACOS(COSPHIL)
      SINPHIL = SIN(PHIL)
      DEN = SQRT(1.0+FMSQ1+2.0*FMACH1*COSPHIL)
      COSPSIL = (COSPHIL+FMACH1)/DEN
      SINPSIL = SINPHIL/DEN
      COFMIN = SQRT(FM11+FMSQ1*COSPSIL**2)/(BETA1*SINPSIL)
C       COFMIN = (1.0+FMACH1*COSPHIL)/(BETA1*SINPHIL)
      END IF
   15 CONTINUE
C  *******************************************************************

      NANGLE = 180.0/DELANG-1
      DO 5 I=1,NANGLE
      FI = I
      ANGLE(I) = FI*DELANG
    5 CONTINUE

```

```
C  ********** PART OF EMPIRICAL COEFFICIENT TAKING PLACE OF RADICAL
C  ********** SQRT(1–1/COF**2) IN P**2 COEFICIENT WHICH WOULD NOT BE
C  ********** ANY GOOD AT CUT–OFF.  FOR NON–PLANE WAVES.

      ACOEF = 0.7/ETA

C  ** RECALL, THE CUT–OFF RATIOS IN THE DUCT ARE INPUT HERE AS ”COFRATD”

C  ********** CALCULATE CUT–OFF RATIOS IN THE NOZZLE AND THE JET *****
      DO 22 I=1,NCOF
      COFRATN(I) = RATCFNOZ*COFRATD(I)
      COFRAT(I) = RATCFJET*COFRATD(I)
   22 CONTINUE
C
C  ****************** INITIALIZE P**2 AT EACH FAR–FIELD ANGLE ********
C
      DO 10 I=1,NANGLE
      PSQRADT(I) = 0.0
      PSQTLOS(I) = 0.0
      PSQTOT(I) = 0.0
   10 CONTINUE
C
C  ****************************** START LOOP ON CUT–OFF RATIO ********
C
      POWCON = 8.36424*RHOSUR*CSUR
      WATTS = 0.0
      WATTRAN = 0.0
      DO 70 J=1,NCOF
      WATTS = WATTS+WATTSCOF(J)
C
C  ** DETERMINE IF COFRAT IS WITHIN COMPLETE REFLECTION RANGE DUE TO
C  ** REFRACTION THROUGH THE SLIP LAYER OR IF COMPLETE REFLECTION
C  ** OCCURS AT THE NOZZLE THROAT
C
      IF(COFRAT(J).LT.COFMIN.OR.COFRATN(J).LE.1.0) GO TO 70


C  *******************************************************************
C  !!!!!!!! VERY IMPORTANT! FOLLOWING DEFINES PLANE WAVE REGIME !!!!!!
C  *******************************************************************

C  ********** DETERMINE IF PLANE WAVE RADIATION ALGORITHM SHOULD BE USED
C  ********** IF PLANE WAVE IPW = 1 (YES) FOR COFRATD>=3 OR LAST BIN
      IPW = 0
      IF(COFRATD(J).GE.3.0.OR.J.EQ.NCOF) IPW=1




C  ** CALCULATE TRANSMISSION LOSS AT NOZZLE THROAT CUT–OFF RATIO AND
C  ** FREQUENCY PARAMETER.

      FMSQN = FMACHN**2

      IF(IPW.EQ.1) THEN

C  *************************************** IN PLANE–WAVE REGIME ******

      X = 0.5*(PI*ETAN)**2
      RADRES = 1.0+X*EXP(–0.325226*X)–EXP(–0.101669*ETAN**5.7848)
      A = 0.023567
```

```
      Y = 0.5*PI**2*ETAN
      RADREC=EXP(-3.574331*ETAN**1.957292)*8.*
     1          ETAN/3.+A*Y**2/(1.+A*Y**3)
      QDEN = (1.0+FMACHN)**2*((RADRES+1.0)**2+RADREC**2)
      TLCF = 4.*(RADRES*(1.+FMSQN)+FMACHN*(RADRES**2+
     1         RADREC**2+1.))/QDEN
      GO TO 55
      END IF
C  ********** IN NON-PLANE WAVE, RADIAL OR SPINNING MODE REGION ******
      QF = PI*ETAN*(1.0-1.0/COFRATN(J))
      QF15SQ = (QF-1.5)**2
      RADREC = 1.135*EXP(-0.29*(QF+0.18)**2)
      IF(QF.LE.1.5) THEN
      RADRES = 1.5*EXP(-0.2124*QF15SQ)
      GO TO 53
      END IF
      RADRES = 1.0+0.5*EXP(-0.5338*QF15SQ)
   53 CONTINUE
      TAU = SQRT(1.0-1.0/COFRATN(J)**2)
      TPM = TAU+FMACHN
      TTM = TAU*FMACHN
      QDEN = (RADRES*TPM+TTM+1.0)**2+(RADREC*TPM)**2
       QNUM = (RADRES+FMACHN)*(RADRES*FMACHN+1.0)+FMACHN*RADREC**2
      TLCF = 4.0*TAU*QNUM/QDEN
C  ***************************** CALCULATE TRANSMITTED POWER ********
C
   55 CONTINUE
      WATTRAN = WATTRAN+TLCF*WATTSCOF(J)
C
C  ********** CALCULATE P**2 COEF. TO ACCOUNT FOR WATTS **************
C     TO ACCOUNT FOR MIC. RADIUS, DIVIDE BY DISTANCE**2 AT PSQ BELOW.
C
      POWCOEF = POWCON*WATTSCOF(J)
C
C  ********** PROGRAM SPITS HERE.  IT WILL CONTINUE ON FOR NON-PLANE
C  ********** WAVES AND WILL JUMP FOR THE PLANE WAVE
      IF(IPW.EQ.1) GO TO 45
C  ******** NOW IN "NON-PLANE" WAVE, RADIAL OR SPINNING MODE REGIME !!
      COFBETIN = 1.0/(COFRAT(J)*BETA1)
      COFINV = 1.0/COFRAT(J)
      COFINVSQ = COFINV**2
      COFM1 = 1.0-COFINVSQ
      EP = SQRT(COFM1)
      GDEN = (1.0+EP)**2
C  ****** HERE IS REMAINDER OF EMPIRICAL COEFFICIENT USING "ACOEF" ABOVE
      A90 = 2.0*(ACOEF+EP)/(ACOEF+1.0)
C  ****** THEORETICAL NORMALIZATION COEFFICENT WITH FLOW ATTACHED TO A90
C  ** INCLUDES INTEGRATED POWER NORMALIZATION "AFPOWFAC" (EMPIRICAL) *
```

```
      PSQCOEF = AFPOWFAC*A90*(1.0-FMSQ1*COFM1)**1.5/BETA1
      COSPK1 = BETA1*EP/SQRT(1.0-FMSQ1*COFM1)
      ANGPK1 = ACOS(COSPK1)
C  ********** GROUP VELOCITY VECTOR ANGLE IN REGION 1, PSIPK1 (DEGREES)
      PSIPK1 = ANGPK1*180.0/PI
      SINPK1 = SIN(ANGPK1)
C  ************** PHASE VELOCITY VECTOR ANGLE FOR PEAK IN REGION 1 (JET)
      SIN2 = SINPK1**2
      COSPHI1 = -FMACH1*SIN2+COSPK1*SQRT(1.0-FMSQ1*SIN2)
C
C  ************************************** PHI1 TO PHI2 ACROSS SLIP LAYER
C  ********************* PHASE VELOCITY ANGLE IN REGION 2 (SURROUNDINGS)

      COSPHI2 = COSPHI1/(CRAT+(CRAT*FMACH1-FMACH2)*COSPHI1)

C  *********** PHASE TO GROUP VELOCITY ANGLES IN REGION 2 (SURROUNDINGS)

       COSPSI2 = (COSPHI2+FMACH2)/SQRT(1.0+FMSQ2+2.0*FMACH2*COSPHI2)
      PSI2RAD = ACOS(COSPSI2)
      SINPSI2 = SIN(PSI2RAD)

C  ******************* ANGLE CHANGE ACOUSTIC POWER CORRECTION ********

      FREFRCT = SINPK1/SINPSI2

C  ******************************************************************

      Q22NUM = SQRT(1.0+FMSQ2+2.0*FMACH2*COSPHI2)

      COSPSPK2 = (COSPHI2+FMACH2)/Q22NUM
      ANGPK2 = ACOS(COSPSPK2)

C  ********** GROUP VELOCITY VECTOR ANGLE IN REGION 2, PSIPK2 (DEGREES)
      PSIPK2 = ANGPK2*180.0/PI

C  GROUP VELOCITY VECTOR ANGLE CHANGE, REG. 1 TO REG. 2, DELPSI (DEG.)
      DELPSI = PSIPK2-PSIPK1
C  ******************************************************************

      SIN2PK2 = SIN(PSIPK2*PI/180.0)

C  ********** P**2 PRINCIPAL LOBE PEAK FOR 1 WATT POWER INPUT ********
      PSQPK = PSQCOEF*FREFRCT*ETA*COFRAT(J)/(2.0*BETA1)
C  ******************************************************************


C  ****** START SORTING INTO REGIMES TO HANDLE ANGLES BEYOND PEAK ******
C
      COF = COFRAT(J)
      IREG = 0
      ETAC1 = 0.6*BETA1/(1.0-COFINV)
      IF(ETA.GT.ETAC1) THEN
      IREG = 1

C ********** REGION 1, SLOPE AT ARG=PI/2 USED TO PROJECT BEYOND PEAK

      EPS = 1.0/(BETA1*COF)+0.5/ETA
      EPSQ = EPS**2
      QNUM = 1.0+FMSQ1*EPSQ
      DEPDPSI = QNUM*SQRT(1.0-FM11*EPSQ)
```

```
      PSQRATC1 = (4.0/PI)**2*EPS*COFBETIN/(COFBETIN+EPS)**2
      FDEN = CFBTINSQ-EPSQ
      DPSQDPSI = (FDEN+4.0*EPSQ)*PSQRATC1*DEPDPSI/(EPS*FDEN)
      SINPSIC1 = EPS/SQRT(QNUM)
      PSIC = ASIN(SINPSIC1)*180.0/PI
      AC = ALOG(PSQRATC1)
      BC = 0.8889*DPSQDPSI/PSQRATC1
      BC = BC*PI/180.0
      CC = -0.1781*BC
      GO TO 50
      END IF
      ETAC2 = 0.6*BETA1*COF
      IF(ETA.GT.ETAC2) THEN
      IREG = 2
C ********** REGION 2, PSQratio AT ARG=-PI/2 USED TO FIT EXPONENTIAL FOR
C            USE BEYOND PEAK
      EPS = 1.0/(BETA1*COF)-0.5/ETA
      PSQRATC2 = (4.0/PI)**2*EPS*COFBETIN/(COFBETIN+EPS)**2
      EPSQ = EPS**2
      QDEN = 1.0+FMSQ1*EPSQ
      SINPSIC2 = EPS/SQRT(QDEN)
      PSIC2 = ASIN(SINPSIC2)*180.0/PI
      AC = ALOG(PSQRATC2)/(PSIPK1-PSIC2)**2
      GO TO 50
      END IF
C ********** REGION 3, LOW ETA REGION, PSIPK1>60 DEG. FIT EXPONENTIAL AT
C    0.5*PSIPK1 FOR USE BEYOND PEAK.  CODE IREG=3.  EXPONENTIAL EQUATION
C    USED IN PSQ SUBROUTINE FOR PSI > PSIPK1.
      IF(PSIPK1.GT.60.0) THEN
      IREG = 3
      ANGF = 0.5*PSIPK1
      ANGRAD = ANGF*PI/180.0
      SINF = SIN(ANGRAD)
      EPS = SINF/SQRT(1.0-FMSQ1*SINF**2)
      ARG = PI*ETA*(COFBETIN-EPS)
      SINARG = SIN(ARG)
      PSQRATC3 = 4.0*EPS*COFBETIN/(COFBETIN+EPS)**2
      PSQRATC3 = PSQRATC3*(SINARG/ARG)**2
      AC = ALOG(PSQRATC3)/(PSIPK1-ANGF)**2
      GO TO 50
      END IF
C ********** REGION 4, LOW ETA REGION, PSIPK1<60 DEG. FIT EXPONENTIAL AT
C    80 deg. FOR USE BEYOND PEAK.  CODE IREG=4.  EXPONENTIAL EQUATION
C    USED IN PSQ SUBROUTINE FOR PSI>80 deg.
      IREG = 4
      ANGF = 80.0
      ANGRAD = ANGF*PI/180.0
      SINF = SIN(ANGRAD)
```

```
      EPS = SINF/SQRT(1.0-FMSQ1*SINF**2)
      ARG = PI*ETA*(COFBETIN-EPS)
      SINARG = SIN(ARG)
      PSQRATC3 = 4.0*EPS*COFBETIN/(COFBETIN+EPS)**2
      PSQRATC3 = PSQRATC3*(SINARG/ARG)**2
      AC = ALOG(PSQRATC3)/(PSIPK1-ANGF)**2

   50 CONTINUE
C
C  ********** FINISHED WITH 4 REGION DEFINITIONS, START PSQ CALCULATION

      DO 25 I=1,NANGLE
      FI = I
      ANGDEG2 = ANGLE(I)

      IF(ANGDEG2.EQ.0.0.AND.ISIDELN.EQ.1) THEN
      PSQRADT(I) = 0.0
      PSQTOT(I) = 0.0
      PSQTLOS(I) = 0.0
      GO TO 25
      END IF
C
      ANGDEG1 = ANGDEG2-DELPSI
      ANG = ANGDEG1
      ANGRAD1 = ANGDEG1*PI/180.0
      IF(ANGDEG1.LT.0.0) GO TO 25
      SINANG = SIN(ANGRAD1)
      COSANG = COS(ANGRAD1)

      Q1DEN = SQRT(1.0-FMSQ1*SINANG**2)
      Q1 = SINANG/Q1DEN
      ARG = PI*ETA*(Q1-COFBETIN)
      SINSQNUM = (SIN(ARG))**2
      GG = (1.0+COSANG/Q1DEN)**2/GDEN
      PSQRAT = 4.0*Q1/(BETA1*COFRAT(J)*(Q1+COFBETIN)**2)

      PSQDEN = ARG**2
      ANGCK = PSIPK1+1.0
      IF(ANG.GT.ANGCK) GO TO 6
C  ********** CHECK FOR 0/0, USE LIMITING CASE IF INDETERMINATE ******
C  ********** DON'T CHECK IF ANGLE ABOVE PEAK ANGLE *****************
      IF(PSQDEN.LT.1.E-06) GO TO 39
    6 CONTINUE

      IF(ANG.LT.PSIPK1) GO TO 38
      IF(ANG.GE.PSIC.AND.IREG.EQ.1) THEN

C  ** FOLLOWING TO REMOVE THE P**2 OSCILLATIONS BEYOND THE PEAK ******
C  ** USES SLOPE AT ARG = PI/2 TO EXTRAPOLATE TO HIGH ANGLES *********
      DANG = ANG-PSIC
      QEXP = AC+BC*DANG/(1.0+CC*DANG)
      IF(QEXP.LT.-20.) QEXP=-20.

      PSQRAT = EXP(QEXP)
      GO TO 39
      END IF

      IF(ANG.GE.PSIPK1.AND.IREG.EQ.2) THEN

C  ** FOLLOWING TO REMOVE THE P**2 OSCILLATIONS BEYOND THE PEAK ******
C  ** USES EXPONENTIAL FIT AT ARG = -PI/2 TO EXTRAPOLATE TO HIGH ANGLES
```

```
      QEXP = AC*(ANG-PSIPK1)**2
      IF(QEXP.LT.-20.) QEXP=-20.
      PSQRAT = EXP(QEXP)
      GO TO 39
      END IF
      IF(ANG.GE.PSIPK1.AND.IREG.EQ.3) THEN
C  ** ONE OF THE LOW FREQUENCY REGIONS, REGION 3.  FOLLOWING ALLOWS
C  ** REASONABLE EXTRAPOLATION BEYOND 90 deg, STARTING AT PEAK.
C  ** USES EXPONENTIAL FIT AT PSI = PSIPK1 AND 0.5*PSIPK1. PSIPK1>60 deg
      QEXP = AC*(ANG-PSIPK1)**2
      IF(QEXP.LT.-20.) QEXP=-20.
      PSQRAT = EXP(QEXP)
      GO TO 39
      END IF
C  ** ONLY REGION LEFT, REGION 4, WITH PSIPK1<60 deg.
C  ** ONE OF THE LOW FREQUENCY REGIONS.  FOLLOWING ALLOWS REASONABLE
C  ** EXTRAPOLATION BEYOND 90 deg, STARTING THIS TIME AT 80 deg.
C  ** USES EXPONENTIAL FIT AT PSI = PSIPK1 AND 80 deg. PSIPK1<60 deg.
      IF(ANG.LT.80.0) GO TO 38
      QEXP = AC*(ANG-PSIPK1)**2
      IF(QEXP.LT.-20.) QEXP=-20.
      PSQRAT = EXP(QEXP)
      GO TO 39
   38 PSQRAT = PSQRAT*SINSQNUM/PSQDEN
   39 CONTINUE
      PSQ = PSQRAT*PSQPK*GG
      PSQRAD = PSQ
C
      RAD = DISTANCE
      IF(ISIDELN.EQ.1) THEN
      RAD = DISTANCE/SIN(ANGDEG2*PI/180.0)
      END IF
      PSQ = PSQ/RAD**2
C
      PSQRADT(I) = PSQRADT(I)+POWCOEF*PSQRAD
      PSQTOT(I) = PSQTOT(I)+POWCOEF*PSQ
      PSQTLOS(I) = PSQTLOS(I)+POWCOEF*PSQ*TLCF
C  ************ NOTE THAT A TRANMISSION LOSS (TLCF) HAS BEEN USED ****
   25 CONTINUE
   26 CONTINUE
      GO TO 70
   45 CONTINUE
C  ********** IN PLANE-WAVE CALCULATION PROCEDURE !!!!!!!!!!!!!!!!!!!!
```

```
      GDEN = 4.0

      IF(FMACH1.EQ.FMACH2) THEN
      DELPSI = 0.0
      GO TO 27
      END IF

      COSPK1 = 1.0
      ANGPK1 = 0.0
C  ********** GROUP VELOCITY VECTOR ANGLE IN REGION 1, PSIPK1 (DEGREES)
      PSIPK1 = 0.0
      SINPK1 = 0.0
C  ************** PHASE VELOCITY VECTOR ANGLE FOR PEAK IN REGION 1 (JET)
      SIN2 = SINPK1**2
      COSPHI1 = 1.0
      PHI1RAD = 0.0
      PHI1DEG = 0.0
      SINPHI1 = 0.0
C
C  ********************* PHASE VELOCITY ANGLE IN REGION 2 (SURROUNDINGS)

      COSPHI2 = 1.0/(CRAT+CRAT*FMACH1-FMACH2)
      PHI2RAD = ACOS(COSPHI2)
      PHI2DEG = PHI2RAD*180.0/PI
      SINPHI2 = SIN(PHI2RAD)
       COSPSI2 = (COSPHI2+FMACH2)/SQRT(1.0+FMSQ2+2.0*FMACH2*COSPHI2)
      PSI2RAD = ACOS(COSPSI2)
      PSI2DEG = PSI2RAD*180.0/PI
      SINPSI2 = SIN(PSI2RAD)

      Q22DEN = SQRT(1.0+FMSQ2+2.0*FMACH2*COSPHI2)

      COSPSPK2 = (COSPHI2+FMACH2)/Q22DEN
      ANGPK2 = ACOS(COSPSPK2)
      PSIPK2 = ANGPK2*180.0/PI

C  GROUP VELOCITY VECTOR ANGLE CHANGE, REG. 1 TO REG. 2, DELPSI (DEG.)
      DELPSI = PSIPK2-PSIPK1
C  *******************************************************************

C
   27 CONTINUE

C  ********** P**2 PRINCIPAL LOBE PEAK FOR 1 WATT POWER INPUT ********
      PSQPK = 2.0*PSQCOEFP
C  *******************************************************************

C  **** PSI10 BELOW IS SMALLEST ANGLE WHERE PLANE WAVE RADIATION, P**2=0
C  **** IF PSI10 > 90, PSI10 = 90 IS USED
      SINPSI10 = 1.0/SQRT(ETA**2+FMACH1**2)
      IF(SINPSI10.LT.1.0) THEN
      ANG10 = ASIN(SINPSI10)
      PSI10 = ANG10*180.0/PI
      COSPSI10 = COS(ANG10)
      GO TO 28
      END IF
      ANG10 = PI/2.0
      PSI10 = 90.0
      SINPSI10 = 1.0
      COSPSI10 = 0.0
   28 CONTINUE
```

```
C  ********* LOW ETA REGION. FIT EXPONENTIAL AT PSICRPL FOR BEYOND PEAK.
C  ********* IF PSICRPL < 90 CAN'T BE OBTAINED, USE PSICRPL = 90.
      ANGF = 90.0
      ETACRPL = 0.5*BETA1
      SINCRPL = 1.0/SQRT(4.0*ETA**2+FMACH1**2)
      IF(ETA.GT.ETACRPL) ANGF=ASIN(SINCRPL)*180./PI
      PSICRPL = ANGF
      ANGFRAD = ANGF*PI/180.0
      SINF = SIN(ANGFRAD)
      ARG = PI*ETA*SINF/SQRT(1.0-FMSQ1*SINF**2)
      SINARG = SIN(ARG)
      PSQRATPL = (SINARG/ARG)**2
      ACPL = ALOG(PSQRATPL)/ANGF**2
C ********** ACPL IS THE AMPLITUDE OF THE EXPONENTIAL AT PSICRPL *****
C ********** END LOW ETA REGION EXPONENTIAL FIT AT PSICRPL. **********

C  CALCULATE P**2 AMPLITUDE CHANGE DUE TO ANGLE SHIFT FROM PSI = 0 TO
C  PSI = PSIPK2 FOR THE PLANE WAVE PASSING THROUGH THE JET SHEAR LAYER

      PSQPKMUL = 1.0
      AREA1 = 1.0-COSPSI10
      AREA2 = 1.0+SINPSI2*SINPSI10-COSPSI2*COSPSI10

      IF(PSIPK2.GT.0.0.AND.PSI10.LT.PSIPK2) THEN
      AREA2 = 2.0*SINPSI2*SINPSI10
      END IF

      PSQPKMUL = AREA1/AREA2
      PSQPK = PSQPK*PSQPKMUL

      CKPSI0 = -PSI10
      SUMPSQ = 0.0


      DO 40 I=1,NANGLE
      FI = I
      ANGDEG2 = ANGLE(I)
      IF(ANGDEG2.EQ.0.0.AND.ISIDELN.EQ.1) THEN
      PSQRADT(I) = 0.0
      PSQTOT(I) = 0.0
      PSQTLOS(I) = 0.0
      GO TO 40
      END IF
C
      ANGRAD2 = ANGDEG2*PI/180.0
      ANGDEG1 = ANGDEG2-DELPSI
      ANGRAD1 = ANGDEG1*PI/180.0

      IF(ANGDEG1.LT.CKPSI0) GO TO 40

      SINANG = SIN(ANGRAD1)
      COSANG = COS(ANGRAD1)

      Q1DEN = SQRT(1.0-FMSQ1*SINANG**2)
      Q1 = SINANG/Q1DEN
      ARG = PI*ETA*Q1
      SINSQNUM = (SIN(ARG))**2
      GG = (1.0+COSANG/Q1DEN)**2/GDEN
      PSQRAT = 1.0
```

```
      PSQDEN = ARG**2
      IF(PSQDEN.LT.1.E-06.AND.ANGDEG1.LE.90.0) GO TO 49


C  ** LOW FREQUENCY REGION.  FOLLOWING ALLOWS REASONABLE
C  ** EXTRAPOLATION BEYOND 90 deg, STARTING AT ARG = PI/2 IF ETA>ETAcrit
C  ** OR AT 90 deg. OTHERWISE.  USES EXPONENTIAL FIT AT PSI = PSIPK1
C  ** AND PSI = PSIFIT.

      IF(ANGDEG1.LT.PSICRPL) GO TO 48

      QEXP = ACPL*(ANGDEG1)**2
      IF(QEXP.LT.-20.) QEXP=-20.

      PSQRAT = EXP(QEXP)
      GO TO 49


   48 PSQRAT = PSQRAT*SINSQNUM/PSQDEN
   49 CONTINUE

      PSQ = PSQRAT*PSQPK*GG

      PSQRAD = PSQ
C
      RAD = DISTANCE
      IF(ISIDELN.EQ.1) THEN
      RAD = DISTANCE/SIN(ANGDEG2*PI/180.0)
      END IF

      PSQ = PSQ/RAD**2

C
      PSQRADT(I) = PSQRADT(I)+POWCOEF*PSQRAD
      PSQTOT(I) = PSQTOT(I)+POWCOEF*PSQ
      PSQTLOS(I) = PSQTLOS(I)+POWCOEF*PSQ*TLCF

C  ************ NOTE THAT A TRANMISSION LOSS (TLCF) HAS BEEN USED ****

   40 CONTINUE
   41 CONTINUE
C
   70 CONTINUE

      FNANGLE = NANGLE
      SUMWATT = 0.0
      DO 75 I=1,NANGLE
      ANGRAD = ANGLE(I)*PI/180.0
      SUMWATT = SUMWATT+PSQRADT(I)*SIN(ANGRAD)

C  ** CONVERTING TO ANGLE FROM INLET AXIS FOR THIS AFT RADIATED NOISE

      ANGLE(I) = 180.0-ANGLE(I)
      IF(PSQTOT(I).LT.4.E-08) THEN
      SPLTL(I) = 20.0
      SPL(I) = 20.0
      GO TO 75
      END IF
      SPLTL(I) = 10.0*ALOG10(PSQTLOS(I))+93.9794
```

```
      SPL(I) = 10.0*ALOG10(PSQTOT(I))+93.9794
   75 CONTINUE

      WATTINT = SUMWATT*PI/(POWCON*FNANGLE)
      SPLDIF = 10.0*ALOG10(WATTS/WATTINT)

      DO 80 I=1,NANGLE
      SPLTL(I) = SPLTL(I)+SPLDIF
      SPL(I) = SPL(I)+SPLDIF
   80 CONTINUE


      RETURN
      END


C
C  *******************************************************************
C  ********** END OF MAIN SUBROUTINE ”BBRDCFEX” *********************
C  ********** ALTERED 02/19/1998, E. J. RICE ************************
C  *******************************************************************
C
C
C********************************************************************
C  ** SUBROUTINE FOR CALC NOZZLE CONDITIONS, FINAL JET MACH NUMBER,
C     VELOCITY, AND DIAMETER.  ** NOTE ** OUTER DIAM CHANGES FOR NOZZLE.
C
      SUBROUTINE CONOZ(TTOT,PTOT,PSTS,HTRAT,ANOZRAT,DDUCT,FMACHD,FMACH1
     1,CJET,DJET,TJET,PNOZ,DNOZ,CNOZ,FMACHN)

C
      PI = 3.1415927
      QM = 1.0+0.2*FMACHD**2
      DIN = DDUCT*HTRAT
      ADUCT = PI*(DDUCT**2–DIN**2)/4.0
      ANOZ = ADUCT*ANOZRAT
      DNOZ = SQRT(4.0*ANOZ/PI+DIN**2)
      TDUCT = TTOT/QM
      VSOND = 49.0421*SQRT(TDUCT)
      VDUCT = FMACHD*VSOND
      RHOT = 144.0*PTOT/(53.3*TTOT)
      RHOD = RHOT/QM**2.5
      FMASS = RHOD*ADUCT*VDUCT
C  ************************ NOTE – AREAS ARE IN SQUARE INCHES ********
C
C  **************** SOLVE FOR NOZZLE MACH NUMBER ********************
C
      QQDUCT = FMACHD/QM**3/ANOZRAT
      FN = 1.0
      DIFP = FN/(1.0+0.2*FN**2)**3–QQDUCT
      FNP = 1.0

      DO 10 I=1,50
      FN = 0.975*FN
      DIF = FN/(1.0+0.2*FN**2)**3–QQDUCT
C       WRITE(3,100) I,FN,DIF
C  100 FORMAT(/,’ I=’,I2,’ FN=’,F7.4,’ DIF=’,1PE9.2)
      IF(DIF.LE.0.0) GO TO 12
      FNP = FN
      DIFP = DIF
```

```
   10 CONTINUE
      FN = QQDUCT
  111 DO 11 I=1,10
      FN = QQDUCT*(1.0+0.2*FN**2)**3
C       WRITE(3,102) I,FN
C  102 FORMAT(/,' REFINED, I=',I2,' FN=',F7.4)

   11 CONTINUE
      GO TO 14
   12 CONTINUE
      FN = (DIFP*FN-DIF*FNP)/(DIFP-DIF)
C       WRITE(3,101) FN
C  101 FORMAT(/,' INTERPOLATED FN =',F7.4)

      GO TO 111
   14 CONTINUE
      FMACHN = FN
C       WRITE(3,103) FMACHN
C  103 FORMAT(/,' FINAL ********** FMACHN =',F7.4)

C  ****************************** "FMACH1" FINAL JET VELOCITY ********

      FMACH1 = SQRT(5.0*((PTOT/PSTS)**(2./7.)-1.0))
      QNTJ = 1.0+0.2*FMACH1**2
      TJET = TTOT/QNTJ
      RHOJ = RHOT/QNTJ**2.5
      CJET = 49.0421*SQRT(TJET)
      VJET = CJET*FMACH1
      AJET = FMASS/(RHOJ*VJET)
      DJET = SQRT(4.0*AJET/PI+DIN**2)

C ** FOLLOWING NOT USED HERE BUT MIGHT BE HANDY FOR LATER USE ********
C  ** CHECK NOZZLE THROAT PRESSURE VRS. SURROUNDING AMBIENT PRESSURE *
      QMN =  1.0/(1.0+0.2*FMACHN**2)
      PNOZ = PTOT*QMN**3.5
      TNOZ = TTOT*QMN
      CNOZ = 49.0421*SQRT(TNOZ)
      RETURN
      END
C
C  *******************************************************************
C  ******************* END OF SUBROUTINE "CONOZ" ********************
C  *******************************************************************

```

2.2.2.7 Sample Run Program ROTOR

Current code name is RDIRNEW1. To run the program first move to the directory that the code executable file resides in, then invoke the program by typing after the system prompt. From a Unix system type “program_name.” From a VAX system type “run program_name.” A typical run will look like this:

prompt> **rdirnew1**
Enter input file name : **bbn_input.dat**
Enter output file name : **rotor_power.dat**
Enter 2nd output file name: **rotor_debug.dat**
Enter spl plot output file name: **rotor_spl.dat**
prompt>

2.2.2.8 Sample Input File

```
$Input
 RPM = 9782.2
 RHO = 0.079005
 DTIP =      22
 HTR = 0.43
 NBLADE =    22
 NSTR =      12
 NVANE =     54
 GAM = 1.4
 KASE =      1
 LINLET =    0.99
 LEXIT =     1.99
 IABSOR =    0
 NBSTD =     22
 SCLOPTR =   4
 SCLOPTS =   2
 NHM = 10
 BW =        0
 NF =        11
 NTOBNI =    7
 NCOF =      15
 RADMIC =    20
 ISIDELN =   1
 ALIP =      5.558
 BLIP =      1.05
 MACHS =     0.2
 ANOZRAT =   0.6875
 ETAFAN =    0.920
 DELANG =    10.0
 ITL = 1
 TOBN =      36  37  38  39  40  41  42  43  44  45  46
 SEMA =      0.418,0.422,0.428,0.436,0.444,0.450,0.453,0.454,0.451,
             0.447,0.443,0.438,
 SPERC =     4.77, 5.23, 5.77, 6.44, 7.32, 8.54,10.32, 9.00, 9.41,
             .63, 6.77, 6.77,
SINCDR =     11.84,20.04,24.57,29.37,32.30,32.08,34.45,35.49,34.85,
             32.70,30.83,27.32,
 SATIR =     0.095,0.002,0.001,0.001,0.001,0.001,0.001,0.001,0.001,
             .001,0.001,0.001,
SATIS =      0.081,0.021,0.018,0.021,0.023,0.023,0.022,0.018,0.016,
             .013,0.012,0.024,
SELINR =     12*0.110,
 SELINS =    0.128,0.063,0.064,0.067,0.072,0.075,0.092,0.091,0.126,
             0.132,0.119,0.106,
 SEMT =      0.81608 0.78311 0.74889 0.71207 0.67321 0.63208
             .58778 0.53878 0.50051 0.46351 0.43564 0.41233
SCO =  1138.1  1132.5  1130.2  1129.9  1129.2  1127.8
             .1  1124.4  1122.8  1121.3  1120.3  1119
STHETA =     0.28304 0.29918 0.32337 0.35848 0.39996 0.44971
             .51579 0.61069 0.70143 0.81039 0.90401 0.99027
SAXSP =      1.4713  1.4837  1.5001  1.5247  1.5563  1.5928
             .6373  1.6972  1.7526  1.8172  1.8753  1.9333
SROTCD =     0.06511    0.036664   0.016138   0.01422    0.012293   0.0066824
             .0019007  0.0026553  0.0013424  0.0013326  0.0069932  0.01341
SSADIN =     12.289  11.351  11.008  11.028  11.187  11.454
             .877  12.526  13.033  13.539  13.868  14.172
SCHDR =      4.227   4.124   4.020   3.911   3.794   3.675
             .546   3.399   3.285   3.176   3.096   3.028
SCHDS =      1.839   1.886   1.921   1.947   1.964   1.970
```

```
              .964   1.944   1.919   1.888   1.861   1.837
STPRIN =      1.344   1.363   1.365   1.355   1.339   1.321
              .299   1.271   1.252   1.235   1.223   1.214
SDIA = 21.988  20.939  19.844  18.699  17.494  16.214
              .829  13.298  12.101  10.962  10.126  9.440
SSTATCD =     0.02    0.02    0.02    0.02    0.02    0.02
              .02    0.02    0.02    0.02    0.02    0.02
SINCDS =      1  1  1  1  1  1  1  1  1  1  1  1
 SATIW =      0.1     0.1     0.1     0.1     0.1     0.1
              .1     0.1     0.1     0.1     0.1     0.1
SCONTR =      1  1  1  1  1  1  1  1  1  1  1  1
 SCONTS =     1  1  1  1  1  1  1  1  1  1  1  1
 SCONTW =     1  1  1  1  1  1  1  1  1  1  1  1
 SELINW =     0.1     0.1     0.1     0.1     0.1     0.1
              .1     0.1     0.1     0.1     0.1     0.1
SSCLR =       1  1  1  1  1  1  1  1  1  1  1  1
 SSCLS =      1  1  1  1  1  1  1  1  1  1  1  1
 SSCLW =      1  1  1  1  1  1  1  1  1  1  1  1
 STVELR =     1  1  1  1  1  1  1  1  1  1  1  1
 STVELS =     1  1  1  1  1  1  1  1  1  1  1  1
 STVELW =     1  1  1  1  1  1  1  1  1  1  1  1
$
```

2.2.2.9 Sample Output Files

The ROTOR power and directivity output files are shown in the following sections. The debug output file is not listed.

2.2.2.9.1 Power Output File from ROTOR

```
HARD WALL ASSUMED
 MICROPHONE IS ON A SIDELINE
  MICROPHONE DISTANCE IN FEET IS =     20.00000
  MACH NUMBER OF SURROUNDING MEDIUM =   0.2000000
 ESTIMATED FAN ADIABATIC EFFICIENCY =   0.9200000

                PROGRAM *** RDIRNEW1 ***

             RESPONSE OF AN ISOLATED ROTOR
            TO INGESTION OF INLET TURBULENCE

                CASE NUMBER   1   OF   1

***** STRIP AREA NUMBER    1

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.418    0.816   0.0950    11.84   1.000   0.11

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1138.   21.988   4.770    1.344

     RPM        NB     NBSTD    HTR    DTIP      CHDR
   9782.2       22       22    0.430  22.000    4.227

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.900     1.00   1.0000    0.110   0.0950    1.483

   CDROTOR =   6.5109998E-02
  INLET LENGTH/TIP DIAMETER =   0.9900000
 STHI,STHUSED   0.2830400      0.2830400

 STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT=  4
```

*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(–13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL		
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST	MUGRIDGE
3981	1.1099	114.4	116.0	118.1	116.2	119.6	119.1	122.2
5011	1.3973	114.1	115.4	123.5	121.8	124.0	122.7	121.8
6309	1.7591	115.0	116.3	124.1	123.6	124.6	124.3	120.8
7943	2.2146	118.0	121.6	124.2	122.3	125.2	125.0	119.8
10000	2.7880	111.5	114.1	126.2	124.6	126.4	125.0	118.3
12589	3.5099	110.7	113.3	126.7	125.1	126.8	125.3	115.6
15848	4.4187	111.3	114.7	126.8	125.3	126.9	125.6	113.0
19952	5.5628	107.2	111.6	126.4	124.9	126.5	125.1	110.3
25118	7.0031	103.5	108.9	124.5	123.0	124.5	123.2	107.6
31622	8.8164	99.6	105.9	120.9	120.6	121.0	120.8	105.0
39810	11.0992	95.7	102.2	118.4	118.8	118.4	118.9	102.3

***** STRIP AREA NUMBER 2

EMA	EMTIP	TI	SINCD	CONTR	L/SSTD
0.422	0.783	0.0020	20.04	1.000	0.11

GAM	RHO	C	SDIA	SPERC	TPR
1.400	0.0790	1133.	20.939	5.230	1.363

RPM	NB	NBSTD	HTR	DTIP	CHDR
9782.2	22	22	0.430	22.000	4.124

EMR	RSCAL	RVEL	ELT	TIT	AR
0.872	1.00	1.0000	0.110	0.0020	1.520

CDROTOR = 3.6664002E–02
INLET LENGTH/TIP DIAMETER = 0.9900000
STHI,STHUSED 0.2991800 0.2991800

STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT= 4

*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(–13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL		
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST	MUGRIDGE
3981	1.1099	78.6	81.6	88.4	86.9	88.9	88.1	118.8
5011	1.3973	79.5	81.0	91.8	90.3	92.1	90.8	118.9
6309	1.7591	81.5	82.0	93.9	93.4	94.1	93.7	118.9
7943	2.2146	82.6	84.4	95.7	93.8	95.9	94.3	118.9
10000	2.7880	79.2	81.8	96.0	94.2	96.1	94.5	118.0
12589	3.5099	77.4	81.4	97.2	95.7	97.2	95.9	117.0
15848	4.4187	76.0	79.3	96.5	95.3	96.6	95.4	116.0
19952	5.5628	72.4	76.3	96.0	94.7	96.0	94.8	113.5
25118	7.0031	69.7	75.4	94.3	93.7	94.3	93.7	110.8
31622	8.8164	66.2	71.8	90.4	90.9	90.5	90.9	108.2
39810	11.0992	61.9	68.0	88.2	89.1	88.2	89.1	105.5

```
***** STRIP AREA NUMBER    3

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.428    0.749   0.0010    24.57   1.000   0.11

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1130.   19.844   5.770    1.365

     RPM         NB     NBSTD    HTR    DTIP      CHDR
   9782.2        22       22    0.430  22.000    4.020

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.844     1.00   1.0000    0.110   0.0010    1.560

   CDROTOR =   1.6138000E-02
  INLET LENGTH/TIP DIAMETER =   0.9900000
 STHI,STHUSED   0.3233700      0.3233700

 STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT=  4

   *** COMPONENT PWL CONTRIBUTIONS  -  DB RE 10**(-13) WATTS ***

                       ONE THIRD OCTAVE

     FREQUENCY        DIPOLE        QUADRUPOLE        TOTAL
   HERTZ   F/BPF   INLET EXHAUST   INLET EXHAUST   INLET EXHAUST MUGRIDGE
    3981  1.1099    74.9    76.6    86.3    84.6    86.6    85.2   110.9
    5011  1.3973    74.7    76.5    87.8    86.1    88.0    86.5   111.9
    6309  1.7591    73.6    75.5    88.2    88.1    88.3    88.3   112.9
    7943  2.2146    72.5    74.9    90.0    88.6    90.0    88.7   113.9
   10000  2.7880    72.2    74.9    92.3    90.8    92.3    90.9   114.5
   12589  3.5099    72.2    75.6    92.3    91.2    92.4    91.3   114.5
   15848  4.4187    70.6    74.7    91.4    90.7    91.5    90.8   114.5
   19952  5.5628    65.6    70.6    91.4    90.6    91.4    90.7   114.1
   25118  7.0031    62.5    68.1    89.1    88.8    89.1    88.8   113.1
   31622  8.8164    59.4    65.2    85.9    86.8    86.0    86.9   112.1
   39810 11.0992    55.4    62.2    83.7    85.6    83.7    85.6   110.5

***** STRIP AREA NUMBER    4

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.436    0.712   0.0010    29.37   1.000   0.11

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1130.   18.699   6.440    1.355

     RPM         NB     NBSTD    HTR    DTIP      CHDR
   9782.2        22       22    0.430  22.000    3.911

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.815     1.00   1.0000    0.110   0.0010    1.603

   CDROTOR =   1.4220000E-02
  INLET LENGTH/TIP DIAMETER =   0.9900000
 STHI,STHUSED   0.3584800      0.3584800

 STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT=  4
```

*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(-13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL		
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST	MUGRIDGE
3981	1.1099	74.5	77.2	89.3	87.5	89.4	87.9	109.1
5011	1.3973	74.6	77.8	91.7	89.8	91.8	90.1	110.1
6309	1.7591	76.0	77.8	92.3	91.8	92.4	92.0	111.1
7943	2.2146	73.8	76.5	92.1	91.5	92.2	91.7	112.1
10000	2.7880	74.8	78.5	91.9	91.0	92.0	91.3	113.1
12589	3.5099	70.0	74.2	92.5	92.1	92.5	92.2	113.1
15848	4.4187	67.4	72.1	93.7	92.9	93.7	92.9	113.1
19952	5.5628	65.3	70.7	93.6	92.9	93.6	92.9	113.1
25118	7.0031	62.6	68.5	91.0	91.1	91.0	91.1	112.2
31622	8.8164	59.1	65.4	88.4	89.3	88.4	89.3	111.2
39810	11.0992	54.9	61.7	85.4	87.1	85.4	87.1	110.2

***** STRIP AREA NUMBER 5

EMA	EMTIP	TI	SINCD	CONTR	L/SSTD
0.444	0.673	0.0010	32.30	1.000	0.11

GAM	RHO	C	SDIA	SPERC	TPR
1.400	0.0790	1129.	17.494	7.320	1.339

RPM	NB	NBSTD	HTR	DTIP	CHDR
9782.2	22	22	0.430	22.000	3.794

EMR	RSCAL	RVEL	ELT	TIT	AR
0.786	1.00	1.0000	0.110	0.0010	1.653

CDROTOR = 1.2293000E-02
INLET LENGTH/TIP DIAMETER = 0.9900000
STHI,STHUSED 0.3999600 0.3999600

STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT= 4

*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(-13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL		
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST	MUGRIDGE
3981	1.1099	73.7	76.9	90.2	88.5	90.3	88.8	107.0
5011	1.3973	76.4	78.8	92.8	91.0	92.9	91.2	108.0
6309	1.7591	74.7	77.2	94.5	93.6	94.5	93.7	109.0
7943	2.2146	76.3	79.5	95.5	94.6	95.6	94.8	110.0
10000	2.7880	74.9	78.6	96.4	95.3	96.5	95.4	111.0
12589	3.5099	70.9	75.7	96.9	96.1	96.9	96.2	111.7
15848	4.4187	68.9	74.4	96.6	96.1	96.6	96.1	111.7
19952	5.5628	66.3	72.5	95.6	95.4	95.6	95.4	111.7
25118	7.0031	63.3	70.3	93.6	94.0	93.6	94.0	111.3
31622	8.8164	60.6	67.5	90.9	92.2	90.9	92.2	110.3
39810	11.0992	55.9	63.5	88.4	90.3	88.4	90.3	109.3

```
***** STRIP AREA NUMBER    6

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.450    0.632   0.0010    32.08   1.000   0.11

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1128.   16.214   8.540    1.321

     RPM        NB     NBSTD    HTR    DTIP      CHDR
   9782.2       22       22    0.430  22.000    3.675

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.754     1.00   1.0000    0.110   0.0010    1.706

   CDROTOR =   6.6824001E-03
  INLET LENGTH/TIP DIAMETER =   0.9900000
 STHI,STHUSED   0.4497100      0.4497100

 STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT=  4

   *** COMPONENT PWL CONTRIBUTIONS  -  DB RE 10**(-13) WATTS ***

                       ONE THIRD OCTAVE
```

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL		
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST	MUGRIDGE
3981	1.1099	73.3	75.8	88.8	87.2	88.9	87.5	100.9
5011	1.3973	73.3	75.7	91.0	89.4	91.1	89.6	101.9
6309	1.7591	73.9	75.3	93.0	92.0	93.0	92.1	102.9
7943	2.2146	73.7	76.1	94.2	93.5	94.3	93.6	103.9
10000	2.7880	73.0	76.3	95.3	94.3	95.4	94.4	104.9
12589	3.5099	70.0	74.5	96.2	95.5	96.2	95.5	105.9
15848	4.4187	68.6	73.6	96.8	96.2	96.8	96.2	106.9
19952	5.5628	66.7	72.5	97.2	96.6	97.2	96.6	107.9
25118	7.0031	64.9	71.2	97.3	96.8	97.3	96.8	108.1
31622	8.8164	62.8	69.3	97.3	96.8	97.3	96.8	108.1
39810	11.0992	60.6	67.5	97.0	96.7	97.0	96.7	108.1

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***** STRIP AREA NUMBER    7

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.453    0.588   0.0010    34.45   1.000   0.11

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1126.   14.829  10.320    1.299

     RPM        NB     NBSTD    HTR    DTIP      CHDR
   9782.2       22       22    0.430  22.000    3.546

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.718     1.00   1.0000    0.110   0.0010    1.768

   CDROTOR =   1.9007000E-03
  INLET LENGTH/TIP DIAMETER =   0.9900000
 STHI,STHUSED   0.5157900      0.5157900

 STREAMLINE LIFT COEFFICIENT CALCULATED USING SCLOPT=  4
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*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(-13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL		
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST	MUGRIDGE
3981	1.1099	71.3	73.5	86.9	85.1	87.0	85.4	89.0
5011	1.3973	72.1	74.3	88.9	87.5	89.0	87.7	90.0
6309	1.7591	72.2	72.9	90.7	89.7	90.8	89.8	91.0
7943	2.2146	71.8	73.4	91.8	91.2	91.9	91.3	92.0
10000	2.7880	70.6	73.2	92.6	91.9	92.7	92.0	93.0
12589	3.5099	68.1	72.2	93.2	92.7	93.2	92.8	94.0
15848	4.4187	65.9	70.6	93.3	93.1	93.3	93.2	95.0
19952	5.5628	63.6	68.9	93.2	93.3	93.3	93.3	96.0
25118	7.0031	61.6	67.3	93.0	93.2	93.0	93.2	97.0
31622	8.8164	59.4	65.2	92.6	92.9	92.6	92.9	98.0
39810	11.0992	56.9	63.0	92.1	92.4	92.1	92.4	99.0

***** STRIP AREA NUMBER 8

EMA	EMTIP	TI	SINCD	CONTR	L/SSTD
0.454	0.539	0.0010	35.49	1.000	0.11

GAM	RHO	C	SDIA	SPERC	TPR
1.400	0.0790	1124.	13.298	9.000	1.271

RPM	NB	NBSTD	HTR	DTIP	CHDR
9782.2	22	22	0.430	22.000	3.399

EMR	RSCAL	RVEL	ELT	TIT	AR
0.686	1.00	1.0000	0.110	0.0010	1.845

CDROTOR = 2.6553001E-03
INLET LENGTH/TIP DIAMETER = 0.9900000
STHI,STHUSED 0.6106900 0.6106900

STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT= 4

*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(-13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL		
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST	MUGRIDGE
3981	1.1099	66.5	69.0	82.1	80.2	82.2	80.5	89.6
5011	1.3973	67.3	69.1	84.0	82.4	84.0	82.6	90.6
6309	1.7591	67.5	68.0	85.9	84.8	85.9	84.9	91.6
7943	2.2146	68.0	69.4	87.1	86.3	87.1	86.4	92.6
10000	2.7880	66.2	68.8	88.0	87.3	88.1	87.3	93.6
12589	3.5099	66.2	69.6	88.6	88.1	88.7	88.2	94.6
15848	4.4187	64.9	68.8	88.8	88.6	88.8	88.7	95.6
19952	5.5628	59.8	64.5	88.7	88.8	88.7	88.8	96.6
25118	7.0031	57.4	62.6	88.5	88.8	88.5	88.8	97.6
31622	8.8164	54.9	60.6	88.0	88.5	88.0	88.5	98.6
39810	11.0992	52.3	58.3	87.5	88.1	87.5	88.1	99.6

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***** STRIP AREA NUMBER    9

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.451    0.501   0.0010    34.85   1.000   0.11

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1123.   12.101   9.410    1.252

     RPM         NB     NBSTD    HTR    DTIP      CHDR
   9782.2        22       22    0.430  22.000    3.285

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.656     1.00   1.0000    0.110   0.0010    1.909

   CDROTOR =   1.3424000E-03
  INLET LENGTH/TIP DIAMETER =   0.9900000
 STHI,STHUSED   0.7014300      0.7014300

 STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT=  4

   *** COMPONENT PWL CONTRIBUTIONS  -  DB RE 10**(-13) WATTS ***

                       ONE THIRD OCTAVE

     FREQUENCY        DIPOLE        QUADRUPOLE        TOTAL
   HERTZ   F/BPF   INLET EXHAUST   INLET EXHAUST   INLET EXHAUST MUGRIDGE
    3981  1.1099    63.0    66.2    79.1    77.2    79.2    77.6    82.3
    5011  1.3973    65.7    67.9    80.6    79.3    80.8    79.6    83.3
    6309  1.7591    67.6    68.0    82.6    81.5    82.7    81.7    84.3
    7943  2.2146    66.0    66.6    84.1    83.1    84.2    83.2    85.3
   10000  2.7880    64.6    66.8    85.1    84.2    85.2    84.3    86.3
   12589  3.5099    64.4    66.7    85.6    85.0    85.6    85.1    87.3
   15848  4.4187    61.4    63.9    85.7    85.5    85.8    85.6    88.3
   19952  5.5628    58.9    62.3    85.8    85.8    85.8    85.8    89.3
   25118  7.0031    56.2    60.0    85.4    85.8    85.4    85.8    90.3
   31622  8.8164    54.1    58.3    85.0    85.5    85.0    85.5    91.3
   39810 11.0992    51.4    55.7    84.4    85.0    84.4    85.1    92.3

***** STRIP AREA NUMBER   10

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.447    0.464   0.0010    32.70   1.000   0.11

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1121.   10.962   7.630    1.235

     RPM         NB     NBSTD    HTR    DTIP      CHDR
   9782.2        22       22    0.430  22.000    3.176

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.631     1.00   1.0000    0.110   0.0010    1.974

   CDROTOR =   1.3326000E-03
  INLET LENGTH/TIP DIAMETER =   0.9900000
 STHI,STHUSED   0.8103900      0.8103900

 STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT=  4
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*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(–13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL		
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST	MUGRIDGE
3981	1.1099	60.8	63.3	75.6	73.0	75.8	73.5	79.9
5011	1.3973	59.7	62.1	77.0	75.3	77.0	75.5	80.9
6309	1.7591	61.6	63.1	78.2	77.3	78.2	77.5	81.9
7943	2.2146	60.0	60.8	79.0	78.6	79.1	78.7	82.9
10000	2.7880	62.2	64.8	79.8	79.3	79.9	79.4	83.9
12589	3.5099	64.4	67.7	80.9	80.1	81.0	80.3	84.9
15848	4.4187	57.8	60.2	81.3	80.7	81.3	80.8	85.9
19952	5.5628	56.0	59.1	81.5	81.2	81.5	81.2	86.9
25118	7.0031	53.0	56.4	81.2	81.2	81.2	81.2	87.9
31622	8.8164	50.5	54.4	80.8	81.1	80.8	81.1	88.9
39810	11.0992	48.0	52.2	80.2	80.7	80.2	80.7	89.9

***** STRIP AREA NUMBER 11

EMA	EMTIP	TI	SINCD	CONTR	L/SSTD
0.443	0.436	0.0010	30.83	1.000	0.11

GAM	RHO	C	SDIA	SPERC	TPR
1.400	0.0790	1120.	10.126	6.770	1.223

RPM	NB	NBSTD	HTR	DTIP	CHDR
9782.2	22	22	0.430	22.000	3.096

EMR	RSCAL	RVEL	ELT	TIT	AR
0.611	1.00	1.0000	0.110	0.0010	2.025

CDROTOR = 6.9932002E–03
INLET LENGTH/TIP DIAMETER = 0.9900000
STHI,STHUSED 0.9040100 0.9040100

STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT= 4

*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(–13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL		
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST	MUGRIDGE
3981	1.1099	64.9	67.1	73.2	70.3	73.8	72.0	92.6
5011	1.3973	61.0	63.0	75.0	72.8	75.2	73.2	93.6
6309	1.7591	63.2	64.9	76.7	75.1	76.9	75.5	94.6
7943	2.2146	65.8	68.9	78.1	77.0	78.4	77.6	95.6
10000	2.7880	60.4	63.2	79.0	78.0	79.1	78.2	96.6
12589	3.5099	58.1	60.7	79.4	78.7	79.5	78.8	97.6
15848	4.4187	55.6	58.7	79.4	79.2	79.5	79.2	98.6
19952	5.5628	53.1	56.9	79.2	79.3	79.2	79.3	99.0
25118	7.0031	52.3	56.6	78.8	79.1	78.8	79.1	99.0
31622	8.8164	48.1	52.3	78.2	78.7	78.2	78.7	99.0
39810	11.0992	45.2	50.0	77.5	78.1	77.5	78.2	98.4

***** STRIP AREA NUMBER 12

EMA	EMTIP	TI	SINCD	CONTR	L/SSTD
0.438	0.412	0.0010	27.32	1.000	0.11

GAM	RHO	C	SDIA	SPERC	TPR
1.400	0.0790	1119.	9.440	6.770	1.214

RPM	NB	NBSTD	HTR	DTIP	CHDR
9782.2	22	22	0.430	22.000	3.028

EMR	RSCAL	RVEL	ELT	TIT	AR
0.592	1.00	1.0000	0.110	0.0010	2.071

CDROTOR = 1.3410000E-02
INLET LENGTH/TIP DIAMETER = 0.9900000
STHI,STHUSED 0.9902700 0.9902700

STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT= 4

*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(-13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL		
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST	MUGRIDGE
3981	1.1099	61.7	63.5	71.0	68.1	71.4	69.4	97.1
5011	1.3973	58.8	60.7	72.9	70.7	73.1	71.1	98.1
6309	1.7591	60.6	61.6	74.6	73.0	74.7	73.3	99.1
7943	2.2146	61.3	62.8	76.0	74.9	76.1	75.2	100.1
10000	2.7880	58.3	61.2	77.0	76.1	77.1	76.2	100.6
12589	3.5099	56.5	59.2	77.4	76.8	77.5	76.8	100.6
15848	4.4187	54.0	57.3	77.4	77.2	77.5	77.3	100.6
19952	5.5628	51.8	55.8	77.3	77.4	77.3	77.4	100.0
25118	7.0031	49.3	53.7	76.8	77.1	76.8	77.1	99.0
31622	8.8164	46.8	51.4	76.2	76.7	76.2	76.7	98.0
39810	11.0992	43.7	49.0	75.5	76.2	75.5	76.2	96.2

FAN TOTAL POWER SPECTRUM

TOBN	F/BPF	PWL-UP	PWL-DN	PWL-TOT	MUGR-TOT
36	1.1099	119.66	119.13	122.41	127.30
37	1.3973	123.98	122.70	126.40	127.23
38	1.7591	124.60	124.34	127.48	126.85
39	2.2146	125.18	125.00	128.11	126.60
40	2.7880	126.39	125.02	128.77	125.93
41	3.5099	126.85	125.37	129.18	124.94
42	4.4187	126.95	125.65	129.36	124.16
43	5.5628	126.52	125.17	128.90	123.13
44	7.0031	124.52	123.23	126.93	121.93
45	8.8164	121.01	120.83	123.93	120.76
46	11.0992	118.46	118.93	121.71	119.55

2.2.2.9.2 Directivity Output File from ROTOR

ROTOR SPL PLOT OUTPUT FILE

FREQUENCY = 3981, OBN = 36

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	64.0	40.9	64.0
20.0	65.0	51.9	65.2
30.0	80.8	59.7	80.8
40.0	79.4	65.9	79.6
50.0	82.5	71.1	82.8
60.0	86.5	75.4	86.8
70.0	88.3	78.9	88.8
80.0	83.5	84.2	86.9
90.0	73.7	81.1	81.8
100.0	67.9	80.8	81.0
110.0	63.2	82.4	82.5
120.0	58.2	82.2	82.2
130.0	52.6	81.4	81.4
140.0	46.1	86.6	86.6
150.0	37.9	60.3	60.3
160.0	26.8	19.7	27.6
170.0	20.5	19.7	23.2

FREQUENCY = 5011, OBN = 37

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	57.8	46.7	58.1
20.0	66.9	57.7	67.4
30.0	82.3	65.5	82.4
40.0	82.8	71.7	83.1
50.0	86.8	76.9	87.2
60.0	91.4	81.2	91.8
70.0	93.8	84.8	94.3
80.0	87.5	90.1	92.0
90.0	76.1	86.3	86.7
100.0	71.1	84.9	85.0
110.0	66.5	84.3	84.4
120.0	61.6	82.4	82.4
130.0	56.2	80.8	80.9
140.0	49.8	89.7	89.7
150.0	41.7	57.3	57.4
160.0	30.7	19.8	31.0
170.0	20.5	19.8	23.2

FREQUENCY = 6309, OBN = 38

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	54.5	47.8	55.4
20.0	65.4	58.9	66.3
30.0	78.7	66.8	78.9
40.0	83.1	73.1	83.5
50.0	88.7	78.4	89.1
60.0	92.5	82.7	93.0
70.0	94.4	86.4	95.0
80.0	80.4	91.5	91.8
90.0	82.7	89.1	90.0
100.0	77.3	87.3	87.7
110.0	72.3	88.7	88.8
120.0	67.2	83.7	83.8
130.0	61.5	77.2	77.3
140.0	54.9	90.5	90.5
150.0	46.7	58.0	58.3
160.0	35.6	19.9	35.7
170.0	20.2	19.9	23.1

FREQUENCY = 7943, OBN = 39

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	54.4	48.5	55.4
20.0	67.0	59.6	67.7
30.0	83.1	67.4	83.2
40.0	85.1	73.7	85.4
50.0	89.3	78.9	89.7
60.0	92.0	83.3	92.5
70.0	93.7	86.9	94.6
80.0	87.4	92.3	93.5
90.0	80.0	87.0	87.8
100.0	74.6	86.4	86.6
110.0	69.8	89.0	89.0
120.0	64.8	84.6	84.6
130.0	59.4	74.8	75.0
140.0	53.0	88.8	88.8
150.0	45.0	54.7	55.1
160.0	34.0	20.0	34.2
170.0	19.5	20.0	22.7

FREQUENCY = 10000, OBN = 40

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	49.3	49.4	52.4
20.0	61.7	60.5	64.1
30.0	85.6	68.3	85.7
40.0	84.5	74.6	84.9
50.0	88.8	79.8	89.3
60.0	94.1	84.2	94.5
70.0	96.3	87.9	96.9
80.0	87.9	92.9	94.1
90.0	80.2	86.8	87.7
100.0	75.0	84.5	84.9
110.0	70.4	86.2	86.3
120.0	65.7	85.0	85.1
130.0	60.4	76.8	76.9
140.0	54.1	92.6	92.6
150.0	46.2	57.7	58.0
160.0	35.3	19.7	35.4
170.0	19.0	19.7	22.3

FREQUENCY = 12589, OBN = 41

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	54.5	48.7	55.5
20.0	62.8	59.8	64.6
30.0	84.0	67.6	84.1
40.0	79.2	73.9	80.4
50.0	89.4	79.2	89.8
60.0	95.5	83.6	95.8
70.0	96.7	87.3	97.1
80.0	86.7	91.8	93.0
90.0	79.2	87.9	88.5
100.0	74.4	86.1	86.4
110.0	70.1	86.7	86.8
120.0	65.6	84.0	84.0
130.0	60.5	79.4	79.5
140.0	54.4	93.7	93.7
150.0	46.6	51.1	52.4
160.0	35.7	19.1	35.8
170.0	18.9	19.1	22.0

FREQUENCY = 15848, OBN = 42

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	53.0	48.6	54.4
20.0	60.7	59.7	63.2
30.0	80.5	67.5	80.7
40.0	83.5	73.8	83.9
50.0	90.6	79.1	90.9
60.0	96.1	83.5	96.4
70.0	96.1	87.1	96.6
80.0	84.6	90.9	91.8
90.0	77.6	86.1	86.7
100.0	73.3	85.0	85.3
110.0	69.3	84.5	84.7
120.0	65.0	82.3	82.4
130.0	60.0	79.6	79.7
140.0	54.0	95.1	95.1
150.0	46.3	50.3	51.7
160.0	35.5	18.3	35.6
170.0	18.3	18.3	21.3

FREQUENCY = 19952, OBN = 43

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	49.3	46.5	51.1
20.0	62.8	57.5	63.9
30.0	78.4	65.4	78.6
40.0	84.1	71.7	84.3
50.0	89.3	77.0	89.5
60.0	96.6	81.4	96.7
70.0	94.8	85.1	95.2
80.0	82.6	88.1	89.2
90.0	76.3	84.5	85.1
100.0	72.4	83.5	83.9
110.0	68.7	84.6	84.7
120.0	64.6	82.6	82.6
130.0	59.7	79.5	79.5
140.0	53.7	95.3	95.3
150.0	46.1	48.6	50.5
160.0	35.4	17.1	35.4
170.0	18.1	17.1	20.7

FREQUENCY = 25118, OBN = 44

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	47.0	42.6	48.3
20.0	60.6	53.7	61.4
30.0	69.6	61.6	70.2
40.0	80.9	67.9	81.1
50.0	88.4	73.2	88.5
60.0	95.2	77.6	95.3
70.0	91.4	81.4	91.8
80.0	79.4	84.5	85.6
90.0	74.0	82.0	82.7
100.0	70.6	81.3	81.7
110.0	67.0	82.4	82.6
120.0	63.0	80.3	80.4
130.0	58.2	77.4	77.4
140.0	52.3	93.8	93.8
150.0	44.7	43.7	47.3
160.0	34.1	15.9	34.1
170.0	18.2	15.9	20.2

FREQUENCY = 31622, OBN = 45

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	46.0	34.6	46.3
20.0	56.8	45.8	57.1
30.0	75.0	53.7	75.0
40.0	80.9	60.1	80.9
50.0	86.2	65.4	86.2
60.0	92.0	69.9	92.0
70.0	83.0	73.7	83.4
80.0	73.9	76.8	78.6
90.0	70.0	76.0	77.0
100.0	67.1	76.4	76.9
110.0	63.8	78.0	78.2
120.0	59.9	76.8	76.9
130.0	55.2	71.6	71.7
140.0	49.4	92.0	92.0
150.0	41.8	37.2	43.1
160.0	31.1	13.4	31.2
170.0	18.5	13.4	19.7

FREQUENCY = 39810, OBN = 46

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	46.7	31.3	46.9
20.0	58.2	42.3	58.3
30.0	79.1	50.2	79.1
40.0	77.8	56.5	77.9
50.0	83.5	61.8	83.5
60.0	88.5	66.2	88.5
70.0	79.8	69.9	80.2
80.0	75.3	73.0	77.3
90.0	71.4	69.0	73.4
100.0	68.4	70.4	72.5
110.0	65.2	72.3	73.0
120.0	61.3	72.4	72.7
130.0	56.6	68.6	68.9
140.0	50.7	90.5	90.5
150.0	43.2	33.9	43.7
160.0	32.5	11.4	32.6
170.0	22.5	11.4	22.8

2.2.3 STATOR – Stator / Turbulence Interaction Noise Program

2.2.3.1 Description of Prediction Code

A discussion of the main program and subroutines of the prediction code is found in Section 2.2.2.1, page 4 (Description of Prediction Code, program ROTOR). The last paragraph highlights the differences between the ROTOR and STATOR codes.

2.2.3.2 Description of Input File

The input file is identical to the input file for program ROTOR. See Section 2.2.2.4, page 6.

2.2.3.3 Description of Output Files

The power output file and SPL directivity output file are the same format as those produced by program ROTOR except for header information. The files are described in Section 2.2.2.5, page 9.

2.2.3.4 STATOR Source Code Listing

```
C     PROGRAM SDIRFIN.FOR
C*#RUN *=;16130ER/PG/ROTIN2C(BCD,NOGO,CORE=2)
C  ROTIN       STATOR/TURBULENCE INTERACTION NOISE PREDICTION
C
      DIMENSION AEV(46),AED(46),ZMM(46),ZPP(46),DCV1(91),DCD1(91),
     &           F(200),DCV2(91),DCD2(91),STHOSR(91),AEVETC(2,91),
     &           AEDETC(2,91),TOBN(200),SAXSP(21),SCHDS(21),
     &           TROGV(91),F3D(4,200,91),CTFRAT(200,91),
     &           CTFRATN(20000),IPERM(20000),CTFRATO(20000),
     &           POWTOT(20000),SPIMPR(200),SPIMPI(200),
     &           SPIMPRE(200),SPIMPIE(200),FINT(200),SPIMPZ2(200),
     &           SPIMPZ2E(200),RICEV(4,200,91),RICED(4,200,91),
     &           REROT1(91),REROT2(91)
C
      DIMENSION SAREA(21),SCLR(21),SEMA(21),SEMT(21),SSIGR(21),
     &          SSADIN(21),FOB(200),PVT(200),PDT(200),ANGLEO(100),
     &          SCONTR(21),SCONTS(21),STVELR(21),SSCLR(21),
     &          STPRIN(21),SCO(21),SROTCD(21),SDIA(21),SNCD(2,91),
     &          SPERC(21),SINCDR(21),SCHDR(21),SCLS(21),SCONTW(21),
     &          SINCDS(21),SSCLS(21),SSCLW(21),STVELS(21),STVELW(21)
C
      DIMENSION DVP(21),DDP(21),QVP(21),QDP(21),CVP(21),CDP(21),
     &          SSIGS(21),SDELU(21),NDSTLB(21),SALD(21),STHD(21),
     &          SPHD(21),SDELP(21),TVP(21),TDP(21),FJJ(21)
C
      DIMENSION SATIR(21),SATIS(21),SATIW(21),SELINR(21),SELINS(21),
     &          SELINW(21),SNCU(2,91),SSTATCD(21),STHETA(21)
C
      DIMENSION FDVTH(3,200,91),FDDTH(3,200,91),FQVTH(3,200,91),
     &          FQDTH(3,200,91),SWWND(21),TRROT1(91),TRROT2(91)
      DIMENSION SDVTH(200,91),SDDTH(200,91),SQVTH(200,91),
     &          SQDTH(200,91),STVTH(200,91),STDTH(200,91)
      DIMENSION WSUMDV(3,200),WSUMDD(3,200),WSUMQV(3,200),
     &          WSUMQD(3,200),WSNDV(3,200),WSNDD(3,200),WSNQV(3,200),
     &          WSNQD(3,200),WSDV(200),WSDD(200),WSQV(200),
     &          WSTV(200),WSTD(200),ANGLE(100),WSUMIN(200),
     &          WSQD(200),WSNDV1(200),WSNDD1(200),WSNQV1(200),
     &          WSNQD1(200),SPLVDB(100),SPLDDB(100),SPLOUT(100),
```

```
     &          SPLVDBT(100,200),SPLDDBT(100,200),SPLDB(100),
     &          SPLDBT(100),WUP(200,200),WDN(200,200),SPLTL(100)
      REAL      NDVTH(200,91),NDDTH(200,91),NQVTH(200,91),
     &          NQDTH(200,91),MACHS
      REAL LEXIT,IXP,IXM,NBNP,NBNM,KYS,KTOTP,KTOTM,KR,LEXLOC
      REAL ID,LINLET,LSHOCK,LINLOC,LINOVD,LEXOVD
      COMPLEX CTU,CTV,CTRM,CTEXP,CGX,CGY,CSYM,CASYM,CDEN,CDEN1,CPART,
     &        IM
      REAL    FREQNCY
      INTEGER FHZ
      INTEGER SCLOPTS,SCLOPTR
      LOGICAL CHECK
C
      CHARACTER *60 INFILE,OUTFILE,OUTFILE1,PLOTFILE
C
C
      NAMELIST/INPUT/
     &         BW, DTIP, GAM, HTR, IDIST, IPRINT, KASE, NBLADE,
     &         NBSTD, NDSTLB, NF, NHM, NSTR, NVANE, RHO, RPM, SALD,
     &         SCHDR,SCLOPTS,SCLOPTR,SCO, SCONTR, SDELP, SDELU,
     &         SDIA, SELINR, SEMA, SEMT, SINCDR, SPERC, SPHD, SROTCD,
     &         SSCLR, SSIGS, STHD, STHETA, STPRIN, STVELR, TOBN,
     &         SATIR,SATIW,SATIS,SCLR,SCLS,SCONTS,SCONTW,SELINS,
     &         SELINW,SINCDS,SSCLS,SSCLW,STVELS,STVELW,SCHDS,SAXSP,
     &         SSADIN,SSTATCD,LEXIT,LINLET,SPIMPR,SPIMPI,
     &         SPIMPRE,SPIMPIE,IABSOR,NTOBNI,NCOF,RADMIC,ISIDELN,
     &         ALIP,BLIP,MACHS,ANOZRAT,ETAFAN,DELANG,ITL
C     OPEN INPUT FILE
C
      WRITE(*,41)
   41 FORMAT(' Enter input file name  : ',$)
      READ(*,42) INFILE
   42 FORMAT(A60)
C
      OPEN (UNIT=11,STATUS='OLD',FORM='FORMATTED',FILE=INFILE,
     & ERR=45)
      GO TO 46
   45     PRINT *,'INPUT FILE NOT FOUND'
          GO TO 10001
C
C     OPEN OUTPUT FILES
C
   46 WRITE(*,47)
   47 FORMAT(' Enter output file name : ',$)
      READ(*,42) OUTFILE
C
      OPEN (UNIT=12,STATUS='NEW',FORM='FORMATTED',FILE=OUTFILE,
     & CARRIAGECONTROL='LIST')
C
      WRITE(*,48)
   48 FORMAT(' Enter 2nd output file name : ',$)
      READ(*,42) OUTFILE1
C
      OPEN (UNIT=13,STATUS='NEW',FORM='FORMATTED',FILE=OUTFILE1,
     & CARRIAGECONTROL='LIST')
C
      WRITE(*,49)
   49 FORMAT(' Enter spl plot output file name : ',$)
      READ(*,42) PLOTFILE
C
```

```
        OPEN (UNIT=14,STATUS=’NEW’,FORM=’FORMATTED’,FILE=PLOTFILE,
      & CARRIAGECONTROL=’LIST’)
C
C     WRITE TO SPL PLOT OUTPUT FILE TO INDICATE STATOR INFO
C
        WRITE(14,’(’’STATOR SPL PLOT OUTPUT FILE’’)’)
C
C     READ INPUT DATA
C
        KASE=1
        NCASE=0
        BW=0.0
        IM = CMPLX(0.0,1.0)
C
C****    LOOP TO PROCESS ALL CASES
C
        DO WHILE (NCASE .LT. KASE)
 1        NCASE=NCASE+1
          READ(11,INPUT,ERR=1000,END=9999)
       IF(IABSOR.EQ.0) WRITE(12,*)’       HARD WALL ASSUMED’
       IF(IABSOR.NE.0) WRITE(12,*)’    TREATED WALL ASSUMED’
       FCOF = NCOF
       IF(ISIDELN.EQ.0)WRITE(12,*)’MICROPHONE IS ON AN ARC’
       IF(ISIDELN.EQ.1)WRITE(12,*)’MICROPHONE IS ON A SIDELINE’
       WRITE(12,*)’ MICROPHONE DISTANCE IN FEET IS = ’,RADMIC
       WRITE(12,*)’ MACH NUMBER OF SURROUNDING MEDIUM = ’,MACHS
       WRITE(13,*)’NOZZLE EXIT AREA/DUCT AREA = ’,ANOZRAT
       WRITE(12,*)’ESTIMATED FAN ADIABATIC EFFICIENCY = ’,ETAFAN
       IF ( ITL.NE.0 ) WRITE(13,*)’ NO DUCT TRANS LOSS ASSUMED’
       IF ( ITL.NE.0 ) WRITE(13,*)’ ’
       WRITE(12,*)’  ’
          WRITE(12,108)
          WRITE(12,106) NCASE,KASE
          NJJ=10
C
       CHECK = .TRUE.
       PI=3.1415926
       BPF=RPM*NBLADE/60.
       DSTAT=FLOAT(NBLADE)/FLOAT(NVANE)
       DO 20 J=1,NF
         DO 18 I = 1,NCOF
           WUP(I,J) = 0.00
           WDN(I,J) = 0.00
 18         CONTINUE
         DO 19 I = 1,100
           SPLVDBT(I,J) = –150.
           SPLDDBT(I,J) = –150.
           IF ( J.EQ.1 ) SPLDBT(I)  = –150.
 19         CONTINUE
         PDT(J)=–150.
         PVT(J)=–150.
         FOB(J)=10.**(TOBN(J)*0.1)
         FINT(J)=FOB(J)/BPF
         SPIMPZ2(J) = SPIMPR(J)**2+SPIMPI(J)**2
         SPIMPZ2E(J)= SPIMPRE(J)**2+SPIMPIE(J)**2
 20       END DO
C
C     INDEX OVER STRIP NUMBER – KJI
C
       IF ( NSTR.EQ.1 ) MIDSTR = 1
```

```
      IF ( NSTR.GT.1 ) MIDSTR = NSTR/2
         DO 1949 KJI=1,NSTR
        LINLOC = LINLET*DTIP/SDIA(KJI)
        LINOVD = FLOAT(NBLADE)*LINLOC/PI
        LEXLOC = LEXIT*DTIP/SDIA(KJI)
        LEXOVD = FLOAT(NBLADE)*LEXLOC/PI
        AR  = 0.5*DTIP*(1.-HTR)/SCHDS(KJI)
        SAR = AR
        PER = SPERC(KJI)
        OD  = SDIA(KJI)
        ID  = (1.-0.01*PER)*OD
        RUPP = OD/DTIP
        IF ( RUPP.GT.1.00 ) RUPP = 1.00
        RLOW = RUPP*(1.-0.01*PER)
        IF ( RLOW.LT.HTR ) RLOW = HTR
        IF ( RLOW.LE.HTR ) RUPP = RLOW/(1.-0.01*PER)
        BNEW = DTIP*FLOAT(NBLADE)/(2.*PI*SDIA(KJI))
        ANEW = BNEW*HTR
C          PRINT *,'BNEW,ANEW ',BNEW,ANEW
        A   = PI*(OD**2-ID**2)/576.
        CDR=SROTCD(KJI)
        TI=SATIS(KJI)
        CONTR=SCONTS(KJI)
        SIGS=SCHDS(KJI)*FLOAT(NVANE)/(PI*SDIA(KJI))
          EMA=SEMA(KJI)
        EMT=SEMT(KJI)*(1.-0.005*PER)
        EMR=EMA
        EMRSP2=EMA**2
        EMRSP=SQRT(EMRSP2)
          SSAD=SSADIN(KJI)
C Does this  (the following line) make all that much sense ? Who knows!
      EL=SELINS(KJI)*FLOAT(NBLADE)/FLOAT(NBSTD)
        RSCAL=SSCLS(KJI)
        RVEL=STVELS(KJI)
          TPR=STPRIN(KJI)
          ELT=EL/RSCAL
          TIT=TI*RVEL
          AAA=A
          C=SCO(KJI)
        WWND=1.00
        SPCON=(EMA*C)*(EMRSP2)*(C**2)
        TABS = (C/49.0422)**2
        PABS = 53.3*TABS*RHO/144.
        IF (KJI.EQ.1) PTOT = PABS*TPR
C
C
C     WRITE INPUT DATA
C
        WRITE(12,118) KJI,WWND
          WRITE(12,120)
        WRITE(12,122) EMA,SEMT(KJI),TI,SINCDS(KJI),CONTR,
     &                   SELINS(KJI)
          WRITE(12,124)
        WRITE(12,126) GAM,RHO,C,SDIA(KJI),SPERC(KJI),TPR
        WRITE(12,125)
        WRITE(12,127) RPM,NBLADE,NBSTD,HTR,DTIP,SCHDR(KJI)
          WRITE(12,136)
          WRITE(12,138) EMR,RSCAL,RVEL,ELT,TIT,AR
        WRITE(12,142)
        WRITE(12,144) NBLADE,NVANE
```

```
       WRITE(12,*)'  '
       WRITE(12,*)'  '
       WRITE(12,*)'  CDROTOR = ',CDR
       WRITE(12,*)' INLET LENGTH/TIP DIAMETER = ',LINLET
C
C
C     PRELIMINARY CONSTANTS AND COEFFICIENTS
C
       DBL=130.+4.342945*ALOG(.105*RHO*(SPCON)*TI**2*A*WWND)
       DBLSPL = 4.342945*ALOG(.105*RHO*(SPCON)*TI**2*A*WWND)
       WATCON = .105*RHO*(SPCON)*TI**2*A*WWND
          PI=3.1415926
          TPI=2.*PI
          G1OV2=(GAM-1.)/2.
          G1OVG=(GAM-1.)/GAM
       TDGP1=2./(GAM+1.)
       GEXP = (GAM+1.)/(2.*(GAM-1.))
          T11=TPR**G1OVG-1.
       IF (KJI.EQ.1) TTOT = TABS*(1.+T11/ETAFAN)
          T12=1.+1./(G1OV2*EMA**2)
       OMM2 =1.-EMA**2
          SR1MM2=SQRT(1.-EMA**2)
          SR1MR2=SQRT(1.-EMR**2)
       CR=EMA/EMRSP
          CR2=CR*CR
       SR2=1.-CR2
       SR=SQRT(SR2)
          SRCR=SR*CR
       TR=SR/CR
       EMRC=EMR/5.
C
C
C     STEADY STATE LIFT COEFFICIENT CALCULATION
C
       IF (SCLOPTS .EQ. 1) THEN
C
C CL BASED ON INPUT LIFT COEFFICIENTS
C
         CL=SCLS(KJI)
       ELSE IF (SCLOPTS .EQ. 2) THEN
C
C CL BASED ON WORK COEFFICIENT
C
         CL=2.0*EMT*STHETA(KJI)/(EMR*SIGS)
       ELSE IF (SCLOPTS .EQ. 3) THEN
C
C CL BASED ON TOTAL PRESSURE RATIO
C
         CL=1.25*(CR2*T12*T11/(SIGS*SR))
          ELSE
C
C CL BASED ON STAGGER ANGLE
C
            SSAR=SSAD*PI/180.
         AINC=SINCDS(KJI)*PI/180.
            CLF1=5.65/(1.0+1.8/AR)
            CLF2=1.8+AR
            CLF3=1.8+AR*SR1MR2
            CLPR=CLF1*CLF2/CLF3
            CL=CLPR*AINC
```

```
          END IF
C
 500      AA=1.0-EMA**2
       WRITE(12,140)SCLOPTS
C
C     MORE CONSTANTS AND COEFFICIENTS
C
       A=0.00
       AROT=ATAN(EMT/EMA)
       B=CL*SIGS*SR1MR2/(4.*AA)
       C=CL*SIGS/4.
       FNBL=FLOAT(NBLADE)
       FNV =FLOAT(NVANE)
       DSNCT=0.5*SIGS*(FNBL/FNV)/(1.-EMA**2)
          ALC=TPI*SR1MR2
          BETC=TPI
          CHIC=BETC*EMT
       CHINC = BNEW*(1.-HTR)/(PI*SR1MM2)
       DELC=0.00
       CDP2=(PI*SIGS/2.0)**2
          CAE=1./(EMA*SR1MM2)
          NINCO2=6
       NINCO2P1=NINCO2+1
          NINC=2*NINCO2
          FNINC=NINC
          DELTH=PI/FNINC
          THETA=-PI/2.
          IMAX=NINC+1
C
C
C     CALCULATION OF WAVE PROPAGATION FACTORS
C
C
          WRITE(12,110)
          IF (BW .LE. 0.0) THEN
             WRITE(12,111)
          ELSE
             WRITE(12,113) BW
          END IF
          WRITE(12,112)
          WRITE(12,114)
C
C
C     INDEX OVER FREQUENCY  -  J
C
          DO 3000 J=1,NF
            F(J)=FOB(J)/BPF
            ISKIP=0
         IF(BW.GT.0.0.OR.F(J).LT.0.5) ISKIP=1
C
            IF (ISKIP .NE. 1) THEN
              FHI=1.122462*F(J)
              FLO=0.890899*F(J)
              FJJ(1)=FLO
           FJJ(2)=F(J)
           FJJ(3)=FHI
           JJMAX=3
            ELSE
              FJJ(1)=F(J)
              JJMAX=1
```

```
            END IF
         CHI=F(J)*CHIC
         CHI2=CHI*CHI
         NMAXC = CHI*CHINC-0.000001
         NMP1C = NMAXC+1
         DO IRAD = 1,NMP1C
            IRADM1 = IRAD-1
            ENR    = FLOAT(IRAD-1)
            ENRC   = ENR/CHINC
            ENRC2  = ENRC**2
            THETA  = -PI/2.
            DO I = 1,IMAX
              CTH   = COS(THETA)
              STH   = SIN(THETA)
              CTH2  = CTH**2
              STH2  = STH**2
              IF ((IRAD.GT.1).OR.(I.NE.NINCO2P1)) THEN
                   CTF   = SQRT (CHI2*STH2+ENRC2*CTH2)
                   CTFRAT(IRAD,I) = CHI/CTF
                 ELSE
                   CTFRAT(IRAD,I) = 1.E+06
              ENDIF
              THETA = THETA+DELTH
            ENDDO
         ENDDO
C
            SDV=0.
            SDD=0.
            SQV=0.
            SQD=0.
         DO IJR = 1,NCOF
            WSDV(IJR) = 0.00
            WSDD(IJR) = 0.00
            WSQV(IJR) = 0.00
            WSQD(IJR) = 0.00
         ENDDO
         DO IRAD = 1,NMP1C
          DO I = 1,IMAX
           SDVTH(IRAD,I)=0.00
           SDDTH(IRAD,I)=0.00
           SQVTH(IRAD,I)=0.00
           SQDTH(IRAD,I)=0.00
          ENDDO
         ENDDO
            NVAL=30
            NVALP1=NVAL+1
C
C
C      INDEX OVER BPF HARMONIC NUMBER  -  N
C
         NNCNT     = 0
            DO 2800 NN=1,NVALP1
              N=NN-1
              FLTN=N
 1580         EN=N
            NNCNT = NNCNT+1
                AL=ABS(EN)*ALC
                AL2=AL*AL
                ALSGNB=AL*SGN(FLTN)*B
            BET=EN*BETC/DSTAT
```

```
                DEL=DELC*EN
            ZQI=0.5*ABS(AL)*SIGS/(1.-EMA**2)
            ZQ=ABS(ZQI)
            SNQA=SQRT(PI*ZQ*0.5)
            SNQDEN=(1.+SNQA)**2
C
C
C       INITIATE BANDWIDTH SUBDIVISION AND NUMERICAL INTEGRATION
C       FOR 1/3-OCTAVE SPECTRUM CALCULATION
C
                JJ=1
                DO WHILE (JJ .LE. JJMAX)
              DO JR = 1,NCOF
                 WSUMDV(JJ,JR)=0.00
                 WSUMDD(JJ,JR)=0.00
                 WSUMQV(JJ,JR)=0.00
                 WSUMQD(JJ,JR)=0.00
              ENDDO
              ETARICE = FJJ(JJ)*BPF*DTIP/(12.*SCO(KJI))
                  CHI=FJJ(JJ)*CHIC
                  CHI2=CHI*CHI
              FVAL=FJJ(JJ)
              THE = QDVAL(FVAL,NF,FINT,SPIMPRE,CHECK)
              THI = QDVAL(FVAL,NF,FINT,SPIMPR,CHECK)
              Z2E = QDVAL(FVAL,NF,FINT,SPIMPZ2E,CHECK)
              Z2I = QDVAL(FVAL,NF,FINT,SPIMPZ2,CHECK)
              IF (NNCNT.EQ.1) THEN
                 IF((J.EQ.1).OR.(J.EQ.NF)) THEN
                   TRME  = SQRT(Z2E-THE**2)
                   TRMI  = SQRT(Z2I-THI**2)
                   TFREQ = FVAL*BPF
                 ENDIF
              ENDIF
                  SUMDV=0.
                  SUMDD=0.
                  SUMQV=0.
                  SUMQD=0.
                  THETA=-PI/2.
              NMAX = CHI*CHINC-0.000001
              NMP1 = NMAX+1
              IF ( JJ.EQ.1 ) NMP1L = NMP1
 2345             CONTINUE
C     INDEX OVER RADIAL MODE ORDERS
              DO 2700 IRAD = 1,NMP1
                 ENR = FLOAT(IRAD-1)
                 ENRC = ENR/CHINC
                 ENRC2 = ENRC**2
                 NRAD = IRAD-1
                 CHIN = SQRT ( CHI2-(ENR/CHINC)**2 )
                 RCHI = CHI/CHIN
                 KR    = (ENR*PI)/(BNEW*(1.-HTR)*CHIN)
                 SUMDVR=0.
                 SUMDDR=0.
                 SUMQVR=0.
                 SUMQDR=0.
          THETA=-PI/2.
          DO 1230 I=1,IMAX
            CTH=COS(THETA)
         EMAMC=EMA*RCHI-CTH
         EMAPC=EMA*RCHI+CTH
```

```
             IF (I .LE. (NINCO2+1)) THEN
               ZMM(I)=EMAMC
               ZPP(I)=EMAPC
               AEV(I)=CAE/(1.+EMA*CTH)**2
               AED(I)=CAE/(1.-EMA*CTH)**2
             END IF
C
           STH=SIN(THETA)
           TERM=SR1MM2*STH
           TERM2=TERM**2
           DCV1(I)=TERM2
           SNCU(1,I)=ABS(EMAPC)*DSNCT
           DCV2(I)=TERM2
           SNCU(2,I)=SNCU(1,I)
           DCD1(I)=TERM2
           SNCD(1,I)=ABS(EMAMC)*DSNCT
           DCD2(I)=TERM2
           SNCD(2,I)=SNCD(1,I)
             STHOSR(I)=STH/SR1MM2
           ANG = ATAN(SR1MM2*STH/(CTH+EMA*RCHI))
           IF ( ANG.GE.0.00 ) PHI =  PI-ANG
           IF ( ANG.LT.0.00 ) PHI = -PI-ANG
           CALL TRANSROT(PHI,EMA,AROT,TR2,RE2)
           TRROT1(I)=TR2
           REROT1(I)=RE2
           IF ( ANG.GE.0.00 ) PHI =  ANG-PI
           IF ( ANG.LT.0.00 ) PHI =  ANG+PI
           CALL TRANSROT(PHI,EMA,AROT,TR2,RE2)
           TRROT2(I)=TR2
           REROT2(I)=RE2
             INDEX=I
             IF (I .GT. (NINCO2+1)) INDEX=IMAX+1-I
             AEVETC(1,I)=AEV(INDEX)*CDP2*DCV1(I)
             AEVETC(2,I)=AEV(INDEX)*CDP2*DCV2(I)
             AEDETC(1,I)=AED(INDEX)*CDP2*DCD1(I)
             AEDETC(2,I)=AED(INDEX)*CDP2*DCD2(I)
             THETA=THETA+DELTH
 1230      END DO
C
C
C      INDEX OVER (I) FOR INTEGRATION OVER KY
C
               THETA=-PI/2.
                   DO 2600 I=1,IMAX
                 CTH   = COS(THETA)
                 STH   = SIN(THETA)
                 CTH2  = CTH**2
                 STH2  = STH**2
                 IF ((IRAD.GT.1).OR.(I.NE.NINCO2P1)) THEN
                    CTF   = SQRT (CHI2*STH2+ENRC2*CTH2)
                    CTFR = CHI/CTF
                 ELSE
                    CTFR = 1.E+09
                 ENDIF
                 CTFR2 = CTFR**2
                 IKY = I-(NINCO2+1)
                 AKX=-CHI/EMA
                     AKY=-BET+CHI*STHOSR(I)
                     INDEX=I
                     IF (I .GT. (NINCO2+1)) INDEX=IMAX+1-I
```

```
                ZM=ZMM(INDEX)*CHIN
                ZP=ZPP(INDEX)*CHIN
                    DO 2310 L1=1,2
C
C        INLET TURBULENCE SPECTRUM CALCULATION
C
                  CALL PHICAL(AKX,AKY,CONTR,EL,RSCAL,RVEL,CR,SR,
     &                        PHIXX,PHIXY,PHIYY)
                      TPHIXY=2.*PHIXY
C
C        DIPOLE CONTRIBUTION
C
                  OMR=SIGS*AKX*DSTAT/2.
                      OM=ABS(OMR)
                  CALL FKCAL(OM,AR,SIGS,ELT,EMR,FK)
                      SRF=FK*FK
                      SRF2=2.0*FK
                      OMR=ABS(OMR)
                      PHIT=PHIXX*SR2-TPHIXY*SRCR+PHIYY*CR2
                  PHITS=ABS(PHIT*SRF)
C
                      IF (L1 .EQ. 2) THEN
                     SNZ  =CHI*SNCU(2,I)
                     SNA  =SQRT(PI*SNZ*0.5)
                     SNDEN=(1.+SNA)**2
                     FNDVM=AEVETC(2,I)*PHITS*TRROT2(I)/SNDEN
                     FNDVMR=AEVETC(2,I)*PHITS*REROT2(I)/SNDEN
                     SNZ  =CHI*SNCD(2,I)
                     SNA  =SQRT(PI*SNZ*0.5)
                     SNDEN=(1.+SNA)**2
                     FNDDM=AEDETC(2,I)*PHITS/SNDEN+FNDVMR
                   ELSE
                     SNZ  =CHI*SNCU(1,I)
                     SNA  =SQRT(PI*SNZ*0.5)
                     SNDEN=(1.+SNA)**2
                     FNDVP=AEVETC(1,I)*PHITS*TRROT1(I)/SNDEN
                     FNDVPR=AEVETC(1,I)*PHITS*REROT1(I)/SNDEN
                     SNZ  =CHI*SNCD(1,I)
                     SNA  =SQRT(PI*SNZ*0.5)
                     SNDEN=(1.+SNA)**2
                     FNDDP=AEDETC(1,I)*PHITS/SNDEN+FNDVPR
                      END IF
C
C        QUADRUPOLE CONTRIBUTION
C
 2060                 ZTERM=ZP
                      AKXA=AKX*AA
                      DO 2200 L2=1,2
                        ZDELAK=ZTERM-DEL-AKXA
                        DEN=(AL2+ZDELAK**2)**2
                        PART=ZTERM*(ZDELAK*A-ALSGNB)+C*ZDELAK*
     &                    CHIN*STHOSR(I)*AA
                        GX=ZTERM*PART
                   GY=CHIN*STHOSR(I)*PART*AA
               TQ=ABS((GX**2*PHIXX+GY**2*PHIYY+GX*GY*TPHIXY)/DEN)
                        IF (L2 .EQ. 2) THEN
                     FNQD=TQ*AED(INDEX)+FNQVR
                        ELSE
                     IF(L1.EQ.1) TRANS2 = TRROT1(I)
                     IF(L1.EQ.2) TRANS2 = TRROT2(I)
```

```
                     IF(L1.EQ.1) REFL2  = REROT1(I)
                     IF(L1.EQ.2) REFL2  = REROT2(I)
                     FNQV=TQ*AEV(INDEX)*TRANS2
                     FNQVR=TQ*AEV(INDEX)*REFL2
                        END IF
C
                        ZTERM=ZM
 2200                 END DO
C
                      IF (L1 .EQ. 2) THEN
                        FNQVM=FNQV
                        FNQDM=FNQD
                      ELSE
                        FNQVP=FNQV
                        FNQDP=FNQD
                   AKX=CHI/EMA
                        ZP=-ZP
                        ZM=-ZM
                      END IF
C
 2310               END DO
C
                    FDV=FNDVP+FNDVM
                    FDD=FNDDP+FNDDM
                    FQV=FNQVP+FNQVM
                    FQD=FNQDP+FNQDM
C
                    IF ((I .EQ. 1) .OR. (I .EQ. IMAX)) THEN
                      FDV=FDV/2.
                      FDD=FDD/2.
                      FQV=FQV/2.
                      FQD=FQD/2.
                    END IF
C
                AKYN = CHIN*STHOSR(I)*BNEW
                IF (NNCNT.EQ.1) THEN
                 IF(IABSOR.EQ.0)RICEV(JJ,IRAD,I)=1.00
                 IF(IABSOR.EQ.0)RICED(JJ,IRAD,I)=1.00
                 IF(IABSOR.NE.0)THEN
                  CTH    = COS(THETA)
                  STH    = SIN(THETA)
                  ALP    = ( CTH-RCHI*EMA)/OMM2
                  ALM    = (-CTH-RCHI*EMA)/OMM2
                  KYS    = STH/SR1MM2
                  KTOTP  = (RCHI-EMA*ALP)
                  KTOTM  = (RCHI-EMA*ALM)
                  CPHXP  = ALP/KTOTP
                  CPHXM  = ALM/KTOTM
                  CPHRP  = KR/KTOTP
                  CPHRM  = KR/KTOTM
                  DENP   = SQRT(CPHXP**2+CPHRP**2)
                  DENM   = SQRT(CPHXM**2+CPHRM**2)
                  CPHYP  = CPHRP/DENP
                  CPHYP2 = CPHYP**2
                  SPHYP  = CPHXP/DENP
                  CPHYM  = CPHRM/DENM
                  CPHYM2 = CPHYM**2
                  SPHYM  = CPHXM/DENM
                  OMSYP  = 1.+EMA*SPHYP
                  TOMSYP = 2.*OMSYP
```

```
                     OMSYM  = 1.+EMA*SPHYM
                     TOMSYM = 2.*OMSYM
                     OMSYP2 = OMSYP**2
                     OMSYM2 = OMSYM**2
                     IF ((I.GT.1).AND.(I.LT.IMAX)) THEN
                      TPSIXP = CPHRP/(CPHXP+EMA)
                      TPSIXM = CPHRM/(CPHXM+EMA)
                      NBNP   =  LEXOVD*TPSIXP/(1.-HTR)
                      NBNM   = -LINOVD*TPSIXM/(1.-HTR)
                      RIXP=(Z2E*CPHYP2*OMSYP2-THE*TOMSYP*CPHYP+1.)/
     &                         (Z2E*CPHYP2*OMSYP2+THE*TOMSYP*CPHYP+1.)
                      RIXM=(Z2I*CPHYM2*OMSYM2-THI*TOMSYM*CPHYM+1.)/
     &                        (Z2I*CPHYM2*OMSYM2+THI*TOMSYM*CPHYM+1.)
                      IXP = RIXP**NBNP
                      IXM = RIXM**NBNM
                     ELSE
                      IXP    = 0.00
                      IXM    = 0.00
                     ENDIF
                     RICEV(JJ,IRAD,I) = IXM
                     RICED(JJ,IRAD,I) = IXP
                    ENDIF
                CALL NEWSUB ( RLOW,RUPP,HTR,AKYN,IKY,IRAD,FC )
                F3D ( JJ,IRAD,I ) = FC
                   ENDIF
                   RICECV = RICEV(JJ,IRAD,I)
                   RICECD = RICED(JJ,IRAD,I)
                   F3DF  = F3D ( JJ,IRAD,I )
                   SUMDVR=SUMDVR+FDV*F3DF*RICECV
                   SUMDDR=SUMDDR+FDD*F3DF*RICECD
                   SUMQVR=SUMQVR+(FQV/SNQDEN)*F3DF*RICECV
                   SUMQDR=SUMQDR+(FQD/SNQDEN)*F3DF*RICECD
                   FDVTH(JJ,IRAD,I) = FDV*F3DF*RICECV
                   FDDTH(JJ,IRAD,I) = FDD*F3DF*RICECD
                   FQVTH(JJ,IRAD,I) = FQV*F3DF*RICECV/SNQDEN
                   FQDTH(JJ,IRAD,I) = FQD*F3DF*RICECD/SNQDEN
                   TJR1  = (1.-1./CTFR2)
                   TJR   = FCOF*TJR1
                   JR    = 1+INT(TJR)
                   IF ( JR.GT.NCOF ) JR = NCOF
                   WSUMDV(JJ,JR)=WSUMDV(JJ,JR)+FDVTH(JJ,IRAD,I)
                   WSUMDD(JJ,JR)=WSUMDD(JJ,JR)+FDDTH(JJ,IRAD,I)
                   WSUMQV(JJ,JR)=WSUMQV(JJ,JR)+FQVTH(JJ,IRAD,I)
                   WSUMQD(JJ,JR)=WSUMQD(JJ,JR)+FQDTH(JJ,IRAD,I)
                       THETA=THETA+DELTH
 2600                END DO
                   SUMDV=SUMDV+SUMDVR
                   SUMDD=SUMDD+SUMDDR
                   SUMQV=SUMQV+SUMQVR
                   SUMQD=SUMQD+SUMQDR
 2700                CONTINUE
C
                 PROD = CHI2*DELTH
                 SNDV=PROD*SUMDV
                 SNDD=PROD*SUMDD
                     SNQV=SUMQV*DELTH
                     SNQD=SUMQD*DELTH
                 DO IJR = 1,NCOF
                    WSNDV(JJ,IJR)=PROD*WSUMDV(JJ,IJR)
                    WSNDD(JJ,IJR)=PROD*WSUMDD(JJ,IJR)
```

```
                WSNQV(JJ,IJR)=DELTH*WSUMQV(JJ,IJR)
                WSNQD(JJ,IJR)=DELTH*WSUMQD(JJ,IJR)
             ENDDO
C
             DO IRAD = 1,NMP1
                DO I = 1,IMAX
                  FDVTH(JJ,IRAD,I) = PROD*FDVTH(JJ,IRAD,I)
                  FDDTH(JJ,IRAD,I) = PROD*FDDTH(JJ,IRAD,I)
                  FQVTH(JJ,IRAD,I) = FQVTH(JJ,IRAD,I)*DELTH
                  FQDTH(JJ,IRAD,I) = FQDTH(JJ,IRAD,I)*DELTH
                ENDDO
             ENDDO
C
             DVP(JJ)=SNDV
                 DDP(JJ)=SNDD
                 QVP(JJ)=SNQV
                 QDP(JJ)=SNQD
             DO IRAD = 1,NMP1
               DO I = 1,IMAX
                 NDVTH(IRAD,I)=FDVTH(JJ,IRAD,I)
                 NDDTH(IRAD,I)=FDDTH(JJ,IRAD,I)
                 NQVTH(IRAD,I)=FQVTH(JJ,IRAD,I)
                 NQDTH(IRAD,I)=FQDTH(JJ,IRAD,I)
               ENDDO
             ENDDO
             DO IJR = 1,NCOF
                WSNDV1(IJR) = WSNDV(JJ,IJR)
                WSNDD1(IJR) = WSNDD(JJ,IJR)
                WSNQV1(IJR) = WSNQV(JJ,IJR)
                WSNQD1(IJR) = WSNQD(JJ,IJR)
             ENDDO
C
                 IF (ISKIP .NE. 1) THEN
                   DVP(JJ)=DVP(JJ)/FJJ(JJ)
                   DDP(JJ)=DDP(JJ)/FJJ(JJ)
                   QVP(JJ)=QVP(JJ)/FJJ(JJ)
                   QDP(JJ)=QDP(JJ)/FJJ(JJ)
               DO IJR = 1,NCOF
                  WSNDV(JJ,IJR) = WSNDV(JJ,IJR)/FJJ(JJ)
                  WSNDD(JJ,IJR) = WSNDD(JJ,IJR)/FJJ(JJ)
                  WSNQV(JJ,IJR) = WSNQV(JJ,IJR)/FJJ(JJ)
                  WSNQD(JJ,IJR) = WSNQD(JJ,IJR)/FJJ(JJ)
               ENDDO
                 END IF
                 IF (ISKIP .NE. 1) THEN
               DO IRAD = 1,NMP1
                DO I = 1,IMAX
                 FDVTH(JJ,IRAD,I) = FDVTH(JJ,IRAD,I)/FJJ(JJ)
                 FDDTH(JJ,IRAD,I) = FDDTH(JJ,IRAD,I)/FJJ(JJ)
                 FQVTH(JJ,IRAD,I) = FQVTH(JJ,IRAD,I)/FJJ(JJ)
                 FQDTH(JJ,IRAD,I) = FQDTH(JJ,IRAD,I)/FJJ(JJ)
                ENDDO
               ENDDO
                 END IF
C
                 JJ=JJ+1
               END DO
C
               IF (ISKIP .NE. 1) THEN
                 IF (JJMAX .EQ. 3) THEN
```

```
FJ=F(J)
CALL EXINT(DVP(1),DVP(2),FLO,FJ,SNDV1)
CALL EXINT(DVP(2),DVP(3),FJ,FHI,SNDV2)
    SNDV=SNDV1+SNDV2
DO IJR = 1,NCOF
   W1 = WSNDV(1,IJR)
   W2 = WSNDV(2,IJR)
   W3 = WSNDV(3,IJR)
   CALL EXINT(W1,W2,FLO,FJ,R1)
   CALL EXINT(W2,W3,FJ,FHI,R2)
   WSNDV1(IJR) = R1+R2
ENDDO
CALL EXINT(DDP(1),DDP(2),FLO,FJ,SNDD1)
CALL EXINT(DDP(2),DDP(3),FJ,FHI,SNDD2)
    SNDD=SNDD1+SNDD2
DO IJR = 1,NCOF
   W1 = WSNDD(1,IJR)
   W2 = WSNDD(2,IJR)
   W3 = WSNDD(3,IJR)
   CALL EXINT(W1,W2,FLO,FJ,R1)
   CALL EXINT(W2,W3,FJ,FHI,R2)
   WSNDD1(IJR) = R1+R2
ENDDO
CALL EXINT(QVP(1),QVP(2),FLO,FJ,SNQV1)
CALL EXINT(QVP(2),QVP(3),FJ,FHI,SNQV2)
    SNQV=SNQV1+SNQV2
DO IJR = 1,NCOF
   W1 = WSNQV(1,IJR)
   W2 = WSNQV(2,IJR)
   W3 = WSNQV(3,IJR)
   CALL EXINT(W1,W2,FLO,FJ,R1)
   CALL EXINT(W2,W3,FJ,FHI,R2)
   WSNQV1(IJR) = R1+R2
ENDDO
CALL EXINT(QDP(1),QDP(2),FLO,FJ,SNQD1)
CALL EXINT(QDP(2),QDP(3),FJ,FHI,SNQD2)
    SNQD=SNQD1+SNQD2
DO IJR = 1,NCOF
   W1 = WSNQD(1,IJR)
   W2 = WSNQD(2,IJR)
   W3 = WSNQD(3,IJR)
   CALL EXINT(W1,W2,FLO,FJ,R1)
   CALL EXINT(W2,W3,FJ,FHI,R2)
   WSNQD1(IJR) = R1+R2
ENDDO
  ELSE
    CALL EXINT(DVP(1),DVP(2),FLO,FHI,SNDV)
DO IJR = 1,NCOF
   W1 = WSNDV(1,IJR)
   W2 = WSNDV(2,IJR)
   CALL EXINT(W1,W2,FLO,FHI,R1)
   WSNDV1(IJR) = R1
ENDDO
    CALL EXINT(DDP(1),DDP(2),FLO,FHI,SNDD)
DO IJR = 1,NCOF
   W1 = WSNDD(1,IJR)
   W2 = WSNDD(2,IJR)
   CALL EXINT(W1,W2,FLO,FHI,R1)
   WSNDD1(IJR) = R1
ENDDO
```

```
                    CALL EXINT(QVP(1),QVP(2),FLO,FHI,SNQV)
                DO IJR = 1,NCOF
                   W1 = WSNQV(1,IJR)
                   W2 = WSNQV(2,IJR)
                   CALL EXINT(W1,W2,FLO,FHI,R1)
                   WSNQV1(IJR) = R1
                ENDDO
                    CALL EXINT(QDP(1),QDP(2),FLO,FHI,SNQD)
                DO IJR = 1,NCOF
                   W1 = WSNQD(1,IJR)
                   W2 = WSNQD(2,IJR)
                   CALL EXINT(W1,W2,FLO,FHI,R1)
                   WSNQD1(IJR) = R1
                ENDDO
                  END IF
C
                END IF
C
                IF (ISKIP .NE. 1) THEN
                  IF (JJMAX .EQ. 3) THEN
                DO IRAD = 1,NMP1
                 DO I = 1,IMAX
                  DVP(1) = FDVTH(1,IRAD,I)
                  DDP(1) = FDDTH(1,IRAD,I)
                  QVP(1) = FQVTH(1,IRAD,I)
                  QDP(1) = FQDTH(1,IRAD,I)
                  DVP(2) = FDVTH(2,IRAD,I)
                  DDP(2) = FDDTH(2,IRAD,I)
                  QVP(2) = FQVTH(2,IRAD,I)
                  QDP(2) = FQDTH(2,IRAD,I)
                  DVP(3) = FDVTH(3,IRAD,I)
                  DDP(3) = FDDTH(3,IRAD,I)
                  QVP(3) = FQVTH(3,IRAD,I)
                  QDP(3) = FQDTH(3,IRAD,I)
                  CALL EXINT(DVP(1),DVP(2),FLO,FJ,SNDV1)
                  CALL EXINT(DVP(2),DVP(3),FJ,FHI,SNDV2)
                  NDVTH(IRAD,I)    = SNDV1+SNDV2
                  CALL EXINT(DDP(1),DDP(2),FLO,FJ,SNDD1)
                  CALL EXINT(DDP(2),DDP(3),FJ,FHI,SNDD2)
                  NDDTH(IRAD,I)    = SNDD1+SNDD2
                  CALL EXINT(QVP(1),QVP(2),FLO,FJ,SNQV1)
                  CALL EXINT(QVP(2),QVP(3),FJ,FHI,SNQV2)
                  NQVTH(IRAD,I)    = SNQV1+SNQV2
                  CALL EXINT(QDP(1),QDP(2),FLO,FJ,SNQD1)
                  CALL EXINT(QDP(2),QDP(3),FJ,FHI,SNQD2)
                  NQDTH(IRAD,I)    = SNQD1+SNQD2
                 ENDDO
                ENDDO
               ELSE
                DO IRAD = 1,NMP1
                 DO I = 1,IMAX
                  DVP(1) = FDVTH(1,IRAD,I)
                  DDP(1) = FDDTH(1,IRAD,I)
                  QVP(1) = FQVTH(1,IRAD,I)
                  QDP(1) = FQDTH(1,IRAD,I)
                  DVP(2) = FDVTH(2,IRAD,I)
                  DDP(2) = FDDTH(2,IRAD,I)
                  QVP(2) = FQVTH(2,IRAD,I)
                  QDP(2) = FQDTH(2,IRAD,I)
                  CALL EXINT(DVP(1),DVP(2),FLO,FHI,DUM)
```

```
                  NDVTH(IRAD,I)    = DUM
                  CALL EXINT(DDP(1),DDP(2),FLO,FHI,DUM)
                  NDDTH(IRAD,I)    = DUM
                  CALL EXINT(QVP(1),QVP(2),FLO,FHI,DUM)
                  NQVTH(IRAD,I)    = DUM
                  CALL EXINT(QDP(1),QDP(2),FLO,FHI,DUM)
                  NQDTH(IRAD,I)    = DUM
                 ENDDO
                ENDDO
               END IF
C
                END IF
C
                IF (N .GT. 0) THEN
                  SDV=SDV+4.*SNDV
                  SDD=SDD+4.*SNDD
                  SQV=SQV+4.*SNQV
                  SQD=SQD+4.*SNQD
              DO IJR = 1,NCOF
                 WSDV(IJR)=WSDV(IJR)+4.*WSNDV1(IJR)
                 WSDD(IJR)=WSDD(IJR)+4.*WSNDD1(IJR)
                 WSQV(IJR)=WSQV(IJR)+4.*WSNQV1(IJR)
                 WSQD(IJR)=WSQD(IJR)+4.*WSNQD1(IJR)
              ENDDO
                ELSE
                  SDV=SDV+SNDV
                  SDD=SDD+SNDD
                  SQV=SQV+SNQV
                  SQD=SQD+SNQD
              DO IJR = 1,NCOF
                 WSDV(IJR)=WSDV(IJR)+WSNDV1(IJR)
                 WSDD(IJR)=WSDD(IJR)+WSNDD1(IJR)
                 WSQV(IJR)=WSQV(IJR)+WSNQV1(IJR)
                 WSQD(IJR)=WSQD(IJR)+WSNQD1(IJR)
              ENDDO
                END IF
                IF (N .GT. 0) THEN
             DO IRAD = 1,NMP1
              DO I = 1,IMAX
               SDVTH(IRAD,I)=SDVTH(IRAD,I)+4.*NDVTH(IRAD,I)
               SDDTH(IRAD,I)=SDDTH(IRAD,I)+4.*NDDTH(IRAD,I)
               SQVTH(IRAD,I)=SQVTH(IRAD,I)+4.*NQVTH(IRAD,I)
               SQDTH(IRAD,I)=SQDTH(IRAD,I)+4.*NQDTH(IRAD,I)
              ENDDO
             ENDDO
                ELSE
             DO IRAD = 1,NMP1
              DO I = 1,IMAX
               SDVTH(IRAD,I)=SDVTH(IRAD,I)+NDVTH(IRAD,I)
               SDDTH(IRAD,I)=SDDTH(IRAD,I)+NDDTH(IRAD,I)
               SQVTH(IRAD,I)=SQVTH(IRAD,I)+NQVTH(IRAD,I)
               SQDTH(IRAD,I)=SQDTH(IRAD,I)+NQDTH(IRAD,I)
              ENDDO
             ENDDO
                END IF
C
 2800       END DO
C
            SDV=SDV*EMRC
            SDD=SDD*EMRC
```

```
             SQV=SQV*EMRC
             SQD=SQD*EMRC
             STV=SDV+SQV
             STD=SDD+SQD
          DO IJR = 1,NCOF
             WSDV(IJR)=WSDV(IJR)*EMRC
             WSDD(IJR)=WSDD(IJR)*EMRC
             WSQV(IJR)=WSQV(IJR)*EMRC
             WSQD(IJR)=WSQD(IJR)*EMRC
             WSTV(IJR)=WSDV(IJR)+WSQV(IJR)
             WSTD(IJR)=WSDD(IJR)+WSQD(IJR)
          ENDDO
          TRMDV1= 0.00
          TRMDD1= 0.00
          TRMQV1= 0.00
          TRMQD1= 0.00
          TRMV1 = 0.00
          TRMD1 = 0.00
          DO I = 1,NCOF
             TRMDV1= WSDV(I)+TRMDV1
             TRMDD1= WSDD(I)+TRMDD1
             TRMQV1= WSQV(I)+TRMQV1
             TRMQD1= WSQD(I)+TRMQD1
             TRMV1 = WSTV(I)+TRMV1
             TRMD1 = WSTD(I)+TRMD1
          ENDDO
          DO IRAD = 1,NMP1
           DO I = 1,IMAX
            SDVTH(IRAD,I)=SDVTH(IRAD,I)*EMRC
            SDDTH(IRAD,I)=SDDTH(IRAD,I)*EMRC
            SQVTH(IRAD,I)=SQVTH(IRAD,I)*EMRC
            SQDTH(IRAD,I)=SQDTH(IRAD,I)*EMRC
            STVTH(IRAD,I)=SDVTH(IRAD,I)+SQVTH(IRAD,I)
            STDTH(IRAD,I)=SDDTH(IRAD,I)+SQDTH(IRAD,I)
           ENDDO
          ENDDO
             FHZ=FOB(J)
             DBNB=0.0
          IF (J.EQ.NTOBNI) THEN
             WRITE(13,*) '    '
             POWMAX  = STVTH(1,1)+SDVTH(1,1)
             ICOUNT = 0
             DO IRAD = 1,NMP1
              DO I = 1,IMAX
                ICOUNT = ICOUNT+1
                CTFRATN ( ICOUNT ) = CTFRAT ( IRAD,I )
                POWTOT  ( ICOUNT ) = STVTH ( IRAD,I ) +
     &                                   STDTH ( IRAD,I )
                IF(POWTOT(ICOUNT).GT.POWMAX)
     &                POWMAX = POWTOT( ICOUNT )
              ENDDO
             ENDDO
             DO ISP = 1,ICOUNT
               IPERM ( ISP ) = ISP
             ENDDO
             CALL SVRGP ( ICOUNT,CTFRATN,CTFRATO,IPERM )
             DO IRAD = 1,NMP1
              DO I = 1,IMAX
                CTFINT  = CTFRAT ( IRAD,I )
                POWINT  = STVTH ( IRAD,I ) + STDTH ( IRAD,I )
```

```
               IF (POWINT.GT.0.00) THEN
                 POWDB   = 10.00*ALOG10(POWINT/POWMAX)
               ELSE
                 POWDB   = -1.00E+06
               ENDIF
             ENDDO
            ENDDO
            DO ISP = 1,ICOUNT
              CTFINT = CTFRATO ( ISP )
              IREL   = IPERM ( ISP )
              POWRAT = POWTOT ( IREL )/ POWMAX
              IF (POWRAT.GT.0.00) THEN
                 POWDB   = 10.00*ALOG10(POWRAT)
               ELSE
                 POWDB   = -1.00E+06
               ENDIF
            ENDDO
            SUMCHKDV = 0.00
            SUMCHKDD = 0.00
            SUMCHKQV = 0.00
            SUMCHKQD = 0.00
            SUMCHKV  = 0.00
            SUMCHKD  = 0.00
            DO IRAD = 1,NMP1
             DO I = 1,IMAX
               SUMCHKDV = SUMCHKDV+SDVTH(IRAD,I)
               SUMCHKDD = SUMCHKDD+SDDTH(IRAD,I)
               SUMCHKQV = SUMCHKQV+SQVTH(IRAD,I)
               SUMCHKQD = SUMCHKQD+SQDTH(IRAD,I)
               SUMCHKV  = SUMCHKV+STVTH(IRAD,I)
               SUMCHKD  = SUMCHKD+STDTH(IRAD,I)
             ENDDO
            ENDDO
            WRITE(13,*) '                         SUMCHK   ',
     &                    '     SUM'
            WRITE(13,*)'  '
            WRITE(13,*) 'UPSTR DIPOLE CHECKS ',SUMCHKDV,SDV,TRMDV1
            WRITE(13,*) 'DNSTR DIPOLE CHECKS ',SUMCHKDD,SDD,TRMDD1
            WRITE(13,*) 'UPSTR QUADRU CHECKS ',SUMCHKQV,SQV,TRMQV1
            WRITE(13,*) 'DNSTR QUADRU CHECKS ',SUMCHKQD,SQD,TRMQD1
            WRITE(13,*) 'UPSTR TOTAL  CHECKS ',SUMCHKV,STV,TRMV1
            WRITE(13,*) 'DNSTR TOTAL  CHECKS ',SUMCHKD,STD,TRMD1
         ENDIF
C
            IF (BW .LE. 0.0) THEN
              IF (F(J) .LT. 0.5) DBNB= -6.35
            ELSE
              DBNB=10.0*ALOG10(BW/FOB(J))
            END IF
         DBNBT = 10.**(0.1*DBNB)
C
         IF ( SDV.GT.0.00 ) THEN
            SDVDB=10.0*ALOG10(SDV) + DBL + DBNB
         ELSE
            SDVDB=-100.
         ENDIF
            SDDDB=10.0*ALOG10(SDD) + DBL + DBNB
         IF ( SQV.GT.0.00 ) THEN
            SQVDB=10.0*ALOG10(SQV) + DBL + DBNB
         ELSE
```

```
            SQVDB=-100.
         ENDIF
            SQDDB=10.0*ALOG10(SQD) + DBL + DBNB
         IF ( STV.GT.0.00 ) THEN
            STVDB=10.0*ALOG10(STV) + DBL + DBNB
         ELSE
            STVDB=-100.
         ENDIF
            STDDB=10.0*ALOG10(STD) + DBL + DBNB
         IF ( J.EQ.NTOBNI ) WRITE(13,* ) ' OBN = ',TOBN(J)
         IF ( J.EQ.NTOBNI ) WRITE(13,* ) '  '
         DO IJR = 1,NCOF
            WUP(IJR,J) = WUP(IJR,J)+ DBNBT*WSTV(IJR)*WATCON
            WDN(IJR,J) = WDN(IJR,J)+ DBNBT*WSTD(IJR)*WATCON
         ENDDO
            PVT(J)=10.0*ALOG10(10.0**(PVT(J)/10.0)+
     &                10.0**(STVDB/10.0))
            PDT(J)=10.0*ALOG10(10.0**(PDT(J)/10.0)+
     &                10.0**(STDDB/10.0))
C
C
            WRITE(12,116) FHZ,F(J),SDVDB,SDDDB,SQVDB,
     &                     SQDDB,STVDB,STDDB
C
 3000     END DO
C
 1949   END DO
C
C
C     FAN TOTAL POWER SPECTRUM
C
        WRITE(12,132)
      TPR    =  STPRIN(MIDSTR)
      TABS   =  (SCO(MIDSTR)/49.0422)**2
      PABS   =  53.3*TABS*RHO/144.
      PTOT   =  PABS*TPR
      T11    =  TPR**G1OVG-1.
      TTOT   =  TABS*(1.+T11/ETAFAN)
      FMACH  = -ABS(SEMA(MIDSTR))
      FMACHS = -ABS(MACHS)
      FMACHD =  ABS(SEMA(MIDSTR))
      XM     =  FMACHD
      XM2    =  XM**2
      AOAST  =  (TDGP1*(1.+G1OV2*XM2))**GEXP/XM
      ANOZRATC = 1./AOAST
      IF ( ANOZRATC.GT.ANOZRAT ) ANOZRAT = 1.02*ANOZRATC
      FMACH2 =  ABS(MACHS)
        DO 101 J=1,NF
       ETARICE = FOB(J)*DTIP/(12.*SCO(MIDSTR))
          PVDBT=PVT(J)
          PDDBT=PDT(J)
       PTDB=10.0*ALOG10(10.0**(PVDBT/10.0)+
     &          10.0**(PDDBT/10.0))
       WRITE(12,134) NINT(TOBN(J)), F(J) ,PVDBT,PDDBT,PTDB
       DO IJR = 1,NCOF
          WSUMIN(IJR) = WUP (IJR,J)
       END DO
      CALL BBRDCFIN(TABS,PABS,RADMIC,ISIDELN,DTIP,ALIP,BLIP,FMACH,
     &FMACHS,NCOF,WSUMIN,ETARICE,DELANG,NANGLE,ANGLE,
     &SPLOUT,SPLTL,WATTS,WATTRAN)
```

```
          WATTDB = 130.00 + 10.00*ALOG10(WATTS)
          WRITE(13,*)' INPOWER CHECK IN DB',WATTDB,TOBN(J),PVDBT
          NANGI   = NANGLE
          DO IANG = 1,NANGI
             SPLVDB(IANG) = SPLOUT(IANG)
          ENDDO
          DO IJR = 1,NCOF
             WSUMIN(IJR) = WDN (IJR,J)
          END DO
         CALL BBRDCFEX(TTOT,PTOT,TABS,PABS,HTR,ANOZRAT,RADMIC,
     & ISIDELN,DTIP,DJET,FMACHD,FMACH1,FMACH2,NCOF,WSUMIN,DELANG,
     & ETARICE,NANGLE,ANGLE,SPLOUT,SPLTL,WATTS,WATTRAN,FMACHN,
     & COFMIN)
          WATTDB = 130.00 + 10.00*ALOG10(WATTS)
          WRITE(13,*)' EXPOWER CHECK IN DB',WATTDB,TOBN(J),PDDBT
          NANG    = NANGLE
          DO IANG = 1,NANG
             II           = NANGLE+1-IANG
             SPLDDB(IANG) = SPLOUT(II)
             ANGLEO(IANG) = ANGLE(II)
             IF ( IANG.GT.NANGI ) SPLVDB (IANG ) = -150.00
             P2IN         = 10.**(0.1*SPLVDB(IANG))
             P2EX         = 10.**(0.1*SPLDDB(IANG))
             SPLDBT(IANG) = 10.*ALOG10(P2IN+P2EX)
          ENDDO
          IF ( J.EQ.NTOBNI ) THEN
             DO IANG = 1,NANG
               IF ( IANG.EQ.1 ) WRITE(13,*)' TOTAL OVER ALL STRIPS'
               IF ( IANG.EQ.1 ) WRITE(13,*)
               IF ( IANG.EQ.1 ) WRITE(13,150)
               IF ( IANG.EQ.1 ) WRITE(13,*)
               WRITE(13,160)ANGLEO(IANG),SPLVDB(IANG),
     &                      SPLDDB(IANG),SPLDBT(IANG)
             ENDDO
          ENDIF
C
C         .. Write data to spl plot file
C
             FREQNCY  = 10.00**(0.1*TOBN(J))
             DO IANG = 1,NANG
            IF ( IANG.EQ.1 ) WRITE(14,148)INT(FREQNCY),INT(TOBN(J))
            IF ( IANG.EQ.1 ) WRITE(14,*)
            IF ( IANG.EQ.1 ) WRITE(14,150)
            IF ( IANG.EQ.1 ) WRITE(14,*)
            WRITE(14,160)ANGLEO(IANG),SPLVDB(IANG),
     &                    SPLDDB(IANG),SPLDBT(IANG)
          ENDDO
C
 101    END DO
C
      END DO
      GO TO 9999
C
C****    ERROR DURING READ
C
 1000 WRITE(12,1002)
C
C     FORMAT SECTION
C
106   FORMAT(/,27H                CASE NUMBER,I4,5H   OF,I4)
```

```
 108   FORMAT(//16X,22HPROGRAM *** STATIN ***//
      &13X,39HRESPONSE OF AN ISOLATED OGV LIKE STATOR
      &//12X,32HTO INGESTION OF INLET TURBULENCE)
 110   FORMAT(/,'   *** COMPONENT PWL CONTRIBUTIONS  -  DB RE 10**(-13)',
      & ' WATTS ***')
 111   FORMAT(/,'                        ONE THIRD OCTAVE')
 112   FORMAT(/,'     FREQUENCY        DIPOLE        QUADRUPOLE',
      & '         TOTAL')
 113   FORMAT(/,'                    BANDWIDTH = ',F6.1,' Hz')
 114   FORMAT('   HERTZ   F/BPF   INLET EXHAUST   INLET EXHAUST   INLET',
      & ' EXHAUST')
 116   FORMAT(I8,F8.4,6F8.1)
 118   FORMAT(//24H***** STRIP AREA NUMBER ,I4,9H  WWND = ,F6.4)
 120   FORMAT(//52H     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD)
 122   FORMAT(2F9.3,F9.4,F9.2,F8.3,F7.2)
 124   FORMAT(//53H     GAM     RHO        C      SDIA    SPERC      TPR)
 125   FORMAT(//53H     RPM        NB     NBSTD    HTR    DTIP      CHDR)
 126   FORMAT(F9.3,F9.4,F9.0,F9.3,F8.3,F9.3)
 127   FORMAT(F9.1,I9,I9,F9.3,F8.3,F9.3)
 128   FORMAT(//3X,6H  CLW=F08.4,4X,6HCLINC=F08.4,4X,6HCLINP=F08.4)
 132   FORMAT(///12X,24HFAN TOTAL POWER SPECTRUM//
      &7X,4HTOBN,8X,5HF/BPF,6X,6HPWL-UP,6X,6HPWL-DN,5X,7HPWL-TOT,4X)
 134   FORMAT(I11,F13.4,3F12.2)
 136   FORMAT(//53H     EMR     RSCAL    RVEL      ELT      TIT      AR )
 138   FORMAT(F9.3,F9.2,F9.4,F9.3,F9.4,F9.3)
 140   FORMAT(/,' STREAMLINE LIFT COEFFICIENT CALCULATED U
      &SING SCLOPT= ',I2)
 142   FORMAT(//30X,2HNB,4X,2HNS)
 144   FORMAT(29X,I3,3X,I3)
 148   FORMAT(/,1x,'FREQUENCY =',I6,',  OBN =',I3)
 150   FORMAT(1X,'ANGLE',1X,'INL SPL',1X,'EXH SPL',1X,'TOT SPL')
 160   FORMAT(1X,F5.1,1X,3(1X,F7.1))
 1002  FORMAT(//6X,41H** INPUT ERROR ** PROCEEDING TO NEXT CASE//)
 C
  9999 CLOSE (UNIT=11)
       CLOSE (UNIT=12)
       CLOSE (UNIT=13)
       CLOSE (UNIT=14)
 10001 CONTINUE
 C
       STOP
       END
```

```
 C
 C        FKCAL        CALCULATION OF FK
 C
       SUBROUTINE FKCAL(OM,AR,SIGS,ELT,EMR,FK)
 C
       PI=3.1415926
 C
       IF(EMR.GT.0.8) GOTO 15
       BETASQ=1.0-EMR*EMR
       OMS=OM/BETASQ
       AMU=EMR*OMS
       IF(AMU.GT.1.0) GOTO 15
       BETA=SQRT(BETASQ)
       OMK=OMS*EMR*EMR
       SEARS=SQRT(1.0/(2.0*PI*OMS+1.0/(1.0+2.4*OMS)))
       SEARS=SEARS/BETA
       SEARS=SEARS*SQRT(1.0-(0.5*OMK)**2)
```

```
      GOTO 25
   15 CONTINUE
      EX=2.0*EMR*OM/(1.0+EMR)
      Z =SQRT(2.0*EX/PI)
      CALL FRESNL(Z,C2X,S2X)
      SEARS=1.0/(PI*OM)
      SEARS=SEARS*SQRT(2.0*(C2X**2+S2X**2)/EMR)
   25 CONTINUE
      ELTOH=ELT/(AR*SIGS)
      A=1.0/(2.0*ELTOH)
      ASQ=A*A
      BSQ=(AR**2)*(OM**2+2.0/PI**2)
      B=SQRT(BSQ)
      DEN=BSQ-ASQ
      ANUM=0.0
C
      IF (A .LE. 25.0) ANUM=EXP(-2.0*A) -1.0
      ACON=ANUM/DEN
      BNUM=0.0
C
      IF (B .LE. 25.0) BNUM=EXP(-2.0*B) -1.0
      BCON=BNUM/DEN
      FKSQ=1.0/A + 0.5*(BSQ/ASQ)*ACON - 0.5*(A/B)*BCON
      AFKSQ=ABS(FKSQ)
      FK=SEARS*SQRT(AFKSQ)
C
      RETURN
      END
```

```
C
C        PHICAL     CALCULATION OF PHIXX, PHIXY, AND PHIYY
C
      SUBROUTINE PHICAL(AKXI,AKYI,CONTR,EL,RSCAL,RVEL,CR,SR,
     &                  PHIXXO,PHIXYO,PHIYYO)
C
      PI=3.1415926
      RVEL2=RVEL**2
      RSCAL2=RSCAL**2
      C=CONTR
      IF(C.LE.0.0) C=1.0
      EPS=1.0/C**3
      OMEPS=1.0-EPS
      OMEPS2=OMEPS**2
      CR2=CR**2
      SR2=SR**2
      TCRSR=2.*CR*SR
      AKX=AKXI*CR+AKYI*SR
      AKY=-AKXI*SR+AKYI*CR
C
      ELA=EL
      ELT=EL/RSCAL
      AK1=AKX*C
      AK2=AKY/SQRT(C)
      AKNX=AK1*ELA
      AKNY=AK2*ELT
      AKNX2=AKNX**2
      AKNY2=AKNY**2
C
      ALT2=1.0+AKNX2+AKNY2
      ALT=SQRT(ALT2)
```

```
      RA5=1.0/ALT**5
      A=ALT/ELT
C
      FPHIYY=2.0*RVEL2-1.0/RSCAL2
      IF (C .LE. 1.01 .AND. C .GE. 0.99) THEN
C
C     ANALYTIC TWO-DIMENSIONAL SPECTRA FOR CONTRACTION RATIO = 1.0
C
        CPHIXX=ELT*ELA*RA5/(4.0*PI)
        CPHIXY=-3.0*CPHIXX/RSCAL
        CPHIYY=CPHIXX
C
        PHIXX=CPHIXX*(3.0*AKNY2+ALT2)
        PHIXY=CPHIXY*(AKNX*AKNY)
        PHIYY=CPHIYY*(3.0*AKNX2/RSCAL2+ALT2*FPHIYY)
     PHIXXO=PHIXX*CR2-TCRSR*PHIXY+PHIYY*SR2
     PHIXYO=(PHIXX-PHIYY)*CR*SR+PHIXY*(CR2-SR2)
     PHIYYO=PHIXX*SR2+TCRSR*PHIXY+PHIYY*CR2
        RETURN
      END IF
C
C     NUMERICAL INTEGRATION OVER K3 FOR CONTRACTION RATIO .NE. 1.0
C
      RC2 =1.0/C**2
      RSQC=1.0/SQRT(C)
      CPHI=4.0*SQRT(C)*ELA*ELT/PI**2
      PHI11=0.0
      PHI12=0.0
      PHI22=0.0
      DELTH=PI/36.
      CPHI=CPHI*RA5*DELTH
C
      DO 30 I=1,18
        FI=I-1
        TH=FI*DELTH
        CTH4=COS(TH)**4
        AK3=A*SIN(TH)/COS(TH)
        AKNZ=AK3*ELT
        AKNZ2=AKNZ**2
        AKNT2=AKNY2+AKNZ2
        GAM11=AKNT2
        GAM12=-AKNX*AKNY/RSCAL
        GAM22=AKNX2/RSCAL2+AKNZ2*FPHIYY
        B2=EPS*AK1**2+AK2**2+AK3**2
C
        IF (B2 .LT. 1.0E-05) THEN
          TERM11=CTH4*GAM11
          TERM12=CTH4*GAM12
          TERM22=CTH4*GAM22
        ELSE
          RB2=1.0/B2
          B4=B2**2
          RB4=1.0/B4
          TERM11=CTH4*RC2*GAM11*(1.0+AK1**2*OMEPS*RB2)**2
          TERM12=CTH4*RSQC*(GAM12+RB2*OMEPS*AK1*(GAM11*AK2+GAM12*AK1)
     &      +RB4*OMEPS2*AK1**3*AK2*GAM11)
          TERM22=CTH4*C*(GAM22+2.0*RB2*OMEPS*AK1*AK2*GAM12
     &      +RB4*OMEPS2*((AK1*AK2)**2)*GAM11)
        END IF
C
```

```
        IF (I .LE. 1) THEN
          TERM11=0.5*TERM11
          TERM12=0.5*TERM12
          TERM22=0.5*TERM22
        END IF
C
        PHI11=PHI11+TERM11
        PHI12=PHI12+TERM12
        PHI22=PHI22+TERM22
   30 END DO
C
      PHIXX=PHI11*CPHI
      PHIXY=PHI12*CPHI
      PHIYY=PHI22*CPHI
      PHIXXO=PHIXX*CR2-TCRSR*PHIXY+PHIYY*SR2
      PHIXYO=(PHIXX-PHIYY)*CR*SR+PHIXY*(CR2-SR2)
      PHIYYO=PHIXX*SR2+TCRSR*PHIXY+PHIYY*CR2
C
      RETURN
      END
```

```
C
C        EXINT      SUBROUTINE EXINT  -  EXPONENTIAL CURVE INTEGRATION
C
      SUBROUTINE EXINT(Y1,Y2,X1,X2,YINT)
C
C
      YMAX=AMAX1(Y1,Y2)
      YMIN=AMIN1(Y1,Y2)
      DELX=ABS(X1-X2)
      YINT=YMAX*DELX
      IF (YMIN.EQ.00) YINT =  0.5*YINT
      IF (YMIN.EQ.00) GO TO 100
C
      DELY=ALOG(YMAX/YMIN)
      IF (DELY .GE. 0.01) THEN
        COR1=(1.0-YMIN/YMAX)/DELY
        X   =SQRT(YMAX/YMIN-1.0)
        COR2=(ATAN(X))/X
        COR =SQRT(COR1*COR2)
        YINT=YINT*COR
      END IF
C
  100 CONTINUE
      RETURN
      END
```

```
C
C        SGN         SIGN OF A FUNCTION OR PARAMETER
C
      FUNCTION SGN(X)
C
      IF (X .EQ. 0.) THEN
        SGN=0.
      ELSE
        SGN=X/ABS(X)
      END IF
C
```

```
      RETURN
      END
```

```
C
C        FRESNL      FRESNEL INTEGRAL FUNCTIONS C(Z) AND S(Z)
C
      SUBROUTINE FRESNL(Z,C,S)
C
      PI=3.1415926
      X =0.5*PI*Z*Z
      COSX=COS(X)
      SINX=SIN(X)
C
      TOP=1.0+0.926*Z
      BOT=2.0+Z*(1.792+3.104*Z)
      F  =TOP/BOT
C
      TOP=1.0
      BOT=2.0+Z*(4.142+Z*(3.492+6.670*Z))
      G  =TOP/BOT
C
      C  =  0.5 + F*SINX - G*COSX
      S  =  0.5 - F*COSX - G*SINX
C
      RETURN
      END
```

```
C
       SUBROUTINE TRANSROT ( PHI,M,AL,TR2,RE2 )
       REAL M,MT,MREL
       PI     = 3.14159265
       MT     = M*TAN(AL)
       MREL   = SQRT ( MT**2+M**2 )
       CPHI   = COS(PHI)
       SPHI   = SIN(PHI)
       DENPHI = 1.+M**2+2.*M*CPHI
       CRIT   = ABS ( CPHI+M )
       CTH    = (-CPHI*(1.+M**2)-2.*M)/DENPHI
       STH    = (1.-M**2)*SPHI/DENPHI
       THETAD = ATAN2(STH,CTH)*180./PI
       OPMCTH = 1.+M*CTH
       STHPAL = STH*COS(AL)+CTH*SIN(AL)
       RC     = -SIN(PHI+AL)/STHPAL
       RS     = -(COS(AL)-M*STH*SIN(AL)/OPMCTH)/STHPAL
       A11    = (1.+CPHI/M)
       A12    = (1.+CTH/M)*RS-STH/OPMCTH
       A21    = 1.+M*CPHI-MT*SPHI
       A22    = (OPMCTH-MT*STH)*RS-(M**2*STH/OPMCTH+MT)
       B1     = -(1.+CTH/M)*RC
       B2     = -(OPMCTH-MT*STH)*RC
       DET    = A11*A22-A12*A21
       OMT    = (A22*B1-A12*B2)/DET
       S      = (A11*B2-A21*B1)/DET
       R      = RC+RS*S
       TR     = 1.-OMT
       IF ( MREL.LT.1. ) TR2    = TR**2
       IF ( MREL.GE.1. ) TR2    = 0.000
       IF ( CRIT.GT.0.00 ) THEN
```

```
          RE2P   = R**2*(1.+M*CTH)*(CTH+M)/((1.+M*CPHI)*(CPHI+M))
         ELSE
          RE2P   = R**2*(1.+M*CTH)/(1.+M*CPHI)
         END IF
         IF ( MREL.LT.1. ) RE2    = ABS(RE2P)
         IF ( MREL.GE.1. ) RE2    = 1.000
         RETURN
         END
```

```
C
      SUBROUTINE NEWSUB ( RLOW,RUPP,HTR,AKYN,IKY,NR,F3DB )
C
      ord     = abs(akyn)*(1.+htr)/2.
C
      N         = NR-1
      CALL SUB3D ( AKYN,IKY,HTR,RLOW,RUPP,N,F3DB )
      RETURN
      END
```

```
C
      SUBROUTINE SUB3D ( KY,IKY,SIG,RL,RU,N,f3d1 )
      REAL KY,KMN,kmn2,kmns
      if ( (iky.eq.0).and.(n.eq.0) ) then
       f3d1 = (ru**2-rl**2)/(1.-sig**2)
       go to 100
      endif
      pi      = 3.14159265
      enc     = pi*float(n)
      kmn     = sqrt ( ky**2+(enc/(1.-sig))**2 )
      kmns    = kmn*sig
      kmn2    = kmn**2
      sig2    = sig**2
      ord     = abs(ky)*(1.+sig)/2.
      call simp ( rl,ru,kmn,sig,ord,cnn )
      call simp1 ( kmn,sig,ord,dencn1 )
      f3d1    = ( 2.*cnn**2/dencn1 )/(ru**2-rl**2)
  100 continue
      return
      end
```

```
c
      SUBROUTINE SIMP ( RL,RU,KMN,SIG,ORD,RES )
      REAL KMN
c     # of points for Simpson's rule (minimum value 7:also needs to be odd)
c     # of points determined assuming period of "2*pi."This must be
c     reflected in rescaling of argument as below
      a       = kmn*rl
      b       = kmn*ru
      args    = kmn*sig
      factor  = 1./kmn**2
c     # of points for Simpson's rule (minimum value 7:also needs to be odd)
      pi      = 3.14159265
      rint    = (b-a)
      npm1    = 5.*(rint/pi)
      np      = 2*(npm1/2)+1
      if (np.lt.7) np = 7
      npm1    = np-1
c     evaluation by Simpson's rule with np points
```

```
      delx    = (b-a)/float(npm1)
c     multipliers for end,even and odd terms
      mulend  = 1.00
      muleven = 4.00
      mulodd  = 2.00
      sum     = 0.00
      rargs   = args/ord
      if ((ord.le.30).or.(rargs.gt.0.9)) then
       call  phijd ( args,ord,bjd  )
       call phiryd ( args,ord,rbyd )
      endif
      if ((ord.gt.30).and.(rargs.le.0.9)) then
       call  abesjd ( args,ord,bjd  )
       call arbesyd ( args,ord,rbyd )
      endif
      do 200 i = 1,np
       x     = a+float(i-1)*delx
       rx    = x/ord
       if ((ord.le.30).or.(rx.gt.0.9)) then
          call  phij ( x,ord,bj )
          call  phiy ( x,ord,by )
          trm= by*rbyd
       endif
       if ((ord.gt.30).and.(rx.le.0.9)) then
          call  abesj  ( x,ord,bj )
          call  abesyr ( x,args,ord,trm )
       endif
       y     = (bj-trm*bjd)*x
       if ((i.eq.1).or.(i.eq.np)) sum    = sum+y*mulend
       if ((i.ne.1).and.(i.ne.np)) then
          idisc   = 2*(i/2)-i
          if (idisc.ne.0) sum     = sum+y*mulodd
          if (idisc.eq.0) sum     = sum+y*muleven
         endif
  200 continue
      aints   = delx*sum/3.
      res     = aints*factor
      return
      end


c
      SUBROUTINE SIMP1 ( KMN,SIG,ORD,RES )
      REAL KMN
c     # of points for Simpson's rule (minimum value 7:also needs to be odd)
c     # of points determined assuming period of "2*pi."This must be
c     reflected in rescaling of argument as below
      a       = kmn*sig
      b       = kmn
      args    = a
      factor  = 1./kmn**2
c     # of points for Simpson's rule (minimum value 7:also needs to be odd)
      pi      = 3.14159265
      rint    = (b-a)
      npm1    = 5.*(rint/pi)
      np      = 2*(npm1/2)+1
      if (np.lt.7) np = 7
      npm1    = np-1
c     evaluation by Simpson's rule with np points
      delx    = (b-a)/float(npm1)
c     multipliers for end,even and odd terms
```

```
      mulend  = 1.00
      muleven = 4.00
      mulodd  = 2.00
      sum     = 0.00
      rargs   = args/ord
      if ((ord.le.30).or.(rargs.gt.0.9)) then
       call  phijd ( args,ord,bjd  )
       call phiryd ( args,ord,rbyd )
      endif
      if ((ord.gt.30).and.(rargs.le.0.9)) then
       call  abesjd ( args,ord,bjd  )
       call arbesyd ( args,ord,rbyd )
      endif
      do 200 i = 1,np
       x     = a+float(i–1)*delx
       rx    = x/ord
       if ((ord.le.30).or.(rx.gt.0.9)) then
          call  phij ( x,ord,bj )
          call  phiy ( x,ord,by )
          trm= by*rbyd
       endif
       if ((ord.gt.30).and.(rx.le.0.9)) then
          call  abesj  ( x,ord,bj )
          call  abesyr ( x,args,ord,trm )
       endif
       y     = (bj–trm*bjd)**2*x
       if ((i.eq.1).or.(i.eq.np)) sum    = sum+y*mulend
       if ((i.ne.1).and.(i.ne.np)) then
          idisc   = 2*(i/2)–i
          if (idisc.ne.0) sum     = sum+y*mulodd
          if (idisc.eq.0) sum     = sum+y*muleven
        endif
  200 continue
      aints   = delx*sum/3.
      res     = aints*factor
      return
      end
```

```
c
      SUBROUTINE PHIJ ( ARG,ORD,BJARG )
      DIMENSION BJ(1000)
C     CALCULATES ” JORD(ARG) ”
      NORD   = ORD
      NB     = NORD+1
      AL     = ORD–FLOAT(NORD)
      IF ( NB.GT.1000 ) PRINT *,’NEED TO INCREASE DIMENSIONS OF’,
     1                   ’ BJ IN SUBROUTINE PHIJ BEYOND 1000’
      IF ( NB.GT.1000 ) GO TO 200
C     WRITE(12,*)’RJBESL,ARG,ORD ’,ARG,ORD
      CALL RJBESL ( ARG,AL,NB,BJ,NCALC )
      IF ( NCALC.LT.NB ) PRINT *,’ ERROR IN BJ CALCULATION !–PHIJ’
      IF ( NCALC.LT.NB ) PRINT *,’ORD,ARG = ’,ORD,ARG
      IF ( NCALC.LT.NB ) GO TO 100
      BJARG  = BJ(NB)
C     WRITE(12,*)’RJBESL,RES ’,BJARG
  100 CONTINUE
  200 CONTINUE
      return
      END
```

```
C
      SUBROUTINE PHIY ( ARG,ORD,BYARG )
      DIMENSION BY(1000)
C     CALCULATES ” YORD(ARG) ”
      NORD   = ORD
      NB     = NORD+1
      AL     = ORD–FLOAT(NORD)
C     WRITE(12,*)’RYBESL,ARG,ORD ’,ARG,ORD
      CALL RYBESL ( ARG,AL,NB,BY,NCALC )
      IF ( NCALC.LT.NB ) PRINT *,’ ERROR IN BY CALCULATION !–PHIY’
      IF ( NCALC.LT.NB ) PRINT *,’ORD,ARG = ’,ORD,ARG
      IF ( NCALC.LT.NB ) GO TO 100
      BYARG  = BY(NB)
C     WRITE(12,*)’RYBESL,RES ’,BYARG
  100 CONTINUE
  200 CONTINUE
      return
      END
```

```
C
      SUBROUTINE PHIJD ( ARG,ORD,BJDER )
      DIMENSION BJ(1000)
C     CALCULATES ” JORD’(ARG) ”
      NORD   = ORD
      NB     = NORD+1
      NBP1   = NB+1
      IF ( NBP1.GT.1000 ) PRINT *,’NEED TO INCREASE DIMENSIONS OF’,
     1                   ’ BJ IN SUBROUTINE PHIJD BEYOND 1000’
      IF ( NBP1.GT.1000 ) GO TO 200
      AL     = ORD–FLOAT(NORD)
C     WRITE(12,*)’RJBESL,ARG,ORD ’,ARG,(ORD+1.)
      CALL RJBESL ( ARG,AL,NBP1,BJ,NCALC )
      IF ( NCALC.LT.NBP1 ) PRINT *,’ ERROR IN BJDER CALCULATION !’
      IF ( NCALC.LT.NBP1 ) PRINT *,’ ERROR IN PHIJD!’
      IF ( NCALC.LT.NBP1 ) PRINT *,’ORD,ARG= ’,ORD,ARG
      IF ( NCALC.LT.NBP1 ) GO TO 100
      BJDER = –BJ(NBP1)+ORD*BJ(NB)/ARG
C     WRITE(12,*)’RJBESL,RES ’,BJ(NBP1)
  100 CONTINUE
  200 CONTINUE
      return
      END
```

```
C
      SUBROUTINE PHIRYD ( ARG,ORD,RBYDER )
      DIMENSION BY(1000)
C     CALCULATES ” JORD’(ARG) AND YORD’(ARG) ”
      NORD   = ORD
      NB     = NORD+1
      NBP1   = NB+1
      IF ( NBP1.GT.1000 ) PRINT *,’NEED TO INCREASE DIMENSIONS OF’,
     1                   ’ BY IN SUBROUTINE PHIYD BEYOND 1000’
      IF ( NBP1.GT.1000 ) GO TO 200
      AL     = ORD–FLOAT(NORD)
C     WRITE(12,*)’RYBESL,ARG,ORD ’,ARG,(ORD+1.)
      CALL RYBESL ( ARG,AL,NBP1,BY,NCALC )
```

```
      IF ( NCALC.LT.NBP1 ) PRINT *,' ERROR IN BYDER CALCULATION !'
      IF ( NCALC.LT.NBP1 ) PRINT *,' ERROR IN PHIYD!'
      IF ( NCALC.LT.NBP1 ) PRINT *,'ORD,ARG = ',ORD,ARG
      IF ( NCALC.LT.NBP1 ) GO TO 100
      BYDER = -BY(NBP1)+ORD*BY(NB)/ARG
      RBYDER = 1./BYDER
C     WRITE(12,*)'RYBESL,RES ',BY(NBP1)
  100 CONTINUE
  200 CONTINUE
      return
      END
```

```
C
      SUBROUTINE RJBESL(X, ALPHA, NB, B, NCALC)
C---------------------------------------------------------------------
C This routine calculates Bessel functions J sub(N+ALPHA) (X)
C   for non-negative argument X, and non-negative order N+ALPHA.
C
C
C  Explanation of variables in the calling sequence.
C
C   X     - working precision non-negative real argument for which
C           J's are to be calculated.
C   ALPHA - working precision fractional part of order for which
C           J's or exponentially scaled J'r (J*exp(X)) are
C           to be calculated.  0 <= ALPHA < 1.0.
C   NB  - integer number of functions to be calculated, NB > 0.
C           The first function calculated is of order ALPHA, and the
C           last is of order (NB - 1 + ALPHA).
C   B  - working precision output vector of length NB.  If RJBESL
C           terminates normally (NCALC=NB), the vector B contains the
C           functions J/ALPHA/(X) through J/NB-1+ALPHA/(X), or the
C           corresponding exponentially scaled functions.
C   NCALC - integer output variable indicating possible errors.
C           Before using the vector B, the user should check that
C           NCALC=NB, i.e., all orders have been calculated to
C           the desired accuracy.  See Error Returns below.
C
C
C*******************************************************************
C*******************************************************************
C
C  Explanation of machine-dependent constants
C
C   it     = Number of bits in the mantissa of a working precision
C            variable
C   NSIG   = Decimal significance desired.  Should be set to
C            INT(LOG10(2)*it+1).  Setting NSIG lower will result
C            in decreased accuracy while setting NSIG higher will
C            increase CPU time without increasing accuracy.  The
C            truncation error is limited to a relative error of
C            T=.5*10**(-NSIG).
C   ENTEN  = 10.0 ** K, where K is the largest integer such that
C            ENTEN is machine-representable in working precision
C   ENSIG  = 10.0 ** NSIG
C   RTNSIG = 10.0 ** (-K) for the smallest integer K such that
C            K .GE. NSIG/4
C   ENMTEN = Smallest ABS(X) such that X/4 does not underflow
C   XLARGE = Upper limit on the magnitude of X.  If ABS(X)=N,
```

```
C             then at least N iterations of the backward recursion
C             will be executed.  The value of 10.0 ** 4 is used on
C             every machine.
C
C
C      Approximate values for some important machines are:
C
C
C                                 it    NSIG    ENTEN       ENSIG
C
C    CRAY-1        (S.P.)      48     15    1.0E+2465   1.0E+15
C    Cyber 180/855
C      under NOS   (S.P.)      48     15    1.0E+322    1.0E+15
C    IEEE (IBM/XT,
C      SUN, etc.)  (S.P.)      24      8    1.0E+38     1.0E+8
C    IEEE (IBM/XT,
C      SUN, etc.)  (D.P.)      53     16    1.0D+308    1.0D+16
C    IBM 3033      (D.P.)      14      5    1.0D+75     1.0D+5
C    VAX           (S.P.)      24      8    1.0E+38     1.0E+8
C    VAX D-Format  (D.P.)      56     17    1.0D+38     1.0D+17
C    VAX G-Format  (D.P.)      53     16    1.0D+307    1.0D+16
C
C
C                               RTNSIG      ENMTEN      XLARGE
C
C    CRAY-1        (S.P.)     1.0E-4    1.84E-2466   1.0E+4
C    Cyber 180/855
C      under NOS   (S.P.)     1.0E-4    1.25E-293    1.0E+4
C    IEEE (IBM/XT,
C      SUN, etc.)  (S.P.)     1.0E-2    4.70E-38     1.0E+4
C    IEEE (IBM/XT,
C      SUN, etc.)  (D.P.)     1.0E-4    8.90D-308    1.0D+4
C    IBM 3033      (D.P.)     1.0E-2    2.16D-78     1.0D+4
C    VAX           (S.P.)     1.0E-2    1.17E-38     1.0E+4
C    VAX D-Format  (D.P.)     1.0E-5    1.17D-38     1.0D+4
C    VAX G-Format  (D.P.)     1.0E-4    2.22D-308    1.0D+4
C
C*******************************************************************
C*******************************************************************
C
C   Error returns
C
C     In case of an error,  NCALC .NE. NB, and not all J's are
C     calculated to the desired accuracy.
C
C     NCALC .LT. 0:  An argument is out of range. For example,
C        NBES .LE. 0, ALPHA .LT. 0 or .GT. 1, or X is too large.
C        In this case, B(1) is set to zero, the remainder of the
C        B-vector is not calculated, and NCALC is set to
C        MIN(NB,0)-1 so that NCALC .NE. NB.
C
C     NB .GT. NCALC .GT. 0: Not all requested function values could
C        be calculated accurately.  This usually occurs because NB is
C        much larger than ABS(X).  In this case, B(N) is calculated
C        to the desired accuracy for N .LE. NCALC, but precision
C        is lost for NCALC .LT. N .LE. NB.  If B(N) does not vanish
C        for N .GT. NCALC (because it is too small to be represented),
C        and B(N)/B(NCALC) = 10**(-K), then only the first NSIG-K
C        significant figures of B(N) can be trusted.
C
```

```
C
C  Intrinsic and other functions required are:
C
C     ABS, AINT, COS, DBLE, GAMMA (or DGAMMA), INT, MAX, MIN,
C
C     REAL, SIN, SQRT
C
C
C  Acknowledgement
C
C   This program is based on a program written by David J. Sookne
C   (2) that computes values of the Bessel functions J or I of real
C   argument and integer order.  Modifications include the restriction
C   of the computation to the J Bessel function of non-negative real
C   argument, the extension of the computation to arbitrary positive
C   order, and the elimination of most underflow.
C
C  References: "A Note on Backward Recurrence Algorithms," Olver,
C               F. W. J., and Sookne, D. J., Math. Comp. 26, 1972,
C               pp 941-947.
C
C              "Bessel Functions of Real Argument and Integer Order,"
C               Sookne, D. J., NBS Jour. of Res. B. 77B, 1973, pp
C               125-132.
C
C  Latest modification: March 19, 1990
C
C  Author: W. J. Cody
C          Applied Mathematics Division
C          Argonne National Laboratory
C          Argonne, IL  60439
C
C---------------------------------------------------------------------
      INTEGER I,J,K,L,M,MAGX,N,NB,NBMX,NCALC,NEND,NSTART
      REAL               GAMMA,
CD    DOUBLE PRECISION  DGAMMA,
     1 ALPHA,ALPEM,ALP2EM,B,CAPP,CAPQ,CONV,EIGHTH,EM,EN,ENMTEN,ENSIG,
     2 ENTEN,FACT,FOUR,FUNC,GNU,HALF,HALFX,ONE,ONE30,P,PI2,PLAST,
     3 POLD,PSAVE,PSAVEL,RTNSIG,S,SUM,T,T1,TEMPA,TEMPB,TEMPC,TEST,
     4 THREE,THREE5,TOVER,TWO,TWOFIV,TWOPI1,TWOPI2,X,XC,XIN,XK,XLARGE,
     5 XM,VCOS,VSIN,Z,ZERO
      DIMENSION B(NB), FACT(25)
C---------------------------------------------------------------------
C  Mathematical constants
C
C   PI2    - 2 / PI
C   TWOPI1 - first few significant digits of 2 * PI
C   TWOPI2 - (2*PI - TWOPI) to working precision, i.e.,
C            TWOPI1 + TWOPI2 = 2 * PI to extra precision.
C---------------------------------------------------------------------
DATA PI2, TWOPI1, TWOPI2 /0.636619772367581343075535E0,6.28125E0,
1 1.935307179586476925286767E-3/
      DATA ZERO, EIGHTH, HALF, ONE /0.0E0,0.125E0,0.5E0,1.0E0/
      DATA TWO, THREE, FOUR, TWOFIV /2.0E0,3.0E0,4.0E0,25.0E0/
      DATA ONE30, THREE5 /130.0E0,35.0E0/
CD    DATA PI2, TWOPI1,TWOPI2/0.636619772367581343075535D0,6.28125D0,
CD   1 1.935307179586476925286767D-3/
CD    DATA ZERO, EIGHTH, HALF, ONE /0.0D0,0.125D0,0.5D0,1.0D0/
CD    DATA TWO, THREE, FOUR, TWOFIV /2.0D0,3.0D0,4.0D0,25.0D0/
CD    DATA ONE30, THREE5 /130.0D0,35.0D0/
```

```
C-------------------------------------------------------------------
C  Machine-dependent parameters
C-------------------------------------------------------------------
      DATA ENTEN, ENSIG, RTNSIG /1.0E38,1.0E8,1.0E-2/
      DATA ENMTEN, XLARGE /1.2E-37,1.0E4/
CD    DATA ENTEN, ENSIG, RTNSIG /1.0D38,1.0D17,1.0D-4/
CD    DATA ENMTEN, XLARGE /1.2D-37,1.0D4/
C-------------------------------------------------------------------
C     Factorial(N)
C-------------------------------------------------------------------
      DATA FACT /1.0E0,1.0E0,2.0E0,6.0E0,24.0E0,1.2E2,7.2E2,5.04E3,
     1 4.032E4,3.6288E5,3.6288E6,3.99168E7,4.790016E8,6.2270208E9,
     2 8.71782912E10,1.307674368E12,2.0922789888E13,3.55687428096E14,
     3 6.402373705728E15,1.21645100408832E17,2.43290200817664E18,
     4 5.109094217170944E19,1.124000727777607680E21,
     5 2.585201673888497664E22,6.204484017332394393 6E23/
CD    DATA FACT /1.0D0,1.0D0,2.0D0,6.0D0,24.0D0,1.2D2,7.2D2,5.04D3,
CD   1 4.032D4,3.6288D5,3.6288D6,3.99168D7,4.790016D8,6.2270208D9,
CD   2 8.71782912D10,1.307674368D12,2.0922789888D13,3.55687428096D14,
CD   3 6.402373705728D15,1.21645100408832D17,2.43290200817664D18,
CD   4 5.109094217170944D19,1.12400072777760768D21,
CD   5 2.585201673888497664D22,6.2044840173323943936D23/
C-------------------------------------------------------------------
C Statement functions for conversion and the gamma function.
C-------------------------------------------------------------------
      CONV(I) = REAL(I)
      FUNC(X) = GAMMA(X)
CD    CONV(I) = DBLE(I)
CD    FUNC(X) = DGAMMA(X)
C-------------------------------------------------------------------
C Check for out of range arguments.
C-------------------------------------------------------------------
      MAGX = INT(X)
      IF ((NB.GT.0) .AND. (X.GE.ZERO) .AND. (X.LE.XLARGE)
     1       .AND. (ALPHA.GE.ZERO) .AND. (ALPHA.LT.ONE))
     2   THEN
C-------------------------------------------------------------------
C Initialize result array to zero.
C-------------------------------------------------------------------
            NCALC = NB
            DO 20 I=1,NB
              B(I) = ZERO
   20       CONTINUE
C-------------------------------------------------------------------
C Branch to use 2-term ascending series for small X and asymptotic
C form for large X when NB is not too large.
C-------------------------------------------------------------------
            IF (X.LT.RTNSIG) THEN
C-------------------------------------------------------------------
C Two-term ascending series for small X.
C-------------------------------------------------------------------
               TEMPA = ONE
               ALPEM = ONE + ALPHA
               HALFX = ZERO
               IF (X.GT.ENMTEN) HALFX = HALF*X
               IF (ALPHA.NE.ZERO)
     1            TEMPA = HALFX**ALPHA/(ALPHA*FUNC(ALPHA))
               TEMPB = ZERO
               IF ((X+ONE).GT.ONE) TEMPB = -HALFX*HALFX
               B(1) = TEMPA + TEMPA*TEMPB/ALPEM
```

```
                    IF ((X.NE.ZERO) .AND. (B(1).EQ.ZERO)) NCALC = 0
                    IF (NB .NE. 1) THEN
                       IF (X .LE. ZERO) THEN
                             DO 30 N=2,NB
                               B(N) = ZERO
   30                        CONTINUE
                          ELSE
C-------------------------------------------------------------------
C Calculate higher order functions.
C-------------------------------------------------------------------
                             TEMPC = HALFX
                             TOVER = (ENMTEN+ENMTEN)/X
                             IF (TEMPB.NE.ZERO) TOVER = ENMTEN/TEMPB
                             DO 50 N=2,NB
                               TEMPA = TEMPA/ALPEM
                               ALPEM = ALPEM + ONE
                               TEMPA = TEMPA*TEMPC
                               IF (TEMPA.LE.TOVER*ALPEM) TEMPA = ZERO
                               B(N) = TEMPA + TEMPA*TEMPB/ALPEM
                               IF ((B(N).EQ.ZERO) .AND. (NCALC.GT.N))
     1                            NCALC = N-1
   50                        CONTINUE
                       END IF
                    END IF
                 ELSE IF ((X.GT.TWOFIV) .AND. (NB.LE.MAGX+1)) THEN
C-------------------------------------------------------------------
C Asymptotic series for X .GT. 21.0.
C-------------------------------------------------------------------
                    XC = SQRT(PI2/X)
                    XIN = (EIGHTH/X)**2
                    M = 11
                    IF (X.GE.THREE5) M = 8
                    IF (X.GE.ONE30) M = 4
                    XM = FOUR*CONV(M)
C-------------------------------------------------------------------
C Argument reduction for SIN and COS routines.
C-------------------------------------------------------------------
                    T = AINT(X/(TWOPI1+TWOPI2)+HALF)
                    Z = ((X-T*TWOPI1)-T*TWOPI2) - (ALPHA+HALF)/PI2
                    VSIN = SIN(Z)
                    VCOS = COS(Z)
                    GNU = ALPHA + ALPHA
                    DO 80 I=1,2
                      S = ((XM-ONE)-GNU)*((XM-ONE)+GNU)*XIN*HALF
                      T = (GNU-(XM-THREE))*(GNU+(XM-THREE))
                      CAPP = S*T/FACT(2*M+1)
                      T1 = (GNU-(XM+ONE))*(GNU+(XM+ONE))
                      CAPQ = S*T1/FACT(2*M+2)
                      XK = XM
                      K = M + M
                      T1 = T
                      DO 70 J=2,M
                        XK = XK - FOUR
                        S = ((XK-ONE)-GNU)*((XK-ONE)+GNU)
                        T = (GNU-(XK-THREE))*(GNU+(XK-THREE))
                        CAPP = (CAPP+ONE/FACT(K-1))*S*T*XIN
                        CAPQ = (CAPQ+ONE/FACT(K))*S*T1*XIN
                        K = K - 2
                        T1 = T
   70                 CONTINUE
```

```
                  CAPP = CAPP + ONE
                  CAPQ = (CAPQ+ONE)*(GNU*GNU-ONE)*(EIGHTH/X)
                  B(I) = XC*(CAPP*VCOS-CAPQ*VSIN)
                  IF (NB.EQ.1) GO TO 300
                  T = VSIN
                  VSIN = -VCOS
                  VCOS = T
                  GNU = GNU + TWO
   80          CONTINUE
C-------------------------------------------------------------------
C If  NB .GT. 2, compute J(X,ORDER+I)  I = 2, NB-1
C-------------------------------------------------------------------
               IF (NB .GT. 2) THEN
                  GNU = ALPHA + ALPHA + TWO
                  DO 90 J=3,NB
                    B(J) = GNU*B(J-1)/X - B(J-2)
                    GNU = GNU + TWO
   90             CONTINUE
               END IF
C-------------------------------------------------------------------
C Use recurrence to generate results.  First initialize the
C calculation of P*S.
C-------------------------------------------------------------------
            ELSE
               NBMX = NB - MAGX
               N = MAGX + 1
               EN = CONV(N+N) + (ALPHA+ALPHA)
               PLAST = ONE
               P = EN/X
C-------------------------------------------------------------------
C Calculate general significance test.
C-------------------------------------------------------------------
               TEST = ENSIG + ENSIG
               IF (NBMX .GE. 3) THEN
C-------------------------------------------------------------------
C Calculate P*S until N = NB-1.  Check for possible overflow.
C-------------------------------------------------------------------
                  TOVER = ENTEN/ENSIG
                  NSTART = MAGX + 2
                  NEND = NB - 1
                  EN = CONV(NSTART+NSTART) - TWO + (ALPHA+ALPHA)
                  DO 130 K=NSTART,NEND
                     N = K
                     EN = EN + TWO
                     POLD = PLAST
                     PLAST = P
                     P = EN*PLAST/X - POLD
                     IF (P.GT.TOVER) THEN
C-------------------------------------------------------------------
C To avoid overflow, divide P*S by TOVER.  Calculate P*S until
C ABS(P) .GT. 1.
C-------------------------------------------------------------------
                        TOVER = ENTEN
                        P = P/TOVER
                        PLAST = PLAST/TOVER
                        PSAVE = P
                        PSAVEL = PLAST
                        NSTART = N + 1
  100                   N = N + 1
                           EN = EN + TWO
```

```
                           POLD = PLAST
                           PLAST = P
                           P = EN*PLAST/X - POLD
                        IF (P.LE.ONE) GO TO 100
                        TEMPB = EN/X
C-------------------------------------------------------------------
C Calculate backward test and find NCALC, the highest N such that
C the test is passed.
C-------------------------------------------------------------------
                        TEST = POLD*PLAST*(HALF-HALF/(TEMPB*TEMPB))
                        TEST = TEST/ENSIG
                        P = PLAST*TOVER
                        N = N - 1
                        EN = EN - TWO
                        NEND = MIN(NB,N)
                        DO 110 L=NSTART,NEND
                           POLD = PSAVEL
                           PSAVEL = PSAVE
                           PSAVE = EN*PSAVEL/X - POLD
                           IF (PSAVE*PSAVEL.GT.TEST) THEN
                              NCALC = L - 1
                              GO TO 190
                           END IF
  110                   CONTINUE
                        NCALC = NEND
                        GO TO 190
                     END IF
  130             CONTINUE
                  N = NEND
                  EN = CONV(N+N) + (ALPHA+ALPHA)
C-------------------------------------------------------------------
C Calculate special significance test for NBMX .GT. 2.
C-------------------------------------------------------------------
                  TEST = MAX(TEST,SQRT(PLAST*ENSIG)*SQRT(P+P))
               END IF
C-------------------------------------------------------------------
C Calculate P*S until significance test passes.
C-------------------------------------------------------------------
  140          N = N + 1
                  EN = EN + TWO
                  POLD = PLAST
                  PLAST = P
                  P = EN*PLAST/X - POLD
               IF (P.LT.TEST) GO TO 140
C-------------------------------------------------------------------
C Initialize the backward recursion and the normalization sum.
C-------------------------------------------------------------------
  190          N = N + 1
               EN = EN + TWO
               TEMPB = ZERO
               TEMPA = ONE/P
               M = 2*N - 4*(N/2)
               SUM = ZERO
               EM = CONV(N/2)
               ALPEM = (EM-ONE) + ALPHA
               ALP2EM = (EM+EM) + ALPHA
               IF (M .NE. 0) SUM = TEMPA*ALPEM*ALP2EM/EM
               NEND = N - NB
               IF (NEND .GT. 0) THEN
C-------------------------------------------------------------------
```

```
C Recur backward via difference equation, calculating (but not
C storing) B(N), until N = NB.
C-------------------------------------------------------------------
                  DO 200 L=1,NEND
                     N = N - 1
                     EN = EN - TWO
                     TEMPC = TEMPB
                     TEMPB = TEMPA
                     TEMPA = (EN*TEMPB)/X - TEMPC
                     M = 2 - M
                     IF (M .NE. 0) THEN
                        EM = EM - ONE
                        ALP2EM = (EM+EM) + ALPHA
                        IF (N.EQ.1) GO TO 210
                        ALPEM = (EM-ONE) + ALPHA
                        IF (ALPEM.EQ.ZERO) ALPEM = ONE
                        SUM = (SUM+TEMPA*ALP2EM)*ALPEM/EM
                     END IF
  200             CONTINUE
               END IF
C-------------------------------------------------------------------
C Store B(NB).
C-------------------------------------------------------------------
  210          B(N) = TEMPA
               IF (NEND .GE. 0) THEN
                  IF (NB .LE. 1) THEN
                        ALP2EM = ALPHA
                        IF ((ALPHA+ONE).EQ.ONE) ALP2EM = ONE
                        SUM = SUM + B(1)*ALP2EM
                        GO TO 250
                     ELSE
C-------------------------------------------------------------------
C Calculate and store B(NB-1).
C-------------------------------------------------------------------
                        N = N - 1
                        EN = EN - TWO
                        B(N) = (EN*TEMPA)/X - TEMPB
                        IF (N.EQ.1) GO TO 240
                        M = 2 - M
                        IF (M .NE. 0) THEN
                           EM = EM - ONE
                           ALP2EM = (EM+EM) + ALPHA
                           ALPEM = (EM-ONE) + ALPHA
                           IF (ALPEM.EQ.ZERO) ALPEM = ONE
                           SUM = (SUM+B(N)*ALP2EM)*ALPEM/EM
                        END IF
                  END IF
               END IF
               NEND = N - 2
               IF (NEND .NE. 0) THEN
C-------------------------------------------------------------------
C Calculate via difference equation and store B(N), until N = 2.
C-------------------------------------------------------------------
                  DO 230 L=1,NEND
                     N = N - 1
                     EN = EN - TWO
                     B(N) = (EN*B(N+1))/X - B(N+2)
                     M = 2 - M
                     IF (M .NE. 0) THEN
                        EM = EM - ONE
```

```
                            ALP2EM = (EM+EM) + ALPHA
                            ALPEM = (EM-ONE) + ALPHA
                            IF (ALPEM.EQ.ZERO) ALPEM = ONE
                            SUM = (SUM+B(N)*ALP2EM)*ALPEM/EM
                         END IF
  230                 CONTINUE
                   END IF
C---------------------------------------------------------------------
C Calculate B(1).
C---------------------------------------------------------------------
                   B(1) = TWO*(ALPHA+ONE)*B(2)/X - B(3)
  240              EM = EM - ONE
                   ALP2EM = (EM+EM) + ALPHA
                   IF (ALP2EM.EQ.ZERO) ALP2EM = ONE
                   SUM = SUM + B(1)*ALP2EM
C---------------------------------------------------------------------
C Normalize.  Divide all B(N) by sum.
C---------------------------------------------------------------------
  250              IF ((ALPHA+ONE).NE.ONE)
     1                  SUM = SUM*FUNC(ALPHA)*(X*HALF)**(-ALPHA)
                   TEMPA = ENMTEN
                   IF (SUM.GT.ONE) TEMPA = TEMPA*SUM
                   DO 260 N=1,NB
                     IF (ABS(B(N)).LT.TEMPA) B(N) = ZERO
                     B(N) = B(N)/SUM
  260              CONTINUE
                END IF
C---------------------------------------------------------------------
C Error return -- X, NB, or ALPHA is out of range.
C---------------------------------------------------------------------
             ELSE
                B(1) = ZERO
                NCALC = MIN(NB,0) - 1
          END IF
C---------------------------------------------------------------------
C Exit
C---------------------------------------------------------------------
  300 RETURN
C ---------- Last line of RJBESL ----------
      END
```

```





      SUBROUTINE RYBESL(X,ALPHA,NB,BY,NCALC)
C----------------------------------------------------------------------
C
C  This routine calculates Bessel functions Y SUB(N+ALPHA) (X)
C  for non-negative argument X, and non-negative order N+ALPHA.
C
C
C Explanation of variables in the calling sequence
C
C X     - Working precision non-negative real argument for which
C         Y's are to be calculated.
C ALPHA - Working precision fractional part of order for which
C         Y's are to be calculated.  0 .LE. ALPHA .LT. 1.0.
C NB    - Integer number of functions to be calculated, NB .GT. 0.
```

```
C         The first function calculated is of order ALPHA, and the
C         last is of order (NB - 1 + ALPHA).
C BY    - Working precision output vector of length NB.  If the
C         routine terminates normally (NCALC=NB), the vector BY
C         contains the functions Y(ALPHA,X), ... , Y(NB-1+ALPHA,X),
C         If (0 .LT. NCALC .LT. NB), BY(I) contains correct function
C         values for I .LE. NCALC, and contains the ratios
C         Y(ALPHA+I-1,X)/Y(ALPHA+I-2,X) for the rest of the array.
C NCALC - Integer output variable indicating possible errors.
C         Before using the vector BY, the user should check that
C         NCALC=NB, i.e., all orders have been calculated to
C         the desired accuracy.  See error returns below.
C
C
C*******************************************************************
C*******************************************************************
C
C Explanation of machine-dependent constants
C
C   beta   = Radix for the floating-point system
C   p      = Number of significant base-beta digits in the
C            significand of a floating-point number
C   minexp = Smallest representable power of beta
C   maxexp = Smallest power of beta that overflows
C   EPS    = beta ** (-p)
C   DEL    = Machine number below which sin(x)/x = 1; approximately
C            SQRT(EPS).
C   XMIN   = Smallest acceptable argument for RBESY; approximately
C            max(2*beta**minexp,2/XINF), rounded up
C   XINF   = Largest positive machine number; approximately
C            beta**maxexp
C   THRESH = Lower bound for use of the asymptotic form; approximately
C            AINT(-LOG10(EPS/2.0))+1.0
C   XLARGE = Upper bound on X; approximately 1/DEL, because the sine
C            and cosine functions have lost about half of their
C            precision at that point.
C
C
C     Approximate values for some important machines are:
C
C                       beta    p     minexp      maxexp      EPS
C
C  CRAY-1        (S.P.)    2    48     -8193        8191    3.55E-15
C  Cyber 180/185
C    under NOS   (S.P.)    2    48      -975        1070    3.55E-15
C  IEEE (IBM/XT,
C    SUN, etc.)  (S.P.)    2    24      -126         128    5.96E-8
C  IEEE (IBM/XT,
C    SUN, etc.)  (D.P.)    2    53     -1022        1024    1.11D-16
C  IBM 3033      (D.P.)   16    14       -65          63    1.39D-17
C  VAX           (S.P.)    2    24      -128         127    5.96E-8
C  VAX D-Format  (D.P.)    2    56      -128         127    1.39D-17
C  VAX G-Format  (D.P.)    2    53     -1024        1023    1.11D-16
C
C
C                        DEL      XMIN      XINF     THRESH  XLARGE
C
C CRAY-1        (S.P.)  5.0E-8  3.67E-2466 5.45E+2465  15.0E0  2.0E7
C Cyber 180/855
C   under NOS   (S.P.)  5.0E-8  6.28E-294  1.26E+322   15.0E0  2.0E7
```

```
C IEEE (IBM/XT,
C   SUN, etc.)  (S.P.)  1.0E-4  2.36E-38   3.40E+38     8.0E0  1.0E4
C IEEE (IBM/XT,
C   SUN, etc.)  (D.P.)  1.0D-8  4.46D-308  1.79D+308   16.0D0  1.0D8
C IBM 3033      (D.P.)  1.0D-8  2.77D-76   7.23D+75    17.0D0  1.0D8
C VAX           (S.P.)  1.0E-4  1.18E-38   1.70E+38     8.0E0  1.0E4
C VAX D-Format  (D.P.)  1.0D-9  1.18D-38   1.70D+38    17.0D0  1.0D9
C VAX G-Format  (D.P.)  1.0D-8  2.23D-308  8.98D+307   16.0D0  1.0D8
C
C*******************************************************************
C*******************************************************************
C
C Error returns
C
C  In case of an error, NCALC .NE. NB, and not all Y's are
C  calculated to the desired accuracy.
C
C  NCALC .LT. -1:  An argument is out of range. For example,
C       NB .LE. 0, IZE is not 1 or 2, or IZE=1 and ABS(X) .GE.
C       XMAX.  In this case, BY(1) = 0.0, the remainder of the
C       BY-vector is not calculated, and NCALC is set to
C       MIN0(NB,0)-2  so that NCALC .NE. NB.
C  NCALC = -1:  Y(ALPHA,X) .GE. XINF.  The requested function
C       values are set to 0.0.
C  1 .LT. NCALC .LT. NB: Not all requested function values could
C       be calculated accurately.  BY(I) contains correct function
C       values for I .LE. NCALC, and and the remaining NB-NCALC
C       array elements contain 0.0.
C
C
C Intrinsic functions required are:
C
C     DBLE, EXP, INT, MAX, MIN, REAL, SQRT
C
C
C Acknowledgement
C
C  This program draws heavily on Temme's Algol program for Y(a,x)
C  and Y(a+1,x) and on Campbell's programs for Y_nu(x).  Temme's
C  scheme is used for  x < THRESH, and Campbell's scheme is used
C  in the asymptotic region.  Segments of code from both sources
C  have been translated into Fortran 77, merged, and heavily modified.
C  Modifications include parameterization of machine dependencies,
C  use of a new approximation for ln(gamma(x)), and built-in
C  protection against over/underflow.
C
C References: "Bessel functions J_nu(x) and Y_nu(x) of real
C              order and real argument," Campbell, J. B.,
C              Comp. Phy. Comm. 18, 1979, pp. 133-142.
C
C             "On the numerical evaluation of the ordinary
C              Bessel function of the second kind," Temme,
C              N. M., J. Comput. Phys. 21, 1976, pp. 343-350.
C
C  Latest modification: March 19, 1990
C
C  Modified by: W. J. Cody
C                Applied Mathematics Division
C                Argonne National Laboratory
C                Argonne, IL  60439
```

```
C
C---------------------------------------------------------------------
      INTEGER I,K,NA,NB,NCALC
      REAL
CD    DOUBLE PRECISION
     1 ALFA,ALPHA,AYE,B,BY,C,CH,COSMU,D,DEL,DEN,DDIV,DIV,DMU,D1,D2,
     2 E,EIGHT,EN,ENU,EN1,EPS,EVEN,EX,F,FIVPI,G,GAMMA,H,HALF,ODD,
     3 ONBPI,ONE,ONE5,P,PA,PA1,PI,PIBY2,PIM5,Q,QA,QA1,Q0,R,S,SINMU,
     4 SQ2BPI,TEN9,TERM,THREE,THRESH,TWO,TWOBYX,X,XINF,XLARGE,XMIN,
     5 XNA,X2,YA,YA1,ZERO
      DIMENSION BY(NB),CH(21)
C---------------------------------------------------------------------
C  Mathematical constants
C    FIVPI = 5*PI
C    PIM5 = 5*PI - 15
C    ONBPI = 1/PI
C    PIBY2 = PI/2
C    SQ2BPI = SQUARE ROOT OF 2/PI
C---------------------------------------------------------------------
      DATA ZERO,HALF,ONE,TWO,THREE/0.0E0,0.5E0,1.0E0,2.0E0,3.0E0/
      DATA EIGHT,ONE5,TEN9/8.0E0,15.0E0,1.9E1/
      DATA FIVPI,PIBY2/1.5707963267948966192E1,1.5707963267948966192E0/
      DATA PI,SQ2BPI/3.1415926535897932385E0,7.9788456080286535588E-1/
      DATA PIM5,ONBPI/7.0796326794896619231E-1,3.1830988618379067154E-1/
CD    DATA ZERO,HALF,ONE,TWO,THREE/0.0D0,0.5D0,1.0D0,2.0D0,3.0D0/
CD    DATA EIGHT,ONE5,TEN9/8.0D0,15.0D0,1.9D1/
CD    DATA FIVPI,PIBY2/1.5707963267948966192D1,1.5707963267948966192D0/
CD    DATA PI,SQ2BPI/3.1415926535897932385D0,7.9788456080286535588D-1/
CD    DATA PIM5,ONBPI/7.0796326794896619231D-1,3.1830988618379067154D-1/
C---------------------------------------------------------------------
C  Machine-dependent constants
C---------------------------------------------------------------------
      DATA DEL,XMIN,XINF,EPS/1.0E-4,2.36E-38,1.70E38,5.96E-8/
      DATA THRESH,XLARGE/8.0E0,1.0E4/
CD    DATA DEL,XMIN,XINF,EPS/1.0D-8,4.46D-308,1.79D308,1.11D-16/
CD    DATA THRESH,XLARGE/16.0D0,1.0D8/
C---------------------------------------------------------------------
C  Coefficients for Chebyshev polynomial expansion of
C         1/gamma(1-x), abs(x) .le. .5
C---------------------------------------------------------------------
      DATA CH/-0.67735241822398840964E-23,-0.61455180116049879894E-22,
     1         0.29017595056104745456E-20, 0.13639417919073099464E-18,
     2         0.23826220476859635824E-17,-0.90642907957550702534E-17,
     3        -0.14943667065169001769E-14,-0.33919078305362211264E-13,
     4        -0.17023776642512729175E-12, 0.91609750938768647911E-11,
     5         0.24230957900482704055E-09, 0.17451364971382984243E-08,
     6        -0.33126119768180852711E-07,-0.86592079961391259661E-06,
     7        -0.49717367041957398581E-05, 0.76309597585908126618E-04,
     8         0.12719271366545622927E-02, 0.17063050710955562222E-02,
     9        -0.76852840844786673690E-01,-0.28387654227602353814E+00,
     A         0.92187029365045265648E+00/
CD    DATA CH/-0.67735241822398840964D-23,-0.61455180116049879894D-22,
CD   1         0.29017595056104745456D-20, 0.13639417919073099464D-18,
CD   2         0.23826220476859635824D-17,-0.90642907957550702534D-17,
CD   3        -0.14943667065169001769D-14,-0.33919078305362211264D-13,
CD   4        -0.17023776642512729175D-12, 0.91609750938768647911D-11,
CD   5         0.24230957900482704055D-09, 0.17451364971382984243D-08,
CD   6        -0.33126119768180852711D-07,-0.86592079961391259661D-06,
CD   7        -0.49717367041957398581D-05, 0.76309597585908126618D-04,
CD   8         0.12719271366545622927D-02, 0.17063050710955562222D-02,
```

```
CD   9        -0.76852840844786673690D-01,-0.28387654227602353814D+00,
CD   A         0.92187029365045265648D+00/
C----------------------------------------------------------------------
      EX = X
      ENU = ALPHA
      IF ((NB .GT. 0) .AND. (X .GE. XMIN) .AND. (EX .LT. XLARGE)
     1       .AND. (ENU .GE. ZERO) .AND. (ENU .LT. ONE))  THEN
            XNA = AINT(ENU+HALF)
            NA = INT(XNA)
            IF (NA .EQ. 1) ENU = ENU - XNA
            IF (ENU .EQ. -HALF) THEN
                  P = SQ2BPI/SQRT(EX)
                  YA = P * SIN(EX)
                  YA1 = -P * COS(EX)
               ELSE IF (EX .LT. THREE) THEN
C----------------------------------------------------------------------
C  Use Temme's scheme for small X
C----------------------------------------------------------------------
                  B = EX * HALF
                  D = -LOG(B)
                  F = ENU * D
                  E = B**(-ENU)
                  IF (ABS(ENU) .LT. DEL) THEN
                        C = ONBPI
                     ELSE
                        C = ENU / SIN(ENU*PI)
                  END IF
C----------------------------------------------------------------------
C  Computation of sinh(f)/f
C----------------------------------------------------------------------
                  IF (ABS(F) .LT. ONE) THEN
                        X2 = F*F
                        EN = TEN9
                        S = ONE
                        DO 80 I = 1, 9
                           S = S*X2/EN/(EN-ONE)+ONE
                           EN = EN - TWO
   80                   CONTINUE
                     ELSE
                        S = (E - ONE/E) * HALF / F
                  END IF
C----------------------------------------------------------------------
C  Computation of 1/gamma(1-a) using Chebyshev polynomials
C----------------------------------------------------------------------
                  X2 = ENU*ENU*EIGHT
                  AYE = CH(1)
                  EVEN = ZERO
                  ALFA = CH(2)
                  ODD = ZERO
                  DO 40 I = 3, 19, 2
                     EVEN = -(AYE+AYE+EVEN)
                     AYE = -EVEN*X2 - AYE + CH(I)
                     ODD = -(ALFA+ALFA+ODD)
                     ALFA = -ODD*X2 - ALFA + CH(I+1)
   40             CONTINUE
                  EVEN = (EVEN*HALF+AYE)*X2 - AYE + CH(21)
                  ODD = (ODD+ALFA)*TWO
                  GAMMA = ODD*ENU + EVEN
C----------------------------------------------------------------------
C  End of computation of 1/gamma(1-a)
```

```
C--------------------------------------------------------------------
                  G = E * GAMMA
                  E = (E + ONE/E) * HALF
                  F = TWO*C*(ODD*E+EVEN*S*D)
                  E = ENU*ENU
                  P = G*C
                  Q = ONBPI / G
                  C = ENU*PIBY2
                  IF (ABS(C) .LT. DEL) THEN
                        R = ONE
                     ELSE
                        R = SIN(C)/C
                  END IF
                  R = PI*C*R*R
                  C = ONE
                  D = - B*B
                  H = ZERO
                  YA = F + R*Q
                  YA1 = P
                  EN = ZERO
  100             EN = EN + ONE
                  IF (ABS(G/(ONE+ABS(YA)))
     1                      + ABS(H/(ONE+ABS(YA1))) .GT. EPS) THEN
                        F = (F*EN+P+Q)/(EN*EN-E)
                        C = C * D/EN
                        P = P/(EN-ENU)
                        Q = Q/(EN+ENU)
                        G = C*(F+R*Q)
                        H = C*P - EN*G
                        YA = YA + G
                        YA1 = YA1+H
                        GO TO 100
                  END IF
                  YA = -YA
                  YA1 = -YA1/B
               ELSE IF (EX .LT. THRESH) THEN
C--------------------------------------------------------------------
C  Use Temme's scheme for moderate X
C--------------------------------------------------------------------
                  C = (HALF-ENU)*(HALF+ENU)
                  B = EX + EX
                  E = (EX*ONBPI*COS(ENU*PI)/EPS)
                  E = E*E
                  P = ONE
                  Q = -EX
                  R = ONE + EX*EX
                  S = R
                  EN = TWO
  200             IF (R*EN*EN .LT. E) THEN
                        EN1 = EN+ONE
                        D = (EN-ONE+C/EN)/S
                        P = (EN+EN-P*D)/EN1
                        Q = (-B+Q*D)/EN1
                        S = P*P + Q*Q
                        R = R*S
                        EN = EN1
                        GO TO 200
                  END IF
                  F = P/S
                  P = F
```

```
                  G = -Q/S
                  Q = G
  220             EN = EN - ONE
                  IF (EN .GT. ZERO) THEN
                        R = EN1*(TWO-P)-TWO
                        S = B + EN1*Q
                        D = (EN-ONE+C/EN)/(R*R+S*S)
                        P = D*R
                        Q = D*S
                        E = F + ONE
                        F = P*E - G*Q
                        G = Q*E + P*G
                        EN1 = EN
                        GO TO 220
                  END IF
                  F = ONE + F
                  D = F*F + G*G
                  PA = F/D
                  QA = -G/D
                  D = ENU + HALF -P
                  Q = Q + EX
                  PA1 = (PA*Q-QA*D)/EX
                  QA1 = (QA*Q+PA*D)/EX
                  B = EX - PIBY2*(ENU+HALF)
                  C = COS(B)
                  S = SIN(B)
                  D = SQ2BPI/SQRT(EX)
                  YA = D*(PA*S+QA*C)
                  YA1 = D*(QA1*S-PA1*C)
               ELSE
C---------------------------------------------------------------------
C  Use Campbell's asymptotic scheme.
C---------------------------------------------------------------------
                  NA = 0
                  D1 = AINT(EX/FIVPI)
                  I = INT(D1)
                  DMU = ((EX-ONE5*D1)-D1*PIM5)-(ALPHA+HALF)*PIBY2
                  IF (I-2*(I/2) .EQ. 0) THEN
                        COSMU = COS(DMU)
                        SINMU = SIN(DMU)
                     ELSE
                        COSMU = -COS(DMU)
                        SINMU = -SIN(DMU)
                  END IF
                  DDIV = EIGHT * EX
                  DMU = ALPHA
                  DEN = SQRT(EX)
                  DO 350 K = 1, 2
                     P = COSMU
                     COSMU = SINMU
                     SINMU = -P
                     D1 = (TWO*DMU-ONE)*(TWO*DMU+ONE)
                     D2 = ZERO
                     DIV = DDIV
                     P = ZERO
                     Q = ZERO
                     Q0 = D1/DIV
                     TERM = Q0
                     DO 310 I = 2, 20
                        D2 = D2 + EIGHT
```

```
                        D1 = D1 - D2
                        DIV = DIV + DDIV
                        TERM = -TERM*D1/DIV
                        P = P + TERM
                        D2 = D2 + EIGHT
                        D1 = D1 - D2
                        DIV = DIV + DDIV
                        TERM = TERM*D1/DIV
                        Q = Q + TERM
                        IF (ABS(TERM) .LE. EPS) GO TO 320
  310                CONTINUE
  320                P = P + ONE
                     Q = Q + Q0
                     IF (K .EQ. 1) THEN
                           YA = SQ2BPI * (P*COSMU-Q*SINMU) / DEN
                        ELSE
                           YA1 = SQ2BPI * (P*COSMU-Q*SINMU) / DEN
                     END IF
                     DMU = DMU + ONE
  350             CONTINUE
            END IF
            IF (NA .EQ. 1) THEN
               H = TWO*(ENU+ONE)/EX
               IF (H .GT. ONE) THEN
                  IF (ABS(YA1) .GT. XINF/H) THEN
                     H = ZERO
                     YA = ZERO
                  END IF
               END IF
               H = H*YA1 - YA
               YA = YA1
               YA1 = H
            END IF
C---------------------------------------------------------------------
C  Now have first one or two Y's
C---------------------------------------------------------------------
            BY(1) = YA
            BY(2) = YA1
            IF (YA1 .EQ. ZERO) THEN
                  NCALC = 1
               ELSE
                  AYE = ONE + ALPHA
                  TWOBYX = TWO/EX
                  NCALC = 2
                  DO 400 I = 3, NB
                     IF (TWOBYX .LT. ONE) THEN
                           IF (ABS(BY(I-1))*TWOBYX .GE. XINF/AYE)
     1                                                     GO TO 450
                        ELSE
                           IF (ABS(BY(I-1)) .GE. XINF/AYE/TWOBYX )
     1                                                     GO TO 450
                     END IF
                     BY(I) = TWOBYX*AYE*BY(I-1) - BY(I-2)
                     AYE = AYE + ONE
                     NCALC = NCALC + 1
  400             CONTINUE
            END IF
  450       DO 460 I = NCALC+1, NB
               BY(I) = ZERO
  460       CONTINUE
```

```
         ELSE
            BY(1) = ZERO
            NCALC = MIN(NB,0) - 1
      END IF
  900 RETURN
C---------- Last line of RYBESL ----------
      END
```

```
      REAL FUNCTION GAMMA(X)
CD    DOUBLE PRECISION FUNCTION DGAMMA(X)
C----------------------------------------------------------------------
C
C This routine calculates the GAMMA function for a real argument X.
C   Computation is based on an algorithm outlined in reference 1.
C   The program uses rational functions that approximate the GAMMA
C   function to at least 20 significant decimal digits.  Coefficients
C   for the approximation over the interval (1,2) are unpublished.
C   Those for the approximation for X .GE. 12 are from reference 2.
C   The accuracy achieved depends on the arithmetic system, the
C   compiler, the intrinsic functions, and proper selection of the
C   machine-dependent constants.
C
C
C*******************************************************************
C*******************************************************************
C
C Explanation of machine-dependent constants
C
C beta   - radix for the floating-point representation
C maxexp - the smallest positive power of beta that overflows
C XBIG   - the largest argument for which GAMMA(X) is representable
C          in the machine, i.e., the solution to the equation
C                  GAMMA(XBIG) = beta**maxexp
C XINF   - the largest machine representable floating-point number;
C          approximately beta**maxexp
C EPS    - the smallest positive floating-point number such that
C          1.0+EPS .GT. 1.0
C XMININ - the smallest positive floating-point number such that
C          1/XMININ is machine representable
C
C     Approximate values for some important machines are:
C
C                            beta       maxexp        XBIG
C
C CRAY-1         (S.P.)        2         8191        966.961
C Cyber 180/855
C   under NOS    (S.P.)        2         1070        177.803
C IEEE (IBM/XT,
C   SUN, etc.)   (S.P.)        2          128        35.040
C IEEE (IBM/XT,
C   SUN, etc.)   (D.P.)        2         1024        171.624
C IBM 3033       (D.P.)       16           63        57.574
C VAX D-Format   (D.P.)        2          127        34.844
C VAX G-Format   (D.P.)        2         1023        171.489
C
C                            XINF         EPS        XMININ
C
C CRAY-1         (S.P.)   5.45E+2465   7.11E-15    1.84E-2466
C Cyber 180/855
C   under NOS    (S.P.)   1.26E+322    3.55E-15    3.14E-294
```

```
C IEEE (IBM/XT,
C   SUN, etc.)   (S.P.)   3.40E+38     1.19E-7     1.18E-38
C IEEE (IBM/XT,
C   SUN, etc.)   (D.P.)   1.79D+308    2.22D-16    2.23D-308
C IBM 3033       (D.P.)   7.23D+75     2.22D-16    1.39D-76
C VAX D-Format   (D.P.)   1.70D+38     1.39D-17    5.88D-39
C VAX G-Format   (D.P.)   8.98D+307    1.11D-16    1.12D-308
C
C*******************************************************************
C*******************************************************************
C
C Error returns
C
C  The program returns the value XINF for singularities or
C     when overflow would occur.  The computation is believed
C     to be free of underflow and overflow.
C
C
C  Intrinsic functions required are:
C
C     INT, DBLE, EXP, LOG, REAL, SIN
C
C
C References: ”An Overview of Software Development for Special
C              Functions,” W. J. Cody, Lecture Notes in Mathematics,
C              506, Numerical Analysis Dundee, 1975, G. A. Watson
C              (ed.), Springer Verlag, Berlin, 1976.
C
C              Computer Approximations, Hart, Et. Al., Wiley and
C              sons, New York, 1968.
C
C  Latest modification: October 12, 1989
C
C  Authors: W. J. Cody and L. Stoltz
C           Applied Mathematics Division
C           Argonne National Laboratory
C           Argonne, IL 60439
C
C----------------------------------------------------------------------
      INTEGER I,N
      LOGICAL PARITY
      REAL
CD    DOUBLE PRECISION
     1    C,CONV,EPS,FACT,HALF,ONE,P,PI,Q,RES,SQRTPI,SUM,TWELVE,
     2    TWO,X,XBIG,XDEN,XINF,XMININ,XNUM,Y,Y1,YSQ,Z,ZERO
      DIMENSION C(7),P(8),Q(8)
C----------------------------------------------------------------------
C  Mathematical constants
C----------------------------------------------------------------------
      DATA ONE,HALF,TWELVE,TWO,ZERO/1.0E0,0.5E0,12.0E0,2.0E0,0.0E0/,
     1     SQRTPI/0.9189385332046727417803297E0/,
     2     PI/3.1415926535897932384626434E0/
CD    DATA ONE,HALF,TWELVE,TWO,ZERO/1.0D0,0.5D0,12.0D0,2.0D0,0.0D0/,
CD   1     SQRTPI/0.9189385332046727417803297D0/,
CD   2     PI/3.1415926535897932384626434D0/
C----------------------------------------------------------------------
C  Machine dependent parameters
C----------------------------------------------------------------------
      DATA XBIG,XMININ,EPS/35.040E0,1.18E-38,1.19E-7/,
     1     XINF/1.7E38/
```

```
CD    DATA XBIG,XMININ,EPS/171.624D0,2.23D-308,2.22D-16/,
CD   1     XINF/1.79D308/
C---------------------------------------------------------------------
C  Numerator and denominator coefficients for rational minimax
C     approximation over (1,2).
C---------------------------------------------------------------------
      DATA P/-1.71618513886549492533811E+0,2.47656508055759199108314E+1,
     1       -3.79804256470945635097577E+2,6.29331155312818442661052E+2,
     2       8.66966202790413211295064E+2,-3.14512729688483675254357E+4,
     3       -3.61444134186911729807069E+4,6.64561438202405440627855E+4/
      DATA Q/-3.08402300119738975254353E+1,3.15350626979604161529144E+2,
     1      -1.01515636749021914166146E+3,-3.10777167157231109440444E+3,
     2        2.25381184209801510330112E+4,4.75584627752788110767815E+3,
     3      -1.34659959864969306392456E+5,-1.15132259675553483497211E+5/
CD    DATA P/-1.71618513886549492533811D+0,2.47656508055759199108314D+1,
CD   1       -3.79804256470945635097577D+2,6.29331155312818442661052D+2,
CD   2       8.66966202790413211295064D+2,-3.14512729688483675254357D+4,
CD   3       -3.61444134186911729807069D+4,6.64561438202405440627855D+4/
CD    DATA Q/-3.08402300119738975254353D+1,3.15350626979604161529144D+2,
CD   1      -1.01515636749021914166146D+3,-3.10777167157231109440444D+3,
CD   2        2.25381184209801510330112D+4,4.75584627752788110767815D+3,
CD   3      -1.34659959864969306392456D+5,-1.15132259675553483497211D+5/
C---------------------------------------------------------------------
C  Coefficients for minimax approximation over (12, INF).
C---------------------------------------------------------------------
      DATA C/-1.910444077728E-03,8.4171387781295E-04,
     1     -5.952379913043012E-04,7.93650793500350248E-04,
     2     -2.777777777777681622553E-03,8.333333333333333331554247E-02,
     3      5.7083835261E-03/
CD    DATA C/-1.910444077728D-03,8.4171387781295D-04,
CD   1     -5.952379913043012D-04,7.93650793500350248D-04,
CD   2     -2.777777777777681622553D-03,8.333333333333333331554247D-02,
CD   3      5.7083835261D-03/
C---------------------------------------------------------------------
C  Statement functions for conversion between integer and float
C---------------------------------------------------------------------
      CONV(I) = REAL(I)
CD    CONV(I) = DBLE(I)
      PARITY = .FALSE.
      FACT = ONE
      N = 0
      Y = X
      IF (Y .LE. ZERO) THEN
C---------------------------------------------------------------------
C  Argument is negative
C---------------------------------------------------------------------
            Y = -X
            Y1 = AINT(Y)
            RES = Y - Y1
            IF (RES .NE. ZERO) THEN
                  IF (Y1 .NE. AINT(Y1*HALF)*TWO) PARITY = .TRUE.
                  FACT = -PI / SIN(PI*RES)
                  Y = Y + ONE
               ELSE
                  RES = XINF
                  GO TO 900
            END IF
      END IF
C---------------------------------------------------------------------
C  Argument is positive
```

```
C---------------------------------------------------------------------
      IF (Y .LT. EPS) THEN
C---------------------------------------------------------------------
C  Argument .LT. EPS
C---------------------------------------------------------------------
            IF (Y .GE. XMININ) THEN
                  RES = ONE / Y
               ELSE
                  RES = XINF
                  GO TO 900
            END IF
         ELSE IF (Y .LT. TWELVE) THEN
            Y1 = Y
            IF (Y .LT. ONE) THEN
C---------------------------------------------------------------------
C  0.0 .LT. argument .LT. 1.0
C---------------------------------------------------------------------
                  Z = Y
                  Y = Y + ONE
               ELSE
C---------------------------------------------------------------------
C  1.0 .LT. argument .LT. 12.0, reduce argument if necessary
C---------------------------------------------------------------------
                  N = INT(Y) - 1
                  Y = Y - CONV(N)
                  Z = Y - ONE
            END IF
C---------------------------------------------------------------------
C  Evaluate approximation for 1.0 .LT. argument .LT. 2.0
C---------------------------------------------------------------------
            XNUM = ZERO
            XDEN = ONE
            DO 260 I = 1, 8
               XNUM = (XNUM + P(I)) * Z
               XDEN = XDEN * Z + Q(I)
  260       CONTINUE
            RES = XNUM / XDEN + ONE
            IF (Y1 .LT. Y) THEN
C---------------------------------------------------------------------
C  Adjust result for case  0.0 .LT. argument .LT. 1.0
C---------------------------------------------------------------------
                  RES = RES / Y1
               ELSE IF (Y1 .GT. Y) THEN
C---------------------------------------------------------------------
C  Adjust result for case  2.0 .LT. argument .LT. 12.0
C---------------------------------------------------------------------
                  DO 290 I = 1, N
                     RES = RES * Y
                     Y = Y + ONE
  290             CONTINUE
            END IF
         ELSE
C---------------------------------------------------------------------
C  Evaluate for argument .GE. 12.0,
C---------------------------------------------------------------------
            IF (Y .LE. XBIG) THEN
                  YSQ = Y * Y
                  SUM = C(7)
                  DO 350 I = 1, 6
                     SUM = SUM / YSQ + C(I)
```

```
  350             CONTINUE
                  SUM = SUM/Y - Y + SQRTPI
                  SUM = SUM + (Y-HALF)*LOG(Y)
                  RES = EXP(SUM)
               ELSE
                  RES = XINF
                  GO TO 900
            END IF
      END IF
C----------------------------------------------------------------------
C  Final adjustments and return
C----------------------------------------------------------------------
      IF (PARITY) RES = -RES
      IF (FACT .NE. ONE) RES = FACT / RES
  900 GAMMA = RES
CD900 DGAMMA = RES
      RETURN
C ---------- Last line of GAMMA ----------
      END


C  **** INLET FAN RADIATION SUBROUTINE, E. J. RICE, REVISED 02/21/1998
C  ** CONTAINS PLANE WAVE RADIATION AND IMPROVED TERMINATION LOSS
C  ** THE FOLLOWING "BBRDCFIN" IS THE MAIN SUBROUTINE.  ALL ARGUMENTS
C     ARE INPUTS EXCEPT "NANGLE," "ANGLE," "SPL," "SPLTL" AND WATTS
C     RETURNED TO THE MAIN PROGRAM FOR PRINTING, FILE STORAGE ETC.
C
C  ** THIS VERSION REMOVES THE P**2 OSCILLATIONS BEYOND THE PEAK.  FOUR
C     REGIONS (ETA AND CUT-OFF RATIO) DETERMINE PROPER APPROXIMATION FOR
C     HIGH ANGLE RADIATION. DEVELOPED 01/30/98.

      SUBROUTINE BBRDCFIN(TTOT,PTOT,DISTANCE,
     1ISIDELN,DIAM,ALIP,BLIP,FMACHI,FMACHS,NCOF,WATTSCOF,ETAI,
     2DELANG,NANGLE,ANGLE,SPL,SPLTL,WATTS,WATTRAN)
C
      DIMENSION ANGLE(200),SPL(200),SPLTL(200),WATTSCOF(200),
     1COFRAT(200),PSQTOT(200),PSQTLOS(200),PSQRADT(200)

      COMMON FMSQ,FM1,BETA,COFBETIN,CFBTINSQ,GDEN,HDEN,
     1PSQPK,PSIC,AC,BC,CC,IREG

C
C  ** SUBROUTINES REQUIRED "LIPEF3" AND "PSQGCOF"
C
C  ***************** DEFINITION OF SUBROUTINE ARGUMENTS **************
C
C TTOT    ABSOLUTE TEMPERATURE, (DEGREES RANKINE)
C PTOT    ABSOLUTE PRESSURE, (PSIA)
C DISTANCE  RADIUS OR SIDELINE DISTANCE OF MICROPHONE ARRAY, (FT.)
C ISIDELN = 0 FOR CONSTANT RADIUS, = 1 FOR CONSTANT SIDELINE CALCULATION
C DIAM    INLET DUCT DIAMETER, (INCHES)
C ALIP    MAJOR OR AXIAL RUNNING DIMENSION OF ELLIPTIC INLET LIP (INCHES)
C BLIP    MINOR OR TRANSVERSE DIMENSION OF ELLIPTIC INLET LIP (INCHES)
C FMACH   INLET MACH NUMBER, NEGATIVE FOR INLET
C FMACHS  SURROUNDING MACH NUMBER, ALSO NEGATIVE FOR INLET
C NCOF    NUMBER OF CUT-OFF RATIO BINS TO SORT ACOUSTIC POWER
C WATTSCOF VECTOR WITH ACOUSTIC POWER FOR EACH BIN, (WATTS)
C ETA     FREQUENCY PARAMETER, (DUCT DIAMETER)/(SOUND WAVELENGTH)
C DELANG  ANGLE INCREMENT DESIRED ON FAR-FIELD RADIAL TRAVERSE, (DEGREES)
C NANGLE  NUMBER OF ANGLES USED IN CALCULATION, DETERMINED BY DELANG AND
```

```
C         THE MAXIMUM ANGLE OF 90 DEGREES
C ANGLE   VECTOR OF ANGLES ON THE FAR-FIELD TRAVERSE, (DEGREES)
C SPL     THE SOUND PRESSURE LEVEL VECTOR ON THE FAR-FIELD TRAVERSE
C         "IGNORING" THE EXIT TRANSMISSION LOSS (DECIBELS) RELATIVE TO
C         2*10**(-5) NEWTONS/METER**2
C SPLTL   THE SOUND PRESSURE LEVEL VECTOR ON THE FAR-FIELD TRAVERSE
C         "INCLUDING" THE EXIT TRANSMISSION LOSS (DECIBELS) RELATIVE TO
C         2*10**(-5) NEWTONS/METER**2
C WATTS   SUM OF ACOUSTIC POWER IN ALL THE CUT-OFF RATIO BINS, (WATTS)
C WATTRAN SUM OF TRANSMITTED ACOUSTIC POWER, ALL BINS, (WATTS)
      FMACH = FMACHI
      ETA = ETAI
      DRAD = 0.5*DIAM
      PI = 3.1415927
      AREAD = PI*DRAD**2
      ABELEX = AREAD+2.0*PI*BLIP*(BLIP+0.5*PI*DRAD)
      FMBELEX =FMACH*AREAD/ABELEX
      ETABELEX = ETA*(DIAM+2.0*BLIP)/DIAM
C  CALCULATE COEF. (PLANE WAVE) INTEGRATION OF RAD. DIRECTIVITY, MACH=0
      IF(ETABELEX.LT.1.0) THEN
      ACOEFPW = 0.741697+3.190822*ETABELEX**2.650078
      GO TO 14
      END IF
      ACOEFPW = 3.932518*ETABELEX**1.96285
   14 CONTINUE
C
      PSQCOEFP = ACOEFPW
      QM = 1.0+0.2*FMACHS**2
      TSUR = TTOT/QM
      PSUR = PTOT/QM**3.5
      SONIC = 49.0422*SQRT(TSUR)
      RHO = 144.*PSUR/(53.3*TSUR)
      POWCON = 8.36424*RHO*SONIC
      ETAEXP = ETA**1.08156
      WATINFIX = (1.0+1.9036*ETAEXP)/(PI*0.71385*ETAEXP)
C  **************** DIMENSIONS, SONIC (FT/SEC), RHO (LBm/FT**3) ******
C  ***** NOTE!! THIS VERSION CALCULATES TO 178 DEGREES FROM INLET AXIS
      NANGLE = 178.0/DELANG
      DO 5 I=1,NANGLE
      FI = I
      ANGLE(I) = FI*DELANG
    5 CONTINUE
      FMSQ = FMACH**2
      FM1 = 1.0-FMSQ
      BETA = SQRT(FM1)
      ACOEF = 0.7/ETA
      FCOF = NCOF
```

```
      FCOFINV = 1./FCOF
      FCOFIND2 = 0.5/FCOF
C    ********************** SET UP CUT-OFF RATIOS IN THE DUCT **********
      COFSQPR = 1.0
      DO 20 I=1,NCOF
      COFRAT(I) = SQRT(1.0/(COFSQPR-FCOFIND2))
      COFSQPR = COFSQPR-FCOFINV
   20 CONTINUE

C    ****************** INITIALIZE P**2 AT EACH FAR-FIELD ANGLE ********
C
      DO 10 I=1,NANGLE
      PSQRADT(I) = 0.0
      PSQTLOS(I) = 0.0
      PSQTOT(I) = 0.0
   10 CONTINUE
C
C    **************************** START LOOP ON CUT-OFF RATIO **********
C
      WATTS = 0.0
      WATTRAN = 0.0

      DO 70 J=1,NCOF
      WATTS = WATTS+WATTSCOF(J)
      POWCOEF = POWCON*WATTSCOF(J)

C    ******************************************************************
C    !!!!!!!! VERY IMPORTANT! FOLLOWING DEFINES PLANE WAVE REGIME !!!!!!
C    ******************************************************************

C    ******** DETERMINE IF PLANE WAVE RADIATION ALGORITHM SHOULD BE USED
C    ******** IF PLANE WAVE IPW = 1 (YES) FOR COFRATD>=3 OR LAST BIN
      IPW = 0
      IF(COFRAT(J).GE.3.0.OR.J.EQ.NCOF) IPW=1
C
C    ********** PROGRAM SPITS HERE.  IT WILL CONTINUE ON FOR NON-PLANE
C    ********** WAVES AND WILL JUMP FOR THE PLANE WAVE

      IF(IPW.EQ.1) GO TO 45

C    ******** NOW IN "NON-PLANE" WAVE, RADIAL OR SPINNING MODE REGIME !!



      XID = COFRAT(J)
      FRAC = 0.85
      IF(XID.LE.2.5) FRAC=1.0-0.1*(XID-1.0)
C
C    ** FOLLOWING ALLOWS SHARP EDGE OR UNFLANGED DUCT APPROXIMATION
      BTHK = BLIP/DIAM
      IF(BTHK.LT.0.01.OR.XID.GT.10.0) THEN
      XIBEL = XID
      FMBEL = FMACH
      DIAMBEL = DIAM
      XDARAD = 1.0
      GO TO 23
      END IF
C
      CALL LIPEF3(XID,XIBEL,FMACH,FMBEL,DIAMBEL,DIAM,ALIP,BLIP,XDARAD,FR
     1AC)
```

```
      IF(FMACH.NE.0.0) THEN
      FMBEL = FMACH*ABS(FMBEL/FMACH)
      GO TO 23
      END IF
      FMBEL = 0.0
C
C
   23 CONTINUE
      ETABEL = ETA*DIAMBEL/DIAM
      FMSQ = FMBEL**2
      FM1 = 1.0-FMSQ
      BETA = SQRT(FM1)

      COF = XIBEL
      COFINV = 1.0/XIBEL
      COFINVSQ = COFINV**2
      COFBETIN = 1.0/(XIBEL*BETA)
      CFBTINSQ = COFBETIN**2
      COFM1 = 1.0-COFINVSQ
      COFSQRT = SQRT(COFM1)

      A90 = 2.0*(ACOEF+COFSQRT)/(ACOEF+1.0)
      PSQCOEF = A90*(1.0-FMSQ*COFM1)**1.5/BETA
      PSQCOEF = PSQCOEF*WATINFIX

      GDEN = (1.0+COFSQRT)**2
      COSPK = BETA*COFSQRT/SQRT(1.0-FMSQ*COFM1)
      PSIPK = ACOS(COSPK)*180.0/PI
      HDEN = 1.0-FMBEL*COSPK


C  ********* CALCULATE TRANSMISSION LOSS IN NON-PLANE WAVE REGION ****

      QF = PI*ETABEL*(1.0-1.0/XIBEL)
      QF15SQ = (QF-1.5)**2
      RADREC = 1.135*EXP(-0.29*(QF+0.18)**2)

      IF(QF.LE.1.5) THEN
      RADRES = 1.5*EXP(-0.2124*QF15SQ)
      GO TO 53
      END IF

      RADRES = 1.0+0.5*EXP(-0.5338*QF15SQ)
   53 CONTINUE

      TAU = SQRT(1.0-1.0/XIBEL**2)
      TPM = TAU+FMBEL
      TTM = TAU*FMBEL
      QDEN = (RADRES*TPM+TTM+1.0)**2+(RADREC*TPM)**2
      QNUM = (RADRES+FMBEL)*(RADRES*FMBEL+1.0)+FMBEL*RADREC**2
      TLCF = 4.0*TAU*QNUM/QDEN

      IF(TLCF.GT.1.0) TLCF=1.0
      IF(TLCF.LT.0.0) TLCF=0.0001

C  ******* FINISHED WITH TRANSMISSION LOSS AT CURRENT CUT-OFF RATIO **

C  ****************************** CALCULATE TRANSMITTED POWER ********
C
      WATTRAN = WATTRAN+TLCF*WATTSCOF(J)
```

```
C
C  ********** CALCULATE P**2 COEF. TO ACCOUNT FOR WATTS.
C     TO ACCOUNT FOR MIC. RADIUS, DIVIDE BY DISTANCE**2 AT PSQ BELOW.
C

      PSQPK = PSQCOEF*ETABEL*XIBEL/(2.0*BETA)
C
C  ********** START SORTING INTO REGIMES TO HANDLE LARGE ANGLES ******
C
      IREG = 0
      ETAC1 = 0.6*BETA/(1.0-COFINV)
      IF(ETABEL.GT.ETAC1) THEN
      IREG = 1

C ********** REGION 1, SLOPE AT ARG=PI/2 USED TO PROJECT BEYOND PEAK

      EPS = 1.0/(BETA*COF)+0.5/ETABEL
      EPSQ = EPS**2
      QNUM = 1.0+FMSQ*EPSQ
      DEPDPSI = QNUM*SQRT(1.0-FM1*EPSQ)
      PSQRATC1 = (4.0/PI)**2*EPS*COFBETIN/(COFBETIN+EPS)**2
      FDEN = CFBTINSQ-EPSQ
      DPSQDPSI = (FDEN+4.0*EPSQ)*PSQRATC1*DEPDPSI/(EPS*FDEN)
      SINPSIC1 = EPS/SQRT(QNUM)
      PSIC = ASIN(SINPSIC1)*180.0/PI
      AC = ALOG(PSQRATC1)
      BC = 0.8889*DPSQDPSI/PSQRATC1
      BC = BC*PI/180.0
      CC = -0.1781*BC
      GO TO 50
      END IF

      ETAC2 = 0.6*BETA*COF
      IF(ETABEL.GT.ETAC2) THEN
      IREG = 2

C ******** REGION 2, PSQratio AT ARG=-PI/2 USED TO FIT EXPONENTIAL FOR
C             USE BEYOND PEAK

      EPS = 1.0/(BETA*COF)-0.5/ETABEL
      PSQRATC2 = (4.0/PI)**2*EPS*COFBETIN/(COFBETIN+EPS)**2
      EPSQ = EPS**2
      QDEN = 1.0+FMSQ*EPSQ
      SINPSIC2 = EPS/SQRT(QDEN)
      PSIC2 = ASIN(SINPSIC2)*180.0/PI
      AC = ALOG(PSQRATC2)/(PSIPK-PSIC2)**2
      GO TO 50
      END IF



C ******** REGION 3, LOW ETA REGION, PSIPK>60 DEG. FIT EXPONENTIAL AT
C    0.5*PSIPK FOR USE BEYOND PEAK.  CODE IREG=3.  EXPONENTIAL EQUATION
C    USED IN PSQ SUBROUTINE FOR PSI > PSIPK.

      IF(PSIPK.GT.60.0) THEN

      IREG = 3

      ANGF = 0.5*PSIPK
```

```
      ANGRAD = ANGF*PI/180.0
      SINF = SIN(ANGRAD)
      EPS = SINF/SQRT(1.0-FMSQ*SINF**2)
      ARG = PI*ETABEL*(COFBETIN-EPS)
      SINARG = SIN(ARG)
      PSQRATC3 = 4.0*EPS*COFBETIN/(COFBETIN+EPS)**2
      PSQRATC3 = PSQRATC3*(SINARG/ARG)**2
      AC = ALOG(PSQRATC3)/(PSIPK-ANGF)**2
      GO TO 50
      END IF

C ******** REGION 4, LOW ETA REGION, PSIPK<60 DEG. FIT EXPONENTIAL AT
C    80 deg. FOR USE BEYOND PEAK.  CODE IREG=4.  EXPONENTIAL EQUATION
C    USED IN PSQ SUBROUTINE FOR PSI>80 deg.

      IREG = 4

      ANGF = 80.0
      ANGRAD = ANGF*PI/180.0
      SINF = SIN(ANGRAD)
      EPS = SINF/SQRT(1.0-FMSQ*SINF**2)
      ARG = PI*ETABEL*(COFBETIN-EPS)
      SINARG = SIN(ARG)
      PSQRATC3 = 4.0*EPS*COFBETIN/(COFBETIN+EPS)**2
      PSQRATC3 = PSQRATC3*(SINARG/ARG)**2
      AC = ALOG(PSQRATC3)/(PSIPK-ANGF)**2

   50 CONTINUE

C
      DO 25 I=1,NANGLE
      ANG = ANGLE(I)
      IF(ANG.EQ.0.0.AND.ISIDELN.EQ.1) THEN
      PSQRADT(I) = 0.0
      PSQTOT(I) = 0.0
      PSQTLOS(I) = 0.0
      GO TO 25
      END IF
C
      CALL PSQGCOF(ANG,PSQ,FMBEL,ETABEL,XIBEL,PSIPK)

      PSQRAD = PSQ
      RAD = DISTANCE
      IF(ISIDELN.EQ.1) THEN
      RAD = DISTANCE/SIN(ANG*PI/180.0)
      END IF
      PSQ = PSQ/RAD**2

      PSQRADT(I) = PSQRADT(I)+POWCOEF*PSQRAD
      PSQTOT(I) = PSQTOT(I)+POWCOEF*PSQ
      PSQTLOS(I) = PSQTLOS(I)+POWCOEF*PSQ*TLCF
C  ***** NOTE THAT AN INLET TRANMISSION LOSS (TLCF) HAS BEEN USED ****
   25 CONTINUE

      GO TO 70


   45 CONTINUE
C  ********** IN PLANE-WAVE CALCULATION PROCEDURE !!!!!!!!!!!!!!!!!!!!

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```
C  ********** P**2 PRINCIPAL LOBE PEAK FOR 1 WATT POWER INPUT ********
      PSQPK = 2.0*PSQCOEFP
C  *******************************************************************
      GDEN = 4.0
      FMSQEX = FMBELEX**2
C  ******* LOW ETA REGION. FIT EXPONENTIAL AT PSICRPL FOR BEYOND PEAK.
C  ******* IF PSICRPL < 90 CAN'T BE OBTAINED, USE PSICRPL = 90.
      ANGF = 90.0
      ETACRPL = 0.5*SQRT(1.0-FMSQEX)
      SINCRPL = 1.0/SQRT(4.0*ETABELEX**2+FMSQEX)
      IF(ETABELEX.GT.ETACRPL) ANGF=ASIN(SINCRPL)*180./PI
      PSICRPL = ANGF
      ANGFRAD = ANGF*PI/180.0
      SINF = SIN(ANGFRAD)
      ARG = PI*ETABELEX*SINF/SQRT(1.0-FMSQEX*SINF**2)
      SINARG = SIN(ARG)
      PSQRATPL = (SINARG/ARG)**2
      ACPL = ALOG(PSQRATPL)/ANGF**2
C ********** ACPL IS THE AMPLITUDE OF THE EXPONENTIAL AT PSICRPL *****
C ********** END LOW ETA REGION EXPONENTIAL FIT AT PSICRPL. **********
C  ** CALCULATE TRANSMISSION LOSS AT BELMOUTH EXIT CUT-OFF RATIO AND
C  ** FREQUENCY PARAMETER.
      X = 0.5*(PI*ETABELEX)**2
      RADRES = 1.0+X*EXP(-0.325226*X)-
     1                 EXP(-0.101669*ETABELEX**5.7848)
      A = 0.023567
      Y = 0.5*PI**2*ETABELEX
      RADREC=EXP(-3.574331*ETABELEX**1.957292)*8.*ETABELEX/
     13.+A*Y**2/(1.+A*Y**3)
      QDEN = (1.0+FMBELEX)**2*((RADRES+1.0)**2+RADREC**2)
      TLCF=4.*(RADRES*(1.+FMSQEX)+FMBELEX*(RADRES**2+
     1       RADREC**2+1.))/QDEN
      IF(TLCF.GT.1.0) TLCF=1.0
      IF(TLCF.LT.0.0) TLCF=0.0001
C  ** END TRANSMISSION LOSS CALCULATION FOR PLANE WAVE AT BELLMOUTH EXIT
C  ****************************** CALCULATE TRANSMITTED POWER ********
C
      WATTRAN = WATTRAN+TLCF*WATTSCOF(J)
C
      DO 40 I=1,NANGLE
      FI = I
      ANGDEG = ANGLE(I)
      IF(ANGDEG.EQ.0.0.AND.ISIDELN.EQ.1) THEN
      PSQRADT(I) = 0.0
      PSQTOT(I) = 0.0
      PSQTLOS(I) = 0.0
      GO TO 40
      END IF
C
      ANGRAD = ANGDEG*PI/180.0
```

```
      SINANG = SIN(ANGRAD)
      COSANG = COS(ANGRAD)
      Q1DEN = SQRT(1.0-FMSQEX*SINANG**2)
      Q1 = SINANG/Q1DEN
      ARG = PI*ETABELEX*Q1
      SINSQNUM = (SIN(ARG))**2
      GG = (1.0+COSANG/Q1DEN)**2/GDEN
      PSQRAT = 1.0
      PSQDEN = ARG**2
      IF(PSQDEN.LT.1.E-06.AND.ANGDEG.LE.90.0) GO TO 49
C  ** LOW FREQUENCY REGION.  FOLLOWING ALLOWS REASONABLE
C  ** EXTRAPOLATION BEYOND 90 deg, STARTING AT ARG = PI/2 IF ETA>ETAcrit
C  ** OR AT 90 deg. OTHERWISE.  USES EXPONENTIAL FIT AT PSI = 0
C  ** AND PSI = PSIFIT.
      IF(ANGDEG.LT.PSICRPL) GO TO 48
      QEXP = ACPL*(ANGDEG)**2
      IF(QEXP.LT.-20.) QEXP=-20.
      PSQRAT = EXP(QEXP)
      GO TO 49
   48 PSQRAT = PSQRAT*SINSQNUM/PSQDEN
   49 CONTINUE
      PSQ = PSQRAT*PSQPK*GG
      PSQRAD = PSQ
C
      RAD = DISTANCE
      IF(ISIDELN.EQ.1) THEN
      RAD = DISTANCE/SIN(ANGDEG*PI/180.0)
      END IF
      PSQ = PSQ/RAD**2
C
      PSQRADT(I) = PSQRADT(I)+POWCOEF*PSQRAD
      PSQTOT(I) = PSQTOT(I)+POWCOEF*PSQ
      PSQTLOS(I) = PSQTLOS(I)+POWCOEF*PSQ*TLCF
C  ************ NOTE THAT A TRANMISSION LOSS (TLCF) HAS BEEN USED ****
   40 CONTINUE
   41 CONTINUE
   70 CONTINUE
      FNANGLE = NANGLE
      SUMWATT = 0.0
      DO 75 I=1,NANGLE
      ANGRAD = ANGLE(I)*PI/180.0
      SUMWATT = SUMWATT+PSQRADT(I)*SIN(ANGRAD)
```

```
      IF(PSQTOT(I).LT.4.E-08) THEN
      SPLTL(I) = 20.0
      SPL(I) = 20.0
      GO TO 75
      END IF
      SPLTL(I) = 10.0*ALOG10(PSQTLOS(I))+93.9794
      SPL(I) = 10.0*ALOG10(PSQTOT(I))+93.9794
   75 CONTINUE

      WATTINT = SUMWATT*PI/(POWCON*FNANGLE)
      SPLDIF = 10.0*ALOG10(WATTS/WATTINT)

      DO 80 I=1,NANGLE
      SPLTL(I) = SPLTL(I)+SPLDIF
      SPL(I) = SPL(I)+SPLDIF
   80 CONTINUE


      RETURN
      END
```

```
C
C  *******************************************************************
C  ********** END OF MAIN SUBROUTINE ”BBRDCFIN” **********************
C  ********** MODIFIED 02/21/1998, E. J. RICE ***********************
C  *******************************************************************
C
C  *******************************************************************
C  ** SUBROUTINE FOR CALC PSQ FOR EQUAL ENERGY PER MODE AT AN ANGLE
C  ** CUT-OFF RATIO APPROXIMATE EQUATIONS USED, BLOCK BUILD-UP AS IN
C     AIAA PAPER 96-1774, EMPIRICAL NORMALIZATION REPLACES FACTOR
C     SQRT(1.-1/XI**2).  FOUR REGIONS (ETA AND CUT-OFF RATIO) DETERMINE
C     PROPER APPROXIMATION FOR HIGH ANGLE RADIATION. DEVELOPED 01/30/98.
C
      SUBROUTINE PSQGCOF(ANG,PSQ,FMACH,ETA,XI,PSIPK)
C
      COMMON FMSQ,FM1,BETA,COFBETIN,CFBTINSQ,GDEN,HDEN,
     1PSQPK,PSIC,AC,BC,CC,IREG

      PI = 3.1415927

      ANGRAD = ANG*PI/180.0
      SINANG = SIN(ANGRAD)
      COSANG = COS(ANGRAD)

      Q1DEN = SQRT(1.0-FMSQ*SINANG**2)
      Q1 = SINANG/Q1DEN
      ARG = PI*ETA*(Q1-COFBETIN)
      SINSQNUM = (SIN(ARG))**2
      GG = (1.0+COSANG/Q1DEN)**2/GDEN
      HH = (1.0-FMACH*COSANG)/HDEN
      PSQRAT = 4.0*Q1/(BETA*XI*(Q1+COFBETIN)**2)

      PSQDEN = ARG**2
      ANGCK = PSIPK+1.0

      IF(ANG.GT.ANGCK) GO TO 5
C  ********** CHECK FOR 0/0, USE LIMITING CASE IF INDETERMINATE ******
```

```
      C  ********** DON'T CHECK IF ANGLE ABOVE PEAK ANGLE ******************
            IF(PSQDEN.LT.1.E-06) GO TO 39
          5 CONTINUE
            IF(ANG.LT.PSIPK) GO TO 38
            IF(ANG.GE.PSIC.AND.IREG.EQ.1) THEN
      C  ** FOLLOWING TO REMOVE THE P**2 OSCILLATIONS BEYOND THE PEAK ******
      C  ** USES SLOPE AT ARG = PI/2 TO EXTRAPOLATE TO HIGH ANGLES *********
            DANG = ANG-PSIC
            QEXP = AC+BC*DANG/(1.0+CC*DANG)
            IF(QEXP.LT.-20.) QEXP=-20.
            PSQRAT = EXP(QEXP)
            GO TO 39
            END IF
            IF(ANG.GE.PSIPK.AND.IREG.EQ.2) THEN
      C  ** FOLLOWING TO REMOVE THE P**2 OSCILLATIONS BEYOND THE PEAK ******
  C  ** USES EXPONENTIAL FIT AT ARG = -PI/2 TO EXTRAPOLATE TO HIGH ANGLES
      C  ** ALSO HANDLES LOW FREQUENCY REGIMES 3 AND 4 FOR ANGLES BEYOND PEAK.
            QEXP = AC*(ANG-PSIPK)**2
            IF(QEXP.LT.-20.) QEXP=-20.
            PSQRAT = EXP(QEXP)
            GO TO 39
            END IF
            IF(ANG.GE.PSIPK.AND.IREG.EQ.3) THEN
      C  ** ONE OF THE LOW FREQUENCY REGIONS, REGION 3.  FOLLOWING ALLOWS
      C  ** REASONABLE EXTRAPOLATION BEYOND 90 deg, STARTING AT PEAK.
      C  ** USES EXPONENTIAL FIT AT PSI = PSIPK AND 0.5*PSIPK. PSIPK>60 deg.
            QEXP = AC*(ANG-PSIPK)**2
            IF(QEXP.LT.-20.) QEXP=-20.
            PSQRAT = EXP(QEXP)
            GO TO 39
            END IF
      C  ** ONLY REGION LEFT, REGION 4, WITH PSIPK<60 deg.
      C  ** ONE OF THE LOW FREQUENCY REGIONS.  FOLLOWING ALLOWS REASONABLE
      C  ** EXTRAPOLATION BEYOND 90 deg, STARTING THIS TIME AT 80 deg.
      C  ** USES EXPONENTIAL FIT AT PSI = PSIPK AND 80 deg. PSIPK<60 deg.
            IF(ANG.LT.80.0) GO TO 38
            QEXP = AC*(ANG-PSIPK)**2
            IF(QEXP.LT.-20.) QEXP=-20.
            PSQRAT = EXP(QEXP)
            GO TO 39
         38 PSQRAT = PSQRAT*SINSQNUM/PSQDEN
         39 CONTINUE
            PSQ = PSQRAT*PSQPK*GG*HH
```

```
C

      RETURN
      END


C*******************************************************
C  ** END OF PSQGCOF.FOR ********************************
C  *******************************************************************
C



C
C  *******************************************************************
C  ******** ALLOWS CUT OFF MODES TO PROPAGATE IN BELLMOUTH IF THEY CAN
C  ******** BE CUT ON OR PROPAGATING BEFORE THE BELLMOUTH EXIT *******
C  *******************************************************************
C  ** SUBROUTINE "LIPEF3" CALCULATES THE EFFECT OF THE INLET LIP OR
C     BELLMOUTH ON THE INLET FAR-FIELD RADIATION, SECOND MODEL
C  *******************************************************************
C  *******************************************************************
C
      SUBROUTINE LIPEF3(XID,XIBEL,FMACK,FMBEL,DBEL,DIAM,ALIP,BLIP,XDARAD
     1,FRAC)
C
C  ********** DEFINITION OF VARIABLES *********************************
C
C     ALIP =  MINOR AXIS OF THE ELLIPTICAL INLET LIP, INCHES
C     BLIP =  MAJOR AXIS OF THE ELLIPTICAL INLET LIP, INCHES
C             FOR CIRCULAR ARC, ALIP = BLIP
C     DIAM =  DIAMETER OF INLET DUCT, INCHES
C     FMACH=  MACH NUMBER OF UNIFORM FLOW IN THE STRAIGHT DUCT SECTION
C     XID =   CUT-OFF RATIO OF MODE IN THE STRAIGHT DUCT SECTION
C     XIBEL = CUT-OFF RATIO OF MODE IN THE ELLIPTIC BELLMOUTH AS THE
C            MODE RELEASES AND RADIATES.  USE THIS VALUE FOR RADIATION.
C     XDARAD=VALUE OF X/A WHERE RADIATION RELEASES FROKM BELLMOUTH
C
C  **  AN ITERATION IS REQUIRED TO DETERMINE XIRAD, START THE ITERATION
C
      FMACH = FMACK
      IF(FMACK.LT.0.0) FMACH=-FMACK
      PI = 3.1415927
      N = 100
      FN = N
      RAD = DIAM/2.0
      BDA = BLIP/ALIP
      ADUCT = PI*DIAM**2/4.0
      FM1 = SQRT(1.0-FMACH**2)
      IF(XID.LE.1.0) GO TO 40
C  ** IF THE MODE DOES NOT PROPAGATE IN THE DUCT, THE BELLMOUTH MAY
C     STILL CUT THE MODE ON AND ALLOW PROPAGATION. SKIP DUCT
C     CALCULATIONS BELOW IF DUCT CUT-OFF RATIO LESS THAN UNITY.
      QXI = 1.0-1.0/XID**2
      QNT = QXI/(1.0-QXI*FMACH**2)
      QNT = FM1*SQRT(QNT)
C  ** ANGDUCT IS THE PROPAGATION ANGLE OF THE MODE IN THE STRAIGHT DUCT
      ANGDUCT = ACOS(QNT)
      TANANG = TAN(ANGDUCT)
      TANANG2 = TANANG**2
      XDATSQ = TANANG2/(TANANG2+BDA**2)
```

```
      XDAT = SQRT(XDATSQ)
      QNT = 1.0-XDATSQ
      RT = RAD+BLIP*(1.0-SQRT(QNT))
      XT = XDAT*ALIP
      DELX = (RT-FRAC*RAD)/TANANG
      XRAD = XT-DELX
      IF(DELX.GE.XT) THEN
      XIBEL = XID
      ANGDUCT = ANGDUCT*180.0/PI
      FMBEL = FMACH
      DBEL = DIAM
C
C  ** THE BELLMOUTH DOES NOT EFFECT THE RADIATION AT THIS CUTOFF RATIO
      GO TO 501
      END IF
   40 CONTINUE
      XDAPR = 0.0
      XDIFPR = XRAD
      ICALC = 0
      DO 50 I=1,N
      FI = I
      XDA = SQRT(FI/FN)
      IF(XDA.GE.1.0) XDA=0.9999
      SQXA = SQRT(1.0-XDA**2)
      QNT = BDA*XDA/SQXA
C  ******** ANGWAL IS THE SLOPE OF THE BELLMOUTH WALL AT THIS X/A (XDA)
      ANGWAL = ATAN(QNT)
C
C  ** CALCULATE THE INCREASED FLOW AREA DUE TO THE BELLMOUTH AT THIS XDA
C
      QRB = BLIP*(1.0-SQXA)
      RC = QRB/SIN(ANGWAL)
      AEX = 2.0*PI*RC*(RAD*ANGWAL+RC*(1.0-COS(ANGWAL)))
C
C  ** AEX IS THE EXTRA FLOW AREA DUE TO THE BELLMOUTH AT THIS XDA
      ATOT = AEX+ADUCT
      FMBEL = FMACH*ADUCT/ATOT
      RADBEL = RAD+QRB
      FM1B = SQRT(1.0-FMBEL**2)
      XIBEL= XID*RADBEL*FM1/(RAD*FM1B)
      QXI = 1.0-1.0/XIBEL**2
      QNT = QXI/(1.0-QXI*FMBEL**2)
C  ********** CHECK IF MODE HAS STARTED PROPAGATING IN BELLMOUTH *****
      IF(QXI.LT.0.0) GO TO 50
      ICALC = ICALC+1
      QNT = FM1B*SQRT(QNT)
C  ******** ANGPROP IS THE ANGLE OF PROPAGATION OF THE MODE AT THIS XDA
      ANGPROP = ACOS(QNT)
      TANANG = TAN(ANGPROP)
      TANANG2 = TANANG**2
      XDATSQ = TANANG2/(TANANG2+BDA**2)
      XDAT = SQRT(XDATSQ)
      QNT = 1.0-XDATSQ
      RT = RAD+BLIP*(1.0-SQRT(QNT))
      XT = XDAT*ALIP
      DELX = (RT-FRAC*RADBEL)/TANANG
      XRAD = XT-DELX
      XDIF = XRAD-XDA*ALIP
      IF(XDIF.LE.0.0) GO TO 55
```

```
      XDIFPR = XDIF
      XDAPR = XDA
   50 CONTINUE
      IF(ICALC.EQ.0) THEN
      WRITE(*,100)
  100 FORMAT(' ******** ALERT ******** ALERT ******** ALERT ******')
      WRITE(*,101)
  101 FORMAT(' ** THIS MODE CAN NOT ESCAPE THE BELLMOUTH EXIT.  PLEASE M
     1AKE MODIFICATIONS ** ')
      WRITE(*,100)
      XIBEL = .1
      GO TO 500
      END IF
      IF(ICALC.EQ.1) THEN
C  *************** MODE CUT-ON ACHIEVED AT BELLMOUTH EXIT ************
      XIBEL = 1.0001
      GO TO 500
      END IF
   55 CONTINUE
      IF(ICALC.EQ.1) THEN
      XDARAD = XDA
      GO TO 60
      END IF
      X2 = XDA
      X1 = XDAPR
      Y2 = XDIF
      Y1 = XDIFPR
      DY21 = ABS(Y2-Y1)
      IF(DY21.EQ.0.0) THEN
      XDARAD = XDAPR
      GO TO 60
      END IF
      XDARAD = (X1*Y2-X2*Y1)/(Y2-Y1)
C
C  ** ITERATION DONE, CALCULATE OUTPUTS AT X/A = XDARAD
C
   60 CONTINUE
      SQXA = SQRT(1.0-XDARAD**2)
      QNT = BDA*XDARAD/SQXA
C  ******** ANGWAL IS THE SLOPE OF THE BELLMOUTH WALL AT MODE RADIATION
      ANGWAL = ATAN(QNT)
C
C  ** CALCULATE THE FINAL FLOW AREA INCREASE DUE TO THE BELLMOUTH
C
      QRB = BLIP*(1.0-SQXA)
      RC = QRB/SIN(ANGWAL)
      AEX = 2.0*PI*RC*(RAD*ANGWAL+RC*(1.0-COS(ANGWAL)))
C
C  ** AEX IS THE EXTRA FLOW AREA DUE TO THE BELLMOUTH AT THIS XDA
      ATOT = AEX+ADUCT
      FMBEL = FMACH*ADUCT/ATOT
      RADBEL = RAD+QRB
      FM1B = SQRT(1.0-FMBEL**2)
      XIBEL= XID*RADBEL*FM1/(RAD*FM1B)
      QXI = 1.0-1.0/XIBEL**2
      QNT = QXI/(1.0-QXI*FMBEL**2)
      QNT = FM1B*SQRT(QNT)
      IF(XID.GE.1.0) THEN
      QXI = 1.0-1.0/XID**2
      QNT = QXI/(1.0-QXI*FMACH**2)
```

```
      QNT = FM1*SQRT(QNT)
C  ** "ANGDUCT" IS THE PROPAGATION ANGLE OF THE MODE FROM THE DUCT IF
C     BELLMOUTH IS "NOT" CONSIDERED ************************************
      ANGDUCT = ACOS(QNT)*180.0/PI
      ELSE
      ANGDUCT = 90.0
      END IF
  500 CONTINUE
      DBEL = 2.0*RADBEL
  501 CONTINUE
      RETURN
      END


C
C  *******************************************************************
C  ********** END OF SUBROUTINE "LIPEF3" *****************************
C  *******************************************************************

C
C  **** AFT FAN RADIATION SUBROUTINE, E. J. RICE, REVISED 02/19/1998
C  **** NORMALIZED PLANE WAVE RADIATION INCLUDED HERE.
C  ** THE FOLLOWING "BBRDCFEX" IS THE MAIN SUBROUTINE.  ALL ARGUMENTS
C     ARE INPUTS EXCEPT "DJET," "FMACH1," "NANGLE," "ANGLE," "SPL,"
C     "SPLTL," "WATTS," "FMACHN," AND "COFMIN" AND WATTS
C     RETURNED TO THE MAIN PROGRAM FOR PRINTING, FILE STORAGE ETC.
C
C  ** THIS VERSION REMOVES THE P**2 OSCILLATIONS BEYOND THE PEAK.  FOUR
C     REGIONS (ETA AND CUT-OFF RATIO) DETERMINE PROPER APPROXIMATION FOR
C     HIGH ANGLE RADIATION. DEVELOPED 01/30/98.

      SUBROUTINE BBRDCFEX(TTOT,PTOT,TSUR,PSUR,HTRAT,
     1ANOZRAT,DISTANCE,ISIDELN,DDUCT,DJET,FMACHD,FMACH1,FMACH2,
     2NCOF,WATTSCOF,DELANG,ETAD,
     3NANGLE,ANGLE,SPL,SPLTL,WATTS,WATTRAN,FMACHN,COFMIN)

C
      DIMENSION ANGLE(200),SPL(200),SPLTL(200),WATTSCOF(200),
     1COFRAT(200),COFRATD(200),COFRATN(200),PSQTOT(200),
     2PSQTLOS(200),PSQRADT(200)

C
C  ** SUBROUTINE REQUIRED "CONOZ"
C
C  ***************** DEFINITION OF SUBROUTINE ARGUMENTS **************
C
C TTOT    TOTAL TEMPERATURE IN AFT FAN DUCT, (DEGREES RANKINE)
C PTOT    TOTAL PRESSURE IN AFT FAN DUCT, (PSIA)
C TSUR    TOTAL TEMPERATURE IN SURROUNDING MEDIUM, (DEGREES RANKINE)
C PSUR    TOTAL PRESURE IN SURROUNDING MEDIUM, (PSIA)
C HTRAT   AFT FAN DUCT HUB-TIP RATIO
C ANOZRAT (NOZZLE THROAT AREA)/(FAN DUCT AREA)
C DISTANCE  RADIUS OF MICROPHONE ARRAY OR TRAVERSE, (FT.)
C ISIDELN = 0 FOR CONSTANT RADIUS, = 1 FOR CONSTANT SIDELINE CALCULATION
C DDUCT   AFT FAN DUCT OUTSIDE DIAMETER, (INCHES)
C DJET    FINAL JET DIAMETER, (INCHES)
C FMACHD  AFT FAN DUCT MACH NUMBER, POSITIVE FOR EXHAUST
C FMACH1  FINAL JET MACH NUMBER
C FMACH2  MACH NUMBER OF SURROUNDING MEDIUM
C FMACHN  NOZZLE EXIT (THROAT) MACH NUMBER
```

```
C NCOF    NUMBER OF CUT-OFF RATIO BINS TO SORT ACOUSTIC POWER
C WATTSCOF VECTOR WITH ACOUSTIC POWER FOR EACH BIN, (WATTS)
C FREQ    FREQUENCY OF SOUND, (HERTZ)
C DELANG  ANGLE INCREMENT DESIRED ON FAR-FIELD RADIAL TRAVERSE, (DEGREES)
C NANGLE  NUMBER OF ANGLES USED IN CALCULATION, DETERMINED BY DELANG AND
C         THE MAXIMUM ANGLE OF 180 DEGREES
C ANGLE   VECTOR OF ANGLES ON THE FAR-FIELD TRAVERSE, CONVERTED TO
C         THAT MEASURED FROM THE ENGINE "INLET" AXIS, (DEGREES)
C SPL     THE SOUND PRESSURE LEVEL VECTOR ON THE FAR-FIELD TRAVERSE
C         "IGNORING" THE EXIT TRANSMISSION LOSS (DECIBELS) RELATIVE TO
C         2*10**(-5) NEWTONS/METER**2
C SPLTL   THE SOUND PRESSURE LEVEL VECTOR ON THE FAR-FIELD TRAVERSE
C         "INCLUDING" THE EXIT TRANSMISSION LOSS (DECIBELS) RELATIVE TO
C         2*10**(-5) NEWTONS/METER**2
C WATTS   SUM OF ACOUSTIC POWER IN ALL THE CUT-OFF RATIO BINS, (WATTS)
C WATTRAN SUM OF TRANSMITTED ACOUSTIC POWER IN ALL BINS, (WATTS)
C COFMIN  THE MINIMUM CUT-OFF RATIO BELOW WHICH COMPLETE REFLECTION
C         OCCURS DUE TO REFRACTION THROUGH THE SLIP LAYER
C
      PI = 3.1415927
      QAFP = 1.0+0.328766*ETAD**1.702882
      AFPOWFAC = 1.741*(QAFP+1.274989*ETAD**2)/(PI*ETAD*QAFP)

C  CALCULATE COEF. (PLANE WAVE) INTEGRATION OF RAD. DIRECTIVITY, MACH=0
      IF(ETAD.LT.1.0) THEN
      ACOEFPW = 1.733303+5.30259*ETAD**2.28937
      GO TO 14
      END IF
      ACOEFPW = 7.035893*ETAD**1.773669
   14 CONTINUE
C
C  CALC. COEF. FOR INTEGRATION WITH AFT SHEAR LAYERS, PLANE WAVE
C
      AFPOWFPW = (1.0+0.127683*ETAD)/(3.0+0.137590*ETAD)
      PSQCOEFP = ACOEFPW*AFPOWFPW*(1.0+2.6557*ETAD)/(1.0515+3.8508*ETAD)
      PSQCOEFP = 1.3704*PSQCOEFP
C  ******************************************************************

      FCOF = NCOF
      FCOFINV = 1./FCOF
      FCOFIND2 = 0.5/FCOF
C  *********************** SET UP CUT-OFF RATIOS IN THE DUCT ********
      COFSQPR = 1.0
      DO 20 I=1,NCOF
      COFRATD(I) = SQRT(1.0/(COFSQPR-FCOFIND2))
      COFSQPR = COFSQPR-FCOFINV
   20 CONTINUE

      TDUCT = TTOT/(1.0+0.2*FMACHD**2)
      CDUCT = 49.0421*SQRT(TDUCT)

      QSUR = 1.0+0.2*FMACH2**2
      TSTS = TSUR/QSUR
      PSTS = PSUR/QSUR**3.5
      CSUR = 49.0421*SQRT(TSTS)
      RHOSUR = 144.0*PSTS/(53.3*TSTS)

C
C  ************************ DETERMINE NOZZLE FLOW PROPERTIES ********

```

```
      CALL CONOZ(TTOT,PTOT,PSTS,HTRAT,ANOZRAT,DDUCT,FMACHD,FMACH1,CJET,D
     1JET,TJET,PNOZ,DNOZ,CNOZ,FMACHN)

      CRAT = CJET/CSUR

      ETA = ETAD*DJET*CDUCT/(DDUCT*CJET)
      ETAN= ETAD*DNOZ*CDUCT/(DDUCT*CNOZ)

      RATCFNOZ = DNOZ*CDUCT*SQRT(1.0-FMACHD**2)/(DDUCT*CNOZ*
     1SQRT(1.0-FMACHN**2))

      RATCFJET = DJET*CDUCT*SQRT(1.0-FMACHD**2)/(DDUCT*CJET*
     1SQRT(1.0-FMACH1**2))


      FMSQ1 = FMACH1**2
      FM11 = 1.0-FMSQ1
      BETA1 = SQRT(FM11)
      FMSQ2 = FMACH2**2
C
C  ********** ESTABLISH CUT-OFF LIMITS FOR COMPLETE REFLECTION
      COFMIN = 1.0
      IF(FMACH1.EQ.0.0) GO TO 15

      CKM2 = 1.0-CRAT*FM11/FMACH1
      IF(FMACH2.LT.CKM2) THEN
      COSPHIL = -CRAT/(1.0+CRAT*FMACH1-FMACH2)
      PHIL = ACOS(COSPHIL)
      SINPHIL = SIN(PHIL)
      DEN = SQRT(1.0+FMSQ1+2.0*FMACH1*COSPHIL)
      COSPSIL = (COSPHIL+FMACH1)/DEN
      SINPSIL = SINPHIL/DEN
      COFMIN = SQRT(FM11+FMSQ1*COSPSIL**2)/(BETA1*SINPSIL)
C       COFMIN = (1.0+FMACH1*COSPHIL)/(BETA1*SINPHIL)
      END IF
   15 CONTINUE
C  *******************************************************************

      NANGLE = 180.0/DELANG-1
      DO 5 I=1,NANGLE
      FI = I
      ANGLE(I) = FI*DELANG
    5 CONTINUE

C  ********** PART OF EMPIRICAL COEFFICIENT TAKING PLACE OF RADICAL
C  ********** SQRT(1-1/COF**2) IN P**2 COEFICIENT WHICH WOULD NOT BE
C  ********** ANY GOOD AT CUT-OFF.  FOR NON-PLANE WAVES.

      ACOEF = 0.7/ETA

C  ** RECALL, THE CUT-OFF RATIOS IN THE DUCT ARE INPUT HERE AS "COFRATD"

C  ********** CALCULATE CUT-OFF RATIOS IN THE NOZZLE AND THE JET *****
      DO 22 I=1,NCOF
      COFRATN(I) = RATCFNOZ*COFRATD(I)
      COFRAT(I) = RATCFJET*COFRATD(I)
   22 CONTINUE
C
C  ****************** INITIALIZE P**2 AT EACH FAR-FIELD ANGLE ********
C
      DO 10 I=1,NANGLE
```

```
      PSQRADT(I) = 0.0
      PSQTLOS(I) = 0.0
      PSQTOT(I) = 0.0
   10 CONTINUE
C
C ****************************** START LOOP ON CUT-OFF RATIO ********
C
      POWCON = 8.36424*RHOSUR*CSUR
      WATTS = 0.0
      WATTRAN = 0.0
      DO 70 J=1,NCOF
      WATTS = WATTS+WATTSCOF(J)
C
C ** DETERMINE IF COFRAT IS WITHIN COMPLETE REFLECTION RANGE DUE TO
C ** REFRACTION THROUGH THE SLIP LAYER OR IF COMPLETE REFLECTION
C ** OCCURS AT THE NOZZLE THROAT
C
      IF(COFRAT(J).LT.COFMIN.OR.COFRATN(J).LE.1.0) GO TO 70
C ******************************************************************
C !!!!!!!! VERY IMPORTANT! FOLLOWING DEFINES PLANE WAVE REGIME !!!!!!
C ******************************************************************
C ******** DETERMINE IF PLANE WAVE RADIATION ALGORITHM SHOULD BE USED
C ******** IF PLANE WAVE IPW = 1 (YES) FOR COFRATD>=3 OR LAST BIN
      IPW = 0
      IF(COFRATD(J).GE.3.0.OR.J.EQ.NCOF) IPW=1
C ** CALCULATE TRANSMISSION LOSS AT NOZZLE THROAT CUT-OFF RATIO AND
C ** FREQUENCY PARAMETER.
      FMSQN = FMACHN**2
      IF(IPW.EQ.1) THEN
C *************************************** IN PLANE-WAVE REGIME ******
      X = 0.5*(PI*ETAN)**2
      RADRES = 1.0+X*EXP(-0.325226*X)-EXP(-0.101669*ETAN**5.7848)
      A = 0.023567
      Y = 0.5*PI**2*ETAN
      RADREC=EXP(-3.574331*ETAN**1.957292)*8.*
     1          ETAN/3.+A*Y**2/(1.+A*Y**3)
      QDEN = (1.0+FMACHN)**2*((RADRES+1.0)**2+RADREC**2)
      TLCF = 4.*(RADRES*(1.+FMSQN)+FMACHN*(RADRES**2+
     1         RADREC**2+1.))/QDEN
      GO TO 55
      END IF
C ********** IN NON-PLANE WAVE, RADIAL OR SPINNING MODE REGION ******
      QF = PI*ETAN*(1.0-1.0/COFRATN(J))
      QF15SQ = (QF-1.5)**2
      RADREC = 1.135*EXP(-0.29*(QF+0.18)**2)
      IF(QF.LE.1.5) THEN
```

```
      RADRES = 1.5*EXP(-0.2124*QF15SQ)
      GO TO 53
      END IF

      RADRES = 1.0+0.5*EXP(-0.5338*QF15SQ)
   53 CONTINUE

      TAU = SQRT(1.0-1.0/COFRATN(J)**2)
      TPM = TAU+FMACHN
      TTM = TAU*FMACHN
      QDEN = (RADRES*TPM+TTM+1.0)**2+(RADREC*TPM)**2
       QNUM = (RADRES+FMACHN)*(RADRES*FMACHN+1.0)+FMACHN*RADREC**2
      TLCF = 4.0*TAU*QNUM/QDEN

C  ****************************** CALCULATE TRANSMITTED POWER ********
C
   55 CONTINUE
      WATTRAN = WATTRAN+TLCF*WATTSCOF(J)
C
C  ********** CALCULATE P**2 COEF. TO ACCOUNT FOR WATTS **************
C      TO ACCOUNT FOR MIC. RADIUS, DIVIDE BY DISTANCE**2 AT PSQ BELOW.
C
      POWCOEF = POWCON*WATTSCOF(J)
C
C  ********** PROGRAM SPITS HERE.  IT WILL CONTINUE ON FOR NON-PLANE
C  ********** WAVES AND WILL JUMP FOR THE PLANE WAVE

      IF(IPW.EQ.1) GO TO 45

C  ******** NOW IN "NON-PLANE" WAVE, RADIAL OR SPINNING MODE REGIME !!

      COFBETIN = 1.0/(COFRAT(J)*BETA1)
      COFINV = 1.0/COFRAT(J)
      COFINVSQ = COFINV**2
      COFM1 = 1.0-COFINVSQ
      EP = SQRT(COFM1)
      GDEN = (1.0+EP)**2

C  **** HERE IS REMAINDER OF EMPIRICAL COEFFICIENT USING "ACOEF" ABOVE

      A90 = 2.0*(ACOEF+EP)/(ACOEF+1.0)

C  **** THEORETICAL NORMALIZATION COEFFICENT WITH FLOW ATTACHED TO A90
C  ** INCLUDES INTEGRATED POWER NORMALIZATION "AFPOWFAC" (EMPIRICAL) **

      PSQCOEF = AFPOWFAC*A90*(1.0-FMSQ1*COFM1)**1.5/BETA1

      COSPK1 = BETA1*EP/SQRT(1.0-FMSQ1*COFM1)
      ANGPK1 = ACOS(COSPK1)
C  ******** GROUP VELOCITY VECTOR ANGLE IN REGION 1, PSIPK1 (DEGREES)
      PSIPK1 = ANGPK1*180.0/PI
      SINPK1 = SIN(ANGPK1)
C  ************** PHASE VELOCITY VECTOR ANGLE FOR PEAK IN REGION 1 (JET)
      SIN2 = SINPK1**2
      COSPHI1 = -FMACH1*SIN2+COSPK1*SQRT(1.0-FMSQ1*SIN2)
C
C  ************************************* PHI1 TO PHI2 ACROSS SLIP LAYER
C  ****************** PHASE VELOCITY ANGLE IN REGION 2 (SURROUNDINGS)

      COSPHI2 = COSPHI1/(CRAT+(CRAT*FMACH1-FMACH2)*COSPHI1)

```

```
C  ********* PHASE TO GROUP VELOCITY ANGLES IN REGION 2 (SURROUNDINGS)

       COSPSI2 = (COSPHI2+FMACH2)/SQRT(1.0+FMSQ2+2.0*FMACH2*COSPHI2)
      PSI2RAD = ACOS(COSPSI2)
      SINPSI2 = SIN(PSI2RAD)

C  ****************** ANGLE CHANGE ACOUSTIC POWER CORRECTION ********

      FREFRCT = SINPK1/SINPSI2

C  ******************************************************************

      Q22NUM = SQRT(1.0+FMSQ2+2.0*FMACH2*COSPHI2)

      COSPSPK2 = (COSPHI2+FMACH2)/Q22NUM
      ANGPK2 = ACOS(COSPSPK2)

C  ******** GROUP VELOCITY VECTOR ANGLE IN REGION 2, PSIPK2 (DEGREES)
      PSIPK2 = ANGPK2*180.0/PI

C  GROUP VELOCITY VECTOR ANGLE CHANGE, REG. 1 TO REG. 2, DELPSI (DEG.)
      DELPSI = PSIPK2-PSIPK1
C  ******************************************************************

      SIN2PK2 = SIN(PSIPK2*PI/180.0)

C  ********** P**2 PRINCIPAL LOBE PEAK FOR 1 WATT POWER INPUT ********
      PSQPK = PSQCOEF*FREFRCT*ETA*COFRAT(J)/(2.0*BETA1)
C  ******************************************************************


C  ****** START SORTING INTO REGIMES TO HANDLE ANGLES BEYOND PEAK ****
C
      COF = COFRAT(J)
      IREG = 0
      ETAC1 = 0.6*BETA1/(1.0-COFINV)
      IF(ETA.GT.ETAC1) THEN
      IREG = 1

C ********** REGION 1, SLOPE AT ARG=PI/2 USED TO PROJECT BEYOND PEAK

      EPS = 1.0/(BETA1*COF)+0.5/ETA
      EPSQ = EPS**2
      QNUM = 1.0+FMSQ1*EPSQ
      DEPDPSI = QNUM*SQRT(1.0-FM11*EPSQ)
      PSQRATC1 = (4.0/PI)**2*EPS*COFBETIN/(COFBETIN+EPS)**2
      FDEN = CFBTINSQ-EPSQ
      DPSQDPSI = (FDEN+4.0*EPSQ)*PSQRATC1*DEPDPSI/(EPS*FDEN)
      SINPSIC1 = EPS/SQRT(QNUM)
      PSIC = ASIN(SINPSIC1)*180.0/PI
      AC = ALOG(PSQRATC1)
      BC = 0.8889*DPSQDPSI/PSQRATC1
      BC = BC*PI/180.0
      CC = -0.1781*BC
      GO TO 50
      END IF

      ETAC2 = 0.6*BETA1*COF
      IF(ETA.GT.ETAC2) THEN
      IREG = 2
```

```
C ******** REGION 2, PSQratio AT ARG=-PI/2 USED TO FIT EXPONENTIAL FOR
C             USE BEYOND PEAK

      EPS = 1.0/(BETA1*COF)-0.5/ETA
      PSQRATC2 = (4.0/PI)**2*EPS*COFBETIN/(COFBETIN+EPS)**2
      EPSQ = EPS**2
      QDEN = 1.0+FMSQ1*EPSQ
      SINPSIC2 = EPS/SQRT(QDEN)
      PSIC2 = ASIN(SINPSIC2)*180.0/PI
      AC = ALOG(PSQRATC2)/(PSIPK1-PSIC2)**2
      GO TO 50
      END IF



C ******** REGION 3, LOW ETA REGION, PSIPK1>60 DEG. FIT EXPONENTIAL AT
C  0.5*PSIPK1 FOR USE BEYOND PEAK.  CODE IREG=3.  EXPONENTIAL EQUATION
C  USED IN PSQ SUBROUTINE FOR PSI > PSIPK1.

      IF(PSIPK1.GT.60.0) THEN

      IREG = 3

      ANGF = 0.5*PSIPK1
      ANGRAD = ANGF*PI/180.0
      SINF = SIN(ANGRAD)
      EPS = SINF/SQRT(1.0-FMSQ1*SINF**2)
      ARG = PI*ETA*(COFBETIN-EPS)
      SINARG = SIN(ARG)
      PSQRATC3 = 4.0*EPS*COFBETIN/(COFBETIN+EPS)**2
      PSQRATC3 = PSQRATC3*(SINARG/ARG)**2
      AC = ALOG(PSQRATC3)/(PSIPK1-ANGF)**2
      GO TO 50
      END IF

C ******** REGION 4, LOW ETA REGION, PSIPK1<60 DEG. FIT EXPONENTIAL AT
C  80 deg. FOR USE BEYOND PEAK.  CODE IREG=4.  EXPONENTIAL EQUATION
C  USED IN PSQ SUBROUTINE FOR PSI>80 deg.

      IREG = 4

      ANGF = 80.0
      ANGRAD = ANGF*PI/180.0
      SINF = SIN(ANGRAD)
      EPS = SINF/SQRT(1.0-FMSQ1*SINF**2)
      ARG = PI*ETA*(COFBETIN-EPS)
      SINARG = SIN(ARG)
      PSQRATC3 = 4.0*EPS*COFBETIN/(COFBETIN+EPS)**2
      PSQRATC3 = PSQRATC3*(SINARG/ARG)**2
      AC = ALOG(PSQRATC3)/(PSIPK1-ANGF)**2

   50 CONTINUE
C
C  ******** FINISHED WITH 4 REGION DEFINITIONS, START PSQ CALCULATION

      DO 25 I=1,NANGLE
      FI = I
      ANGDEG2 = ANGLE(I)
```

```
      IF(ANGDEG2.EQ.0.0.AND.ISIDELN.EQ.1) THEN
      PSQRADT(I) = 0.0
      PSQTOT(I) = 0.0
      PSQTLOS(I) = 0.0
      GO TO 25
      END IF
C
      ANGDEG1 = ANGDEG2–DELPSI
      ANG = ANGDEG1
      ANGRAD1 = ANGDEG1*PI/180.0
      IF(ANGDEG1.LT.0.0) GO TO 25
      SINANG = SIN(ANGRAD1)
      COSANG = COS(ANGRAD1)

      Q1DEN = SQRT(1.0–FMSQ1*SINANG**2)
      Q1 = SINANG/Q1DEN
      ARG = PI*ETA*(Q1–COFBETIN)
      SINSQNUM = (SIN(ARG))**2
      GG = (1.0+COSANG/Q1DEN)**2/GDEN
      PSQRAT = 4.0*Q1/(BETA1*COFRAT(J)*(Q1+COFBETIN)**2)

      PSQDEN = ARG**2
      ANGCK = PSIPK1+1.0
      IF(ANG.GT.ANGCK) GO TO 6
C  ********** CHECK FOR 0/0, USE LIMITING CASE IF INDETERMINATE ******
C  ********** DON’T CHECK IF ANGLE ABOVE PEAK ANGLE ******************
      IF(PSQDEN.LT.1.E–06) GO TO 39
    6 CONTINUE

      IF(ANG.LT.PSIPK1) GO TO 38
      IF(ANG.GE.PSIC.AND.IREG.EQ.1) THEN

C  ** FOLLOWING TO REMOVE THE P**2 OSCILLATIONS BEYOND THE PEAK ******
C  ** USES SLOPE AT ARG = PI/2 TO EXTRAPOLATE TO HIGH ANGLES *********
      DANG = ANG–PSIC
      QEXP = AC+BC*DANG/(1.0+CC*DANG)
      IF(QEXP.LT.–20.) QEXP=–20.

      PSQRAT = EXP(QEXP)
      GO TO 39
      END IF

      IF(ANG.GE.PSIPK1.AND.IREG.EQ.2) THEN

C  ** FOLLOWING TO REMOVE THE P**2 OSCILLATIONS BEYOND THE PEAK ********
C  ** USES EXPONENTIAL FIT AT ARG = –PI/2 TO EXTRAPOLATE TO HIGH ANGLES

      QEXP = AC*(ANG–PSIPK1)**2
      IF(QEXP.LT.–20.) QEXP=–20.

      PSQRAT = EXP(QEXP)
      GO TO 39
      END IF

      IF(ANG.GE.PSIPK1.AND.IREG.EQ.3) THEN

C  ** ONE OF THE LOW FREQUENCY REGIONS, REGION 3.  FOLLOWING ALLOWS
C  ** REASONABLE EXTRAPOLATION BEYOND 90 deg, STARTING AT PEAK.
C  ** USES EXPONENTIAL FIT AT PSI = PSIPK1 AND 0.5*PSIPK1. PSIPK1>60 deg

      QEXP = AC*(ANG–PSIPK1)**2
```

```
      IF(QEXP.LT.–20.) QEXP=–20.

      PSQRAT = EXP(QEXP)
      GO TO 39
      END IF

C  ** ONLY REGION LEFT, REGION 4, WITH PSIPK1<60 deg.
C  ** ONE OF THE LOW FREQUENCY REGIONS.  FOLLOWING ALLOWS REASONABLE
C  ** EXTRAPOLATION BEYOND 90 deg, STARTING THIS TIME AT 80 deg.
C  ** USES EXPONENTIAL FIT AT PSI = PSIPK1 AND 80 deg. PSIPK1<60 deg.

      IF(ANG.LT.80.0) GO TO 38

      QEXP = AC*(ANG–PSIPK1)**2
      IF(QEXP.LT.–20.) QEXP=–20.

      PSQRAT = EXP(QEXP)
      GO TO 39

   38 PSQRAT = PSQRAT*SINSQNUM/PSQDEN
   39 CONTINUE

      PSQ = PSQRAT*PSQPK*GG
      PSQRAD = PSQ
C
      RAD = DISTANCE
      IF(ISIDELN.EQ.1) THEN
      RAD = DISTANCE/SIN(ANGDEG2*PI/180.0)
      END IF

      PSQ = PSQ/RAD**2

C
      PSQRADT(I) = PSQRADT(I)+POWCOEF*PSQRAD
      PSQTOT(I) = PSQTOT(I)+POWCOEF*PSQ
      PSQTLOS(I) = PSQTLOS(I)+POWCOEF*PSQ*TLCF

C  ************ NOTE THAT A TRANMISSION LOSS (TLCF) HAS BEEN USED ****

   25 CONTINUE
   26 CONTINUE
      GO TO 70


   45 CONTINUE
C  ********** IN PLANE–WAVE CALCULATION PROCEDURE !!!!!!!!!!!!!!!!!!!!!!

      GDEN = 4.0

      IF(FMACH1.EQ.FMACH2) THEN
      DELPSI = 0.0
      GO TO 27
      END IF

      COSPK1 = 1.0
      ANGPK1 = 0.0
C  ******** GROUP VELOCITY VECTOR ANGLE IN REGION 1, PSIPK1 (DEGREES)
      PSIPK1 = 0.0
      SINPK1 = 0.0
C  ************ PHASE VELOCITY VECTOR ANGLE FOR PEAK IN REGION 1 (JET)
      SIN2 = SINPK1**2
```

```
      COSPHI1 = 1.0
      PHI1RAD = 0.0
      PHI1DEG = 0.0
      SINPHI1 = 0.0
C
C  ******************* PHASE VELOCITY ANGLE IN REGION 2 (SURROUNDINGS)

      COSPHI2 = 1.0/(CRAT+CRAT*FMACH1-FMACH2)
      PHI2RAD = ACOS(COSPHI2)
      PHI2DEG = PHI2RAD*180.0/PI
      SINPHI2 = SIN(PHI2RAD)
       COSPSI2 = (COSPHI2+FMACH2)/SQRT(1.0+FMSQ2+2.0*FMACH2*COSPHI2)
      PSI2RAD = ACOS(COSPSI2)
      PSI2DEG = PSI2RAD*180.0/PI
      SINPSI2 = SIN(PSI2RAD)

      Q22DEN = SQRT(1.0+FMSQ2+2.0*FMACH2*COSPHI2)

      COSPSPK2 = (COSPHI2+FMACH2)/Q22DEN
      ANGPK2 = ACOS(COSPSPK2)
      PSIPK2 = ANGPK2*180.0/PI

C  GROUP VELOCITY VECTOR ANGLE CHANGE, REG. 1 TO REG. 2, DELPSI (DEG.)
      DELPSI = PSIPK2-PSIPK1
C  ****************************************************************

C
   27 CONTINUE

C  ********** P**2 PRINCIPAL LOBE PEAK FOR 1 WATT POWER INPUT ********
      PSQPK = 2.0*PSQCOEFP
C  ****************************************************************

C  ** PSI10 BELOW IS SMALLEST ANGLE WHERE PLANE WAVE RADIATION, P**2=0
C  ** IF PSI10 > 90, PSI10 = 90 IS USED
      SINPSI10 = 1.0/SQRT(ETA**2+FMACH1**2)
      IF(SINPSI10.LT.1.0) THEN
      ANG10 = ASIN(SINPSI10)
      PSI10 = ANG10*180.0/PI
      COSPSI10 = COS(ANG10)
      GO TO 28
      END IF
      ANG10 = PI/2.0
      PSI10 = 90.0
      SINPSI10 = 1.0
      COSPSI10 = 0.0
   28 CONTINUE

C  ******* LOW ETA REGION. FIT EXPONENTIAL AT PSICRPL FOR BEYOND PEAK.
C  ******* IF PSICRPL < 90 CAN'T BE OBTAINED, USE PSICRPL = 90.
      ANGF = 90.0
      ETACRPL = 0.5*BETA1
      SINCRPL = 1.0/SQRT(4.0*ETA**2+FMACH1**2)
      IF(ETA.GT.ETACRPL) ANGF=ASIN(SINCRPL)*180./PI
      PSICRPL = ANGF
      ANGFRAD = ANGF*PI/180.0
      SINF = SIN(ANGFRAD)
      ARG = PI*ETA*SINF/SQRT(1.0-FMSQ1*SINF**2)
      SINARG = SIN(ARG)
      PSQRATPL = (SINARG/ARG)**2
```

```
      ACPL = ALOG(PSQRATPL)/ANGF**2
C ********** ACPL IS THE AMPLITUDE OF THE EXPONENTIAL AT PSICRPL *****
C ********** END LOW ETA REGION EXPONENTIAL FIT AT PSICRPL. **********
C  CALCULATE P**2 AMPLITUDE CHANGE DUE TO ANGLE SHIFT FROM PSI = 0 TO
C  PSI = PSIPK2 FOR THE PLANE WAVE PASSING THROUGH THE JET SHEAR LAYER
      PSQPKMUL = 1.0
      AREA1 = 1.0-COSPSI10
      AREA2 = 1.0+SINPSI2*SINPSI10-COSPSI2*COSPSI10
      IF(PSIPK2.GT.0.0.AND.PSI10.LT.PSIPK2) THEN
      AREA2 = 2.0*SINPSI2*SINPSI10
      END IF
      PSQPKMUL = AREA1/AREA2
      PSQPK = PSQPK*PSQPKMUL
      CKPSI0 = -PSI10
      SUMPSQ = 0.0
      DO 40 I=1,NANGLE
      FI = I
      ANGDEG2 = ANGLE(I)
      IF(ANGDEG2.EQ.0.0.AND.ISIDELN.EQ.1) THEN
      PSQRADT(I) = 0.0
      PSQTOT(I) = 0.0
      PSQTLOS(I) = 0.0
      GO TO 40
      END IF
C
      ANGRAD2 = ANGDEG2*PI/180.0
      ANGDEG1 = ANGDEG2-DELPSI
      ANGRAD1 = ANGDEG1*PI/180.0
      IF(ANGDEG1.LT.CKPSI0) GO TO 40
      SINANG = SIN(ANGRAD1)
      COSANG = COS(ANGRAD1)
      Q1DEN = SQRT(1.0-FMSQ1*SINANG**2)
      Q1 = SINANG/Q1DEN
      ARG = PI*ETA*Q1
      SINSQNUM = (SIN(ARG))**2
      GG = (1.0+COSANG/Q1DEN)**2/GDEN
      PSQRAT = 1.0
      PSQDEN = ARG**2
      IF(PSQDEN.LT.1.E-06.AND.ANGDEG1.LE.90.0) GO TO 49
C  ** LOW FREQUENCY REGION.  FOLLOWING ALLOWS REASONABLE
C  ** EXTRAPOLATION BEYOND 90 deg, STARTING AT ARG = PI/2 IF ETA>ETAcrit
C  ** OR AT 90 deg. OTHERWISE.  USES EXPONENTIAL FIT AT PSI = PSIPK1
C  ** AND PSI = PSIFIT.
      IF(ANGDEG1.LT.PSICRPL) GO TO 48
      QEXP = ACPL*(ANGDEG1)**2
```

```
      IF(QEXP.LT.-20.) QEXP=-20.

      PSQRAT = EXP(QEXP)
      GO TO 49


   48 PSQRAT = PSQRAT*SINSQNUM/PSQDEN
   49 CONTINUE

      PSQ = PSQRAT*PSQPK*GG

      PSQRAD = PSQ
C
      RAD = DISTANCE
      IF(ISIDELN.EQ.1) THEN
      RAD = DISTANCE/SIN(ANGDEG2*PI/180.0)
      END IF

      PSQ = PSQ/RAD**2

C
      PSQRADT(I) = PSQRADT(I)+POWCOEF*PSQRAD
      PSQTOT(I) = PSQTOT(I)+POWCOEF*PSQ
      PSQTLOS(I) = PSQTLOS(I)+POWCOEF*PSQ*TLCF

C  ************ NOTE THAT A TRANMISSION LOSS (TLCF) HAS BEEN USED ****

   40 CONTINUE
   41 CONTINUE
C
   70 CONTINUE

      FNANGLE = NANGLE
      SUMWATT = 0.0
      DO 75 I=1,NANGLE
      ANGRAD = ANGLE(I)*PI/180.0
      SUMWATT = SUMWATT+PSQRADT(I)*SIN(ANGRAD)

C  ** CONVERTING TO ANGLE FROM INLET AXIS FOR THIS AFT RADIATED NOISE **

      ANGLE(I) = 180.0-ANGLE(I)
      IF(PSQTOT(I).LT.4.E-08) THEN
      SPLTL(I) = 20.0
      SPL(I) = 20.0
      GO TO 75
      END IF
      SPLTL(I) = 10.0*ALOG10(PSQTLOS(I))+93.9794
      SPL(I) = 10.0*ALOG10(PSQTOT(I))+93.9794
   75 CONTINUE

      WATTINT = SUMWATT*PI/(POWCON*FNANGLE)
      SPLDIF = 10.0*ALOG10(WATTS/WATTINT)

      DO 80 I=1,NANGLE
      SPLTL(I) = SPLTL(I)+SPLDIF
      SPL(I) = SPL(I)+SPLDIF
   80 CONTINUE


      RETURN
      END
```

```
C
C  ******************************************************************
C  ********** END OF MAIN SUBROUTINE "BBRDCFEX" *********************
C  ********** ALTERED 02/19/1998, E. J. RICE ************************
C  ******************************************************************
C
C
C******************************************************************
C  ** SUBROUTINE FOR CALC NOZZLE CONDITIONS, FINAL JET MACH NUMBER,
C  VELOCITY, AND DIAMETER.  ** NOTE ** OUTER DIAM CHANGES FOR NOZZLE.
C
      SUBROUTINE CONOZ(TTOT,PTOT,PSTS,HTRAT,ANOZRAT,DDUCT,FMACHD,FMACH1
     1,CJET,DJET,TJET,PNOZ,DNOZ,CNOZ,FMACHN)

C
      PI = 3.1415927
      QM = 1.0+0.2*FMACHD**2
      DIN = DDUCT*HTRAT
      ADUCT = PI*(DDUCT**2-DIN**2)/4.0
      ANOZ = ADUCT*ANOZRAT
      DNOZ = SQRT(4.0*ANOZ/PI+DIN**2)
      TDUCT = TTOT/QM
      VSOND = 49.0421*SQRT(TDUCT)
      VDUCT = FMACHD*VSOND
      RHOT = 144.0*PTOT/(53.3*TTOT)
      RHOD = RHOT/QM**2.5
      FMASS = RHOD*ADUCT*VDUCT
C  *********************** NOTE - AREAS ARE IN SQUARE INCHES ********
C
C  **************** SOLVE FOR NOZZLE MACH NUMBER ********************
C
      QQDUCT = FMACHD/QM**3/ANOZRAT
      FN = 1.0
      DIFP = FN/(1.0+0.2*FN**2)**3-QQDUCT
      FNP = 1.0

      DO 10 I=1,50
      FN = 0.975*FN
      DIF = FN/(1.0+0.2*FN**2)**3-QQDUCT
C       WRITE(3,100) I,FN,DIF
C  100 FORMAT(/,' I=',I2,' FN=',F7.4,' DIF=',1PE9.2)
      IF(DIF.LE.0.0) GO TO 12
      FNP = FN
      DIFP = DIF
   10 CONTINUE
      FN = QQDUCT
  111 DO 11 I=1,10
      FN = QQDUCT*(1.0+0.2*FN**2)**3
C       WRITE(3,102) I,FN
C  102 FORMAT(/,' REFINED, I=',I2,' FN=',F7.4)

   11 CONTINUE
      GO TO 14
   12 CONTINUE
      FN = (DIFP*FN-DIF*FNP)/(DIFP-DIF)
C       WRITE(3,101) FN
C  101 FORMAT(/,' INTERPOLATED FN =',F7.4)

```

```
      GO TO 111
   14 CONTINUE
      FMACHN = FN
C       WRITE(3,103) FMACHN
C  103 FORMAT(/,' FINAL ********** FMACHN =',F7.4)

C  ****************************** "FMACH1" FINAL JET VELOCITY ********

      FMACH1 = SQRT(5.0*((PTOT/PSTS)**(2./7.)-1.0))
      QNTJ = 1.0+0.2*FMACH1**2
      TJET = TTOT/QNTJ
      RHOJ = RHOT/QNTJ**2.5
      CJET = 49.0421*SQRT(TJET)
      VJET = CJET*FMACH1
      AJET = FMASS/(RHOJ*VJET)
      DJET = SQRT(4.0*AJET/PI+DIN**2)

C ** FOLLOWING NOT USED HERE BUT MIGHT BE HANDY FOR LATER USE ********
C ** CHECK NOZZLE THROAT PRESSURE VRS. SURROUNDING AMBIENT PRESSURE *
      QMN =  1.0/(1.0+0.2*FMACHN**2)
      PNOZ = PTOT*QMN**3.5
      TNOZ = TTOT*QMN
      CNOZ = 49.0421*SQRT(TNOZ)
      RETURN
      END
```

```
C
C  ******************************************************************
C  ****************** END OF SUBROUTINE "CONOZ" *******************
C  ******************************************************************

      FUNCTION SINH(X)
      SINH    = (EXP(X)-EXP(-X))/2.
      RETURN
      END
```

```
      FUNCTION TANH(X)
      TX      = 2.*X
      ETX     = EXP(-TX)
      TANH    = (1.-ETX)/(1.+ETX)
      RETURN
      END
```

```
      FUNCTION ARCSECH(X)
      RX      =1./X
      TRM     = SQRT(RX**2-1.)
      ARCSECH = ALOG(RX+TRM)
      RETURN
      END
```

```
      FUNCTION COTH(X)
      COTH    = 1./TANH(X)
      RETURN
      END
```

```
      FUNCTION U1(X)
      X3      = X**3
      U1      = (3.*X-5.*X3)/24.
      RETURN
      END
```

```
      FUNCTION U2(X)
      X2      = X**2
      X4      = X2**2
      X6      = X2*X4
      U2      = (81.*X2-462.*X4+385.*X6)/1152.
      RETURN
      END
```

```
      FUNCTION V1(X)
      X3      = X**3
      V1      = (-9.*X+7.*X3)/24.
      RETURN
      END
```

```
      FUNCTION V2(X)
      X2      = X**2
      X4      = X2**2
      X6      = X2*X4
      V2      = (-135.*X2+594.*X4-455.*X6)/1152.
      RETURN
      END
```

```
      SUBROUTINE ABESJ ( ARG,ORD,BESJ )
      IF ( ARG.GE.ORD ) PRINT *,'ARG.GE.ORD-ABESJ NOT APPLICABLE'
      IF ( ARG.GE.ORD ) GO TO 100
      PI      = 3.14159265
      ORD2    = ORD**2
      SECHAL  = ARG/ORD
      AL      = ARCSECH(SECHAL)
      TANHAL  = TANH(AL)
      COTHAL  = 1./TANHAL
      RNUMJ   = EXP(ORD*(TANHAL-AL))
      DENJ    = SQRT(2.*PI*ORD*TANHAL)
      BESJ    = (RNUMJ/DENJ)*(1.+U1(COTHAL)/ORD+U2(COTHAL)/ORD2)
  100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ABESY ( ARG,ORD,BESY,RBESY )
      IF ( ARG.GE.ORD ) PRINT *,'ARG.GE.ORD-ABESY NOT APPLICABLE'
      IF ( ARG.GE.ORD ) GO TO 100
      PI      = 3.14159265
      ORD2    = ORD**2
      SECHAL  = ARG/ORD
      AL      = ARCSECH(SECHAL)
      TANHAL  = TANH(AL)
      COTHAL  = 1./TANHAL
      RNUMJ   = EXP(ORD*(TANHAL-AL))
      DENJ    = SQRT(2.*PI*ORD*TANHAL)
```

```
      BESJ    = (RNUMJ/DENJ)*(1.+U1(COTHAL)/ORD+U2(COTHAL)/ORD2)
      ABESJ   = ABS(BESJ)
      IF ( ABESJ.LE.1.E–36 ) GO TO 90
      RNUMY   = –1./RNUMJ
      DENY    = 0.5*DENJ
      BESY    = (RNUMY/DENY)*(1.–U1(COTHAL)/ORD+U2(COTHAL)/ORD2)
      RBESY   = 1./BESY
      GO TO 100
   90   BESY    = –1.E+36
      RBESY   = 0.00
  100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ABESJD ( ARG,ORD,BESJD )
      IF ( ARG.GE.ORD ) PRINT *,'ARG.GE.ORD–ABESJD NOT APPLICABLE'
      IF ( ARG.GE.ORD ) GO TO 100
      PI      = 3.14159265
      ORD2    = ORD**2
      SECHAL  = ARG/ORD
      AL      = ARCSECH(SECHAL)
      TANHAL  = TANH(AL)
      COTHAL  = 1./TANHAL
      RNUMJ   = SQRT(SINH(2.*AL))*EXP(ORD*(TANHAL–AL))
      DENJ    = SQRT(4.*PI*ORD)
      BESJD   = (RNUMJ/DENJ)*(1.+V1(COTHAL)/ORD+V2(COTHAL)/ORD2)
  100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ARBESYD ( ARG,ORD,RBESYD )
      IF ( ARG.GE.ORD ) PRINT *,'ARG.GE.ORD–ABESJY NOT APPLICABLE'
      IF ( ARG.GE.ORD ) GO TO 100
      PI      = 3.14159265
      ORD2    = ORD**2
      SECHAL  = ARG/ORD
      AL      = ARCSECH(SECHAL)
      TANHAL  = TANH(AL)
      COTHAL  = 1./TANHAL
      RNUMJ   = SQRT(SINH(2.*AL))*EXP(ORD*(TANHAL–AL))
      DENJ    = SQRT(4.*PI*ORD)
      BESJD   = (RNUMJ/DENJ)*(1.+V1(COTHAL)/ORD+V2(COTHAL)/ORD2)
      ABESJD  = ABS(BESJD)
      IF ( ABESJD.LE.1.E–36 ) GO TO 90
      RNUMY   = SQRT(SINH(2.*AL))*EXP(ORD*(AL–TANHAL))
      DENY    = 0.5*DENJ
      BESYD   = (RNUMY/DENY)*(1.–V1(COTHAL)/ORD+V2(COTHAL)/ORD2)
      RBESYD  = 1./BESYD
      GO TO 100
   90   BESYD   = 1.E+36
      RBESYD  = 0.00
  100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ABESYR ( A1,A2,ORD,RES )
      IF ( A1.GE.ORD ) PRINT *,'1ST ARG.GE.ORD–ABESYR ',
```

```
     &                           'NOT APPLICABLE'
      IF ( A1.GE.ORD ) GO TO 100
      IF ( A2.GE.ORD ) PRINT *,'2ND ARG.GE.ORD-ABESYR ',
     &                           'NOT APPLICABLE'
      IF ( A2.GE.ORD ) GO TO 100
      PI      = 3.14159265
      ORD2    = ORD**2
      SECHAL1 = A1/ORD
      AL1     = ARCSECH(SECHAL1)
      TANHAL1 = TANH(AL1)
      COTHAL1 = 1./TANHAL1
      SECHAL2 = A2/ORD
      AL2     = ARCSECH(SECHAL2)
      TANHAL2 = TANH(AL2)
      COTHAL2 = 1./TANHAL2
      SINH2AL2= SINH(2.*AL2)
      EXPON   = -ORD*((AL2-TANHAL2)-(AL1-TANHAL1))
      DEN     = -SQRT(TANHAL1*SINH2AL2/2.)
      SRAT    = (1.-U1(COTHAL1)/ORD+U2(COTHAL1)/ORD2)/
     &            (1.-V1(COTHAL2)/ORD+V2(COTHAL2)/ORD2)
      RES     = EXP(EXPON)*SRAT/DEN
  100   CONTINUE
      RETURN
      END
```

2.2.3.5 Sample Run Program STATOR

Current code name is SDIRFIN. To run the program first move to the directory that the code executable file resides in, then invoke the program by typing after the system prompt. From a Unix system type "program_name." From a VAX system type "run program_name." A typical run will look like this:

prompt> **sdirfin**
Enter input file name : **bbn_input.dat**
Enter output file name : **stator_power.dat**
Enter 2nd output file name: **stator_debug.dat**
Enter spl plot output file name: **stator_spl.dat**
prompt>

2.2.3.6 Sample Input File

```
$Input
 RPM = 9782.2
 RHO = 0.079005
 DTIP =       22
 HTR = 0.43
 NBLADE =     22
 NSTR =       12
 NVANE =      54
 GAM = 1.4
 KASE =       1
 LINLET =     0.99
 LEXIT =      1.99
 IABSOR =     0
 NBSTD =      22
 SCLOPTR =    4
```

```
 SCLOPTS =    2
 NHM = 10
 BW =         0
 NF =         11
 NTOBNI =     7
 NCOF =       15
 RADMIC =     20
 ISIDELN =    1
 ALIP =       5.558
 BLIP =       1.05
 MACHS =      0.2
 ANOZRAT =    0.6875
 ETAFAN =     0.920
 DELANG =     10.0
 ITL = 1
 TOBN =       36  37  38  39  40  41  42  43  44  45  46
 SEMA =       0.418,0.422,0.428,0.436,0.444,0.450,0.453,0.454,0.451,0.447,0.443,0.438,
 SPERC =      4.77, 5.23, 5.77, 6.44, 7.32, 8.54,10.32, 9.00, 9.41,.63, 6.77, 6.77,
SINCDR =      11.84,20.04,24.57,29.37,32.30,32.08,34.45,35.49,34.85,32.70,30.83,27.32,
 SATIR =      0.095,0.002,0.001,0.001,0.001,0.001,0.001,0.001,0.001,.001,0.001,0.001,
SATIS =       0.081,0.021,0.018,0.021,0.023,0.023,0.022,0.018,0.016,.013,0.012,0.024,
SELINR =      12*0.110,
 SELINS =     0.128,0.063,0.064,0.067,0.072,0.075,0.092,0.091,0.126,0.132,0.119,0.106,
 SEMT =       0.81608 0.78311 0.74889 0.71207 0.67321 0.63208,
               .58778 0.53878 0.50051 0.46351 0.43564 0.41233
SCO =  1138.1  1132.5  1130.2  1129.9  1129.2  1127.8
              .1  1124.4  1122.8  1121.3  1120.3  1119
STHETA =      0.28304 0.29918 0.32337 0.35848 0.39996 0.44971
              .51579 0.61069 0.70143 0.81039 0.90401 0.99027
SAXSP =       1.4713  1.4837  1.5001  1.5247  1.5563  1.5928
              .6373  1.6972  1.7526  1.8172  1.8753  1.9333
SROTCD =      0.06511    0.036664   0.016138   0.01422    0.012293   0.0066824
              .0019007  0.0026553  0.0013424  0.0013326  0.0069932  0.01341
SSADIN =      12.289  11.351  11.008  11.028  11.187  11.454
              .877  12.526  13.033  13.539  13.868  14.172
SCHDR =       4.227   4.124   4.020   3.911   3.794   3.675
              .546   3.399   3.285   3.176   3.096   3.028
SCHDS =       1.839   1.886   1.921   1.947   1.964   1.970
              .964   1.944   1.919   1.888   1.861   1.837
STPRIN =      1.344   1.363   1.365   1.355   1.339   1.321
              .299   1.271   1.252   1.235   1.223   1.214
SDIA = 21.988  20.939  19.844  18.699  17.494  16.214
              .829  13.298  12.101  10.962  10.126  9.440
SSTATCD =     0.02    0.02    0.02    0.02    0.02    0.02
              .02    0.02    0.02    0.02    0.02    0.02
SINCDS =      1  1  1  1  1  1  1  1  1  1  1  1
 SATIW =      0.1     0.1     0.1     0.1     0.1     0.1
              .1     0.1     0.1     0.1     0.1     0.1
SCONTR =      1  1  1  1  1  1  1  1  1  1  1  1
 SCONTS =     1  1  1  1  1  1  1  1  1  1  1  1
 SCONTW =     1  1  1  1  1  1  1  1  1  1  1  1
 SELINW =     0.1     0.1     0.1     0.1     0.1     0.1
              .1     0.1     0.1     0.1     0.1     0.1
SSCLR =       1  1  1  1  1  1  1  1  1  1  1  1
 SSCLS =      1  1  1  1  1  1  1  1  1  1  1  1
 SSCLW =      1  1  1  1  1  1  1  1  1  1  1  1
 STVELR =     1  1  1  1  1  1  1  1  1  1  1  1
 STVELS =     1  1  1  1  1  1  1  1  1  1  1  1
 STVELW =     1  1  1  1  1  1  1  1  1  1  1  1
$
```

2.2.3.7 Sample Output Files

The STATOR power and directivity output files are shown in the following sections. The debug output file is not listed.

2.2.3.7.1 Power Output File from STATOR

```
       HARD WALL ASSUMED
 MICROPHONE IS ON A SIDELINE
  MICROPHONE DISTANCE IN FEET IS =    20.00000
  MACH NUMBER OF SURROUNDING MEDIUM =   0.2000000
 ESTIMATED FAN ADIABATIC EFFICIENCY =   0.9200000

               PROGRAM *** STATIN ***

            RESPONSE OF AN ISOLATED OGV LIKE STATOR

           TO INGESTION OF INLET TURBULENCE

               CASE NUMBER   1   OF   1

***** STRIP AREA NUMBER    1  WWND = 1.0000

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.418    0.816   0.0810     1.00   1.000   0.13

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1138.   21.988   4.770    1.344

     RPM         NB     NBSTD    HTR    DTIP      CHDR
   9782.2        22       22    0.430  22.000    4.227

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.418     1.00   1.0000    0.128   0.0810    3.409

                              NB    NS
                              22    54

   CDROTOR =   6.5109998E-02
  INLET LENGTH/TIP DIAMETER =   0.9900000

 STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT=  2

   *** COMPONENT PWL CONTRIBUTIONS  -  DB RE 10**(-13) WATTS ***

                      ONE THIRD OCTAVE

     FREQUENCY        DIPOLE        QUADRUPOLE        TOTAL
   HERTZ   F/BPF   INLET EXHAUST   INLET EXHAUST   INLET EXHAUST
    3981  1.1099    93.4   108.2    97.4   109.2    98.9   111.7
    5011  1.3973    94.2   109.3   100.3   112.6   101.2   114.3
    6309  1.7591    91.7   107.7   100.4   113.4   100.9   114.4
    7943  2.2146    86.6   102.7    99.0   112.1    99.2   112.6
   10000  2.7880    84.4   100.2   100.0   112.9   100.1   113.1
   12589  3.5099    84.5   101.1    99.4   112.4    99.5   112.7
   15848  4.4187    82.4    99.5    98.5   111.8    98.6   112.0
   19952  5.5628    76.8    94.5    96.7   110.7    96.8   110.8
   25118  7.0031    71.9    90.6    93.2   108.0    93.2   108.1
   31622  8.8164    63.1    84.3    87.2   104.9    87.3   104.9
   39810 11.0992    61.5    80.5    86.0   101.8    86.0   101.9
```

```
***** STRIP AREA NUMBER    2  WWND = 1.0000

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.422    0.783   0.0210     1.00   1.000   0.06

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1133.   20.939   5.230    1.363

     RPM        NB     NBSTD    HTR    DTIP      CHDR
   9782.2       22        22    0.430  22.000    4.124

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.422     1.00   1.0000    0.063   0.0210    3.324

                              NB    NS
                              22    54

   CDROTOR =   3.6664002E-02
  INLET LENGTH/TIP DIAMETER =   0.9900000

 STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT=  2

   *** COMPONENT PWL CONTRIBUTIONS  -  DB RE 10**(-13) WATTS ***

                       ONE THIRD OCTAVE

     FREQUENCY        DIPOLE        QUADRUPOLE        TOTAL
   HERTZ   F/BPF   INLET EXHAUST   INLET EXHAUST   INLET EXHAUST
    3981  1.1099    79.6    93.7    85.3    96.6    86.3    98.4
    5011  1.3973    79.1    93.5    87.4    98.6    88.0    99.8
    6309  1.7591    78.1    93.2    90.3   101.8    90.6   102.4
    7943  2.2146    76.2    91.6    92.1   103.7    92.2   104.0
   10000  2.7880    72.5    88.6    90.9   103.1    91.0   103.2
   12589  3.5099    74.0    89.4    91.9   103.8    92.0   104.0
   15848  4.4187    71.5    88.0    90.9   103.2    91.0   103.3
   19952  5.5628    66.1    82.7    89.6   102.1    89.6   102.2
   25118  7.0031    61.9    79.7    86.4   100.1    86.4   100.2
   31622  8.8164    53.6    73.0    81.0    96.4    81.0    96.4
   39810 11.0992    51.8    69.3    79.4    93.7    79.4    93.7

***** STRIP AREA NUMBER    3  WWND = 1.0000

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.428    0.749   0.0180     1.00   1.000   0.06

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1130.   19.844   5.770    1.365

     RPM        NB     NBSTD    HTR    DTIP      CHDR
   9782.2       22        22    0.430  22.000    4.020

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.428     1.00   1.0000    0.064   0.0180    3.264

                              NB    NS
                              22    54

   CDROTOR =   1.6138000E-02
  INLET LENGTH/TIP DIAMETER =   0.9900000

 STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT=  2
```

*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(–13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL	
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST
3981	1.1099	80.3	95.0	87.3	98.5	88.1	100.1
5011	1.3973	78.1	93.4	87.3	98.7	87.8	99.8
6309	1.7591	77.1	91.1	88.8	99.3	89.1	99.9
7943	2.2146	74.4	88.8	90.8	101.3	90.9	101.6
10000	2.7880	74.2	89.0	93.1	103.6	93.1	103.7
12589	3.5099	74.3	89.4	92.7	103.6	92.8	103.8
15848	4.4187	71.2	86.9	91.0	102.5	91.1	102.6
19952	5.5628	66.7	82.5	90.8	102.1	90.8	102.2
25118	7.0031	62.5	79.5	87.3	99.8	87.4	99.8
31622	8.8164	55.4	73.2	83.1	96.6	83.1	96.6
39810	11.0992	52.1	69.3	80.2	94.1	80.2	94.1

***** STRIP AREA NUMBER 4 WWND = 1.0000

EMA	EMTIP	TI	SINCD	CONTR	L/SSTD
0.436	0.712	0.0210	1.00	1.000	0.07

GAM	RHO	C	SDIA	SPERC	TPR
1.400	0.0790	1130.	18.699	6.440	1.355

RPM	NB	NBSTD	HTR	DTIP	CHDR
9782.2	22	22	0.430	22.000	3.911

EMR	RSCAL	RVEL	ELT	TIT	AR
0.436	1.00	1.0000	0.067	0.0210	3.220

NB	NS
22	54

CDROTOR = 1.4220000E–02
INLET LENGTH/TIP DIAMETER = 0.9900000

STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT= 2

*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(–13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL	
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST
3981	1.1099	84.1	97.8	92.2	102.2	92.9	103.6
5011	1.3973	83.8	97.2	94.0	103.9	94.4	104.8
6309	1.7591	81.4	95.6	94.5	104.8	94.7	105.3
7943	2.2146	78.0	92.1	94.7	104.9	94.8	105.2
10000	2.7880	75.5	90.0	94.1	104.3	94.2	104.5
12589	3.5099	76.3	90.8	94.5	104.6	94.6	104.8
15848	4.4187	75.1	89.7	95.8	105.8	95.9	105.9
19952	5.5628	70.8	85.9	95.4	105.7	95.4	105.7
25118	7.0031	66.7	83.0	91.9	103.3	91.9	103.3
31622	8.8164	60.3	77.0	88.3	100.5	88.3	100.5
39810	11.0992	55.9	72.7	84.9	97.4	84.9	97.4

```
***** STRIP AREA NUMBER    5  WWND = 1.0000

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.444    0.673   0.0230     1.00   1.000   0.07

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1129.   17.494   7.320    1.339

     RPM        NB     NBSTD    HTR    DTIP      CHDR
   9782.2       22       22    0.430  22.000    3.794

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.444     1.00   1.0000    0.072   0.0230    3.192

                              NB    NS
                              22    54

   CDROTOR =   1.2293000E-02
  INLET LENGTH/TIP DIAMETER =   0.9900000

 STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT=  2

   *** COMPONENT PWL CONTRIBUTIONS  -  DB RE 10**(-13) WATTS ***

                       ONE THIRD OCTAVE

     FREQUENCY        DIPOLE        QUADRUPOLE        TOTAL
   HERTZ   F/BPF   INLET EXHAUST   INLET EXHAUST   INLET EXHAUST
    3981  1.1099    87.1    99.5    95.1   103.9    95.7   105.3
    5011  1.3973    86.7    99.8    97.1   106.2    97.5   107.1
    6309  1.7591    85.1    98.1    98.9   108.0    99.1   108.5
    7943  2.2146    82.5    96.0   100.2   109.4   100.3   109.6
   10000  2.7880    81.3    95.0   101.0   110.3   101.0   110.4
   12589  3.5099    81.9    96.0   101.2   110.6   101.2   110.8
   15848  4.4187    79.3    93.8   100.6   110.3   100.7   110.4
   19952  5.5628    74.3    89.2    99.2   109.2    99.3   109.2
   25118  7.0031    71.2    86.7    96.7   107.1    96.7   107.2
   31622  8.8164    64.9    81.1    93.1   104.3    93.1   104.4
   39810 11.0992    60.2    76.5    89.9   101.5    89.9   101.5

***** STRIP AREA NUMBER    6  WWND = 1.0000

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.450    0.632   0.0230     1.00   1.000   0.08

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1128.   16.214   8.540    1.321

     RPM        NB     NBSTD    HTR    DTIP      CHDR
   9782.2       22       22    0.430  22.000    3.675

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.450     1.00   1.0000    0.075   0.0230    3.183

                              NB    NS
                              22    54

   CDROTOR =   6.6824001E-03
  INLET LENGTH/TIP DIAMETER =   0.9900000

 STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT=  2
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*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(–13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL	
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST
3981	1.1099	87.2	99.5	94.8	103.0	95.5	104.6
5011	1.3973	86.5	99.1	97.0	105.3	97.4	106.2
6309	1.7591	85.2	98.1	99.0	107.3	99.1	107.8
7943	2.2146	82.9	95.9	100.6	109.0	100.6	109.2
10000	2.7880	82.1	95.5	101.7	110.2	101.7	110.3
12589	3.5099	83.3	96.8	102.5	111.1	102.5	111.2
15848	4.4187	81.5	95.3	102.9	111.6	103.0	111.7
19952	5.5628	78.2	92.3	103.1	111.9	103.2	112.0
25118	7.0031	77.4	91.7	103.1	112.0	103.2	112.1
31622	8.8164	74.6	89.1	103.0	112.0	103.0	112.0
39810	11.0992	72.3	87.0	102.7	111.8	102.7	111.8

***** STRIP AREA NUMBER 7 WWND = 1.0000

EMA	EMTIP	TI	SINCD	CONTR	L/SSTD
0.453	0.588	0.0220	1.00	1.000	0.09

GAM	RHO	C	SDIA	SPERC	TPR
1.400	0.0790	1126.	14.829	10.320	1.299

RPM	NB	NBSTD	HTR	DTIP	CHDR
9782.2	22	22	0.430	22.000	3.546

EMR	RSCAL	RVEL	ELT	TIT	AR
0.453	1.00	1.0000	0.092	0.0220	3.192

NB	NS
22	54

CDROTOR = 1.9007000E–03
INLET LENGTH/TIP DIAMETER = 0.9900000

STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT= 2

*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(–13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL	
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST
3981	1.1099	86.3	98.4	93.5	101.0	94.2	102.9
5011	1.3973	86.5	98.4	95.7	103.1	96.2	104.4
6309	1.7591	84.6	96.8	97.2	104.7	97.4	105.3
7943	2.2146	82.0	94.5	98.4	105.9	98.5	106.2
10000	2.7880	80.9	94.0	99.1	106.7	99.2	106.9
12589	3.5099	81.9	95.1	99.5	107.2	99.6	107.4
15848	4.4187	79.6	93.3	99.6	107.3	99.6	107.5
19952	5.5628	75.9	90.2	99.4	107.2	99.4	107.3
25118	7.0031	74.9	89.9	99.0	107.0	99.0	107.1
31622	8.8164	71.7	87.1	98.5	106.6	98.6	106.6
39810	11.0992	69.2	85.0	98.0	106.0	98.0	106.1

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***** STRIP AREA NUMBER    8  WWND = 1.0000

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.454    0.539   0.0180     1.00   1.000   0.09

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1124.   13.298   9.000    1.271

     RPM         NB     NBSTD    HTR    DTIP      CHDR
   9782.2        22       22    0.430  22.000    3.399

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.454     1.00   1.0000    0.091   0.0180    3.225

                               NB    NS
                               22    54

   CDROTOR =   2.6553001E-03
  INLET LENGTH/TIP DIAMETER =   0.9900000

 STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT=  2

   *** COMPONENT PWL CONTRIBUTIONS  -  DB RE 10**(-13) WATTS ***

                       ONE THIRD OCTAVE
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FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL	
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST
3981	1.1099	80.9	92.0	87.3	94.0	88.2	96.1
5011	1.3973	80.3	92.0	89.3	96.0	89.8	97.4
6309	1.7591	78.6	90.4	91.1	97.8	91.4	98.6
7943	2.2146	76.4	88.1	92.4	99.2	92.5	99.5
10000	2.7880	75.7	87.9	93.4	100.3	93.5	100.5
12589	3.5099	76.9	88.9	94.0	100.9	94.1	101.1
15848	4.4187	74.3	86.8	94.1	101.1	94.2	101.3
19952	5.5628	71.1	83.8	94.1	101.2	94.1	101.3
25118	7.0031	69.9	82.7	93.8	101.0	93.8	101.1
31622	8.8164	66.8	80.0	93.4	100.6	93.4	100.7
39810	11.0992	64.3	77.8	92.8	100.1	92.8	100.1

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***** STRIP AREA NUMBER    9  WWND = 1.0000

     EMA     EMTIP      TI     SINCD   CONTR  L/SSTD
    0.451    0.501   0.0160     1.00   1.000   0.13

     GAM     RHO        C      SDIA    SPERC      TPR
    1.400   0.0790    1123.   12.101   9.410    1.252

     RPM         NB     NBSTD    HTR    DTIP      CHDR
   9782.2        22       22    0.430  22.000    3.285

     EMR     RSCAL    RVEL      ELT      TIT      AR
    0.451     1.00   1.0000    0.126   0.0160    3.267

                               NB    NS
                               22    54

   CDROTOR =   1.3424000E-03
  INLET LENGTH/TIP DIAMETER =   0.9900000

 STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT=  2
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*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(–13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL	
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST
3981	1.1099	79.2	90.2	85.3	91.7	86.3	94.0
5011	1.3973	78.4	89.3	86.6	92.9	87.2	94.5
6309	1.7591	76.8	88.2	87.9	94.2	88.2	95.1
7943	2.2146	74.3	85.9	89.0	95.2	89.1	95.7
10000	2.7880	74.0	85.3	89.8	96.0	89.9	96.3
12589	3.5099	74.6	86.1	89.9	96.3	90.0	96.7
15848	4.4187	71.8	83.8	89.9	96.4	89.9	96.6
19952	5.5628	68.6	80.6	89.8	96.4	89.8	96.5
25118	7.0031	67.1	79.3	89.3	96.0	89.4	96.1
31622	8.8164	64.1	76.4	88.8	95.6	88.9	95.7
39810	11.0992	61.5	74.0	88.2	95.1	88.3	95.1

***** STRIP AREA NUMBER 10 WWND = 1.0000

EMA	EMTIP	TI	SINCD	CONTR	L/SSTD
0.447	0.464	0.0130	1.00	1.000	0.13

GAM	RHO	C	SDIA	SPERC	TPR
1.400	0.0790	1121.	10.962	7.630	1.235

RPM	NB	NBSTD	HTR	DTIP	CHDR
9782.2	22	22	0.430	22.000	3.176

EMR	RSCAL	RVEL	ELT	TIT	AR
0.447	1.00	1.0000	0.132	0.0130	3.321

NB	NS
22	54

CDROTOR = 1.3326000E–03
INLET LENGTH/TIP DIAMETER = 0.9900000

STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT= 2

*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(–13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL	
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST
3981	1.1099	75.2	86.3	80.9	86.7	81.9	89.5
5011	1.3973	73.8	84.8	82.1	88.0	82.7	89.7
6309	1.7591	70.9	82.1	82.9	88.8	83.1	89.7
7943	2.2146	68.0	79.0	83.3	89.3	83.4	89.7
10000	2.7880	67.8	79.3	83.4	89.6	83.5	90.0
12589	3.5099	69.3	81.2	84.1	90.1	84.2	90.6
15848	4.4187	66.7	78.7	84.4	90.4	84.4	90.7
19952	5.5628	64.0	76.1	84.5	90.6	84.6	90.7
25118	7.0031	62.2	74.5	84.1	90.3	84.2	90.4
31622	8.8164	59.3	71.5	83.7	90.0	83.7	90.0
39810	11.0992	56.6	68.8	83.1	89.5	83.1	89.5

***** STRIP AREA NUMBER 11 WWND = 1.0000

EMA	EMTIP	TI	SINCD	CONTR	L/SSTD
0.443	0.436	0.0120	1.00	1.000	0.12

GAM	RHO	C	SDIA	SPERC	TPR
1.400	0.0790	1120.	10.126	6.770	1.223

RPM	NB	NBSTD	HTR	DTIP	CHDR
9782.2	22	22	0.430	22.000	3.096

EMR	RSCAL	RVEL	ELT	TIT	AR
0.443	1.00	1.0000	0.119	0.0120	3.369

NB	NS
22	54

CDROTOR = 6.9932002E-03
INLET LENGTH/TIP DIAMETER = 0.9900000

STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT= 2

*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(-13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL	
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST
3981	1.1099	72.7	83.5	78.1	83.4	79.2	86.4
5011	1.3973	71.9	83.0	80.0	85.3	80.7	87.3
6309	1.7591	70.0	81.1	81.4	86.7	81.7	87.8
7943	2.2146	67.3	78.9	82.5	88.0	82.7	88.5
10000	2.7880	67.2	78.7	83.1	88.6	83.2	89.0
12589	3.5099	67.4	79.2	83.3	88.9	83.4	89.4
15848	4.4187	64.3	76.3	83.2	89.0	83.3	89.2
19952	5.5628	61.5	73.4	82.9	88.8	82.9	88.9
25118	7.0031	59.6	71.6	82.3	88.3	82.3	88.4
31622	8.8164	56.8	68.8	81.7	87.7	81.7	87.8
39810	11.0992	53.9	66.1	80.9	87.0	80.9	87.1

***** STRIP AREA NUMBER 12 WWND = 1.0000

EMA	EMTIP	TI	SINCD	CONTR	L/SSTD
0.438	0.412	0.0240	1.00	1.000	0.11

GAM	RHO	C	SDIA	SPERC	TPR
1.400	0.0790	1119.	9.440	6.770	1.214

RPM	NB	NBSTD	HTR	DTIP	CHDR
9782.2	22	22	0.430	22.000	3.028

EMR	RSCAL	RVEL	ELT	TIT	AR
0.438	1.00	1.0000	0.106	0.0240	3.413

NB	NS
22	54

CDROTOR = 1.3410000E-02
INLET LENGTH/TIP DIAMETER = 0.9900000

STREAMLINE LIFT COEFFICIENT CALCULATED U SING SCLOPT= 2

*** COMPONENT PWL CONTRIBUTIONS – DB RE 10**(–13) WATTS ***

ONE THIRD OCTAVE

FREQUENCY		DIPOLE		QUADRUPOLE		TOTAL	
HERTZ	F/BPF	INLET	EXHAUST	INLET	EXHAUST	INLET	EXHAUST
3981	1.1099	77.1	87.7	83.0	87.9	84.0	90.8
5011	1.3973	76.4	87.3	85.1	90.1	85.7	91.9
6309	1.7591	74.6	85.5	86.7	91.7	87.0	92.7
7943	2.2146	72.1	83.3	88.1	93.3	88.2	93.7
10000	2.7880	72.2	83.7	88.9	94.2	89.0	94.5
12589	3.5099	72.5	84.0	89.2	94.6	89.3	95.0
15848	4.4187	69.4	81.1	89.2	94.8	89.3	95.0
19952	5.5628	66.8	78.6	89.0	94.7	89.1	94.8
25118	7.0031	64.8	76.6	88.4	94.2	88.4	94.3
31622	8.8164	62.1	74.0	87.8	93.7	87.9	93.7
39810	11.0992	59.3	71.3	87.2	93.1	87.2	93.1

FAN TOTAL POWER SPECTRUM

TOBN	F/BPF	PWL–UP	PWL–DN	PWL–TOT
36	1.1099	103.48	114.46	114.79
37	1.3973	105.39	116.50	116.83
38	1.7591	106.24	117.13	117.47
39	2.2146	106.75	116.87	117.28
40	2.7880	107.50	117.53	117.94
41	3.5099	107.81	117.75	118.17
42	4.4187	107.71	117.61	118.03
43	5.5628	107.24	117.07	117.50
44	7.0031	106.27	115.93	116.38
45	8.8164	105.40	114.80	115.27
46	11.0992	104.82	113.94	114.44

2.2.3.7.2 Directivity Output File from STATOR

STATOR SPL PLOT OUTPUT FILE

FREQUENCY = 3981, OBN = 36

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	36.9	39.9	41.7
20.0	44.9	50.9	51.9
30.0	56.3	58.8	60.7
40.0	60.1	65.0	66.2
50.0	64.9	70.1	71.3
60.0	70.5	74.4	75.9
70.0	73.7	78.0	79.4
80.0	69.1	83.1	83.2
90.0	58.4	81.3	81.3
100.0	52.1	79.2	79.2
110.0	47.3	77.4	77.4
120.0	42.2	72.9	72.9
130.0	36.5	71.2	71.2
140.0	29.9	72.7	72.7
150.0	21.7	51.3	51.3
160.0	20.2	20.4	23.3
170.0	20.2	20.4	23.3

FREQUENCY = 5011, OBN = 37

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	36.7	42.2	43.3
20.0	44.0	53.3	53.7
30.0	57.1	61.1	62.6
40.0	60.4	67.4	68.1
50.0	65.8	72.6	73.4
60.0	72.2	76.9	78.1
70.0	76.4	80.5	81.9
80.0	70.1	85.6	85.8
90.0	57.9	83.0	83.0
100.0	52.6	81.1	81.1
110.0	47.9	79.6	79.6
120.0	42.9	74.4	74.4
130.0	37.4	69.8	69.8
140.0	30.9	74.0	74.0
150.0	22.8	50.1	50.1
160.0	20.4	20.6	23.5
170.0	20.4	20.6	23.5

FREQUENCY = 6309, OBN = 38

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	35.3	42.5	43.2
20.0	45.8	53.6	54.2
30.0	58.1	61.4	63.1
40.0	59.7	67.7	68.3
50.0	67.9	73.0	74.1
60.0	73.3	77.3	78.8
70.0	77.5	81.0	82.6
80.0	62.4	86.1	86.1
90.0	65.8	83.8	83.9
100.0	60.4	80.9	80.9
110.0	55.3	81.4	81.4
120.0	50.0	75.1	75.1
130.0	44.3	68.3	68.3
140.0	37.6	75.1	75.1
150.0	29.4	50.1	50.1
160.0	20.2	20.6	23.4
170.0	20.2	20.6	23.4

FREQUENCY = 7943, OBN = 39

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	33.7	42.1	42.7
20.0	45.4	53.2	53.8
30.0	59.1	61.1	63.2
40.0	60.9	67.4	68.2
50.0	67.6	72.6	73.8
60.0	74.0	77.0	78.8
70.0	77.5	80.7	82.4
80.0	70.9	85.8	85.9
90.0	63.4	82.8	82.8
100.0	57.9	80.1	80.1
110.0	52.9	82.0	82.0
120.0	47.8	76.2	76.2
130.0	42.3	66.8	66.8
140.0	35.8	76.4	76.4
150.0	27.8	48.3	48.3
160.0	19.2	20.7	23.0
170.0	19.2	20.7	23.0

FREQUENCY = 10000, OBN = 40

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	30.2	43.4	43.6
20.0	40.7	54.5	54.7
30.0	59.2	62.4	64.1
40.0	61.8	68.7	69.5
50.0	68.3	73.9	75.0
60.0	74.9	78.3	80.0
70.0	78.6	82.0	83.6
80.0	70.1	86.9	87.0
90.0	62.3	82.8	82.8
100.0	57.0	79.8	79.8
110.0	52.3	81.2	81.2
120.0	47.5	77.3	77.3
130.0	42.1	65.3	65.3
140.0	35.8	78.0	78.0
150.0	27.9	50.9	51.0
160.0	19.0	20.9	23.1
170.0	19.0	20.9	23.1

FREQUENCY = 12589, OBN = 41

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	33.2	43.5	43.9
20.0	41.5	54.6	54.8
30.0	58.4	62.5	63.9
40.0	61.0	68.8	69.5
50.0	68.9	74.1	75.2
60.0	75.7	78.5	80.3
70.0	78.9	82.2	83.8
80.0	68.7	86.6	86.7
90.0	61.0	83.4	83.4
100.0	56.0	80.9	80.9
110.0	51.6	80.6	80.6
120.0	47.0	77.0	77.0
130.0	41.8	68.9	68.9
140.0	35.7	79.8	79.8
150.0	27.8	45.2	45.3
160.0	18.7	20.8	22.9
170.0	18.7	20.8	22.9

FREQUENCY = 15848, OBN = 42

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	33.0	43.3	43.7
20.0	40.2	54.4	54.6
30.0	57.3	62.3	63.5
40.0	61.5	68.6	69.4
50.0	69.1	73.9	75.2
60.0	76.4	78.4	80.5
70.0	78.4	82.1	83.6
80.0	66.8	85.7	85.8
90.0	59.5	83.0	83.0
100.0	55.0	81.0	81.0
110.0	50.9	80.4	80.4
120.0	46.5	76.9	76.9
130.0	41.5	68.5	68.6
140.0	35.4	81.5	81.5
150.0	27.7	44.7	44.8
160.0	18.4	20.8	22.8
170.0	18.4	20.8	22.8

FREQUENCY = 19952, OBN = 43

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	29.6	42.4	42.6
20.0	40.5	53.5	53.7
30.0	53.3	61.4	62.0
40.0	61.5	67.8	68.7
50.0	69.6	73.0	74.7
60.0	76.8	77.5	80.2
70.0	77.2	81.2	82.7
80.0	64.6	84.3	84.4
90.0	58.0	82.3	82.3
100.0	53.9	80.0	80.1
110.0	50.1	80.5	80.5
120.0	45.9	76.8	76.8
130.0	40.9	67.7	67.7
140.0	35.0	82.4	82.4
150.0	27.3	42.9	43.1
160.0	18.0	20.5	22.4
170.0	18.0	20.5	22.4

FREQUENCY = 25118, OBN = 44

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	26.7	40.7	40.8
20.0	38.2	51.8	52.0
30.0	46.7	59.7	59.9
40.0	60.4	66.0	67.1
50.0	69.6	71.3	73.5
60.0	76.7	75.8	79.3
70.0	74.9	79.5	80.8
80.0	62.5	82.6	82.7
90.0	56.5	80.8	80.8
100.0	52.8	79.0	79.1
110.0	49.1	79.5	79.5
120.0	45.0	75.7	75.7
130.0	40.2	67.4	67.4
140.0	34.3	82.3	82.3
150.0	26.7	39.2	39.5
160.0	17.8	19.9	22.0
170.0	17.8	19.9	22.0

FREQUENCY = 31622, OBN = 45

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	24.2	39.0	39.1
20.0	37.1	50.1	50.3
30.0	50.5	58.0	58.7
40.0	59.0	64.4	65.5
50.0	68.9	69.6	72.3
60.0	76.9	74.1	78.7
70.0	71.6	77.8	78.8
80.0	60.9	80.9	81.0
90.0	55.6	78.9	78.9
100.0	52.2	77.2	77.2
110.0	48.7	77.9	77.9
120.0	44.7	74.6	74.6
130.0	39.9	65.0	65.0
140.0	34.1	82.3	82.3
150.0	26.5	35.8	36.3
160.0	17.8	19.2	21.5
170.0	17.8	19.2	21.5

FREQUENCY = 39810, OBN = 46

ANGLE	INL SPL	EXH SPL	TOT SPL
10.0	24.3	37.9	38.1
20.0	33.4	49.1	49.2
30.0	51.9	57.0	58.1
40.0	57.3	63.3	64.3
50.0	68.4	68.6	71.5
60.0	77.1	73.0	78.5
70.0	65.2	76.8	77.1
80.0	59.9	79.9	79.9
90.0	55.3	77.4	77.5
100.0	52.1	75.4	75.5
110.0	48.7	76.2	76.2
120.0	44.8	73.1	73.1
130.0	40.0	63.0	63.0
140.0	34.2	82.2	82.2
150.0	26.7	35.6	36.2
160.0	17.8	18.5	21.2
170.0	17.8	18.5	21.2

2.2.4 BBNPLOTS – Postprocessor

Program BBNPLOTS, a suggested postprocessor implementation, reads output files from programs ROTOR and STATOR and produces plots to help the user visualize and compare the outputs from these programs. The program reads sound power level and sound pressure level (directivity) predictions produced by programs ROTOR and STATOR, calculates logsums of rotor and stator predictions to get totals, and produces input plot files for Unix utility XMGR. The user is presented with a menu of plot types to choose from.

PWL type plots (sound power level vs. frequency) may be made for inlet, exhaust, or total values. Lines will be plotted for rotor, stator, and rotor + stator or for rotor + stator with optional line of input data points. SPL type plots may be sound pressure level versus frequency at a given angle or sound pressure level versus angle at a given frequency. Lines will be plotted for rotor, stator, and rotor + stator or for rotor + stator. SPL type plots can include an optional line of input data points.

BBNPLOTS supplies default titles, labels, and axis limits for the plots it creates, but the user may customize these plot attributes by supplying a plot-options file to override the default plot attributes.

The plot-options file is Fortran namelist format so that only the desired attributes must be supplied. The plot options file is also used to supply data points to be plotted against the ROTOR and STATOR noise predictions.

This implementation uses Unix utility XMGR to produce plots. (See website: http://plasma–gate.weizmann.ac.il/Xmgr/ to obtain software.)

The program prompts for 4 input files, then presents a menu of 17 options for choosing plot types. An output method is then requested (XMGR plot input files with or without the associated hard copy plots). After that an optional namelist plot options file may be specified and then the program creates the indicated files and/or plots.

2.2.4.1 Description of Input Files

BBNPLOTS requires four input files: the ROTOR power output file, ROTOR directivity output file, STATOR power output file, and STATOR directivity output file. These files are described in Section 2.2.2.4, page 6.

An optional plot-options file (Fortran namelist format) may be used to override program defaults for titles, labels, and axis limits and to supply data points that may be plotted along with the predictions. There is a namelist group corresponding to most plot types. This file may be used if a single plot is to be produced or if all of the PWL type plots are to be produced. The options file will be ignored when multiple SPL plots are to be produced because, so far, there is no namelist group of common plot titles, legend labels, etc. for every possible frequency or angle.

2.2.4.2 Description of Output Files

BBNPLOTS creates an output file, for each plot containing data points and plot attributes, in the format required by plot utility XMGR.

3.0 Fan MPT Superposition Code Descriptions and Users Guides

3.1 MPT Prediction System

To predict MPT spectra, the user needs to:

1. Obtain a CFD code capable of predicting turbomachinery flows in multiple passages. A commercial code or one of the many codes developed by NASA would be suitable.
2. Obtain a grid generator capable of producing meshes for single-passage fan geometries. Again, a commercial code or one of the many grid generators developed by NASA would be suitable.
3. Develop the API routines described in Section 3.3 to generate the multiple-passage meshes required for the prediction.
4. Develop capability to obtain circumferential pressure distributions at the required axial location. (The freely available Visual3 software is recommended.)

MPT predictions can then be made by first generating a single-passage mesh and CFD solution at the required operating point. A multiple-passage mesh is then generated using the ROTBLD program; one blade will have been modified to reflect the geometry change of interest. Circumferential pressure distributions are extracted from these two solutions and input to the SUPERPOSE program together with details of the distribution of geometry changes around the annulus. The output from this program is the predicted MPT spectra.

3.2 Software Installation

The SUPERPOSE and ROTBLD programs are supplied in a gzipped tar file (**superpose.tar.gz**). After decompressing and untaring, the following directories and files should exist:

superpose	Source code and Makefile for SUPERPOSE program
rotbld	Source code and Makefile for ROTBLD program
lib	Source code and Makefile for libraries
inc	Include files
test	Test case
makefile	Makefile for program
make_defs	Compiler options

To make the program type: **make ARCH=*****

In the main directory, the architecture variable is one of:

iris4d	SGI
sgi–irix6	SGI
hp9000s700	HP (PA2 chip)
hp9000s700PA1	HP (PA1 chip)
sun4	Sun
OSF1	Dec
rs6000	IBM

Note GNU make is required for this to work. When the make has finished, the executable resides in **src/ARCH/superpose**. It is possible to make a version for the PC; however the DEC FORTRAN compiler is needed to handle the dynamic allocation.

3.3 ROTBLD Users Guide

This program is designed to interface with a variety of file formats. The file read and write is done through a well-defined API. The skeleton routines for this API are stored in **file_read_api.f**. It is the user's responsibility to modify this to read and write files in their formats.

On executing the program, it will first prompt for the input files; the number of nodes and the geometrical stretching factor for the inlet block are prompted for next. This is the region of mesh added onto the inlet to prevent spurious refections from contaminating the solution.

The number of blades to be analyzed is now prompted for. For each blade, the geometry may be modified through stagger, thickness, theta shift, or camber changes:

1. **Stagger:** Angle change (degrees) requested, positive is clockwise looking radially inward.
2. **Thickness:** The maximum thickness (units = length) change is first requested. Three scale factors are input to define how this thickness change varies around the blade. The factors are specified at the leading edge, midchord, and trailing edge. Linear variation as assumed between these points.
3. **Theta shift:** The shift in θ (degrees) is requested. This shift is applied uniformly up the span.
4. **Camber:** The maximum camber change (units = length) is now input. As with the thickness variation, three scale factors are input representing the scaled change at the leading edge, midchord, and trailing edge.

3.4 SUPERPOSE Users Guide

On executing the program, it will prompt for three input file names and one output file name. The input files are all ASCII and in free format, as follows:

1. **.mps** file **–** This is the file giving the circumferential pressure distribution for the multiple passage solution at the axial location of interest. The format is as follows:

   npass nmps del
   x_1 p_1
   x_2 p_2
   .
   .
   x_{nmps} p_{nmps}

where *npass* is the number of passages in the multiple passage solution, *n* is the number of points in the file, and *del* is the geometry change applied to on the blade; *x* and *p* are the circumferential distributions of position and pressure.

2. **.sps** file **–** This is the file giving the circumferential pressure distribution for a single passage at the axial location of interest. The format is as follows:

   nsps
   x_1 p_1
   x_2, p_2
   .
   .x_{nsps} p_{nsps}

where n is the number of points in the file; x and p are the circumferential distribution of position and pressure.

3. **psv** file **–** This file contains the distribution of blade shape variation (*del*) that the estimate of the MPT spectra is required for:

$$\begin{array}{l} nblds \\ del_1 \\ del_2 \\ . \\ . \\ del_{nblds} \end{array}$$

4. **.mde** This is the output file containing the predicted amplitudes of the Fourier components:

$$\begin{array}{llll} 1 & A_m{}^1 & A^1 & B^1 \\ 2 & A_m{}^2 & A^2 & B^2 \\ . & & & \\ . & & & \\ n & A_m{}^n & A^n & B^n \end{array}$$

A_m is the magnitude of the fourier mode; (A_i, B_i) are the Fourier series coefficients.

Example input and output files are provided in the test directory. The input files can be in any unit system. The flow chart on page 3 of this document illustrates the flow of data within the MPT predictions system.

4.0 Core Noise Code Description and Users Guide

The following section describes software written to support Contract NAS3–27720, Sub AOI 13.4, Core Noise Model.

4.1 Software Requirements

The core noise program is written in standard Fortran 77.

4.2 Description of Core Noise Code

Initially all inputs needed to run the program are described. Program inputs are read-in through a input data file and output is also written to a designated output file. A first set of calculations to set program constants, calculate frequently derived quantities, etc., is performed. All input is next written to the output file.

The PWL for all frequencies as well as the distribution of this PWL into the the NCOF cut-off ratio bins is initialized to zero. Next, we invoke the principal subroutine STRIP for all the NRHT strips. Prior to this call, a call to INTSTR sets up inputs needed to run STRIP including free-vortex based interpolation of required mean flow properties of the various turbine blade rows based on hub tip ratios fore and aft of each blade row and the nondimensional radial height of each strip. This subroutine returns the PWL contribution from each strip in SWATTIN (for all NF 1/3-octave bands of interest whose center values are input in TOBF) and further in SWCOF the partitioning of SWATTIN into the NCOF cut-off ratio bins (for each of the NF frequencies) is calculated. We store in WATTIN and WATTSCOF the sums of SWATTIN and SWCOF obtained from each strip. Finally E.J. Rice's subroutine BBRDCFCR is called to supply farfield SPL spectra based on WATTSCOF (and other parameters). The Rice module returns SPL spectra for angles in the farfield from DELANG to (180.–DELANG) degrees to the inlet axis and returns two sets SPLTL and SPL which correspond to including a nozzle transmission loss or not including this. As a final step, since the SPL information is required at angles ASPL, the angles calculated by the Rice module that are closest to each of the ASPL are found and the SPL spectra (with and without transmission loss) at these angles are printed out.

All subroutine and function subprograms are comprehensively described within the source code. A description is offered of the key subroutine STRIP.

Inputs to this subroutine are very similar to those of the main program except they are localized to the strip of interest. A key initial check is performed to determine if any blade row has supersonic exit relative Mach number (corresponding to whether the blade row is choked) and (if so) if there is only one blade row which is choked that is also the last blade row. For each frequency, based on conditions in that strip at turbine exit, a range of tangential wave numbers corresponding to waves above cut-off and also discrete values of tangential wave number that yield an integer number of waves that can be accommodated in a circumference are determined. For each such discrete tangential wave number, actuator disk theory is excercized in CALC or CALC1 (depending on the choking issue) to determine the emitted downstream sound wave amplitude (ADSW) corresponding to a unit input "hot spot" wave. Via TSPEC1, TSPEC2 (and also ISPEC, LOVR, LOVR2, etc.) the amplitude of the relevant spectral component of the "hot spot" spectrum is determined. The output is in WATTIN (PWL contributions neglecting exit nozzle transmission loss for all NF 1/3-octave bands) and in WATTSCOF resides the allocation of WATTIN into the NCOF cut-off ratio bins (some of which may have no power allocated to them).

To avoid taking logarithms of zero or negative quantities, if the program output yields decibel values of –1000 dB for either power levels or SPL's, such values should really be interpreted as vanishingly low values.

4.3 Description of Core Noise Input File

NR denotes the total number of blade rows and NS=NR+1 the number of spaces. Thus space 1 denotes "upstream" and space NS denotes "downstream." For axial components, positive is downstream. For tangential (y) components, a direction must be selected as positive and consistently adhered to.

NR =	Number of blade rows .le. 49 (integer input) such that the last blade row is choked i.e. has subsonic relative mean flow at inlet and supersonic relative mean flow at exit. (note that ns = nr + 1)
NF =	Number of 1/3-octave power levels to be calculated
NRHT =	Number of radial heights at which temperature fluctuation and entropy wave length scale inputs are given
NSPL =	Number of far field acoustic angles from inlet axis at which third octave spl spectra (re: 2.10**(–5) N/m**2) are desired
TOBF =	Center frequencies of the third octave bands to be calculated, "NF" values in hertz (all positive)
RHT =	NRHT values of nondimensional radial height i.e. (radius – inner radius)/(outer radius – inner radius). Thus: "0.00 .le. RHT .le. 1.00"
TFPV =	Percent temperature fluctuations (rms in percent of mean) — NRHT values
LOVRV =	Axial length scale of temperature fluctuations nondimensionalized by radius in upstream annulus — NRHT values (radius corresponds to RHT(I))
LOVR2V =	Tangential length scale of temperature fluctuations nondimensionalized by radius in upstream annulus; NRHT (radius corresponds to RHT(I))
CE =	Downstream static speed of sound: ft/s at the pitch line
GAM =	Specific heat ratio of gas
GAMA =	Specific heat ratio of gas in ambient
PE =	Downstream static pressure, psia, at the pitch line
RMX =	Vector of NS values of axial mach numbers in NS spaces at the pitch line
RMY =	Vector of NS values of tangential mach numbers in NS spaces. Again sign convention must be adhered to at the pitch line.

RPM =	Vector of NR values of wheel rpm's of the blade rows. Consistent sign convention must be adhered to depending on the direction of wheel motion . Value of 0.0 denotes a stator.
DIN =	Vector of NR values of mean diameters upstream of the blade rows (inches) at the pitch line
DOUT =	Vector of NR values of mean diameters downstream of the blade rows (inches) at the pitch line
SIGIN =	Vector of NR values of hub to tip ratios upstream of the blade rows
SIGOUT =	Vector of NR values of hub to tip ratios downstream of the blade rows
CRD =	Vector of (N – 1 = NR) values of ratio static speed of sound in space to static speed of sound in discharge space: CRD(NS) =1.00 (by definition, obviously) at the pitch line.
AXV =	Vector of (NR – 1) values of ratio of spacing between blade row actuator disks to mean radius. AXV(1) and AXV(NR + 1 = NS) are taken as zero. No input for this vector is needed if NR = 1 at the pitch line.
TTOT =	Total temperature in aft duct (°R)
PTOT =	Total pressure in aft duct (psia)
TSUR =	Total temperature in surrounding medium (°R)
PSUR =	Total presure in surrounding medium, (psia)
HTRAT =	Aft duct hub/tip ratio
ANOZRAT =	Nozzle throat area ÷ aft duct area
DISTANCE =	Radius of microphone array or traverse (ft)
ISIDELN =	0 for constant radius, = 1 for constant sideline calculation
DDUCT =	Aft duct outside diameter, (inches)
FMACH2 =	Mach number of surrounding medium
NCOF =	Number of cut-off ratio bins to sort acoustic power (must be .LE. 200)
DELANG =	Angle increment desired on farfield radial traverse (degrees)
ASPL =	Angles (degrees) from inlet axis at which spl spectra are desired — NSPL values
ISPEC =	Input "1" means correlation function in tangential or axial direction is as exp(–r/l), "2" means as exp (–(r/l)**2); "3" means as 1/(1+(r*pi/2l)**2)

4.4 Description of Core Noise Output File

All the input values are printed out first. The PWL spectrum with and without exit nozzle transmission loss is the first output. Following this , the SPL spectra at the required NF frequencies at angles from the Rice subroutine closest to the required ASPL angles are tabulated. As with the PWL, the SPL values are printed out both with and without exit nozzle transmission loss.

4.5 Core Noise Program Source Code Listing

```
C *****************************************************************
C *                                                               *
C *                      'CNOISE' PROGRAM                         *
C *                                                               *
C *****************************************************************
C
C          THIS PROGRAM CALCULATES THE NOISE GENERATED WHEN
C   "TEMPERATURE FLUCTUATIONS" OF  GIVEN AMPLITUDES AND LENGTH SCALES
C IMPINGE ON A MULTI STAGE TURBINE FROM THE UPSTREAM END.STANDARD ACTUATOR
C DISK THEORY APPLICABLE TO BLADE ROWS CHARACTERIZED BY SUBSONIC OR SUPERSONIC
C EXIT RELATIVE MEAN FLOW THROUGH THE BLADE ROW IS USED.UPTO 49 ROWS ARE
C ALLOWED FOR.THE TURBINE MEAN FLOW DATA IS ASSUMED GIVEN AT PITCH LINE
C AND IS THEN EXTRAPOLATED TO OTHER RADII BY ASSUMING "FREE VORTEX"
C DISTRIBUTIONS.THE 'SPL' SPECTRUM AT THE 'NF' FREQUENCIES AT THE 'NSPL'
C ANGLES IS CALCULATED AS WELL AS THE 'PWL' SPECTRUM.
C
C *****************************************************************
C
C     INPUT :
C           'NR' denotes the total number of blade rows and 'NS=NR+1' the
C           number of spaces . Thus space 1 denotes 'upstream' and space
C           NS denotes ' downstream' . For axial components , positive
C           is downstream . For tangential ( y ) components , a direction
C           must be selected as positive and consistently adhered to.
C
C               NR = NUMBER OF BLADE ROWS .LE. 49 ( integer input )
C                    SUCH THAT THE LAST BLADE ROW IS CHOKED i.e. HAS
C                    SUBSONIC RELATIVE MEAN FLOW AT INLET AND SUPERSONIC
C                    RELATIVE MEAN FLOW AT EXIT.
C
C                      NOTE THAT NS = NR + 1
C
C               NF = NUMBER OF THIRD OCTAVE POWER LEVELS TO BE CALCULATED
C
C             NRHT = NUMBER OF RADIAL HEIGHTS AT WHICH TEMPERATURE FLUCTUATION
C                    AND ENTROPY WAVE LENGTH SCALE INPUTS ARE GIVEN
C
C             NSPL = NUMBER OF FAR FIELD ACOUSTIC ANGLES FROM INLET AXIS
C                    AT WHICH THIRD OCTAVE SPL SPECTRA (RE: 2.10**(-5) N/m**2
c                    ARE DESIRED
C
C             TOBF = CENTER FREQUENCIES OF THE THIRD OCTAVE BANDS TO BE
C                       CALCULATED,"NF" VALUES IN HERTZ (ALL POSITIVE)
C
C             RHT  = 'NRHT' VALUES OF NON DIMENSIONAL RADIAL HEIGHT I.E.
C                    (RADIUS-INNER RADIUS)/(OUTER RADIUS-INNER RADIUS).
C                    THUS '0.00.LE.RHT.LE.1.00'
C
C             TFPV = PER CENT TEMPERATURE FLUCTUATIONS (RMS IN PERCENT OF
C                               MEAN)-'NRHT' VALUES
C
C            LOVRV = AXIAL LENGTH SCALE OF TEMPERATURE FLUCTUATIONS
C                       NONDIMENSIONALIZED BY RADIUS IN UPSTREAM ANNULUS-
C                       'NRHT' VALUES ( RADIUS CORRESPONDS TO 'RHT(I)' )
C
C           LOVR2V = TANGENTIAL LENGTH SCALE OF TEMPERATURE FLUCTUATIONS
C                       NONDIMENSIONALIZED BY RADIUS IN UPSTREAM ANNULUS-
C                       'NRHT' VALUES ( RADIUS CORRESPONDS TO 'RHT(I)' )
```

```
C
C              CE = DOWNSTREAM STATIC SPEED OF SOUND : feet/second:
C                      AT THE PITCH LINE
C
C             GAM = SPECIFIC HEAT RATIO OF GAS
C
C            GAMA = SPECIFIC HEAT RATIO OF GAS IN AMBIENT
C
C              PE = DOWNSTREAM STATIC PRESSURE, psia,AT THE PITCH LINE
C
C             RMX = VECTOR OF NS VALUES OF AXIAL MACH NUMBERS IN
C                   NS SPACES AT THE PITCH LINE
C
C             RMY = VECTOR OF NS VALUES OF TANGENTIAL MACH NUMBERS IN
C                   NS SPACES . AGAIN SIGN CONVENTION MUST BE ADHERED
C                   TO . AT THE PITCH LINE.
C
C             RPM = VECTOR OF NR VALUES OF WHEEL RPM’S OF THE
C                   BLADE ROWS . CONSISTENT SIGN CONVENTION
C                   MUST BE ADHERED TO DEPENDING ON THE DIRECTION OF
C                   WHEEL MOTION . VALUE OF 0.00 DENOTES A STATOR .
C
C             DIN = VECTOR OF NR VALUES OF MEAN DIAMETERS UPSTREAM
C                   OF THE BLADE ROWS ( inches ) AT THE PITCH LINE
C
C            DOUT = VECTOR OF NR VALUES OF MEAN DIAMETERS DOWNSTREAM
C                   OF THE BLADE ROWS ( inches ) AT THE PITCH LINE
C
C           SIGIN = VECTOR OF NR VALUES OF HUB TO TIP RATIOS UPSTREAM
C                   OF THE BLADE ROWS
C
C          SIGOUT = VECTOR OF NR VALUES OF HUB TO TIP RATIOS DOWNSTREAM
C                   OF THE BLADE ROWS
C
C             CRD = VECTOR OF (NS-1=NR) VALUES OF RATIO STATIC SPEED OF
C                   SOUND IN SPACE TO STATIC SPEED OF SOUND IN DISCHARGE
C                   SPACE : CRD ( NS ) =1.00 ( by definition , obviously ).
C                   AT THE PITCH LINE.
C
C             AXV = VECTOR OF (NR-1) VALUES OF RATIO OF SPACING
C                   BETWEEN BLADE ROW ACTUATOR DISKS TO MEAN RADIUS.
C                   AXV(1) AND AXV(NR+1=NS) ARE TAKEN AS ZERO .
C                   NO INPUT FOR THIS VECTOR IS NEEDED IF NR=1 .
C                   AT THE PITCH LINE.
C
C            TTOT = TOTAL TEMPERATURE IN AFT  DUCT, (DEGREES RANKINE)
C
C            PTOT = TOTAL PRESSURE IN AFT  DUCT, (PSIA)
C
C          TSUR   = TOTAL TEMPERATURE IN SURROUNDING MEDIUM,(DEGREES RANKINE)
C
C          PSUR   = TOTAL PRESURE IN SURROUNDING MEDIUM, (PSIA)
C
C           HTRAT = AFT  DUCT HUB-TIP RATIO
C
C         ANOZRAT = (NOZZLE THROAT AREA)/(AFT DUCT AREA)
C
C        DISTANCE = RADIUS OF MICROPHONE ARRAY OR TRAVERSE, (FT.)
C
C      ISIDELN = 0 FOR CONSTANT RADIUS, = 1 FOR CONSTANT SIDELINE CALCULATION
```

```
C
C            DDUCT = AFT DUCT OUTSIDE DIAMETER, (INCHES)
C
C           FMACH2 = MACH NUMBER OF SURROUNDING MEDIUM
C
C           NCOF   = NUMBER OF CUT-OFF RATIO BINS TO SORT ACOUSTIC POWER
C                    (must be .LE. 200)
C
C     DELANG = ANGLE INCREMENT DESIRED ON FAR-FIELD RADIAL TRAVERSE, (DEGREES)
C
C           ASPL   = ANGLES (DEGREES) FROM INLET AXIS AT WHICH SPL SPECTRA
C                    ARE DESIRED -'NSPL' VALUES
C
C          ISPEC   = INPUT "1" MEANS CORRELATION FUNCTION IN TANGENTIAL
C                    OR AXIAL DIRECTION IS AS EXP(-r/l):"2" MEANS
C                    AS EXP (-(r/l)**2):"3" MEANS AS 1/(1+(r*pi/2l)**2)
C
C ******************************************************************
C
C     OUTPUT :
C
C                 AFT RADIATED THIRD OCTAVE PWL's re: 10**(-13) WATTS.
C
C                 THIRD OCTAVE SPL RE: (2.*10**(-5) N/m**2)
c
C                 RESULTS ARE GIVEN BOTH WITH & WITHOUT TRANS LOSS DUE TO
C
C                                    EXIT NOZZLE
C
C ******************************************************************
C
C                       BEGIN  MAIN  PROGRAM
C
C ******************************************************************
C
      DIMENSION RPM(50),TOBF(20),PWL(20),TFPV(25),
     &          WATTSCOF(200,20),ANGLE(200),SPL(200),SPLTL(200),
     &          SPLF(200,20),SPLTLF(200,20),PWLTL(20),DWCOF(200),
     &          SWCOF(200,20),SWATTIN(20),WATTIN(20),ASPL(20)
C
      REAL      MXD,MYD,MRD,LOVR,LOVR2,LOVRV(25),LOVR2V(25)
C
      COMMON    CE,PE,RMX(50),RMY(50),DIN(50),DOUT(50),CRD(50),GAM,
     &          AXV(50),RHT(25),SIGIN(50),SIGOUT(50),NR,NS,NRHT,
     &          SMX(50),SMY(50),SDIN(50),SDOUT(50),SCRD(50),
     &          SAXV(50),ShOVH,SANNHT,SCE,SPE
C
      CHARACTER*32 INPF
      CHARACTER*32 OUTF
C
C***  READ INPUT AND OUTPUT FILE NAMES ( MUST BE LE. 32 CHARACTERS
C***                                   LONG )
C
      PRINT *,' INPUT FILE NAME ?  (MUST BE LE. 32 CHARS LONG)'
      READ 1000, INPF
      OPEN ( UNIT=7,FILE=INPF,STATUS='OLD' )
      PRINT *,' OUTPUT FILE NAME ? (MUST BE LE. 32 CHARS LONG)'
      READ 1000, OUTF
      OPEN ( UNIT=8,FILE=OUTF,STATUS='NEW' )
C
```

```
C***  END READ OF INPUT AND OUTPUT FILE NAMES
C
C***  READ IN ALL INPUTS-ALSO SET 'NS' AS 'NR+1'
C
      READ (7,*) NR,NF,NRHT,NSPL
                 NS = NR+1
      DO I = 1,NF
        READ (7,*) TOBF(I)
      END DO
      READ (7,*) CE,GAM,GAMA,PE
      DO I = 1,NRHT
        READ (7,*) RHT(I),TFPV(I),LOVRV(I),LOVR2V(I)
      END DO
      READ (7,*) TTOT,PTOT,TSURS,PSURS,HTRAT,ANOZRAT,DISTANCE
      READ (7,*) ISIDELN,DDUCT,FMACH2,NCOF,DELANG
      DO I = 1,NSPL
        READ (7,*) ASPL(I)
      END DO
      DO 10 I = 1,NS
         READ (7,*) RMX(I),RMY(I)
   10 CONTINUE
      DO 20 I = 1,NR
        READ (7,*) RPM(I),DIN(I),DOUT(I),CRD(I),SIGIN(I),SIGOUT(I)
   20 CONTINUE
      IF ( NR.GE.2 ) THEN
         DO 30 I = 2,NR
            READ (7,*) AXV(I)
   30    CONTINUE
      ENDIF
      READ (7,*) NCOF
      READ (7,*) ISPEC
C
C***  END OF READING OF INPUTS
C
C***  PROGRAM CONSTANTS AND SOME RELABELLING,PREPROCESSING OF
C***  INPUTS
C
      AXV(1)   = 0.00
      AXV(NS)  = 0.00
      CRD(NS)  = 1.00
      FCOF     = FLOAT(NCOF)
C***  DISCHARGE RELATED
      MXD     = RMX(NS)
      MYD     = RMY(NS)
      FMACHD  = MXD
      MRD     = SQRT (MXD**2+MYD**2)
      TDUCT   = TTOT/(1.+.5*(GAM-1.)*MRD**2)
      CDUCT   = 49.0421*SQRT(TDUCT)
      GC1     = (GAMA-1.)/2.
      GC2     = GAMA/(GAMA-1.)
      TSUR    = TSURS*(1.+GC1*FMACH2**2)
      PSUR    = PSURS*(1.+GC1*FMACH2**2)**GC2
C
C***  END OF CALCULATION OF
C***  PROGRAM CONSTANTS AND SOME RELABELLING,PREPROCESSING OF
C***  INPUTS
C
C***  WRITE OUT INPUT DATA
C
      WRITE (8,1010)
```

```
      WRITE (8,1020) NR,CE,GAM,GAMA,PE
      WRITE (8,1021) TTOT,PTOT,TSURS,PSURS,HTRAT,ANOZRAT
      WRITE (8,1022) DDUCT,FMACH2
      WRITE (8,1025)
      WRITE (8,1026)
      DO I = 1,NRHT
        WRITE (8,1027) RHT(I),TFPV(I),LOVRV(I),LOVR2V(I)
      END DO
C
      DO 70 I = 1,NS
         IF ( I.EQ.1 ) WRITE (8,1030)
         IF ( (I.GT.1).AND.(I.LT.NS) ) WRITE (8,1040) I
         IF ( I.EQ.NS ) WRITE (8,1050)
         WRITE (8,1060) RMX(I),RMY(I)
        IF ( I.NE.NS ) WRITE (8,1070) RPM(I),CRD(I),DIN(I),
     &                        DOUT(I),SIGIN(I),SIGOUT(I)
         IF ( (I.GT.1).AND.(I.LT.NS) ) WRITE (8,1080) AXV(I)
   70 CONTINUE
C
      WRITE (8,1090)
C
C***  END OF WRITE OUT OF INPUT DATA
C
C
C***  HEADER FOR WRITE OF OUTPUT DATA
      WRITE (8,1100)
      WRITE (8,1104) ISPEC,NCOF
      WRITE (8,1105)
      WRITE (8,1106)
C     INITIALIZE 'WATTIN' AND 'WATTSCOF' TO ZERO
      DO I = 1,NF
        WATTIN(I) = 0.00
        DO J = 1,NCOF
           WATTSCOF(J,I) = 0.00
        END DO
      END DO
C
C***  DO VARIOUS STRIPS
C
      DO ISTR = 1,NRHT
        CALL INTSTR ( ISTR )
        TFP   = TFPV(ISTR)
        LOVR  = LOVRV(ISTR)
        LOVR2 = LOVR2V(ISTR)
        CALL STRIP ( NR,NF,TOBF,TFP,LOVR,LOVR2,SCE,GAM,SPE,
     &             SANNHT,SMX,SMY,RPM,SDIN,SDOUT,SCRD,SAXV,
     &             ShOVH,NCOF,ISPEC,SWATTIN,SWCOF )

        DO I = 1,NF
           WATTIN(I) = WATTIN(I)+SWATTIN(I)
           DO J = 1,NCOF
              WATTSCOF(J,I) = WATTSCOF(J,I)+SWCOF(J,I)
           END DO
        END DO
      END DO
C
C***  DO VARIOUS FREQUENCY BANDS
C
      DO I = 1,NF
        IF ( WATTIN(I).GT.0.00 ) THEN
           ETAD   = TOBF(I)*DDUCT/(12.*CDUCT)
```

```
          PWL(I) = 130.+10.*ALOG10(WATTIN(I))
          DO J = 1,NCOF
             DWCOF(J) = WATTSCOF(J,I)
          END DO
          CALL BBRDCFCR(TTOT,PTOT,TSUR,PSUR,HTRAT,ANOZRAT,
     &            DISTANCE,ISIDELN,DDUCT,DJET,FMACHD,FMACH1,FMACH2,
     &            NCOF,DWCOF,DELANG,ETAD,NANGLE,ANGLE,SPL,
     &            SPLTL,WATTSUM,WATTRAN,FMACHN,COFMIN,CRAT)
          DO IANG = 1,NANGLE
             SPLF(IANG,I)   = SPL(IANG)
             SPLTLF(IANG,I) = SPLTL(IANG)
          END DO
          PWLTL(I) = 130.+10.*ALOG10(WATTRAN)
        ELSE
          PWL(I) = -1000.
          DO IANG = 1,NANGLE
             SPL(IANG)      = -1000.
             SPLTL(IANG)    = -1000.
             SPLF(IANG,I)   = SPL(IANG)
             SPLTLF(IANG,I) = SPLTL(IANG)
          END DO
          PWLTL(I) = -1000.
        ENDIF
      END DO
C
      DO I = 1,NF
        WRITE (8,1107) TOBF(I),PWL(I),PWLTL(I)
      END DO
C
C***  WRITE OUT SPL'S AT THE REQUIRED ANGLES
C
      DO I = 1,NSPL
       ANGSPL  = ASPL(I)
       CALL ANGSRT ( NANGLE,ANGLE,ANGSPL,IANG,ANGO )
       IF ( ISIDELN.EQ.0 ) WRITE (8,1110) DISTANCE
       IF ( ISIDELN.EQ.1 ) WRITE (8,1115) DISTANCE
       WRITE (8,1104) ISPEC,NCOF
       WRITE (8,1120) ANGO
       WRITE (8,1121)
       DO II = 1,NF
          WRITE (8,1108) TOBF(II),SPLF(IANG,II),SPLTLF(IANG,II)
       END DO
      END DO
C
C***  FORMAT STATEMENTS***------------------------------------------
C
 1000 FORMAT(A32)
 1010 FORMAT(20X,'************* INPUT PARAMETERS **************',
     1           ///////)
 1020 FORMAT(20X,'NUMBER OF BLADE ROWS                =',I8,//,
     1       20X,'EXIT STATIC SPD. OF SOUND ( fps )   =',F8.1,/,
     2       20X,'SPECIFIC HEAT RATIO OF GAS          =',F8.2,/,
     2       20X,'SPECIFIC HEAT RATIO OF GAS-AMBIENT  =',F8.2,/,
     3       20X,'EXIT STATIC PRESSURE (psia)         =',F8.2,///)
 1021 FORMAT(20X,'TOTAL TEMP. IN AFT DUCT,DEG R       =',F8.1,/,
     1       20X,'TOTAL PRESSURE IN AFT DUCT ,psia    =',F8.2,/,
     2       20X,'AMBIENT STATIC TEMPERATURE,DEG R    =',F8.1,/,
     3       20X,'AMBIENT STATIC PRESSURE,psia        =',F8.2,/,
     4       20X,'AFT DUCT HUB TIP RATIO              =',F8.3,/,
     5       20X,'NOZZLE THROAT/AFT DUCT AREA RATIO   =',F8.3)
```

```
 1022 FORMAT(20X,'AFT DUCT DIAMETER,inches            =',F8.2,/,
     1       20X,'AMBIENT MACH NUMBER                 =',F8.3,///)
 1025 FORMAT(20X,'TEMPERATURE FLUCTUATION RELATED INPUTS',//)
 1026 FORMAT(20X,3X,'RHT  ',2X,'Trms/T %',2X,'Ax L/R',3X,'Ta L/R',
     &          //)
 1027 FORMAT(20X,1X,F6.2,4X,F6.2,2X,F7.4,2X,F7.4)
 1030 FORMAT('1',///,20X,' UPSTREAM SPACE-@ PITCH LINE',/)
 1040 FORMAT(///,20X,' SPACE NUMBER    ',I5,' -@ PITCH LINE',/)
 1050 FORMAT(///,20X,' DOWNSTREAM SPACE-@ PITCH LINE',/)
 1060 FORMAT(20X,'AXIAL MACH NUMBER IN SPACE          =',F8.4,/,
     1       20X,'TANGENTIAL MACH NUMBER IN SPACE     =',F8.4)
 1070 FORMAT(20X,'WHEEL RPM OF BLADE ROW AT AFT END  ',/,
     1       20X,'OF SPACE                            =',F8.1,/,
     2       20X,'SPEED OF SOUND IN SPACE NORMALISED BY',/,
     3       20X,'EXIT SPEED OF SOUND                 =',F8.4,/,
     4       20X,'DIAMETER AHEAD OF BLADE ROW (ins)   =',F8.2,/,
     5       20X,'DIAMETER AFT OF BLADE ROW (ins)     =',F8.2,/,
     6       20X,'HUB TO TIP RATIO AHEAD OF BLADE ROW =',F8.4,/,
     7       20X,'HUB TO TIP RATIO AFT OF BLADE ROW   =',F8.4,/)
 1080 FORMAT(20X,'AXIAL SPACING OF SPACE NORMALISED BY',/,
     1       20X,'MEAN RADIUS OF ANNULUS              =',F8.4)
 1090 FORMAT(////,17X,'***END WRITE OF INPUT PARAMETERS***')
 1100 FORMAT('1',20X,'************OUTPUT FROM PROGRAM**************',
     1          //)
 1104 FORMAT(10X,'EXPONENT RELATED TO CORRELATION FUNCTION    = ',
     1           I3,/,
     2       10X,'# OF CUT OFF RATIO BINS USED IN CALCULATION = ',
     3           I3,//)
 1105 FORMAT(10X,'THIRD OCTAVE BAND POWER RE: 10**(-13) WATTS',/,
     &       10X,'      TL denotes Transmission Loss',//)
 1106 FORMAT('      CENTER FREQUENCY,Hz      no TL dB',
     &       ' with TL dB',///)
 1107 FORMAT('            ',F7.1,'          ',F8.1,2X,F8.1)
 1108 FORMAT(10X,'            ',F7.1,'          ',F8.1,2X,F8.1)
 1110 FORMAT('1',10X,'MIKES ON AN ARC OF RADIUS ',F8.1,' FT.',//)
 1115 FORMAT('1',10X,'MIKES ON A SIDELINE,DISTANCE ',F8.1,' FT.',
     &       //)
 1120 FORMAT(10X,'THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2',
     &    //,10X,'      TL denotes Transmission Loss',//,
     &       10X,'      ANGLE FROM INLET (degrees) = ',F8.2,///)
 1121 FORMAT(10X,'      CENTER FREQUENCY,Hz     no TL dB',
     &       ' with TL dB',///)
C
C***  END OF FORMAT STATEMENTS***-----------------------------------
C
      STOP
C
      END
C
C                        ************************
C************************  END OF MAIN PROGRAM ********************
C                        ************************
C
C                     **********************
C********************  SUBROUTINE 'STRIP'*************************
C                     **********************
C
C          THIS SUBROUTINE CALCULATES THE NOISE GENERATED WHEN
C   "TEMPERATURE FLUCTUATIONS" OF A GIVEN AMPLITUDE AND LENGTH SCALE
C IMPINGE ON A MULTI STAGE TURBINE FROM THE UPSTREAM END.STANDARD ACTUATOR
```

```
C DISK THEORY APPLICABLE TO BLADE ROWS CHARACTERIZED BY SUBSONIC OR SUPERSONIC
C EXIT RELATIVE MEAN FLOW THROUGH THE BLADE ROW IS USED.UPTO 49 ROWS ARE
C ALLOWED FOR.
C
C *******************************************************************
C
C     INPUT :
C           Since the subroutine is for an "unwrapped" annular strip ,
C           all inputs below are for the relevant strip . 'NR' denotes
C           the total number of blade rows and 'NS=NR+1' the number
C           of spaces . Thus space 1 denotes 'upstream' and space
C           NS denotes ' downstream' . For axial components , positive
C           is downstream . For tangential ( y ) components , a direction
C           must be selected as positive and consistently adhered to.
C
C               NR = NUMBER OF BLADE ROWS .LE. 49 ( integer input )
C
C                      NOTE THAT NS = NR + 1
C
C               NF = NUMBER OF THIRD OCTAVE POWER LEVELS TO BE CALCULATED
C
C             TOBF = CENTER FREQUENCIES OF THE THIRD OCTAVE BANDS TO BE
C                       CALCULATED,"NF" VALUES IN HERTZ (ALL POSITIVE)
C
C              TFP = PER CENT TEMPERATURE FLUCTUATIONS (RMS IN PERCENT OF
C                               MEAN)
C
C             LOVR = AXIAL LENGTH SCALE OF TEMPERATURE FLUCTUATIONS
C                       NONDIMENSIONALIZED BY MEAN RADIUS IN UPSTREAM ANNULUS
C
C            LOVR2 = TANGENTIAL LENGTH SCALE OF TEMPERATURE FLUCTUATIONS
C                       NONDIMENSIONALIZED BY MEAN RADIUS IN UPSTREAM ANNULUS
C
C               CE = DOWNSTREAM STATIC SPEED OF SOUND : feet/second
C
C              GAM = SPECIFIC HEAT RATIO OF GAS
C
C               PE = DOWNSTREAM STATIC PRESSURE, psia
C
C            ANNHT = RADIAL HEIGHT OF ANNULUS AT EXIT OF LAST BLADE ROW,
C                               inches
C
C              RMX = VECTOR OF NS VALUES OF AXIAL MACH NUMBERS IN
C                    NS SPACES .
C
C              RMY = VECTOR OF NS VALUES OF TANGENTIAL MACH NUMBERS IN
C                    NS SPACES . AGAIN SIGN CONVENTION MUST BE ADHERED
C                    TO .
C
C              RPM = VECTOR OF NR VALUES OF WHEEL RPM'S OF THE
C                    BLADE ROWS . CONSISTENT SIGN CONVENTION
C                    MUST BE ADHERED TO DEPENDING ON THE DIRECTION OF
C                    WHEEL MOTION . VALUE OF 0.00 DENOTES A STATOR .
C
C              DIN = VECTOR OF NR VALUES OF STRIP MEAN DIAMETERS UPSTREAM
C                    OF THE BLADE ROWS ( inches )
C
C             DOUT = VECTOR OF NR VALUES OF STRIP MEAN DIAMETERS DOWNSTREAM
C                    OF THE BLADE ROWS ( inches )
C
```

```
C              CRD = VECTOR OF (NS-1=NR) VALUES OF RATIO STATIC SPEED OF
C                    SOUND IN SPACE TO STATIC SPEED OF SOUND IN DISCHARGE
C                    SPACE : CRD ( NS ) =1.00 ( by definition , obviously )
C
C              AXV = VECTOR OF (NR-1) VALUES OF RATIO OF SPACING
C                    BETWEEN BLADE ROW ACTUATOR DISKS TO MEAN RADIUS.
C                    AXV(1) AND AXV(NR+1=NS) ARE TAKEN AS ZERO .
C                    NO INPUT FOR THIS VECTOR IS NEEDED IF NR=1 .
C
C             hOVH = ANNULAR STRIP HEIGHT/ANNULUS HEIGHT
C
C           NCOF   = NUMBER OF CUT-OFF RATIO BINS TO SORT ACOUSTIC POWER
C                    (must be .LE. 200)
C
C          ISPEC   = INPUT "1" MEANS CORRELATION FUNCTION IN TANGENTIAL
C                    OR AXIAL DIRECTION IS AS EXP(-r/l):"2" MEANS
C                    AS EXP (-(r/l)**2):"3" MEANS AS 1/(1+(r*pi/2l)**2)
C
C     NON DIMENSIONALISATION OF WAVE AMPLITUDES:
C
C     SOUND WAVES : If "p'" is amplitude of fluctuating pressure,non
C                   dimensional amplitude is "p'/(gam*Pst)" where "Pst"
C                   is the mean static pressure in the relevant space.
C
C     SHEAR WAVE  : If "v'" is the amplitude of fluctuating tangential
C                   velocity, non dimensional amplitude is "v'/C" where
C                   "C" is the mean speed of sound in the relevant space.
C
C     ENTROPY WAVE: If "s'" is the amplitude of fluctuating entropy,then
C                   non dimensional amplitude is "s'/Cp" where "Cp" is
C                   the specific heat at constant pressure.
C
C ******************************************************************
C
C     OUTPUT :
C
C            1.AFT RADIATED THIRD OCTAVE POWER IN WATTS FOR 'NF' FREQUENCIES,
C              AS 'WATTIN(I),I=1,NF'
C            2.AFT RADIATED THIRD OCTAVE POWER IN WATTS FOR 'NF' FREQUENCIES
C              SEGREGATED INTO 'NCOF' CUT-OFF RATIO BINS,AS 'WATTSCOF(JR,I),
C              JR=1,NCOF AND I=1,NF'.
C
C ******************************************************************
C
C     SOME COMMENTS CONCERNING THE PRESENT SUBROUTINE:
C
C        1. PROPAGATION EFFECTS DUE TO THE PRESCENCE OF ADJACENT
C           BLADE ROWS ARE INCLUDED IN THE ACTUATOR DISK
C           APPROXIMATION VALID FOR BLADE ROWS CARRYING SUBSONIC
C           EXIT RELATIVE MEAN FLOW i.e ASSUMING CONTINUITY OF
C           MASS FLUX,STAGNATION ENTHALPY RELATIVE TO THE BLADE ROW
C           AND NO CHANGE IN FLOW ANGLE AT THE TRAILING EDGE.FOR CHOKED
C           BLADE ROWS, A CHOKING CONDITION PREVAILS DOWNSTREAM OF THE
C           CHOKED ROW AND IS USED IN PLACE OF THE "NO CHANGE IN FLOW
C           ANGLE" CONDITION AT THE TRAILING EDGE.
C        2. ONLY AN ENTROPY WAVE IS PRESUMED INCIDENT ON THE UPSTREAM
C           BLADE ROW.
C        3. THE TWO DIMENSIONAL ACTUATOR DISK APPROACH IS BASED ON
C           LINEARISING ABOUT UNIFORM FLOWS ( DIFFERENT ON
C           EITHER SIDE OF A BLADE ROW ).
```

```
C        4. REFLECTION FREE CONDITIONS ARE ASSUMED BEYOND LAST ROW.
C
C ******************************************************************
C
      SUBROUTINE STRIP ( NR,NF,TOBF,TFP,LOVR,LOVR2,CE,GAM,PE,
     &             ANNHT,RMX,RMY,RPM,DIN,DOUT,CRD,AXV,
     &             hOVH,NCOF,ISPEC,WATTIN,WATTSCOF )
C
      DIMENSION RMT(50),RMX(50),RMY(50),RPM(50),CRD(50),AXV(50),
     &          TOBF(20),RAD(50),DIN(50),DOUT(50),ICH(50),
     &          WATTSCOF(200,20),WATTIN(20)
C
      REAL      KIN(50),KY,MXD,MYD,MRD,MRU,LOVR,KU,KETA,KXI,
     &          KIN1,KINR,LOVR2,MT,MYR,MX,MREL
C
      COMPLEX   CZERO,IM,CUNITY
C
C***  PROGRAM CONSTANTS AND SOME RELABELLING,PREPROCESSING OF
C***  INPUTS
C
      NS       = NR+1
      AXV(1)   = 0.00
      AXV(NS)  = 0.00
      CRD(NS)  = 1.00
      FCOF     = FLOAT(NCOF)
      PI       = 3.141593
C***  SWITCH "RPM'S" TO WHEEL TIP MACH NUMBERS BASED ON 'CE'
      FACT     = PI/(1440.*CE)
      DO 60 I = 1,NR
        RMT(I) = FACT*RPM(I)*(DIN(I)+DOUT(I))
        RAD(I) = (DIN(I)+DOUT(I))/48.00
   60 CONTINUE
C***  AREA OF DISCHARGE ANNULUS IN SQUARE FEET
      AREA     = PI*(DIN(NR)+DOUT(NR))*ANNHT/288.
C***  "CZERO" DENOTES THE COMPLEX NUMBER WHOSE REAL AND IMAGINARY PARTS
C***  ARE BOTH ZERO
      CZERO   = CMPLX(0.00,0.00)
C***  "CUNITY" DENOTES THE COMPLEX NUMBER WHOSE REAL PART IS UNITY AND
C***  IMAGINARY PART IS ZERO
      CUNITY  = CMPLX(1.00,0.00)
C***  DETERMINE BLADE ROWS WITH SUPERSONIC EXIT RELATIVE MACH NUMBERS
C***  I.E. WHICH ARE CHOKED
      NCHR    = 0
      DO I = 1,NR
        ICH(I) = 0
      END DO
      DO I = 2,NS
        IM1  = I-1
        MT   = RMT(IM1)/CRD(I)
        MX   = RMX(I)
        MYR  = RMY(I)-MT
        MREL = SQRT(MX**2+MYR**2)
        IF ( MREL.GT.1. ) NCHR = NCHR+1
        IF ( MREL.GT.1. ) ICH(NCHR) = IM1
      END DO
C***  'ICHCR' IS SET 'GT' 1 IF A NON ZERO NUMBER OF ROWS IS CHOKED AND
C***  IT IS NOT THE CASE THAT ONLY THE LAST BLADE ROW IS CHOKED.
      ICHCR   = 0
      IF ( (NCHR.GT.0).AND.(ICH(1).LT.NR) ) ICHCR = 1
C***  DISCHARGE & UPSTREAM RELATED
```

```
      MRU     = SQRT(RMX(1)**2+RMY(1)**2)
      CTHU    = RMX(1)/MRU
      TTHU    = RMY(1)/RMX(1)
      MXD     = RMX(NS)
      MYD     = RMY(NS)
      MRD     = SQRT (MXD**2+MYD**2)
      OMMRD2  = 1.-MRD**2
      SROMRD2 = SQRT(OMMRD2)
      SROMXD2 = SQRT(1.-MXD**2)
      DPHI    = PI/100.
      CON     = (0.2316/MRU)*(GAM*PE*144.*CE)*1.3558*AREA*
     &          hOVH*LOVR*LOVR2*(TFP/100.)**2*2./PI**2
C***  "IM" DENOTES THE COMPLEX NUMBER WHOSE REAL PART IS ZERO AND
C***  IMAGINARY PART IS UNITY
      IM      = CMPLX(0.00,1.00)
C
C***  END OF CALCULATION OF
C***  PROGRAM CONSTANTS AND SOME RELABELLING,PREPROCESSING OF
C***  INPUTS
C
C***  DO VARIOUS FREQUENCY BANDS
C
      DO I = 1,NF
        DO J = 1,NR
           KIN(J)  = 2.*PI*TOBF(I)*RAD(J)/CE
        END DO
        DO JR = 1,NCOF
           WATTSCOF(JR,I)=0.00
        ENDDO
        KINR   = KIN(NR)
        KIN1   = KIN(1)
        KU     = KIN1/CRD(1)
        KXI    = KU/MRU
        IF ( ISPEC.EQ.1 ) THEN
           TSPEC1 = 1./(1.+(KXI*LOVR)**2)
        ELSE
           IF ( ISPEC.EQ.2 ) THEN
              TSPEC1 = EXP(-(KXI*LOVR)**2/PI)
           ELSE
              TSPEC1 = EXP(-2.*KXI*LOVR/PI)
           END IF
        END IF
        JMIN   = -KINR*MYD/OMMRD2-KINR*SROMXD2/OMMRD2
        JMAX   = -KINR*MYD/OMMRD2+KINR*SROMXD2/OMMRD2
        SUMM   = 0.00
C
        DO J = JMIN,JMAX
           FJ    = FLOAT(J)
           KY    = FJ
           S     = (KY*OMMRD2+KINR*MYD)/(KINR*SROMXD2)
           C     = SQRT(1.-S**2)
           IF ( ICHCR.EQ.0 ) THEN
              CALL CALC ( NR,KY,KIN,AXV,RMX,RMY,RMT,CRD,GAM,ADSW )
           ELSE
              CALL CALC1 ( NR,KY,KIN,AXV,RMX,RMY,RMT,CRD,GAM,NCHR,
     &                      ICH,ADSW )
           END IF
           IF ( FJ.GT.0.00 ) CTF = (SROMXD2-MYD)/(S*SROMXD2-MYD)
           IF ( FJ.LT.0.00 ) CTF = (SROMXD2+MYD)/(MYD-S*SROMXD2)
           IF ( FJ.EQ.0.00 ) CTF = 1.E+09
```

```
          CTFR2 = CTF**2
          TJR1  = (1.-1./CTFR2)
          TJR   = FCOF*TJR1
          JR    = 1+INT(TJR)
          IF ( JR.GT.NCOF ) JR = NCOF
          KETA  = KY/CTHU-KU*TTHU/MRU
          IF ( ISPEC.EQ.1 ) THEN
             TSPEC2 = 1./(1.+(FJ*LOVR2)**2)
          ELSE
             IF ( ISPEC.EQ.2 ) THEN
              TSPEC2 = EXP(-(FJ*LOVR2)**2/PI)
             ELSE
              AFJ    = ABS(FJ)
              TSPEC2 = EXP(-2.*AFJ*LOVR2/PI)
             END IF
          END IF
          PHIT  = TSPEC1*TSPEC2
          AEF   = (OMMRD2*SROMXD2/(SROMXD2-MYD*S-SROMRD2*MXD*C))*
     &              (MXD+(C*SROMRD2+MXD*MYD*S-MXD*SROMXD2)/
     &              (SROMXD2-MXD*SROMRD2*C-MYD*S))
          TSUM  = PHIT*ADSW**2*AEF
          SUMM  = SUMM+TSUM
          WATTSCOF(JR,I) = WATTSCOF(JR,I)+TSUM*CON*KU
        END DO
C
        WATTIN(I) = SUMM*CON*KU
C
      END DO
C
      RETURN
C
      END
C
C                        *****************************
C************************  END OF SUBROUTINE 'STRIP'****************
C                        *****************************
C
C                         ********************
C************************  FUNCTION 'SGNF'   *********************
C                         ********************
C
C***  FUNCTION SGNF ( I,J ) GIVES (-1)**(I+J) WHICH IS +1 IF (I+J) IS
C***  EVEN AND -1 IF (I+J) IS ODD .
C
      FUNCTION SGNF ( I,J )
C
      IPJ       = I+J
      IDISC     = MOD ( IPJ,2 )
      IF ( IDISC.EQ.0 ) SGNF =  1.00
      IF ( IDISC.NE.0 ) SGNF = -1.00
C
      RETURN
C
      END
C
C                     **************************
C******************** END OF FUNCTION ' SGNF ' **********************
C                     **************************
C
C                        *******************
```

```
C************************  FUNCTION DETM   *********************
C                         *******************
C
C***  FUNCTION DETM ( D ) YIELDS THE COMPLEX DETERMINANT ' DETM ' OF
C***  THE COMPLEX 2X2 MATRIX ' D '.
C
      COMPLEX FUNCTION DETM ( D )
C
      COMPLEX D(2,2)
      DETM      = D(1,1)*D(2,2)-D(1,2)*D(2,1)
C
      RETURN
C
      END
C
C                      **************************
C******************** END OF FUNCTION ' DETM ' *********************
C                      **************************
C
C                         *******************
C********************** SUBROUTINE MATINV *********************
C                         *******************
C
C***  SUBROUTINE MATINV INVERTS THE COMPLEX 3X3 MATRIX 'INP' STORING
C***  THE RESULT IN 'INV'. THE PROCEDURE INVOLVES COMPUTING THE
C***  COFACTORS 'A' OF 'INP' WHICH ITSELF ENTAILS THE CALCULATION OF
C***  THE MINORS OF 'INP'.
C
      SUBROUTINE MATINV ( INP,INV )
C
      COMPLEX INP(3,3),INV(3,3),A(3,3),D(2,2),DET,DETM
C
      DO 400 I = 1,3
         DO 300 J = 1,3
C*** SET UP 2X2 MATRIX 'D' FOR EVALUATION OF COFACTOR
            II    = 0
            DO 200 I1 = 1,3
               IF ( I1.NE.I ) THEN
                  II = II+1
                  JJ = 0
                  DO 100 J1 = 1,3
                     IF ( J1.NE.J ) THEN
                        JJ       = JJ+1
                        D(II,JJ) = INP(I1,J1)
                     ENDIF
  100             CONTINUE
               ENDIF
  200       CONTINUE
C*** EVALUATE COFACTOR
            A(I,J) = DETM(D)*SGNF(I,J)
  300       CONTINUE
  400 CONTINUE
C*** EVALUATE DETERMINANT OF OVERALL MATIX
      DET = CMPLX( 0.00,0.00 )
      DO 500 J = 1,3
         DET = DET+A(1,J)*INP(1,J)
  500 CONTINUE
C*** EVALUTE THE INVERSE MATRIX
      DO 700 I = 1,3
         DO 600 J = 1,3
```

```
            INV(I,J) = A(J,I)/DET
  600    CONTINUE
  700 CONTINUE
C
      RETURN
C
      END
C
C                    ****************************
C******************** END OF SUBROUTINE 'MATINV' ********************
C                    ****************************
C
C                       *******************
C*********************** SUBROUTINE MATINV1 **********************
C                       *******************
C
C***  SUBROUTINE MATINV1 INVERTS THE COMPLEX 3X4 MATRIX 'INP' STORING
C***  THE RESULT IN 'INV'. THE MATRIX "INP" HAS 3 ROWS AND 4 COLUMNS
C***  AND IS PART OF AN ORIGINAL 4 by 4 MATRIX WHOSE FOURTH ROW IS
C***  (0,0,0,1)."INV" HAS THE SAME STRUCTURE AS "INP."
C
      SUBROUTINE MATINV1 ( INP,INV )
C
      COMPLEX INP(3,4),INV(3,4),A(3,3),AI(3,3),B(3),BO(3)
C
C*** SET UP 3X3 MATRIX 'A' FOR INVERSION
      DO 200 I = 1,3
        DO 100 J = 1,3
           A(I,J) = INP(I,J)
  100    CONTINUE
  200 CONTINUE
C*** INVERT "A" AS "AI"
      CALL MATINV ( A,AI )
C
C*** FOURTH COLUMN OF "INP"
      DO 300 I =1,3
        B(I) = INP(I,4)
  300 CONTINUE
C*** NEGATIVE OF FOURTH COLUMN OF "INV"
      CALL MATPRD ( AI,B,BO )
C*** SET UP 3X3 PART OF "INV"
      DO 500 I = 1,3
        DO 400 J = 1,3
           INV(I,J) = AI(I,J)
  400    CONTINUE
  500 CONTINUE
C***  FOURTH COLUMN OF "INV"
      DO 600 I =1,3
        INV(I,4) = -BO(I)
  600 CONTINUE
C
      RETURN
C
      END
C
C                    ****************************
C******************** END OF SUBROUTINE 'MATINV1' *******************
C                    ****************************
C
C                         ********************
```

```
C************************* SUBROUTINE 'WNUMB' ********************
C                          ********************
C
C    SUBROUTINE WNUMB COMPUTES THE (COMPLEX) AXIAL WAVE NUMBER OF THE
C    DOWNSTREAM SOUND WAVE IN KX(1),OF THE UPSTREAM SOUND WAVE IN KX(2) AND
C    OF THE REAL AXIAL WAVENUMBER OF THE SHEAR WAVE IN KXSH.
C
      SUBROUTINE WNUMB ( K,KY,MX,MY,KX,KXSH )
      COMPLEX DELB,IM,KX(2)
      DIMENSION SGN(2)
      REAL K,KXSH,KY,MX,MY
C
      SGN(1)   =  1.00
      SGN(2)   = -1.00
      IM       = CMPLX(0.00,1.00)
      A1       = 1.00
      SK       = SIGN(A1,K)
C
      DEL      = K-KY*MY
      OMMX2    = 1.00-MX**2
      ARG2     = DEL**2-KY**2*OMMX2
      AARG     = SQRT(ABS(ARG2))
      IF ( ARG2.GE.0.00 ) DELB = AARG*SK
      IF ( ARG2.LT.0.00 ) DELB = IM*AARG
      DO 100 I = 1,2
         KX(I) = (-MX*DEL+SGN(I)*DELB)/OMMX2
  100 CONTINUE
      KXSH     = DEL/MX
C
      RETURN
      END
C
C                     ***************************
C******************** END OF SUBROUTINE 'WNUMB' ********************
C                     ***************************
C
C                          *********************
C************************* SUBROUTINE 'FLUXES' ********************
C                          *********************
C
C     SUBROUTINE FLUXES COMPUTES LINEARISED AXIAL MASS FLUX AND
C     STAGNATION ENTHALPY PER UNIT MASS RELATIVE TO BLADE ROW
C     FOR SOUND AND SHEAR WAVES.
C
      SUBROUTINE FLUXES ( CR,MT,MX,MY,P,U,V,MAF,SEF )
      COMPLEX MAF,P,RHO,SEF,U,V
      REAL MT,MX,MY
C
      RHO      = P
      MAF      = RHO+U/MX
      SEF      = (P+MX*U+(MY-MT)*V)*CR**2
C
      RETURN
C
      END
C
C                     ****************************
C******************** END OF SUBROUTINE 'FLUXES' ********************
C                     ****************************
C
```

```
C                          ******************
C************************** SUBROUTINE 'UVP' ********************
C                          ******************
C
C     SUBROUTINE UVP COMPUTES THE NON DIMENSIONAL AXIAL VELOCITY,
C     TANGENTIAL VELOCITY,PRESSURE ASSOCIATED WITH SOUND WAVES FOR
C     I = 1 or 2 AND WITH SHEAR WAVES FOR I = 3.
C
      SUBROUTINE UVP ( I,K,KX,KXSH,KY,MX,MY,P,U,V )
      COMPLEX KX,K0,P,U,V
      REAL K,KXSH,KY,MX,MY
C
      IM3      = I-3
      IF ( IM3.NE.0 ) THEN
           K0    = K-KX*MX-KY*MY
           U     = KX/K0
           V     = KY/K0
           P     = CMPLX(1.00,0.00)
         ELSE
           U     = -KY/KXSH
           V     = CMPLX(1.00,0.00)
           P     = CMPLX(0.00,0.00)
      ENDIF
C
      RETURN
C
      END
C
C                     *************************
C******************** END OF SUBROUTINE 'UVP' ********************
C                     *************************
C
C                          *********************
C************************** SUBROUTINE 'MATPRD' ********************
C                          *********************
C
C     YIELDS PRODUCT OF 3 by 3 MATRIX (A) AND A COLUMN VECTOR (B)
C     AND RESULT IS COLUMN VECTOR (C).
C
      SUBROUTINE MATPRD ( A,B,C )
      COMPLEX A(3,3),B(3),C(3)
C
      DO 200 I = 1,3
         C(I)  = CMPLX(0.00,0.00)
         DO 100 J = 1,3
            C(I)  = A(I,J)*B(J)+C(I)
  100    CONTINUE
  200 CONTINUE
C
      RETURN
C
      END
C
C                     *****************************
C******************** END OF SUBROUTINE 'MATPRD'  ********************
C                     *****************************
C
C                          *********************
C************************** SUBROUTINE 'MATPRD1'********************
C                          *********************
```

```
C
C     ”A” IS A COMPLEX 3 by 4 MATRIX AS IS ”AOUT.””B” IS A COMPLEX 2 by 4
C     MATRIX AS IS ”BOUT.”BOTH ”A” AND ”B” ARE INPUTS.
C     WE OBTAIN A PRODUCT ”AOUT” WHICH IS A 3 BY 4 OBTAINED
C     BY PREMULTPLYING ”B” by ”A.”
C     UNDEFINED ROWS OF ”A” (4th ROW) AND OF ”B”
C     (3rd AND 4th ROWS) ARE TAKEN AS ZERO FOR PURPOSES OF THE MATRIX
C     PRODUCT EVALUATION EXCEPT THAT THE DIAGONAL 4-4 ELEMENT OF BOTH
C     A,B IS UNITY.
C
      SUBROUTINE MATPRD1 ( A,B,AOUT )
      COMPLEX A(3,4),B(2,4),AOUT(3,4)
C
C     INITIALIZE AOUT  TO ZERO
      DO 200 I = 1,3
        DO 100 J = 1,4
           AOUT(I,J) = CMPLX(0.00,0.00)
  100    CONTINUE
  200 CONTINUE
C
      DO 302 I = 1,3
        DO 202 J = 1,4
           AOUT(I,J) = CMPLX(0.00,0.00)
           DO 102 K = 1,2
              AOUT(I,J) = AOUT(I,J)+A(I,K)*B(K,J)
  102       CONTINUE
           IF ( J.EQ.4 ) AOUT(I,J) = AOUT(I,J)+A(I,4)
  202    CONTINUE
  302 CONTINUE
C
      RETURN
      END
C
C                    *****************************
C******************** END OF SUBROUTINE ’MATPRD1’ ********************
C                    *****************************
C
C                    **********************
C********************  SUBROUTINE ’SETMAT’ ********************
C                    **********************
C
C    THIS SUBROUTINE SETS UP THE MATRICES ”BU” (WHOSE THIRD ROW HAS ALL
C    ZEROS AND FOURTH ROW HAS THREE ZEROS FOLLOWED BY UNITY) AND ”BD”
C    (WHOSE FOURTH ROW HAS THREE ZEROS FOLLOWED BY UNITY).BECAUSE OF THE
C    PROPERTIES OF ”BU” AND ”BD” , ”BU” IS CALCULATEED AS A 2 by 4 MATRIX
C    AND ”BD” AS A 3 by 4 MATRIX. THE CONSERVED QUANTITY AND WAVE TYPE
C    CONVENTION FOR BOTH ”BU” AND ”BD” ARE AS UNDER.”R1,R2,R3” ARE PHASE
C    FACTORS GIVING THE CHANGE OF AMPLITUDE & PHASE OF DOWNSTREAM SOUND,
C    UPSTREAM SOUND,SHEAR & ENTROPY WAVES FROM UPSTREAM TO DOWNSTREAM
C    BLADE ROW.
C
C    ROW (CONSERVED QTY)                  COLUMN (WAVE TYPE)
C                                DNSTR SOUND-UPSTR SOUND-SHEAR-ENTROPY
C    LINEARISED MASS FLUX
C    LINEARISED SGN. ENTH.
C    per unit mass relative
C    to blade row
C    CHOKING OR KUTTA CODITION
C    ENTROPY
C
```

```
C     INTEGER INPUT "IMAT" IS USED TO CALCULATE (i) "BU" ONLY IN WHICH
C     CASE INPUTS "MTUPS,AXSP" AND OUTPUTS "BD,R1,R2,R3" ARE NOT USED
C     -SET "IMAT" EQUAL TO "1" (ii) "BD" ONLY IN WHICH CASE INPUTS
C     "MTDNS,AXSP" AND OUTPUTS "BU,R1,R2,R3" ARE NOT USED-SET "IMAT"
C     EQUAL TO "2" AND (iii) BOTH "BD,BU" IN WHICH CASE ALL INPUTS AND
C     ALL OUTPUTS ARE USED-SET "IMAT" EQUAL TO "3"
C
      SUBROUTINE SETMAT ( IMAT,CR,G,KIN,KY,MTDNS,MTUPS,
     1                    MX,MY,AXSP,BD,BU,R1,R2,R3 )
      COMPLEX BD(3,4),BU(2,4),R1,R2,R3,IM,KX(2),MFL,SE,KXI,APCH
      COMPLEX R1E,R2E,R3E,U,V,P
C
      REAL KIN,KY,MTDNS,MTUPS,MX,MY,K,KXSH,MTU,MTD,MRELU
C
      IU       = 0
      CG       = CR**2/(G-1.)
      IM       = CMPLX(0.00,1.00)
      K        = KIN/CR
      MTD      = MTDNS/CR
      MTU      = MTUPS/CR
      MRELU    = SQRT(MX**2+(MY-MTU)**2)
      IF ( MRELU.GE.1.00 ) IU = 1
      IF ( MRELU.GE.1.00 ) TMREL = 1.-MRELU**2
C
C     I = 1 , LINEARIZED AXIAL MASS FLUX
C     I = 2 , LINEARIZED SGN. ENTH./UNIT MASS RELATIVE TO UPSTREAM
C             (IN CASE OF "BD") AND DOWNSTREAM (IN CASE OF "BU") BLADE
C             ROWS
C     I = 3 , CHOKING OR KUTTA CONDITION RELATIVE TO UPSTREAM BLADE ROW
C             (FOR "BD")
C     J = 1 , DOWNSTREAM SOUND
C     J = 2 , UPSTREAM SOUND
C     J = 3 , SHEAR
C     J = 4 , ENTROPY
C
      CALL WNUMB ( K,KY,MX,MY,KX,KXSH )
C     CALCULATE "BD"
      IF ( (IMAT.EQ.2).OR.(IMAT.EQ.3) ) THEN
        KXI      = KX(1)
        CALL UVP ( 1,K,KXI,KXSH,KY,MX,MY,P,U,V )
        CALL FLUXES ( CR,MTU,MX,MY,P,U,V,MFL,SE )
        IF ( IU.EQ.0 ) CALL ANGP ( MTU,MX,MY,U,V,APCH )
        IF ( IU.EQ.1 ) CALL CHOKP ( G,MTU,MX,MY,U,V,P,APCH )
        BD(1,1)  = MFL
        BD(2,1)  = SE
        BD(3,1)  = APCH
C
        KXI      = KX(2)
        CALL UVP ( 2,K,KXI,KXSH,KY,MX,MY,P,U,V )
        CALL FLUXES ( CR,MTU,MX,MY,P,U,V,MFL,SE )
        IF ( IU.EQ.0 ) CALL ANGP ( MTU,MX,MY,U,V,APCH )
        IF ( IU.EQ.1 ) CALL CHOKP ( G,MTU,MX,MY,U,V,P,APCH )
        BD(1,2)  = MFL
        BD(2,2)  = SE
        BD(3,2)  = APCH
C
        KXI      = CMPLX(0.00,0.00)
        CALL UVP ( 3,K,KXI,KXSH,KY,MX,MY,P,U,V )
        CALL FLUXES ( CR,MTU,MX,MY,P,U,V,MFL,SE )
        IF ( IU.EQ.0 ) CALL ANGP ( MTU,MX,MY,U,V,APCH )
```

```
        IF ( IU.EQ.1 ) CALL CHOKP ( G,MTU,MX,MY,U,V,P,APCH )
        BD(1,3)  = MFL
        BD(2,3)  = SE
        BD(3,3)  = APCH
C
        BD(1,4)  = CMPLX(-1.00,0.00)
        BD(2,4)  = CMPLX(CG,0.00)
        IF ( IU.EQ.0 ) BD(3,4)  = CMPLX(0.00,0.00)
        IF ( IU.EQ.1 ) BD(3,4)  = CMPLX(0.50,0.00)*TMREL
      END IF
C     END OF "BD" CALCULATION
C
C     CALCULATE "BU"
      IF ( (IMAT.EQ.1).OR.(IMAT.EQ.3) ) THEN
        KXI      = KX(1)
        CALL UVP ( 1,K,KXI,KXSH,KY,MX,MY,P,U,V )
        CALL FLUXES ( CR,MTD,MX,MY,P,U,V,MFL,SE )
        BU(1,1)  = MFL
        BU(2,1)  = SE
C
        KXI      = KX(2)
        CALL UVP ( 2,K,KXI,KXSH,KY,MX,MY,P,U,V )
        CALL FLUXES ( CR,MTD,MX,MY,P,U,V,MFL,SE )
        BU(1,2)  = MFL
        BU(2,2)  = SE
C
        KXI      = CMPLX(0.00,0.00)
        CALL UVP ( 3,K,KXI,KXSH,KY,MX,MY,P,U,V )
        CALL FLUXES ( CR,MTD,MX,MY,P,U,V,MFL,SE )
        BU(1,3)  = MFL
        BU(2,3)  = SE
C
        BU(1,4)  = CMPLX(-1.00,0.00)
        BU(2,4)  = CMPLX(CG,0.00)
      END IF
C     END OF "BD" CALCULATION
C
C     CALCULATE R1,R2,R3
      IF ( IMAT.EQ.3 ) THEN
        R1E      = IM*KX(1)*AXSP
        R2E      = IM*KX(2)*AXSP
        R3E      = IM*KXSH*AXSP
        R3       = CEXP(R3E)
        R2       = CEXP(R2E)
        R1       = CEXP(R1E)
      END IF
C
      RETURN
      END
C
C              ****************************
C************** END OF SUBROUTINE 'SETMAT' ********************
C              ****************************
C
C                         *******************
C************************* SUBROUTINE 'ANGP' ********************
C                         *******************
C
C     SUBROUTINE ANGP COMPUTES LINEARISED ANGLE PERTURBATION
C     RELATIVE TO BLADE ROW.
```

```
C
      SUBROUTINE ANGP ( MT,MX,MY,U,V,AP )
      COMPLEX AP,U,V
      REAL MT,MX,MY
C
      TANA     = (MY-MT)/MX
      C2A      = 1./(1.+TANA**2)
C
      AP       = (V-TANA*U)*C2A/MX
C
      RETURN
C
      END
C
C                    **************************
C******************** END OF SUBROUTINE 'ANGP' ********************
C                    **************************
C
C                         ********************
C************************* SUBROUTINE 'CHOKP' ********************
C                         ********************
C
C     SUBROUTINE CHOKP COMPUTES A LINEARISED QUANTITY THE SUM OF WHICH
C     DUE TO ALL WAVE SYSTEMS NEEDS TO BE ZERO DOWNSTREAM OF A CHOKED
C     BLADE ROW FOR SOND AND SHEAR WAVES.
C
      SUBROUTINE CHOKP ( G,MT,MX,MY,U,V,P,CH )
      COMPLEX CH,U,V,P,PTRM,WTRM,THTRM
      REAL MT,MX,MY,M,M2
C
      M2       = MX**2+(MY-MT)**2
      M        = SQRT(M2)
      CTH      = MX/M
      STH      = (MY-MT)/M
      TTH      = STH/CTH
      GCON     = (G-1.)/2.
      THCON    = (1.+GCON*M2)*TTH
C
      PTRM     = GCON*P*(1.-M2)
      WTRM     = -(U*CTH+V*STH)*(1.-M2)/M
      THTRM    = ((V*CTH-U*STH)/M)*THCON
C
      CH       = PTRM+WTRM+THTRM
C
      RETURN
C
      END
C
C                    ***************************
C******************** END OF SUBROUTINE 'CHOKP' ********************
C                    ***************************
C
C                         ********************
C************************* SUBROUTINE 'CALC'  ********************
C                         ********************
C
C     "CALC" CARRIES OUT CORE CALCULATIONS FOR DETERMINING RESPONSE OF
C     MULTI BLADE ROW TO AN INCIDENT ENTROPY WAVE IN THE CASE OF NO
C     CHOKED ROWS OR ONLY LAST BLADE ROW CHOKED.
C
```

```
      SUBROUTINE CALC ( NR,KY,KIN,AXV,RMX,RMY,RMT,CRD,GAM,ADSW )
      DIMENSION RMT(50),RMX(50),RMY(50),CRD(50),AXV(50)
C
      REAL      KIN(50),KY,MTDNS,MTUPS,MX,MY
C
      COMPLEX   CZERO,BD(3,4),BU(2,4),IM,SU(3,4),TPROD(3,4),
     1          CUNITY,BI(3,4),BO(3,4),R1,R2,R3,BDI(3,4),R3CUM,
     2          VI(4),VO(4),BOI(3,4),RHS(3),
     3          BUP(2,4),SU4,SUT(3,4)
C***  "CZERO" DENOTES THE COMPLEX NUMBER WHOSE REAL AND IMAGINARY PARTS
C***  ARE BOTH ZERO
      CZERO   = CMPLX(0.00,0.00)
C***  "CUNITY" DENOTES THE COMPLEX NUMBER WHOSE REAL PART IS UNITY AND
C***  IMAGINARY PART IS ZERO
      CUNITY  = CMPLX(1.00,0.00)
C***  "IM" DENOTES THE COMPLEX NUMBER WHOSE REAL PART IS ZERO AND
C***  IMAGINARY PART IS UNITY
      IM      = CMPLX(0.00,1.00)
C
      IWAVE    = 4
      NS       = NR+1
C     INITIALIZE "INCOMING" WAVE SYSTEM AND SET "OUTGOING" WAVE SYSTEM
C     TO ZERO
      DO I = 1,4
        IF ( I.NE.IWAVE ) VI(I) = CZERO
        IF ( I.EQ.IWAVE ) VI(I) = CUNITY
        VO(I) = CZERO
      END DO
C     "R3CUM" IS PHASE FACTOR FOR CONVECTED WAVES
      R3CUM    = CUNITY
      IMAT     = 1
      CR       = CRD(1)
      MTDNS    = RMT(1)
      MTUPS    = RMT(1)
      MX       = RMX(1)
      MY       = RMY(1)
      AXSP     = AXV(1)
C     SET "BUP" & "SU"
      CALL SETMAT ( IMAT,CR,GAM,KIN(1),KY,MTDNS,MTUPS,
     1                    MX,MY,AXSP,BD,BU,R1,R2,R3 )
      DO I = 1,3
        DO J = 1,4
           IF ( NR.EQ.1 ) THEN
              IF ( I.EQ.3 ) SU(I,J)  = CZERO
              IF ( I.LT.3 ) SU(I,J)  = BU(I,J)
           ELSE
              IF ( I.EQ.J ) SU(I,J)  = CUNITY
              IF ( I.NE.J ) SU(I,J)  = CZERO
           END IF
           IF ( I.LT.3 ) BUP(I,J)    = BU(I,J)
        END DO
      END DO
      SU4      = R3CUM
C     DOWNSTREAM SPACE CALCULATION IF THERE IS ONLY ONE BLADE ROW
C     I.E SET "BD" IF NR=1
      IF ( NR.EQ.1 ) THEN
        IMAT     = 2
        CR       = 1.00
        MTDNS    = RMT(1)
        MTUPS    = RMT(1)
```

```
         MX       = RMX(2)
         MY       = RMY(2)
         AXSP     = AXV(2)
         CALL SETMAT ( IMAT,CR,GAM,KIN(1),KY,MTDNS,MTUPS,
     1                        MX,MY,AXSP,BD,BU,R1,R2,R3 )
       ENDIF
C      CALCULATION TO DOWNSTREAM SPACE IF THERE IS MORE THAN ONE BLADE ROW
       IF ( NR.GT.1 ) THEN
         DO 110 I = 2,NR
            IM1      = I-1
            IMAT     = 3
            CR       = CRD(I)
            MTDNS    = RMT(I)
            MTUPS    = RMT(IM1)
            MX       = RMX(I)
            MY       = RMY(I)
            AXSP     = AXV(I)
            CALL SETMAT ( IMAT,CR,GAM,KIN(I),KY,MTDNS,MTUPS,
     1                        MX,MY,AXSP,BD,BU,R1,R2,R3 )
            R3CUM    = R3CUM*R3
            CALL MATINV1 ( BD,BDI )
            CALL MATPRD1 ( BDI,BUP,TPROD )
            CALL MPRD34 ( TPROD,SU,SU4,SUT )
            CALL SHIFT ( SUT,R1,R2,R3,SU )
            SU4      = R3CUM
            DO L = 1,2
               DO M = 1,4
                 BUP(L,M) = BU(L,M)
               END DO
            END DO
  110    CONTINUE
C      CALCULATE "BD" FOR DOWNSTREAM SPACE: ALSO FINAL "SU"
         IMAT     = 2
         CR       = 1.00
         MTDNS    = RMT(NR)
         MTUPS    = RMT(NR)
         MX       = RMX(NS)
         MY       = RMY(NS)
         AXSP     = AXV(NS)
         CALL SETMAT ( IMAT,CR,GAM,KIN(NR),KY,MTDNS,MTUPS,
     1                        MX,MY,AXSP,BD,BU,R1,R2,R3 )
C
         DO L = 1,3
            DO M = 1,4
               SUT ( L,M ) = SU ( L,M )
               IF ( L.NE.3 ) TPROD(L,M) = BUP(L,M)
               IF ( L.EQ.3 ) TPROD(L,M) = CZERO
            END DO
         END DO
         CALL MPRD34 ( TPROD,SUT,SU4,SU )
       ENDIF
C
C      CALCULATE "BI" AND "BO" BASICALLY BY RESETTING COLUMNS IN "SU"
C      AND "BD" AND CHANGING SIGNS.ALSO OBTAIN "VO(4)"EXPLICITLY SINCE
C      INCIDENT WAVE IS AN ENTROPY WAVE
C
       VO(4)    = VI(4)*R3CUM
       DO 210 I = 1,3
         DO 200 J = 1,4
            IF ( J.NE.2 ) THEN
```

```
            IF ( I.NE.3 ) BI(I,J) = SU(I,J)
            IF ( I.EQ.3 ) BI(I,J) = CZERO
            BO(I,J) = BD(I,J)
          ELSE
            BI(I,J) = -BD(I,J)
            IF ( I.NE.3 ) BO(I,J) = -SU(I,J)
            IF ( I.EQ.3 ) BO(I,J) =  CZERO
          END IF
  200    CONTINUE
  210 CONTINUE
      DO 310 I =1,3
        RHS(I) = CZERO
        DO 300 J = 1,4
          RHS(I) = RHS(I)+BI(I,J)*VI(J)
  300    CONTINUE
  310 CONTINUE
      CALL MATINV1 ( BO,BOI )
      DO 410 I =1,3
        VO(I) = BOI(I,4)*VO(4)
        DO 400 J = 1,3
          VO(I) = VO(I)+BOI(I,J)*RHS(J)
  400    CONTINUE
  410 CONTINUE
C
      ADSW  = CABS (VO(1))
C
      RETURN
      END
C                    **************************
C******************** END OF SUBROUTINE 'CALC' ********************
C                    **************************
C
C                         ********************
C************************* SUBROUTINE 'CALC1'  ********************
C                         ********************
C
C     "CALC1" CARRIES OUT CORE CALCULATIONS FOR DETERMINING RESPONSE OF
C     MULTI BLADE ROW TO AN INCIDENT ENTROPY WAVE IN THE CASE OF NON ZERO #
C     OF CHOKED ROWS AND WHEN IT IS NOT THE CASE THAT THE ONLY CHOKED ROW
C     IS THE LAST ROW.
C
      SUBROUTINE CALC1 ( NR,KY,KIN,AXV,RMX,RMY,RMT,CRD,GAM,NCHR,ICH,
     &                   ADSW )
      DIMENSION RMT(50),RMX(50),RMY(50),CRD(50),AXV(50),ICH(50)
C
      REAL      KIN(50),KY,MTDNS,MTUPS,MX,MY
C
      COMPLEX   CZERO,BD(3,4),BU(2,4),IM,SU(3,4),SEFL,
     1          CUNITY,R1,R2,R3,BDI(3,4),R3CUM,MFL,
     2          EWAVE,ENT,BC(4),ALP(3),P(4),MFLN,SEFLN,
     3          BUP(2,4),SU4,SUT(3,4),SD(3,4),AL(4)
C***  "CZERO" DENOTES THE COMPLEX NUMBER WHOSE REAL AND IMAGINARY PARTS
C***  ARE BOTH ZERO
      CZERO   = CMPLX(0.00,0.00)
C***  "CUNITY" DENOTES THE COMPLEX NUMBER WHOSE REAL PART IS UNITY AND
C***  IMAGINARY PART IS ZERO
      CUNITY  = CMPLX(1.00,0.00)
C***  "IM" DENOTES THE COMPLEX NUMBER WHOSE REAL PART IS ZERO AND
C***  IMAGINARY PART IS UNITY
      IM      = CMPLX(0.00,1.00)
```

```
C
      IWAVE    = 4
      NS       = NR+1
      ICHOKE   = 0
C     INITIALIZE WAVE SYSTEM TO LEFT OF BLADE ROW
C     TO ZERO EXCEPT FOR INCOMING ENTROPY WAVE
      DO I = 1,4
        IF ( I.NE.IWAVE ) AL(I) = CZERO
        IF ( I.EQ.IWAVE ) AL(I) = CUNITY
      END DO
C     START WITH UPSTREAM SPACE BOUNDED TO THE RIGHT BY THE FIRST BLADE ROW.
C     "R3CUM" IS PHASE FACTOR FOR CONVECTED WAVES
      IR       = 1
      R3CUM    = CUNITY
      R1       = CUNITY
      R2       = CUNITY
      R3       = CUNITY
      EWAVE    = R3CUM
      IMAT     = 1
      CR       = CRD(1)
      MTDNS    = RMT(1)
      MTUPS    = RMT(1)
      MX       = RMX(1)
      MY       = RMY(1)
      AXSP     = AXV(1)
      CALL SETMAT ( IMAT,CR,GAM,KIN(1),KY,MTDNS,MTUPS,
     1                    MX,MY,AXSP,BD,BU,R1,R2,R3 )
      CALL CHOKE ( NCHR,IR,ICH,IC )
      ICPR     = IC
      IF ( IC.EQ.1 ) THEN
        ICHOKE  = ICHOKE+1
        CALL SMATCH ( CR,GAM,KIN(1),KY,MTDNS,MX,MY,BC )
        AL(2)   = -BC(4)*AL(4)/BC(2)
        DO IJ = 1,3
           ALP(IJ) = AL(IJ)
        END DO
        CALL MSFL ( ALP,EWAVE,BU,MFL,SEFL )
        ENT     = EWAVE
      ELSE
        CALL EQAT1 ( BU,BUP )
        CALL DIAG ( R1,R2,R3,SU,SU4 )
      END IF
C
C     CALCULATION TO DOWNSTREAM SPACE
C
      DO 110 I = 2,NR
        IM1      = I-1
        IMAT     = 3
        CR       = CRD(I)
        MTDNS    = RMT(I)
        MTUPS    = RMT(IM1)
        MX       = RMX(I)
        MY       = RMY(I)
        AXSP     = AXV(I)
        CALL SETMAT ( IMAT,CR,GAM,KIN(I),KY,MTDNS,MTUPS,
     1                        MX,MY,AXSP,BD,BU,R1,R2,R3 )
        R3CUM    = R3CUM*R3
        EWAVE    = R3CUM
C
        IF ( ICPR.EQ.1 ) THEN
```

```
            CALL DIAG ( R1,R2,R3,SU,SU4 )
            CALL EQAT ( BD,SD )
         ELSE
            CALL MATINV1 ( BD,BDI )
            CALL MPR4 ( BDI,BUP,SU,SU4,R1,R2,R3,SUT )
            CALL EQAT ( SUT,SU )
            SU4      = SU4*R3
         END IF
C
         CALL CHOKE ( NCHR,I,ICH,IC )
         ICPR     = IC
         IF ( IC.EQ.1 ) THEN
            ICHOKE  = ICHOKE+1
            CALL SMATCH ( CR,GAM,KIN(1),KY,MTDNS,MX,MY,BC )
            IF ( ICHOKE.EQ.1 ) THEN
               DO M = 1,4
                 P(M) = CMPLX(0.00,0.00)
                 DO L = 1,3
                    P(M) = P(M)+BC(L)*SU(L,M)
                 END DO
               END DO
               P(4)  = P(4)+BC(4)*SU4
               AL(2) = -P(4)/P(2)
               DO L = 1,3
                 ALP(L) = CMPLX(0.00,0.00)
                 DO M = 1,4
                    ALP(L) = ALP(L)+SU(L,M)*AL(M)
                 END DO
               END DO
               CALL MSFL ( ALP,EWAVE,BU,MFL,SEFL )
            ELSE
               CALL CHSOL ( BC,SU,SU4,SD,BU,ENT,EWAVE,MFL,SEFL,
     &                       MFLN,SEFLN )
               MFL  = MFLN
               SEFL = SEFLN
            END IF
            ENT     = EWAVE
         ELSE
            CALL EQAT1 ( BU,BUP )
         END IF
  110    CONTINUE
C     CALCULATE "BD" FOR DOWNSTREAM SPACE AND 'ADSW' I.E. REQUIRED OUTPUT
         IMAT     = 2
         CR       = 1.00
         MTDNS    = RMT(NR)
         MTUPS    = RMT(NR)
         MX       = RMX(NS)
         MY       = RMY(NS)
         AXSP     = AXV(NS)
         CALL SETMAT ( IMAT,CR,GAM,KIN(NR),KY,MTDNS,MTUPS,
     1                        MX,MY,AXSP,BD,BU,R1,R2,R3 )
C
         IF ( ICPR.EQ.1 ) THEN
            CALL DICH ( BD,MFL,SEFL,ENT,ADSW )
         ELSE
            CALL DISOL ( SU,SD,ENT,MFL,SEFL,ADSW )
         END IF
C
      RETURN
      END
```

```
C                     ***************************
C******************* END OF SUBROUTINE 'CALC1' *******************
C                     ***************************
C
C  **** AFT CORE RADIATION SUBROUTINE, E. J. RICE, REVISED 02/19/1998
C  **** NORMALIZED PLANE WAVE RADIATION AND NEW TERMINATION TRANSMISSION
C  **** LOSS MODEL INCLUDED HERE.
C  ** THE FOLLOWING "BBRDCFCR" IS THE MAIN SUBROUTINE.  ALL ARGUMENTS
C     ARE INPUTS EXCEPT "DJET," "FMACH1," "NANGLE," "ANGLE," "SPL,"
C     "SPLTL," "WATTS," "FMACHN," AND "COFMIN" AND WATTS
C     RETURNED TO THE MAIN PROGRAM FOR PRINTING, FILE STORAGE ETC.
C
C  ** THIS VERSION REMOVES THE P**2 OSCILLATIONS BEYOND THE PEAK.  FOUR
C     REGIONS (ETA AND CUT-OFF RATIO) DETERMINE PROPER APPROXIMATION FOR
C     HIGH ANGLE RADIATION FOR THE NON-PLANE WAVES. DEVELOPED 01/30/98.

      SUBROUTINE BBRDCFCR(TTCOR,PTCOR,TSUR,PSUR,HTRATC,ANOZRATC,
     1DISTANCE,ISIDELN,DDUCTC,DJET,FMACHC,FMACH1,FMACH2,
     2NCOF,WATTSCOF,DELANG,ETAC,NANGLE,ANGLE,SPL,SPLTL,WATTS,
     3WATTRAN,FMACHN,COFMIN,CRAT)
C
      DIMENSION ANGLE(200),SPL(200),SPLTL(200),WATTSCOF(200),
     1COFRAT(200),COFRATD(200),COFRATN(200),PSQTOT(200),PSQTLOS(200),
     2PSQRADT(200)

C  *********************************************** 02/19/1998 **********
C
C  ** SUBROUTINE REQUIRED "CORNOZ"
C
C  *********************************************************************
C  NOTE!  SUBROUTINE "CORNOZ" COULD BE MOVED OUT OF THIS SUBROUTINE TO
C  SAVE COMPUTATION TIME IF DESIRED.  THE NOZZLE FLOW CONDITIONS, USING
C  AN ITERATION, ARE CALCULATED EVERY TIME THIS SUBROUTINE IS ENTERED.
C  OF COURCE, THE SUBROUTINE ARGUMENTS MUST BE CAREFULLY CONSTRUCTED TO
C  GET ALL OF THE ARGUMENTS PROPERLY INCLUDED WHERE THEY ARE NEEDED.
C  *********************************************************************
C
C  ***************** DEFINITION OF SUBROUTINE ARGUMENTS ****************
C
C ANGLE   VECTOR OF ANGLES ON THE FAR-FIELD TRAVERSE, CONVERTED TO
C         THAT MEASURED FROM THE ENGINE "INLET" AXIS, (DEGREES)
C ANOZRATC (CORE NOZZLE THROAT AREA)/(CORE DUCT AREA)
C COFMIN  THE MINIMUM CUT-OFF RATIO BELOW WHICH COMPLETE REFLECTION
C         OCCURS DUE TO REFRACTION THROUGH THE SLIP LAYER
C DDUCTC   AFT CORE DUCT OUTSIDE DIAMETER, (INCHES)
C DELANG  ANGLE INCREMENT DESIRED ON FAR-FIELD RADIAL TRAVERSE,(DEGREES)
C DISTANCE  RADIUS OF MICROPHONE ARRAY OR TRAVERSE, (FT.)
C DJET    FINAL JET DIAMETER, (INCHES)
C FMACHC  AFT CORE DUCT MACH NUMBER, POSITIVE FOR EXHAUST
C FMACHN  NOZZLE EXIT (THROAT) MACH NUMBER
C FMACH1  FINAL JET MACH NUMBER
C FMACH2  MACH NUMBER OF SURROUNDING MEDIUM
C FREQ    FREQUENCY OF SOUND, (HERTZ)
C HTRATC   AFT CORE DUCT HUB-TIP RATIO
C ISIDELN = 0 FOR CONSTANT RADIUS, = 1 FOR CONSTANT SIDELINE CALCULATION
C NANGLE  NUMBER OF ANGLES USED IN CALCULATION, DETERMINED BY DELANG AND
C         THE MAXIMUM ANGLE OF 180 DEGREES
C NCOF    NUMBER OF CUT-OFF RATIO BINS TO SORT ACOUSTIC POWER
C PSUR    TOTAL PRESURE IN SURROUNDING MEDIUM, (PSIA)
C PTCOR    TOTAL PRESSURE IN AFT FAN DUCT, (PSIA)
C SPL     THE SOUND PRESSURE LEVEL VECTOR ON THE FAR-FIELD TRAVERSE
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```
C         "IGNORING" THE EXIT TRANSMISSION LOSS (DECIBELS) RELATIVE TO
C         2*10**(-5) NEWTONS/METER**2
C SPLTL   THE SOUND PRESSURE LEVEL VECTOR ON THE FAR-FIELD TRAVERSE
C         "INCLUDING" THE EXIT TRANSMISSION LOSS (DECIBELS) RELATIVE TO
C         2*10**(-5) NEWTONS/METER**2
C TSUR    TOTAL TEMPERATURE IN SURROUNDING MEDIUM, (DEGREES RANKINE)
C TTCOR    TOTAL TEMPERATURE IN AFT CORE DUCT, (DEGREES RANKINE)
C WATTRAN SUM OF TRANSMITTED ACOUSTIC POWER IN ALL BINS, (WATTS)
C WATTS   SUM OF ACOUSTIC POWER IN ALL THE CUT-OFF RATIO BINS, (WATTS)
C WATTSCOF VECTOR WITH ACOUSTIC POWER FOR EACH BIN, (WATTS)
C
      PI = 3.1415927
      QAFP = 1.0+0.328766*ETAC**1.702882
      AFPOWFAC = 1.741*(QAFP+1.274989*ETAC**2)/(PI*ETAC*QAFP)

C  CALCULATE COEF. (PLANE WAVE) INTEGRATION OF RAD. DIRECTIVITY, MACH=0
      IF(ETAC.LT.1.0) THEN
      ACOEFPW = 1.733303+5.30259*ETAC**2.28937
      GO TO 14
      END IF
      ACOEFPW = 7.035893*ETAC**1.773669
   14 CONTINUE
C
C  CALC. COEF. FOR INTEGRATION WITH AFT SHEAR LAYERS, PLANE WAVE
C
      AFPOWFPW = (1.0+0.127683*ETAC)/(3.0+0.137590*ETAC)
      PSQCOEFP = ACOEFPW*AFPOWFPW*(1.0+2.6557*ETAC)/
     &             (1.0515+3.8508*ETAC)
C  *********************************************************************

      FCOF = NCOF
      FCOFINV = 1./FCOF
      FCOFIND2 = 0.5/FCOF
C  *********************** SET UP CUT-OFF RATIOS IN THE DUCT **********
      COFSQPR = 1.0
      DO 20 I=1,NCOF
      COFRATD(I) = SQRT(1.0/(COFSQPR-FCOFIND2))
      COFSQPR = COFSQPR-FCOFINV
   20 CONTINUE

      TDUCT = TTCOR/(1.0+0.2*FMACHC**2)
      CDUCT = 49.0421*SQRT(TDUCT)

      QSUR = 1.0+0.2*FMACH2**2
      TSTS = TSUR/QSUR
      PSTS = PSUR/QSUR**3.5
      CSUR = 49.0421*SQRT(TSTS)
      RHOSUR = 144.0*PSTS/(53.3*TSTS)

C
C  ************************ DETERMINE NOZZLE FLOW PROPERTIES **********

      CALL CORNOZ(TTCOR,PTCOR,PSTS,HTRATC,ANOZRATC,DDUCTC,FMACHC,
     1FMACH1,CJET,DJET,TJET,PNOZ,DNOZ,CNOZ,FMACHN)

      CRAT = CJET/CSUR

      ETA = ETAC*DJET*CDUCT/(DDUCTC*CJET)
      ETAN= ETAC*DNOZ*CDUCT/(DDUCTC*CNOZ)

      RATCFNOZ = DNOZ*CDUCT*SQRT(1.0-FMACHC**2)/(DDUCTC*CNOZ*
```

```
     1SQRT(1.0-FMACHN**2))

       RATCFJET = DJET*CDUCT*SQRT(1.0-FMACHC**2)/(DDUCTC*CJET*
     1SQRT(1.0-FMACH1**2))


       FMSQ1 = FMACH1**2
       FM11 = 1.0-FMSQ1
       BETA1 = SQRT(FM11)
       FMSQ2 = FMACH2**2
C
C  ********** ESTABLISH CUT-OFF LIMITS FOR COMPLETE REFLECTION
       COFMIN = 1.0
       IF(FMACH1.EQ.0.0) GO TO 15

       CKM2 = 1.0-CRAT*FM11/FMACH1
       IF(FMACH2.LT.CKM2) THEN
       COSPHIL = -CRAT/(1.0+CRAT*FMACH1-FMACH2)
       PHIL = ACOS(COSPHIL)
       SINPHIL = SIN(PHIL)
       DEN = SQRT(1.0+FMSQ1+2.0*FMACH1*COSPHIL)
       COSPSIL = (COSPHIL+FMACH1)/DEN
       SINPSIL = SINPHIL/DEN
       COFMIN = SQRT(FM11+FMSQ1*COSPSIL**2)/(BETA1*SINPSIL)
C      COFMIN = (1.0+FMACH1*COSPHIL)/(BETA1*SINPHIL)
       END IF
   15 CONTINUE
C  *********************************************************************

       NANGLE = 180.0/DELANG-1
       DO 5 I=1,NANGLE
       FI = I
       ANGLE(I) = FI*DELANG
    5 CONTINUE

C  ********** PART OF EMPIRICAL COEFFICIENT TAKING PLACE OF RADICAL
C  ********** SQRT(1-1/COF**2) IN P**2 COEFICIENT WHICH WOULD NOT BE
C  ********** ANY GOOD AT CUT-OFF.  FOR NON-PLANE WAVES.

       ACOEF = 0.7/ETA

C  ** RECALL, THE CUT-OFF RATIOS IN THE DUCT ARE INPUT HERE AS "COFRATD"

C  ********** CALCULATE CUT-OFF RATIOS IN THE NOZZLE AND THE JET *******
       DO 22 I=1,NCOF
       COFRATN(I) = RATCFNOZ*COFRATD(I)
       COFRAT(I) = RATCFJET*COFRATD(I)
   22 CONTINUE
C
C  ****************** INITIALIZE P**2 AT EACH FAR-FIELD ANGLE **********
C
       DO 10 I=1,NANGLE
       PSQRADT(I) = 0.0
       PSQTLOS(I) = 0.0
       PSQTOT(I) = 0.0
   10 CONTINUE
C
C  ****************************** START LOOP ON CUT-OFF RATIO **********
C
       POWCON = 8.36424*RHOSUR*CSUR
       WATTS = 0.0
```

```
      WATTRAN = 0.0
      DO 70 J=1,NCOF
      WATTS = WATTS+WATTSCOF(J)
C
C  ** DETERMINE IF COFRAT IS WITHIN COMPLETE REFLECTION RANGE DUE TO
C  ** REFRACTION THROUGH THE SLIP LAYER OR IF COMPLETE REFLECTION
C  ** OCCURS AT THE NOZZLE THROAT
C
      IF(COFRAT(J).LT.COFMIN.OR.COFRATN(J).LE.1.0) GO TO 70


C  *********************************************************************
C  !!!!!!!! VERY IMPORTANT! FOLLOWING DEFINES PLANE WAVE REGIME !!!!!!!!
C  *********************************************************************

C  ********** DETERMINE IF PLANE WAVE RADIATION ALGORITHM SHOULD BE USED
C  ********** IF PLANE WAVE IPW = 1 (YES) FOR COFRATD>=3 OR LAST BIN
      IPW = 0
      IF(COFRATD(J).GE.3.0.OR.J.EQ.NCOF) IPW=1




C  ** CALCULATE TRANSMISSION LOSS AT NOZZLE THROAT CUT-OFF RATIO AND
C  ** FREQUENCY PARAMETER.

      FMSQN = FMACHN**2

      IF(IPW.EQ.1) THEN

C  *************************************** IN PLANE-WAVE REGIME ********

      X = 0.5*(PI*ETAN)**2
      RADRES = 1.0+X*EXP(-0.325226*X)-EXP(-0.101669*ETAN**5.7848)
      A = 0.023567
      Y = 0.5*PI**2*ETAN
      RADREC=EXP(-3.574331*ETAN**1.957292)*8.*ETAN/3.+A*Y**2/
     &          (1.+A*Y**3)
      QDEN = (1.0+FMACHN)**2*((RADRES+1.0)**2+RADREC**2)
      TLCF = 4.*(RADRES*(1.+FMSQN)+FMACHN*
     &         (RADRES**2+RADREC**2+1.))/QDEN
      GO TO 55
      END IF

C  ********** IN NON-PLANE WAVE, RADIAL OR SPINNING MODE REGION ********

      QF = PI*ETAN*(1.0-1.0/COFRATN(J))
      QF15SQ = (QF-1.5)**2
      RADREC = 1.135*EXP(-0.29*(QF+0.18)**2)

      IF(QF.LE.1.5) THEN
      RADRES = 1.5*EXP(-0.2124*QF15SQ)
      GO TO 53
      END IF

      RADRES = 1.0+0.5*EXP(-0.5338*QF15SQ)
   53 CONTINUE

      TAU = SQRT(1.0-1.0/COFRATN(J)**2)
      TPM = TAU+FMACHN
      TTM = TAU*FMACHN
      QDEN = (RADRES*TPM+TTM+1.0)**2+(RADREC*TPM)**2
```

```
      QNUM = (RADRES+FMACHN)*(RADRES*FMACHN+1.0)+FMACHN*RADREC**2
      TLCF = 4.0*TAU*QNUM/QDEN

C  ****************************** CALCULATE TRANSMITTED POWER **********
C
   55 CONTINUE
      WATTRAN = WATTRAN+TLCF*WATTSCOF(J)
C
C  ********** CALCULATE P**2 COEF. TO ACCOUNT FOR WATTS ****************
C     TO ACCOUNT FOR MIC. RADIUS, DIVIDE BY DISTANCE**2 AT PSQ BELOW.
C
      POWCOEF = POWCON*WATTSCOF(J)
C
C  ********** PROGRAM SPITS HERE.  IT WILL CONTINUE ON FOR NON–PLANE
C  ********** WAVES AND WILL JUMP FOR THE PLANE WAVE

      IF(IPW.EQ.1) GO TO 45

C  ********** NOW IN ”NON–PLANE” WAVE REGIME !!!!!!!!!!!!!!!!!!!!!!!!!!

      COFBETIN = 1.0/(COFRAT(J)*BETA1)
      COFINV = 1.0/COFRAT(J)
      COFINVSQ = COFINV**2
      COFM1 = 1.0–COFINVSQ
      EP = SQRT(COFM1)
      GDEN = (1.0+EP)**2

C  ****** HERE IS REMAINDER OF EMPIRICAL COEFFICIENT USING ”ACOEF” ABOVE

      A90 = 2.0*(ACOEF+EP)/(ACOEF+1.0)

C  ****** THEORETICAL NORMALIZATION COEFFICENT WITH FLOW ATTACHED TO A90
C  ** INCLUDES INTEGRATED POWER NORMALIZATION ”AFPOWFAC” (EMPIRICAL) **

      PSQCOEF = AFPOWFAC*A90*(1.0–FMSQ1*COFM1)**1.5/BETA1
      COSPK1 = BETA1*EP/SQRT(1.0–FMSQ1*COFM1)
      ANGPK1 = ACOS(COSPK1)
C  ********** GROUP VELOCITY VECTOR ANGLE IN REGION 1, PSIPK1 (DEGREES)
      PSIPK1 = ANGPK1*180.0/PI
      SINPK1 = SIN(ANGPK1)
C  ************** PHASE VELOCITY VECTOR ANGLE FOR PEAK IN REGION 1 (JET)
      SIN2 = SINPK1**2
      COSPHI1 = –FMACH1*SIN2+COSPK1*SQRT(1.0–FMSQ1*SIN2)
C
C  *************************************** PHI1 TO PHI2 ACROSS SLIP LAYER
C  ********************* PHASE VELOCITY ANGLE IN REGION 2 (SURROUNDINGS)

      COSPHI2 = COSPHI1/(CRAT+(CRAT*FMACH1–FMACH2)*COSPHI1)

C  *********** PHASE TO GROUP VELOCITY ANGLES IN REGION 2 (SURROUNDINGS)

     COSPSI2 = (COSPHI2+FMACH2)/SQRT(1.0+FMSQ2+2.0*FMACH2*COSPHI2)
      PSI2RAD = ACOS(COSPSI2)
      SINPSI2 = SIN(PSI2RAD)

C  ******************* ANGLE CHANGE ACOUSTIC POWER CORRECTION **********

      FREFRCT = SINPK1/SINPSI2

C  *********************************************************************

      Q22NUM = SQRT(1.0+FMSQ2+2.0*FMACH2*COSPHI2)
```

```
      COSPSPK2 = (COSPHI2+FMACH2)/Q22NUM
      ANGPK2 = ACOS(COSPSPK2)

C  ********** GROUP VELOCITY VECTOR ANGLE IN REGION 2, PSIPK2 (DEGREES)
      PSIPK2 = ANGPK2*180.0/PI

C  GROUP VELOCITY VECTOR ANGLE CHANGE, REG. 1 TO REG. 2, DELPSI (DEG.)
      DELPSI = PSIPK2-PSIPK1
C  *********************************************************************

      SIN2PK2 = SIN(PSIPK2*PI/180.0)

C  ********** P**2 PRINCIPAL LOBE PEAK FOR 1 WATT POWER INPUT **********
      PSQPK = PSQCOEF*FREFRCT*ETA*COFRAT(J)/(2.0*BETA1)
C  *********************************************************************


C  ****** START SORTING INTO REGIMES TO HANDLE ANGLES BEYOND PEAK ******
C
      COF = COFRAT(J)
      IREG = 0
      ETAC1 = 0.6*BETA1/(1.0-COFINV)
      IF(ETA.GT.ETAC1) THEN
      IREG = 1

C ********** REGION 1, SLOPE AT ARG=PI/2 USED TO PROJECT BEYOND PEAK

      EPS = 1.0/(BETA1*COF)+0.5/ETA
      EPSQ = EPS**2
      QNUM = 1.0+FMSQ1*EPSQ
      DEPDPSI = QNUM*SQRT(1.0-FM11*EPSQ)
      PSQRATC1 = (4.0/PI)**2*EPS*COFBETIN/(COFBETIN+EPS)**2
      FDEN = CFBTINSQ-EPSQ
      DPSQDPSI = (FDEN+4.0*EPSQ)*PSQRATC1*DEPDPSI/(EPS*FDEN)
      SINPSIC1 = EPS/SQRT(QNUM)
      PSIC = ASIN(SINPSIC1)*180.0/PI
      AC = ALOG(PSQRATC1)
      BC = 0.8889*DPSQDPSI/PSQRATC1
      BC = BC*PI/180.0
      CC = -0.1781*BC
      GO TO 50
      END IF

      ETAC2 = 0.6*BETA1*COF
      IF(ETA.GT.ETAC2) THEN
      IREG = 2

C ********** REGION 2, PSQratio AT ARG=-PI/2 USED TO FIT EXPONENTIAL FOR
C            USE BEYOND PEAK

      EPS = 1.0/(BETA1*COF)-0.5/ETA
      PSQRATC2 = (4.0/PI)**2*EPS*COFBETIN/(COFBETIN+EPS)**2
      EPSQ = EPS**2
      QDEN = 1.0+FMSQ1*EPSQ
      SINPSIC2 = EPS/SQRT(QDEN)
      PSIC2 = ASIN(SINPSIC2)*180.0/PI
      AC = ALOG(PSQRATC2)/(PSIPK1-PSIC2)**2
      GO TO 50
      END IF


C ********** REGION 3, LOW ETA REGION, PSIPK1>60 DEG. FIT EXPONENTIAL AT
```

```
C    0.5*PSIPK1 FOR USE BEYOND PEAK.  CODE IREG=3.  EXPONENTIAL EQUATION
C    USED IN PSQ SUBROUTINE FOR PSI > PSIPK1.

      IF(PSIPK1.GT.60.0) THEN

      IREG = 3

      ANGF = 0.5*PSIPK1
      ANGRAD = ANGF*PI/180.0
      SINF = SIN(ANGRAD)
      EPS = SINF/SQRT(1.0-FMSQ1*SINF**2)
      ARG = PI*ETA*(COFBETIN-EPS)
      SINARG = SIN(ARG)
      PSQRATC3 = 4.0*EPS*COFBETIN/(COFBETIN+EPS)**2
      PSQRATC3 = PSQRATC3*(SINARG/ARG)**2
      AC = ALOG(PSQRATC3)/(PSIPK1-ANGF)**2
      GO TO 50
      END IF

C ********** REGION 4, LOW ETA REGION, PSIPK1<60 DEG. FIT EXPONENTIAL AT
C    80 deg. FOR USE BEYOND PEAK.  CODE IREG=4.  EXPONENTIAL EQUATION
C    USED IN PSQ SUBROUTINE FOR PSI>80 deg.

      IREG = 4

      ANGF = 80.0
      ANGRAD = ANGF*PI/180.0
      SINF = SIN(ANGRAD)
      EPS = SINF/SQRT(1.0-FMSQ1*SINF**2)
      ARG = PI*ETA*(COFBETIN-EPS)
      SINARG = SIN(ARG)
      PSQRATC3 = 4.0*EPS*COFBETIN/(COFBETIN+EPS)**2
      PSQRATC3 = PSQRATC3*(SINARG/ARG)**2
      AC = ALOG(PSQRATC3)/(PSIPK1-ANGF)**2

   50 CONTINUE
C
C  ********** FINISHED WITH 4 REGION DEFINITIONS, START PSQ CALCULATION

      DO 25 I=1,NANGLE
      FI = I
      ANGDEG2 = ANGLE(I)

      IF(ANGDEG2.EQ.0.0.AND.ISIDELN.EQ.1) THEN
      PSQRADT(I) = 0.0
      PSQTOT(I) = 0.0
      PSQTLOS(I) = 0.0
      GO TO 25
      END IF
C
      ANGDEG1 = ANGDEG2-DELPSI
      ANG = ANGDEG1
      ANGRAD1 = ANGDEG1*PI/180.0
      IF(ANGDEG1.LT.0.0) GO TO 25
      SINANG = SIN(ANGRAD1)
      COSANG = COS(ANGRAD1)

      Q1DEN = SQRT(1.0-FMSQ1*SINANG**2)
      Q1 = SINANG/Q1DEN
      ARG = PI*ETA*(Q1-COFBETIN)
      SINSQNUM = (SIN(ARG))**2
```

```
      GG = (1.0+COSANG/Q1DEN)**2/GDEN
      PSQRAT = 4.0*Q1/(BETA1*COFRAT(J)*(Q1+COFBETIN)**2)

      PSQDEN = ARG**2
      ANGCK = PSIPK1+1.0
      IF(ANG.GT.ANGCK) GO TO 6
C  ********** CHECK FOR 0/0, USE LIMITING CASE IF INDETERMINATE ********
C  ********** DON'T CHECK IF ANGLE ABOVE PEAK ANGLE ********************
      IF(PSQDEN.LT.1.E-06) GO TO 39
    6 CONTINUE

      IF(ANG.LT.PSIPK1) GO TO 38
      IF(ANG.GE.PSIC.AND.IREG.EQ.1) THEN

C  ** FOLLOWING TO REMOVE THE P**2 OSCILLATIONS BEYOND THE PEAK ********
C  ** USES SLOPE AT ARG = PI/2 TO EXTRAPOLATE TO HIGH ANGLES ***********
      DANG = ANG-PSIC
      QEXP = AC+BC*DANG/(1.0+CC*DANG)
      IF(QEXP.LT.-20.) QEXP=-20.

      PSQRAT = EXP(QEXP)
      GO TO 39
      END IF

      IF(ANG.GE.PSIPK1.AND.IREG.EQ.2) THEN

C  ** FOLLOWING TO REMOVE THE P**2 OSCILLATIONS BEYOND THE PEAK ********
C  ** USES EXPONENTIAL FIT AT ARG = -PI/2 TO EXTRAPOLATE TO HIGH ANGLES

      QEXP = AC*(ANG-PSIPK1)**2
      IF(QEXP.LT.-20.) QEXP=-20.

      PSQRAT = EXP(QEXP)
      GO TO 39
      END IF

      IF(ANG.GE.PSIPK1.AND.IREG.EQ.3) THEN

C  ** ONE OF THE LOW FREQUENCY REGIONS, REGION 3.  FOLLOWING ALLOWS
C  ** REASONABLE EXTRAPOLATION BEYOND 90 deg, STARTING AT PEAK.
C  ** USES EXPONENTIAL FIT AT PSI = PSIPK1 AND 0.5*PSIPK1. PSIPK1>60 deg

      QEXP = AC*(ANG-PSIPK1)**2
      IF(QEXP.LT.-20.) QEXP=-20.

      PSQRAT = EXP(QEXP)
      GO TO 39
      END IF

C  ** ONLY REGION LEFT, REGION 4, WITH PSIPK1<60 deg.
C  ** ONE OF THE LOW FREQUENCY REGIONS.  FOLLOWING ALLOWS REASONABLE
C  ** EXTRAPOLATION BEYOND 90 deg, STARTING THIS TIME AT 80 deg.
C  ** USES EXPONENTIAL FIT AT PSI = PSIPK1 AND 80 deg. PSIPK1<60 deg.

      IF(ANG.LT.80.0) GO TO 38

      QEXP = AC*(ANG-PSIPK1)**2
      IF(QEXP.LT.-20.) QEXP=-20.

      PSQRAT = EXP(QEXP)
      GO TO 39

   38 PSQRAT = PSQRAT*SINSQNUM/PSQDEN
```

```
   39 CONTINUE

       PSQ = PSQRAT*PSQPK*GG
       PSQRAD = PSQ
C
       RAD = DISTANCE
       IF(ISIDELN.EQ.1) THEN
       RAD = DISTANCE/SIN(ANGDEG2*PI/180.0)
       END IF

       PSQ = PSQ/RAD**2

C
       PSQRADT(I) = PSQRADT(I)+POWCOEF*PSQRAD
       PSQTOT(I) = PSQTOT(I)+POWCOEF*PSQ
       PSQTLOS(I) = PSQTLOS(I)+POWCOEF*PSQ*TLCF

C  ************ NOTE THAT A TRANMISSION LOSS (TLCF) HAS BEEN USED ******

   25 CONTINUE
   26 CONTINUE
       GO TO 70


   45 CONTINUE
C  ********** IN PLANE-WAVE CALCULATION PROCEDURE !!!!!!!!!!!!!!!!!!!!!!

       GDEN = 4.0

       IF(FMACH1.EQ.FMACH2) THEN
       DELPSI = 0.0
       GO TO 27
       END IF

       COSPK1 = 1.0
       ANGPK1 = 0.0
C  ********** GROUP VELOCITY VECTOR ANGLE IN REGION 1, PSIPK1 (DEGREES)
       PSIPK1 = 0.0
       SINPK1 = 0.0
C  ************** PHASE VELOCITY VECTOR ANGLE FOR PEAK IN REGION 1 (JET)
       SIN2 = SINPK1**2
       COSPHI1 = 1.0
       PHI1RAD = 0.0
       PHI1DEG = 0.0
       SINPHI1 = 0.0
C
C  ******************** PHASE VELOCITY ANGLE IN REGION 2 (SURROUNDINGS)

       COSPHI2 = 1.0/(CRAT+CRAT*FMACH1-FMACH2)
       PHI2RAD = ACOS(COSPHI2)
       PHI2DEG = PHI2RAD*180.0/PI
       SINPHI2 = SIN(PHI2RAD)
       COSPSI2 = (COSPHI2+FMACH2)/SQRT(1.0+FMSQ2+2.0*FMACH2*COSPHI2)
       PSI2RAD = ACOS(COSPSI2)
       PSI2DEG = PSI2RAD*180.0/PI
       SINPSI2 = SIN(PSI2RAD)

       Q22DEN = SQRT(1.0+FMSQ2+2.0*FMACH2*COSPHI2)

       COSPSPK2 = (COSPHI2+FMACH2)/Q22DEN
       ANGPK2 = ACOS(COSPSPK2)
       PSIPK2 = ANGPK2*180.0/PI
```

```
C  GROUP VELOCITY VECTOR ANGLE CHANGE, REG. 1 TO REG. 2, DELPSI (DEG.)
      DELPSI = PSIPK2-PSIPK1
C  *********************************************************************

C
   27 CONTINUE

C  ********** P**2 PRINCIPAL LOBE PEAK FOR 1 WATT POWER INPUT **********
      PSQPK = 2.0*PSQCOEFP
C  *********************************************************************

C  **** PSI10 BELOW IS SMALLEST ANGLE WHERE PLANE WAVE RADIATION, P**2=0
C  **** IF PSI10 > 90, PSI10 = 90 IS USED
      SINPSI10 = 1.0/SQRT(ETA**2+FMACH1**2)
      IF(SINPSI10.LT.1.0) THEN
      ANG10 = ASIN(SINPSI10)
      PSI10 = ANG10*180.0/PI
      COSPSI10 = COS(ANG10)
      GO TO 28
      END IF
      ANG10 = PI/2.0
      PSI10 = 90.0
      SINPSI10 = 1.0
      COSPSI10 = 0.0
   28 CONTINUE

C  ********* LOW ETA REGION. FIT EXPONENTIAL AT PSICRPL FOR BEYOND PEAK.
C  ********* IF PSICRPL < 90 CAN'T BE OBTAINED, USE PSICRPL = 90.
      ANGF = 90.0
      ETACRPL = 0.5*BETA1
      SINCRPL = 1.0/SQRT(4.0*ETA**2+FMACH1**2)
      IF(ETA.GT.ETACRPL) ANGF=ASIN(SINCRPL)*180./PI
      PSICRPL = ANGF
      ANGFRAD = ANGF*PI/180.0
      SINF = SIN(ANGFRAD)
      ARG = PI*ETA*SINF/SQRT(1.0-FMSQ1*SINF**2)
      SINARG = SIN(ARG)
      PSQRATPL = (SINARG/ARG)**2
      ACPL = ALOG(PSQRATPL)/ANGF**2
C ********** ACPL IS THE AMPLITUDE OF THE EXPONENTIAL AT PSICRPL *******
C ********** END LOW ETA REGION EXPONENTIAL FIT AT PSICRPL. ************

C  CALCULATE P**2 AMPLITUDE CHANGE DUE TO ANGLE SHIFT FROM PSI = 0 TO
C  PSI = PSIPK2 FOR THE PLANE WAVE PASSING THROUGH THE JET SHEAR LAYER

      PSQPKMUL = 1.0
      AREA1 = 1.0-COSPSI10
      AREA2 = 1.0+SINPSI2*SINPSI10-COSPSI2*COSPSI10

      IF(PSIPK2.GT.0.0.AND.PSI10.LT.PSIPK2) THEN
      AREA2 = 2.0*SINPSI2*SINPSI10
      END IF

      PSQPKMUL = AREA1/AREA2
      PSQPK = PSQPK*PSQPKMUL

      CKPSI0 = -PSI10
      SUMPSQ = 0.0


      DO 40 I=1,NANGLE
```

```
      FI = I
      ANGDEG2 = ANGLE(I)
      IF(ANGDEG2.EQ.0.0.AND.ISIDELN.EQ.1) THEN
      PSQRADT(I) = 0.0
      PSQTOT(I) = 0.0
      PSQTLOS(I) = 0.0
      GO TO 40
      END IF
C
      ANGRAD2 = ANGDEG2*PI/180.0
      ANGDEG1 = ANGDEG2-DELPSI
      ANGRAD1 = ANGDEG1*PI/180.0

      IF(ANGDEG1.LT.CKPSI0) GO TO 40

      SINANG = SIN(ANGRAD1)
      COSANG = COS(ANGRAD1)

      Q1DEN = SQRT(1.0-FMSQ1*SINANG**2)
      Q1 = SINANG/Q1DEN
      ARG = PI*ETA*Q1
      SINSQNUM = (SIN(ARG))**2
      GG = (1.0+COSANG/Q1DEN)**2/GDEN
      PSQRAT = 1.0

      PSQDEN = ARG**2
      IF(PSQDEN.LT.1.E-06.AND.ANGDEG1.LE.90.0) GO TO 49


C  ** LOW FREQUENCY REGION.  FOLLOWING ALLOWS REASONABLE
C  ** EXTRAPOLATION BEYOND 90 deg, STARTING AT ARG = PI/2 IF ETA>ETAcrit
C  ** OR AT 90 deg. OTHERWISE.  USES EXPONENTIAL FIT AT PSI = PSIPK1
C  ** AND PSI = PSIFIT.

      IF(ANGDEG1.LT.PSICRPL) GO TO 48

      QEXP = ACPL*(ANGDEG1)**2
      IF(QEXP.LT.-20.) QEXP=-20.

      PSQRAT = EXP(QEXP)
      GO TO 49


   48 PSQRAT = PSQRAT*SINSQNUM/PSQDEN
   49 CONTINUE

      PSQ = PSQRAT*PSQPK*GG

      PSQRAD = PSQ
C
      RAD = DISTANCE
      IF(ISIDELN.EQ.1) THEN
      RAD = DISTANCE/SIN(ANGDEG2*PI/180.0)
      END IF

      PSQ = PSQ/RAD**2

C
      PSQRADT(I) = PSQRADT(I)+POWCOEF*PSQRAD
      PSQTOT(I) = PSQTOT(I)+POWCOEF*PSQ
      PSQTLOS(I) = PSQTLOS(I)+POWCOEF*PSQ*TLCF

C  ************ NOTE THAT A TRANMISSION LOSS (TLCF) HAS BEEN USED ******
```

```
   40 CONTINUE
   41 CONTINUE
C
   70 CONTINUE


      FNANGLE = NANGLE
      SUMWATT = 0.0
      DO 75 I=1,NANGLE
      ANGRAD = ANGLE(I)*PI/180.0
      SUMWATT = SUMWATT+PSQRADT(I)*SIN(ANGRAD)

C  ** CONVERTING TO ANGLE FROM INLET AXIS FOR THIS AFT RADIATED NOISE **

      ANGLE(I) = 180.0-ANGLE(I)
      IF(PSQTOT(I).LT.4.E-08) THEN
      SPLTL(I) = 20.0
      SPL(I) = 20.0
      GO TO 75
      END IF
      SPLTL(I) = 10.0*ALOG10(PSQTLOS(I))+93.9794
      SPL(I) = 10.0*ALOG10(PSQTOT(I))+93.9794
   75 CONTINUE

      WATTINT = SUMWATT*PI/(POWCON*FNANGLE)
      SPLDIF = 10.0*ALOG10(WATTS/WATTINT)

      DO 80 I=1,NANGLE
      SPLTL(I) = SPLTL(I)+SPLDIF
      SPL(I) = SPL(I)+SPLDIF
   80 CONTINUE


      RETURN
      END
C
C  *********************************************************************
C  ********** END OF MAIN SUBROUTINE "BBRDCFCR" ************************
C  ********** ALTERED 02/19/1998, E. J. RICE ***************************
C  *********************************************************************
C
C
C*********************************************************************
C   SUBROUTINE FOR CALC NOZZLE CONDITIONS, FINAL "CORE" JET MACH NUMBER,
C   VELOCITY, AND DIAMETER.  ** NOTE ** ASSUME ANNULAR CORE DUCT AND
C   CIRCULAR CORE NOZZLE.
C
      SUBROUTINE CORNOZ(TTCOR,PTCOR,PSTS,HTRATC,ANOZRATC,DDUCTC,FMACHC,
     1FMACH1,CJET,DJET,TJET,PNOZ,DNOZ,CNOZ,FMACHN)

C
      PI = 3.1415927
      QM = 1.0+0.2*FMACHC**2
      DIN = DDUCTC*HTRATC
C  ************************************** ANNULAR CORE DUCT **********
      ADUCT = PI*(DDUCTC**2-DIN**2)/4.0
      ANOZ = ADUCT*ANOZRATC
C  *********************************** CIRCULAR CORE NOZZLE **********
      DNOZ = SQRT(4.0*ANOZ/PI)
      TDUCT = TTCOR/QM
      VSOND = 49.0421*SQRT(TDUCT)
```

```
      VDUCT = FMACHC*VSOND
      RHOT = 144.0*PTCOR/(53.3*TTCOR)
      RHOD = RHOT/QM**2.5
      FMASS = RHOD*ADUCT*VDUCT
C  ************************ NOTE – AREAS ARE IN SQUARE INCHES **********
C
C  **************** SOLVE FOR NOZZLE MACH NUMBER ***********************
C
      QQDUCT = FMACHC/QM**3/ANOZRATC
      FN = 1.0
      DIFP = FN/(1.0+0.2*FN**2)**3–QQDUCT
      FNP = 1.0

      DO 10 I=1,50
      FN = 0.975*FN
      DIF = FN/(1.0+0.2*FN**2)**3–QQDUCT
C      WRITE(3,100) I,FN,DIF
C  100 FORMAT(/,' I=',I2,' FN=',F7.4,' DIF=',1PE9.2)
      IF(DIF.LE.0.0) GO TO 12
      FNP = FN
      DIFP = DIF
   10 CONTINUE
      FN = QQDUCT
  111 DO 11 I=1,10
      FN = QQDUCT*(1.0+0.2*FN**2)**3
C      WRITE(3,102) I,FN
C  102 FORMAT(/,' REFINED, I=',I2,' FN=',F7.4)

   11 CONTINUE
      GO TO 14
   12 CONTINUE
      FN = (DIFP*FN–DIF*FNP)/(DIFP–DIF)
C      WRITE(3,101) FN
C  101 FORMAT(/,' INTERPOLATED FN =',F7.4)

      GO TO 111
   14 CONTINUE
      FMACHN = FN
C      WRITE(3,103) FMACHN
C  103 FORMAT(/,' FINAL ********** FMACHN =',F7.4)

C  ****************************** "FMACH1" FINAL JET VELOCITY **********

      FMACH1 = SQRT(5.0*((PTCOR/PSTS)**(2./7.)–1.0))
      QNTJ = 1.0+0.2*FMACH1**2
      TJET = TTCOR/QNTJ
      RHOJ = RHOT/QNTJ**2.5
      CJET = 49.0421*SQRT(TJET)
      VJET = CJET*FMACH1
      AJET = FMASS/(RHOJ*VJET)
      DJET = SQRT(4.0*AJET/PI)

C ** FOLLOWING NOT USED HERE BUT MIGHT BE HANDY FOR LATER USE **********
C  ** CHECK NOZZLE THROAT PRESSURE VRS. SURROUNDING AMBIENT PRESSURE **
      QMN =  1.0/(1.0+0.2*FMACHN**2)
      PNOZ = PTCOR*QMN**3.5
      TNOZ = TTCOR*QMN
      CNOZ = 49.0421*SQRT(TNOZ)
      RETURN
      END
C
```

```
C  *********************************************************************
C  ****************** END OF SUBROUTINE ”CORNOZ” *********************
C  *********************************************************************
C
C                          **********************
C************************ SUBROUTINE ’MATPRD33’********************
C                          **********************
C
C     YIELDS PRODUCT OF TWO COMPLEX 3 BY 3 MATRICES (A,B) AS A COMPLEX
C     3 BY 3 COMPLEX MATRIX ”C.”
C
      SUBROUTINE MATPRD33 ( A,B,C )
      COMPLEX A(3,3),B(3,3),C(3,3)
C
      DO 300 I = 1,3
        DO 200 J = 1,3
           C(I,J) = CMPLX(0.00,0.00)
             DO 100 K = 1,3
               C(I,J) = C(I,J)+A(I,K)*B(K,J)
  100         CONTINUE
  200    CONTINUE
  300 CONTINUE
C
      RETURN
      END
C
C                     ******************************
C******************* END OF SUBROUTINE ’MATPRD33’ *******************
C                     ******************************
C
C                          *********************
C************************ SUBROUTINE ’VECPRDS’********************
C                          *********************
C
C     YIELDS PRODUCT OF COMPLEX VECTOR BY A COMPLEX SCALAR.
C
      SUBROUTINE VECPRDS ( A,B,C )
      COMPLEX A(3),B,C(3)
C
      DO 100 I = 1,3
        C(I)   = A(I)*B
  100 CONTINUE
C
      RETURN
      END
C
C                     *****************************
C******************* END OF SUBROUTINE ’VECPRDS’ *******************
C                     *****************************
C
C                          ********************
C************************ SUBROUTINE ’MPRD34’********************
C                          ********************
C
C     INPUT MATRICES ”A,B” ARE COMPLEX ”3 BY 4” MATRICES.”A” IS PART
C     OF A ”4 BY 4” MATRIX (SAY ”AO”) WHOSE 4TH ROW HAS FIRST THREE COLUMNS AS
C     ZERO AND FOURTH COLUMN AS ”1.””B” IS SIMILAR TO ”A” EXCEPT THAT FOURTH
C     ROW, FOURTH COLUMN IS ”Z.””C” IS THE COMPLEX (3 BY 4) PART OF THE
C     PRODUCT ”AO*BO.”4TH ROW,4TH COLUMN OF ”CO” WOULD BE ”Z” AND FIRST 3
C     COLUMNS OF 4TH ROW OF ”CO” WOULD BE ZERO.
```

```
C
      SUBROUTINE MPRD34 ( A,B,Z,C )
      COMPLEX A(3,4),B(3,4),Z,C(3,4),TTA(3,3),T1A(3),TTB(3,3),
     &        T1B(3),TTC(3,3),T1CP(3),T1C(3)
C
      DO 200 I = 1,3
        DO 100 J = 1,3
           TTA(I,J) = A(I,J)
           TTB(I,J) = B(I,J)
  100    CONTINUE
  200 CONTINUE
C
      DO 300 I = 1,3
        T1A(I) = A(I,4)
        T1B(I) = B(I,4)
  300 CONTINUE
C
      CALL MATPRD33 ( TTA,TTB,TTC )
      CALL MATPRD ( TTA,T1B,T1CP )
      DO 400 I = 1,3
        T1C(I) = T1CP(I)+Z*T1A(I)
  400 CONTINUE
C
      DO 600 I = 1,3
        DO 500 J = 1,3
           C(I,J) = TTC(I,J)
  500    CONTINUE
  600 CONTINUE
C
      DO 700 I = 1,3
        C(I,4) = T1C(I)
  700 CONTINUE
C
      RETURN
      END
C
C                     ****************************
C******************** END OF SUBROUTINE 'MPRD34' ********************
C                     ****************************
C
C                          *******************
C************************* SUBROUTINE 'SHIFT'*******************
C                          *******************
C
C     GIVEN AN INPUT COMPLEX (3 BY 4) MATRIX "A"
C     AND THREE INPUT COMPLEX CONSTANTS "R1,R2,R3" , RETURNS
C     A COMPLEX (3 BY 4) MATRIX "B" WHOSE FIRST,SECOND AND THIRD ROWS ARE THE
C     CORRESPONDING ROWS OF "A" MULTIPLIED BY "R1,R2,R3."
C
      SUBROUTINE SHIFT ( A,R1,R2,R3,B )
      COMPLEX A(3,4),B(3,4),R1,R2,R3,R(3)
C
      R(1)     = R1
      R(2)     = R2
      R(3)     = R3
C
      DO 200 I = 1,3
        DO 100 J = 1,4
           B(I,J) = A(I,J)*R(I)
  100    CONTINUE
```

```
  200 CONTINUE
C
      RETURN
      END
C
C                    ***************************
C******************** END OF SUBROUTINE 'SHIFT' ********************
C                    ***************************
C
C                         *******************
C************************* SUBROUTINE 'CHOKE'********************
C                         *******************
C
C     GIVEN THE NUMBER OF CHOKED BLADE ROWS "NCHR" AND THE SPECIFIC
C     VECTOR "ICH' OF THE NUMBERS OF THE CHOKED BLADE ROWS, DETERMINES
C     IF INPUT ROW NUMBER "IR' IS ONE OF THE CHOKED ROWS. "ICHOKE' IS
C     SET AS ZERO OR UNITY DEPENDING ON IF ROW 'IR' IS UNCHOKED OR CHOKED.
C
      SUBROUTINE CHOKE ( NCHR,IR,ICH,ICHOKE )
      DIMENSION ICH(20)
C
      ICHOKE   = 0
      DO 100 I = 1,NCHR
        IF ( IR.EQ.ICH(I) ) ICHOKE = 1
  100 CONTINUE
C
      RETURN
      END
C
C                    ***************************
C******************** END OF SUBROUTINE 'CHOKE' ********************
C                    ***************************
C                         *********************
C************************* SUBROUTINE 'VRM33P' ********************
C                         *********************
C
C     YIELDS PRODUCT OF ROW VECTOR 'A' AND '3 BY 3' MATRIX 'B' AND
C     RESULT IS THE ROW VECTOR 'C'
C
      SUBROUTINE VRM33P ( A,B,C )
      COMPLEX A(3),B(3,3),C(3)
C
      DO 200 I = 1,3
         C(I)  = CMPLX(0.00,0.00)
         DO 100 J = 1,3
           C(I)  = A(J)*B(J,I)+C(I)
  100    CONTINUE
  200 CONTINUE
C
      RETURN
      END
C
C                    *****************************
C******************** END OF SUBROUTINE 'VRM33P'  ********************
C                    *****************************
C
C                    **********************
C********************  SUBROUTINE 'SMATCH' ********************
C                    **********************
C
```

```
C     THIS SUBROUTINE SETS UP THE ROW VECTOR 'BUCH' WHOSE FOUR ELEMENTS
C     ARE 'INFLUENCE COEFFICIENTS' REPRESENTING THE 'CHOKING CONDITION'
C     FOR THE BLADE ROW AT THE DOWNSTREAM END FOR WAVE SYSTEMS AS TABULATED
C     BELOW:
C
C      DNSTR SOUND(1)    UPSTR SOUND(2)    SHEAR(3)     ENTROPY(4)
C
      SUBROUTINE SMATCH ( CR,G,KIN,KY,MTDNS,MX,MY,BUCH )
C
      COMPLEX BUCH(4),KX(2),KXI,APCH,U,V,P
      REAL KIN,KY,MTDNS,MX,MY,K,KXSH,MTD,MRELD
C
      K         = KIN/CR
      MTD       = MTDNS/CR
      MRELD     = SQRT(MX**2+(MY-MTD)**2)
      TMREL     = 1.-MRELD**2
C
C     NOTATION FOR "BUCH(I)" WITH "I=1,4"
C     I = 1 , DOWNSTREAM SOUND
C     I = 2 , UPSTREAM SOUND
C     I = 3 , SHEAR
C     I = 4 , ENTROPY
C
      CALL WNUMB ( K,KY,MX,MY,KX,KXSH )
C     CALCULATE "BUCH"
      KXI       = KX(1)
      CALL UVP ( 1,K,KXI,KXSH,KY,MX,MY,P,U,V )
      CALL CHOKP ( G,MTD,MX,MY,U,V,P,APCH )
      BUCH(1)  = APCH
C
      KXI       = KX(2)
      CALL UVP ( 2,K,KXI,KXSH,KY,MX,MY,P,U,V )
      CALL CHOKP ( G,MTD,MX,MY,U,V,P,APCH )
      BUCH(2)  = APCH
C
      KXI       = CMPLX(0.00,0.00)
      CALL UVP ( 3,K,KXI,KXSH,KY,MX,MY,P,U,V )
      CALL CHOKP ( G,MTD,MX,MY,U,V,P,APCH )
      BUCH(3)  = APCH
C
      BUCH(4)  = CMPLX(0.50,0.00)*TMREL
C
      RETURN
      END
C
C              ****************************
C************** END OF SUBROUTINE 'SMATCH' ********************
C              ****************************
C
C                         *******************
C************************* SUBROUTINE 'INV2' ********************
C                         *******************
C
C     SOLVES "A*X=Y" WHERE "A" IS A COMPLEX "2 BY 2" MATRIX AND "X,Y"
C     ARE 2 ELEMENT COMPLEX COLUMN VECTORS."A,Y" ARE INPUTS AND "X" IS
C     THE OUTPUT.
C
      SUBROUTINE INV2 ( A,Y,X )
      COMPLEX A(2,2),Y(2),X(2),DET
C
```

```
      DET      = DETM(A)
C
      X(1)     = (A(2,2)*Y(1)-A(1,2)*Y(2))/DET
      X(2)     = (A(1,1)*Y(2)-A(2,1)*Y(1))/DET
C
      RETURN
      END
C
C                    ***************************
C******************** END OF SUBROUTINE 'INV2'  ********************
C                    ***************************
C
C                         *******************
C************************* SUBROUTINE 'INV3' ********************
C                         *******************
C
C     SOLVES "A*X=Y" WHERE "A" IS A COMPLEX "3 BY 3" MATRIX AND "X,Y"
C     ARE 3 ELEMENT COMPLEX COLUMN VECTORS."A,Y" ARE INPUTS AND "X" IS
C     THE OUTPUT.
C
      SUBROUTINE INV3 ( A,Y,X )
      COMPLEX A(3,3),Y(3),X(3),AI(3,3)
C
      CALL MATINV ( A,AI )
      CALL MATPRD ( AI,Y,X )
C
      RETURN
      END
C
C                    ***************************
C******************** END OF SUBROUTINE 'INV3'  ********************
C                    ***************************
C
C                         *******************
C************************* SUBROUTINE 'MSFL' ********************
C                         *******************
C
C     CALCULATES MASS FLUX AND STAGNATION ENTHALPY FLUX GIVEN COMPLEX
C     AMPLITUDES OF DNSTR SOUND,UPSTR SOUND,SHEAR AND ENTROPY WAVES (AS
C     A(1),A(2),A(3) AND 'ENT') AND (2 BY 4) INFLUENCE COEFFICIENT MATRIX
C     'B'
C
      SUBROUTINE MSFL ( A,ENT,B,MF,SF )
      COMPLEX A(3),ENT,B(2,4),MF,SF
C
      MF = CMPLX(0.0,0.0)
      SF = CMPLX(0.0,0.0)
C
      DO I = 1,3
        MF = MF+A(I)*B(1,I)
        SF = SF+A(I)*B(2,I)
      END DO
      MF    = MF+ENT*B(1,4)
      SF    = SF+ENT*B(2,4)
      RETURN
      END
C
C                    ***************************
C******************** END OF SUBROUTINE 'MSFL'  ********************
C                    ***************************
```

```
C
C                          *******************
C************************* SUBROUTINE ’MPR4’ ********************
C                          *******************
C
C     CALCULATES FIRST THE TRIPLE PRODUCT ”BDI*BU*SU” WHERE ’BDI,BU,SU’
C     HAVE THEIR USUAL SIGNIFICANCE AND THEN SHIFTS ROWS BY ’R1,R2,R3’.
C
      SUBROUTINE MPR4 ( BDI,BU,SU,S4,R1,R2,R3,RES )
      COMPLEX BDI(3,4),BU(2,4),SU(3,4),S4,R1,R2,R3,RES(3,4),
     &        TRES(3,4),TRES1(3,4)
C
      CALL MATPRD1 ( BDI,BU,TRES )
      CALL MPRD34 ( TRES,SU,S4,TRES1 )
      CALL SHIFT  ( TRES1,R1,R2,R3,RES )
C
      RETURN
      END
C
C                     ***************************
C******************** END OF SUBROUTINE ’MPR4’  ********************
C                     ***************************
C
C                          *******************
C************************* SUBROUTINE ’EQAT’ ********************
C                          *******************
C
C     EQUATES TWO COMPLEX (3 BY 4) MATRICES.
C
      SUBROUTINE EQAT ( A,B )
      COMPLEX A(3,4),B(3,4)
C
      DO I = 1,3
        DO J = 1,4
           B(I,J) = A(I,J)
        END DO
      END DO
C
      RETURN
      END
C
C                     ***************************
C******************** END OF SUBROUTINE ’EQAT’  ********************
C                     ***************************
C
C                          ********************
C************************* SUBROUTINE ’EQAT1’ ********************
C                          ********************
C
C     EQUATES TWO COMPLEX (2 BY 4) MATRICES.
C
      SUBROUTINE EQAT1 ( A,B )
      COMPLEX A(2,4),B(2,4)
C
      DO I = 1,2
        DO J = 1,4
           B(I,J) = A(I,J)
        END DO
      END DO
C
```

```
      RETURN
      END
C
C                     ***************************
C******************** END OF SUBROUTINE 'EQAT1' ********************
C                     ***************************
C
C                          *******************
C************************ SUBROUTINE 'DIAG' ********************
C                          *******************
C
C     SETS DIAGONAL ELEMENTS OF A COMPLEX ( 3 BY 4 ) MATRIX TO R1,R2,R3
C     RESPECTIVELY AND ALL OFF DIAGONAL TERMS TO ZERO.'D4' IS SET TO R3
C
      SUBROUTINE DIAG ( R1,R2,R3,D,D4 )
      COMPLEX D(3,4),R1,R2,R3,R(3),D4
C
      R(1) = R1
      R(2) = R2
      R(3) = R3
      D4   = R3
      DO I = 1,3
        DO J = 1,4
           IF ( I.NE.J ) D(I,J) = CMPLX ( 0.00,0.00 )
           IF ( I.EQ.J ) D(I,J) = R(I)
        END DO
      END DO
C
      RETURN
      END
C
C                     ***************************
C******************** END OF SUBROUTINE 'DIAG'  ********************
C                     ***************************
C
C                          *******************
C************************ SUBROUTINE 'CHSOL'********************
C                          *******************
C
C     SOLVES FOR WAVE SYSTEMS WHEN A CHOKED ROW IS ENCOUNTERED BEYOND
C     THE FIRST TIME AND COMPUTES NEW MASS FLUX AND STAGNATION ENTHALPY FLUX.
C
      SUBROUTINE CHSOL ( BC,SU,S4,SD,BU,ENT,EWAVE,MFL,SEFL,
     &                  MFLN,SEFLN )
      COMPLEX BC(4),SU(3,4),ENT,MFL,MFLN,SEFL,SEFLN,P(4),SD(3,4),
     &        RHS(3),SOL(3),SOLN(3),NEW(3,3),S4,EWAVE,BU(2,4)
C
      DO J = 1,4
        P(J) = CMPLX(0.00,0.00)
        DO I = 1,3
           P(J) = P(J)+BC(I)*SU(I,J)
        END DO
      END DO
      P(4) = P(4)+BC(4)*S4
C
      DO I = 1,3
        IF ( I.LT.3 ) THEN
           DO J = 1,3
              NEW(I,J) = SD(I,J)
           END DO
```

```
        ELSE
           DO J = 1,3
              NEW(I,J) = P(J)
           END DO
        END IF
      END DO
C
      RHS(1) = MFL-SD(1,4)*ENT
      RHS(2) = SEFL-SD(2,4)*ENT
      RHS(3) = -P(4)*ENT
C
      CALL INV3 ( NEW,RHS,SOL )
C
      DO I = 1,3
        SOLN(I) = CMPLX(0.00,0.00)
        DO J = 1,3
           SOLN(I) = SOLN(I)+SU(I,J)*SOL(J)
        END DO
        SOLN(I) = SOLN(I)+SU(I,4)*ENT
      END DO
C
      CALL MSFL ( SOLN,EWAVE,BU,MFLN,SEFLN )
C
      RETURN
      END
C
C                    **************************
C******************** END OF SUBROUTINE 'CHSOL'********************
C                    **************************
C
C                         *******************
C************************* SUBROUTINE 'DISOL'********************
C                         *******************
C
C     SOLVES FOR WAVE SYSTEMS AT DISCHARGE WHEN LAST BLADE ROW IS NOT
C     CHOKED.
C
      SUBROUTINE DISOL ( SU,SD,ENT,MFL,SEFL,ADSW )
      COMPLEX SU(3,4),ENT,P(4),SD(3,4),MFL,SEFL,
     &        RHS(3),SOL(3),SOLN(3),NEW(3,3)
C
      DO J = 1,4
        P(J) = SU(2,J)
      END DO
C
      DO I = 1,3
        IF ( I.LT.3 ) THEN
           DO J = 1,3
              NEW(I,J) = SD(I,J)
           END DO
        ELSE
           DO J = 1,3
              NEW(I,J) = P(J)
           END DO
        END IF
      END DO
C
      RHS(1) = MFL-SD(1,4)*ENT
      RHS(2) = SEFL-SD(2,4)*ENT
      RHS(3) = -P(4)*ENT
```

```
C
      CALL INV3 ( NEW,RHS,SOL )
C
      DO I = 1,3
        SOLN(I) = CMPLX(0.00,0.00)
        DO J = 1,3
           SOLN(I) = SOLN(I)+SU(I,J)*SOL(J)
        END DO
        SOLN(I) = SOLN(I)+SU(I,4)*ENT
      END DO
C
      ADSW = CABS ( SOLN(1) )
C
      RETURN
      END
C
C                    ***************************
C******************** END OF SUBROUTINE 'DISOL'********************
C                    ***************************
C
C                         ******************
C************************* SUBROUTINE 'DICH'********************
C                         ******************
C
C     SOLVES FOR WAVE SYSTEMS AT DISCHARGE WHEN LAST BLADE ROW IS
C     CHOKED.
C
      SUBROUTINE DICH ( BD,MFL,SEFL,ENT,ADSW )
      COMPLEX BD(3,4),ENT,MFL,SEFL,LSP(2,2),LS(2),RHS(2)
C
      LSP(1,1) = BD(1,1)
      LSP(2,1) = BD(2,1)
      LSP(1,2) = BD(1,3)
      LSP(2,2) = BD(2,3)
C
      RHS(1)   = MFL-ENT*BD(1,4)
      RHS(2)   = SEFL-ENT*BD(2,4)
C
      CALL INV2 ( LSP,RHS,LS )
C
      ADSW     = CABS ( LS(1) )
C
      RETURN
C
      END
C
C                    **************************
C******************** END OF SUBROUTINE 'DICH'********************
C                    **************************
C
C                         *********************
C************************* SUBROUTINE 'ANGSRT'*******************
C                         *********************
C
C     GIVEN AN ANGLE SET 'ANGLE(I),I=1,NANG' AND AN ANGLE 'ANG',DETERMINES
C     THE ANGLE OF SET 'ANGLE' WHICH IS CLOSEST TO 'ANG'.RETURNS THIS VALUE
C     OF SET AS 'ANGO' AND ASSOCIATED 'I' AS 'IANG'.
C
      SUBROUTINE ANGSRT ( NANG,ANGLE,ANG,IANG,ANGO )
C
```

```
      DIMENSION ANGLE ( 200 )
C
      AMODMIN = ABS ( ANGLE(1)-ANG )
      IANG    = 1
      ANGO    = ANGLE(1)
C
      DO I = 2,NANG
        ANGMOD = ABS ( ANGLE(I)-ANG )
        IF ( ANGMOD.LT.AMODMIN ) THEN
             ANGO    = ANGLE(I)
             IANG    = I
             AMODMIN = ANGMOD
        END IF
      END DO
C
      RETURN
C
      END
C
C                    ****************************
C******************* END OF SUBROUTINE 'ANGSRT'*****************
C                    ****************************
C
C                         *********************
C************************ SUBROUTINE 'INTSTR'*****************
C                         *********************
C
C     INTERPOLATES "CE,PE,RMX(NS),RMY(NS),DIN(NR),DOUT(NR),CRD(NR),
C     AXV(NR-1),hOVH" FROM PITCH LINE VALUES,NON DIMENSIONAL RADIAL HEIGHT
C     AND UPSTREAM & DOWNSTREAM HUB-TIP RATIOS FOR STRIP OF INTEREST.
C
      SUBROUTINE INTSTR ( NSTR )
C
      REAL      MXP,MYP,M2P,MXT,MYTP,MYT,M2T,MX,MY
C
      COMMON    CE,PE,RMX(50),RMY(50),DIN(50),DOUT(50),CRD(50),GAM,
     &          AXV(50),RHT(25),SIGIN(50),SIGOUT(50),NR,NS,NRHT,
     &          SMX(50),SMY(50),SDIN(50),SDOUT(50),SCRD(50),
     &          SAXV(50),ShOVH,SANNHT,SCE,SPE
C
      GC1       = (GAM-1.)/2.
      GC2       = 2.*GAM/(GAM-1.)
      SAXV(1)   = 0.00
      SAXV(NS)  = 0.00
      SCRD(NS)  = 1.00
      PI        = 3.141593
      SIGD      = SIGOUT(NR)
      DD        = DOUT(NR)
      NP1       = NSTR+1
      NM1       = NSTR-1
      X         = RHT(NSTR)
C
      IF ( NSTR.EQ.1 )    DELX = 0.5*(RHT(2)+RHT(1))
      IF ( NSTR.EQ.NRHT ) DELX = 1.-0.5*(RHT(NSTR)+RHT(NM1))
      IF ( (NSTR.GT.1).AND.(NSTR.LT.NRHT) )
     &    DELX   = 0.5*(RHT(NP1)-RHT(NM1))
      ShOVH     = DELX
      SANNHT    = DD*(1.-SIGD)*DELX/(1.+SIGD)
C
C     DO CALCULATIONS FOR LAST SPACE FIRST
```

```
      RP        = (1.+SIGD)/2.
      MXP       = RMX(NS)
      MYP       = RMY(NS)
      M2P       = MXP**2+MYP**2
      RTP2      = 1./(1.+GC1*M2P)
      RTP       = SQRT(RTP2)
      MXT       = MXP*RTP
      MYTP      = MYP*RTP
      R         = SIGD+X*(1.–SIGD)
      SDOUT(NR) = 2.*DD*R/(1.+SIGD)
      RU        = SIGIN(NR)+X*(1.–SIGIN(NR))
      SDIN(NR)  = 2.*DIN(NR)*RU/(1.+SIGIN(NR))
      MYT       = MYTP*RP/R
      M2T       = MYT**2+MXT**2
      RT2       = 1.–GC1*M2T
      RT        = SQRT(RT2)
      MX        = MXT/RT
      MY        = MYT/RT
      SMX(NS)   = MX
      SMY(NS)   = MY
      CEOCPE    = RT/RTP
      SCE       = CE*CEOCPE
      SPE       = PE*CEOCPE**GC2
C     DO CALCULATIONS FOR SPACES 1 TO (NS–1)
      NSM1      = NS–1
      DO 100 I = 2,NSM1
C        DO CALCULATIONS FOR (I–1) SPACE
        IM1         = I–1
        RP          = (1.+SIGIN(IM1))/2.
        MXP         = RMX(IM1)
        MYP         = RMY(IM1)
        M2P         = MXP**2+MYP**2
        RTP2        = 1./(1.+GC1*M2P)
        RTP         = SQRT(RTP2)
        MXT         = MXP*RTP
        MYTP        = MYP*RTP
        R           = SIGIN(IM1)+X*(1.–SIGIN(IM1))
        MYT         = MYTP*RP/R
        M2T         = MYT**2+MXT**2
        RT2         = 1.–GC1*M2T
        RT          = SQRT(RT2)
        MX          = MXT/RT
        MY          = MYT/RT
        SMX(IM1)    = MX
        SMY(IM1)    = MY
        SDIN(IM1)   = 2.*DIN(IM1)*R/(1.+SIGIN(IM1))
        SCRD(IM1)   = (RT/RTP)*CRD(IM1)/CEOCPE
        SAXV(IM1)   = AXV(IM1)*RP/R
C        DO CALCULATIONS FOR SPACE ”I”
        RP          = (1.+SIGOUT(IM1))/2.
        MXP         = RMX(I)
        MYP         = RMY(I)
        M2P         = MXP**2+MYP**2
        RTP2        = 1./(1.+GC1*M2P)
        RTP         = SQRT(RTP2)
        MXT         = MXP*RTP
        MYTP        = MYP*RTP
        R           = SIGOUT(IM1)+X*(1.–SIGOUT(IM1))
        MYT         = MYTP*RP/R
        M2T         = MYT**2+MXT**2
```

```
       RT2        = 1.-GC1*M2T
       RT         = SQRT(RT2)
       MX         = MXT/RT
       MY         = MYT/RT
       SMX(I)     = MX
       SMY(I)     = MY
       SDOUT(IM1) = 2.*DOUT(IM1)*R/(1.+SIGOUT(IM1))
       SCRD(I)    = (RT/RTP)*CRD(I)/CEOCPE
       SAXV(I)    = AXV(I)*RP/R
  100 CONTINUE
C
      RETURN
C
      END
C
C                     ****************************
C******************** END OF SUBROUTINE 'INTSTR'******************
C                     ****************************
C
```

4.6 Sample Input File for Core Noise Program

```
11 12 8 15                              NR,NF,NRHT,NSPL
200.                                    TOBF(1)
252.                                    TOBF(2)
315.                                    TOBF(3)
405.                                    TOBF(4)
500.                                    TOBF(5)
630.                                    TOBF(6)
800.                                    TOBF(7)
1000.                                   TOBF(8)
1250.                                   TOBF(9)
1575.                                   TOBF(10)
2000.                                   TOBF(11)
2520.                                   TOBF(12)-TOBF(NF)
1695 1.353 1.4 15.33                    CE,GAM,GAMA,PE
.2 8.50 .13 .30                         RHT(1),TFPV(1),LOVRV(1),LOVR2V(1)
.3  8.0 .13 .30                         RHT(2),TFPV(2),LOVRV(2),LOVR2V(2)
.4  8.0 .13 .30                         RHT(3),TFPV(3),LOVRV(3),LOVR2V(3)
.5  8.5 .13 .30                         RHT(4),TFPV(4),LOVRV(4),LOVR2V(4)
.6 10.0 .13 .30                         RHT(5),TFPV(5),LOVRV(5),LOVR2V(5)
.7 10.5 .13 .30                         RHT(6),TFPV(6),LOVRV(6),LOVR2V(6)
.8 12.0 .13 .30                         RHT(7),TFPV(7),LOVRV(7),LOVR2V(7)
.9 12.0 .13 .30                         RHT(8),TFPV(8),LOVRV(8),LOVR2V(8)
1238 15.49 520 14.7 .70 .95 400.        TTOT,PTOT,TA,PA,HTR,ANOZRAT,DISTANCE
1 38 .1 1 5.                            ISIDELN,DDUCT,FMACH2,NCOF,DELANG
90.0                                    ASPL(1)
95.0                                    ASPL(2)
100.0                                   ASPL(3)
105.0                                   ASPL(4)
110.0                                   ASPL(5)
115.0                                   ASPL(6)
120.0                                   ASPL(7)
125.0                                   ASPL(8)
130.0                                   ASPL(9)
135.0                                   ASPL(10)
140.0                                   ASPL(11)
145.0                                   ASPL(12)
150.0                                   ASPL(13)
155.0                                   ASPL(14)
```

```
160.0                                   ASPL(15)
0.0773 0.0000                           RMX(1),RMY(1)
0.2196 0.9961                           RMX(2),RMY(2)
0.3809 0.1438                           RMX(3),RMY(3)
0.2894 0.5625                           RMX(4),RMY(4)
0.2527 0.2905                           RMX(5),RMY(5)
0.2046 0.4094                           RMX(6),RMY(6)
0.1907 0.2126                           RMX(7),RMY(7)
0.1639 0.2770                           RMX(8),RMY(8)
0.1553 0.0944                           RMX(9),RMY(9)
0.1441 0.1792                           RMX(10),RMY(10)
0.1451 -.0321                           RMX(11),RMY(11)
0.1250 -.0013                           RMX(12),RMY(12)-RMX(NS),RMY(NS)
0.     27.125 27.365 1.22 .8378 .8743   S1 HPT,RPM,DIN,DOUT,CRD,SIGIN,SIGOUT
11660. 27.349 27.232 1.12 .8698 .8618   R1 HPT,RPM,DIN,DOUT,CRD,SIGIN,SIGOUT
0.     27.381 28.006 1.04 .8409 .798    S1,RPM,DIN,DOUT,CRD,SIGIN,SIGOUT
2027.  28.144 28.526 1.02 .7923 .7751   R1,RPM,DIN,DOUT,CRD,SIGIN,SIGOUT
0.     28.888 29.690 1.02 .7606 .7366   S2,RPM,DIN,DOUT,CRD,SIGIN,SIGOUT
2027.  29.953 30.435 1.02 .7311 .7203   R2,RPM,DIN,DOUT,CRD,SIGIN,SIGOUT
0.     30.864 31.463 1.01 .7101 .6945   S3,RPM,DIN,DOUT,CRD,SIGIN,SIGOUT
2027.  31.662 32.052 1.01 .6896 .6809   R3,RPM,DIN,DOUT,CRD,SIGIN,SIGOUT
0.     32.282 32.594 1.00 .675  .6657   S4,RPM,DIN,DOUT,CRD,SIGIN,SIGOUT
2027.  32.635 32.638 1.00 .6647 .6646   R4,RPM,DIN,DOUT,CRD,SIGIN,SIGOUT
0.     32.411 31.999 1.00 .6724 .687    OGV,RPM,DIN,DOUT,CRD,SIGIN,SIGOUT
0.0393                                  AXV(2)
0.0402                                  AXV(3)
0.0162                                  AXV(4)
0.0369                                  AXV(5)
0.0284                                  AXV(6)
0.0458                                  AXV(7)
0.0247                                  AXV(8)
0.0386                                  AXV(9)
0.0265                                  AXV(10)
0.0265                                  AXV(11)-AXV(NR)
25                                      NCOF- # of cut off ratio bins
3                                       ISPEC:IF EQ. 1 OR 2 EXPONENT IN CORR
                               FCN e(-(r/l)**ISPEC);3:1/(1+(r*pi/2l)**2)
```

4.7 Sample Output File for Core Noise Program

```
************* INPUT PARAMETERS **************

NUMBER OF BLADE ROWS                =      11

EXIT STATIC SPD. OF SOUND ( fps )  =  1695.0
SPECIFIC HEAT RATIO OF GAS         =    1.35
SPECIFIC HEAT RATIO OF GAS-AMBIENT  =    1.40
EXIT STATIC PRESSURE (psia)         =   15.33

TOTAL TEMP. IN AFT DUCT,DEG R      =  1238.0
TOTAL PRESSURE IN AFT DUCT ,psia   =   15.49
AMBIENT STATIC TEMPERATURE,DEG R   =   520.0
AMBIENT STATIC PRESSURE,psia       =   14.70
AFT DUCT HUB TIP RATIO             =   0.700
NOZZLE THROAT/AFT DUCT AREA RATIO   =   0.950
AFT DUCT DIAMETER,inches            =   38.00
AMBIENT MACH NUMBER                 =   0.100
```

```
TEMPERATURE FLUCTUATION RELATED INPUTS

   RHT    Trms/T %  Ax L/R   Ta L/R

   0.20      8.50   0.1300   0.3000
   0.30      8.00   0.1300   0.3000
   0.40      8.00   0.1300   0.3000
   0.50      8.50   0.1300   0.3000
   0.60     10.00   0.1300   0.3000
   0.70     10.50   0.1300   0.3000
   0.80     12.00   0.1300   0.3000
   0.90     12.00   0.1300   0.3000


 UPSTREAM SPACE-@ PITCH LINE

AXIAL MACH NUMBER IN SPACE          =  0.0773
TANGENTIAL MACH NUMBER IN SPACE     =  0.0000
WHEEL RPM OF BLADE ROW AT AFT END
OF SPACE                            =     0.0
SPEED OF SOUND IN SPACE NORMALISED BY
EXIT SPEED OF SOUND                 =  1.2200
DIAMETER AHEAD OF BLADE ROW (ins)   =   27.13
DIAMETER AFT OF BLADE ROW (ins)     =   27.36
HUB TO TIP RATIO AHEAD OF BLADE ROW =  0.8378
HUB TO TIP RATIO AFT OF BLADE ROW   =  0.8743

 SPACE NUMBER        2 -@ PITCH LINE

AXIAL MACH NUMBER IN SPACE          =  0.2196
TANGENTIAL MACH NUMBER IN SPACE     =  0.9961
WHEEL RPM OF BLADE ROW AT AFT END
OF SPACE                            = 11660.0
SPEED OF SOUND IN SPACE NORMALISED BY
EXIT SPEED OF SOUND                 =  1.1200
DIAMETER AHEAD OF BLADE ROW (ins)   =   27.35
DIAMETER AFT OF BLADE ROW (ins)     =   27.23
HUB TO TIP RATIO AHEAD OF BLADE ROW =  0.8698
HUB TO TIP RATIO AFT OF BLADE ROW   =  0.8618

AXIAL SPACING OF SPACE NORMALISED BY
MEAN RADIUS OF ANNULUS              =  0.0393

 SPACE NUMBER        3 -@ PITCH LINE

AXIAL MACH NUMBER IN SPACE          =  0.3809
TANGENTIAL MACH NUMBER IN SPACE     =  0.1438
WHEEL RPM OF BLADE ROW AT AFT END
OF SPACE                            =     0.0
SPEED OF SOUND IN SPACE NORMALISED BY
EXIT SPEED OF SOUND                 =  1.0400
DIAMETER AHEAD OF BLADE ROW (ins)   =   27.38
DIAMETER AFT OF BLADE ROW (ins)     =   28.01
HUB TO TIP RATIO AHEAD OF BLADE ROW =  0.8409
HUB TO TIP RATIO AFT OF BLADE ROW   =  0.7980

AXIAL SPACING OF SPACE NORMALISED BY
MEAN RADIUS OF ANNULUS              =  0.0402

 SPACE NUMBER        4 -@ PITCH LINE

AXIAL MACH NUMBER IN SPACE          =  0.2894
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TANGENTIAL MACH NUMBER IN SPACE     =  0.5625
WHEEL RPM OF BLADE ROW AT AFT END
OF SPACE                            =  2027.0
SPEED OF SOUND IN SPACE NORMALISED BY
EXIT SPEED OF SOUND                 =  1.0200
DIAMETER AHEAD OF BLADE ROW (ins)   =   28.14
DIAMETER AFT OF BLADE ROW (ins)     =   28.53
HUB TO TIP RATIO AHEAD OF BLADE ROW =  0.7923
HUB TO TIP RATIO AFT OF BLADE ROW   =  0.7751

AXIAL SPACING OF SPACE NORMALISED BY
MEAN RADIUS OF ANNULUS              =  0.0162

 SPACE NUMBER        5 –@ PITCH LINE

AXIAL MACH NUMBER IN SPACE          =  0.2527
TANGENTIAL MACH NUMBER IN SPACE     =  0.2905
WHEEL RPM OF BLADE ROW AT AFT END
OF SPACE                            =     0.0
SPEED OF SOUND IN SPACE NORMALISED BY
EXIT SPEED OF SOUND                 =  1.0200
DIAMETER AHEAD OF BLADE ROW (ins)   =   28.89
DIAMETER AFT OF BLADE ROW (ins)     =   29.69
HUB TO TIP RATIO AHEAD OF BLADE ROW =  0.7606
HUB TO TIP RATIO AFT OF BLADE ROW   =  0.7366

AXIAL SPACING OF SPACE NORMALISED BY
MEAN RADIUS OF ANNULUS              =  0.0369

 SPACE NUMBER        6 –@ PITCH LINE

AXIAL MACH NUMBER IN SPACE          =  0.2046
TANGENTIAL MACH NUMBER IN SPACE     =  0.4094
WHEEL RPM OF BLADE ROW AT AFT END
OF SPACE                            =  2027.0
SPEED OF SOUND IN SPACE NORMALISED BY
EXIT SPEED OF SOUND                 =  1.0200
DIAMETER AHEAD OF BLADE ROW (ins)   =   29.95
DIAMETER AFT OF BLADE ROW (ins)     =   30.43
HUB TO TIP RATIO AHEAD OF BLADE ROW =  0.7311
HUB TO TIP RATIO AFT OF BLADE ROW   =  0.7203

AXIAL SPACING OF SPACE NORMALISED BY
MEAN RADIUS OF ANNULUS              =  0.0284

 SPACE NUMBER        7 –@ PITCH LINE

AXIAL MACH NUMBER IN SPACE          =  0.1907
TANGENTIAL MACH NUMBER IN SPACE     =  0.2126
WHEEL RPM OF BLADE ROW AT AFT END
OF SPACE                            =     0.0
SPEED OF SOUND IN SPACE NORMALISED BY
EXIT SPEED OF SOUND                 =  1.0100
DIAMETER AHEAD OF BLADE ROW (ins)   =   30.86
DIAMETER AFT OF BLADE ROW (ins)     =   31.46
HUB TO TIP RATIO AHEAD OF BLADE ROW =  0.7101
HUB TO TIP RATIO AFT OF BLADE ROW   =  0.6945

AXIAL SPACING OF SPACE NORMALISED BY
MEAN RADIUS OF ANNULUS              =  0.0458

 SPACE NUMBER        8 –@ PITCH LINE
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AXIAL MACH NUMBER IN SPACE          =  0.1639
TANGENTIAL MACH NUMBER IN SPACE     =  0.2770
WHEEL RPM OF BLADE ROW AT AFT END
OF SPACE                            =  2027.0
SPEED OF SOUND IN SPACE NORMALISED BY
EXIT SPEED OF SOUND                 =  1.0100
DIAMETER AHEAD OF BLADE ROW (ins)   =   31.66
DIAMETER AFT OF BLADE ROW (ins)     =   32.05
HUB TO TIP RATIO AHEAD OF BLADE ROW =  0.6896
HUB TO TIP RATIO AFT OF BLADE ROW   =  0.6809

AXIAL SPACING OF SPACE NORMALISED BY
MEAN RADIUS OF ANNULUS              =  0.0247

 SPACE NUMBER        9 -@ PITCH LINE

AXIAL MACH NUMBER IN SPACE          =  0.1553
TANGENTIAL MACH NUMBER IN SPACE     =  0.0944
WHEEL RPM OF BLADE ROW AT AFT END
OF SPACE                            =     0.0
SPEED OF SOUND IN SPACE NORMALISED BY
EXIT SPEED OF SOUND                 =  1.0000
DIAMETER AHEAD OF BLADE ROW (ins)   =   32.28
DIAMETER AFT OF BLADE ROW (ins)     =   32.59
HUB TO TIP RATIO AHEAD OF BLADE ROW =  0.6750
HUB TO TIP RATIO AFT OF BLADE ROW   =  0.6657

AXIAL SPACING OF SPACE NORMALISED BY
MEAN RADIUS OF ANNULUS              =  0.0386

 SPACE NUMBER       10 -@ PITCH LINE

AXIAL MACH NUMBER IN SPACE          =  0.1441
TANGENTIAL MACH NUMBER IN SPACE     =  0.1792
WHEEL RPM OF BLADE ROW AT AFT END
OF SPACE                            =  2027.0
SPEED OF SOUND IN SPACE NORMALISED BY
EXIT SPEED OF SOUND                 =  1.0000
DIAMETER AHEAD OF BLADE ROW (ins)   =   32.63
DIAMETER AFT OF BLADE ROW (ins)     =   32.64
HUB TO TIP RATIO AHEAD OF BLADE ROW =  0.6647
HUB TO TIP RATIO AFT OF BLADE ROW   =  0.6646

AXIAL SPACING OF SPACE NORMALISED BY
MEAN RADIUS OF ANNULUS              =  0.0265

 SPACE NUMBER       11 -@ PITCH LINE

AXIAL MACH NUMBER IN SPACE          =  0.1451
TANGENTIAL MACH NUMBER IN SPACE     = -0.0321
WHEEL RPM OF BLADE ROW AT AFT END
OF SPACE                            =     0.0
SPEED OF SOUND IN SPACE NORMALISED BY
EXIT SPEED OF SOUND                 =  1.0000
DIAMETER AHEAD OF BLADE ROW (ins)   =   32.41
DIAMETER AFT OF BLADE ROW (ins)     =   32.00
HUB TO TIP RATIO AHEAD OF BLADE ROW =  0.6724
HUB TO TIP RATIO AFT OF BLADE ROW   =  0.6870

AXIAL SPACING OF SPACE NORMALISED BY
MEAN RADIUS OF ANNULUS              =  0.0265
```

```
 DOWNSTREAM SPACE–@ PITCH LINE

AXIAL MACH NUMBER IN SPACE          =  0.1250
TANGENTIAL MACH NUMBER IN SPACE     = –0.0013

          ***END WRITE OF INPUT PARAMETERS***


 ************OUTPUT FROM PROGRAM**************

         EXPONENT RELATED TO CORRELATION FUNCTION    =   3
         # OF CUT OFF RATIO BINS USED IN CALCULATION =  25

         THIRD OCTAVE BAND POWER RE: 10**(–13) WATTS

               TL denotes Transmission Loss

     CENTER FREQUENCY,Hz      no TL dB with TL dB

             200.0             136.1     131.1
             252.0             137.9     132.3
             315.0             137.6     133.2
             405.0             139.4     136.2
             500.0             139.9     137.9
             630.0             139.2     137.2
             800.0             138.1     136.1
            1000.0             136.2     134.6
            1250.0             134.2     132.7
            1575.0             131.4     130.4
            2000.0             126.3     125.5
            2520.0             117.7     117.0


          MIKES ON A SIDELINE,DISTANCE    400.0 FT.

         EXPONENT RELATED TO CORRELATION FUNCTION    =   3
         # OF CUT OFF RATIO BINS USED IN CALCULATION =  25

         THIRD OCTAVE BAND SPL RE: 2*10**(–5) N/m**2

               TL denotes Transmission Loss

               ANGLE FROM INLET (degrees) =    90.00

               CENTER FREQUENCY,Hz     no TL dB with TL dB

                       200.0              74.1      72.9
                       252.0              75.8      75.0
                       315.0              75.5      75.0
                       405.0              77.2      76.9
                       500.0              77.6      77.5
                       630.0              76.9      76.8
                       800.0              75.2      75.2
                      1000.0              72.2      72.2
                      1250.0              68.1      68.1
                      1575.0              62.0      62.0
                      2000.0              52.5      52.5
                      2520.0              42.4      42.4


          MIKES ON A SIDELINE,DISTANCE    400.0 FT.
```

```
EXPONENT RELATED TO CORRELATION FUNCTION    =   3
# OF CUT OFF RATIO BINS USED IN CALCULATION =  25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

      TL denotes Transmission Loss

      ANGLE FROM INLET (degrees) =    95.00

      CENTER FREQUENCY,Hz     no TL dB with TL dB

              200.0              74.3      73.1
              252.0              76.1      75.3
              315.0              75.8      75.3
              405.0              77.6      77.3
              500.0              78.1      77.9
              630.0              77.5      77.4
              800.0              76.2      76.1
             1000.0              73.6      73.6
             1250.0              70.2      70.2
             1575.0              65.0      65.0
             2000.0              56.0      56.0
             2520.0              44.8      44.8


 MIKES ON A SIDELINE,DISTANCE    400.0 FT.

EXPONENT RELATED TO CORRELATION FUNCTION    =   3
# OF CUT OFF RATIO BINS USED IN CALCULATION =  25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

      TL denotes Transmission Loss

      ANGLE FROM INLET (degrees) =   100.00

      CENTER FREQUENCY,Hz     no TL dB with TL dB

              200.0              74.4      73.2
              252.0              76.2      75.4
              315.0              76.0      75.5
              405.0              77.9      77.6
              500.0              78.5      78.3
              630.0              78.0      77.9
              800.0              76.9      76.9
             1000.0              74.7      74.7
             1250.0              72.0      71.9
             1575.0              67.6      67.6
             2000.0              59.6      59.6
             2520.0              47.8      47.8


 MIKES ON A SIDELINE,DISTANCE    400.0 FT.
```

EXPONENT RELATED TO CORRELATION FUNCTION   =   3
OF CUT OFF RATIO BINS USED IN CALCULATION = 25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

TL denotes Transmission Loss

ANGLE FROM INLET (degrees) =   105.00

CENTER FREQUENCY,Hz	no TL dB	with TL dB
200.0	74.5	73.2
252.0	76.3	75.5
315.0	76.1	75.6
405.0	78.0	77.7
500.0	78.7	78.5
630.0	78.3	78.2
800.0	77.4	77.4
1000.0	75.6	75.6
1250.0	73.3	73.3
1575.0	69.8	69.8
2000.0	62.9	62.8
2520.0	51.6	51.6

MIKES ON A SIDELINE,DISTANCE   400.0 FT.

EXPONENT RELATED TO CORRELATION FUNCTION   =   3
OF CUT OFF RATIO BINS USED IN CALCULATION = 25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

TL denotes Transmission Loss

ANGLE FROM INLET (degrees) =   110.00

CENTER FREQUENCY,Hz	no TL dB	with TL dB
200.0	74.4	73.2
252.0	76.2	75.4
315.0	76.0	75.5
405.0	78.1	77.8
500.0	78.8	78.6
630.0	78.4	78.4
800.0	77.8	77.7
1000.0	76.2	76.1
1250.0	74.3	74.3
1575.0	71.4	71.4
2000.0	65.5	65.5
2520.0	55.4	55.4

MIKES ON A SIDELINE,DISTANCE   400.0 FT.

EXPONENT RELATED TO CORRELATION FUNCTION   =   3
OF CUT OFF RATIO BINS USED IN CALCULATION = 25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

TL denotes Transmission Loss

ANGLE FROM INLET (degrees) =   115.00

CENTER FREQUENCY,Hz	no TL dB	with TL dB
200.0	74.2	73.0
252.0	76.0	75.2
315.0	75.9	75.3
405.0	78.0	77.7
500.0	78.7	78.5
630.0	78.4	78.3
800.0	77.9	77.8
1000.0	76.4	76.4
1250.0	74.9	74.9
1575.0	72.5	72.5
2000.0	67.5	67.5
2520.0	58.5	58.5

MIKES ON A SIDELINE,DISTANCE   400.0 FT.

EXPONENT RELATED TO CORRELATION FUNCTION   =   3
OF CUT OFF RATIO BINS USED IN CALCULATION = 25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

TL denotes Transmission Loss

ANGLE FROM INLET (degrees) =   120.00

CENTER FREQUENCY,Hz	no TL dB	with TL dB
200.0	73.8	72.6
252.0	75.7	74.9
315.0	75.6	75.0
405.0	77.7	77.4
500.0	78.5	78.3
630.0	78.2	78.1
800.0	77.7	77.7
1000.0	76.4	76.4
1250.0	75.1	75.1
1575.0	73.1	73.0
2000.0	68.6	68.6
2520.0	60.4	60.4

MIKES ON A SIDELINE,DISTANCE   400.0 FT.

```
EXPONENT RELATED TO CORRELATION FUNCTION    =   3
# OF CUT OFF RATIO BINS USED IN CALCULATION =  25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

      TL denotes Transmission Loss

      ANGLE FROM INLET (degrees) =   125.00

      CENTER FREQUENCY,Hz     no TL dB with TL dB

              200.0              73.4      72.2
              252.0              75.3      74.4
              315.0              75.1      74.6
              405.0              77.3      77.0
              500.0              78.1      77.9
              630.0              77.9      77.8
              800.0              77.4      77.4
             1000.0              76.1      76.1
             1250.0              74.9      74.9
             1575.0              73.0      73.0
             2000.0              68.8      68.8
             2520.0              61.0      61.0


 MIKES ON A SIDELINE,DISTANCE    400.0 FT.

EXPONENT RELATED TO CORRELATION FUNCTION    =   3
# OF CUT OFF RATIO BINS USED IN CALCULATION =  25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

      TL denotes Transmission Loss

      ANGLE FROM INLET (degrees) =   130.00

      CENTER FREQUENCY,Hz     no TL dB with TL dB

              200.0              72.8      71.6
              252.0              74.7      73.8
              315.0              74.5      74.0
              405.0              76.8      76.5
              500.0              77.5      77.4
              630.0              77.3      77.2
              800.0              76.8      76.8
             1000.0              75.5      75.5
             1250.0              74.3      74.3
             1575.0              72.4      72.3
             2000.0              68.2      68.2
             2520.0              60.4      60.4


 MIKES ON A SIDELINE,DISTANCE    400.0 FT.
```

EXPONENT RELATED TO CORRELATION FUNCTION = 3
OF CUT OFF RATIO BINS USED IN CALCULATION = 25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

TL denotes Transmission Loss

ANGLE FROM INLET (degrees) = 135.00

CENTER FREQUENCY,Hz	no TL dB	with TL dB
200.0	72.1	70.9
252.0	73.9	73.1
315.0	73.8	73.3
405.0	76.0	75.7
500.0	76.8	76.6
630.0	76.5	76.4
800.0	75.9	75.9
1000.0	74.6	74.6
1250.0	73.2	73.2
1575.0	71.1	71.1
2000.0	66.6	66.6
2520.0	58.4	58.4

MIKES ON A SIDELINE,DISTANCE 400.0 FT.

EXPONENT RELATED TO CORRELATION FUNCTION = 3
OF CUT OFF RATIO BINS USED IN CALCULATION = 25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

TL denotes Transmission Loss

ANGLE FROM INLET (degrees) = 140.00

CENTER FREQUENCY,Hz	no TL dB	with TL dB
200.0	71.2	70.0
252.0	73.0	72.2
315.0	72.9	72.3
405.0	75.0	74.8
500.0	75.8	75.6
630.0	75.4	75.3
800.0	74.8	74.8
1000.0	73.3	73.3
1250.0	71.7	71.7
1575.0	69.3	69.3
2000.0	64.2	64.2
2520.0	54.9	54.9

MIKES ON A SIDELINE,DISTANCE 400.0 FT.

```
EXPONENT RELATED TO CORRELATION FUNCTION    =   3
# OF CUT OFF RATIO BINS USED IN CALCULATION =  25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

      TL denotes Transmission Loss

      ANGLE FROM INLET (degrees) =   145.00

      CENTER FREQUENCY,Hz     no TL dB with TL dB

              200.0              70.1      68.9
              252.0              71.9      71.1
              315.0              71.7      71.2
              405.0              73.8      73.5
              500.0              74.5      74.3
              630.0              74.1      74.0
              800.0              73.4      73.3
             1000.0              71.7      71.7
             1250.0              69.7      69.7
             1575.0              66.7      66.7
             2000.0              60.6      60.6
             2520.0              49.2      49.2


 MIKES ON A SIDELINE,DISTANCE    400.0 FT.


EXPONENT RELATED TO CORRELATION FUNCTION    =   3
# OF CUT OFF RATIO BINS USED IN CALCULATION =  25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

      TL denotes Transmission Loss

      ANGLE FROM INLET (degrees) =   150.00

      CENTER FREQUENCY,Hz     no TL dB with TL dB

              200.0              68.7      67.5
              252.0              70.5      69.7
              315.0              70.3      69.8
              405.0              72.3      72.0
              500.0              72.8      72.7
              630.0              72.4      72.3
              800.0              71.6      71.6
             1000.0              69.6      69.6
             1250.0              67.2      67.2
             1575.0              63.3      63.3
             2000.0              55.3      55.3
             2520.0              38.6      38.6


 MIKES ON A SIDELINE,DISTANCE    400.0 FT.
```

EXPONENT RELATED TO CORRELATION FUNCTION = 3
OF CUT OFF RATIO BINS USED IN CALCULATION = 25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

TL denotes Transmission Loss

ANGLE FROM INLET (degrees) = 155.00

CENTER FREQUENCY,Hz	no TL dB	with TL dB
200.0	67.1	65.9
252.0	68.9	68.0
315.0	68.6	68.1
405.0	70.4	70.1
500.0	70.8	70.6
630.0	70.4	70.3
800.0	69.4	69.4
1000.0	67.0	67.0
1250.0	64.0	64.0
1575.0	58.9	58.9
2000.0	47.2	47.2
2520.0	24.5	24.5

MIKES ON A SIDELINE,DISTANCE 400.0 FT.

EXPONENT RELATED TO CORRELATION FUNCTION = 3
OF CUT OFF RATIO BINS USED IN CALCULATION = 25

THIRD OCTAVE BAND SPL RE: 2*10**(-5) N/m**2

TL denotes Transmission Loss

ANGLE FROM INLET (degrees) = 160.00

CENTER FREQUENCY,Hz	no TL dB	with TL dB
200.0	65.0	63.8
252.0	66.8	66.0
315.0	66.5	66.0
405.0	67.9	67.6
500.0	68.1	67.9
630.0	67.8	67.8
800.0	66.7	66.6
1000.0	63.9	63.8
1250.0	60.0	60.0
1575.0	52.9	52.9
2000.0	29.1	29.1
2520.0	16.5	16.5

5.0 Empirical Combustor Noise Correlation

The empirical combustor noise correlation model computes the 1/3-octave SPL spectra, corrected to a 1-ft arc distance, for a 77°F standard day atmosphere. The code, called COMBUSTOR, is in standard Fortran 77. The input is in NAMELIST format, and the input parameters required are defined at the beginning of the code listing below. Output includes the input data, some calculated parameters (optional), and tabulations of the 1/3-octave SPL values at each observer angle from 10° to 170° from the inlet axis, over a range of 1/3-octave frequencies from 50 Hz to 10 kHz.

5.1 COMBUSTOR Source Code

```
C***********************************************************************
C
C Program Name:  COMBUSTOR –  main program for I/O.
C
C Program Function:
C
C       Calculate the combustor noise spectra for a Single or Double
C       Annular combustor per Diversitech correlations.
C       Output source spectra are SAE 77 deg. Standard day on a 1 ft. arc.
C
C Subroutines/Functions called:
C
C       combustor_dtitrulen
C
C HPUX System routines called:
C
C      date   time
C
C***********************************************************************
C
C INPUT FILE NAMELIST DEFINITIONS:
C
C Namelist /CombData/
C
C   List
C   Name      Type    Description
C   --------  ----    ----------------------------------------------
C   INFO      CHAR*60 Description for predicted combustor spectra.
C   Clength    R      Combustor length, ft
C   AnnHth     R      Annulus height at combustor exit, ft
C   AreaEff    R      Combustor annulus exit area, ft**2
C   SACorDAC  CHAR*3  Combustor type selector:
C
C                     ’SAC’ (Single Annular Combustor)
C                     ’DAC’ (Double Annular Combustor)
C
C   DACType   CHAR*6  ’DAC’ combustor type:
C
C   config   MxFuelNz value          fuel nozzles ignited
C  --------  ----------------  ----------------------------------------------------
C  ’20–20’   40 set by program  20 outer + 20 inner
C  ’20–10’   40 set by user     20 outer + 10 alternating inner  (101010...)
C  ’20–10’   30 set by user     20 outer + 10 inner
C  ’20–2^5’  40 set by program  20 outer + 10 alternating pairs of inner (110011...)
C  ’20–0’    30/40 set by user  20 outer + 0 inner
C
C   MxFuelNz  INTG    Total number of DAC combustor fuel nozzles for
```

```
C                         DACType(s) = '20–10', or '20–0' only. (use 30 or 40)
C   NumFuel   INTG    Number of 'SAC' fuel nozzles ignited
C   DIAHYD     R      Core Nozzle Exit Plane Hydraulic diameter, ft
C   DIAEFF     R      Core Nozzle Exit Plane Effective diameter, ft
C   W3         R      Weight Flow at HP Compressor discharge,lbm/sec
C   T3         R      Temperature at HP Compressor discharge, degrees R
C   P3         R      Pressure at HP Compressor discharge, psia
C   T4         R      Temperature HP Turbine Inlet, degrees R
C   P4         R      Pressure at HP Turbine Inlet, psia
C   T8         R      Temperature at Primary Nozzle (core) throat, degrees R
C   P8         R      Pressure at Primary Nozzle (core) throat, psia
C   IDIAG    INTG     Diagnostic output flag: 0 = no, 1 = yes.
C
C
C SCREEN OR OUTPUT FILE CONTENTS:
C
C   Name      Description
C   --------  ----------------------------------------------
C   INFO      Description for predicted combustor spectra.
C   IALPHA    Data is predicted using the SAE (ARP866A) model.
C   TAMB      Ambient temperature, degrees F
C   PAMB      Ambient pressure, inches Hg (mercury)
C   RELHUM    Ambient Percent relative humidity
C   IARCSL    Data is predicted on an 'ARC'
C   DIST      Data is predicted on a 1 ft. arc.
C   SACorDAC  Combustor type: 'SAC' or 'DAC'
C   DACTYPE   Configuration of the DAC combustor
C   Clength   Combustor length, ft
C   AnnHth    Annulus height at combustor exit, ft
C   AreaEff   Combustor annulus exit area, ft**2
C   NumFuel   Number of fuel nozzles ignited (SAC or DAC)
C   MxFuelNz  Total number of DAC combustor fuel nozzles
C   DIAHYD    Combustor hydralic diameter, ft
C   DIAEFF    Combustor effective diameter, ft
C   T3        Temperature at HP Compressor discharge, degrees R
C   P3        Pressure at HP Compressor discharge, psia
C   T4        Temperature HP Turbine Inlet, degrees R
C   P4        Pressure at HP Turbine Inlet, psia
C   T8        Temperature at Primary Nozzle (core) throat, degrees R
C   P8        Pressure at Primary Nozzle (core) throat, psia
C   SPL       Total Summed SPL(angle,freq) Tabular column spectra
C             for each acoustic angle (10 – 170 degrees).
C
C If IDIAG flag = 1 then these additional parameters are output:
C
C   FFC       Correlation flow function correction term
C   FFT       Correlation turbine loss correction term
C   XK1       Turbine transmission loss parameter
C   SPLFFC    SPL value for FFC
C   SPLTL     SPL value for FFT
C
C   If SAC: CP        Correlation parameter for 63, 160, 630 Hz.
C           OASPK63   Peak OASPL for 63 Hz band.
C           OASPK160  Peak OASPL for 160 Hz band.
C           OASPK630  Peak OASPL for 630 Hz band.
C
C   If DAC: CP160     Correlation Parameter value for 160 Hz.
C           CP500     Correlation Parameter value for 500 Hz.
C           OASPK160  Peak OASPL for 160 Hz band.
C           OASPK500  Peak OASPL for 500 Hz band.
```

```
C
C*********************************************************************
C
      PROGRAM COMBUSTOR
C
      PARAMETER( NANG = 17 )
      PARAMETER( NFREQ = 24 )
C
      CHARACTER *60 INFO
C
      CHARACTER *3   SACORDAC /' '/
      CHARACTER *6   DACTYPE  /' '/
      CHARACTER *255 NLIN     /' '/
      CHARACTER *255 TABOUT   /' '/
      CHARACTER *1   IANS     /' '/
      CHARACTER *9   ADATE    /' '/
      CHARACTER *8   ATIME    /' '/
      CHARACTER *16  PROGNAM  /'COMBUSTOR'/
      CHARACTER *4   PROGVER  /'1.2'/
C
      DIMENSION COMBSPL(NANG,NFREQ)
      DIMENSION ANG    (NANG)
      DIMENSION FREQS  (NFREQ)
C
      DATA ANG  /10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0, 80.0,
     & 90.0, 100.0, 110.0, 120.0, 130.0, 140.0, 150.0, 160.0, 170.0/
C
      DATA FREQS/ 50.0,   63.0,   80.0,  100.0,  125.0,
     &           160.0,  200.0,  250.0,  315.0,  400.0,
     &           500.0,  630.0,  800.0, 1000.0, 1250.0,
     &          1600.0, 2000.0, 2500.0, 3150.0, 4000.0,
     &          5000.0, 6300.0, 8000.0,10000.0/
C
C *** Namelist Input
C
      NAMELIST /COMBDATA/
     & INFO, SACORDAC, DACTYPE, CLENGTH, ANNHTH,
     & AREAEFF, NUMFUEL, MXFUELNZ, DIAHYD, DIAEFF,
     & W3, T3, P3, T4, P4, T8, P8, IDIAG
C
C *** Output Program description
C
      CALL DATE (ADATE)
      CALL TIME (ATIME)
      WRITE(06,*) ' '
      WRITE(06,*)' PROGRAM: ',PROGNAM(1:itrulen(PROGNAM)),
     &           ' Version ',PROGVER,' ',ADATE,' ',ATIME
      WRITE(06,*) ' '
      WRITE(06,*)'This program predicts combustor noise spectra using'
      WRITE(06,*)'correlation procedures developed by Diversitech'
      WRITE(06,*)'while under subcontract to GEAE.'
      WRITE(06,*)'The combustor data were provided by GEAE.'
      WRITE(06,*)' '
      WRITE(06,'(1X$,A23)')'enter <cr> to continue '
      READ(05,'(A)') IANS
      WRITE(06,*)' '
C
C *** Get Namelist input filename.
C
      NLIN = ' '
```

```
      DO WHILE (ITRULEN(NLIN) .LE. 0)
        WRITE(06,*)'Enter Namelist input filename:'
        READ(05,'(A)') NLIN
      ENDDO
      OPEN(UNIT=7, FILE=NLIN, STATUS='UNKNOWN',ERR=1000, IOSTAT=II)
C
C *** Write results to the screen or tabular output file?
C
      IANS = ' '
      DO WHILE (ITRULEN(IANS) .LE. 0)
        WRITE (06,'(1X$,A49)')
     &  'Output Tabular results to Screen or File (S/F)?: '
        READ(05,'(A)') IANS
        IF(IANS .EQ. 'S' .OR. IANS .EQ. 's') THEN
          IFC = 6
        ELSEIF(IANS .EQ. 'F' .OR. IANS .EQ. 'f') THEN
          IFC = 8
          TABOUT = ' '
          DO WHILE (ITRULEN(TABOUT) .LE. 0)
            WRITE(06,*)'Enter Tabular data output filename:'
            READ(05,'(A)') TABOUT
          ENDDO
          OPEN (UNIT=IFC, FILE=TABOUT, STATUS='UNKNOWN',
     &          ERR=1000, IOSTAT=II)
        ELSE
          IANS = ' '
        ENDIF
      ENDDO
C
C *** Read a case from the namelist input file.
C
 100  CONTINUE
      READ(UNIT=7, NML=COMBDATA, END=9999)
C
C *** Check some input parameters.
C
      IF(SACORDAC .NE. 'SAC' .AND. SACORDAC .NE. 'DAC') THEN
        WRITE(06,*)
     &  '*ERROR: Invalid SACORDAC entry. Must be SAC or DAC'
        CALL EXIT
      ENDIF
      IF(SACORDAC .EQ. 'DAC') THEN
        IOK = 0
        IF(DACTYPE .EQ. '20-20' ) THEN
          IOK = 1
          MXFUELNZ = 40
        ELSEIF(DACTYPE .EQ. '20-10' ) THEN
          IOK = 1
          IF(MXFUELNZ .NE. 30 .AND. MXFUELNZ .NE. 40) THEN
            WRITE(06,*)
     &      '*ERROR: Invalid MXFUELNZ value for DACTYPE = ',DACTYPE
            WRITE(06,*)
     &      '        Current value = ',MXFUELNZ
            WRITE(06,*)
     &      '        Set correct value in input file and rerun.'
            CALL EXIT
          ENDIF
        ELSEIF(DACTYPE .EQ. '20-2^5') THEN
          MXFUELNZ = 40
          IOK = 1
```

```
        ELSEIF(DACTYPE .EQ. '20-0'  ) THEN
          IOK = 1
          IF(MXFUELNZ .NE. 30 .AND. MXFUELNZ .NE. 40) THEN
            WRITE(06,*)
     &      '*ERROR: Invalid MXFUELNZ value for DACTYPE = ',DACTYPE
            WRITE(06,*)
     &      '         Current value = ',MXFUELNZ
            WRITE(06,*)
     &      '         Set correct value in input file and rerun.'
            CALL EXIT
          ENDIF
        ENDIF
        IF(IOK .EQ. 0) THEN
          WRITE(06,*) '*ERROR: Invalid DACTYPE entry'
          WRITE(06,*) '         Must be 20-20, 20-10, 20-2^5, or 20-0'
          CALL EXIT
        ENDIF
      ENDIF
C
C *** Call COMBUSTOR_DT to calculate 77 deg. F SAE Std day, 1 ft. Arc
C *** Combustor spectra.
C
      CALL COMBUSTOR_DT (CLENGTH,ANNHTH,AREAEFF,NUMFUEL,MXFUELNZ,
     &                   DIAHYD,DIAEFF,W3,T3,P3,T4,P4,T8,P8,
     &                   SACORDAC,DACTYPE,COMBSPL,CP,CP160,CP500,
     &                   FFC,FFT,XK1,SPLFFC,SPLTL,OASPK63,
     &                   OASPK160,OASPK630,OASPK500)
C
C *** Output the Tabular Combustor SPL(angle, freq) & OASPL(angle) data
C
      IF(IFC .NE. 06) THEN
        WRITE(IFC,*)'PROGRAM: ',PROGNAM,' Version ',PROGVER,
     &              ' ',ADATE,' ',ATIME

      ENDIF
C
      WRITE(IFC,*)' '
      WRITE(IFC,*)'GEAE/ADT Combustor Noise Prediction'
      WRITE(IFC,*)' - Modified Diversitech Correlation'
      WRITE(IFC,*) ' '
      WRITE(IFC,*) 'INFO      = ',INFO(1:ITRULEN(INFO))
      WRITE(IFC,*) 'IALPHA    = SAE77'
      WRITE(IFC,*) 'TAMB      = 77 Deg. F'
      WRITE(IFC,*) 'PAMB      = 29.92 In. Hg'
      WRITE(IFC,*) 'RELHUM    = 70%'
      WRITE(IFC,*) 'DIST      = 1 Ft.'
      WRITE(IFC,*) 'IARCSL    = ARC'
      WRITE(IFC,*) 'SACORDAC  = ',SACORDAC
      IF(SACorDAC .eq. 'DAC') WRITE(IFC,*) 'DACTYPE   = ',DACTYPE
      WRITE(IFC,*) 'CLENGTH   = ',CLENGTH
      WRITE(IFC,*) 'ANNHTH    = ',ANNHTH
      WRITE(IFC,*) 'AERAEFF   = ',AREAEFF
      WRITE(IFC,*) 'NUMFUEL   = ',NUMFUEL
      IF(SACorDAC .eq. 'DAC') WRITE(IFC,*) 'MXFUELNZ  = ',MXFUELNZ
      WRITE(IFC,*) 'DIAHYD    = ',DIAHYD
      WRITE(IFC,*) 'DIAEFF    = ',DIAEFF
      WRITE(IFC,*) 'W3        = ',W3
      WRITE(IFC,*) 'T3        = ',T3
      WRITE(IFC,*) 'P3        = ',P3
      WRITE(IFC,*) 'T4        = ',T4
      WRITE(IFC,*) 'P4        = ',P4
```

```
      WRITE(IFC,*) 'T8        = ',T8
      WRITE(IFC,*) 'P8        = ',P8
      IF(IDIAG .EQ. 1) THEN
        WRITE(IFC,*) 'FFC       = ',FFC
        WRITE(IFC,*) 'FFT       = ',FFT
        WRITE(IFC,*) 'SPLFFC    = ',SPLFFC
        WRITE(IFC,*) 'SPLTL     = ',SPLTL
        WRITE(IFC,*) 'XK1       = ',XK1
      ENDIF
      IF(SACorDAC .eq. 'SAC') THEN
        IF(IDIAG .EQ. 1) THEN
          WRITE(IFC,*) 'CP        = ',CP
          WRITE(IFC,*) 'OASPK63   = ',OASPK63
          WRITE(IFC,*) 'OASPK160  = ',OASPK160
          WRITE(IFC,*) 'OASPK630  = ',OASPK630
        ENDIF
        WRITE(IFC,*) ' '
        WRITE(IFC,*) 'Single Annular Combustor Spectra'
      ELSEIF(SACorDAC .eq. 'DAC') THEN
        IF(IDIAG .EQ. 1) THEN
          WRITE(IFC,*) 'CP160     = ',CP160
          WRITE(IFC,*) 'CP500     = ',CP500
          WRITE(IFC,*) 'OASPK160  = ',OASPK160
          WRITE(IFC,*) 'OASPK500  = ',OASPK500
        ENDIF
        WRITE(IFC,*) ' '
        WRITE(IFC,*) 'Double Annular Combustor Spectra'
      ENDIF
C
C *** Print out angles 10 thru 90.
C
      WRITE(IFC,*) ' '
      WRITE(IFC,'(24X,A32)') 'Acoustic Angles from Inlet, deg.'
      WRITE(IFC,'(8X,9F7.1)') (ANG(II),II = 1,9)
      WRITE(IFC,*) ' Freq.'
      DO JJ = 1,NFREQ
        WRITE(IFC,'(1X,F7.1,9F7.2)')
     &    FREQS(JJ),(COMBSPL(II,JJ),II = 1,9)
      ENDDO
      WRITE(IFC,*) ' '
C
C *** Print out angles 100 thru 170.
C
      WRITE(IFC,*) ' '
      WRITE(IFC,'(24X,A32)') 'Acoustic Angles from Inlet, deg.'
      WRITE(IFC,'(8X,8F7.1)') (ANG(II),II = 10,17)
      WRITE(IFC,*) ' Freq.'
      DO JJ = 1,NFREQ
        WRITE(IFC,'(1X,F7.1,8F7.2)')
     &  FREQS(JJ),(COMBSPL(II,JJ),II = 10,17)
      ENDDO
      WRITE(IFC,*) ' '
C
C *** Loop back and read another input case.
C
      GOTO 100
C
 1000 PRINT *,II
 9999 IF(IFC .NE. 6) CLOSE (IFC)
C
```

```
      STOP
      END
C
C
C>>*********************************************************************
C
C Subroutine Name:  COMBUSTOR_DT
C  (GEAE modified version of original Diversitech program: Combnoise)
C
C Subroutine Function:
C
C       Calculate the combustor noise spectra for a Single or Double
C       Annular combustor per Diversitech correlations.
C
C Comments:  The engine spectral data provided to Diversitech by GEAE
C            were corrected to 150 ft. arc, 77 deg. F Standard day
C            conditions using the SAE ARP866A atmospheric attenuation
C            model. The combustor component spectra were extracted
C            from the total engine spectra by Diversitech under the
C            guidence of GEAE Acoustics.  Diversitech then correlated
C            the combustor spectral data and developed the prediction
C            equations and constants. rsc - 06apr98
C
C Routines called:
C
C       none
C
C***********************************************************************
C
C   Input Arguments:
C
C   Name       Type    Description
C   --------   ----    ----------------------------------------------
C   CLENGTH     R      COMBUSTOR LENGTH, FT
C   ANNHTH      R      ANNULUS HEIGHT AT COMBUSTOR EXIT, FT
C   AREAEFF     R      COMBUSTOR ANNULUS EXIT AREA, FT**2
C   NUMFUEL    INTG    NUMBER OF 'SAC' FUEL NOZZLES IGNITED
C   MXFUELNZ   INTG    TOTAL NUMBER OF 'DAC' COMBUSTOR FUEL NOZZLES
C   DIAHYD      R      COMBUSTOR HYDRALIC DIAMETER, FT
C   DIAEFF      R      COMBUSTOR EFFECTIVE DIAMETER, FT
C   W3          R      WEIGHT FLOW AT HP COMPRESSOR DISCHARGE,LBM/SEC
C   T3          R      TEMPERATURE AT HP COMPRESSOR DISCHARGE, DEGREES R
C   P3          R      PRESSURE AT HP COMPRESSOR DISCHARGE, PSIA
C   T4          R      TEMPERATURE HP TURBINE INLET, DEGREES R
C   P4          R      PRESSURE AT HP TURBINE INLET, PSIA
C   T8          R      TEMPERATURE AT PRIMARY NOZZLE (CORE) THROAT, DEGREES R
C   P8          R      PRESSURE AT PRIMARY NOZZLE (CORE) THROAT, PSIA
C   SACORDAC   CHAR*3  COMBUSTOR TYPE SELECTOR:
C                        'SAC' = Single Annular Combustor
C                        'DAC' = Double Annular Combustor
C   DACTYPE    CHAR*6  DAC TYPE COMBUSTER TYPE:
C                        '20-20', '20-10', '20-2^5', or '20-0'
C   Output Arguments:
C
C   NUMFUEL    INTG    NUMBER OF FUEL NOZZLES IGNITED (SAC or DAC)
C   COMBSPL     R      PREDICTED COMBUSTOR SPECTRA AT 1 FT. ARC, 77 DEG. F
C                      STANDARD DAY FOR
C                        24 FREQUENCIES: 50-10KHZ
C                        17 ACOUSTIC ANGLES: 10 - 170 DEGREES
C   CP          R      'SAC' CORRELATION PARAMETER USED TO CALC PEAK ANGLE OASPL
```

```
C                        AT 63, 160, 630 Hz.
C   CP160       R      'DAC' CORRELATION PARAMETER USED TO CALC PEAK ANGLE OASPL
C                        AT 160 Hz
C   CP500       R      'DAC' CORRELATION PARAMETER USED TO CALC PEAK ANGLE OASPL
C                        AT 500 Hz
C   FFC         R      Correlation flow function correction term
C   FFT         R      Correlation turbine loss correction term
C   XK1         R      Turbine transmission loss parameter
C   SPLFFC      R      SPL value for FFC
C   SPLTL       R      SPL value for FFT
C   OASPK63     R      Peak OASPL for 63 Hz band (SAC only)
C   OASPK160    R      Peak OASPL for 160 Hz band (SAC and DAC)
C   OASPK630    R      Peak OASPL for 630 Hz band (SAC only)
C   OASPK500    R      Peak OASPL for 500 Hz band (DAC only)
C
C>>***********************************************************************
C
      SUBROUTINE COMBUSTOR_DT (CLENGTH,ANNHTH,AREAEFF,NUMFUEL,MXFUELNZ,
     &                         DIAHYD,DIAEFF,W3,T3,P3,T4,P4,T8,P8,
     &                         SACORDAC,DACTYPE,COMBSPL,CP,CP160,CP500,
     &                         FFC,FFT,XK1,SPLFFC,SPLTL,OASPK63,
     &                         OASPK160,OASPK630,OASPK500)
C
      PARAMETER( NUMALPHA = 17 )
      PARAMETER( NUMFREQS = 24 )
C
      CHARACTER *(*) SACORDAC
      CHARACTER *(*) DACTYPE
C
      DIMENSION XNRM63 ( NUMALPHA ), OASPL63 ( NUMALPHA ),
     &          XNRM160( NUMALPHA ), OASPL160( NUMALPHA ),
     &          XNRM500( NUMALPHA ), OASPL500( NUMALPHA ),
     &          XNRM630( NUMALPHA ), OASPL630( NUMALPHA ),
     &          SPL63 ( NUMALPHA, NUMFREQS ),
     &          SPL160( NUMALPHA, NUMFREQS ),
     &          SPL500( NUMALPHA, NUMFREQS ),
     &          SPL630( NUMALPHA, NUMFREQS )
C
      DIMENSION COMBSPL  (NUMALPHA,NUMFREQS)
      DIMENSION ANG      (NUMALPHA)
      DIMENSION FREQS    (NUMFREQS)
      DIMENSION ATMOSABS (NUMFREQS)

      DATA ALPK63  /150.0/
      DATA ALPK160 /130.0/
      DATA ALPK500 /130.0/
      DATA ALPK630 /130.0/
      DATA FPK63   /63.0/
      DATA FPK160  /160.0/
      DATA FPK500  /500.0/
      DATA FPK630  /630.0/
      DATA MINS63 , MAXS63  /1,5/
      DATA MINS160, MAXS160 /2,9/
      DATA MINS630, MAXS630 /6,14/
      DATA MIND160, MAXD160 /1,9/
      DATA MIND500, MAXD500 /5,14/
      DATA RADIAL /150.0/
      DATA PAMB_PSIA /14.696/     !29.92 in. Hg
      DATA TAMB      /77.0/
      DATA RELHUM    /70.0/
C
```

```
      DATA ANG  /10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0, 80.0,
     & 90.0, 100.0, 110.0, 120.0, 130.0, 140.0, 150.0, 160.0, 170.0/
C
      DATA FREQS/ 50.0,   63.0,   80.0,  100.0,  125.0,
     &           160.0,  200.0,  250.0,  315.0,  400.0,
     &           500.0,  630.0,  800.0, 1000.0, 1250.0,
     &          1600.0, 2000.0, 2500.0, 3150.0, 4000.0,
     &          5000.0, 6300.0, 8000.0,10000.0/
C
C *** Set ARP866A model atmospheric absorption values for each
C *** frequency (50-10khz) at 1000 ft for 77 deg.f standard day.
C
      DATA ATMOSABS / 0.08700,  0.10966,  0.13929,  0.17419,
     &                0.21785,  0.27906,  0.34913,  0.43690,
     &                0.55128,  0.70138,  0.87871,  1.11046,
     &                1.41565,  1.77779,  2.23524,  2.88468,
     &                3.63993,  4.60376,  5.88995,  7.62918,
     &                8.58712, 11.07580, 14.94318, 20.32406/
C
C *** Initialize subroutine and output data.
C
      FFC       = 0.00
      FFT       = 0.00
      XK1       = 0.00
      SPLFFC    = 0.00
      SPLTL     = 0.00
C
      OASPK63   = 0.00
      OASPK160  = 0.00
      OASPK500  = 0.00
      OASPK630  = 0.00
C
      DO I = 1, NUMALPHA
        XNRM63  (I) = 0.00
        XNRM160 (I) = 0.00
        XNRM500 (I) = 0.00
        XNRM630 (I) = 0.00
        OASPL63 (I) = 0.00
        OASPL160(I) = 0.00
        OASPL500(I) = 0.00
        OASPL630(I) = 0.00
        DO J = 1, NUMFREQS
          SPL63 (I,J) = 0.00
          SPL160(I,J) = 0.00
          SPL500(I,J) = 0.00
          SPL630(I,J) = 0.00
          COMBSPL(I,J) = 0.0
        ENDDO
      ENDDO
C
C *** Calculate the correlation flow function correction term FFC
C *** along with SPL(FFC).
C *** If DAC: set number of inner fuel nozzles ignited (NUM_INNER) based on DACTYPE.
C ***         set Total number of ignited fuel nozzles (NUMFUEL)
C
      IF(SACORDAC .EQ. 'SAC') THEN
        FFC = W3*SQRT((T4-T3))/(P3*FLOAT(NUMFUEL)*AREAEFF**2)
      ELSEIF(SACORDAC .EQ. 'DAC') THEN
        IF (DACTYPE .EQ. '20-20 ') THEN
          NUM_INNER = 20
```

```
          NUMFUEL = 40
          XK = 0.250
        ELSEIF (DACTYPE .EQ. '20-10 ') THEN
          NUM_INNER = 10
          NUMFUEL = 30
          XK = 0.250
        ELSEIF(DACTYPE .EQ. '20-2^5') THEN
          NUM_INNER = 10
          NUMFUEL = 30
          XK = 0.200
        ELSEIF(DACTYPE .EQ. '20-0') THEN
          NUM_INNER = 0
          NUMFUEL = 20
          XK = 0.000
        ENDIF
        FFC = W3*SQRT((T4-T3))/(P3*SQRT(FLOAT(20+NUM_INNER))*AREAEFF**2)
      ENDIF
      SPLFFC = 20.0D0 * LOG10(FFC)
C
C *** Calculate the correlation turbine loss correction term FFT
C *** along with SPL(FFT).

      PI  = ACOS(-1.0D0)
      FFT = (P4/P8)*SQRT(T8/T4)
      XK1 = ((1.0D0+FFT)**2)/(4.0D0*CLENGTH*FFT/(PI*ANNHTH))
      SPLTL = 20.0D0*LOG10(XK1)
C
C *** Calculate the cycle and geometry dependent term CP used
C *** in the OASPL(PEAK ANGLE) correlation.
C
      IF(SACORDAC .EQ. 'SAC') THEN
C
        CP = ((W3*SQRT(T3))/P3)*((T4-T3)/T4)*
     &       (P3/PAMB_PSIA)*(DIAHYD/DIAEFF)**0.500
C
      ELSEIF(SACORDAC .EQ. 'DAC') THEN
C
        CP160 = ((W3*SQRT(T3))/P3)*((T4-T3)/T4)*
     &          (P3/PAMB_PSIA)*(DIAHYD/DIAEFF)**2.000
        CP500 = ((W3*SQRT(T3))/P3)*((T4-T3)/T4)*
     &          (P3/PAMB_PSIA)*(DIAHYD/DIAEFF)**1.200
      ENDIF
C
C *** Calculate OASPL(PEAK ANGLE) correlation.
C
      IF (SACORDAC .EQ. 'SAC') THEN
C
        HSAC63  = 14.2560 * LOG(CP) +  76.450
        HSAC160 =  3.3150 * LOG(CP) + 108.500
        HSAC630 =  6.9380 * LOG(CP) + 106.380
        OASPK63  = -20.00 * LOG10(RADIAL) + HSAC63 *
     &            (30.00/FLOAT(NUMFUEL))**(-0.225)
        OASPK160 = -20.00 * LOG10(RADIAL) + HSAC160 *
     &            ( 30.00 / FLOAT(NUMFUEL))**0.050
        OASPK630 = -20.00 * LOG10(RADIAL) + HSAC630 *
     &            ( 30.00 / FLOAT(NUMFUEL))**0.020
C
      ELSEIF(SACORDAC .EQ. 'DAC') THEN
C
        HDAC160 = 2.69310 * LOG(CP160) + 110.440
        HDAC500 = 2.99170 * LOG(CP500) + 110.620
```

```
C
        IF (NUM_INNER .EQ. 20) THEN     !20 inner nozzles ignited
C
          OASPK160 = 1.200 * (-20.00 * LOG10(RADIAL) + HDAC160 *
     &               (((20.0 + FLOAT(NUM_INNER)) /
     &               FLOAT(MXFUELNZ))**(-XK)) *
     &               ( 30.00 / (20.0 + FLOAT(NUM_INNER)))**0.020)

          OASPK500 = -20.00 * LOG10(RADIAL) + HDAC500 *
     &               (((20.0 + FLOAT(NUM_INNER)) /
     &               FLOAT(MXFUELNZ))**(-XK)) *
     &               ( 30.00 / (20.0 + FLOAT(NUM_INNER)))**0.180
C
        ELSEIF (NUM_INNER .EQ. 10) THEN !10 inner nozzles ignited
C
          OASPK160 = 0.9800 * (-20.00 * LOG10(RADIAL) + HDAC160 *
     &               (((20.0 + FLOAT(NUM_INNER)) /
     &               FLOAT(MXFUELNZ))**(-XK)) *
     &               ( 30.00 / (20.0 + FLOAT(NUM_INNER)))**(0.020))
          OASPK500 = 0.9000 * (-20.00 * LOG10(RADIAL) + HDAC500 *
     &               (((20.0 + FLOAT(NUM_INNER)) /
     &               FLOAT(MXFUELNZ))**(-XK)) *
     &               ( 30.00 / (20.0 + FLOAT(NUM_INNER)))**(0.180))
C
        ELSEIF (NUM_INNER .EQ. 0) THEN  !0 inner nozzles ignited
C
          OASPK160 = 1.1000 * (-20.00 * LOG10(RADIAL) + HDAC160 *
     &               (((20.0 + FLOAT(NUM_INNER)) /
     &               FLOAT(MXFUELNZ))**(-XK)) *
     &               ( 30.00 / (20.0 + FLOAT(NUM_INNER)))**0.020)
          OASPK500 = 0.9800 * (-20.00 * LOG10(RADIAL) + HDAC500 *
     &               (((20.0 + FLOAT(NUM_INNER)) /
     &               FLOAT(MXFUELNZ))**(-XK)) *
     &               ( 30.00 / (20.0 + FLOAT(NUM_INNER)))**0.180)
        END IF
      END IF
C
C *** Calculate the correlation norm value of OASPL for a
C     SAC or DAC combustor configuration.
C
      DO II = 1, NUMALPHA
        IF(SACORDAC .EQ. 'SAC') THEN
         ALPHN63  = ANG(II)/ALPK63
         ALPHN160 = ANG(II)/ALPK160
         ALPHN630 = ANG(II)/ALPK630
         XNRM63 (II) = -67.8*(ALPHN63)**2+141.7*(ALPHN63)-66.84
         XNRM160(II) = -26.019*(ALPHN160)**3-5.2974*(ALPHN160)**2
     &                  + 93.433*(ALPHN160)- 61.751
         XNRM630(II) = -156.5*(ALPHN630)**2+322.340*(ALPHN630)-164.89
       ELSEIF(SACORDAC .EQ. 'DAC') THEN
         ALPHN160 = ANG(II)/ALPK160
         ALPHN500 = ANG(II)/ALPK500
         XNRM160(II) = -116.95*(ALPHN160)**2+235.23*(ALPHN160)-120.65
         XNRM500(II) = -137.59*(ALPHN500)**2+283.40*(ALPHN500)-147.73
        ENDIF
      ENDDO
C
C *** Calculate the peak frequencies OASPL(ANGLE) for a SAC or DAC
C
      DO II = 1, NUMALPHA
        IF(SACORDAC .EQ. 'SAC') THEN
```

```
          OASPL63 (II) = XNRM63 (II)+OASPK63 +0.40*(SPLFFC−SPLTL)
          OASPL160(II) = XNRM160(II)+OASPK160+0.10*(SPLFFC−SPLTL)
          OASPL630(II) = XNRM630(II)+OASPK630+0.30*(SPLFFC−SPLTL)
        ELSEIF(SACORDAC .EQ. 'DAC') THEN
          OASPL160(II) = XNRM160(II)+OASPK160+0.45*(SPLFFC−SPLTL)
          OASPL500(II) = XNRM500(II)+OASPK500−0.10*(SPLFFC−SPLTL)
        ENDIF
      ENDDO
C
C *** Data correlations are based on 150 ft. arc data corrected to
C *** 77 deg.f standard day using the SAE ARP866A atmospheric attenuation
C *** model.
C
C *** Calculate the 1 ft. arc source SPL(ANGLE, FREQ) for a SAC or DAC
C *** combustor configuration.
C
      SD = 20.0*LOG10(150.0/1.0)  !spherical divergence component
      DO II = 1, NUMALPHA
        IF(SACORDAC .EQ. 'SAC') THEN
          DO JJ = MINS63, MAXS63
            FR63 = FREQS(JJ)/FPK63
            SPL63(II,JJ) = OASPL63(II)− 145.610*(FR63)**2+295.460*
     &                     (FR63)−152.720+ATMOSABS(JJ)*149.0/1000.0
     &                     + SD
            IF(SPL63(II,JJ) .GT. 0.0) THEN
              COMBSPL(II,JJ) = SPL63(II,JJ)
            ENDIF
          ENDDO
          DO KK = MINS160, MAXS160
            FR160 = FREQS(KK)/FPK160
            SPL160(II,KK) = OASPL160(II)−163.340*(FR160)**2+331.330*
     &                      (FR160)−170.070+ATMOSABS(KK)*149.0/1000.0
     &                      + SD
            IF(SPL160(II,KK) .GT. 0.0) THEN
              IF(COMBSPL(II,KK) .GT. 0.0) THEN
                COMBSPL(II,KK) = 10.0*LOG10(10.0**(SPL160(II,KK)/10.0)+
     &                                      10.0**(COMBSPL(II,KK)/10.0))
              ELSE
                COMBSPL(II,KK) = SPL160(II,KK)
              ENDIF
            ENDIF
          ENDDO
          DO LL = MINS630, MAXS630
            FR630 = FREQS(LL)/FPK630
            SPL630(II,LL) = OASPL630(II)−142.310*(FR630)**2+286.440*
     &                      (FR630)−147.500+ATMOSABS(LL)*149.0/1000.0
     &                      + SD
            IF(SPL630(II,LL) .GT. 0.0) THEN
              IF(COMBSPL(II,LL) .GT. 0.0) THEN
                COMBSPL(II,LL) = 10.0*LOG10(10.0**(SPL630(II,LL)/10.0)+
     &                                      10.0**(COMBSPL(II,LL)/10.0))
              ELSE
                COMBSPL(II,LL) = SPL630(II,LL)
              ENDIF
            ENDIF
          ENDDO
C
        ELSEIF(SACORDAC .EQ. 'DAC') THEN
C
          DO KK = MIND160, MAXD160
```

```
            FR160 = FREQS(KK)/FPK160
            SPL160(II,KK) = OASPL160(II)-143.000*(FR160)**2+280.040*
     &                       (FR160)-143.070+ATMOSABS(KK)*149.0/1000.0
     &                       + SD
            IF(SPL160(II,KK) .GT. 0.0) THEN
              COMBSPL(II,KK) = SPL160(II,KK)
            ENDIF
          ENDDO
          DO LL = MIND500, MAXD500
            FR500 = FREQS(LL)/FPK500
            SPL500(II,LL) = OASPL500(II)-135.810*(FR500)**2+268.990*
     &                       (FR500)-137.210+ATMOSABS(LL)*149.0/1000.0
     &                       + SD
            IF(SPL500(II,LL) .GT. 0.0) THEN
              IF(COMBSPL(II,LL) .GT. 0.0) THEN
                COMBSPL(II,LL) = 10.0*LOG10(10.0**(SPL500(II,LL)/10.0)+
     &                                         10.0**(COMBSPL(II,LL)/10.0))
              ELSE
                COMBSPL(II,LL) = SPL500(II,LL)
              ENDIF
            ENDIF
          ENDDO
        ENDIF
      ENDDO
C
 9999 RETURN
      END
c
c***************************** function itrulen *****************************
c
      function itrulen(string)
c
c description    - A function to determine the true length of a string
c
c varaible glossary
c
c character variables
c string         - string for which the length is needed - input
c
c integer variables
c i              - loop counter - internal
c maxlen         - the maximum string length return from the len function &
c                  is equal to the defined character length in the calling
c                  program - internal
c itrulen        - the length of the string - output
c
c define variables
c
      character*(*) string
      integer i,maxlen,itrulen
c
c Set length equal to maxlength then work backward until the first
c printable ascii character is found (in the ascii value range 33 to 126).
c
      maxlen=len(string)
      i=maxlen+1
      loop = 1
      do while (loop .eq. 1 .and. i .gt. 0)
        i=i-1
        ival = ichar(string(i:i))
```

```
        if(ival .gt. 32 .and. ival .lt. 127) loop = 0
      end do
c
c return the true length
c
      itrulen=i
      return
      end
```

5.2 COMBUSTOR Sample Input File

```
 $COMBDATA
  INFO      ='Sample SAC Combustor',
  SACorDAC  ='SAC',
  Clength   =0.4583,
  AnnHth    =0.2083,
  AreaEff   =1.499,
  NumFuel   =20,
  DIAHYD    =13.84,
  DIAEFF    =34.59,
  W3        =86.707,
  T3        =1036.5,
  P3        =114.39,
  T4        =1889.4,
  P4        =109.07,
  T8        =1084.0,
  P8        =14.847
  IDIAG     =1
 $
 $COMBDATA
  INFO      ='Sample DAC Combustor',
  SACorDAC  ='DAC',
  DACType   ='20–10',
  MXFUELNZ  = 40,
  Clength   =0.492,
  AnnHth    =0.250,
  AreaEff   =2.430,
  DIAHYD    =13.4,
  DIAEFF    =39.9,
  W3        =113.9,
  T3        =1189.9,
  P3        =173.1,
  T4        =2260.,
  P4        =162.9,
  T8        =1205.6,
  P8        =15.1,
 $
```

5.3 COMBUSTOR Sample Output File

```
 PROGRAM: COMBUSTOR        Version 1.2  17–May–99 10:01:16

 GEAE/ADT Combustor Noise Prediction
  – Modified Diversitech Correlation

 INFO      = Sample SAC Combustor
 IALPHA    = SAE77
 TAMB      = 77 Deg. F
 PAMB      = 29.92 In. Hg
 RELHUM    = 70%
 DIST      = 1 Ft.
```

```
IARCSL    = ARC
SACORDAC  = SAC
CLENGTH   =  .4583
ANNHTH    =  .2083
AERAEFF   =  1.499
NUMFUEL   =  20
DIAHYD    =  13.84
DIAEFF    =  34.59
W3        =  86.707
T3        =  1036.5
P3        =  114.39
T4        =  1889.4
P4        =  109.07
T8        =  1084.0
P8        =  14.847
FFC       =  .4925858
FFT       =  5.56441
SPLFFC    =  -6.15036
SPLTL     =  8.83203
XK1       =  2.76441
CP        =  54.23838
OASPK63   =  78.22828
OASPK160  =  80.70947
OASPK630  =  91.65606
```

Single Annular Combustor Spectra

Acoustic Angles from Inlet, deg.

Freq.	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0
50.0	48.13	56.67	64.61	71.95	78.69	84.82	90.35	95.27	99.60
63.0	55.21	63.75	71.69	79.03	85.76	91.90	97.42	102.35	106.68
80.0	45.78	54.31	62.25	69.58	76.32	82.45	87.98	92.90	97.23
100.0	41.36	48.37	55.18	61.71	67.89	73.66	78.93	83.65	87.73
125.0	57.25	64.26	71.06	77.59	83.77	89.54	94.81	99.53	103.61
160.0	66.09	73.10	79.90	86.43	92.62	98.38	103.66	108.37	112.46
200.0	57.05	64.06	70.87	77.40	83.58	89.34	94.62	99.34	103.42
250.0	17.04	24.06	30.86	37.39	43.57	49.35	54.70	59.69	64.46
315.0	.00	.00	.00	10.38	26.84	41.45	54.21	65.11	74.17
400.0	.00	.00	8.95	27.26	43.72	58.33	71.09	81.99	91.05
500.0	.00	2.01	22.17	40.48	56.95	71.55	84.31	95.22	104.27
630.0	.00	8.48	28.64	46.95	63.41	78.02	90.78	101.69	110.74
800.0	.00	.00	18.81	37.13	53.59	68.20	80.95	91.86	100.91
1000.0	.00	.00	.00	.00	15.50	30.11	42.86	53.77	62.82
1250.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
1600.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
2000.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
2500.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
3150.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
4000.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
5000.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
6300.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
8000.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
10000.0	.00	.00	.00	.00	.00	.00	.00	.00	.00

Acoustic Angles from Inlet, deg.

Freq.	100.0	110.0	120.0	130.0	140.0	150.0	160.0	170.0
50.0	103.32	106.44	108.95	110.87	112.18	112.89	112.99	112.49

63.0	110.40	113.52	116.03	117.94	119.26	119.96	120.07	119.57
80.0	100.95	104.07	106.58	108.49	109.80	110.51	110.62	110.12
100.0	91.11	93.72	95.49	96.34	96.21	95.02	92.72	89.23
125.0	107.00	109.60	111.37	112.22	112.08	110.89	108.56	105.04
160.0	115.84	118.45	120.21	121.06	120.92	119.73	117.40	113.88
200.0	106.80	109.41	111.18	112.02	111.89	110.69	108.37	104.85
250.0	68.99	72.89	75.70	77.08	76.89	75.12	71.85	67.24
315.0	81.37	86.72	90.21	91.86	91.65	89.59	85.68	79.92
400.0	98.25	103.59	107.09	108.74	108.53	106.47	102.56	96.79
500.0	111.47	116.82	120.31	121.96	121.75	119.69	115.78	110.02
630.0	117.94	123.29	126.78	128.43	128.22	126.16	122.25	116.49
800.0	108.11	113.46	116.96	118.60	118.40	116.34	112.42	106.66
1000.0	70.02	75.37	78.87	80.51	80.30	78.24	74.33	68.57
1250.0	.00	.00	.00	.00	.00	.00	.00	.00
1600.0	.00	.00	.00	.00	.00	.00	.00	.00
2000.0	.00	.00	.00	.00	.00	.00	.00	.00
2500.0	.00	.00	.00	.00	.00	.00	.00	.00
3150.0	.00	.00	.00	.00	.00	.00	.00	.00
4000.0	.00	.00	.00	.00	.00	.00	.00	.00
5000.0	.00	.00	.00	.00	.00	.00	.00	.00
6300.0	.00	.00	.00	.00	.00	.00	.00	.00
8000.0	.00	.00	.00	.00	.00	.00	.00	.00
10000.0	.00	.00	.00	.00	.00	.00	.00	.00

```
PROGRAM: COMBUSTOR        Version 1.2  17–May–99 10:01:16

GEAE/ADT Combustor Noise Prediction
 – Modified Diversitech Correlation

INFO      = Sample DAC Combustor
IALPHA    = SAE77
TAMB      = 77 Deg. F
PAMB      = 29.92 In. Hg
RELHUM    = 70%
DIST      = 1 Ft.
IARCSL    = ARC
SACORDAC  = DAC
DACTYPE   = 20–10
CLENGTH   =  .492
ANNHTH    =  .25
AERAEFF   =  2.43
NUMFUEL   =  30
MXFUELNZ  =  40
DIAHYD    =  13.4
DIAEFF    =  39.9
W3        =  113.9
T3        =  1189.9
P3        =  173.1
T4        =  2260.0
P4        =  162.9
T8        =  1205.6
P8        =  15.1
FFC       =  .6655269
FFT       =  7.87937
SPLFFC    =  –3.53669
SPLTL     =  12.02675
XK1       =  3.99335
CP160     =  14.27774
CP500     =  34.17858
OASPK160  =  81.19081
```

OASPK500 = 78.0304

Double Annular Combustor Spectra

Freq.	Acoustic Angles from Inlet, deg. 10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0
50.0	.00	.00	.00	.00	.72	11.20	20.30	28.02	34.35
63.0	.00	.00	.00	3.41	15.27	25.76	34.85	42.57	48.90
80.0	.00	.00	6.34	19.59	31.45	41.94	51.03	58.75	65.08
100.0	.00	6.60	21.24	34.49	46.35	56.84	65.93	73.65	79.98
125.0	2.93	18.94	33.58	46.83	58.70	69.18	78.28	85.99	92.32
160.0	8.47	24.49	39.13	52.38	64.24	74.73	83.82	91.54	97.87
200.0	.00	14.07	28.71	41.96	53.83	64.31	73.41	81.12	87.45
250.0	.00	.00	.00	13.45	27.70	40.43	51.59	61.14	69.08
315.0	.00	.00	11.88	27.99	42.46	55.30	66.52	76.11	84.07
400.0	.00	6.89	24.62	40.72	55.19	68.04	79.25	88.84	96.80
500.0	.00	11.82	29.55	45.65	60.13	72.97	84.19	93.77	101.73
630.0	.00	1.99	19.72	35.82	50.30	63.14	74.36	83.94	91.90
800.0	.00	.00	.00	.00	9.74	22.58	33.80	43.38	51.34
1000.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
1250.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
1600.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
2000.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
2500.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
3150.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
4000.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
5000.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
6300.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
8000.0	.00	.00	.00	.00	.00	.00	.00	.00	.00
10000.0	.00	.00	.00	.00	.00	.00	.00	.00	.00

Freq.	Acoustic Angles from Inlet, deg. 100.0	110.0	120.0	130.0	140.0	150.0	160.0	170.0
50.0	39.29	42.86	45.04	45.83	45.24	43.27	39.91	35.17
63.0	53.85	57.41	59.59	60.38	59.79	57.82	54.46	49.72
80.0	70.02	73.59	75.77	76.56	75.97	74.00	70.64	65.90
100.0	84.93	88.49	90.67	91.46	90.87	88.90	85.54	80.80
125.0	97.27	100.83	103.01	103.80	103.21	101.24	97.88	93.14
160.0	102.82	106.38	108.56	109.35	108.76	106.79	103.43	98.69
200.0	92.40	95.96	98.14	98.94	98.35	96.38	93.02	88.28
250.0	75.40	80.09	83.16	84.60	84.42	82.61	79.17	74.11
315.0	90.40	95.10	98.17	99.62	99.44	97.63	94.19	89.12
400.0	103.13	107.84	110.91	112.36	112.17	110.36	106.93	101.86
500.0	108.07	112.77	115.84	117.29	117.11	115.30	111.86	106.79
630.0	98.24	102.94	106.01	107.46	107.28	105.47	102.03	96.96
800.0	57.68	62.38	65.45	66.90	66.72	64.91	61.47	56.40
1000.0	.00	.00	.00	.00	.00	.00	.00	.00
1250.0	.00	.00	.00	.00	.00	.00	.00	.00
1600.0	.00	.00	.00	.00	.00	.00	.00	.00
2000.0	.00	.00	.00	.00	.00	.00	.00	.00
2500.0	.00	.00	.00	.00	.00	.00	.00	.00
3150.0	.00	.00	.00	.00	.00	.00	.00	.00
4000.0	.00	.00	.00	.00	.00	.00	.00	.00
5000.0	.00	.00	.00	.00	.00	.00	.00	.00
6300.0	.00	.00	.00	.00	.00	.00	.00	.00
8000.0	.00	.00	.00	.00	.00	.00	.00	.00
10000.0	.00	.00	.00	.00	.00	.00	.00	.00