NASA TECHNICAL MEMORANDUM

NASA TM X-2967

NASA TM X-2967

FORTRAN PROGRAM TO GENERATE ENGINE INLET FLOW CONTOUR MAPS AND DISTORTION PARAMETERS

by John H. Dicus

Lewis Research Center

Cleveland, Ohio 44135

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • FEBRUARY 1974

1. Report No. NASA TM X-2967	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle FORTRAN PROGRAM TO GENERATE ENGINE INLET FLOW CONTOUR MAPS AND DISTORTION PARAMETERS		5. Report Date January 1974
		6. Performing Organization Code
7. Author(s) John H. Dicus		8. Performing Organization Report No. E-7572
9. Performing Organization Name and Address Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio 44135		10. Work Unit No. 501-24
		11. Contract or Grant No.
		13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

A computer program is presented and described that generates jet engine inlet flow contour maps and inlet flow distortion parameters. The program input consists of an array of measurements describing the flow conditions at the engine inlet. User-defined distortion parameters may be calculated.

17. Key Words (Suggested by Author(s)) Jet engine inlet; Inlet contour map; Inlet distortion parameter; Inlet distortion index		18. Distribution Statement Unclassified - unlimited Cat. 28	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 62	22. Price* $3.50

* For sale by the National Technical Information Service, Springfield, Virginia 22151

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Lewis Research Center

SUMMARY

A computer program has been written to generate gas turbine engine inlet flow contour maps and inlet flow distortion parameters based on any array of measurements describing the flow conditions at the engine inlet.

As well as being able to choose the type of contour map that is generated, the user has the ability to construct any distortion parameter desired, as long as it depends solely on the conditions at the engine inlet. To accomplish this, a simple subroutine is written which combines the information generated by the program into a parameter.

The report includes the FORTRAN IV computer program, a discussion of its operation and limitations, and two example cases with the input and output shown.

A CFACE source deck on tape is available from COSMIC (Computer Software Management and Information Center), University of Georgia, 30601. The program can by ordered by using the number of this report as identification.

INTRODUCTION

This report presents a computer program to generate inlet contour maps and inlet distortion parameters for gas turbine engines. Inlet flow distortion poses a problem for all types of gas turbine installations: commercial, civil, and military. The compressor system of a gas turbine engine may stall when subjected to a distorted inlet flow field, whether it be a pressure distortion, a temperature distortion, or a distortion of some other flow parameter. Also, engine and airframe manufacturers need a method to insure compatibility between the inlet and engine of an aircraft before they are tested as a unit.

Currently an intensive effort is being made to correlate a gas turbine engine's susceptibility to stall with a description of the flow field at the engine inlet. One approach to the problem is to generate inlet distortion parameters based solely on the measured flow conditions at the inlet to the engine and to attempt to correlate these distortion parameters with some measure of the loss in the engine stall margin. This procedure requires an accurate definition of the flow field at the engine inlet. Reference 1 presents the stall margin of an engine as a function of an inlet distortion parameter. In reference 2, the value of a distortion parameter causing engine stall is shown as a function of corrected compressor massflow.

The usefulness of the program presented in this report lies in the fact that it is sufficiently general to accommodate almost any inlet probe geometry. The only stipulation is that the probes must lie on some definable rings. The rings may vary in number and in radial location. They may contain different numbers of probes, and the probes may be located at any circumferential position on the rings.

Included in this report is the FORTRAN IV program CFACE, complete with two example cases showing both input and output. Also included is a brief discussion of the methods used to generate the contour maps. Four examples are given to show how to build specific distortion parameters within a special subprogram named DISPAR.

A CFACE source deck on tape is available from COSMIC (Computer Software Management and Information Center), University of Georgia, 30601. The program can be ordered by using the number of this report as identification.

GENERAL PROGRAM DESCRIPTION

The purpose of the program is to generate contour maps and distortion parameters that describe the flow at the measuring station immediately ahead of a gas turbine engine. However, it may be used to generate contour maps for any type of measuring station. Although total and static pressures and temperatures are the most common inputs to the program, provision has been made for the input of special measurements such as flow angles and turbulence levels. The FORTRAN IV program CFACE operates on these input measurements and the probe array geometry, which is also part of the input, to generate the contour maps and distortion parameters. The entire program listing and error messages are contained in appendix A.

Also included in appendix A is a brief description of each subroutine telling what each one accomplishes. Also, comment statements are placed throughout the program. These two features enable the reader to follow the flow of the program and understand what is taking place in each section.

CFACE generates inlet contour maps with a choice of mapping parameters. To provide contour maps and distortion parameters, interpolation between input measurement locations is done by a technique involving linear interpolation. The method of interpolation is discussed in appendix B. The contour maps are represented by symbols (numbers and letters) on a picture produced by a line printer. Twenty mapping symbols are used and they are described by a key which accompanies each contour map. Interpretation of the contour maps is discussed in the section entitled OUTPUT.

Three different types of contour maps are available when the input measurements are pressures. They are $(P_{t,max,f} - P_i)/P_{t,max,f}$, in percent; $(P_i - P_{t,av,f})/P_{t,av,f}$, in percent; and Mach number. (Symbol definitions appear in appendix C.) When temperature is the input, a map of $(T_i - T_{t,av,f})/T_{t,av,f}$, in percent, can be generated.

As mentioned before, provision has been made for the input of special measurements such as flow angles and $(\Delta P)_{rms}/\bar{P}$. Calling this special variable "X", either $(X_i - X_{av,f})/X_{av,f}$, in percent, or $\bar{X} \pm n(\Delta X)$ may be mapped. In the case of $\bar{X} \pm n(\Delta X)$, ΔX is specified by the user; $\bar{X}$ is the mean value of X rounded off to the nearest ΔX; and $n = 0, 1, 2, \ldots, 10$. If a map of pressure in $\bar{P} \pm n(\Delta P)$ or temperature in $\bar{T} \pm n(\Delta T)$ is desired, the special input format can be used.

CFACE generates a variety of simple circumferential and radial distortion parameters that enable the calculation of almost any specific distortion parameter as long as its calculation is based solely on the conditions at the engine inlet. To implement this procedure, user-written FORTRAN IV instructions are inserted into a special subprogram named DISPAR. These instructions combine the general parameters calculated by the program, the probe array geometry (part of the input), and any information unqiue to the specific distortion parameter (inserted by the user) into the desired form. Distortion parameters can be calculated regardless of the type of input. Although the user has access to the input data (in the common block DATTRN) within the subroutine DISPAR, care should be taken not to alter their values as they will be used elsewhere in the program.

The output of all of the distortion parameters is handled by the output subroutine LNPOUT. A special section in LNPOUT is reserved for the output of the specific parameters. Another special section is reserved in LNPOUT for the corresponding output format statements. A special common block named PARTRN is reserved for transmitting the specific distortion parameters from DISPAR to LNPOUT.

The simple distortion parameters calculated by the program are mentioned in the section entitled OUTPUT and are described in appendix D. Appendix D also contains four examples of user-defined specific distortion parameters and the FORTRAN IV instructions to calculate them. A listing showing the use of the common block PARTRN and the subroutines DISPAR and LNPOUT is shown in appendix A.

INPUT

Two example cases showing input and output are contained in this report. They appear in appendix E. Appendix B shows the method of interpolation used to generate the contour maps. Referring to appendixes B and E while reading the following section should aid in its understanding. This particularly applies to figure 2, which is referenced in appendix B.

Input Variables

The input variables are shown below. A more detailed description of these variables is contained in the section entitled Instructions For Preparing Input.

QQ (integer) — indicates how many complete sets of measurements are to be read in

WHICH (integer) — controls the type of contour map to be generated
- WHICH = 1, map of $(P_{t,max,f} - P_i)/P_{t,max,f}$, percent
- WHICH = 2, map of $(P_i - P_{t,av,f})/P_{t,av,f}$, percent
- WHICH = 3, map of Mach number
- WHICH = 4, map of $(T_i - T_{t,av,f})/T_{t,av,f}$, percent
- WHICH = 5, map showing distribution of special variable - can be represented as $(X_i - X_{av,f})/X_{av\ f}$ (in percent) or as $\overline{X} \pm n(\Delta X)$

RANGE (real) — total range of percentage represented on contour map when WHICH = 1, 2, or 4 or when WHICH = 5 and LPCENT = .TRUE..

LPCENT (logical) — controls whether $(X_i - X_{av,f})/X_{av,f}$ or $\overline{X} \pm n(\Delta X)$ will be mapped when WHICH = 5
- LPCENT = .TRUE., causes $(X_i - X_{av,f})/X_{av,f}$ to be mapped
- LPCENT = .FALSE., causes $\overline{X} \pm n(\Delta X)$ to be mapped

DELX (real) — magnitude of ΔX that each of the 20 mapping symbols will represent when WHICH = 5 and LPCENT = .FALSE.

STATI (locigal) — indicates whether or not the innermost ring is treated as ring of static measurements

	STATI = .TRUE. innermost ring is ring of static measurements STATI = .FALSE. innermost ring is not ring of static measurements
STATO (logical)	indicates whether or not the outermost ring is treated as a ring of static measurements STATO = .TRUE. outermost ring is ring of static measurements STATO = .FALSE. outermost ring is not ring of static measurements
LCNTFL (logical)	controls whether or not center of contour map will be filled in LCNTFL = .TRUE. center of map will be filled in LCNTFL = .FALSE. center of map will not be filled in (interpolation will stop with the innermost ring)
RMACH (real)	maximum Mach number that will be represented on contour map when WHICH = 3
LDPAR (logical)	controls whether or not distortion parameters are calculated from the input measurements LDPAR = .TRUE. distortion parameters are to be generated LDPAR = .FALSE. distortion parameters are not to be generated
NR (integer)	number of rings of measurements to be read in (10 is the maximum), numbered from innermost ring out
RADLOC (10)(real)	array of radii, one for each of the NR rings, cm (in.)
NP (10) (integer)	array containing number of measurements on each of the NR rings
ANGLOC (10, 20)(real)	array containing angular position (in deg) of each measurement on each of the NR rings (There may be up to 20 angular positions on each ring.)
TITLE 1(A-format)	can contain up to 80 alphanumeric characters for general title information
TITLE 2(A-format)	can contain up to 80 additional alphanumeric characters for general title information
P (10, 20)(real)	array containing value of each input measurement on each of NR rings (There may be up to 20 measurements on each ring.)

QQ, WHICH, RANGE, LPCENT, DELX, STATI, STATO, LCNTFL, RMACH, and LDPAR are read in under the namelist INIT and go on the first two cards. These two cards should not be repeated for each set of input measurements; they only appear once.

QQ. - QQ may assume any positive integer value and tells the program how many contour maps are to be generated.

WHICH, RANGE, LPCENT, DELX - A value for RANGE is needed when WHICH = 1, 2, or 4 or when WHICH = 5 and LPCENT = .TRUE.. When WHICH = 3 or when WHICH = 5 and LPCENT = .FALSE., RANGE may be omitted from the namelist. There are 20 mapping symbols, and the value of RANGE divided by 20 will be the spread in percentage represented by each mapping symbol. RANGE = 20.0 will cause each mapping symbol to represent a spread of 1 percent. (When WHICH = 1, a total range of 20 percent would correspond to 0 to -20 percent. In all other instances, a total range of 20 percent corresponds to -10 to +10 percent.) This is usually sufficient for most pressure or temperature distributions. If RANGE equals 30.0, each mapping symbol will represent a spread of 1.5 percent. Obviously, care should be taken to avoid choosing values of RANGE that would cause each mapping symbol to represent an inconvenient spread of percentage.

When WHICH = 5, it is necessary to set LPCENT equal to either .TRUE. or .FALSE.. If WHICH ≠ 5, LPCENT can be omitted from the namelist as its value is unimportant. If WHICH = 5 and LPCENT = .FALSE., DELX must also be given a value (otherwise DELX can be omitted from the namelist). Since there are 20 mapping symbols, DELX should be chosen such that 20 times DELX is greater than or equal to the range of measurements being mapped. Consideration should also be given to picking a reasonable DELX such as 0.02 or 30.0, as opposed to 0.0218 or 31.66.

STATI, STATO - When the innermost ring is a ring of static measurements, STATI should be set equal to .TRUE.. Then the measurements on the innermost ring will be excluded in the calculation of the average and in the search for the minimum and the maximum. They will also be treated as static measurements in the calculation of distortion parameters. In general, a ring of static measurements will be treated as just another ring of measurements in all other respects (such as interpolation). The same comments apply for the variable STATO if the outermost ring is a ring of static measurements. Since the calculation of Mach number requires static pressures, WHICH = 3 cannot be chosen when both STATI and STATO are set equal to .FALSE..

LCNTFL - When the innermost ring is not a ring of static values, the user may want the mapping to continue through the center of the profile. If this is the case, LCNTFL should be set equal to .TRUE..

If the user wants the mapping to stop with the innermost ring, LCNTFL should be set equal to .FALSE.. The condition of LCNTFL and STATI both equal to .TRUE. is a condition that cannot be allowed.

RMACH - RMACH determines the maximum Mach number that will be represented on the Mach number contour map when WHICH = 3. Each of the 20 mapping symbols will represent a delta Mach number equal to RMACH ÷ 20. Care should be taken to select RMACH large enough, but of such a value that the delta Mach number will not be awkward. If WHICH ≠ 3, RMACH can be omitted from the namelist.

LDPAR - If the calculation of one or more specific distortion parameters is desired or even if only the calculation of the simple distortion parameters is desired, LDPAR should be set equal to .TRUE.. Otherwise, LDPAR should be set equal to .FALSE.. The calculation of distortion parameters is usally desired when the input measurements are pressures. However, the situation may occur where distortion parameters are desired when the input measurements are temperatures or some other measurement.

The input of NR, RADLOC, NP, and ANGLOC will be subject to specific input formats and should all be on separate cards. They should not be repeated for each set of measurements; they should appear only once.

NR - The number of rings of measurements should be read in as NR with an (I2) format. Rings of static measurements should be counted. The maximum number of rings allowed is 10.

RADLOC - The radius of each ring goes into the array RADLOC. The radii may be in either centimeters or inches. RADLOC(1) corresponds to the innermost ring while RADLOC(NR) corresponds to the outermost ring. The input format is (F5.2,9(1X,F5.2)).

NP - The array NP contains the number of measurements on each ring. Again, NP(1) contains the number of measurements on the innermost ring. The maximum number of measurements that each ring can contain is 20. There may be as few as one measurement on a ring. The input format for NP is (I2, 9(1X,I2)).

ANGLOC - The angular position of each measurement on each ring goes into the array ANGLOC. The first subscript pertains to the ring number, and the second subscript pertains to the measurement referred to on that ring. For example, ANGLOC(5, 14) stores the angular position of the 14th measurement on the 5th ring. The values in ANGLOC should be in degrees, and there can be up to 20 values on each ring. The input format for ANGLOC is (F5.1, 9(1X, F5.1)), hence, only 10 values can go on a card. Each ring has its own card (or cards if there are more than 10 values on a ring) associated with it. Angular position is measured clockwise from the 12 o'clock position. On a given ring, the first measurement falling on or after the 12 o'clock position is the first measurement on that ring (see figure 2 in appendix B).

TITLE1, TITLE2, and P also go on separate cards. However, they appear more than once. The number of sets of these variables should be equal to the number of maps to be generated (QQ).

TITLE1, TITLE2 - TITLE1 is a string of alphanumeric characters which is read in under an (80A1) format. The title can be used for general information such as airflow or reading number. This information will appear as part of the output. The purpose of TITLE2 is the same as TITLE1. It also has an (80A1) format.

P - The measurements that are to be mapped should be read into the array P. As in the case of the subscripts of ANGLOC(5, 14), P(5, 14) contains the 14th measurement on the 5th ring. There can be up to 20 measurements on each ring. The contents of ANGLOC correspond to the contents of P. For example, ANGLOC(5, 14) is the angular position of P(5, 14).

The input format for P depends on the value of WHICH. When WHICH = 1, 2, or 3, the input format for P is (F7.3, 9(1X, F7.3)), where P is expressed in kilopascals (kPa) or psi. When WHICH = 4, the format is (F7.2, 9(1X, F7.2)), where P is expressed in K or ^{O}R. And when WHICH = 5, the format is (F11.5,4(1X, F11.5), where the choice of dimensions for P is left to the user. Except for when WHICH = 5, the values of up to 10 measurements can be placed on one card. If there are more than 10 measurements on a ring, a second card for that ring will be used. Therefore, each ring will have one or two cards corresponding to it. If WHICH = 5, the values of only five measurements will fit on one card, and up to four cards for a given ring may be used.

OUTPUT

Two examples of program output are shown in appendix E. The first page of the output contains input information, specifically, the value of each measurement, its angular position, and the value of the mapping parameter corresponding to each measurement. The first section of this page lists the angular position of each measurement for each ring radius. Section two lists each measurement on each ring. There is a one-to-one correspondence between the angular positions in the first section and the measurements in the second section. The third section shows the value of the parameter being mapped for each measurement location. Again, there is a one-to-one correspondence between the values in this section and the values in the other two sections.

Page two of the output contains the contour map as well as a key to the mapping symbols. A line can be drawn (by hand) between two adjacent regions having different mapping symbols. This line is a line of constant mapping parameter which can be determined from the key. The contour map is to scale with 19 line printer rows (or lines) equalling the radius of the outermost ring of input measurements.

The next two pages (pp. 3 and 4) of the output exist only if distortion parameters are desired (only if the logical variable LDPAR has been set equal to .TRUE.). The first section on page three of the output lists eight simple parameters dealing with the circumferential distortion. They are listed for each of the 10 rings. Section two of this page lists six simple parameters dealing with radial distortion. They are listed for eight discrete circumferential locations. The method used to enable calculation of these simple radial distortion parameters is discussed in appendix F. On this same page there are also seven simple distortion parameters pertaining to the complete array of input measurements. Appendix D discusses the calculation of the simple distortion parameters.

The last page of the output (p. 4) contains information dealing with the specific distortion parameters that can be defined by the user. The format of this page is also user-defined. An example of the output is shown in appendix E, and a sample listing is shown in appendix A.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, October 3, 1973,
501-24.

APPENDIX A

PROGRAM LISTING AND ERROR MESSAGES

A block diagram showing the program flow through the various subroutines is shown in figure 1.

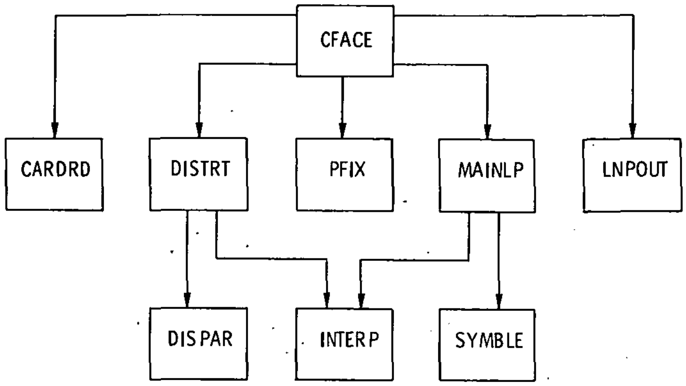


Figure 1. - Calling relation of subroutines.

Once the program flow reaches CALL PFIX(.FALSE.) in CFACE, and if LCNTFL=.TRUE., all input data are moved outward by one ring, and a dummy ring takes the place of ring one. This happens so that the program can interpolate through the center of the contour map. For example, when the program flow reaches CALL PFIX(.FALSE.) in CFACE (if LCNTFL=.TRUE.), ring NR becomes ring NR+1, ring 1 becomes ring 2, and so on. Also in this call to PFIX, the input measurements are transformed into mapping parameters. Therefore, the user must take care not to access the input data in any subroutine other than DISPAR.

CFACE

CFACE is the main driving program. It controls the number of cycles through the program and calls the subroutines in the proper order.

```
C
C   MAIN DRIVING PROGRAM
C
      COMMON/CYCLE/LREAD
      COMMON/READTR/STATI,STATO,LCNTFL,LDPAR
      COMMON/WRANGE/XBAR,RMAV,WHICH,RANGE,LPCENT,RMACH,DELX
      COMMON/FINI/LQUIT
      INTEGER WHICH
      INTEGER QQ
      LOGICAL STATI,STATO,LCNTFL,LDPAR
      LOGICAL LREAD
      LOGICAL LPCENT,LQUIT
      NAMELIST/INIT/QQ,WHICH,RANGE,LPCENT,DELX,STATI,STATO,LCNTFL,RMACH,
     A    LDPAR
      LREAD=.TRUE.
      LQUIT=.FALSE.
C
C   READ IN CONTROL PARAMETERS
C
      READ(5,INIT)
      DO 10 I=1,QQ
C
C   CALL SUBROUTINE TO READ IN GEOMETRY AND MEASUREMENTS
C   FOR THE INPUT MEASUREMENT PLANE
C
      CALL CARDRD
      IF(LQUIT) GO TO 10
C
C   CALL SUBROUTINES TO CALCULATE DISTORTION PARAMETERS
C
      IF(LDPAR) CALL PFIX(.TRUE.)
      IF(LDPAR) CALL DISTRT
C
C   CALL SUBROUTINE TO TRANSFORM INPUT MEASUREMENTS INTO
C   MAPPING PARAMETERS
C
      CALL PFIX(.FALSE.)
      IF(LQUIT) GO TO 10
C
C   CALL SUBROUTINE THAT CONTROLS INTERPOLATION PROCESS
C   IN INPUT MEASUREMENT PLANE
C
      CALL MAINLP
C
C   CALL SUBROUTINE THAT CONTROLS THE OUTPUT
C



      CALL LNPOUT
   10 CONTINUE
      STOP
      END
```

Subroutine CARDRD

The reading of input data from cards is controlled by this subroutine. The output of probe angular locations and input measurement values is handled by CARDRD. "PROGRAM WILL NOT WORK. NR LESS THAN 2" will be printed out and the program will stop if there are less than two rings of input measurements.

```
      SUBROUTINE CARDRD
C
C   SUBROUTINE TO READ IN GEOMETRY AND MEASUREMENTS FOR
C   THE INPUT MEASUREMENT PLANE
C        SUBROUTINE ALSO CONTROLS SOME OUTPUT
C
      COMMON/CYCLE/LREAD
C
C   NP, RADLOC, ANGLOC, AND P HAVE THE FIRST
C   ARRAY DIMENSION EQUAL TO 11.  10 OF THE
C   11 POSITIONS ARE AVAILABLE FOR USE.  THE
C   REMAINING POSITION IS NEEDED FOR INTERNAL MANIPULATION.
C
      COMMON/DATTRN/P(11,20),NR,RADLOC(11),ANGLOC(11,20),
     A     NP(11),FACE(39,65)
      COMMON/READTR/STATI,STATO,LCNTFL,LDPAR
      COMMON/WRANGE/XBAR,RMAV,WHICH,RANGE,LPCENT,RMACH,DELX
      COMMON/SCALE/FACTOR
      COMMON/HEADG/TITLE1(80),TITLE2(80)
      COMMON/FINI/LQUIT
      INTEGER WHICH
      LOGICAL LREAD
      LOGICAL STATI,STATO,LCNTFL,LDPAR
      LOGICAL LPCENT,LQUIT
C
C  SECTION THAT READS IN THE GEOMETRY OF THE MEASUREMENT PLANE
C
      IF(.NOT.LREAD) GO TO 20
      LREAD=.FALSE.
      READ(5,100) NR
      IF(NR.GE.2) GO TO 31
      WRITE(6,130)
      LQUIT=.TRUE.
      RETURN
   31 CONTINUE
      READ(5,101) (RADLOC(I),I=1,NR)
      FACTOR=RADLOC(NR)/19.1
      READ(5,102) (NP(I),I=1,NR)
      DO 10 J=1,NR
      K=NP(J)
      READ(5,103) (ANGLOC(J,I),I=1,K)
   10 CONTINUE
   20 CONTINUE
C
C   SECTION THAT READS TITLES AND INPUT MEASUREMENTS
C
      READ(5,124) TITLE1
```

```
      READ(5,124) TITLE2
      DO 30 J=1,NR
      K=NP(J)
      IF(WHICH.NE.4.AND.WHICH.NE.5) READ(5,104) (P(J,I),I=1,K)
      IF(WHICH.EQ.5) READ(5,107) (P(J,I),I=1,K)
      IF(WHICH.EQ.4) READ(5,106) (P(J,I),I=1,K)
   30 CONTINUE
      WRITE(6,126)
      WRITE(6,125) TITLE1
      WRITE(6,125) TITLE2
      WRITE(6,109)
C
C   SECTION THAT WRITES THE ANGULAR POSITIONS OF THE
C   INPUT MEASUREMENTS
C
      WRITE(6,121)
      DO 41 J=1,NR
      K=NP(J)
      IF(WHICH.NE.5) WRITE(6,123) RADLOC(J),(ANGLOC(J,I),I=1,K)
      IF(WHICH.EQ.5) WRITE(6,122) RADLOC(J),(ANGLOC(J,I),I=1,K)
   41 CONTINUE
      WRITE(6,109)
C
C   SECTION THAT WRITES THE INPUT MEASUREMENTS
C
      IF(WHICH.NE.4.AND.WHICH.NE.5) WRITE(6,113)
      IF(WHICH.EQ.4) WRITE(6,114)
      IF(WHICH.EQ.5) WRITE(6,115)
      DO 40 J=1,NR
      K=NP(J)
      IF(WHICH.NE.4.AND.WHICH.NE.5) WRITE(6,110) RADLOC(J),(P(J,I),I=1,K
     A)
      IF(WHICH.EQ.4) WRITE(6,111) RADLOC(J),(P(J,I),I=1,K)
      IF(WHICH.EQ.5) WRITE(6,112) RADLOC(J),(P(J,I),I=1,K)
   40 CONTINUE
      WRITE(6,109)
C
C   SECTION TO WRITE TITLES FOR NEXT SECTION OF OUTPUT
C       NEXT SECTION OF OUTPUT IS CONTROLLED BY THE
C       SUBROUTINE 'PFIX'
C
      IF(WHICH.EQ.1) WRITE(6,116)
      IF(WHICH.EQ.2) WRITE(6,117)
      IF(WHICH.EQ.3) WRITE(6,118)
      IF(WHICH.EQ.4) WRITE(6,119)
      IF(WHICH.EQ.5.AND.LPCENT) WRITE(6,120)
  100 FORMAT(I2)
  101 FORMAT(F5.2,9(1X,F5.2))
  102 FORMAT(I2,9(1X,I2))
  103 FORMAT(2(F5.1,9(1X,F5.1)/))
  104 FORMAT(2(F7.3,9(1X,F7.3)/))
  106 FORMAT(2(F7.2,9(1X,F7.2)/))
  107 FORMAT(4(F11.5,4(1X,F11.5)/))
  109 FORMAT(1H0)
  110 FORMAT(5X,F5.2,4X,10(3X,F7.3)/14X,10(3X,F7.3))
  111 FORMAT(5X,F5.2,4X,10(3X,F7.2)/14X,10(3X,F7.2))
  112 FORMAT(5X,F5.2,4X,5(2X,F11.5)/3(14X,5(2X,F11.5)/))
  113 FORMAT(1X/4X,6HRADIUS,15X,8HPRESSURE/)
  114 FORMAT(1X/4X,6HRADIUS,15X,11HTEMPERATURE/)
```

```
115 FORMAT(1X/4X,6HRADIUS,15X,13HSPECIAL INPUT/)
116 FORMAT(1X/4X,6HRADIUS,15X,23H(PI-PMAX)/PMAX, PERCENT/)
117 FORMAT(1X/4X,6HRADIUS,15X,23H(PI-PAVG)/PAVG, PERCENT/)
118 FORMAT(1X/4X,6HRADIUS,15X,11HMACH NUMBER/)
119 FORMAT(1X/4X,6HRADIUS,15X,23H(TI-TAVG)/TAVG, PERCENT/)
120 FORMAT(1X/4X,6HRADIUS,15X,32HSPECIAL, (XI-XAVG)/XAVG, PERCENT/)
121 FORMAT(1X//4X,6HRADIUS,15X,43HANGULAR POSITION OF INPUT MEASUREMEN
   ATS, DEG)
122 FORMAT(5X,F5.2,4X,5(8X,F5.1)/3(14X,5(8X,F5.1)/))
123 FORMAT(5X,F5.2,4X,10(5X,F5.1)/14X,10(5X,F5.1))
124 FORMAT(80A1)
125 FORMAT(6X,80A1)
126 FORMAT(1H1)
130 FORMAT(1X,37HPROGRAM WILL NOT WORK. NR LESS THAN 2)
    RETURN
    END
```

Subroutine DISTRT

DISTRT generates all of the simple circumferential and radial distortion parameters that are used in DISPAR. DISTRT calls INTERP and DISPAR, in that order.

"RING HAS ONLY ONE PROBE"

will be printed as a reminder when the subroutine tries to calculate θ^- for a ring which contains only one probe.

"NO STATIC PRESSURES, NOT POSSIBLE TO CALCULATE"
"SPECIFIC DISTORTION PARAMETERS REQUIRING STATIC PRESSURE"

will be written when DISTRT finds no rings of static pressure measurements as part of the input. The average static pressure SMAVG will be set equal to 5.0 and all calculations using SMAVG will be meaningless.

```
      SUBROUTINE DISTRT
C
C  SUBROUTINE TO CALCULATE SIMPLE DISTORTION PARAMETERS
C
C
C  NP, RADLOC, ANGLOC, AND P HAVE THE FIRST
C  ARRAY DIMENSION EQUAL TO 11.  10 OF THE
C  11 POSITIONS ARE AVAILABLE FOR USE.  THE
C  REMAINING POSITION IS NEEDED FOR INTERNAL MANIPULATION.
C
      COMMON/DATTRN/P(11,20),NR,RADLOC(11),ANGLOC(11,20),
     A      NP(11),FACE(39,65)
      COMMON/DISTRN/CMMIN(10),CMMAX(10),CMAVG(10),CDPOP1(10),CDPOP2(10),
     A     CDPOP3(10),THTMIN(10),THTPLS(10),RMMIN(8),RMMAX(8),RMAVG(8),
     B     RDPOP1(8),RDPOP2(8),RDPOP3(8),TMMIN,TMMAX,TMAVG,SMAVG,TDP1,
```

```
     C    TDP2,TDP3,QLOC(10,20)
      COMMON/READTR/STATI,STATO,LCNTFL,LDPAR
      COMMON/INTRN/R,THETA,PVALUE
      DIMENSION SEG(10),RADP(8,10)
      DIMENSION THTTOT(10)
      LOGICAL LADD
      LOGICAL STATI,STATO,LCNTFL,LDPAR
C
C  CALCULATION OF SIMPLE CIRCUMFERENTIAL DISTORTION PARAMETERS
C
      N1=1
      N2=NR
      IF(STATI) N1=2
      IF(STATO) N2=NR-1
      DO 10 I=N1,N2
C
C CALCULATION OF CMMAX, CMMIN, AND CMAVG FOR EACH RING
C
      CMMAX(I)=0.0
      CMMIN(I)=50000.0
      CMAVG(I)=0.0
      J1=NP(I)
      DO 11 J=1,J1
      IF(P(I,J).GT.CMMAX(I)) CMMAX(I)=P(I,J)
      IF(P(I,J).LT.CMMIN(I)) CMMIN(I)=P(I,J)
      CMAVG(I)=CMAVG(I)+(P(I,J)/FLOAT(J1))
   11 CONTINUE
C
C  CALCULATION OF CDPOP'S FOR EACH RING
C
      CDPOP1(I)=(CMMAX(I)-CMMIN(I))/CMMAX(I)
      CDPOP2(I)=(CMMAX(I)-CMMIN(I))/CMAVG(I)
      CDPOP3(I)=(CMAVG(I)-CMMIN(I))/CMAVG(I)
   10 CONTINUE
C
C  CALCULATION OF TMMAX AND TMMIN
C
      TMMAX=0.0
      TMMIN=50000.0
      DO 7 I=N1,N2
      IF(CMMAX(I).GT.TMMAX) TMMAX=CMMAX(I)
      IF(CMMIN(I).LT.TMMIN) TMMIN=CMMIN(I)
    7 CONTINUE
C
C  CALCULATION OF TMAVG
C
      DIV=0.0
      PTSUM=0.0
      DO 33 I=N1,N2
      J1=NP(I)
      DO 33 J=1,J1
      PTSUM=PTSUM+P(I,J)
   33 DIV=DIV+1.0
      TMAVG=PTSUM/DIV
C
C  CALCULATION OF TDP'S
C
      TDP1=(TMMAX-TMMIN)/TMMAX
      TDP2=(TMMAX-TMMIN)/TMAVG
```

```
      TOP3=(TMAVG-TMMIN)/TMAVG
C
C   SECTION TO CALCULATE THTMIN FOR EACH RING
C
      DO 9 I=N1,N2
      DO 13 LL=1,10
   13 SEG(LL)=0.0
      J1=NP(I)
      IF(J1.EQ.1) GO TO 8
      L=1
      LADD=.FALSE.
      DO 12 J=1,J1
      K0=J-1
      IF(K0.EQ.0) K0=J1
      K1=J
      A1=ANGLOC(I,K1)
      K2=J+1
      IF(K2.GT.J1) K2=K2-J1
      A2=ANGLOC(I,K2)
      IF((J+1).GT.J1) A2=A2+360.0
      IF(J.GT.1) GO TO 14
      IF(P(I,K1).LT.CMAVG(I)) GO TO 21
      IF(P(I,K1).EQ.CMAVG(I).AND.P(I,K2).LT.CMAVG(I)) GO TO 22
      GO TO 14
   22 CONTINUE
      IF(P(I,K0).GE.CMAVG(I)) GO TO 14
   21 CONTINUE
      LADD=.TRUE.
   14 CONTINUE
C
C   LOGIC TO DETERMINE EACH SEGMENT'S CONTRIBUTION TO THTMIN
C   ON EACH RING
C
      RINC=0.0
      IF(P(I,K2).LT.CMAVG(I).AND.P(I,K1).LT.CMAVG(I)) RINC=A2-A1
      IF(P(I,K2).LT.CMAVG(I).AND.P(I,K1).EQ.CMAVG(I)) RINC=A2-A1
      IF(P(I,K2).EQ.CMAVG(I).AND.P(I,K1).LT.CMAVG(I)) RINC=A2-A1
      IF(P(I,K2).GT.CMAVG(I).AND.P(I,K1).LT.CMAVG(I))
     A      RINC=((A2-A1)/(P(I,K2)-P(I,K1)))*(CMAVG(I)-P(I,K1))
      IF(P(I,K2).LT.CMAVG(I).AND.P(I,K1).GT.CMAVG(I))
     A      RINC=((A2-A1)/(P(I,K1)-P(I,K2)))*(CMAVG(I)-P(I,K2))
C
C    LOGIC TO DETERMINE HOW TO ADD TOGETHER THE
C    CONTRIBUTIONS OF EACH SEGMENT
C
      IF(RINC.EQ.0.0) GO TO 20
      IF(P(I,K2).LT.CMAVG(I).AND.P(I,K1).GT.CMAVG(I)) GO TO 23
   24 CONTINUE
      SEG(L)=SEG(L)+RINC
      GO TO 25
   23 CONTINUE
      IF(P(I,K0).GE.CMAVG(I)) GO TO 24
      IF(J.EQ.1) GO TO 24
      L=L+1
      GO TO 24
   20 CONTINUE
      IF(J.EQ.1) GO TO 25
      IF(SEG(L).EQ.0.0) GO TO 25
      L=L+1
```

```
   25 CONTINJE
   12 CONTINJE
      KS=0
      THTTOT(I)=0.0
      DO 18 K=1,10
      IF(SEG(K).NE.0.0) KS=KS+1
      THTTOT(I)=THTTOT(I)+SEG(K)
   18 CONTINUE
      IF(LADD) SEG(1)=SEG(1)+SEG(KS)
      IF(LADD) KS=KS-1
C
C  SEARCH FOR LARGEST DEPRESSION BELOW
C  AVG ON EACH RING
C       THIS WILL BECOME THTMIN FOR
C       THAT RING
C
      THTMIN(I)=0.0
      DO 19 K=1,KS
      IF(SEG(K).GT.THTMIN(I)) THTMIN(I)=SEG(K)
   19 CONTINUE
      GO TO 9
    8 CONTINJE
      WRITE(6,100)
  100 FORMAT(1X,25HA RING HAS ONLY ONE PROBE)
      THTMIN(I)=0.0
    9 CONTINUE
C
C  CALCULATION OF THTPLS FOR EACH RING
C
      DO 6 I=N1,N2
      THTPLS(I)=360.0-THTTOT(I)
    6 CONTINJE
C
C CALCULATION OF AVERAGE STATIC PRESSURE
C
      DIV=0.0
      STATSM=0.0
      IF(.NOT.STATI) GO TO 29
      I1=NP(1)
      DO 30 I=1,I1
   30 STATSM=STATSM+P(1,I)
      DIV=DIV+FLOAT(I1)
   29 CONTINJE
      IF(.NOT.STATO) GO TO 31
      I1=NP(NR)
      DO 32 I=1,I1
   32 STATSM=STATSM+P(NR,I)
      DIV=DIV+FLOAT(I1)
   31 CONTINJE
      IF(DIV.EQ.0.0) DIV=1.0
      SMAVG=STATSM/DIV
      IF(SMAVG.EQ.0.0) SMAVG=5.0
      IF(SMAVG.EQ.0.0) WRITE(6,101)
      IF(SMAVG.EQ.0.0) WRITE(6,102)
  101 FORMAT(1X,46HNO STATIC PRESSURES, NOT POSSIBLE TO CALCULATE)
  102 FORMAT(1X,56HSPECIFIC DISTORTION PARAMETERS REQUIRING STATIC PRESS
     AURE)
C
C  CALCULATION OF SIMPLE RADIAL DISTORTION PARAMETERS
```

```
C
      DO 40 IR=1,NR
      DO 40 ITHT=1,8
      R=RADLOC(IR)
      THETA=(ITHT-1)*45
C
C  CALL INTERPOLATION SUBROUTINE TO OBTAIN INTERPOLATED VALUES
C  OF MEASUREMENTS ON EACH RING AT DISCRETE THETA LOCATIONS
C        NOTICE THAT THE SUBROUTINE 'INTERP' WILL GO THROUGH
C        THE PROCESS OF RADIAL INTERPOLATION EVEN THOUGH IT
C        IS NOT NECESSARY.  THIS REDUNDANCY IS NOT EXTREME
C        SINCE THE RADIAL INTERPOLATION IS NOT EXECUTED
C        TOO MANY TIMES.
C
      CALL INTERP
      RADP(ITHT,IR)=PVALUE
   40 CONTINUE
C
C  CALCULATION OF PMMAX, PMMIN, AND PMAVG FOR
C  EACH DISCRETE THETA LOCATION
C
      DO 41 I=1,8
      RMMAX(I)=0.0
      RMMIN(I)=5000000.0
      RMAVG(I)=0.0
      DO 42 J=1,NR
      IF(RADP(I,J).GT.RMMAX(I)) RMMAX(I)=RADP(I,J)
      IF(RADP(I,J).LT.RMMIN(I)) RMMIN(I)=RADP(I,J)
      RMAVG(I)=RMAVG(I)+RADP(I,J)/FLOAT(NR)
   42 CONTINUE
C
C  CALCULATION OF RDPOP'S FOR EACH DISCRETE THETA LOCATION
C
      RDPOP1(I)=(RMMAX(I)-RMMIN(I))/RMMAX(I)
      RDPOP2(I)=(RMMAX(I)-RMMIN(I))/RMAVG(I)
      RDPOP3(I)=(RMAVG(I)-RMMIN(I))/RMAVG(I)
   41 CONTINUE
C
C  CALL SUBROUTINE TO CALCULATE SPECIFIC DISTORTION PARAMETERS
C
      CALL DISPAR
      RETURN
      END
```

Subroutine DISPAR

This subroutine is the one which contains user-written program steps used to calculate specific distortion parameters.

"IDC-MAX AND IDR-MAX CANNOT BE CALCULATED"
"THERE ARE NOT EXACTLY 5 RINGS OF TOTAL PRESSURE MEASUREMENTS"

will be written when the program attempts to calculate IDC_{max} and IDR_{max} when there are less than five rings of total pressure input measurements.

```
      SUBROUTINE DISPAR
C
C   SUBROUTINE TO CALCULATE SPECIFIC DISTORTION PARAMETERS
C
C
C   NP, RADLOC, ANGLOC, AND P HAVE THE FIRST
C   ARRAY DIMENSION EQUAL TO 11.  10 OF THE
C   11 POSITIONS ARE AVAILABLE FOR USE.  THE
C   REMAINING POSITION IS NEEDED FOR INTERNAL MANIPULATION.
C
      COMMON/DATTRN/P(11,20),NR,RADLOC(11),ANGLOC(11,20),
     A      NP(11),FACE(39,65)
      COMMON/DISTRN/CMMIN(10),CMMAX(10),CMAVG(10),CDPOP1(10),CDPOP2(10),
     A    CDPOP3(10),THTMIN(10),THTPLS(10),RMMIN(8),RMMAX(8),RMAVG(8),
     B    RDPOP1(8),RDPOP2(8),RDPOP3(8),TMMIN,TMMAX,TMAVG,SMAVG,TDP1,
     C    TDP2,TDP3,QLOC(10,20)
      COMMON/READTR/STATI,STATO,LCNTFL,LDPAR
C
C   COMMON BLOCK FOR TRANSFERRING SPECIFIC DISTORTION
C   PARAMETERS TO THE OUTPUT SUBROUTINE 'LNPOUT'
C
      COMMON/PARTRN/PSPEC(20)
      DIMENSION QD(10),DTHETA(10,20)
      DIMENSION RIDC(5),RIDR(5)
      LOGICAL STATI,STATO,LCNTFL,LDPAR
C
C   CALCULATION OF KD2
C
      N1=1
      N2=NR
      IF(STATI) N1=2
      IF(STATO) N2=NR-1
      DINVS=0.0
      DO 26 I=N1,N2
      DINVS=DINVS+(1.0/RADLOC(I))
   26 CONTINUE
      DO 27 I=N1,N2
   27 QD(I)=(1.0/RADLOC(I))/DINVS
      RKD2=0.0
      DO 28 I=N1,N2
   28 RKD2=RKD2+(CDPOP3(I)*THTMIN(I)*QD(I)*100.0)
C
C   CALCULATION OF K-THETA
C
      DO 36 I=N1,N2
      J1=NP(I)
      DO 36 J=1,J1
      K1=J-1
      IF(K1.EQ.0) K1=J1
      A1=ANGLOC(I,K1)
      IF((J-1).EQ.0) A1=A1-360.0
      K2=J+1
      IF(K2.GT.J1) K2=1
      A2=ANGLOC(I,K2)
      IF((J+1).GT.J1) A2=A2+360.0
```

```
      DTHETA(I,J)=(A2-A1)/2.0
   36 CONTINUE
      RGAM=.285714
      QAV=(SMAVG/RGAM)*(((ABS(TMAVG/SMAVG))**RGAM)-1.0)
      RKTHT=0.0
      DO 35 I=N1,N2
      RISIN=0.0
      RICOS=0.0
      J1=NP(I)
      DO 34 J=1,J1
      PHI=ANGLOC(I,J)*.017453
      RISIN=RISIN+((P(I,J)/CMAVG(I))*SIN(PHI)*DTHETA(I,J))
      RICOS=RICOS+((P(I,J)/CMAVG(I))*COS(PHI)*DTHETA(I,J))
   34 CONTINUE
      RKTHT=RKTHT+QD(I)*(SQRT(ABS(((ABS(RISIN))**2.0)+((ABS(RICOS))
     A **2.0)))))
   35 CONTINUE
      IF(QAV.EQ.0.0) QAV=1.0
      RKTHT=(RKTHT/(180.0*QAV))*TMAVG
C
C  CALCULATION OF IDC-MAX AND IDR-MAX
C
      NCHK=NR
      IF(STATI) NCHK=NCHK-1
      IF(STATO) NCHK=NCHK-1
      IF(NCHK.NE.5) WRITE(6,100)
      IF(NCHK.NE.5) WRITE(6,101)
      IF(NCHK.NE.5) GO TO 40
      J1=1
      J2=NR
      IF(STATI) J1=2
      IF(STATO) J2=NR-1
      DO 41 J=J1,J2
      RIDC(J)=(CMAVG(J)-CMMIN(J))/TMAVG
   41 RIDR(J)=(TMAVG-CMAVG(J))/TMAVG
      RIDCX1=(RIDC(J1)+RIDC(J1+1))/2.0
      RIDCX2=(RIDC(J1+3)+RIDC(J1+4))/2.0
      RIDCMX=AMAX1(RIDCX1,RIDCX2)
      RIDRMX=AMAX1(RIDR(J1),RIDR(J1+4))
   40 CONTINUE
C
C  SPECIFIC DISTORTION PARAMETERS STORED IN ARRAY 'PSPEC'
C  IN PREPARATION TO BEING TRANSFERRED TO 'LNPOUT'
C
      PSPEC(1)=RKD2
      PSPEC(2)=RKTHT
      PSPEC(3)=RIDCMX
      PSPEC(4)=RIDRMX
  100 FORMAT(10X,40HIDC-MAX AND IDR-MAX CANNOT BE CALCULATED)
  101 FORMAT(10X,51HTHERE ARE NOT EXACTLY 5 RINGS OF TOTAL MEASUREMENTS)
      RETURN
      END
```

Subroutine PFIX

When PFIX(.TRUE.) is called by CFACE, QLOC (see appendix D) is calculated. When PFIX(.FALSE.) is called by CFACE, PFIX transforms the array of input measurements (P) into an array of the proper mapping parameter (controlled by the value of WHICH) and writes it out. Also the call PFIX(.FALSE.) by CFACE allows PFIX to step the input measurements outward by one ring if LCNTFL=.TRUE..

"NO STATIC RINGS, RESULTS HAVE NO MEANING" is a message that is written in two instances: First, if PFIX(.TRUE.) has been called by CFACE, the program will write the message and continue even though it is unable to calculate QLOC. If the user ever decides to modify the program to calculate QLOC without static-pressure inputs, be sure it is done in the subroutine DISPAR. Second, where WHICH has been set to 3 (WHICH=3, Mach no.) and there are no static-pressure input measurements. In this instance program execution will be terminated.

```
      SUBROUTINE PFIX(LQ)
C
C  SUBROUTINE TO TRANSFORM INPUT MEASUREMENTS
C  INTO MAPPING PARAMETERS
C       SUBROUTINE ALSO CONTROLS SOME OUTPUT
C
      COMMON/READTR/STATI,STATO,LCNTFL,LDPAR
      COMMON/WRANGE/XBAR,RMAV,WHICH,RANGE,LPCENT,RMACH,DELX
C
C  NP, RADLOC, ANGLOC, AND P HAVE THE FIRST
C  ARRAY DIMENSION EQUAL TO 11.  10 OF THE
C  11 POSITIONS ARE AVAILABLE FOR USE.  THE
C  REMAINING POSITION IS NEEDED FOR INTERNAL MANIPULATION.
C
      COMMON/DATTRN/P(11,20),NR,RADLOC(11),ANGLOC(11,20),
     A     NP(11),FACE(39,65)
      COMMON/DISTRN/CMMIN(10),CMMAX(10),CMAVG(10),CDPOP1(10),CDPOP2(10),
     A    CDPOP3(10),THTMIN(10),THTPLS(10),RMMIN(8),RMMAX(8),RMAVG(8),
     B    RDPOP1(8),RDPOP2(8),RDPOP3(8),TMMIN,TMMAX,TMAVG,SMAVG,TDP1,
     C    TDP2,TDP3,QLOC(10,20)
      COMMON/FINI/LQUIT
      DIMENSION NRFIT(2),Z(2),F(2)
      DIMENSION PSA(2)
      INTEGER WHICH
      LOGICAL LPCENT,LQUIT
      LOGICAL STATI,STATO,LCNTFL,LDPAR
      LOGICAL LQ
      IF(.NOT.LQ) GO TO 71
      DO 70 I=1,10
      DO 70 J=1,20
      QLOC(I,J)=0.0
   70 CONTINUE
   71 CONTINUE
      IF(LQ) GO TO 55
C
C  SECTION THAT ENABLES INTERPOLATION THROUGH THE
```

```
C     CENTER OF THE CONTOUR MAP
C
         IF(.NOT.LCNTFL) GO TO 50
         DO 51 I=1,NR
         NR1=NR+2-I
         RADLOC(NR1)=RADLOC(NR1-1)
         K=NP(NR1-1)
         DO 52 J=1,K
         ANGLOC(NR1,J)=ANGLOC(NR1-1,J)
         P(NR1,J)=P(NR1-1,J)
      52 CONTINUE
         NP(NR1)=NP(NR1-1)
      51 CONTINUE
         NR=NR+1
         RADLOC(1)=.01
         NP(1)=8
         PSUM=0.0
         K=NP(2)
         DO 54 I=1,K
         I1=I-1
         IF(I1.EQ.0) I1=K
         A1=ANGLOC(2,I1)
         IF((I-1).EQ.0) A1=A1-360.0
         I2=I+1
         IF(I2.GT.K) I2=1
         A2=ANGLOC(2,I2)
         IF((I+1).GT.K) A2=A2+360.0
         DELTHT=((A2-A1)/2.0)/360.0
         PSUM=PSUM+(DELTHT*P(2,I))
      54 CONTINUE
         DO 53 I=1,8
         TH=(I-1)*45
         ANGLOC(1,I)=TH
         P(1,I)=PSUM
      53 CONTINUE
      50 CONTINUE
C
C     CALCULATION OF MAXIMUM, MINIMUM, AND AVERAGE
C     OF MEASUREMENTS
C
         TMMAX=-500000.0
         TMMIN=+500000.0
         PS=0.0
         RN=0.0
         I1=1
         I2=NR
         IF(STATI) I1=2
         IF(LCNTFL) I1=2
         IF(STATO) I2=NR-1
         DO 10 I=I1,I2
         J1=NP(I)
         DO 10 J=1,J1
         RN=RN+1.0
         PS=PS+P(I,J)
         IF(P(I,J).GT.TMMAX) TMMAX=P(I,J)
         IF(P(I,J).LT.TMMIN) TMMIN=P(I,J)
      10 CONTINUE
         TMAVG=PS/RN
C
```

```
C   GO TO 11 FOR MACH NO. CONTOUR MAP
C
       IF(WHICH.EQ.3) GO TO 11
C
C   GO TO 14 FOR SPECIAL DISTRIBUTION CONTOUR MAP
C      X-BAR +/- N*(DELTA-X)
C
       IF(WHICH.EQ.5.AND..NOT.LPCENT) GO TO 14
C
C   MAPPING PARAMETERS GENERATED FROM INPUT MEASUREMENTS
C
       DO 12 I=1,NR
       J1=NP(I)
       DO 12 J=1,J1
       IF(WHICH.NE.1) P(I,J)=(((P(I,J)/TMAVG)-1.0)*100.0)
       IF(WHICH.EQ.1) P(I,J)=((P(I,J)/TMMAX)-1.0)*100.0
    12 CONTINUE
C
C   SECTION TO WRITE OUT MAPPING PARAMETERS
C
       DO 19 J=1,NR
       K=NP(J)
       IF(J.EQ.1.AND.LCNTFL) GO TO 19
       IF(WHICH.NE.5) WRITE(6,100) RADLOC(J),(P(J,I),I=1,K)
       IF(WHICH.EQ.5) WRITE(6,101) RADLOC(J),(P(I,J),I=1,K)
    19 CONTINUE
C
C   MAPPING PARAMETERS PUT INTO PROPER FORM FOR SYMBOL SUBROUTINE
C
       IF(WHICH.EQ.1) GO TO 15
       DO 13 I=1,NR
       J1=NP(I)
       DO 13 J=1,J1
       P(I,J)=(P(I,J)/(RANGE/20.0))-10.0
    13 CONTINUE
       RETURN
    15 CONTINUE
       DO 20 I=1,NR
       J1=NP(I)
       DO 20 J=1,J1
       P(I,J)=P(I,J)/(RANGE/20.0)
    20 CONTINUE
       RETURN
C
C   MACH NO. SECTION
C
    11 CONTINUE
C
C   ENTRY POINT FOR CALCULATION OF QLOC
C
    55 CONTINUE
C
C   TEST FOR EXISTENCE OF STATIC RINGS
C
       IF(.NOT.STATI.AND..NOT.STATO) GO TO 60
       GO TO 51
    60 CONTINUE
       WRITE(5,103)
       IF(.NOT.LQ) LQUIT=.TRUE.
```

```
      RETURN
   61 CONTINUE
C
C  INTERPOLATION TO FIND A STATIC PRESSURE FOR
C  EACH TOTAL PRESSURE MEASUREMENT
C          STATIC PRESSURE WILL BE A RADIUS WEIGHTED AVERAGE
C          OF STATIC PRESSURE ON INNERMOST RING AND STATIC PRESSURE
C          ON OUTERMOST RING, AT ANGLE THETA (IF EITHER RING IS
C          MISSING, THEN IT WILL BE EXCLUDED FROM THE AVERAGE)
C
      I1=1
      I2=NR
      IF(STATI) I1=2
      IF(STATO) I2=NR-1
      RMSUM=0.0
      KMSUM=0
      DO 30 I=I1,I2
      J1=NP(I)
      DO 30 J=1,J1
      PSA(1)=0.0
      PSA(2)=0.0
      KCT=0
      NR1=NR-1
      DO 31 K=1,NR,NR1
      KCT=KCT+1
      IF(.NOT.STATI.AND.K.EQ.1) GO TO 31
      IF(.NOT.STATO.AND.K.EQ.NR) GO TO 31
      L1=NP(K)
      IF(L1.NE.1) GO TO 37
      PSA(KCT)=P(K,1)
      GO TO 31
   37 CONTINUE
      IF(ANGLOC(I,J).GT.ANGLOC(K,L1)) L=1
      IF(ANGLOC(I,J).GT.ANGLOC(K,L1)) GO TO 33
      DO 32 L=1,L1
      IF(ANGLOC(K,L).GE.ANGLOC(I,J)) GO TO 33
   32 CONTINUE
   33 CONTINUE
      NRFIT(1)=L-1
      NRFIT(2)=L
      DO 34 M=1,2
      IF(NRFIT(M).LT.1) GO TO 35
      IF(NRFIT(M).GT.L1) GO TO 36
      N=NRFIT(M)
      Z(M)=ANGLOC(K,N)
      F(M)=P(K,N)
      GO TO 34
   35 CONTINUE
      N=NRFIT(M)+L1
      Z(M)=ANGLOC(K,N)-360.0
      F(M)=P(K,N)
      GO TO 34
   36 CONTINUE
      N=NRFIT(M)-L1
      Z(M)=360.0+ANGLOC(K,N)
      F(M)=P(K,N)
   34 CONTINUE
      Z0=ANGLOC(I,J)
      PSA(KCT)=
```

```
     A   ((((F(2)-F(1))/(Z(2)-Z(1)))*(ZO-Z(1)))+F(1)
   31 CONTINUE
C
C  RADIUS WEIGHTED AVERAGE STATIC PRESSURE
C
      RADIUS=RADLOC(I)
      IF(PSA(1).EQ.0.0) RADIUS=RADLOC(NR)
      IF(PSA(2).EQ.0.0) RADIUS=RADLOC(1)
      PS=PSA(1)+((RADIUS-RADLOC(1))/(RADLOC(NR)-RADLOC(1)))*
     A  (PSA(2)-PSA(1))
C
C  MACH NO. IS CALCULATED FOR EACH INPUT MEASUREMENT LOCATION
C
      GAM=1.4
      IF(PS.EQ.0.0) PS=0.00001
      IF(.NOT.LQ) GO TO 59
      QLOC(I,J)=(GAM/2.0)*PS*SQRT(ABS((2.0/(GAM-1.0))*
     A           ((ABS(P(I,J))**((GAM-1.0)/GAM))-1.0)))
   59 CONTINUE
      IF(LQ) GO TO 63
      PTEMP=P(I,J)
      P(I,J)=SQRT(ABS((2.0/(GAM-1.0))
     A          *(((ABS(P(I,J)/PS))**((GAM-1.0)/GAM))-1.0)))
      IF(PTEMP.LE.PS) P(I,J)=0.0
      RMSUM=RMSUM+P(I,J)
      KMSUM=KMSUM+1
   63 CONTINUE
   30 CONTINUE
      IF(LQ) RETURN
C
C  CALCULATION OF AVERAGE MACH NO.
C
      RMAV=RMSUM/FLOAT(KMSUM)
C
C  SETTING MACH NO. = 0 ON RINGS OF STATIC PRESSURE
C
      IF(.NOT.STATI) GO TO 38
      I1=NP(1)
      DO 40 I=1,I1
   40 P(1,I)=0.0
   38 CONTINUE
      IF(.NOT.STATO) GO TO 39
      I1=NP(NR)
      DO 41 I=1,I1
   41 P(NR,I)=0.0
   39 CONTINUE
      DO 43 I=1,NR
      J1=NP(I)
      IF(I.EQ.1.AND.LCNTFL) GO TO 43
      WRITE(5,102) RADLOC(I),(P(I,J),J=1,J1)
   43 CONTINUE
      DO 44 I=1,NR
      J1=NP(I)
      DO 44 J=1,J1
      P(I,J)=(P(I,J)/RMACH)*(-20.0)
   44 CONTINUE
      RETURN
C
C  SECTION TO CALCULATE MAPPING PARAMETER FOR MAP
```

```
C   OF X-BAR +/- N*(DELTA-X)
C
   14 CONTINUE
C
C   CALCULATION OF X-BAR
C
      XBAR=FLOAT(IFIX(((TMMAX+TMMIN)/(2.0*DELX))+0.5))*DELX
      DO 18 I=1,NR
      J1=NP(I)
      DO 18 J=1,J1
C
C   PUTTING MAPPING PARAMETER INTO PROPER FORM FOR SYMBOL ROUTINE
C
      P(I,J)=((P(I,J)-XBAR)/DELX)-10.0
   18 CONTINUE
      RETURN
  100 FORMAT(5X,F5.2,4X,10(2X,F8.4)/14X,10(2X,F8.4))
  101 FORMAT(5X,F5.2,4X,5(5X,F8.4)/3(14X,5(5X,F8.4)/))
  102 FORMAT(5X,F5.2,4X,10(4X,F6.4)/14X,10(4X,F6.4))
  103 FORMAT(1X,40HNO STATIC RINGS, RESULTS HAVE NO MEANING)
      END
```

Subroutine MAINLP

MAINLP is the driving subroutine for the contour map interpolation. MAINLP calls INTERP and SYMBLE, in that order, for every r, θ location in the contour map output grid.

```
      SUBROUTINE MAINLP
C
C   DRIVING SUBROUTINE TO INDEX THROUGH THE GRID POINTS
C   IN THE INPUT MEASUREMENT PLANE
C
C
C   NP, RADLOC, ANGLOC, AND P HAVE THE FIRST
C   ARRAY DIMENSION EQUAL TO 11.  10 OF THE
C   11 POSITIONS ARE AVAILABLE FOR USE.  THE
C   REMAINING POSITION IS NEEDED FOR INTERNAL MANIPULATION.
C
      COMMON/DATTRN/P(11,20),NR,RADLOC(11),ANGLOC(11,20),
     A      NP(11),FACE(39,65)
      COMMON/SCALE/FACTOR
      COMMON/INTRN/R,THETA,PVALUE
      DATA BLANK/1H /,PLUS/1H+/
      DO 10 IO=1,39
      DO 10 JO=1,65
C
C   CALCULATION OF R AND THETA
C
      Y=(FLOAT(20-IO))*FACTOR
      X=((FLOAT(JO-33))/1.665)*FACTOR
      R=SQRT(X*X+Y*Y)
      IF(X.EQ.0.0) GO TO 26
```

```
      OMEGA=ATAN(ABS(Y/X))
      GO TO 27
   26 CONTINUE
      OMEGA=1.5708
   27 CONTINUE
C
C  CHANGING FROM CONVENTIONAL R-OMEGA SYSTEM TO THE
C  R-THETA SYSTEM USED IN THE INTERPOLATION PROCESS
C
      IF(X.GE.0.0.AND.Y.GE.0.0) THETA=1.5708-OMEGA
      IF(X.GE.0.0.AND.Y.LT.0.0) THETA=1.5708+OMEGA
      IF(X.LT.0.0.AND.Y.LT.0.0) THETA=4.71239-OMEGA
      IF(X.LT.0.0.AND.Y.GE.0.0) THETA=4.71239+OMEGA
      IF(THETA.GE.6.28318) THETA=6.28318
      IF(THETA.LT.0.0) THETA=0.0
      THETA=THETA*(360.0/6.28318)
      IF(R.LT.RADLOC(1).OR.R.GT.RADLOC(NR)) GO TO 9
C
C  CALLING INTERPOLATION AND SYMBOL SUBROUTINES
C
      CALL INTERP
      CALL SYMBLE
      FACE(IO,JO)=PVALUE
      GO TO 10
    9 CONTINUE
      FACE(IO,JO)=BLANK
   10 CONTINUE
      FACE(20,33)=PLUS
      RETURN
      END
```

Subroutine INTERP

INTERP does the actual interpolation in the input measurement plane. It is fed values of r and θ, and it returns an interpolated value at that position. INTERP is first called by DISTRT when the simple radial distortion parameters are being calculated. At this time, interpolation is done using the input measurements in the array P. By the time INTERP is called by MAINLP, the array P contains mapping parameters instead of input measurements, and the interpolation is done on the mapping parameters.

```
      SUBROUTINE INTERP
C
C   INTERPOLATION SUBROUTINE
C
C
C   NP, RADLOC, ANGLOC, AND P HAVE THE FIRST
C   ARRAY DIMENSION EQUAL TO 11.  10 OF THE
C   11 POSITIONS ARE AVAILABLE FOR USE.  THE
C   REMAINING POSITION IS NEEDED FOR INTERNAL MANIPULATION.
C
      COMMON/DATTRN/P(11,20),NR,RADLOC(11),ANGLOC(11,20),
     A     NP(11),FACE(39,65)
```

```
      COMMON/INTRN/R,THETA,PVALUE
      DIMENSION NFIT(2),NRFIT(2),RADFIT(2),Z(2),F(2)
      IF(NR.LT.2) WRITE(6,100)
  100 FORMAT(1X,49HYOU HAVE LESS THAN 2 RINGS, PROGRAM WILL NOT WORK)
      NR1=NR-1
C
C  DETERMINE THE CORRECT TWO RINGS TO
C  USE IN THE INTERPOLATION PROCESS
C
      DO 11 I=1,NR1
      I1=I
      IF(R.GE.RADLOC(I1).AND.R.LT.RADLOC(I1+1)) GO TO 12
   11 CONTINUE
   12 CONTINUE
      NFIT(1)=I1
      NFIT(2)=I1+1
C
C  SET-UP FOR CIRCUMFERENTIAL INTERPOLATION
C  DETERMINE THE TWO MEASUREMENTS ON EACH RING TO USE
C        IN THE CIRCUMFERENTIAL INTERPOLATION PROCESS
C
      DO 15 II=1,2
      K=NFIT(II)
      J1=NP(K)
      IF(J1.NE.1) GO TO 21
      RADFIT(II)=P(K,1)
      GO TO 15
   21 CONTINUE
      IF(THETA.LT.ANGLOC(K,1)) GO TO 19
      DO 16 J=1,J1
      J2=J
      IF(J.EQ.J1) GO TO 17
      IF(THETA.GE.ANGLOC(K,J).AND.THETA.LT.ANGLOC(K,J+1)) GO TO 17
   16 CONTINUE
   17 CONTINUE
      GO TO 20
   19 CONTINUE
      J2=J1
   20 CONTINUE
      NRFIT(1)=J2
      NRFIT(2)=J2+1
      DO 18 I=1,2
      IF(THETA.LT.ANGLOC(K,1)) GO TO 7
      IF(NRFIT(I).LT.1) GO TO 23
      IF(NRFIT(I).GT.J1) GO TO 24
      L=NRFIT(I)
      Z(I)=ANGLOC(K,L)
      F(I)=P(K,L)
      GO TO 18
    7 CONTINUE
      IF(NRFIT(I).LE.J1) GO TO 6
      L=NRFIT(I)-J1
      Z(I)=ANGLOC(K,L)
      F(I)=P(K,L)
      GO TO 18
    6 CONTINUE
      L=NRFIT(I)
      Z(I)=ANGLOC(K,L)-360.0
      F(I)=P(K,L)
```

```
      GO TO 18
   23 CONTINUE
      L=NRFIT(I)+J1
      Z(I)=ANGLOC(K,L)-360.0
      F(I)=P(K,L)
      GO TO 18
   24 CONTINUE
      L=NRFIT(I)-J1
      Z(I)=360.0+ANGLOC(K,L)
      F(I)=P(K,L)
   18 CONTINUE
C
C  LINEAR INTERPOLATION IN THE CIRCUMFERENTIAL DIRECTION
C
      RADFIT(II)=((F(2)-F(1))*((THETA-Z(1))/(Z(2)-Z(1))))+F(1)
   15 CONTINUE
C
C  LINEAR INTERPOLATION IN THE RADIAL DIRECTION
C
      DO 30 I=1,2
      L=NFIT(I)
      Z(I)=RADLOC(L)
      F(I)=RADFIT(I)
   30 CONTINUE
C
C  FINAL INTERPOLATED VALUE
C
      PVALUE=((F(2)-F(1))*((R-Z(1))/(Z(2)-Z(1))))+F(1)
      RETURN
      END
```

Subroutine SYMBLE

This subroutine determines the correct line-printer symbol to be placed on the contour map at each output grid position by the line-printer.

```
      SUBROUTINE SYMBLE
C
C  SUBROUTINE TO SUPPLY THE SYMBOLS FOR
C  THE LINE PRINTER CONTOUR MAP
C
      COMMON/WRANGE/XBAR,RMAV,WHICH,RANGE,LPCENT,RMACH,DELX
      COMMON/INTRN/R,THETA,BETA
      INTEGER WHICH
      LOGICAL LPCENT
      DIMENSION SYMBOL(20),OUTSYM(20)
C
C  TWO LISTS OF SYMBOLS COVER ALL POSSIBLE TYPES OF CONTOUR MAPS
C
      DATA SYMBOL/1H0,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,
     A 1HA,1HB,1HC,1HD,1HE,1HF,1HG,1HH,1HI,1HJ/
      DATA OUTSYM/1H9,1H8,1H7,1H6,1H5,1H4,1H3,1H2,1H1,1H0,1HA,1HB,
     A 1HC,1HD,1HE,1HF,1HG,1HH,1HI,1HJ/
      IF(BETA.LE.-20.0) BETA=-19.9999
      IF(BETA.GE.0.0) BETA=-0.0001
```

```
C
C   SECTION TO DETERMINE THE PROPER SYMBOL FOR THE CONTOUR MAP
C
      DO 10 I=1,20
      UP=1-I
      DN=UP-1.0
      IF(BETA.LE.UP.AND.BETA.GT.DN) GO TO 11
   10 CONTINUE
   11 CONTINUE
      BETA=OUTSYM(I)
      IF(WHICH.EQ.1.OR.WHICH.EQ.3) BETA=SYMBOL(I)
      RETURN
      END
```

Subroutine LNPOUT

LNPOUT controls the output of the contour map and the distortion parameter information. In addition to the output of the simple distortion parameters, LNPOUT contains the user-written output formats for the user-calculated specific distortion parameters.

```
      SUBROUTINE LNPOUT
C
C   SUBROUTINE THAT CONTROLS THE OUTPUT
C        SOME OUTPUT CONTROLLED BY 'CARDRD' AND 'PFIX'
C
C
C   NP, RADLOC, ANGLOC, AND P HAVE THE FIRST
C   ARRAY DIMENSION EQUAL TO 11.  10 OF THE
C   11 POSITIONS ARE AVAILABLE FOR USE.  THE
C   REMAINING POSITION IS NEEDED FOR INTERNAL MANIPULATION.
C
      COMMON/DATTRN/P(11,20),NR,RADLOC(11),ANGLOC(11,20),
     A      NP(11),FACE(39,65)
      COMMON/READTR/STATI,STATO,LCNTFL,LDPAR
      COMMON/WRANGE/XBAR,RMAV,WHICH,RANGE,LPCENT,RMACH,DELX
      COMMON/DISTRN/CMMIN(10),CMMAX(10),CMAVG(10),CDPOP1(10),CDPOP2(10),
     A     CDPOP3(10),THTMIN(10),THTPLS(10),RMMIN(8),RMMAX(8),RMAVG(8),
     B     RDPOP1(8),RDPOP2(8),RDPOP3(8),TMMIN,TMMAX,TMAVG,SMAVG,TDP1,
     C     TDP2,TDP3,QLOC(10,20)
      COMMON/HEADG/TITLE1(80),TITLE2(80)
      COMMON/PARTRN/PSPEC(20)
      DIMENSION ROUT(19)
      INTEGER WHICH
      LOGICAL LPCENT
      LOGICAL STATI,STATO,LCNTFL,LDPAR
C
C   LOGIC TO DETERMINE WHICH KIND OF MAP
C   IS TO BE PRINTED
C
      IF(WHICH.EQ.5) GO TO 11
      IF(WHICH.EQ.4) GO TO 12
      IF(WHICH.EQ.3) GO TO 13
      IF(WHICH.EQ.2) GO TO 14
```

```
C
C   OUTPUT SECTION FOR (PI-PMAX)/PMAX  MAP
C
      DO 21 I=1,19
      ROUT(I)=-FLOAT(I)*(RANGE/20.0)
   21 CONTINUE
      WRITE(5,100)
      WRITE(5,190) TITLE1
      WRITE(5,190) TITLE2
      WRITE(5,105)
      WRITE(5,106)
      WRITE(5,108) (ROUT(I),I=1,19)
      WRITE(5,109)
      WRITE(5,132)
      WRITE(5,138) TMMAX
      GO TO 15
C
C   OUTPUT SECTION FOR (PI-PAVG)/PAVG  MAP
C
   14 CONTINUE
      DO 22 I=1,19
      ROUT(I)=FLOAT(10-I)*(RANGE/20.0)
   22 CONTINUE
      WRITE(5,100)
      WRITE(5,190) TITLE1
      WRITE(5,190) TITLE2
      WRITE(5,105)
      WRITE(5,107)
      WRITE(5,110) (ROUT(I),I=1,19)
      WRITE(5,109)
      WRITE(5,128)
      WRITE(5,137) TMAVG
      GO TO 15
   13 CONTINUE
C
C   OUTPUT SECTION FOR MACH NUMBER MAP
C
      DO 20 I=1,19
      ROUT(I)=(RMACH/20.0)*FLOAT(I)
   20 CONTINUE
      WRITE(5,100)
      WRITE(5,190) TITLE1
      WRITE(5,190) TITLE2
      WRITE(5,105)
      WRITE(5,106)
      WRITE(6,111) (ROUT(I),I=1,19)
      WRITE(5,133)
      WRITE(5,141) RMAV
      GO TO 15
   12 CONTINUE
C
C   OUTPUT SECTION FOR (TI-TAVG)/TAVG  MAP
C
      DO 23 I=1,19
      ROUT(I)=FLOAT(10-I)*(RANGE/20.0)
   23 CONTINUE
      WRITE(5,100)
      WRITE(5,190) TITLE1
      WRITE(5,190) TITLE2
      WRITE(5,190) TITLE2
```

```
      WRITE(5,105)
      WRITE(5,107)
      WRITE(5,112) (ROUT(I),I=1,19)
      WRITE(5,109)
      WRITE(5,129)
      WRITE(5,139) TMAVG
      GO TO 15
C
C   OUTPUT SECTION FO MAP WITH SPECIAL INPUT
C
   11 CONTINUE
      IF(.NOT.LPCENT) GO TO 17
C
C   OUTPUT SECTION FOR (XI-XAVG)/XAVG  MAP
C
      DO 24 I=1,19
      ROUT(I)=FLOAT(10-I)*(RANGE/20.0)
   24 CONTINUE
      WRITE(5,100)
      WRITE(5,190) TITLE1
      WRITE(5,190) TITLE2
      WRITE(5,105)
      WRITE(5,107)
      WRITE(5,113) (ROUT(I),I=1,19)
      WRITE(5,109)
      WRITE(5,131)
      WRITE(5,130)
      WRITE(5,140) TMAVG
      GO TO 15
   17 CONTINUE
C
C   OUTPUT SECTION FOR MAP OF (X-BAR) +/- N(DEL-X)
C
      WRITE(5,100)
      WRITE(5,190) TITLE1
      WRITE(5,190) TITLE2
      WRITE(5,105)
      WRITE(5,107)
      WRITE(5,114)
      WRITE(5,115)
      WRITE(5,116)
      WRITE(5,117)
      WRITE(5,134)
      WRITE(5,135)
      WRITE(5,142) XBAR
      WRITE(5,143) DELX
   15 CONTINUE
      WRITE(5,120)
      DO 10 I=1,39
      IF(I.NE.20) WRITE(6,101) (FACE(I,J),J=1,65)
      IF(I.EQ.20) WRITE(6,121) (FACE(I,J),J=1,65)
   10 CONTINUE
      WRITE(5,122)
C
C   OUTPUT SECTION FOR SIMPLE DISTORTION PARAMETERS
C
      IF(.NOT.LDPAR) GO TO 16
      WRITE(5,100)
      WRITE(5,190) TITLE1
```

```
      WRITE(5,200)
      WRITE(5,201)
      WRITE(5,202) (THTMIN(I),I=1,10)
      WRITE(5,203) (THTPLS(I),I=1,10)
      WRITE(5,204) (CMMIN(I),I=1,10)
      WRITE(5,205) (CMMAX(I),I=1,10)
      WRITE(5,206) (CMAVG(I),I=1,10)
      WRITE(5,207) (CDPOP1(I),I=1,10)
      WRITE(5,208) (CDPOP2(I),I=1,10)
      WRITE(5,209) (CDPOP3(I),I=1,10)
      WRITE(5,210)
      WRITE(5,211)
      WRITE(5,212) (RMMIN(I),I=1,8)
      WRITE(5,213) (RMMAX(I),I=1,8)
      WRITE(5,214) (RMAVG(I),I=1,8)
      WRITE(5,215) (RDPOP1(I),I=1,8)
      WRITE(5,216) (RDPOP2(I),I=1,8)
      WRITE(5,217) (RDPOP3(I),I=1,8)
      WRITE(5,218)
      WRITE(5,219) TMMIN,TDP1
      WRITE(5,220) TMMAX,TDP2
      WRITE(5,221) TMAVG,TDP3
      WRITE(5,222) SMAVG
C
C OUTPUT SECTION FOR USER-DEFINED DISTORTION PARAMETERS
C
      WRITE(5,100)
      WRITE(5,190) TITLE1
      WRITE(5,190) TITLE2
      WRITE(5,102)
      WRITE(5,300)
      WRITE(5,301) PSPEC(1)
      WRITE(5,302) PSPEC(2)
      WRITE(5,303) PSPEC(3)
      WRITE(5,304) PSPEC(4)
      WRITE(5,100)
   16 CONTINUE
  100 FORMAT(1H1)
  101 FORMAT(1X,33X,65A1)
  102 FORMAT(1H0)
  105 FORMAT(1X//51X,22HKEY TO MAPPING SYMBOLS/)
  106 FORMAT(2X,6HBORDER,11X,3H0/1,3X,3H1/2,3X,3H2/3,3X,3H3/4,3X,
     A 3H4/5,3X,3H5/6,3X,3H6/7,3X,3H7/8,3X,3H8/9,3X,3H9/A,3X,3HA/B,
     B 3X,3HB/C,3X,3HC/D,3X,3HD/E,3X,3HE/F,3X,3HF/G,3X,3HG/H,3X,3HH/I,
     C 3X,3HI/J/)
  107 FORMAT(2X,6HBORDER,11X,3H9/8,3X,3H8/7,3X,3H7/6,3X,3H6/5,3X,3H5/4,
     A 3X,3H4/3,3X,3H3/2,3X,3H2/1,3X,3H1/0,3X,3H0/A,3X,3HA/B,
     B 3X,3HB/C,3X,3HC/D,3X,3HD/E,3X,3HE/F,3X,3HF/G,3X,3HG/H,3X,3HH/I,
     C 3X,3HI/J/)
  108 FORMAT(2X,14H(PI-PMAX)/PMAX,20(1X,F5.1))
  109 FORMAT(2X,10HIN PERCENT)
  110 FORMAT(2X,14H(PI-PAVG)/PAVG,20(1X,F5.1))
  111 FORMAT(2X,11HMACH NUMBER,3X,20(2X,F4.3))
  112 FORMAT(2X,14H(TI-TAVG)/TAVG,20(1X,F5.1))
  113 FORMAT(2X,14H(XI-XAVG)/XAVG,20(1X,F5.1))
  114 FORMAT(2X,14HMULTIPLIER FOR,4X,2H+9,4X,2H+8,4X,2H+7,
     A 4X,2H+6,4X,2H+5,4X,2H+4,4X,2H+3,4X,2H+2,4X,2H+1,5X,1H0,
     B 4X,2H-1,4X,2H-2,4X,2H-3,4X,2H-4,4X,2H-5,4X,2H-6,4X,
     C 2H-7,4X,2H-8,4X,2H-9)
```

```
  115 FORMAT(2X,16HDELTA-X ---- D/E)
  116 FORMAT(2X,18HBORDER CORRESPONDS)
  117 FORMAT(2X,23HTO (X-BAR)+(-4*DELTA-X))
  120 FORMAT(1X/66X,16H+  360/0 DEGREES/)
  121 FORMAT(1X,25X,6H270  +,2X,65A1,2X,5H+  90)
  122 FORMAT(1X/56X,6H+  180)
  128 FORMAT(1X///51X,23H(PI-PAVG)/PAVG  PROFILE)
  129 FORMAT(1X///51X,23H(TI-TAVG)/TAVG  PROFILE)
  130 FORMAT(51X,23H(XI-XAVG)/XAVG  PROFILE)
  131 FORMAT(1X///51X,13HSPECIAL INPUT)
  132 FORMAT(1X///51X,23H(PI-PMAX)/PMAX  PROFILE)
  133 FORMAT(1X///51X,16HMACH NO. PROFILE)
  134 FORMAT(51X,20HSPECIAL DISTRIBUTION)
  135 FORMAT(51X,28HX-BAR PLUS/MINUS N*(DELTA-X))
  137 FORMAT(51X,17HAVERAGE PRESSURE=,F7.3)
  138 FORMAT(51X,17HMAXIMUM PRESSURE=,F7.3)
  139 FORMAT(51X,20HAVERAGE TEMPERATURE=,F7.2)
  140 FORMAT(51X,16HAVERAGE SPECIAL=,F11.5)
  141 FORMAT(51X,17HAVERAGE MACH NO.=,F6.4)
  142 FORMAT(51X,6HX-BAR=,F11.5)
  143 FORMAT(51X,8HDELTA-X=,F9.4)
  190 FORMAT(6X,80A1)
  200 FORMAT(1X//45X,37HCIRCUMFERENTIAL DISTORTION PARAMETERS//)
  201 FORMAT(3X,8HRING NO.,17X,1H1,7X,1H2,7X,1H3,7X,
     A  1H4,7X,1H5,7X,1H6,7X,1H7,7X,1H8,7X,1H9,6X,2H10//)
  202 FORMAT(3X,6HTHTMIN,14X,10(2X,F6.2)/)
  203 FORMAT(3X,6HTHTPLS,14X,10(2X,F6.2)/)
  204 FORMAT(3X,5HCMMIN,15X,10(1X,F7.3)/)
  205 FORMAT(3X,5HCMMAX,15X,10(1X,F7.3)/)
  206 FORMAT(3X,5HCMAVG,15X,10(1X,F7.3)/)
  207 FORMAT(3X,19H(CMMAX-CMMIN)/CMMAX,1X,10(2X,F6.5)/)
  208 FORMAT(3X,19H(CMMAX-CMMIN)/CMAVG,1X,10(2X,F6.5)/)
  209 FORMAT(3X,19H(CMAVG-CMMIN)/CMAVG,1X,10(2X,F6.5)/)
  210 FORMAT(1X///45X,28HRADIAL DISTORTION PARAMETERS//)
  211 FORMAT(3X,20HTHETA POSITION (DEG),5X,1H0,6X,2H45,6X,2H90,
     A  5X,3H135,5X,3H180,5X,3H225,5X,3H270,5X,3H315//)
  212 FORMAT(3X,5HRMMIN,15X,8(1X,F7.3)/)
  213 FORMAT(3X,5HRMMAX,15X,8(1X,F7.3)/)
  214 FORMAT(3X,5HRMAVG,15X,8(1X,F7.3)/)
  215 FORMAT(3X,19H(RMMAX-RMMIN)/RMMAX,1X,8(2X,F6.5)/)
  216 FORMAT(3X,19H(RMMAX-RMMIN)/RMAVG,1X,8(2X,F6.5)/)
  217 FORMAT(3X,19H(RMAVG-RMMIN)/RMAVG,1X,8(2X,F6.5)/)
  218 FORMAT(1X///28X,63HPARAMETERS PERTAINING TO THE ENTIRE ARRAY OF IN
     APUT MEASUREMENTS/)
  219 FORMAT(38X,6HTMMIN=,F7.3,8X,5HTDP1=,F6.5)
  220 FORMAT(38X,6HTMMAX=,F7.3,8X,5HTDP2=,F6.5)
  221 FORMAT(38X,6HTMAVG=,F7.3,8X,5HTDP3=,F6.5)
  222 FORMAT(38X,6HSMAVG=,F7.3)
C
C SECTION FOR FORMATS FOR THE OUTPUT
C OF USER-DEFINED DISTORTION PARAMETERS
C
  300 FORMAT(1X//6X,34HUSER-DEFINED DISTORTION PARAMETERS///)
  301 FORMAT(1X/11X,3HKD2,8X,F11.5)
  302 FORMAT(1X/11X,7HK-THETA,4X,F11.5)
  303 FORMAT(1X/11X,9H(IDC)-MAX,2X,F11.5)
  304 FORMAT(1X/11X,9H(IDR)-MAX,2X,F11.5)
      RETURN
      END
```

APPENDIX B

METHOD OF INTERPOLATION

Given the array of input measurements as discussed in the section Instructions For Preparing Input, an interpolated value of the input measurement for any radial and circumferential position (radius r and angle θ) in the measurement plane is desired. Figure 2 shows a hypothetical array of input measurements. The user's array may differ from the example array in the number of rings and in the number of measurements on each ring. The ring radii and the angular positions of the measurements may also be different.

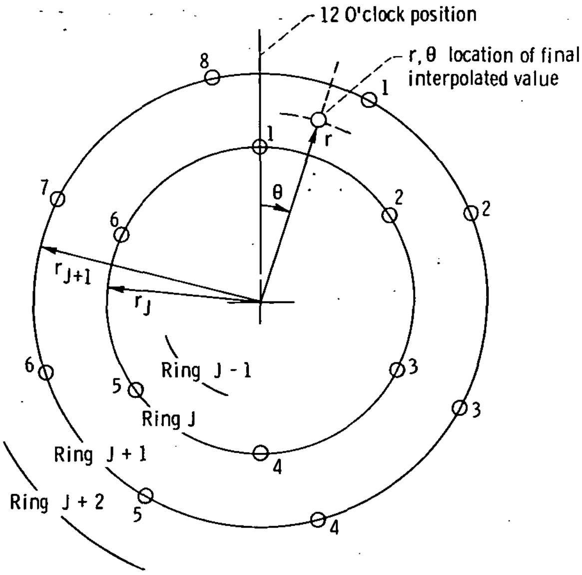


Figure 2. - Hypothetical array of input measurements.

The interpolation process used by the program is shown in figure 3. Figure 3(a) shows the circumferential interpolation process, and figure 3(b) shows the radial interpolation process.

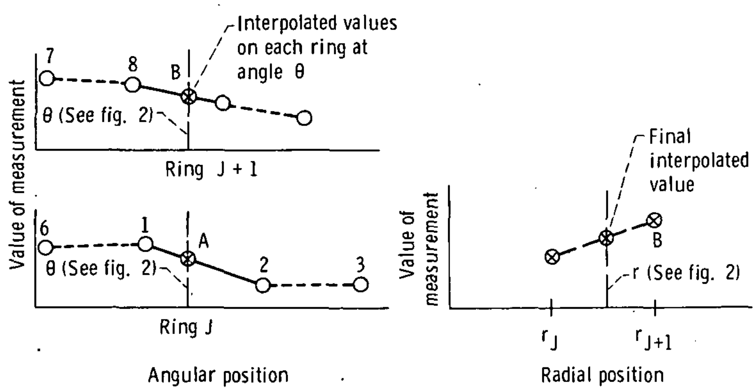
Interpolation is done in the circumferential direction first. An interpolated value of the input measurement is needed at circumferential position θ for each of two rings: one on either side of radius r. In the case shown in figure 2, rings J and J+1 are used. If the user's array of input measurements contains less than two rings, a message to that effect will be printed out and program execution will be terminated.

To find an interpolated value on each ring at angle θ, two measurements on each ring are used: one on one side of angular position θ and one on the other side. For example, ring J would use measurements 1 and 2 while ring J+1 would use measurements 8 and 1. If there are less than two input measurements on any given ring, the whole ring is assumed to have a constant value equal to the sole input measurement on that ring.

A linear interpolation is then performed on both rings using the two input measurements (and their corresponding angular positions) on each ring. Referring to figure 3(a), this would result in obtaining interpolated values A and B for rings J and J+1, respectively.

Finally, a linear interpolation is performed in the radial direction to arrive at the final interpolated value of the input measurement. The radial linear interpolation uses the two interpolated values (and their respective radii) resulting from the two circumferential linear interpolations. Referring to figure 3(b), interpolated values A and B are used to linearly interpolate for the final interpolated value at radius r and angle θ.

Linear interpolation has been proven to be sufficiently accurate for generating contour maps. This determination is based on comparing the computer generated radial and circumferential profiles with those actually obtained from full-scale engine testing.



(a) Circumferential interpolation.

(b) Radial interpolation.

Figure 3. - Method of interpolation.

APPENDIX C

SYMBOLS

CM	input measurement located on given ring
D	diameter of given ring of measurements
NP	number of measurements on ring
NR	total number of rings in array of input measurements
OD	outer duct diameter
P	pressure, total or static, kPa (psi)
Q	dynamic pressure $(\frac{1}{2}\rho u^2)$
RM	input measurement located at discrete θ position
T	temperature, total or static, K (^{o}R)
r	length of radius vector in plane of input measurement, cm (in.)
u	flow velocity in axial direction, m/sec (ft/sec)
X	special input variable, user-defined
ΔX	increment of special input variable represented by each mapping symbol
$\bar{X}$	mean value of special input variable rounded off to nearest ΔX
$(\Delta P)_{rms}$	true root-mean-square value of time-variant pressure
γ	ratio of specific heats
θ	reference angle in plane of measurement, measured clockwise from the 12 o'clock position, deg
θ^-	circumferential extent of largest region wherein the interpolated value of the measurement is below average value of input measurements on that ring, deg
θ^+	defined as $360^o - \sum \theta_K^-$, where $\sum \theta_K^-$ is summation of circumferential extents of all areas on a given ring, wherein the interpolated value of the measurement is below average value of the input measurements on that ring
ρ	air density, kg/m^3 (lbm/ft^3)

Subscripts:

av	average value of measurements

f	over whole array of input measurements
I	denotes particular measurement on given ring
i	denotes local value of measurement
J	denotes particular ring
max	maximum value of measurements
min	minimum value of measurements
s	static (pressure or temperature)
t	total (pressure or temperature)

APPENDIX D

CALCULATION OF DISTORTION PARAMETERS

As mentioned in the section OUTPUT, when the logical variable LDPAR is set to .TRUE., simple circumferential and radial distortion parameters as well as specific distortion parameters are calculated.

For each ring, the circumferential parameters consist of

(1) Theta-minus (θ^-), the circumferential extent (in deg) of the largest area wherein the interpolated value of the measurement is below the average value of the input measurements on that ring (This parameter is in an array named THTMIN.)

(2) Theta-plus (θ^+), defined as $360^\circ - \sum\theta_k^-$ where $\sum\theta_k^-$ is the summation of the circumferential extents of all of the areas on a given ring wherein the interpolated value of the measurements is below the average value of the input measurements on that ring. (This parameter is in an array named THTPLS.)

(3) The minimum input measurement value on a ring, CM_{min}, stored in an array named CMMIN

(4) The maximum input measurement value on a ring, CM_{max}, stored in an array named CMMAX

(5) The average input measurement value on a ring, CM_{av}, stored in an array named CMAVG

(6) $(CM_{max} - CM_{min})/CM_{max}$, stored in array named CDPOP1

(7) $(CM_{max} - CM_{min})/CM_{av}$, stored in array named CDPOP2

(8) $(CM_{av} - CM_{min})/CM_{av}$, stored in array named CDPOP3.

These parameters are calculated from input values. No interpolated values are used in calculating distortion parameters in the circumferential direction except in the case of θ^- and θ^+.

At each of the eight discrete θ positions described in appendix F (0°, 45°, 90°, etc.), the following simple radial distortion parameters are calculating using the circumferential interpolations from each ring:

(1) The minimum interpolated value at angular position θ, RM_{min}, stored in an array named RMMIN

(2) The maximum interpolated value at angular position θ, RM_{max}, stored in an array named RMMAX

(3) The average interpolated value at angular position θ, RM_{av}, stored in an array named RMAVG

(4) $(RM_{max} - RM_{min})/RM_{max}$, at angular position θ, stored in an array named RDPOP1

(5) $(RM_{max} - RM_{min})/RM_{av}$, at angular position θ, stored in an array named RDPOP2

(6) $(RM_{av} - RM_{min})/RM_{av}$, at angular position θ, stored in an array named RDPOP3.

Eight other parameters are calculated from the whole array of input measurements and are as follows:

(1) The minimum total input measurement, TM_{min}, called TMMIN

(2) The maximum total input measurement, TM_{max}, called TMMAX

(3) The average total input measurement, TM_{av}, called TMAVG

(4) The average static input measurement, SM_{av}, called SMAVG

(5) $(TM_{max} - TM_{min})/TM_{max}$, called TDP1

(6) $(TM_{max} - TM_{min})/TM_{av}$, called TDP2

(7) $(TM_{av} - TM_{min})/TM_{av}$, called TDP3

(8) Local values of dynamic head, Q_i, stored in an array named QLOC. QLOC is dimensioned as QLOC(10, 20). (There is a value of Q_i for every corresponding input measurement. QLOC is not printed out but is available in subroutine DISPAR for use in calculating specific distortion parameters. Values of QLOC will only be calculated when the logical variable LDPAR is set equal to .TRUE.. Inner ring and/or outer ring static measurements are necessary, and of course the input measurements need to be pressures. If there are no static measurements, the Q_i's will be set equal to 0.0.)

The user may want to calculate a more complex, specific distortion parameter based on the array of input measurements. More often than not, a specific parameter will use at least some of these simple distortion parameters along with the basic geometry of the input array. Four examples follow showing how to calculate specific distortion parameters at an engine inlet.

The user should place program steps only in the subroutine DISPAR and should be careful to not alter the input data in the common block PARTRN. Altering the program in any other subroutine could cause problems with the remainder of the program (especially the generation of the contour map).

The first example involves a distortion parameter introduced by Pratt & Whitney (see ref. 3) called KD_2, which is defined by the following equation:

$$KD_2 = \frac{\sum_{J=1}^{NR} \theta_J^- \left(\frac{\Delta P}{P}\right)_J \frac{OD}{D_J}}{\sum_{J=1}^{NR} \frac{OD}{D_J}}$$

where

J	particular ring of total pressure measurements
θ_J^-	circumferential extent, of largest single total-pressure depression below $(P_{t,av})_J$ for a particular ring, deg
$(\Delta P/P)_J$	$\left[(P_{t,av} - P_{t,min})/P_{t,av}\right]_J$ for a particular ring, percent
$(P_{t,av})_J$	average measured total pressure for particular ring
$(P_{t,min})_J$	minimum measured total pressure for particular ring
D_J	diameter of particular ring
OD	outer duct diameter (Note that OD is a constant and, since it appears in both the numerator and the denominator, it can be cancelled out.)
NR	number of rings of total pressure measurements (Remember that this is part of the input data.)

Some of the quantities needed to compute KD_2 have already been calculated by the program. The value of θ^- for each ring is stored in THTMIN(J); $(\Delta P/P)_J$ can be easily generated as CDPOP3(J)*100.0; and D_J can be calculated simply as RADLOC(J)*2.0. The parameter KD_2 can then be generated by the following FORTRAN IV statements:

```
      SUM1=0.0
      SUM2=0.0
      J1=1
      J2=NR
      IF(STATI) J1=2
      IF(STATO) J2=NR-1
      DO 10 J=J1,J2
      SUM1=SUM1+1.0/(2.0*RADLOC(J))
   10 SUM2=SUM2+THTMIN(J)*CDPOP3(J)*100.0*(1.0/(2.0*RADLOC(J)))
      RKD2=SUM2/SUM1
```

The tests on STATI and STATO are necessary because no static-pressure rings are used in the calculation of KD_2.

The second distortion parameter to be discussed was also introduced by Pratt & Whitney (see ref. 4). The parameter is called K_θ and is defined by the following equation:

$$K_\theta = \frac{\sum_{J=1}^{NR}\left[\left(\frac{A_L}{L^2}\right)_{max}\right]_J \frac{1}{D_J}}{\frac{Q_{av}}{(P_{t,av,f})}\sum_{J=1}^{NR}\frac{1}{D_J}}$$

The terms appearing in the equation for K_θ are defined as follows:

J	particular ring of total pressure measurements
$\left[\left(\frac{A_L}{L^2}\right)_{max}\right]_J$	maximum $(A_L/L^2)_J$ for $L = 1, 2, 3, \ldots$
Q_{av}	dynamic head at plane of measurement $(\frac{1}{2}\rho u^2)$, calculated from average total and average static pressures
$P_{t,av,f}$	average of all total pressure measurements in input plane
D_J	diameter of a particular ring
NR	number of rings of total pressure measurements

and

$$(A_L)_J = \left[\sqrt{a_L^2 + b_L^2}\right]_J$$

The Fourier coefficients a_L and b_L are defined as

$$a_L = \frac{1}{\pi}\int_{-\pi}^{\pi}\frac{P_t(\theta)}{P_{t,av,f}}\cos L\theta \, d\theta \qquad \text{all values from ring J}$$

$$b_L = \frac{1}{\pi}\int_{-\pi}^{\pi}\frac{P_t(\theta)}{P_{t,av,f}}\sin L\theta \, d\theta \qquad \text{all values from ring J}$$

where

$P_t(\theta)$ local total pressure measurement

θ reference angle in measurement plane

For most commonly encountered distortions, $(A_L/L^2)_{max} = A_1$, and K_θ can be written as

$$K_\theta = \frac{\sum_{J=1}^{NR} (A_1)_J \frac{1}{D_J}}{\frac{Q_{av}}{(P_{t,av,f})} \sum_{J=1}^{NR} \frac{1}{D_J}}$$

The expression $(A_1)_J$ can be written as

$$(A_1)_J = \left[\sqrt{a_1^2 + b_1^2}\right]_J$$

where

$$a_1 = \frac{1}{180} \sum_{I=1}^{NP} \frac{P_t(\theta_I)}{P_{t,av,f}} (\cos \theta_I)\, \Delta\theta_I \qquad \text{all values from ring J}$$

$$b_1 = \frac{1}{180} \sum_{I=1}^{NP} \frac{P_t(\theta_I)}{P_{t,av,f}} (\sin \theta_I)\, \Delta\theta_I \qquad \text{all values from ring J}$$

and

NP number of total pressure measurements on ring J

I denotes particular measurement on ring J

$\Delta\theta_I$ $1/2(\theta_{I+1} - \theta_{I-1})$, for particular ring J and θ_I ($\Delta\theta_I$ is in degrees)

Hence, K_θ can now be written as

$$K_\theta = \frac{P_{t,av,f} \sum_{J=1}^{NR} \frac{1}{D_J} \left[\left(\sum_{I=1}^{NP} \frac{P_t(\theta_I)}{P_{t,av,f}} (\cos \theta_I) \Delta\theta_I \right)_J^2 + \left(\sum_{I=1}^{NP} \frac{P_t(\theta_I)}{P_{t,av,f}} (\sin \theta_I) \Delta\theta_I \right)_J^2 \right]^{1/2}}{180\, Q_{av} \sum_{J=1}^{NR} \frac{1}{D_J}}$$

or

$$K_\theta = \frac{\sum_{J=1}^{NR} \frac{1}{D_J} \left[\left(\sum_{I=1}^{NP} P_t(\theta_I)(\cos \theta_I) \Delta\theta_I \right)_J^2 + \left(\sum_{I=1}^{NP} P_t(\theta_I)(\sin \theta_I) \Delta\theta_I \right)_J^2 \right]^{1/2}}{180\, Q_{av} \sum_{J=1}^{NR} \frac{1}{D_J}}$$

The local total pressures are in the input measurement array P. Measurement I on ring J is P(J, 1). The value of $P_{t,av,f}$ is already calculated and is called TMAVG. Again, D_J = 2.0*RADLOC(J). The θ_I's are stored in ANGLOC, and θ_I for ring J is ANGLOC(J, I). The value of $(P_{t,av})_J$ is equal to CMAVG(J), and $\Delta\theta_I$ is equal to (ANGLOC(J, I+1)-ANGLOC(J, I-1))/2.0 for ring J. The value of NP simply equals NP(J) while Q_{av} can be calculated from the equation

$$Q_{av} = \frac{\gamma\, P_{s,av,f}}{\gamma - 1} \left[\left(\frac{P_{t,av,f}}{P_{s,av,f}} \right)^{(\gamma-1)/\gamma} - 1 \right]$$

where $P_{s,av,f}$ is the average of all static pressure input measurements and γ is the ratio of specific heats. The value of $P_{s,av,f}$ is already calculated and is called SMAVG. Note that, if there are no rings of static pressures, K_θ cannot be calculated unless another method is used to arrive at a value of Q_{av}. One such method would be to input a reasonable value of average static pressure based on corrected airflow or some other knowledge of the flow conditions at the input measurement plane.

Now K_θ can be calculated by the following FORTRAN IV program steps:

```
C-----CALCULATION OF QAVG
      GAM=1.4  } a value of γ was assumed
      RGAM=(GAM-1.0)/GAM
      QAVG=(SMAVG/RGAM)*(((TMAVG/SMAVG)**RGAM)-1.0)
C-----CALCULATION OF DELTA-THETA
      J1=1
      J2=NR
      IF(STAT1) J1=2
      IF(STATO) J2=NR-1
```

(The two IF statements above are bracketed with the note: The summation from J=1 to J=N in the equation for K_θ is done for the first total-pressure ring through the last total-pressure ring.)

```
      DO 10 J=J1, J2
      NPJ=NP(J)
      DO 10 I=1, NPJ
      K1=I-1
      IF(K1.EQ.0) K1=NPJ
      A1=ANGLOC(J,K1)
      IF((I-1).EQ.0) A1=A1-360.0
      K2=I+1
      IF(K2.GT.NPJ) K2=1
      A2=ANGLOC(J,K2)
      IF((I+1).GT.NPJ) A2=A2+360.0
   10 DTHETA(J,I)=(A2-A1)/2.0
C-----CALCULATION OF K-THETA
      SUM1=0.0
      SUM2=0.0
      DO 11 J=J1, J2
      RSIN=0.0
      RCOS=0.0
      NPJ=NP(J)
      DO 12 J=1, NPJ
      THETA=ANGLOC(J, 1)*0.017453
      RCOS=RCOS+ (P(J,I)*COS(THETA)*DTHETA(J,I))
   12 RSIN=RSIN+ (P(J,I)*SIN(THETA)*DTHETA(J,I))
      SUM2=SUM2+(1.0/(RADLOC(J)*2.0)*SQRT((RCOS**2.0)+(RSIN**2.0))
   11 SUM1=SUM1+(1.0/(RADLOC(J)*2.0))
      RKTHT=SUM2/(180.0*QAVG*SUM1)
```

The last two parameters to be discussed were introduced by General Electric and are called IDC_{max} and IDR_{max}. If there are five rings of total pressure measurements in the plane of measurement, IDC_{max} and IDR_{max} can be defined by the following expressions:

$$IDC_{max} = MAX\left[\frac{1}{2}(IDC_1 + IDC_2),\ \frac{1}{2}(IDC_4 + IDC_5)\right]$$

$$IDR_{max} = MAX\,(IDR_1,\ IDR_5)$$

where

$$IDC_J = \frac{(P_{t,av})_J - (P_{t,min})_J}{P_{t,av,f}}$$

$$IDR_J = \frac{P_{t,av,f} - (P_{t,av})_J}{P_{t,av,f}}$$

and

$(P_{t,av})_J$ average total pressure for ring J

$(P_{t,min})_J$ minimum total pressure for ring J

$P_{t,av,f}$ average of all total pressure measurements in the input measurement plane

The average total pressure for ring J, $(P_{t,av})_J$, is stored in CMAVG(J); $(P_{t,min})_J$ is stored in CMMIN(J); and $P_{t,av,f}$ is stored in TMAVG. The following FORTRAN IV program steps may be used to calculate IDC_{max} and IDR_{max}. For the sake of this example, we will assume that there are seven rings of input measurements and that the first and seventh rings consist of static pressure measurements.

```
      DO 10 J=2,6
      RIDC(J)=(CMAVG(J)-CMMIN(J))/TMAVG
   10 RIDR(J)=(TMAVG-CMAVG(J))/TMAVG
      RIDCX1=(RIDC(2)+RIDC(3))/2.0
      RIDCX2=(RIDC(5)+RIDC(6))/2.0
      RIDCMX=AMAX1(RIDCX1,RIDCX2)
      RIDRMX=AMAX1(RIDR(2),RIDR(6))
```

A FORTRAN IV subroutine for these specific parameters may be seen in appendix A. The name of the subprogram is DISPAR. The specific parameters are transferred to the subprogram LNPOUT through the labeled common block PARTRN. A special section in LNPOUT is reserved for user-written output statements to handle the specific user-defined distortion parameters. Input data are available in the common block DATTRN, but should not be altered.

APPENDIX E

TWO EXAMPLES OF INPUT AND OUTPUT

Example 1

This is an example of a circumferential total pressure distortion at the inlet of a jet engine. Figure 4 shows the instrumentation layout for the first example case. There is one ring of static-pressure measurements (at the outer duct wall), and there are five rings of total-pressure measurements. The pressure values corresponding to each measurement location are shown in table I. Ring 6 is actually a ring of static-pressure measurements.

In this example, the interpolation process will continue through the center of the map (interpolation will not stop at the innermost ring), and $(P_i - P_{t,av,f})/P_{t,av,f}$ (in

Ring	Radius, cm (in.)
1	8.00 (3.15)
2	16.03 (6.31)
3	24.03 (9.46)
4	32.03 (12.61)
5	40.03 (15.76)
6	44.04 (17.34)

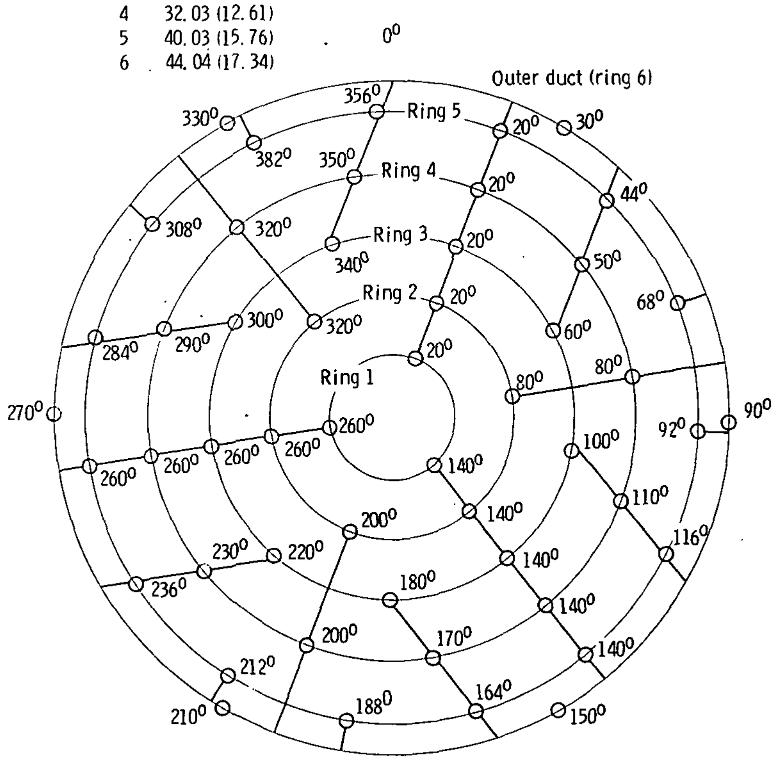


Figure 4. - Instrumentation layout for example 1. (Angles are measured clockwise from 0°.

TABLE II. - TEMPERATURE MEASUREMENTS FOR EXAMPLE 2

Angle, deg	Temperature, K (°R)						
	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7
0	328.1 (590.5)	338.1 (608.5)	337.7 (607.8)	336.2 (605.2)	335.1 (603.1)	331.8 (597.3)	321.8 (579.3)
45	322.7 (580.9)	332.7 (598.9)	331.9 (597.4)	334.4 (601.9)	334.4 (601.9)	332.2 (597.9)	322.2 (579.9)
90	295.8 (532.5)	305.8 (550.5)	299.4 (539.0)	297.5 (535.5)	295.7 (532.3)	295.4 (531.7)	285.4 (513.7)
135	291.2 (524.2)	301.2 (542.2)	296.9 (534.5)	295.9 (532.7)	294.6 (530.2)	292.7 (526.9)	282.7 (508.9)
180	291.4 (524.6)	301.4 (542.6)	297.3 (535.2)	296.3 (533.3)	297.6 (535.7)	296.2 (533.2)	286.2 (515.2)
225	292.3 (526.1)	302.3 (544.1)	298.4 (537.1)	296.7 (534.0)	295.1 (531.2)	294.2 (529.6)	284.2 (511.6)
270	291.0 (523.8)	301.0 (541.8)	298.0 (536.4)	296.6 (533.8)	295.4 (531.7)	295.1 (531.1)	285.1 (513.1)
315	301.2 (542.2)	311.2 (560.2)	301.9 (543.4)	298.3 (536.9)	296.3 (533.3)	294.5 (530.1)	284.5 (512.1)

TITLE | PROJECT NUMBER | ANALYST | SHEET ____ OF ____

STATEMENT NUMBER | CONT | FORTRAN STATEMENT | IDENTIFICATION

```
 $INIT QQ=1, WHICH=2, RANGE=20.0, STATI=.FALSE., STATO=.TRUE., LCNTFL=.TRUE.,
 LDPAR=.TRUE. $
06
08.00 16.03 24.03 32.03 40.03 44.04
03 06 09.12 15 06
020.0 140.0 260.0
020.0 080.0 140.0 200.0 260.0 320.0
020.0 060.0 100.0 140.0 180.0 220.0 260.0 300.0 340.0
020.0 050.0 080.0 110.0 140.0 170.0 200.0 230.0 260.0 290.0
320.0 350.0
020.0 044.0 068.0 092.0 116.0 140.0 164.0 188.0 212.0 236.0
260.0 284.0 308.0 332.0 356.0
030.0 090.0 150.0 210.0 270.0 330.0
 --  EXAMPLE CASE NO. 1
 --  WHICH SET TO 2, CENTER FILLED IN, AND DISTORTION PARAMETERS CALCULATED --
 46.78    45.30    50.61
 45.92    44.11    44.38    49.80    52.39    49.61
 45.71    43.69    42.41    43.04    48.73    52.47    53.57    50.88    50.37
 44.62    43.83    42.55    42.10    42.62    44.34    50.58    50.79    51.73    49.95
 51.23    48.27
 44.62    44.02    42.87    42.28    42.07    42.62    43.86    48.88    50.64    51.02
 51.73    50.42    50.75    50.34    46.88
 42.16    42.27    41.95    41.30    41.28    41.89
```

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Figure 5. - Input for example 1.

```
-- EXAMPLE CASE NO. 1 --
-- WHICH SET TO 2, CENTER FILLED IN, AND DISTORTION PARAMETERS CALCULATED --


RADIUS            ANGULAR POSITION OF INPUT MEASUREMENTS, DEG
  8.00        20.0     140.0     260.0
 16.03        20.0      80.0     140.0     200.0     260.0     320.0
 24.03        20.0      60.0     100.0     140.0     180.0     220.0     260.0     300.0     340.0
 32.03        20.0      50.0      80.0     110.0     140.0     170.0     200.0     230.0     260.0     290.0
             320.0     350.0
 40.03        20.0      44.0      68.0      92.0     116.0     140.0     164.0     188.0     212.0     236.0
             260.0     284.0     308.0     332.0     356.0
 44.00        30.0      90.0     150.0     210.0     270.0     330.0


RADIUS            PRESSURE
  8.00      46.780    45.300    50.610
 16.03      45.920    44.110    44.380    49.800    52.390    49.610
 24.03      45.710    43.690    42.410    43.040    48.730    52.470    53.570    50.880    50.370
 32.03      44.620    43.830    42.550    42.100    42.620    44.340    50.580    50.790    51.730    49.950
            51.230    48.270
 40.03      44.620    44.020    42.870    42.280    42.070    42.620    43.860    48.880    50.640    51.020
            51.730    50.420    50.750    50.340    46.880
 44.00      42.160    42.270    41.950    41.300    41.280    41.890


RADIUS            (PI-PAVG)/PAVG, PERCENT
  8.00     -0.9542   -4.0877    7.1550
 16.03     -2.7750   -6.6073   -6.0356    5.4400   10.9237    5.0377
 24.03     -3.2196   -7.4965  -10.2066   -8.8728    3.1745   11.0931   13.4221    7.7266    6.6468
 32.03     -5.5275   -7.2001   -9.9102  -10.8630   -9.7620   -6.1203    7.0914    7.5361    9.5263    5.7576
            8.4677    2.2006
 40.03     -5.5275   -6.7978   -9.2327  -10.4819  -10.9265   -9.7620   -7.1366    3.4921    7.2185    8.0230
            9.5263    6.7527    7.4514    6.5833   -0.7424
 44.00    -10.7360  -10.5031  -11.1806  -12.5568  -12.5991  -11.3075
```

(a) First page of output.

Figure 6. - Output for example 1.

```
-- EXAMPLE CASE NO. 1 --
-- WHICH SET TO 2, CENTER FILLED IN, AND DISTORTION PARAMETERS CALCULATED --

                                          KEY TO MAPPING SYMBOLS
BORDER           9/8   8/7   7/6   6/5   5/4   4/3   3/2   2/1   1/0   0/A   A/B   B/C   C/D   D/E   E/F   F/G   G/H   H/I   I/J
(PI-PAVG)/PAVG   9.0   8.0   7.0   6.0   5.0   4.0   3.0   2.0   1.0   0.   -1.0  -2.0  -3.0  -4.0  -5.0  -6.0  -7.0  -8.0  -9.0
IN PERCENT


                                           (PI-PAVG)/PAVG  PROFILE
                                           AVERAGE PRESSURE= 47.231

                                                     +  360/0 DEGREES
                                                  JJJJJJJ
                                              JIHGFFEEEEEFFGGHHIJJJ
                                           JHFDBAC1110AABBBCCDDDEFGHIIJJ
                                         JGDA13443322110AABBCCDDDEEFFFGHHIJJ
                                       IEB25665544332210OAABBCCDEEFFFFFFGGHIJJ
                                      IEA36666665544332210OABBCCDEEFFFFFGGGGGHIJJ
                                     JFA377777666554443322100ABBCDEEFFFFGGGGGGGGHIJJ
                                    HC2677777776665554433221OOABCDDEFFFFGGGGGGGGGHIJJ
                                   GA4777777887776665554432210ABBCDEEEFFFFGGGGGGGHHHIIJ
                                  JFA5777777788877766666543321OAABCDDEEFFFGGGGGHHHHHHIJJJ
                                 JF057777777777777776665543210OABCCDDEEEFFFGGGHHHHHHIIIJJJ
                                 GA57766677777777776655443211OAABCDDDEEEFFGGGGHHHHHIIIIIJJ
                                IC36666666677777776665443211OAABCCDDDEEEFFGGGHHHHIIIIIIIJJJ
                               JE166666666677777776655433211OAABCCDDDEEFFFGGHHHHIIIIIIJJJJJJ
                               HB46666656677777776655443221OOABBCCDDEEFFGGHHHHIIIIIJJJJJJJ
                              JF1666666667788888777665443221OOABBCCCDEEFFGGHHHIIIIJJJJJJJJJJ
                              JC37776667788999988777655433211OAABBCCDDEFFGGHHIIIIJJJJJJJJJJJ
                              IB577777777889999988876654432110AABBCCDDEFGGHHHIIIJJJJJJJJJJJJ
                              H07777777899999999999887665432210OAABCCDEEFGGHHIIJJJJJJJJJJJJJJ
                     270  +   G078888889999999999998877654321+0ABBCCDEEFGGHHIIJJJJJJJJJJJJJJ   +  90
                              G07888888999999999999998765432100ABBCCDDEFFGGHHIJJJJJJJJJJJJJJJJ
                              HA799999999999999999999876653211OABCDDEEEFFGGHIIJJJJJJJJJJJJJJJJ
                              JB5999999999999999999998765432100ABCDEEEEFFGGHHIIJJJJJJJJJJJJJJJJ
                              JE3999999999999999999998765432100AABCDEFFFGGGHIIJJJJJJJJJJJJJJJJJ
                               HA79988889999999999999876554321OABCDDEFGGGHHIIJJJJJJJJJJJJJJJJ
                               JE288888888899999999998776554321OABCDEFGGHHIIJJJJJJJJJJJJJJJJJ
                                IB5888888889999999999887665432100ABCDDEFGHIIJJJJJJJJJJJJJJJJJ
                                 GA68888877889999999998766543221OABCDEFGHIJJJJJJJJJJJJJJJJJ
                                 JF068877777788999999877654432100ABCDEFGHIIJJJJJJJJJJJJJJJJ
                                  JF0677777777788888887765543211OARDEFGHHIJJJJJJJJJJJJJJJ
                                   GB47777777777777777765543321OABCDEFGHHIIJJJJJJJJJJJ
                                    ID277777777777777765543210ABCDEEFGHHIIIJJJJJJJJJJ
                                     JFB37777777777777654321OARCDEFGGHHHIIIIJJJJJJJJ
                                      JEA37777666666543210ABCDEFGGGHHHIIIIIJJJJJJ
                                       JFB2566666665443210ABCDEFFGGHHHHIIIIJJJJ
                                         JHEB14555444332100ARCDEFFGHHHHHIIJJJJ
                                           JIFDB0134332100ABBCDEFGHIIJJJJ
                                              JJHGFEDDDDEEFGHHIJJJJ
                                                  JJJJJJJ

                                                     +  180
```

(b) Second page of output.

Figure 6. - Continued.

-- EXAMPLE CASE NO. 1 --
-- WHICH SET TO 2, CENTER FILLED IN, AND DISTORTION PARAMETERS CALCULATED --

CIRCUMFERENTIAL DISTORTION PARAMETERS

RING NO.	1	2	3	4	5	6	7	8	9	10
THTMIN	195.69	185.74	172.56	180.84	182.23	-0.00	-0.00	-0.00	-0.00	-0.00
THTPLS	164.31	174.26	187.44	179.16	177.77	-0.00	-0.00	-0.00	-0.00	-0.00
CMMIN	45.300	44.110	42.410	42.100	42.070	-0.000	-0.000	-0.000	-0.000	-0.000
CMMAX	50.610	52.390	53.570	51.730	51.730	-0.000	-0.000	-0.000	-0.000	-0.000
CMAVG	47.563	47.702	47.874	46.884	46.867	-0.000	-0.000	-0.000	-0.000	-0.000
(CMMAX-CMMIN)/CMMAX	.10492	.15805	.20833	.18616	.18674	.00000	.00000	.00000	.00000	.00000
(CMMAX-CMMIN)/CMAVG	.11164	.17358	.23311	.20540	.20612	.00000	.00000	.00000	.00000	.00000
(CMAVG-CMMIN)/CMAVG	.04759	.07529	.11414	.10204	.10235	.00000	.00000	.00000	.00000	.00000

RADIAL DISTORTION PARAMETERS

THETA POSITION (DEG)	0	45	90	135	180	225	270	315
RMMIN	42.025	42.187	42.270	42.030	41.625	41.295	41.280	41.737
RMMAX	48.040	46.472	45.917	45.362	48.730	52.607	52.898	51.017
RMAVG	46.365	44.368	43.300	43.292	46.507	49.241	49.786	48.795
(RMMAX-RMMIN)/RMMAX	.12521	.09219	.07942	.07345	.14580	.21504	.21962	.18189
(RMMAX-RMMIN)/RMAVG	.12973	.09656	.08422	.07696	.15277	.22974	.23335	.19017
(RMAVG-RMMIN)/RMAVG	.09361	.04914	.02379	.02914	.10498	.16136	.17085	.14463

PARAMETERS PERTAINING TO THE ENTIRE ARRAY OF INPUT MEASUREMENTS

TMMIN= 42.070 TDP1=.21467
TMMAX= 53.570 TDP2=.24349
TMAVG= 47.231 TDP3=.10927
SMAVG= 41.808

(c) Third page of output.

-- EXAMPLE CASE NO. 1 --
-- WHICH SET TO 2, CENTER FILLED IN, AND DISTORTION PARAMETERS CALCULATED --

USER-DEFINED DISTORTION PARAMETERS

KD2	1366.82698
K-THETA	0.78976
(IDC)-MAX	0.10143
(IDR)-MAX	0.00771

(d) Fourth page of output.

Figure 6. - Concluded.

percent) will be mapped. Simple and specific distortion parameters will be calculated. The specific distortion parameters are KD_2, K_θ, IDC_{max}, and IDR_{max}.

The input for the first example is shown in figure 5, and the corresponding output is shown in figure 6.

Example 2

This is an example of a circumferential total temperature distortion at the inlet of a jet engine. Figure 7 shows the instrumentation layout for the second example case. In this example there are five rings of total temperature measurements. Since there is an inner boundary at this measuring station, the interpolation process will not continue through the center of the map. In order to map the entire flow annulus, two imaginary rings (one at the outer wall and one at the inner wall) are generated. These fictitious measurement locations are shown as solid symbols in figure 7.

The air temperature at the wall may be assumed to be at a value between the free-stream total and static temperatures. Therefore, each imaginary measurement will

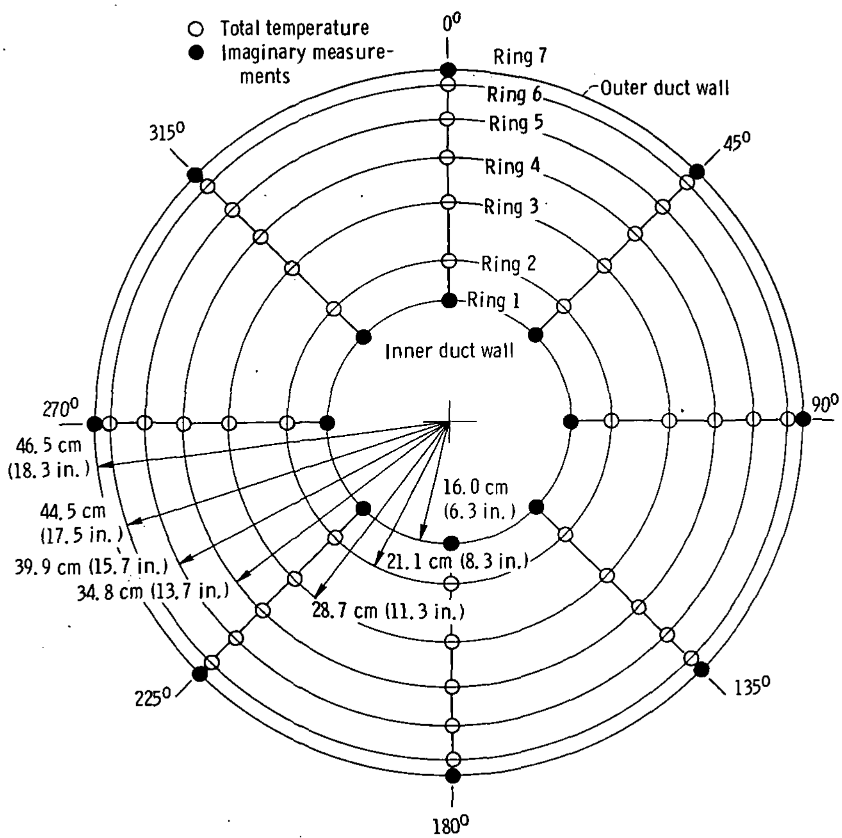
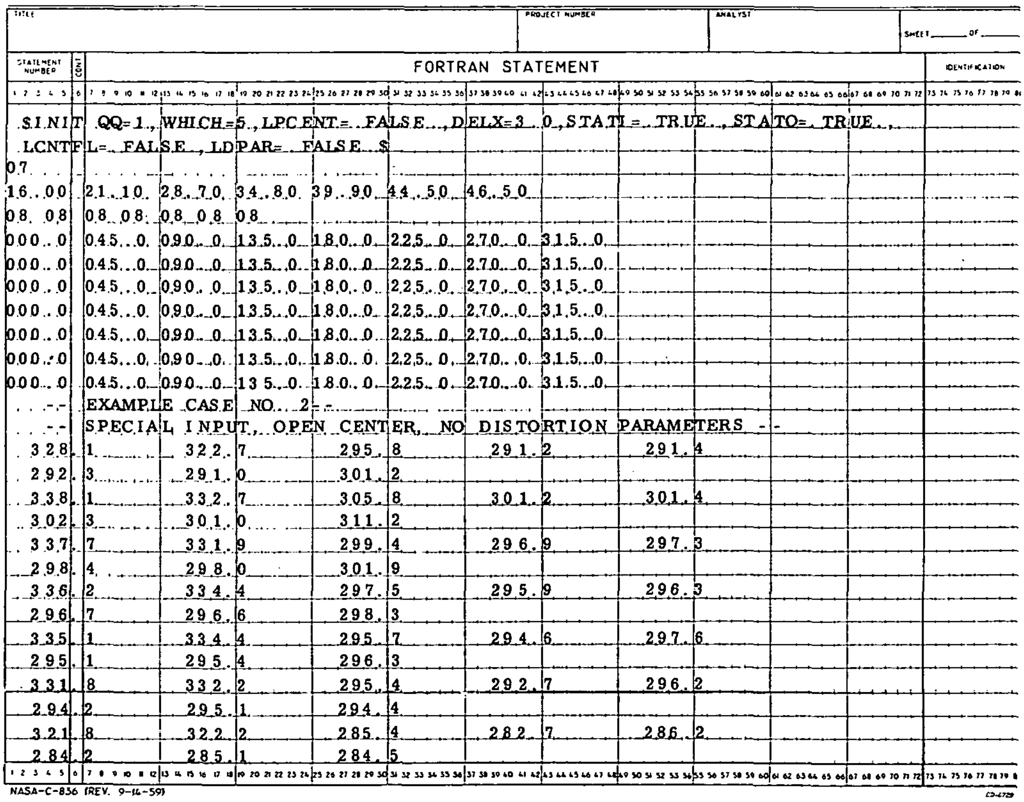


Figure 7. - Instrumentation layout for example 2.

TABLE II. - TEMPERATURE MEASUREMENTS FOR EXAMPLE 2

Angle, deg	Temperature, K (°R)						
	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7
0	328.1 (590.5)	338.1 (608.5)	337.7 (607.8)	336.2 (605.2)	335.1 (603.1)	331.8 (597.3)	321.8 (579.3)
45	322.7 (580.9)	332.7 (598.9)	331.9 (597.4)	334.4 (601.9)	334.4 (601.9)	332.2 (597.9)	322.2 (579.9)
90	295.8 (532.5)	305.8 (550.5)	299.4 (539.0)	297.5 (535.5)	295.7 (532.3)	295.4 (531.7)	285.4 (513.7)
135	291.2 (524.2)	301.2 (542.2)	296.9 (534.5)	295.9 (532.7)	294.6 (530.2)	292.7 (526.9)	282.7 (508.9)
180	291.4 (524.6)	301.4 (542.6)	297.3 (535.2)	296.3 (533.3)	297.6 (535.7)	296.2 (533.2)	286.2 (515.2)
225	292.3 (526.1)	302.3 (544.1)	298.4 (537.1)	296.7 (534.0)	295.1 (531.2)	294.2 (529.6)	284.2 (511.6)
270	291.0 (523.8)	301.0 (541.8)	298.0 (536.4)	296.6 (533.8)	295.4 (531.7)	295.1 (531.1)	285.1 (513.1)
315	301.2 (542.2)	311.2 (560.2)	301.9 (543.4)	298.3 (536.9)	296.3 (533.3)	294.5 (530.1)	284.5 (512.1)



```
 $INIT QQ=1.,WHICH=5,LPCENT=.FALSE.,DELX=3.0,STATI=.TRUE.,STATO=.TRUE.,
 LCNTFL=.FALSE.,LDPAR=.FALSE.$
07
16.00 21.10 28.70 34.80 39.90 44.50 46.50
0.8 0.8 0.8 0.8 0.8 0.8 0.8
000.0 045.0 090.0 135.0 180.0 225.0 270.0 315.0
000.0 045.0 090.0 135.0 180.0 225.0 270.0 315.0
000.0 045.0 090.0 135.0 180.0 225.0 270.0 315.0
000.0 045.0 090.0 135.0 180.0 225.0 270.0 315.0
000.0 045.0 090.0 135.0 180.0 225.0 270.0 315.0
000.0 045.0 090.0 135.0 180.0 225.0 270.0 315.0
000.0 045.0 090.0 135.0 180.0 225.0 270.0 315.0
      EXAMPLE CASE NO. 2
      SPECIAL INPUT, OPEN CENTER, NO DISTORTION PARAMETERS
  328.1       322.7      295.8      291.2      291.4
  292.3       291.0      301.2
  338.1       332.7      305.8      301.2      301.4
  302.3       301.0      311.2
  337.7       331.9      299.4      296.9      297.3
  298.4       298.0      301.9
  336.2       334.4      297.5      295.9      296.3
  296.7       296.6      298.3
  335.1       334.4      295.7      294.6      297.6
  295.1       295.4      296.3
  331.8       332.2      295.4      292.7      296.2
  294.2       295.1      294.4
  321.8       322.2      285.4      282.7      286.2
  284.2       285.1      284.5
```

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CD-4729

Figure 8. - Input for example 2.

```
-- EXAMPLE CASE NO. 2 --
-- SPECIAL INPUT, OPEN CENTER, NO DISTORTION PARAMETERS --


RADIUS              ANGULAR POSITION OF INPUT MEASUREMENTS, DEG
 16.00          0.          45.0        90.0        135.0       180.0
              225.0        270.0       315.0
 21.10          0.          45.0        90.0        135.0       180.0
              225.0        270.0       315.0
 28.70          0.          45.0        90.0        135.0       180.0
              225.0        270.0       315.0
 34.80          0.          45.0        90.0        135.0       180.0
              225.0        270.0       315.0
 39.90          0.          45.0        90.0        135.0       180.0
              225.0        270.0       315.0
 44.50          0.          45.0        90.0        135.0       180.0
              225.0        270.0       315.0
 46.50          0.          45.0        90.0        135.0       180.0
              225.0        270.0       315.0


RADIUS              SPECIAL INPUT
 16.00      328.10000   322.70000   295.80000   291.20000   291.40000
            292.30000   291.00000   301.20000
 21.10      338.10000   332.70000   305.80000   301.20000   301.40000
            302.30000   301.00000   311.20000
 28.70      337.70000   331.90000   299.40000   296.90000   297.30000
            298.40000   298.00000   301.90000
 34.80      336.20000   334.40000   297.50000   295.90000   296.30000
            296.70000   296.60000   298.30000
 39.90      335.10000   334.40000   295.70000   294.60000   297.60000
            295.10000   295.40000   296.30000
 44.50      331.80000   332.20000   295.40000   292.70000   296.20000
            294.20000   295.10000   294.50000
 46.50      321.80000   322.20000   285.40000   282.70000   286.20000
            284.20000   285.10000   284.50000
```

(a) First page of output.

Figure 9. - Output for example 2.

```
-- EXAMPLE CASE NO. 2 --
-- SPECIAL INPUT, OPEN CENTER, NO DISTORTION PARAMETERS --

                                          KEY TO MAPPING SYMBOLS
BORDER               9/8   8/7   7/6   6/5   5/4   4/3   3/2   2/1   1/0   0/A   A/B   B/C   C/D   D/E   E/F   F/G   G/H   H/I   I/J
MULTIPLIER FOR        +9    +8    +7    +6    +5    +4    +3    +2    +1     0    -1    -2    -3    -4    -5    -6    -7    -8    -9
DELTA-X ---- D/E
BORDER CORRESPONDS
TO (X-BAR)+(-4*DELTA-X)
                                          SPECIAL DISTRIBUTION
                                          X-BAR PLUS/MINUS N*(DELTA-X)
                                          X-BAR=  315.00000
                                          DELTA-X=   3.0000

                                                   +  360/0 DEGREES
                                                  0122222
                                              CB0122344555555554432
                                           ECBA00122334556666666665555432
                                         GECBBAA011233445666666666666655542
                                        HFDDCCBAA011233445666666666666666665543
                                      IGFEEDCCBAA001223455677766666666666665553
                                     JHGGFEEDDCBBA0012234556777776666666666666665542
                                    IGGGGFFEEDCCBAA01223455677777666666666666666665542
                                   IGGGGGGFFEDDCBBA0122345667777766666666666666554431
                                  JHGGGGGGFFFFEDCCBA01223456677777666666666666665544433218
                                 JHGGGGGGFFFFFEEDCBA011234566777776666666655555544433322 10C
                                 IGGGGGGFFFFFEEEDCBA0112334556666666666655554443332221110A
                                IGGGGGGFFFFFEEEDDCBA000111234544445556665554333222211100AAC
                               JHGGGGGGFFFFFEEDDCCBBBBBBA         33445554433221111000AAABBE
                               IGGGGGGFFFFFEEEDDCCCDDD              3333332211 0000AAABBBBCE
                              JHGGGGGGFFFFFEEEDDCDDEE                111221100AAAABBBBCCCCDG
                              JGGGGGGGFFFFFEEEDDDEFF                  AA0000AABBBCCCCCDDDDDG
                              IGGGGGGGFFFFFEEEEDEFG                    CBBAABBCCCDDDDDEEEEEG
                              IGGGGGGGFFFFFFEEEEFGH                    EDCCCCCDDEEEEEEEFFFFFH
                    270  +    IGGGGGGGGFFFFFFEEFGGH          +          GFEDDDEEEFFFFFGGGGGGH    +  90
                              IGGGGGGGGFFFFFFEEEFGH                    GFEDDDEEFFFFFFGGGGGGI
                              IGGGGGGGGFFFFFFEEEFGH                    GFEDDEEEFFFFFFGGGGGGI
                              JGGGGGGGGFFFFFFFEEEFGH                  HGFEDEEEFFFFFFGGGGGGGJ
                              JHGGGGGGGGFFFFFFEEEFFGH                 HGFEEEEEEFFFFFFGGGGGGGHJ
                               IGGGGGGGGFFFFFFFEEEEFGG               HGFEEEEEFFFFFFGGGGGGGI
                               JHGGGGGGGGFFFFFFEEEEEEFFGGH          HHGGFEEEEFFFFFFFFGGGGGGGHJ
                                IGGGGGGGGGFFFFFFFEEEEEEFFGGGGHHHHGGGFFEEEFFFFFFFFFGGGGGGGGGI
                                 IGGGGGGGGGFFFFFFFEEEEEEEEEFFFFFFFFEEEEFFFFFFGGGGGGGGGGGHI
                                 JHGGGGGGGGGFFFFFFFFFEEEEEEEEEEEEEEEFFFFFFFGGGGGGGGGGGGGHIJ
                                  JHGGGGGGGGGGFFFFFFFFFFFFFFFFFFFFFFFFFFGGGGGGGGGGGGGHHIJ
                                    IGGGGGGGGGGGFFFFFFFFFFFFFFFFFFFFFFFGGGGGGGGGGGGGGHHHI
                                     IGGGGGGGGGGGGGFFFFFFFFFFFFFFFGGGGGGGGGGGGGGGGGHHHJ
                                      JHGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGHHHIJ
                                        JHGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGHHIJ
                                          JHGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGHIJ
                                            JIHGGGGGGGGGGFFFFFFFFGGGGGGGGGGGHIJ
                                               JIHGGGGGGGGGGFFGGGGGGGGGGGHIJ
                                                  JIHHGGGGGGGGGGGGGHIIJ
                                                        JJJJJJ

                                                   +  180
```

(b) Second page of output.

Figure 9. - Concluded.

be given a value equal to 10 K (18° R) less than each corresponding adjacent total temperature measurement. For example, the imaginary measurement on ring 7 at $\theta = 45^{\circ}$ (see fig. 7) would have a value equal to 10 K (18° R) less than the total temperature measurement on ring 6 at $0 = 45^{\circ}$. (Note that the program does not make this assumption. This is a user-defined assumption applied at the time of input data preparation.) Rings 1 and 7 (the imaginary rings) should be treated as rings of static measurements when preparing the input.

Table II shows the temperature values corresponding to each measurement location. A map of $\overline{T} \pm n(\Delta T)$ will be generated, and ΔT is set to 3.0 K (5.4° R).

The input for the second example is shown in figure 8, and the corresponding output is shown in figure 9.

General Comments

The lines of constant temperature in figure 10 were drawn by hand. The contour map used in figure 10 is the same contour map appearing in figure 6(a). Drawing in lines of constant mapping parameter by hand represents a useful way of looking at the contour maps.

Questionable input measurements can be spotted by examining the contour maps. Referring to figure 6(b) (or fig. 10) near the 270° position, the small region of "5's" could be caused by a bad input measurement. Figure 6(a) shows that the region of "5's" is caused by the measurement of ring 4 (r=12.61 in.) at the 290° position.

Note that the maximum "positive" pressure distortion $(P_i - P_{t,av,f})/P_{t,av,f}$ in example 1 is over 13 percent and the maximum "negative" pressure distortion goes beyond -12 percent. For example 1, a value of RANGE = 20.0 was chosen. RANGE = 20.0 was not large enough to cover the total spread of 25 percent occurring in example 1. Hence, in figure 6(b) areas where $(P_i - P_{t,av,f})/P_{t,av,f}$ is greater than 10 percent are represented by "9's" and areas where $(P_i - P_{t,av,f})/P_{t,av,f}$ is less than -10 percent are represented by "J's". Also realize that making RANGE larger to cover the spread of percentage will reduce the resolution of the contour map.

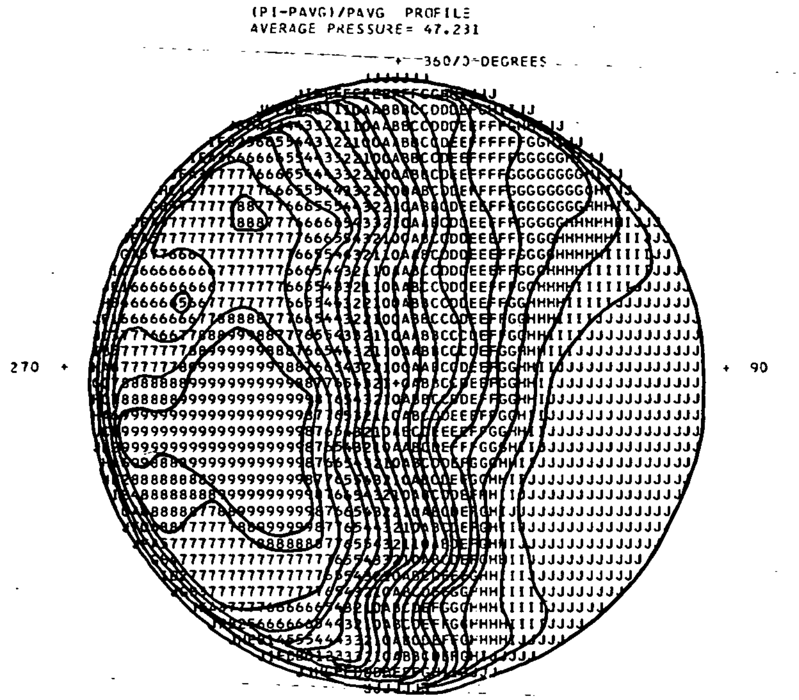

Figure 10. - Example of hand-drawn contour lines.

APPENDIX F

PROCEDURE WHICH ENABLES CALCULATION OF SIMPLE RADIAL DISTORTION PARAMETERS

A geometric requirement of this program is that the input measurements have to be located on defineable rings. However, the measurements may be at any angular position on the rings. This means that a radial vector may exist at some angle θ without intersecting a single input measurement. (Remember that θ is the reference angle for the input measurement plane and is measured clockwise from the 12 o'clock position.)

Calculation of simple radial distortion parameters at given θ positions requires interpolated values of the input measurement for each ring at each given θ position. The circumferential interpolation procedure outlined in appendix B is used to find an interpolated value of the input measurement for each of the NR rings at eight discrete circumferential positions in the input measurement plane. These positions are 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315° (Eight equally spaced θ positions, 45° apart).

Once interpolated values are known on each ring at each of the discrete θ locations, simple radial distortion parameters can be calculated for each discrete value of θ. (The calculation of these simple radial distortion parameters involves only the values found by the circumferential interpolation process; no further radial interpolation is done.) The simple distortion parameters are shown in appendix D.

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4. Oates, Gordon C.; Sherman, Dale A.; and Motycka, David L.: Experimental Study of Inlet-Generated Pressure Fluctuations. Rep. PWA-3682, Pratt & Whitney Aircraft.