REVIEW AND EVALUATION OF RECENT DEVELOPMENTS IN MELIC INLET DYNAMIC FLOW DISTORTION PREDICTION

and

COMPUTER PROGRAM DOCUMENTATION AND USER'S MANUAL

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PART I

REVIEW AND EVALUATION OF RECENT DEVELOPMENTS IN MERLICK INLET DYNAMIC FLOW DISTORTION PREDICTION
A brief review of developments in the Melick method of inlet flow dynamic distortion prediction by statistical means is provided. These developments include the general Melick approach with full dynamic measurements, a limited dynamic measurement approach, and a turbulence modelling approach which requires no dynamic rms pressure fluctuation measurements. These modifications are briefly evaluated by comparing predicted and measured peak instantaneous distortion levels from provisional inlet data sets.

A nonlinear mean-line following vortex model is proposed and evaluated as a potential criterion for improving the peak instantaneous distortion map generated from the conventional linear vortex of the Melick method. The model is simplified to a series of linear vortex segments which lay along the mean line. Maps generated with this new approach are compared with conventionally generated maps, as well as measured peak instantaneous maps.

Results of the developments and modifications discussed compare well with experimental measurements, both in the prediction of peak instantaneous distortion levels, and the peak instantaneous maps. Inlet data sets include subsonic, transonic, and supersonic inlets under various flight conditions. The methods discussed can be used in preliminary inlet design phases in the interest of reducing development costs.
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v ~
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Subscripts

f       filtered
inst     instantaneous
m       measured
max      maximum
min      minimum
p       predicted
rad      radial
rms      root mean square
T       tangential
ss      steady-state

Superscripts

-       mean value \bar{x}

Greek Symbols

\beta, \gamma    vortex orientation angles
\alpha, \beta   angle of attack, sideslip angle
\rho            density
\sigma          standard deviation
INTRODUCTION

Inlet turbulence and other flow nonuniformities have long been known to significantly affect the operational stability of gas turbine engines, especially in high performance military aircraft. This inlet flow distortion is traditionally measured at the compressor face of the engine with an array of total pressure probes mounted on rakes. The time-averaged steady-state pressures at each of the probe locations are processed and combined in such a way as to generate various steady-state distortion factors and an engine face pressure contour map (see Table 1 and Figure 1, respectively). These then correlate to engine surge margins.

The distortion problem is intensified by the time variant component of the total distortion level. Random fluctuations in the total pressure measurements can generate instantaneous distortion levels which can induce engine surges even when the steady-state component is well below compressor stall margins. It becomes important, therefore, to be able to predict the most probable peak instantaneous (dynamic) distortion level early in the inlet design effort.

One method of determining the dynamic distortion level of an inlet is to use an array of high response total pressure probes, with an extensive inventory of support instrumentation and computational equipment to record time histories of the pressure fluctuations for each of the probes. These data are then screened, using the Dynamic Data Editing and Computing (DYNADEC) system, to determine an experimental peak distortion level using the same definitions as the steady-state case. This method is generally quite accurate, compared to statistical methods described later, but it is also extremely expensive in terms of instrumentation and
computational requirements. In order to reduce the cost of inlet distortion tests, several statistical methods have been developed to predict the dynamic distortion component, given the steady-state distortion and limited dynamic data (ref. 1, 2, 3).

Of the many statistical methods of predicting dynamic distortion levels, the most efficient is Melick modelling approach. In the Melick method, it is postulated that the dynamic disturbances in the inlet flow can be modelled by the pressure disturbances resulting from a series of randomly distributed vortices convecting through the inlet duct. Filtered and unfiltered root mean square (rms) total pressure fluctuation levels are used to identify the main variables in this vortex flow model (ref. 2, 3, 4).

The main advantages of the Melick method include low cost relative to other techniques, as well as the fact that it can be used online, while the test is in progress. It has been shown that further cost reduction can be attained by reducing the quantity of dynamic data (ref. 2, 3). In fact, Chen (ref. 3) has derived and demonstrated a new technique for predicting the peak distortion levels with only the steady-state distortion data, that is, with no dynamic data.

One of the main disadvantages of the Melick modelling approach is it is not as accurate as some methods in the generation of the peak dynamic distortion patterns in the engine face contour map. This is due primarily to a limitation in the vortex flow model, namely, the use of a single linear vortex in the generation of the peak instantaneous pressure array. More specifically, the peak instantaneous pressure array is computed by placing a linear vortex along a portion of the mean pressure line in such a way to amplify the distortion pattern pressures (fig. 3). The size and strength of this vortex is determined as a function of the most probable peak instantaneous distortion level. It has
been suggested that a new concept in vortex modelling could improve the accuracy of the predicted peak dynamic distortion pattern (ref. 2).

It is apparent that the mean pressure line in distortion patterns is not generally straight. In most cases, the mean line can be seen to arc across the engine face, frequently forming a distorted ring. One possible solution to the vortex modelling problem is to replace the single straight vortex oriented along a portion of the mean line with a curved mean-line-following vortex. This nonlinear vortex (or vortex ring, where applicable) could provide a more accurate amplification of the pressure levels in the vicinity of the vortex.

In the present work, the concept of replacing the linear vortex model of the traditional Melick model with a nonlinear mean-line-following vortex is proposed and evaluated. For the purposes of demonstrating the concept, this new model is simplified by breaking the vortex into a series of vortex segments, one segment for each of the probe rakes (fig. 4). The radius and strength of these vortex segments is retained from the original Melick dynamic data matching process.

The results of the present method are compared to the original single linear vortex model, as well as the DYNADEC results, for a variety of data sets. These data include example subsonic, transonic, and supersonic inlet configurations at various angles of attack and sideslip.

Major objectives of this study are: 1) to review some of the recent developments in dynamic distortion prediction with the Melick method as a foundation; 2) to demonstrate the utility of a new tool for improving the accuracy of peak instantaneous distortion contour maps; and 3) to evaluate present and recent developments in Melick dynamic distortion analysis.
1. REVIEW OF BASIC CONCEPTS AND DEVELOPMENTS

A. The Melick Vortex Model

The Melick convecting vortex model is a tool used to statistically determine the most probable peak instantaneous distortion level, given the steady-state distortion and the root mean square (rms) total pressure fluctuation level at the engine face. It is formulated around the observation that the total pressure fluctuations exhibit random characteristics, with a near-normal (Beta/Gaussian) distribution (fig. 2). From Bernoulli's flow relationships, it is easily seen that these total pressure fluctuations can be expressed in terms of perturbations in the steady-state flow velocity. These velocity perturbations can in turn be modelled by time-variant vorticity (fig. 5). Thus the Melick method envisions the total pressure fluctuations as being totally attributed to a series of random vortices (random in size, strength, location, and orientation) convecting through the inlet duct (ref. 2).

According to the Melick model, as a vortex passes through the inlet duct, it would create a fluctuation in the steady-state pressure level at all locations in the measurement plane, that is, the engine face. This pressure fluctuation would give rise to an instantaneous distortion level, computed from any of a variety of distortion factors (table 1). Given the properties of an arbitrary vortex, the resulting velocity perturbations can be determined from simple flow relationships (fig. 5). The pressure fluctuation can again be determined from the velocity perturbation, resulting in an instantaneous distortion level.
It is shown in reference 2 that the statistical properties of the convecting vortices of the Melick model are directly related to the statistical properties of the pressure fluctuations. Specifically, the mean vortex size can be determined from the root mean square total pressure fluctuation level. This is accomplished by computing the rms fluctuation level resulting from an assumed vortex size and strength, and then comparing the measured rms level. The vortex size is then adjusted until the analytical and experimental rms levels match.

Once evaluated, the mean vortex properties are then used to compute the mean instantaneous distortion level, which leads to the determination of the most probable maximum instantaneous distortion level. The mean instantaneous distortion is found analytically from the steady-state distortion level and the rms total pressure fluctuation level, along with the mean vortex size (ref. 2). The peak instantaneous value is then statistically extrapolated given the mean instantaneous value, the rms level, and certain statistical parameters (ref. 2). The maximum instantaneous distortion level can be computed for a variety of confidence levels, though the "most probable" (a 50% confidence level) is used in most analyses (fig. 6).

The newly computed maximum instantaneous distortion level is then used to produce the peak dynamic distortion contour map. First, the mean vortex is modified to accommodate the peak dynamic distortion level. This is done by increasing the strength of the vortex until it produces an rms fluctuation level, and consequently a distortion level, which matches the maximum instantaneous distortion level. When this new vortex strength has been established, the resulting pressure disturbances are computed for each of the probe locations, and added to the steady-state pressures. The maximum instantaneous pressure array is then used to generate the peak dynamic distortion map (ref. 2).
8. The Minimum Dynamic Measurement Approach

One of the benefits of the Melick approach to dynamic distortion prediction is its low cost relative to other methods. Traditionally, the Melick method requires steady-state total pressure measurements, along with rms total pressure fluctuation measurements at forty probe locations across the engine face. In the derivation of the mean instantaneous distortion level, the mean value (face-average) rms level is used. The actual number of high-response dynamic probes is not important - just the mean rms value is of interest. In principle, therefore, the Melick method requires only one dynamic rms total pressure measurement, provided an average value is indicated. In the interest of further reducing instrumentation cost, and inlet blockage during a test run, it is desirable to minimise the number of dynamic probes used while retaining the accuracy of the results. Proper placement of a minimum number of dynamic probes is necessary in order to obtain an accurate representation of the average rms level, and the resulting peak dynamic distortion prediction.

Chen (ref. 2) provided a criterion for the selection of dynamic probe locations which yield reasonable accuracies in mean rms level determination. It was observed that there exists an inverse relationship between the rms total pressure fluctuation level and the magnitude of the total pressure. In other words, high rms pressure fluctuations tend to occur in regions of low total pressure, while low rms levels occur in high pressure regions. Furthermore it was noted that average rms levels tend to occur near regions of average pressure. This implies that dynamic probes placed near the steady-state mean pressure line would give rms
total pressure fluctuation levels nearly equal to the face-average value.

Since it is preferred to remain on the conservative side in dynamic distortion prediction, that is it would be more desirable to overpredict rather than underpredict the true peak dynamic distortion in any simplifications, it is suggested that the preferred dynamic probe location should be at or outboard of the mean pressure line (ref. 2). This will allow in most cases an rms level slightly higher than the average value obtained in a 40-probe analysis. In any case, dynamic probe locations selected should avoid regions of very high and very low steady-state pressures.

The accuracy of this criterion is shown herein and in reference 2. It was shown that using 2 probes selected according to the "conservative side" criterion yielded distortion factor errors generally within 5% of the 40-probe prediction. Naturally, if dynamic probes were selected such that the average rms value were exactly equal to the 40-probe average, there would be no error. Conversely, the selection of improper probes can lead to very large errors. Consequently, the careful selection of locations for the placement of dynamic probes is extremely important for the accuracy of the results.

C. The Turbulence Modelling Approach

Because of the sensitivity of the predicted peak distortion level to the indicated mean rms level, which in turn is sensitive to the location of the probes relative to the mean total pressure line, it is desirable to develop an approach which includes the benefits of both the full (40-probe) dynamic data method and the minimum dynamic data approach. In response to this need, Chen (ref. 3) developed a turbulence modelling approach which produces an accurate prediction of the peak instantaneous distortion with no
requirement for dynamic rms total pressure fluctuation data.

In this turbulence modelling approach, the rms total pressure fluctuation levels are simulated from information derived from the steady-state total pressure measurements. First, the axial velocity distribution (relative flow velocity at each steady-state probe location) is calculated from the steady-state measurements. A set of turbulence modelling equations is then employed to compute the turbulent kinetic energy distribution, and the turbulent kinetic energy dissipation rate. These terms represent the turbulence levels required to generate the steady-state distortion. The rms total pressure fluctuation levels are then evaluated from the turbulent kinetic energy and the turbulent kinetic energy dissipation rate. These simulated rms levels are then used to compute the mean vortex properties, the mean instantaneous distortion level, and the peak dynamic distortion in the same manner as the original Melick model (ref. 3).

The advantages of the turbulence modelling approach are obvious. There is no need for rms total pressure fluctuation levels to be measured - hence no high-response dynamic probes are needed. Instrumentation costs are reduced considerably from the fully instrumented 40-probe case. In addition, there is no need for concern over where to most effectively place a minimum number of dynamic probes. The turbulence modelling approach, when coupled with the Melick vortex model, is an efficient tool for determining the most probable peak instantaneous distortion level, given the steady-state measurements.

The accuracy of the turbulence model is demonstrated in reference 3. It is shown that this approach is at least as accurate as the fully instrumented case in comparison to the DYNADEC results for a variety of inlet configurations and operating conditions (ref. 3).
2. A MODIFIED VORTEX MODEL

A. Introduction

Although the original Melick vortex modelling approach (including the modifications summarized in the previous section) is shown to be reasonably accurate in the prediction of peak instantaneous distortion levels, it is not as accurate as some methods in the generation of peak instantaneous distortion maps (ref. 2, 5). It is therefore desirable to develop some modification to the Melick vortex model which can improve the accuracy of the peak instantaneous map.

It has been suggested (ref. 2) that the fault in the Melick peak instantaneous mapping method may lie in one of the vortex modelling assumptions. This modelling approach produces the peak instantaneous pressure distribution by superimposing a linear vortex along the mean shear line of the steady-state distortion pattern (fig. 3). The induced flow velocities produced by this vortex, whose properties are determined from the rms total pressure fluctuation levels, result in an amplification of the total pressure distribution. Both high and low pressure regions are enhanced by this vortex so that the distortion level is magnified.

In reality, the mean shear line of most steady-state distortion patterns is not a straight line, but is instead curved. In fact, often the mean line forms a distorted ring. This suggests that the core of the peak instantaneous vortex should not be a straight line, but should follow the curves of the mean shear line. This will be the basis of the present study.
B. Method of Approach

In the present analysis, a new vortex modelling approach designed to improve the accuracy of Melick peak instantaneous distortion maps is developed. In this new approach, the linear vortex model of the original Melick method (fig. 3) is replaced by a vortex which can have a nonlinear core (fig. 4). This is a justified modification because the mean shear line (the borderline between relatively high and low pressure regions) is generally nonlinear (fig. 4).

There are three general methods in modelling a vortex with a nonlinear core. The first and most complex method would be to formulate a mathematical expression for a curve which fits the desired shape of the vortex core - that is the mean shear line. This expression could be in terms of 2-dimensional cartesian or polar coordinates, derived from a least-squares (or other nonlinear) analysis, or perhaps from an infinite series expansion. This method has the potential of being extremely accurate as far as modelling the vortex is concerned, but would not be very efficient in terms of the computational effort.

A second approach to modelling a nonlinear vortex core might be form a finite element model. The nonlinear vortex would be divided up into a series of linear vortex segments which would lie along the mean line. The number of segments used would depend on amount of curvature in the mean shear line and the desired resolution. This method, depending on the number of divisions selected, could be as accurate as the least squares/infinite series method, with considerably better computational efficiency.

It is clear that these two methods have the capability
of achieving very high resolution in the calculation of the vorticity effects, and in the generation of the peak instantaneous distortion map. This high resolution capability is not necessarily useful, however. It should be kept in mind that the peak instantaneous map is generated by calculating the effect that the vortex has upon the total pressure readings obtained at the steady-state probe locations. Pressures at locations between probes are then interpolated from these new "readings". Consequently any vortex action which occurs between probe locations is ignored, prior to the interpolation process. This limitation in the usable resolution of the vortex model is the basis of the simplifications of the third modelling approach.

The third approach to modelling a nonlinear vortex core is similar to the finite element model, but includes some important simplifying assumptions. First, the vortex is divided up into eight segments, each associated with one of the probe rakes (fig. 4). Each vortex segment is considered the dominant contributor to the pressure disturbances occurring on the rake associated with that vortex segment. It is assumed that each vortex segment affects the pressure only on the rake associated with it. The position of the vortex segment relative to it's associated rake is assumed to be at the probe nearest to the mean pressure line where it crosses the rake. The orientation of each vortex segment is assumed to be perpendicular to it's associated rake, and coplaner with the measurement plane. Each of these simplifying assumptions are illustrated in figure 4, and are discussed separately.

The first assumption involves the division of the nonlinear vortex into eight linear sub-vortices, or vortex segments. Traditionally, there are eight rakes mounted at 45 degree intervals around the measurement plane (fig. 7). Since all probes on a rake are affected by the induced flow velocity caused by the local vorticity, it makes sense
to divide the probes into rake-groups, and to determine the
dominant vortex activity associated with that group. There-
fore, in this study the nonlinear vortex system is divided
into a set of linear vortex segments, with each segment
acting as the dominant vortex activity for one of the rakes.
Eight rakes each require one vortex segment, for a total of
eight sub-vortices. Each vortex segment is considered by
definition to affect only the probes on its respective
rake, and induced vortex activity on adjacent rakes is con-
sidered by definition negligible.

The next assumption involves the definition of the lo-
cation of each of the vortex segments. It is assumed that
the vortex segment is placed directly over the probe loca-
tion nearest to the mean shear line as it crosses over or
passes near to the rake. In addition, it is assumed that
the vortex segment is oriented perpendicular to the rake.
These two simplifying assumptions are illustrated in figure
3. It is suggested that these simplifications introduce
only small errors into the analysis, while they allow con-
siderable improvement in computational efficiency. In any
case, the error produced by these simplifications will
always be less than the error produced in the original
Melick single linear vortex model.

Finally, it is assumed that the vortex properties as
derived in the Melick linear modelling approach are still
valid in the segmented modelling approach. These properties
include: 1) the mean vortex radius, and 2) the vortex
strength. These terms were derived as a function of the
rms total pressure fluctuation level, and the most probable
peak instantaneous distortion level.

Each of these assumptions and simplifications are made
in the interest of providing a straightforward model and a
simplified analysis. None of the assumptions are expected to
introduce significant error into the analysis. The nature
of the model and the analysis is intended to be preliminary,
in the interest of determining whether further research is warranted in this modelling approach.

In the following section, the development of the mathematical formulations is presented based on the simplifying assumptions.

C. Mathematical Formulations

In the Melick approach to peak instantaneous distortion prediction, there are two distinct sections: 1) the development of the most probable peak instantaneous distortion level; and 2) the generation of the peak instantaneous map. Since the present analysis is concerned primarily with the latter of these two sections, the first section will be presented only in summary form. Details on the derivation of the peak instantaneous distortion level may be found in reference 2.

As described in section 1.A., the random total pressure fluctuations measured at the compressor face are attributed to the convection of a series of random vortices through the measurement plane. The pressure fluctuations are to be expressed in terms of velocity perturbations introduced by these vortices. The velocity profile of a one-dimensional steady and incompressible vortex is given as (fig. 5):

\[ V_T = V_{T_{\max}} \frac{r}{a} e^{-\frac{1}{2}[(r/a)^2 - 1]} \]  

where:

- \( V_T \) is the tangential velocity at any radius \( r \)
- \( V_{T_{\max}} \) is the maximum vortex swirling velocity at \( r=a \); a measure of vortex strength.
- \( r \) is the independent variable: radius
- \( a \) is the radius at the point of maximum swirling velocity - also called the vortex size
- \( e \) is the exponential
The total pressure fluctuations produced by the vortex are superimposed onto the steady-state total pressure to form a time variant instantaneous pressure:

\[ P_T = P_{Tss} + dP_T \]  

(2)

where:  
\( P_T \) is the instantaneous total pressure  
\( P_{Tss} \) is the steady-state total pressure  
\( dP_T \) is the pressure fluctuation produced by the vortex

From the incompressible Bernoulli equation:

\[ P_{Tss} = P_S + \frac{1}{2} \rho U^2 \]  

(3a)

\[ P_T = P_S + \frac{1}{2} \rho (U + V_T)^2 \]  

(3b)

where:  
\( P_S \) is the static pressure  
\( \rho \) is the flow density  
\( U \) is the steady-state flow velocity  
\( V_T \) is the vortex-induced velocity

Let \( q = \frac{1}{2} \rho U^2 \) be the steady-state dynamic pressure. Then substituting (3) into (2), we obtain:

\[ dP_T = P_T - P_{Tss} = \frac{1}{2} \rho (U + V_T)^2 - \frac{1}{2} \rho U^2 \]

\[ = \frac{1}{2} \rho (U^2 + 2UV_T + V_T^2 - U^2) \]

\[ = q \left[ \left( \frac{2V_T}{U} \right) + \left( \frac{V_T}{U} \right)^2 \right] = \frac{2qV_T}{U} \]  

(4)

Second order terms have been neglected for \( V_T \) much less than \( U \).
Substituting (1) into (4), we obtain:

\[ dP_T = \frac{2a}{Ua} V_{T \max} \exp \left( -\frac{r}{ce} \right) \]

Equation (5) represents the total pressure fluctuation level produced by the convection of an arbitrary vortex through the inlet duct in terms of the relative size and strength of the vortex, and the position of the probe relative to the vortex.

In the Melick analysis, in order to determine the most probable peak instantaneous distortion level, the mean vortex size must be determined. This parameter is shown (Ref 2) to be a function of the rms total pressure fluctuations:

\[ \left( \frac{dP_{Trms(f)}}{dP_{Trms}} \right)^2 = \text{erf} \left( 7.98 \frac{f_{rms}}{U} \right) \]

The quantity on the left hand side of equation (6) is the square of the ratio of the root mean square total pressure fluctuation level filtered at cut-off frequency \( f \), to the unfiltered rms level. These quantities may be measured, or simulated as developed in reference 3. Using equation (6), the mean vortex size, \( \tilde{a} \), can be solved for iteratively in terms of the filtered and unfiltered rms levels, the filter frequency, and the flow velocity, all of which are known quantities.

The mean vortex size is then used to generate the mean instantaneous distortion level, \( \tilde{k} \): (Reference 2)

\[ \tilde{k} = k_{ss} + f(\tilde{a}, dP_T) \]

where: \( k_{ss} = \) the steady-state distortion level determined from the steady-state total pressure data and table 1
Since \( dP_T \) is a function of the vortex properties, \( \bar{k} \) can be determined from them:

\[
\bar{k} = f(P_T^{ss}, q, U, \bar{a}, V_T^{max})
\]

(8)

where: \( P_T^{ss}, q, \) and \( U \) are measured quantities

\( \bar{a} \) is computed from equation (6)

\( V_T^{max} \) is then determined, using equation (6):

\[
V_T^{max} = \frac{U \bar{a} dP_T}{2qr} \sqrt{\frac{(r/a)^2 - 1}{\pi}}
\]

(9)

For \( r = \bar{a} \), equation (9) is simplified to:

\[
V_T^{max} = \frac{U}{q} \frac{dP_T}{dP_T^{rms}}
\]

(10)

Equation (8) then becomes:

\[
\bar{k} = f(P_T^{ss}, q, U, \bar{a}, dP_T^{rms})
\]

(11)

Since \( q \) and \( U \) are constants, equations (7) and (11) are seen to be identical.

The most probable peak instantaneous distortion level is then statistically extrapolated as a function of the mean instantaneous distortion level, the rms total pressure fluctuation level, and a set of statistical parameters (ref. 2):

\[
k_{max} = f(\bar{k}, dP_T^{rms}, \text{statistical parameters})
\]

(12)

The vortex strength is then adjusted to match the change from
the mean instantaneous distortion level to the maximum instantaneous distortion level:

\[ V_{T_{\text{max}}}/pk = V_{T_{\text{max}}} + f(k_{\text{max}} - R) \]  

Once the most probable peak instantaneous distortion level and the value of \( V_{T_{\text{max}}} \) has been determined, the value for the peak instantaneous total pressure can be determined:

\[ P_{T_{pk}} = P_{T_{ss}} + dP_{T_{pk}} \]  

where \( dP_{T_{pk}} \) is obtained from equations (5) and (13):

\[ dP_{T_{pk}} = \frac{2g}{U_{\text{ss}}} V_{T_{\text{max}}}/pk \ \ e^{-\frac{1}{2}[\left(\frac{r}{\bar{a}}\right)^2 - 1]} \]  

The only variable in equation (15) above is the radius, \( r \). Using the simplifications and assumptions given in section 2.6, the value of \( r \) can be determined on a rake-by-rake and probe-by-probe basis. Substituting (15) into (14) produces the following relationship (let \( V = V_{T_{\text{max}}}/pk \)):

\[ P_{T_{pk}}(k,p) = P_{T_{ss}}(k,p) + 2gV_{T_{\text{max}}}/pk \ \ e^{-\frac{1}{2}[\left(\frac{r(k,p)}{\bar{a}}\right)^2 - 1]} \]  

The subscripts \( k \) and \( p \) refer to the rake and probe number, respectively. The value of \( r(k,p) \) is defined as the distance between the probe with coordinates \( (k,p) \) and the core of the vortex associated with rake \( k \):

\[ r(k,p) = r_p(k,p) - r_v(k) \]
where: $r_p(k,p)$ is the radial location of probe $(k,p)$

$r_v(k)$ is the radial location of the core of the vortex associated with rake $(k)$

The final step in generating the peak instantaneous map is to interpolate values for $P_{Tpk}$ at each of the discrete points between the probes. This is done in the same manner as with the steady-state map (ref. 6).
3. RESULTS AND DISCUSSIONS

In the following sections, numerical and graphical predictions from the analytical methods described in the present work are provided with three inlet data sets. Data comparisons with the DYNADEC results are also provided with each of the inlet configurations. The three inlet data sets consist of provisional experimental results from subsonic, transonic, and supersonic inlet configurations under various flight conditions. Inlet configurations and measured results of the data sets are provided in figures 8 through 10. Data comparisons of predicted and measured peak instantaneous distortion levels, and graphical comparisons of predicted and measured peak instantaneous distortion maps are also provided.

A. Subsonic Inlet

Configuration of a full-scale short S-shaped subsonic inlet duct is shown in figure 8. The engine centerline is tilted approximately six degrees from the horizontal as shown in the figure. The freestream Mach number was given as subsonic. Six test cases were available for data comparison. These data were provided by the Air Force (AFWAL), Wright-Patterson AFB, Ohio.

Comparison of Melick predicted peak instantaneous distortion levels is given in Table 2 and Figures 11 and 12. Figure 13 shows mapping comparisons for the steady-state, DYNADEC measured peak, Melick predicted peak, and the Modified Vortex predicted peak instantaneous distortion patterns. As described in Reference 3, reasonably good accuracy of the distortion level prediction analyses is indicated. In certain
cases, the peak instantaneous distortion level is underpredicted by the Melick approach. This is attributed to the fact that the Melick approach cannot accurately predict the peak distortion level for inlet flows with separated boundary layers. Unfortunately, the subsonic data set contains separated boundary layers at the engine face (ref. 3) Further study will be required to improve the Melick predictive accuracy in separated flow cases.

The Modified (segmented-nonlinear) Vortex technique compares favorably with the Melick modelling approach in the peak distortion map generation, in certain cases. In cases where the Melick linear vortex model produces an accurate prediction of the peak instantaneous map, the modified approach generally overpredicts the distortion pattern slightly. In cases where the Melick approach yields poor results in the peak distortion map, the modified approach tends to improve the map considerably (fig. 13).

B. Transonic Inlet

Configuration of a 15% subscale long S-shaped transonic inlet duct is shown in Figure 9. Six test cases with a transonic freestream Mach number were available for comparison. These data were provided by the Air Force (AFWAL) Wright-Patterson AFB, Ohio.

Comparisons of predicted and measured peak instantaneous distortion levels are given in Table 3 and Figures 14 and 15. Figure 16 shows mapping comparisons for steady-state, DYNADEC measured peak, Melick predicted peak, and the Modified Vortex predicted peak instantaneous distortion patterns. Good accuracy in predicting peak dynamic distortion levels is indicated for these test cases. The Melick method slightly overpredicts the peak distortion level, which is the desired affect.
The Modified Vortex approach again compares favorably with the Melick linear vortex approach. In examples where the original Melick approach yields poor predictions of the peak instantaneous distortion pattern, the modified approach produces superior results (fig. 16). In cases where the Melick approach produces good peak distortion maps, the modified approach produces comparable results.

A notable exception to this can be seen in the first case (case number 464.12). The steady-state map shows a symmetrical pattern, while the DYNADEC predicted pattern is not symmetrical (fig. 16). The Melick approach produces a fairly symmetrical pattern as expected, while the modified approach produces a pattern almost identical to the steady-state pattern, except for enhanced pressure magnitudes, also as expected from the modelling criteria. This is due to the fact that this particular test case represents an extremely high angle of attack, where asymmetrical vortex shedding is evidently taking place. This inlet "pumping" has the effect of alternating high and low pressure levels on either side of the inlet duct instantaneously, while providing apparently symmetrical patterns in the steady-state. Asymmetrical or alternating vortex shedding is the same phenomenon which is associated with wing "rocking" in highly swept delta wings at high angles of attack.

C. Supersonic Inlet

Configurations for four 25% scale supersonic inlet ducts are shown in Figure 10. These inlet models include data for a variety of supersonic freestream Mach numbers, and angles of attack and yaw. There are thirteen test cases available for comparison. These data were also provided by the Air Force (AFWAL) Wright-Patterson AFB, Ohio. The four inlet configurations, test conditions, and some measured results are given in figure 10.
Comparison of predicted and measured peak instantaneous distortion levels is given in Table 4 and Figure 17. Figure 18 shows comparisons of steady-state, DYNADEC measured peak, Melick predicted peak, and modified Melick predicted peak instantaneous distortion contour maps. Many of the peak instantaneous distortion levels are underpredicted slightly, primarily because these cases show separated boundary layers. It is recalled that the Melick approach tends to underpredict peak distortion levels when separated boundary layers occur in the inlet duct. It is noted that in many cases the maps generated by the Melick approach appear to have no apparent pattern as far as relatively high and low pressure regions. The steady-state and peak instantaneous maps in these cases exhibit quasi-random characteristics, indicating severe turbulence levels and flow separation. The Melick prediction technique generally requires a reasonably well-defined mean shear line in order to effectively apply the vortex model. The predicted distortion levels and distortion maps are seen to be fair to good in these cases. In certain cases, when the linear Melick vortex model fails to provide a good prediction of the peak distortion map and the measured peak map resembles the steady-state pattern, the segmented vortex model provides a map superior to the one generated by the linear vortex model (Fig. 13).

D. General Results and Comments

1. The Melick Approach

The Melick approach to predicting the peak instantaneous distortion levels can be evaluated by examining Tables 2, 3 and 4, comparing peak distortion values as measured from the DYNADEC system, and as predicted by the Melick approach. Figures 11, 14 and 17 show these comparisons in graphical form.
It is seen from Figure 11 that the subsonic peak distortion factors are underpredicted in four out of six cases, and has a percent error of greater than plus or minus twenty percent in three out of six cases. At first glance this may be disturbing, but it is recalled that the subsonic inlet data set indicates a separated boundary layer, as described in Reference 3. Since the Melick approach assumes an attached boundary layer, the results are understandable. Nevertheless it can be said that the Melick approach provided a good ball-park figure in distortion level prediction.

Figure 17 shows peak distortion level predictions within 20 percent in 4 out of 6 cases, with an underprediction of the measured peak distortion in only one case. These results can be considered very good. Near-perfect predictions are seen in two cases, which is encouraging. These transonic inlet data sets show a mean percent error of approximately ten percent for all six test cases.

The supersonic test cases show peak distortion predictions within 20 percent in 11 out of 13 cases. However, it is also noted from Figure 17 that the peak distortion is underpredicted in almost all cases. As seen from Figure 18, the supersonic inlet cases in many cases represent highly turbulent separated flow conditions, for which the Melick technique is known to tend to underpredict. The overall results for the supersonic test cases can be said to be fairly good, and very consistent.

The overall accuracy of the Melick approach can be judged with Figure 19. The overall percent error in the predicted peak instantaneous distortion level with non-separated flow shows a mean value of +19.5%, while the separated flow inlets show a mean percent error of -3.3%. These results are considered good for preliminary engineering purposes.
2. The Minimum Dynamic Measurement Approach

In addition to the results indicated in Reference 2, which shows very good results in the minimum dynamic measurement approach with respect to the full (40-probe) approach, Tables 2 and 3, and Figures 12 and 15 indicate excellent correlations between the two approaches. In addition, as indicated in Reference 3, the turbulence modelling approach shows excellent predictions of peak instantaneous distortion levels, with no dynamic measurements. Predictions well within 20 percent of the 40-probe predicted values are indicated for most of the test cases. These results appear to validate these two low-cost approaches.

3. The Segmented Vortex Approach

The segmented vortex approach can be judged in terms of its performance with respect to theoretical expectations. The segmented vortex approach is, again, a simplified model of the nonlinear mean-line following approach. This model will always produce a predicted peak instantaneous distortion pattern similar to the steady-state pattern, with the pressure levels amplified somewhat. This phenomenon can be easily seen in the distortion map comparisons (figs. 13, 16 and 18). In cases where the peak instantaneous map is not similar to the steady-state map, this approach will produce a poor prediction, while cases where the steady-state and peak instantaneous maps have similar patterns as measured by DYNADEC, the approach will produce a map generally superior to the linear Melick vortex approach. In some cases it is seen that the segmented vortex approach is far superior to the linear, while in most cases, the improvement is only marginal (fig. 13, 16, 18). It is possible that the accuracy of this approach can be improved by removing simplifications, though the overall pattern would not change significantly.
4. CONCLUSIONS

A simplified nonlinear vortex model has been developed in order to improve the quality of predicted peak instantaneous distortion maps. The nonlinear mean-line following vortex model is simplified by dividing the vortex into linear vortex segments, one for each rake of probes, oriented perpendicular to each probe, and each having the characteristics of the mean vortex developed in the original Melick approach.

A review and evaluation of recent developments in the Melick peak instantaneous distortion level prediction technique has been included. A simplified description of the Melick method has also been provided, with references to more detailed reports. Predictions using limited, minimum and no dynamic data have been compared to OYNADEC measurements with favorable results for three inlet data sets. Minimum and no dynamic data approaches have also been compared to full (40-probe) predictions with excellent results.

The Melick approach, along with recent improvements, is shown to be an efficient and accurate design tool for predicting peak instantaneous distortion levels in preliminary analyses. It is noted, however, that the approach does not work well with highly turbulent separated flow inlet conditions, due to limitations in the modelling approach. Further research will be required to develop improvements in separated inlet flow predictions.

The segmented vortex approach is a useful method of improving peak instantaneous distortion maps, provided the Melick peak distortion level has been accurately predicted, and provided the actual peak distortion map does resemble the steady-state map pattern. Further improvements in this
modelling approach are possible by removing simplifications and assumptions, as long as these two conditions are met. At this time there exists no modification to the Melick vortex model which can accurately predict the peak instantaneous distortion pattern when the measured peak pattern is significantly different from the steady-state pattern. Further study will be required to understand and predict this particular problem.
REFERENCES


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<th>Factor</th>
<th>Equation</th>
<th>Supplemental equations</th>
<th>Definitions</th>
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<td>IDC&lt;sub&gt;max&lt;/sub&gt; = max[1/2(IDC&lt;sub&gt;1&lt;/sub&gt; + IDC&lt;sub&gt;2&lt;/sub&gt;), 1/2(IDC&lt;sub&gt;4&lt;/sub&gt; + IDC&lt;sub&gt;5&lt;/sub&gt;)]</td>
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<td>(p&lt;sub&gt;t&lt;/sub&gt;)&lt;sub&gt;j&lt;/sub&gt; = average total pressure at engine face</td>
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<td>IDR&lt;sub&gt;max&lt;/sub&gt; = max(IDR&lt;sub&gt;1&lt;/sub&gt;, IDR&lt;sub&gt;5&lt;/sub&gt;)</td>
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</tr>
<tr>
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<tr>
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<td>K&lt;sub&gt;A2&lt;/sub&gt; = K&lt;sub&gt;θ&lt;/sub&gt; + bK&lt;sub&gt;RAD&lt;/sub&gt;</td>
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<td>IDR</td>
<td>IDR = k&lt;sub&gt;c&lt;/sub&gt; (IDC)&lt;sub&gt;c&lt;/sub&gt; + k&lt;sub&gt;r&lt;/sub&gt; (IDR)</td>
<td>k = radial distortion sensitivity factor</td>
<td></td>
</tr>
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### Table 1: Distortion Factor Definitions (Ref. 2)
- A<sub>1</sub> = \( \frac{1}{M} \left( \sum_{i=1}^{M} \frac{p_{t_i}}{\bar{p}_t} \cos(\theta_{t_i}) \right) \)
- A<sub>2</sub> = \( \frac{1}{M} \left( \sum_{i=1}^{M} \frac{p_{t_i}}{\bar{p}_t} \sin(\theta_{t_i}) \right) \)
- Δp<sub>t</sub> = (p<sub>t</sub>)<sub>j</sub> - (p<sub>t</sub> base)<sub>j</sub>
**Figure 1. Determination of Steady-State Distortion**
ILLUSTRATION OF SOME FEATURES OF THE TIME VARIANT TOTAL PRESSURES AND DYNAMIC DISTORTION:

(a) Inlet Test Model:

(b) Total Pressure:

\[ p_t(i,j) \text{ fluctuating} \]

\[ p_{t_{\text{steady state}}} \]

\[ \text{Time-sec} \]

(c) Distortion Factor (resulting from a combination of all probes):

\[ K_{\text{inst}} \text{ instantaneous peak distortion factor.} \]

\[ K_{\text{inst}} \text{ - } K \]

\[ \text{Nearly Normal Distribution} \]

**Figure 2.** Illustration of a Typical Inlet Test Model and Peak Distortion Factor Measurement
a) Vortex Orientation angles

\[ \text{GAMMA} = \text{vortex orientation angle between y axis and the } x'\text{-}y' \text{ plane} \]

\[ \text{BETA} = \text{vortex orientation angle between } x' \text{ and } x \text{ axes, with the } x \text{ axis in the } x'\text{-}y' \text{ plane} \]

b) Vortex Orientation

Figure 3. Melick Linear Vortex Model
Figure 4. Nonlinear/Segmented Vortex Models
Figure 5. Inlet vortex flow model and perturbation of velocity and static pressure and the time variant total pressure fluctuation caused by a single 1-D vortex (Ref. 2)
$\sigma_0 = \text{"most probable" or 50\% Confidence Level}$

$\sigma_2 = 95\% \text{ Confidence Level}$

$\sigma_3 = 99.7\% \text{ Confidence Level}$

Confidence level - percent of area to the left

Figure 6. Definition of Confidence Levels
Figure 7. Ring, Rake, and Probe Assignments for a typical instrument configuration
(a) Subsonic Full Scale Inlet Model:

(b) Test Conditions and Some Measured Results:

<table>
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<tr>
<th>Data pt.</th>
<th>Mach No.</th>
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<th>$\frac{\text{rms}_m}{m}$</th>
<th>$IDC_{max, \text{peak}}$</th>
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Figure 8. Illustration of a Subsonic Inlet Test Model and some Test Results (unpublished data from Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio) [Ref. 3]
(a) Transonic .15 scale Inlet Model:

(b) Test Conditions and Some Measured Results:

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Figure 9. Illustration of a Transonic Inlet Test Model and some Test Results (unpublished data from Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio) [Ref. 3]
(a) Configurations of four .25 scale Tailor-Mate Model:

- A-1
- A-2
- B-4
- B-3

(b) Test Conditions and Some Measured Results:

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Figure 10. Illustration of four Supersonic Inlet Test Model and some Test Results (ref. 3)
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<th>MELICK PREDICTED PEAK</th>
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Table 2. Subsonic Inlet Distortion Factor Comparison
Figure 11. Comparisons of the Predicted and Measured $rms$ Level and Peak Distortion Factor for the Subsonic Inlet Model shown in Figure 8. (unpublished data)
Figure 12. Comparisons of peak distortion factors predicted by the present analyses and the Melick method based on the total pressure rms measurements for the subsonic inlet data set (unpublished data)
steady-state

K-THETA

K1
1.9214

K2
0.1079

K3
0.1051

K4
0.1063

K5
1.0796

K6
1.5570

OSPR

10

DYNADEC peak

K-THETA

K1
0.3622

K2
0.2500

K3
0.3505

K4
0.7150

K5
0.4005

K6
2.3315

ID

20

Melick model peak

K-THETA

K1
1.7955

K2
0.7271

K3
0.1091

K4
0.1043

K5
1.9265

K6
1.1690

OSPR

10

segmented vortex peak

K-THETA

K1
1.5975

K2
0.3017

K3
0.1044

K4
0.5950

K5
2.1760

K6
2.1760

OSPR

10

Figure 13a. Subsonic Inlet Map Comparisons (20.40)
Figure 13b. Subsonic Inlet Map Comparison (54.30)
percent from average pressure

steady-state

K-THETA 0.30337
KU2 0.30325
(1DC)-MAX 1.0791A
KRA 0.40786
KAR 0.40759
DSPR 0.00006
ID 1.54862

DYNADEC peak

K-THETA 0.72763
KU2 0.72754
(1DC)-MAX 1.0512A
KRA 0.41725
KAR 0.41697
DSPR 1.13402
ID 1.13402

percent from average pressure

Melick model peak

K-THETA 1.03546
KU2 1.03532
(1DC)-MAX 0.18101
KRA 0.40800
KAR 0.40766
DSPR 0.00040
ID 1.50487

segmented vortex peak

K-THETA 0.74568
KU2 0.74557
(1DC)-MAX 0.15806
KRA 0.41414
KAR 0.41383
DSPR 0.00677
ID 1.50862

Figure 13c. Subsonic Inlet Map Comparisons (81.40)
percent from average pressure

steady-state

DYNADEC peak

percent from average pressure

Melick model peak

segmented vortex peak

Figure 13d. Subsonic Inlet Map Comparisons (111.30)
Figure 13e. Subsonic Inlet Map Comparisons (112.30)
percent from average pressure

steady-state

DYNADEC peak

Melick model peak

segmented vortex peak

Figure 13f. Subsonic Inlet Map Comparisons (137,50)
### Table 3: Transient Inter Distortion Factor

<table>
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<tr>
<th>Time (s)</th>
<th>Inter Distortion Factor</th>
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<th>Predicted Peak Distortion</th>
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**Dynamic Case**

- **None**
- **Full MIN**
- **Peak**

**Peak Factor**

- **Predicted Peak**
- **Distortion**
- **Steady-DNASA**
Figure 14. Comparisons of the Predicted and Measured $\text{rms}$ Level and Peak Distortion Factor for the Transonic Inlet Model shown in Figure 9. (unpublished data)
Figure 15. Comparisons of peak distortion factors predicted by the present analysis and the Melick method based on the total pressure measurements for the transonic inlet data set (unpublished data)
Fig. 16a. Transonic Inlet Map Comparison (464.12)
<table>
<thead>
<tr>
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<td>(l</td>
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<tr>
<td>(l</td>
<td>H)-MAX</td>
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<td>KAA</td>
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steady-state

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DynaDEC peak

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<td>H)-MAX</td>
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Melick model peak

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<td>(l</td>
<td>H)-MAX</td>
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segmented vortex peak

Figure 16b. Transonic Inlet Map Comparison (465.11)
Figure 16c. Transonic Inlet Map Comparison (473.12)
Figure 16d. Transonic Inlet Map Comparison (485.10)
Figure 16e. Transonic Inlet Map Comparison (487.80)
percent from average pressure

steady-state

DYNADDEC peak

Melick model peak

segmented vortex peak

Figure 16f. Transonic Inlet Map Comparisons (498.12)
<table>
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<tr>
<th>CASE#</th>
<th>DISTORTION FACTOR</th>
<th>STAND-STATE PEAK</th>
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<th>PREDICTED PEAK</th>
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Table 4. Supersonic Inlet Distortion Comparison
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Table 4. Supersonic Inlet Distortion Comparison (cont'd)
Note: The measured data was screened on $K_{A2}$ for peak distortion

Figure 17. Comparisons of the Predicted and Measured Peak Distortion Factors for four Tailor-Mate Supersonic Inlet Models (ref. 3; see Figure 10)
Figure 18a. Supersonic Inlet Map Comparison (182/1)
Figure 18b. Supersonic Inlet Map Comparisons (189/3)
Figure 18c. Supersonic Inlet Map Comparison (216/3)
percent from average pressure

steady-state

DynaDec peak

percent from average pressure

Melick peak

segmented vortex peak

Figure 18e. Supersonic Inlet Map Comparison (246/3)
Figure 18f. Supersonic Inlet Map Comparison (247/2)
Figure 18g. Supersonic Inlet Map Comparison (640/2)
percent from average pressure

steady-state

DYNADEC peak

percent from average pressure

Melick peak

segmented vortex peak

Figure 18h. Supersonic Inlet Map Comparison (643/3)
percent from average pressure

steady-state

DYNADEC peak

percent from average pressure

Melick peak

segmented vortex peak

Figure 18i. Supersonic Inlet Map Comparisons (695/1)
Figure 18j. Supersonic Inlet Map Comparisons (1334/2)
Figure 18k. Supersonic Inlet Map Comparison (433/3)
percent from average pressure

steady-state  

DYNADEC peak

percent from average pressure

Melick peak  

segmented vortex peak

Figure 181. Supersonic Inlet Map Comparison (473/3)
Figure 18m. Supersonic Inlet Map Comparison (1554/4)
Figure 19. Accuracy of the Present Method in Predicting rms Levels and Dynamic Peak Distortion Factors

For rms level:
mean = 15.5%
$\sigma_{\text{rms}} = 15.2$

For peak distortion factor:
(with non-separated flow)
mean = 19.51%
$\sigma_{\text{pdf}} = 15.57$

For peak distortion factor:
(with separated flow)
mean = -3.31%
$\sigma_{\text{pdf}} = 17.86$
PART II

COMPUTER PROGRAM DOCUMENTATION AND USER'S MANUAL

ESTIMATING MAXIMUM INSTANTANEOUS INLET FLOW
DISTORTION FROM STEADY-STATE TOTAL PRESSURE
MEASUREMENTS WITH FULL, LIMITED, OR NO DYNAMIC
DATA
ABSTRACT

A computer program for statistically predicting peak instantaneous dynamic distortion, given steady-state distortion data and dynamic root mean square pressure fluctuation levels in gas turbine inlets, is presented. The statistical approach utilizes a physical flow model which characterizes inlet flow distortion as due to random vorticity convecting through the inlet duct. Characteristics of a mean vortex are statistically determined to match steady-state distortion data and contour map, as measured by steady-state total pressure probes. The mean vortex characteristics are then intensified according to the mean rms fluctuation level as measured by full or limited high response pressure transducer instrumentation, or as simulated by turbulence modeling, to produce the most probable peak instantaneous distortion level. The computer program utilizes this approach to solve for the dynamic distortion and print the results, including contour maps.
FOREWORD

This Report is designed to be a User's Manual and Documentation Guide for the improved Melick [ref. 1-3] dynamic distortion computer program developed at the University of Kansas. This program characterizes the random vortices used to describe the unsteady, turbulent flow in jet engine inlets, and statistically calculates the most probable peak instantaneous (dynamic) distortion level for a particular inlet operating condition. Steady-state distortion levels are computed for eight common distortion factors given the time-averaged steady-state probe pressure array, and the root mean square pressure fluctuation levels are used to project the maximum peak instantaneous distortion for the given conditions.

Details of the derivation and development of the random vortex modelling approach are not included in this User's Guide as the Guide is orientated more towards application than theory. The References, however, provide exhaustive detailing of the general Melick approach, especially References 1 through 3. Reference 4 provides an extensive list of other sources which relate to distortion prediction. Finally References 5, 6, and 8 show details of some specific developments in distortion research at the University of Kansas.

Major segments in this Guide include descriptions of the main program and subprograms as well as input and output data. Sample problems are included for illustration. A listing is provided in an appendix. The fully documented program requires memory capacity for 70,000 characters in 2300 lines. Hardware requirements include, in addition to the mainframe computer, an on-line printer for high speed output.
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I. INTRODUCTION

Turbulence and other flow nonuniformities in aircraft engine inlets have long been known to cause an unwanted flow distortion phenomena at the compressor face. These imperfections in the ideally smooth inlet airflow is frequently due to the turning and shaping of the flow as it passes through the inlet duct. Generally the magnitude of the distortion is a function of the angle of attack and sideslip (yaw angle) of the aircraft. The time averaged steady-state distortion level is relatively easy to determine experimentally by locating an array of total pressure probes ahead of the compressor face, and evaluating specific distortion parameters based on these steady-state measurements. Steady-state distortion can be of sufficient magnitude to disrupt the proper operation of the engine by stalling the compressor. Efforts to develop high performance engine and inlet configurations has been hampered because of the inherent sensitivity of highly loaded compressors to flow distortion.

It has also been found that random fluctuations in the distortion level, known as dynamic distortion, can have an even greater effect on engine stability as the steady-state distortion. It has been demonstrated that the dynamic distortion can cause the engine to surge even though the steady state distortion is well below the level at which the engine would be expected to stall. It becomes of particular importance to be able to predict the dynamic distortion levels which could occur at any instant in time.

One of the most common experimental methods of determining the maximum instantaneous distortion is to use fast response (dynamic) probes to produce time histories of the total pressure fluctuations at the compressor face. These
instantaneous pressures are then translated, as in the steady state case, into distortion parameters. These data are then screened by the Dynamic Data Editing and Computing System, DYNADEC, to determine the maximum instantaneous distortion during the test run. An estimation of the most probable peak distortion level is then available for the inlet designer.

The DYNADEC approach to dynamic distortion prediction is generally quite accurate, but is extremely expensive in terms of test instrumentation and computing time. For preliminary design purposes, it becomes difficult to justify the cost of a full DYNADEC test run. It is for this reason that methods of statistically predicting peak distortion levels have been developed. Further information on the DYNADEC and various statistical prediction methods can be obtained with the aid of References 4 and 7.

Of the many statistical approaches for predicting peak dynamic distortion, the Melick random vortex model (Ref. 1 - 3) is of particular interest because of its high efficiency in terms of data requirements and numerical analyses. The basis of the Melick approach is formulated around the observation of the randomness of the total pressure fluctuations during a test run. It was hypothesized that the inlet flow could be modelled as having randomly distributed vortices of random strength, size, and orientation convecting with the steady-state flow, which itself is distorted by a large steady-state vortex. By applying fluid mechanics to convecting vortices, a mathematical model of the inlet turbulence can be generated. The vortices are then translated into dynamic distortion parameters using a statistical criterion.

The distortion level, or the extent to which the flow is distorted, is generally defined in terms of distortion factors. These distortion factors are designed to indicate the distortion relative to some reference value, typically the level at which the engine could be expected to surge.
The maximum dynamic distortion prediction in the Melick approach makes use of rms total pressure fluctuation levels to identify the main variables in the convecting vortex flow model (Ref. 5). Filtered and unfiltered rms levels are required so that any unwanted effects, such as engine speed, can be removed. The rms levels are somewhat easier to process than the instantaneous distortion computations done by DYNADEC, but the instrumentation requirements are much the same. It is seen that instrumentation costs can be reduced by using fewer dynamic probes. The Melick method allows a reduction in probes since it actually uses the face-averaged fluctuation level in the analysis. In principle, the use of very few dynamic probes is feasible, as long as they produce the same face-average rms fluctuation level as the fully instrumented case.

There is some difficulty in choosing the locations for the placement of a limited number of dynamic probes, because it requires some knowledge of the solution before the test begins. Reference 5, however, provides a simplified scheme for locating as few as two dynamic probes at the engine face while retaining sufficient accuracy in the dynamic distortion prediction. It is apparent that even further cost reductions could be achieved if the requirement for dynamic probes and the associated instrumentation could be eliminated entirely. Until recently, however, no methods have been available for reasonably accurate peak dynamic distortion prediction without dynamic data.

Research at the University of Kansas has produced a new technique for estimating maximum instantaneous distortion based only on the steady-state total pressure measurements. Chen (Reference 6) has developed an approach to inlet turbulence modelling which analytically simulates the rms total pressure fluctuation levels using the predicted turbulent kinetic energy distribution at the compressor face. These simulated rms levels replace the rms level data which had to
be measured previously. The simulated rms fluctuation levels are then used to compute the variables of the random vortex model, from which the peak dynamic distortion parameters are derived, just as if the rms levels had been input as data.

The purpose of this work is to present a computer program which statistically computes the most probable peak dynamic distortion level, based on the methods of Chen and Melick. The program is designed to be highly adaptable in that the user may decide on the extent of the dynamic data to be input. There are three main alternatives available to the user. First, the user may select a full set of dynamic data, a partial set can be considered (to a minimum of two dynamic probes), or the user can opt to input no dynamic data. In the last case, the program automatically executes the computations related to the turbulence modelling and dynamic data simulation. This flexibility is designed not only to allow the user to select and control the quantity of dynamic data to be processed, but also to allow comparison of different dynamic probe configurations in a single data run.

In summary, the subject computer program solves for an estimation of the maximum instantaneous distortion, given the steady-state distortion data and rms total pressure fluctuation levels. The mathematical and theoretical derivations are well documented in the Melick references (Ref. 1 - 3) and the improvements by Chen are detailed in References 5 and 6. Additional information on inlet flow distortion in general can be found with the aid of Reference 4.

This Users Manual is designed to assist the user toward an understanding of the operational capabilities of the program. The three major sections of the Manual include a breakdown of the program elements, an input and output data section, and a set of sample problems. A listing of the program is included at the end of the Manual. Suggestions for possible future studies in improving the program or the analytical techniques are also included.
II. PROGRAM DESCRIPTION

The subject computer program, the MAXIDYN peak dynamic distortion estimator, is written in FORTRAN IV and can be run as is or with minor modification on most FORTRAN compilers. MAXIDYN requires memory capacity for about 70,000 words in 2300 program lines, including comments. Deletion of the comment lines would reduce the memory space needed to about 45,000 characters and 1600 lines. Appendix A of this work includes a listing of the program and subprograms.

This program is designed to be flexible in nature, and can be used to run with a variety of inlet pressure probe configurations. Individual test cases can be analyzed separately, or groups of data sets can be run in sequence. A set of typical distortion factors are included in the program, though these can be modified by the user. Figure 7 gives the definitions of the distortion factors used in this program.

The program may be used with or without dynamic rms total pressure fluctuation data, with a minimum of two probes in the case that dynamic data is included.

A block diagram of calling sequences of subprograms is given in figure 1. A description of each of the subprograms is given in this section. The subprogram descriptions are alphabetized, for convenience. An operational sequence of events is included to illustrate key events during a data run.

Peripheral requirements are limited to a line printer. The program is suitable for use online while data is being collected, provided format requirements (sect. III) are met.
II.A. SUBPROGRAM DESCRIPTION

1. MAXIDYN main driver

The main driver of the MAXIDYN program controls some of the data input, including the inlet probe configuration, and the steady-state pressure array. In addition, the main driver controls the subprograms which handle the remaining input data, distortion computations, and the output. Specifically, the main driver controls directly the following:

a. Reading in of pressure probe ring and rake geometry.

b. Reading in of data titles and identifying comments after checking for an End Of File command which stops program execution.

c. Reading in of steady-state pressure data.

d. Controlling the subroutines which control other data input, check for errors, assign default values, and control distortion computations and output.

2. Function ARNTU

This function subprogram computes the vortex flux rate and its effect on the root mean square distortion level. ARNTU is controlled by subroutine MAXDP.
3. Subroutine CUBIC

This subroutine controls the cubic spline interpolations for subroutines TURBUL and INIVEL. These slope-based cubic spline interpolations are used to compute velocity gradients and turbulent kinetic energies at the fine grid points during turbulence modelling computations.

4. Subroutine DISPAR

This subroutine is used to calculate the eight distortion factors used by the program. These distortion factors are defined in figure 7 and can be modified by the user. DISPAR is controlled by subroutine DISTRT, a subdriver which controls most of the distortion computations. The actual formulas for the distortion factors are contained in DISPAR.

5. Subroutine DISTRT

Subroutine DISTRT is a subdriver which controls the computation of the distortion factors. Some of the duties of DISTRT includes the following:

a. Calculation of simple distortion parameters; for instance, the locations of the rake or ring with maximum and minimum average pressure.

b. Calculation of average static pressure at the engine face, and the average Mach number.

c. Control subroutines INTERP and DISPAR which continue the distortion factor computations.
6. Subroutine EXTRME

This subroutine manages the computation of extreme values of the distortion factors. Called by subroutine MAXDP, EXTRME controls the solution of the most probable peak distortion level for each of the distortion factors. The peak distortion factor is calculated by adding an incremental distortion level to the steady state distortion. The incremental distortion level is computed via the SEARCH subroutine. EXTRME returns the peak distortion level to MAXDP after summing the steady state and incremental distortion values.

7. Subroutine FINITE

FINITE is a subroutine which is used to solve the finite difference equations for subroutine TURBUL. These equations are the turbulence modelling set formed by an implicit tridiagonal matrix scheme. The elements of the tridiagonal matrix equations, which consist of the turbulent kinetic energies and the turbulent kinetic energy dissipation rates, are formed by FINITE and solved by subroutine TRIDIA. FINITE also computes the relative errors in the turbulent kinetic energy and the turbulent kinetic energy dissipation rate for each of the fine grid points at the compressor face.

8. Subroutine FRF

This subroutine evaluates the mean vortex core size by an iterative inverse solution scheme. FRF evaluates the vortex core size as a function of the filtered-to-unfiltered root mean square total pressure fluctuation level. Subroutine SUMMER evaluates the error function of the vortex core size, and the solution is iterated until the error is small.
9. Subroutine INITL

This subroutine solves for the initial values of the turbulent kinetic energy and the turbulent kinetic energy dissipation rate. These initial values are used as a starting point in the iteration of the solution of these parameters. INITL is controlled by the TURBUL subdriver, which uses the turbulent kinetic energies to solve for the turbulent model in the synthesis of the rms pressure fluctuation levels.

10. Subroutine INIVEL

This subroutine calculates the circumferential and radial velocity gradients at each of the grid points at the compressor face. INIVEL is called by TURBUL and uses subroutine CUBIC to carry out spline interpolations of the velocity gradients.

11. Subroutine INTERP

This is an interpolation subroutine which calculates the total pressure recovery at each of the discrete points in the measurement plane. These points are used to generate the pressure contour map. INTERP uses linear interpolation to find the pressure at points between the pressure probe locations. Two linear interpolations are carried out: a radial one and a circumferential one. The final value is taken to be the average of these interpolations. INTERP is called by both MAINLP and DISTRT; when called by MAINLP, the interpolated values are used to generate the contour map, while DISTRT uses the interpolations to compute the distortion factors. A call to subroutine PRNT has been nulled - it had provided a message when interpolations could not be performed.
12. Subroutine LNPOUT

This subroutine controls some of the output from the program. When called by UNSTDY, LNPOUT prints two of the tables in the output: the Overall Flow Descriptors and the Flow Distortion Factors. The Overall Flow Descriptors table gives values for some of the simple distortion parameters, and the Flow Distortion Factors table gives values for the eight user-defined distortion factors. LNPOUT prints these tables for both the steady-state and peak instantaneous case. In addition, LNPOUT prints the distortion contour maps for the steady-state and peak instantaneous case. UNSTDY controls LNPOUT by passing a control parameter; LNPOUT then selects the output to be printed.

13. Subroutine MAINLP

Subroutine MAINLP controls the calculations involved in the development of the pressure distortion contour map. MAINLP calls on INTERP to calculate the pressure at any of the discrete points at the compressor face, given the pressure at the probe locations. Subroutine SYMBLE then assigns a symbol for each of the discrete points, based on the pressure found by INTERP. MAINLP then passes the pressure and symbol information to the main driver, and ultimately to LNPOUT for printing of the distortion map.

14. Subroutine MAXDP

This subroutine is a subdriver which controls the computation of the peak distortion levels for the eight distortion factors. MAXDP computes the mean vortex size and the mean rms pressure fluctuation level, from which the peak
instantaneous distortion is derived. MAXDP also controls the calculations involved in producing the effects of other parameters on the peak distortion, like the vortex flux rate and engine filters, via subroutine RATK. Subroutine RSIGMA is called to compute the filtered and unfiltered rms level of the distortion factors. Subroutine EXTREME then computes the peak instantaneous distortion statistically at 50%, 95%, and 99.7% confidence levels. MAXDP then prints the results in tables, namely the Distortion Factor Extreme Value table and others. The user-selected most probable peak instantaneous distortion factor is also printed. It is this distortion factor that the peak distortion map is based in the iterative matching process.

15. Subroutine NEWPSD

This subroutine is a major subdriver which controls some of the input data and manages most of the computations involved in the prediction of the peak instantaneous distortion. NEWPSD controls the input of the dynamic data, including the filter frequencies, the datapoint dwell time (time on point), identification and program control parameters, and the rms pressure fluctuation data at each of the dynamic probe locations. NEWPSD also passes program execution to the turbulence modelling subroutine, TURBUL, if the user has selected the option of not entering dynamic data. Once the dynamic data has been entered or synthesized, NEWPSD controls subroutines MAXDP and FRF which manage the computations in the peak instantaneous distortion prediction. NEWPSD also prints the dynamic data and the identification and control parameters. NEWPSD is controlled by the main driver and subroutine UNSTDY.
16. Subroutine PFIX

This subroutine has two primary functions. The first part of the routine transforms the steady-state or dynamic distortion data from pressure recoveries to percent differences from the average values. These percents are then used by the mapping routines for the plotting of the pressure distortion contour maps. PFIX also calculates the dynamic pressure and Mach number at each of the pressure probe locations as a secondary function. The face-average Mach number is also computed by PFIX. PFIX is called by the main driver in the steady-state case, and UNSTDY in the peak dynamic estimation case.

17. Subroutines PFX and PFXL

These twin subroutines are used in the computation of the eddy (vortex) flux rate as a function of the distortion level. The difference between the two subroutines is in the computation of the vortex flux rate which depends on the magnitude of the ratio of steady-state to root mean square distortion: when this ratio is greater than 2.0, PFX is called, while PFXL is called when the ratio is less than 2. The computational procedure for these two cases is somewhat different and an error would probably occur during computations which involve logarithms and exponentials if the cases were not separated.

18. Subroutine PRNT

This subroutine controls the printing of steady-state and peak instantaneous pressure arrays, the printing of some of the titles and the listing of messages in the output.
19. Subroutine RATK

RATK is a subroutine which evaluates the effect of the engine filter frequency, FO, on the root mean square distortion level. The variation of rms distortion with engine filter frequency is analytically determined.

20. Subroutine RSIGMA

This subroutine is called by MAXDP and computes the root mean square distortion level for the eight distortion factors. The routine is divided into separate groups for individual distortion factor evaluations.

21. Subroutine SEARCH

Subroutine SEARCH controls the computation of a peak distortion parameter which is used by EXTRME to form an estimation of the peak instantaneous distortion level. The ratio of the difference between the peak and steady-state to the rms distortion is solved for in an iterative search for the peak distortion level.

22. Subroutine SUMMER

This subroutine evaluates the error function in the iterative calculation of the mean vortex core size. SUMMER is called by FRF.
23. Subroutine SYMBLE

This subroutine supplies the mapping symbols for the generation of the compressor face pressure distortion contour map. Called by MAINLP, SYMBLE assigns a symbol for each discrete point at the engine face, depending on the pressure indicated at that point by the interpolation routine, INTERP. The spelling of SYMBLE was selected to avoid possible conflicts with library functions in some compilers.

24. Subroutine TRIDIA

Subroutine TRIDIA solves the tridiagonal matrix equations in the turbulence modelling computations. TRIDIA is controlled by subroutine FINITE, which sets up the finite difference equations to be solved by TRIDIA.

25. Subroutine UNSTDOY

This subroutine is the primary subdriver responsible for the predictive evaluation of the peak instantaneous distortion. Called by the main driver of MAXIDYN, UNSTDOY controls the input and output of dynamic data, manages the computations leading to the peak distortion prediction, and controls the output of results. Some of the more important activities and functions of UNSTDOY are listed below:

a. Call NEWPSD to input identification and data control parameters for the test run.

b. Compute compressor face averaged dynamic pressure and Mach number, inlet vortex properties, and other parameters leading to the peak distortion prediction.
c. Call subroutine LNOUT to print some of the tables of distortion data, and the distortion contour map.

d. Call subdriver NEWPSD to read in and analyse the dynamic data or select the turbulence modelling routines if there is no dynamic data in the input file.

e. Control the subroutines which iteratively evaluate the most probable peak distortion level and print the results.

26. Subroutine TURBUL

TURBUL is the subdriver responsible for the turbulence modelling prediction when there is no dynamic data in the input file. TURBUL controls subroutines CUBIC, INITL, INIVEL, FINITE, TRIDIA, and PRNT in the synthesis of simulated dynamic data for processing by the subdriver UNSTDY. TURBUL is called by subroutine NEWPSD when the user specifies the "no dynamic data" option in the input data file. TURBUL assigns a finite-element grid to represent the discrete points on the compressor face for the finite difference analytical scheme. The boundary conditions for the turbulence model are estimated based on the total pressure measurements from the steady-state data, and the initial values of the turbulent kinetic energy and dissipation rate are found via INITL. The inlet face velocities are then found via INIVEL, and the turbulent equations are solved by FINITE. These result in estimates for the rms total pressure fluctuation levels, which are then fed back to NEWPSD for the computation of the most probable peak instantaneous distortion.
Figure 1. Block Diagram Subprogram Arrangement
II.B. TYPICAL DATA RUN SEQUENCE DESCRIPTION

A typical data run of the MAXIDYN dynamic distortion prediction program can be traced as follows.

The main driver initiates the data input sequence with the reading of control parameters and the inlet pressure probe configuration. After the radial and angular locations of the probe rings and rakes are read in, subroutine NEWPSD is called to read in the engine filter frequency, the rms dynamic data cut-off frequency, the data-point dwell time, or the length of time in which the dynamic data is measured, and the specific distortion factor which the user selects as primary for the peak instantaneous distortion analysis.

The main driver then reads in any data identification titles which the user may elect to input. The resulting set of comments are printed at the top of each page of the output. If an "end of file" or "endjob" instruction is entered at this point, program execution is aborted. After the titles are read in, the main driver reads in the base radial profile and steady-state pressure array. The steady-state pressure recoveries are stored into the instantaneous array as a starting point for the peak instantaneous computations.

Subroutine PRNT is then called to print the table of steady-state pressures and the base radial profile. These items are included on the first page of the output. Subroutine PFX is called next to compute the face-average Mach number. Subroutine DISTRT is then called to control the computation of the steady-state distortion factors.

Subroutine DISTRT is a subdriver which manages distortion factor computations. DISTRT computes the simple distortion parameters before calling subroutines INTERP and DISPAR to calculate the eight primary distortion factors. Subroutine
PRNT is called if there are an insufficient number of probe rings to allow accurate radial interpolation for some distortion factors, in which case a message to that effect is printed in the output. Subroutine INTERP is called to carry out circumferential interpolations at discrete locations on each of the probe rings, in preparation for the computation of the distortion factors by DISPAR. This subroutine contains a set of sample distortion factor which can be modified by the user as desired. The results of these computations are eight primary steady-state distortion factors used to define the distortion level at the compressor face. After computation of the steady-state distortion level is completed, DISTRT returns control to the main driver.

The main driver then calls subroutine PFIX to set up certain parameters required to develop the distortion contour map for the steady-state case. A "dummy ring" of probes is set up to enable interpolations through the centerbody. PFIX then transforms the input pressure measurements into parameters used by the map-generating subdriver routine MAINLP. MAINLP controls subroutines INTERP and SYMBLE which generate the symbols in the distortion map. INTERP interpolates the pressure at the discrete locations on the engine face based on the steady-state input data, while SYMBLE assigns a character based on the interpolated value at each of the discrete points. After all interpolations and symbol assignments have been completed, MAINLP returns program control to the main driver. At this point the steady-state distortion has been completely defined and the dynamic distortion evaluations are commenced with the calling of the main subdriver, UNSTDY.

UNSTDY controls the subroutines and subdrivers which compute the total pressure fluctuation levels which translate into so-called "delta pressures". These are added to the steady-state pressures to produce the dynamic distortion level and the most likely peak dynamic distortion. After all of the dynamic calculations are completed, UNSTDY returns to
the main driver to start another data run. Before this takes place, however, the main subdriver, UNSTDY, manages all of the dynamic data input and calculations, or the dynamic data simulation if the user selects this option.

After setting initial values for some of the vortex properties, UNSTDY calls on NEWPSD to read in inlet operating parameters and some program control parameters. Most of the inlet parameters are non-functional, that is they are not involved in distortion computations, but rather are of interest for identification and comparison purposes. One control parameter, NTUR, allows the user to select the no-dynamic-data option, or to input the required dynamic data conventionally. After checking the control parameters for errors, assigning default values if necessary, NEWPSD returns to UNSTDY, which evaluates the flow velocity and Mach number, and the vortex properties. LNPOUT is called to print the simple distortion parameters and flow descriptors, and the distortion factors for the steady-state case. After printing the steady-state vortex properties, UNSTDY again calls LNPOUT to print the steady-state distortion contour map. Subroutine NEWPSD is then called to begin the evaluation of the most probable peak instantaneous distortion.

After printing out the identification and control parameters, NEWPSD branches according to the dynamic data option selected by the user. If the no-dynamic-data option has been selected, NEWPSD calls the turbulence modelling subdriver, TURBUL, to compute the rms fluctuation levels which would otherwise be input as data. After setting up a fine grid at the compressor face for finite element modelling of the flow distortion, TURBUL controls subroutines CUBIC, PRNT, INIVEL, FINITE and TRIDIA in the development and solution of the turbulence equations. Subroutine INITL sets initial values for the turbulent kinetic energy, INIVEL computes the velocity gradients, and subroutine FINITE uses finite difference formulations to solve the turbulence model. CUBIC performs cubic spline interpolations and TRIDIA solves tridiag-
gonal matrices generated by the finite difference equations. TURBUL then calculates the rms total pressure fluctuation levels at each of the probe locations, and the results are printed. Control is then returned to subdriver NEWPSD, and program execution continues as if the dynamic data had been input, rather than computed.

If the user selects the option for the reading in of dynamic probe data, then these data are input at this point in program execution. In either case, NEWPSD then calls subroutine FRF to evaluate the vortex core size as a function of the filtered-to-unfiltered rms pressure fluctuation level ratio using an iterative scheme. FRF calls subroutine SUMMER to evaluate the error function of the inverse solution. After the vortex core size is found, the results are printed by NEWPSD. When all of the dynamic probe data have been read in, subroutine MAXDP is called to compute the most probable maximum instantaneous distortion levels.

MAXDP is the subdriver which controls the computation of the most probable maximum peak in the distortion level. After determining the mean values for the vortex core size and filtered-to-unfiltered rms pressure fluctuation ratio, and the effects of engine filters and vortex flux rates via subroutines RSIGMA and RATK, the rms and mean instantaneous levels are computed by adding a "delta" distortion value to the steady-state value. Subroutine EXTRME is then called to evaluate the most probable (50% confidence level) extreme value of the peak instantaneous distortion. EXTRME utilizes subroutine SEARCH which controls the twin subroutines PFXL and PFX in the determination of the "delta" distortion used to find the maximum instantaneous distortion. EXTRME is also used to determine the distortion factor extreme values for the 95% and 99.7% confidence levels, using the same plan as for the 50% confidence level. After printing the results of these computations, program control is returned to NEWPSD, and then back to UNSTDY.
After re-evaluating the vortex properties for the maximum instantaneous case, UNSTDY finds the pressure recoveries at each of the probe locations based on the predicted maximum instantaneous distortion and the steady-state data. Subroutine PRNT is called to print some output, then PFIX is called to compute flow velocities and Mach number at each of the probe locations. The face-average Mach number for the peak instantaneous case is also determined by PFIX. In the same manner as with the steady-state case, subroutine DISTAT manages the computation of the distortion factors given the total pressure recoveries found by UNSTDY for the maximum instantaneous distortion case. Subroutine MAINLP controls the printing of the pressure distortion contour map for the peak instantaneous case as for the steady-state case, and LNPOUT is again called to assist with the printing of output of the peak instantaneous data. After all the output for the test run has been printed, UNSTDY returns to the main driver. The main driver checks for additional sets of data or new test cases. If there data, then program execution begins with the reading in of data titles and the steady-state pressure data for the new case. If an END OF FILE or ENJOB command is encountered, meaning there is not an additional test case.

In summary, the MAXIDYN dynamic distortion program computes the most probable maximum peak instantaneous distortion given the steady-state distortion data and limited dynamic data. After reading in the steady-state pressure recoveries and computing the steady-state distortion factors, the steady-state distortion contour map is printed along with the distortion data. The average rms pressure fluctuation level is then used to determine the most probable peak instantaneous distortion. The rms fluctuation data may be read in, or simulated by the turbulence modelling routines. After the prediction for the most probable peak distortion level has been made, a new distortion contour map
is generated to represent this case.

The results of the calculations in the MAXIDYN distortion program are printed on several pages of output. This material includes a listing of all input data, the steady-state distortion factors and parameters, the properties of the convecting vortex used to describe the flow in the inlet, the dynamic rms pressure fluctuation data and/or turbulence modelling data, and the pressure distortion contour maps for the steady-state and maximum instantaneous cases. Details on the input and output data are provided in their respective sections.
III. INPUT DATA DESCRIPTION

The input data are divided into three primary groups. The first group defines the inlet pressure probe arrangement at the measurement plane, and some data control parameters. The second group includes identification titles and the steady-state inlet distortion data. The last group is the "dynamic data" - the rms total pressure fluctuation levels - for each of the probe locations. These data may be limited to as few as two probes, or omitted entirely as an option to utilize the turbulence modelling dynamic data simulation capabilities of the program.

The general arrangement and formatting rules for the input data are given in Figures 2 and 3. Further illustration on the arrangement can be found in the sample problems in Section V. The following is a description of the input data items, presented in the order in which they are read by the software. Items marked with an asterisk (*) can be omitted from the input file without disrupting program execution. In this case default values are usually assigned, or simulated in the case of the dynamic data when turbulence modelling has been selected by the user.

The first group of input data include specifications for the inlet probe configuration, data filter frequencies, data point dwell time, and a parameter with which the user may select the specific distortion factor used in the generation of the distortion contour maps. NR and NP are the total number of probe rings and rakes, respectively, and RACL and ANGLOC are the radial and angular locations of the probes. KD is the distortion factor key used to select one of the eight distortion factors available in the program.
The time on point, or data point dwell time, $T$, represents the duration of time in which the rms pressure fluctuations are measured and calculated. $F_0$ and $F_{CO}$ are the engine filter and rms dynamic data cutoff frequencies respectively. Further information can be found for each of these variables in the detailed descriptions below:

$NR$ is an integer corresponding to the number of pressure probe rings used in the test run. $NR$ should include static pressure rings located at the centerbody hub and at the outer radius, even if these are not included in the instrumentation, so that the distortion contour map resembles the engine face geometry. If, for example, there are five total pressure probes located along the inlet rakes, $NR$ should be entered as seven to account for the static pressure probes.

$NP$ is an integer corresponding to the number of pressure probe rakes used in the test run. These rakes are generally positioned between the hub and the inside surface of the nacelle, and are evenly spaced along radii around the centerbody hub. $NR$ represents the number of probes along the rakes.

$RADLOC$ is a one-by-$NR$ array of real numbers corresponding to the radial locations of the pressure probes placed along the probe rakes. $RADLOC$ includes the radial location of the centerbody hub, as well as the outer radius of the inlet at the nacelle inner surface. $RADLOC$ may be dimensional, or a dimensionless fraction of the outer inlet radius. Units may be arbitrary in the dimensional case. It is noted, however, that the vortex dimensions will be in terms of the dimensions of $RADLOC$. See figure 4.
ANGLOC is a one-by-NP array of real numbers which correspond to the angular locations of the probe rakes. The units of ANGLOC are degrees, with the top rake being 'zero' and with the angle increasing clockwise, as viewed from the front. See Figure 4.

KD is an integer with which the user selects the distortion factor of primary interest in the test run. Of eight available distortion factors included in the program, one is selected for use in generating the peak instantaneous distortion contour map which matches and represents the predicted peak distortion level. Definitions of the eight distortion factors provided in the program are given in Figure 9. Below is a key for use in selecting the desired distortion factor. Entering an integer (1 through 8) effects the selection of the distortion factor indicated below:

1: KTHETA (Pratt & Whitney circumferential distortion #1)
2: KD2 (Pratt & Whitney circumferential distortion #2)
3: IOC (General Electric circumferential distortion)
4: IDR (General Electric radial distortion factor)
5: KRA (Pratt & Whitney radial distortion factor)
6: KA2 (Pratt & Whitney combined distortion factor)
7: DSPR (Delta [loss in] stall pressure ratio)
8: ID (General Electric combined distortion factor)

It is noted that are two distinct Pratt & Whitney circumferential distortion factors from two distinct definitions (see Figure 9). The combined distortion factors are found by combining the circumferential and radial distortion factors. In the case of KA2, the circumferential distortion factor used in the combination is KTHETA. The distortion factors represented in this program are only examples - the user is free to redefine or modify them at will.
This is the dynamic data time on point or "dwell" time during which the total pressure fluctuation level is measured and the root mean square value is determined. The units are seconds, and a default value of one second is assigned if no value is input. T may be omitted if the no-dynamic-data option has been selected for all test cases.

This is the engine filter frequency, in Hertz. F0 is used in the computation of the mean peak instantaneous distortion levels. The purpose of the filter is to remove the effect of engine speed on the measured pressure fluctuations. A default value of 500 Hz is assigned if no value is input.

This is the low pass cutoff filter frequency used when measuring the filtered rms total pressure fluctuation levels. The ratio of filtered-to-unfiltered mean square pressure fluctuations are used to predict the most probable maximum instantaneous distortion. The units of FCO are Hertz, with a default value of 1000 Hz, when no value is input directly.

The second part of the input data includes title blocks, the steady-state total pressure recovery array, and several inlet flow parameters. TITLE1 and TITLE2 provide space for 160 characters of identifying comments. PS is an NR by NP array of steady-state pressure recoveries. The base radial profile BRP is the ratio of ring-average pressures to the face-average pressure. ALPHA and PSI are the angle of attack and sideslip angle respectively, and the freestream Mach number is given by MO. The flow velocity at the engine face is U2. BF, CKP, and RKP are weighting factors used in the computation of combined radial/circumferential distortion factors. The mass flow ratio, MFR, gives an indication of the
the mass flow rate before and after inlet duct bleed-off.
NTUR is a control parameter which allows the user to select
the option of inputting the dynamic data, or having these
data simulated by the turbulence modelling scheme. Finally,
SPTRC is the total pressure recovery through the inlet shock
system in a supersonic inlet.

More detailed descriptions of the data items in the
second group are given below. Most of these data may be de-
leted from the input data deck, without causing any real
difficulties. Many of these are simply included for identi-
fication purposes, while others are provided with default
values to avoid data errors. Default values are included in
the detailed descriptions below:

**TITLE1** and **TITLE2** are alphanumeric hollerith arrays used
for test run identification. Two lines of up to eighty
characters each are available for information such as
engine/inlet type, Mach number, angle of attack, yaw
angle, altitude, and so forth. **TITLE1** and **TITLE2** are
printed at the top of each page of output for easy
reference. **TITLE1** also is used to check for an END OF
FILE or ENDJOB command at the end of the data file, in
which case program execution is stopped.

**EFP** is the compressor face base radial profile. This is
defined as the ratio of the average pressure around a
ring to the face-average pressure. **BRP** is a one-by-NR
array with a value at each of the radial locations gi-
ven by RADLOC. **EFP** has a default value of 1.

**PS** is an array of steady-state total pressure recoveries.
The dimensions of the array are NR rows by NP columns.
The rows of **PS** are pressures at radial locations RADLOC
while the columns are at angular locations ANGLOC. The
first and last rows of **PS** are static pressures associ-
ated with the static pressure rings located at the
centerbody hub and the surface of the inlet at the engine face. These static pressures can be measured or computed values. The pressure array is eventually used to generate the distortion contour map, and also is the basis for finding the instantaneous pressure array, \( P \).

**ALPH** is the aircraft/inlet angle of attack relative to the freestream, typically in degrees. ALPH is used for run identification, and does not enter into any computations.

**PSI** is the aircraft/inlet sideslip or yaw angle relative to the freestream, typically in degrees. Like ALPH, PSI is of interest for identification and analysis, and does not enter into the computations.

**MO** is the freestream Mach number. Of interest for identification of test runs, MO does not enter into calculations.

**U2** is the flow velocity in the inlet at the compressor face, in feet per second.

**BF** is the b-factor used as a weighting term for the computation of the combined radial and circumferential distortion factor \( KA_2 \) (Pratt & Whitney). BF is multiplied by the radial contribution, and the result added to the circumferential distortion to get the combined distortion factor. BF has a default value of 1.

**CKP** is the circumferential weighting factor used in the computation of ID, the General Electric combined radial/circumferential distortion factor. CKP is multiplied by the circumferential distortion, then added to the radial contribution. CKP default value is 16.4.
RKP is the radial weighting factor used in the computation of ID, the General Electric combined radial/circumferential distortion factor. RKP is multiplied by the radial distortion factor, and the result added to the circumferential contribution. The default value for RKP has been set at 11.1 in the program.

MFR is the inlet mass flow ratio, defined in terms of the streamtube geometry. Specifically, MFR is the ratio of actual inlet mass flow rate, to the maximum inlet mass flow rate. The maximum inlet mass flow rate is defined as the product of the freestream velocity times the inlet slit area. Low MFR implies a large amount of inlet spillage. MFR is generally a function of the engine thrust level and flight velocity.

NTUR is a control parameter which allows the user to select the turbulence modelling dynamic data simulation capabilities of the program as an alternative to using measured dynamic data. Inputting a value of 1.0 for NTUR causes the program to branch to the turbulence modelling routines within the program. A value of zero or defaulting the input of a value causes the program to branch to the routines requiring the input of dynamic data.

SPTRC is the total pressure recovery through the inlet shock system of a supersonic inlet duct. For subsonic and transonic inlets, SPTRC is equal to one. If SPTRC is unknown for an arbitrary supersonic inlet, it can be estimated by using Figure 5, with a value of 0.90 being reasonable as a rough preliminary estimate for most inlet configurations. A default value of 1.0 has been set in the program. It is noted that SPTRC should always be less than or equal to one.
The third part of the input data consists of the dynamic data. These data consist of rms total pressure fluctuation levels from fast-response total pressure probes. The number of dynamic probe data sets in each run is fully under control of the user — within certain limitations. In a normal run, the number of dynamic probes is equal to the number of steady-state total pressure probes. In a reduced dynamic data run, the number of dynamic probes can be anywhere from two to as many as would be used in a normal run. Finally, if the user selects the no dynamic data option by setting $NTUR$ equal to 1.0 (see previous page), these dynamic data may be completely omitted from the input data.

There are four input variables in the dynamic data. $NPG$ is a run identification code, $NPR$ is the probe identification code, $RS$ is the filtered to unfiltered ratio of mean square pressure fluctuation levels, and $SIG$ is the root mean square level of total pressure fluctuations. Further details on these data can be found below.

$NPG$ is a code number for identifying data runs. This user definable integer can be completely arbitrary, though entering a value of zero, or defaulting the input signals the end of the dynamic data set. Therefore $NPG$ can be any integer greater than one. When all of the dynamic data has been input, entering a value of zero for $NPG$ (or leaving it blank) will signal the program to move on to the next phase of computations.

$NPR$ is the numeral designation for the location of the dynamic probe. This identification code can be found with the aid of Figure 4, which is given as an example for the convenience of the user. Other inlet probe and instrumentation configurations may result in a different numeration scheme, so Figure 4 should be used as a guideline.
RS is the ratio of filtered to unfiltered mean square pressure fluctuations. RS is found by squaring the ratio of the rms pressure fluctuation level filtered at the cut-off filter frequency $FCO$, to the unfiltered level. This ratio is used in the prediction of the maximum instantaneous distortion level, and a default value of 0.50 has been included in the program. In addition, a maximum value of 0.70 has been set to avoid errors in certain computations. These values are easily modified, if necessary, by the user.

SIG is the unfiltered root mean square value of the total pressure fluctuations measured by the dynamic (fast response) total pressure probes. Generally, the units of SIG are identical to those of the PS array, which are nondimensional total pressure recoveries (local total pressure divided by the freestream or inlet lip total pressure).

Sample problems have been included in this manual to illustrate the arrangement of the input data, and to further clarify the utility of the various capabilities of the program. Figures 2 and 3 show formatting rules and the general arrangement scheme of the input data.
Figure 2. Batch Input Data Deck Formatting Arrangement
<table>
<thead>
<tr>
<th>FORTRAN STATEMENT</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>NP</td>
</tr>
<tr>
<td>RADLOC(1)</td>
<td>RADLOC(2)</td>
</tr>
<tr>
<td>ANGLOC(1)</td>
<td>ANGLOC(2)</td>
</tr>
<tr>
<td>KD</td>
<td>T</td>
</tr>
<tr>
<td>TITLE1</td>
<td></td>
</tr>
<tr>
<td>TITLE2</td>
<td></td>
</tr>
<tr>
<td>BRP(1)</td>
<td>BRP(2)</td>
</tr>
<tr>
<td>PS(1,1)</td>
<td>PS(1,2)</td>
</tr>
<tr>
<td>PS(2,1)</td>
<td>PS(2,2)</td>
</tr>
<tr>
<td>PS(NR,1)</td>
<td>PS(NR,2)</td>
</tr>
<tr>
<td>ALPH</td>
<td>PSI</td>
</tr>
<tr>
<td>NPG</td>
<td>NPR1</td>
</tr>
<tr>
<td>NPG</td>
<td>NPR2</td>
</tr>
<tr>
<td>NPG</td>
<td>NPR3</td>
</tr>
<tr>
<td>0.</td>
<td>0.</td>
</tr>
</tbody>
</table>

**Figure 3. Input Data File Formatting Arrangement**
Note: NR = 7 = number of probe rings
NP = 8 = number of probe rakes

Figure 4. Ring, Rake, and Probe Assignments for a typical instrument configuration
IV. PRINTED OUTPUT DATA DESCRIPTION

The printed output of the MAXIDYN dynamic distortion program consists of from five to seven pages of data (sixty lines on each page) depending on the options selected by the user. The first two pages pertain to the steady-state distortion characteristics, with the steady-state pressure array, vortex properties, distortion factors, and related parameters, along with the steady-state distortion contour map. The next page or two involves the dynamic data, with rms pressure fluctuations levels, turbulence data, and some additional flow parameters. The following page is a listing of a summary of distortion factor extreme values as predicted in the Melick prediction technique. The final two pages are similar to the first two, but pertain to the peak instantaneous distortion level.

The following is a page-by-page description of the output. Since the content of the output depends on the dynamic data input option chosen by the user, some variables described may not apply to a specific case. Data affected by the dynamic data options are so indicated, and all of the affected data are found in the middle pages with the dynamic data groups. Some data are provided with default values as described in the input section, and the default values are repeated here for convenience.

Page 1

The first page of output consists of five tables of steady-state distortion data. Immediately below the title block provided by TITLE1 and TITLE2, the steady-state total pressure recovery array is printed. The rows in this matrix
are identified with the RADLOC radial probe locations, and the columns with the ANGLOC angular rake locations. The static pressure rings associated with the innermost and outermost RADLOCs are not included in the pressure array. The numbers of the pressure array P are otherwise identical to the input array PS.

Beneath the pressure array is a table of base radial profiles. These are defined as the ratio of probe ring average pressures to the average pressure over the entire engine face. For each radial location RADLOC (including static rings) a value of PTR/PTA is given. This BRP array is identical to the input array BRP. A default value of 1.0 is assigned for each term in BRP when no value is input.

The next table is a listing of the overall flow descriptors. These simple distortion parameters are used to evaluate the distortion factors and vortex properties. The terms appearing in this table are defined below:

PTMIN (also PTMN and TMMIN) This is the minimum total pressure recovery value from the pressure array, P, exclusive of the static pressure data.

PTMAX (also PTMX and TMMAX) This is the maximum total pressure recovery value from the pressure array, P, exclusive of the static pressure data.

PTAVG (also PTAV and TMAVG) This is the face-average total pressure recovery from the pressure array, P, exclusive of the static pressure data.

PSAVG (also SMAVG) This is the average value of static pressure from the static pressure data in the pressure array, PS. The two static pressure rings at the centerbody hub and outer radius of the inlet supply these data.
QAVG (also QAV) This is the face-average dynamic pressure
recovery, computed as the difference between the average
total pressure recovery and the static pressure.
Mathematically stated, QAVG = PTAVG - PSAVG.

The three remaining terms in the flow descriptors table
are algebraic manipulations of PTMAX, PTMIN, and PTAVG. These
terms are self explanatory - for example, (PTMX-PTMN)/PTAV
is interpreted as the difference between the maximum and
minimum total pressure recoveries, divided by the average
value.

Following the overall flow descriptors table is a table
of flow distortion factors. The eight distortion factors
listed in this table are representative of a variety avail-
able to the industry, and are intended as examples. The user
is free to redefine the distortion factors within the pro-
gram. Next to the distortion factors in the table are some
weighting factors used in calculating combined distortion
factors. The eight distortion factors and their weighting
factors are described below:

K-THETA (also KTHETA, K8, and KTTA) Pratt & Whitney
circumferential distortion factor [#1] - see Figure 9.

KD2 Pratt & Whitney circumferential distortion factor
[#2] - see Figure 9.

(IDC)-MAX General Electric maximum circumferential dis-
tortion factor - see Figure 9.

(IDR)-MAX General Electric maximum radial distortion
factor - see Figure 9.

KRA Pratt & Whitney radial distortion factor - see Fig-
ure 9.
KA2  Pratt & Whitney combined radial/circumferential distortion factor - see Figure 9.

DSPR Delta (loss in) stall pressure ratio - see Figure 9.

ID  General Electric combined radial/circumferential distortion factor - see Figure 9.

B-FACTOR (also BF) Radial weighting factor used in computing KA2 - see Figure 9.

BSF Intermediate weighting factor used in computing ID - see Figure 9.

KC (also CKP) Circumferential weighting factor used in computing ID - see Figure 9.

KR (also RKP) Radial weighting factor used in computing ID - see Figure 9.

Beneath the flow distortion factors table is a list of vortex properties. These properties are described below:

THMN (Theta Min) Angular location of the probe rake with the minimum average total pressure recovery, in degrees. The 'zero' rake is the upper vertical rake. THMN is one of the ANGLOC angular locations, and depends on the steady-state pressure array.

RKMN The average pressure recovery along the rake designated by THMN.

THMX (Theta Max) Angular location of the probe rake with the maximum average total pressure recovery, in degrees. See THMN, above.
RKMX The average total pressure recovery along the rake designated by THMX.

\(DTH\) (Delta Theta) The angular difference between \(THMX\) and \(THMN\).\( DTH = THMX - THMN.\)

\(THETA\) (also \(THE\)) The angular location of the rake midway between the rakes designated by \(THMX\) and \(THMN\).\( THETA = \frac{1}{2}(THMX + THMN).\)

\(A1\) (also ART, etc.) The vortex core size which fits within the boundaries of the rakes designated by \(THMN\) and \(THMX\). \(A1\) represents the size of the steady-state vortex.

\(G1\) (also GAMMA) The orientation angle of the steady-state vortex. This is used to satisfy the amplification of the steady-state distortion level by the vortex field, in determining the peak distortion level.

Page 2

The second page of the printed output is the pressure distortion contour map for the steady-state case. A representation of the high and low pressure regions at the compressor face of the engine, this map is useful in identifying and visualizing the nature of the distortion of the flow through the inlet. Symbols are used for identifying the pressure at any point in the measurement plane, and a key to the mapping symbols is provided. The numbers provided in the key are interpreted to mean the percent difference between the local pressure and the face-average pressure - for example, an indication of \(-3.0\) is interpreted as three percent below the average pressure over the engine face.
The third page of output is related to the dynamic data, which may be included in the input file, or simulated by the turbulence modelling scheme. The content of this page (and sometimes the next page) depends on whether the dynamic data is input or simulated, as described in the cases below:

**Case 1: Dynamic Data is Input**

Immediately following the title block is a listing of several inlet parameters, along with some parameters used with the dynamic data. These parameters are described below:

- **T** The dynamic data time-on-point, or dwell time during which the dynamic data are measured for each of the dynamic probes. The units are seconds.

- **F0** The engine filter frequency, in Hertz. F0 is often associated with the engine rpm speed.

- **RT** The outer radius of the inlet at the compressor face, or the location of the outermost static pressure probes - the maximum value of the RAOLOC array.

- **RI** The inner radius of the compressor face, the radius of the centerbody hub, or the minimum value of the RAOLOC array.

- **ALPH** (also ALPHA) The inlet angle of attack, relative to the freestream, in degrees.

- **PSI** The sideslip or yaw angle of the inlet in degrees.

- **SPTRC** The total pressure recovery through the inlet shock

41
SPTRC (cont'd) system in a supersonic inlet configuration. For supersonic inlets SPTRC is less than 1.0, while subsonic and transonic inlets will have SPTRC equal to 1.0.

MO The freestream Mach number.

ETA The face-average total pressure recovery from the steady-state pressure array, PS.

MFR The mass flow ratio of the inlet system. This gives an indication of how much of the inlet air remains after bleed-air has been removed.

U2 The inlet flow velocity at the engine face in feet per second.

QPT2 The dynamic pressure divided by the total pressure. 
QPT2 = QAVG/PTAVG, where QAVG is the face-average dynamic pressure and PTAVG is the face-average total pressure. (see "overall flow descriptors" table description in Page 1 descriptions.)

RS AT FC = The cutoff frequency of the rms dynamic data. 
[see FCO in input data descriptions]

The next table of data includes the dynamic data as input by the user. For each dynamic probe location selected, values for the rms pressure fluctuations and the resulting vortex core size are given. The specific terms in this table are described below:

PROBE The numerical designation for the location of a dynamic probe. See Figure 4
RS  The ratio of the filtered to unfiltered mean square total pressure fluctuation level.

SG/PTZ (also SIG) The unfiltered rms total pressure fluctuation level.

A/RT (also ART) The mean vortex core size, based on the magnitude of SIG. The vortex core size is nondimensionalized to the inlet radius, RT.

Immediately below the dynamic data table, the average value for the rms unfiltered total pressure fluctuation level, SIG, is printed along with the average vortex size. These terms are actually used in the Melick peak distortion prediction technique (Reference 5).

In some cases, specifically when the number of dynamic probes in the dynamic data is relatively few, the distortion factor extreme value table is printed on page three immediately below the dynamic distortion table. The reader should refer to Page 4 output descriptions for identification of the terms in this table.

The following is a description of the terms on page 3 of the output when the no dynamic data option is selected in the input file, that is, when the dynamic data is simulated by the turbulence modelling techniques:

Case 2: Dynamic Data is Simulated

The data appearing on the third page of output includes all of the data appearing in Case 1, excluding the dynamic data listing. The reader should refer to the descriptions in Case 1, except for the dynamic data - PROBE, RS, SIG, and ART. These terms are replaced by three tables of turbulence calculations, and the simulated values of SIG for each of the available dynamic probe locations.
The following is a descriptive listing of the data on the third page of output when the dynamic data are simulated by the turbulence modelling technique. The parameters listed in Case 1 are included in these data, and the reader should refer to the description listing there for details.

The first table following the inlet and control parameter listing gives dimensionless velocities of the flow at the compressor face for each of the pressure probe locations. These velocities are calculated based on the steady-state pressure data from the input file. The rows of the velocity array are associated with the ANGLOC angular locations of the rakes, while the columns are associated with the RADLOC radial probe locations along the rakes. The first and last columns reflect the static pressure probes located at the centerbody hub and outer inlet radius.

Following the table of dimensionless velocities for each of the probe locations is a listing showing the iteration of the turbulent kinetic energy, and the kinetic energy dissipation rate. The relative error in these terms is minimized during the iterations. The first column shows the error in the turbulent kinetic energy; the second, the error in the turbulent kinetic energy dissipation rate, and the third gives the sum of these two. These errors should decrease rapidly within the thirty iterations allowed. Once the errors have been minimized, the turbulent kinetic energy and dissipation rates are used to generate the synthesized dynamic data.

The next table is a listing of the results of the turbulence calculations, including the synthesized dynamic data and the turbulence modelling parameters. This table is similar to the dynamic data table in the Case 1 descriptions, but includes some additional terms. This table is large, and may actually be slipped to the fourth page. The terms appearing in this table are defined on the following page.
**PROBE** The numerical designation of a dynamic probe, used to define the location of the probe. See Figure 4.

**UU** The sum of the squares of the radial and circumferential velocity gradients in (ft/sec)^2.

**E** The turbulent kinetic energy dissipation rate in units of ft^2/sec^3.

**K** The turbulent kinetic energy in (ft/sec)^2.

**SG/PT2** (or SIG) The synthesized unfiltered rms pressure fluctuation level.

Printed below the synthesized dynamic data table are values for the face-average SIG, and the mean vortex size, ART. These values are used to predict the most probable peak instantaneous dynamic distortion level.

Page 4

The fourth page of output is a table of distortion factors and parameters leading to the most probable peak instantaneous distortion for each of the eight sample distortion factors. The terms and distortion factors appearing in this table are described below:

**KITA** (or KTHETA) The Pratt & Whitney circumferential distortion factor, definition #1 (see Fig. 9).

**KD2** The Pratt & Whitney circumferential distortion factor, definition #2 (see Fig. 9).

**IDC** The General Electric circumferential distortion fac-
tor (see Fig. 9).

**IDR** The General Electric radial distortion factor (see Fig. 9).

**KRA** The Pratt & Whitney radial distortion factor (see Fig. 9).

**KA2** The Pratt & Whitney combined radial/circumferential distortion factor (see Fig. 9).

**DSPR** The loss in stall pressure ratio (see Fig. 9).

**ID** The General Electric combined radial/circumferential distortion factor (see Fig. 9).

**STEADY STATE** This column indicates the steady-state values for the distortion factors, as computed from the input distortion data.

**MEAN VALUE** The mean instantaneous distortion level, computed by adding the mean instantaneous rms fluctuation level to the steady-state distortion.

**SIGMA INF** The unfiltered rms distortion fluctuation level.

**SIGMA FO** The rms distortion fluctuation level, filtered at the engine filter frequency, FO.

**MOST PROB** The most probable peak instantaneous distortion level at a 50% confidence level. Statistically, this is the most likely value for the peak distortion level in the statistical prediction analysis. Moving away from this value decreases the probability.
Figure 5. Estimation of SPTRC

note: ———— Conical Shocks
      ———— Oblique Shocks

conical shocks
[dashed lines]

Isentropic Spike
Triple cone
Double cone
Single cone
Normal Shock

number of 2-0 oblique shocks
[solid lines]

Figure 6. Definition of Confidence Levels

0σ = "most probable" or 50% Confidence Level
2σ = 95% Confidence Level
3σ = 99.7% Confidence Level

confidence level = percent of area under curve to left
95% PROB  The peak instantaneous distortion level at a 95% confidence level. This is interpreted as meaning there is a 95% chance the actual peak instantaneous distortion level will be less than the indicated level. The likelihood that the actual peak will reach this level is small.

99.7% PROB  The peak instantaneous distortion level at a 99.7% confidence level - there is a 99.7% chance that the actual peak will be less than this level. It is very unlikely that the actual peak distortion level will ever be this high.

The most probable peak instantaneous distortion level for the distortion factor selected by the user is printed immediately below the distortion factor extreme value table. This distortion factor is used to develop the peak instantaneous pressure array and contour map.

Page 5

The fifth page of output is much the same as the first page, except the data applies to the peak instantaneous distortion rather than the steady-state. The terms in the tables are defined in the descriptions of Page 1, though any references to the steady-state case are understood to be replaced by the peak instantaneous case.

A major difference between the fifth page and the first page is that the vortex properties table has been replaced by a vortex location table, with some new terms. These are defined on the following page. Many of the terms are similar to some of the steady-state vortex properties, though they apply to the peak instantaneous vortex.
\textbf{VBAR} The average vortex strength in terms of the vortex tangential velocity vector nondimensionalized by dividing by the flow velocity at the engine face. This property is used to define the source of the pressure fluctuations.

\textbf{A/RT} (also ART) The vortex core size in terms of the vortex radius divided by the inlet radius. See AY/RT.

\textbf{GAMMA} A vortex orientation angle in degrees, due to the rotation of the vortex core about the x axis. See Figure 10.

\textbf{BETA} A vortex orientation angle in degrees, due to the rotation of the vortex core about the z axis. See Figure 10.

\textbf{AY/RT} (also AYRT) The vortex core size in terms of the vortex radius (the radius at the maximum tangential velocity of the vortex system) divided by the inlet radius. AY/RT is also the same as A/RT.

\textbf{VL} The nondimensional vortex length limit. VL has been set at 999.999 (infinity for all intents and purposes) in the current program, though this is easily altered. VL should represent the true vortex length limit divided by the inlet radius.

\textbf{R/RT} (also RRT) The radial location of the vortex central core. R/RT is a dimensionless value with a maximum value of unity.

\textbf{THETA} The angular location of the vortex center in degrees. Zero degrees is the top vertical position, with positive THETA being clockwise about the engine face.
**VBMAX** The maximum vortex strength in terms of the tangential velocity of the vortex divided by the flow velocity at the engine face. VBMAX also appears as VBM in the FORTRAN coding.

**VBQ** The vortex strength as approximated from the total pressure rms fluctuation dynamic data

**AO/RT** The vortex core size computed from the average of the dynamic data power spectral density (PSD) functions.

---

The sixth and last page of the printed output consists of the pressure distortion contour map for the peak instantaneous case. The terms and parameters appearing with this map are identical to those in the steady-state map. These parameters are described in the Page 2 description in this section.

**SUMMARY OF DEFAULT VALUES**

The following is a summary list of default values for the input/output variables which have such values:

- \( T = 1.000 \)
- \( F_0 = 500 \text{ Hz} \)
- \( F_{CO} = 1000 \text{ Hz} \)
- \( BF = 1.000 \)
- \( RS = 0.500 \)
- \( CKP \text{ (or } KC) = 16.4 \)
- \( BRP = 1.000 \)
- \( MFR = 1.000 \)
- \( SPTRC = 1.000 \)
- \( VL = 999.999 \)
- \( \max RS = 0.700 \)
- \( RKP \text{ (or } KR) = 11.1 \)
V. SAMPLE PROBLEM
V. SAMPLE PROBLEM

A. Introduction

Four sample data sets are provided to illustrate the input/output capabilities of the MAXIDYN distortion program. These problems are taken from provisional data, and represent a variety of inlet operating conditions. The first and second cases are supersonic inlets with a full set of 40 dynamic probes, and a partial set of 14, respectively. The third case is a subsonic inlet with the minimum number of high-response dynamic probes - 2. The final case is a transonic inlet with no dynamic data input. This case makes use of the turbulence modelling capabilities of the program, which simulates the dynamic data.

Some of the primary data parameters are shown in the table of part B, below. Figure 7 gives a complete listing of the input data files for the sample problems. Figure 6 in part C shows the output from the four sample problems. Definitions of each of the terms in the input and output listings may be found in the input and output data descriptions of section II, parts B and C, respectively.

B. Sample Problem Input

The four test cases provided here have similar probe ring/rake configurations. Figure 4 illustrates the arrangement of the pressure probes at the engine face. Some of the main parameters in the input data are tabulated on the following page, with a complete input data listing in Fig. 7.
C. Sample Problem Output

The line-printer generated output for the four test cases is presented in Figure 8. The number of pages of output varies with the dynamic data content, but never exceeds seven pages, unless there are run-time errors (exponential overflows, negative square root radicals, etc.) or compile-time errors. Run-time errors can occur with bad data. The terms given in the output are defined in Section II, part C.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CASE 1</th>
<th>CASE 2</th>
<th>CASE 3</th>
<th>CASE 4</th>
</tr>
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<tbody>
<tr>
<td>NR</td>
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<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>NP</td>
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<td>8</td>
<td>8</td>
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<td>1.430</td>
<td>0.283</td>
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<td>RT</td>
<td>5.169</td>
<td>4.346</td>
<td>1.000</td>
<td>5.000</td>
</tr>
<tr>
<td>KD</td>
<td>3 (IDC)</td>
<td>3 (IDC)</td>
<td>3 (IDC)</td>
<td>6 (KA2)</td>
</tr>
<tr>
<td>T (sec)</td>
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<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>FO (Hz)</td>
<td>500.0</td>
<td>500.0</td>
<td>1000.0</td>
<td>1000.0</td>
</tr>
<tr>
<td>FCO (Hz)</td>
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<td>400.0</td>
<td>500.0</td>
<td>500.0</td>
</tr>
<tr>
<td>ALPH (deg)</td>
<td>4.0</td>
<td>5.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PSI (deg)</td>
<td>0.0</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MO</td>
<td>1.36</td>
<td>2.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>U2 (fps)</td>
<td>514.3</td>
<td>278.5</td>
<td>432.4</td>
<td>575.8</td>
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<td>BF</td>
<td>0.733</td>
<td>0.733</td>
<td>0.733</td>
<td>0.784</td>
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<td>CKP/KC</td>
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<td>-</td>
</tr>
<tr>
<td>RKP/KR</td>
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<td>1.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MFR</td>
<td>-</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
</tr>
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<td>NTUR</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>SPTRC</td>
<td>-</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
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<tr>
<td>probes</td>
<td>40</td>
<td>14</td>
<td>2</td>
<td>0</td>
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</tbody>
</table>

[A dash "-" indicates a defaulted entry, or zero. The program assigns default values in these cases.]
Figure 7. Sample Problem Input Data
<table>
<thead>
<tr>
<th></th>
<th>0.283</th>
<th>0.419</th>
<th>0.594</th>
<th>0.737</th>
<th>0.852</th>
<th>0.953</th>
<th>1.000</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
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<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

--- SAMPLE PROBLEM #3 --- USAF SORBONTE INLET - 22 DEC 1983 ---

<table>
<thead>
<tr>
<th>PART-POINT = 20.00</th>
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</tr>
</thead>
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<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>0.902</td>
<td>0.841</td>
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<tr>
<td>0.886</td>
<td>0.817</td>
</tr>
<tr>
<td>0.857</td>
<td>0.814</td>
</tr>
<tr>
<td>0.835</td>
<td>0.885</td>
</tr>
<tr>
<td>0.825</td>
<td>0.870</td>
</tr>
<tr>
<td>0.804</td>
<td>0.804</td>
</tr>
<tr>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

2040 17:38:00 0.000
2040 34:24:00 0.000

END.TUB

Figure 7 (cont'd)
Figure 7. (cont'd)
--- SAMPLE PROBLEM #1 ---

\[ \mu = 1.36 \quad \alpha = 4.0 \]

### PRESSURE ARRAY

<table>
<thead>
<tr>
<th>RADIUS</th>
<th>0.0</th>
<th>45.0</th>
<th>90.0</th>
<th>135.0</th>
<th>180.0</th>
<th>225.0</th>
<th>270.0</th>
<th>315.0</th>
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<tbody>
<tr>
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<td>0.978</td>
<td>0.981</td>
<td>0.979</td>
<td>0.978</td>
<td>0.978</td>
<td>0.978</td>
<td>0.978</td>
<td>0.978</td>
</tr>
<tr>
<td>2.585</td>
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<td>0.948</td>
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<td>0.979</td>
<td>0.978</td>
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<tr>
<td>3.615</td>
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<td>0.965</td>
<td>0.949</td>
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<td>0.978</td>
<td>0.979</td>
<td>0.978</td>
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<tr>
<td>4.469</td>
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<td>0.970</td>
<td>0.979</td>
<td>0.979</td>
<td>0.979</td>
<td>0.979</td>
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<td>4.967</td>
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<td>0.958</td>
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<td>0.957</td>
<td>0.967</td>
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### BASE RADIAL PROFILE

<table>
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<th>2.585</th>
<th>3.615</th>
<th>4.469</th>
<th>4.962</th>
<th>5.169</th>
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</thead>
<tbody>
<tr>
<td>PTR/PTA</td>
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<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

### OVERALL FLOW DESCRIPTORS

- \( P_{\text{TMN}} = 0.937 \)
- \( P_{\text{MAX}} = 0.981 \)
- \( P_{\text{TAVG}} = 0.966 \)
- \( P_{\text{SAVG}} = 0.860 \)

### FLOW DISSERTATION FACTORS

- \( K = \theta \) 0.0324
- \( K_2 = 138.2 \)
- \( (T\theta) = 0.855 \)
- \( (TDR) = 0.02397 \)
- \( K_R = 0.07476 \)
- \( K_2 = 0.11794 \)
- \( B = 0.73300 \)
- \( B = 0.0470 \)
- \( I_B = 0.01016 \)

### VORTEX PROPERTIES

<table>
<thead>
<tr>
<th>THMN</th>
<th>MKMN</th>
<th>THMX</th>
<th>RKMN</th>
<th>DTH</th>
<th>THETA</th>
<th>A1</th>
<th>C1</th>
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</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.055</td>
<td>135.0</td>
<td>0.975</td>
<td>135.0</td>
<td>67.56</td>
<td>1.178</td>
<td>90.00</td>
</tr>
</tbody>
</table>
Sample Problem #1

\[ \mu = 1.36, \quad \alpha = 0.0 \]

Key to Mapping Symbols:

\[ \begin{array}{cccccccc}
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\end{array} \]

\[ \begin{array}{cccccccc}
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\end{array} \]

\[ \begin{array}{cccccccc}
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} & \text{Pi} \\
\end{array} \]

Average Pressure: 0.964

Figure 8, cont'd.

Original page is of poor quality.
**Figure 8.** (cont'd)

<table>
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<tr>
<th>PRB</th>
<th>RS</th>
<th>SCR/PRT2</th>
<th>A/RT</th>
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</thead>
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<td>0.0326</td>
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<tr>
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<td>0.0650</td>
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<tr>
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<td>0.0626</td>
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<tr>
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<tr>
<td>5</td>
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<td>0.0032</td>
<td>0.0779</td>
</tr>
<tr>
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<td>9</td>
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<td>0.0583</td>
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<tr>
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<td>0.0645</td>
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<td>0.0777</td>
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<tr>
<td>17</td>
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<td>0.0767</td>
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<tr>
<td>18</td>
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<td>0.0779</td>
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<td>19</td>
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<td>0.0011</td>
<td>0.0684</td>
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</tr>
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<td>0.0020</td>
<td>0.0580</td>
</tr>
<tr>
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<tr>
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<td>0.4930</td>
<td>0.0026</td>
<td>0.0625</td>
</tr>
</tbody>
</table>

**FACE-AVERAGE RMS (S/P12) = 0.00212**

**MFD VORTEX STZF (ADS/RT) = 0.06473**
--- SAMPLE PROBLEM #1 ---

\[ \mu = 1.36 \quad \alpha = 4.0 \]

DISTORTION FACTOR FOR \( \text{MAXIMUM INSTANTANEOUS} \) VALUE

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>( \text{MEAN} )</th>
<th>( \text{SIGMA} )</th>
<th>( \text{SIGMA} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>KS1</td>
<td>0.0631</td>
<td>0.0634</td>
<td>0.0054</td>
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<tr>
<td>KS2</td>
<td>0.182</td>
<td>0.179</td>
<td>0.179</td>
</tr>
<tr>
<td>ID</td>
<td>0.0156</td>
<td>0.0157</td>
<td>0.0016</td>
</tr>
<tr>
<td>INR</td>
<td>0.0140</td>
<td>0.0140</td>
<td>0.0004</td>
</tr>
<tr>
<td>KRA</td>
<td>0.0741</td>
<td>0.0748</td>
<td>0.0003</td>
</tr>
<tr>
<td>KA2</td>
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<td>0.1182</td>
<td>0.0009</td>
</tr>
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</tr>
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<td>0.0182</td>
<td>0.0005</td>
</tr>
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MAXIMUM INSTANTANEOUS DISTORTION FACTOR

\[ \text{IDC} = 0.0183 \]
SAMPLE PROBLEM #1
MD = 1.36
ALPHA = 0.0

PRESSURE ARRAY

<table>
<thead>
<tr>
<th>RADIUS</th>
<th>ANGULAR POSITION OF INPUT MEASUREMENTS, DEF</th>
<th>0.0</th>
<th>45.0</th>
<th>90.0</th>
<th>135.0</th>
<th>180.0</th>
<th>225.0</th>
<th>270.0</th>
<th>315.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.331</td>
<td>0.975</td>
<td>0.979</td>
<td>0.980</td>
<td>0.981</td>
<td>0.980</td>
<td>0.979</td>
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<td></td>
</tr>
<tr>
<td>2.585</td>
<td>0.939</td>
<td>0.967</td>
<td>0.949</td>
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<tr>
<td>3.615</td>
<td>0.948</td>
<td>0.964</td>
<td>0.951</td>
<td>0.981</td>
<td>0.979</td>
<td>0.979</td>
<td>0.956</td>
<td>0.968</td>
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</tr>
<tr>
<td>4.469</td>
<td>0.946</td>
<td>0.947</td>
<td>0.952</td>
<td>0.963</td>
<td>0.939</td>
<td>0.959</td>
<td>0.968</td>
<td>0.945</td>
<td></td>
</tr>
</tbody>
</table>

BASE RADIAL PROFILE

<table>
<thead>
<tr>
<th>RADIUS</th>
<th>PTR/PTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>1.331</td>
<td>1.000</td>
</tr>
<tr>
<td>2.585</td>
<td>1.000</td>
</tr>
<tr>
<td>3.615</td>
<td>1.000</td>
</tr>
<tr>
<td>4.469</td>
<td>1.000</td>
</tr>
<tr>
<td>4.962</td>
<td>1.000</td>
</tr>
<tr>
<td>5.169</td>
<td>1.000</td>
</tr>
</tbody>
</table>

OVERALL FLOW DESCRIPTORS

| PTMIN | 0.839 |
| PTMAX | 0.916 |
| PTAVG | 0.866 |
| PSAVG | 0.860 |

FLOW DISTORTION FACTORS

| K-THETA | 0.07663 |
| KD2     | 176.0   |
| (TDC)-MAX | 0.01607 |
| (IDR)-MAX | 0.01397 |
| KRA     | 0.07946 |
| KAP     | 0.13143 |
| D3PR    | 0.00524 |
| ID      | 0.01228 |
| B-FACTOR | 0.73300 |

VORTEX LOCATION

| VBAR | 0.013 |
| A/R | 1.178 |
| GAMMA | 90.0 |
| BETA | 0.0 |
| V/A | 1.178 |
| V/RT | 999.999 |
| VI  | 0.597 |
| R/RT | 67.50 |

| VBMX | 1.063 |
| V/R0 | 0.027 |
| A/V | 0.0647 |
### SAMPLE PROBLEM #1

**MU** = 1.36  **ALPHA** = 9.0

<table>
<thead>
<tr>
<th>KEY IN MAPPING SYMBOLS</th>
<th>%/S</th>
<th>%/U</th>
<th>D/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>14.0</td>
<td>10.0</td>
<td>8.0</td>
</tr>
<tr>
<td>+</td>
<td>14.0</td>
<td>10.0</td>
<td>8.0</td>
</tr>
<tr>
<td>A</td>
<td>14.0</td>
<td>10.0</td>
<td>8.0</td>
</tr>
<tr>
<td>B</td>
<td>14.0</td>
<td>10.0</td>
<td>8.0</td>
</tr>
</tbody>
</table>

**IN PERCENT**

- X
- +
- A
- B

**AVERAGE PRESSURE** = 0.964

---

**Figure 8. (cont'd)**

- 270 + 90

**Figure B.**

- 360 + 180

**PEAK DISTORTION**
SAMPLE PROBLEM NO. 2  MAR. 14, 1981
M0 = 2.5  ALPHA = 5.0

PRESURE ARRAY

<table>
<thead>
<tr>
<th>RADIUS</th>
<th>ANGULAR POSITION OF INPUT MEASUREMENTS, DEG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.934</td>
<td>0, 45.0, 90.0, 135.0, 180.0, 225.0, 270.0, 315.0</td>
</tr>
<tr>
<td>2.669</td>
<td>0.905, 0.908, 0.885, 0.861, 0.882, 0.849, 0.863, 0.846</td>
</tr>
<tr>
<td>3.218</td>
<td>0.844, 0.849, 0.871, 0.844, 0.849, 0.846, 0.871, 0.846</td>
</tr>
<tr>
<td>3.721</td>
<td>0.846, 0.882, 0.847, 0.842, 0.851, 0.854, 0.870, 0.877</td>
</tr>
<tr>
<td>4.151</td>
<td>0.886, 0.857, 0.837, 0.850, 0.858, 0.870, 0.877</td>
</tr>
</tbody>
</table>

BASE RADIAL PROFILE

<table>
<thead>
<tr>
<th>RADIUS</th>
<th>PTR/PTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.430</td>
<td>1.0000</td>
</tr>
<tr>
<td>1.934</td>
<td>1.0000</td>
</tr>
<tr>
<td>2.669</td>
<td>1.0000</td>
</tr>
<tr>
<td>3.218</td>
<td>1.0000</td>
</tr>
<tr>
<td>3.721</td>
<td>1.0000</td>
</tr>
<tr>
<td>4.151</td>
<td>1.0000</td>
</tr>
<tr>
<td>4.346</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

OVERALL FLOW DESCRIPTORS

<table>
<thead>
<tr>
<th>INDICATOR</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTRA2</td>
<td>0.835</td>
</tr>
<tr>
<td>PTMAX</td>
<td>0.838</td>
</tr>
<tr>
<td>PTAVG</td>
<td>0.842</td>
</tr>
<tr>
<td>GAVG</td>
<td>0.032</td>
</tr>
</tbody>
</table>

FLOW DISTORTION FACTORS

<table>
<thead>
<tr>
<th>INDICATOR</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>K=1/ETA</td>
<td>0.505</td>
</tr>
<tr>
<td>KD2</td>
<td>482.7</td>
</tr>
<tr>
<td>(IDC)-MAX</td>
<td>0.029</td>
</tr>
<tr>
<td>(IDR)-MAX</td>
<td>0.015</td>
</tr>
<tr>
<td>KRA</td>
<td>0.277</td>
</tr>
<tr>
<td>KA2</td>
<td>0.749</td>
</tr>
<tr>
<td>B-FACOH</td>
<td>0.733</td>
</tr>
<tr>
<td>ID</td>
<td>0.025</td>
</tr>
</tbody>
</table>

VORTEX PROPERTIES

<table>
<thead>
<tr>
<th>INDICATOR</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTMN</td>
<td>180.0</td>
</tr>
<tr>
<td>KMMN</td>
<td>0.856</td>
</tr>
<tr>
<td>TTMX</td>
<td>0.896</td>
</tr>
<tr>
<td>KMMX</td>
<td>180.0</td>
</tr>
<tr>
<td>DTH</td>
<td>90.0</td>
</tr>
<tr>
<td>THTA</td>
<td>1.571</td>
</tr>
<tr>
<td>A1</td>
<td>90.0</td>
</tr>
</tbody>
</table>
Figure B. Continued

<STANDBY-STATE DISTURBANCE>
### SAMPLE PROBLEM NO. 2  
**MARCH 14, 1981**

<table>
<thead>
<tr>
<th>T</th>
<th>FO</th>
<th>RT</th>
<th>RT</th>
<th>S P T R C</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.000</td>
<td>500.0</td>
<td>4.346</td>
<td>1.430</td>
<td>1.000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALPH</th>
<th>PSI</th>
<th>MD</th>
<th>ETA</th>
<th>MFR</th>
<th>U2</th>
<th>QPT2</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.000</td>
<td>0.0</td>
<td>2500</td>
<td>0.875</td>
<td>1.000</td>
<td>274.5</td>
<td>0.0970</td>
</tr>
</tbody>
</table>

**RS AT FC = 400.0**

**PROBE RS**  
SG/PT2 A/RT  
1 0.4000 0.0079 0.1233  
4 0.3800 0.0140 0.0869  
6 0.4630 0.0127 0.1062  
17 0.3940 0.0081 0.0879  
18 0.3610 0.0072 0.0850  
19 0.3420 0.0108 0.0754  
20 0.4220 0.0265 0.0988  
21 0.6670 0.0139 0.1650  
22 0.5170 0.0127 0.1196  
23 0.4160 0.0078 0.0933  
24 0.4720 0.0128 0.1076  
36 0.5210 0.0109 0.1266  
37 0.4090 0.0079 0.1147  
38 0.4990 0.0079 0.1147  

**FACE AVERAGE RMS (SG/PT2) = 0.01261**  
**MEAN VORTEX SIZE (A0/RT) = 0.10779**

### DISTORTION FACTOR EXTREMELY VALUABLE

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>STADY</th>
<th>MEAN</th>
<th>SIGMA</th>
<th>SIGMA</th>
<th>MAXIMUM</th>
<th>INSTANTANEOUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>KITA</td>
<td>0.5860</td>
<td>0.5999</td>
<td>0.1069</td>
<td>0.0081</td>
<td>0.9427</td>
<td>0.9996</td>
</tr>
<tr>
<td>K12</td>
<td>4.257</td>
<td>475.7</td>
<td>34.7</td>
<td>26.0</td>
<td>582.7</td>
<td>600.2</td>
</tr>
<tr>
<td>CDC</td>
<td>0.0298</td>
<td>0.0312</td>
<td>0.0025</td>
<td>0.0018</td>
<td>0.0389</td>
<td>0.0481</td>
</tr>
<tr>
<td>DOR</td>
<td>0.0156</td>
<td>0.0157</td>
<td>0.0007</td>
<td>0.0005</td>
<td>0.0179</td>
<td>0.0181</td>
</tr>
<tr>
<td>K1RA</td>
<td>0.2776</td>
<td>0.2811</td>
<td>0.0541</td>
<td>0.005</td>
<td>0.4563</td>
<td>0.4856</td>
</tr>
<tr>
<td>K2P</td>
<td>0.7394</td>
<td>0.8660</td>
<td>0.142</td>
<td>0.0854</td>
<td>1.1638</td>
<td>1.2726</td>
</tr>
<tr>
<td>DSRP</td>
<td>0.0152</td>
<td>0.0153</td>
<td>0.0023</td>
<td>0.0018</td>
<td>0.0327</td>
<td>0.0279</td>
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<tr>
<td>TD</td>
<td>0.0754</td>
<td>0.0259</td>
<td>0.0011</td>
<td>0.0008</td>
<td>0.0791</td>
<td>0.0297</td>
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</table>

**MAXIMUM INSTANTANEOUS DISTORTION FACTOR**  
**IDC = 0.0389**
**SAMPLE PROBLEM NO. 2**  MAR. 14, 1981  M0 = 2.5  ALPHA = 5.0

**PRESSURE ARRAY**

<table>
<thead>
<tr>
<th>RADIUS</th>
<th>ANGULAR POSITION OF INPUT MEASUREMENTS, DEG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.934</td>
<td>0.914 0.914 0.885 0.877 0.872 0.871 0.870 0.890</td>
</tr>
<tr>
<td>2.669</td>
<td>0.913 0.900 0.890 0.881 0.852 0.864 0.861 0.866</td>
</tr>
<tr>
<td>3.238</td>
<td>0.902 0.864 0.896 0.864 0.840 0.852 0.856 0.858</td>
</tr>
<tr>
<td>3.721</td>
<td>0.903 0.902 0.882 0.841 0.834 0.844 0.854 0.81</td>
</tr>
<tr>
<td>4.151</td>
<td>0.895 0.895 0.857 0.824 0.828 0.847 0.858 0.884</td>
</tr>
</tbody>
</table>

**BASE RADIAL PROFILE**

<table>
<thead>
<tr>
<th>RADII</th>
<th>1.430 1.934 2.669 3.238 3.721 4.151 4.346</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTR/PIA</td>
<td>1.000 1.000 1.000 1.000 1.000 1.000 1.000</td>
</tr>
</tbody>
</table>

**OVERALL FLOW DESCRIPTORS**

<table>
<thead>
<tr>
<th>PTWNE</th>
<th>0.678</th>
<th>(PTWX*PTMN)/PTNY = 0.0937</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTMAX</td>
<td>0.914</td>
<td>(PTWX*PTMN)/PTAV = 0.0880</td>
</tr>
<tr>
<td>PTAV</td>
<td>0.874</td>
<td>(PTAV*PTMN)/PTAV = 0.0524</td>
</tr>
<tr>
<td>QAVS</td>
<td>0.842</td>
<td>QAVS = 0.0720</td>
</tr>
</tbody>
</table>

**FLOW DISSOLUTION FACTORS**

| R-THETA | 0.83940 |
| KD2     | 598.8 |
| IDC-MAX | 0.03786 |
| KUR-MAX | 0.01564 |
| KRA     | 0.27757 |
| K2     | 1.04796 |
| DFR    | 0.02164 |
| ID     | 0.02803 |

**VOXET LOCATION**

<table>
<thead>
<tr>
<th>VIX2</th>
<th>0.131</th>
<th>A/RI</th>
<th>GAMMA</th>
<th>B/LTA</th>
<th>AV/RI</th>
<th>VL-</th>
<th>R/RT</th>
<th>THETA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.131</td>
<td>1.571</td>
<td>0.0</td>
<td>1.571</td>
<td>0.599999</td>
<td>0.645</td>
<td>90.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VRNX</th>
<th>VRI</th>
<th>A/RT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.402</td>
<td>0.464</td>
<td>0.1078</td>
</tr>
</tbody>
</table>
-- SAMPLE PROBLEM #3 -- USAF SUBSONIC INLET -- DTF 1982 --
PART-POINT = 20.40
MO = SUBSONIC

PRESSURE ARRAY

<table>
<thead>
<tr>
<th>RADIUS</th>
<th>0.419</th>
<th>0.599</th>
<th>0.737</th>
<th>0.857</th>
<th>0.953</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.500</td>
<td>0.861</td>
<td>0.846</td>
<td>0.935</td>
<td>0.992</td>
<td>0.985</td>
</tr>
<tr>
<td>0.902</td>
<td>0.790</td>
<td>0.817</td>
<td>0.936</td>
<td>0.992</td>
<td>0.980</td>
</tr>
<tr>
<td>0.866</td>
<td>0.783</td>
<td>0.814</td>
<td>0.950</td>
<td>0.965</td>
<td>0.962</td>
</tr>
<tr>
<td>0.835</td>
<td>0.786</td>
<td>0.785</td>
<td>0.944</td>
<td>0.920</td>
<td>0.985</td>
</tr>
<tr>
<td>0.825</td>
<td>0.786</td>
<td>0.785</td>
<td>0.830</td>
<td>0.820</td>
<td>0.887</td>
</tr>
</tbody>
</table>

BASE RADIAL PROFILE

<table>
<thead>
<tr>
<th>RADIUS</th>
<th>0.283</th>
<th>0.419</th>
<th>0.599</th>
<th>0.777</th>
<th>0.852</th>
<th>0.953</th>
<th>1.000</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTR/PIA</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>

OVERALL FLOW DESCRIPTORS

PTMN = 0.758
PTMAX = 0.933
PTAVG = 0.837
PSAVG = 0.804

FLOW DISTORTION FACTORS

| K-THETA | 0.05777 |
| K2     | 1801.4  |
| (IUC)/MAX | 0.15759 |
| (IUR)/MAX | 0.06516 |
| KRA    | 0.30434 |
| K2     | 1.18065 |
| FATS   | 0.57600 |
| D1     | 1.25700 |

VORTEX PROPERTIES

<table>
<thead>
<tr>
<th>TMIN</th>
<th>KMIN</th>
<th>TMAX</th>
<th>RMAX</th>
<th>DTH</th>
<th>THETA</th>
<th>A1</th>
<th>C1</th>
</tr>
</thead>
<tbody>
<tr>
<td>45.00</td>
<td>0.801</td>
<td>225.00</td>
<td>0.959</td>
<td>180.00</td>
<td>185.00</td>
<td>1.571</td>
<td>90.00</td>
</tr>
</tbody>
</table>
Figure 6. (cont'd)
<table>
<thead>
<tr>
<th>FACTOR</th>
<th>STEADY VALUE</th>
<th>MEAN</th>
<th>SIGMA</th>
<th>SIGMA</th>
<th>MAXIMUM INSTANTANEOUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>KITA</td>
<td>0.9574</td>
<td>0.9746</td>
<td>0.2082</td>
<td>0.1566</td>
<td>1.6487</td>
</tr>
<tr>
<td>KPA</td>
<td>1.0144</td>
<td>1.0456</td>
<td>0.2385</td>
<td>0.1566</td>
<td>1.6487</td>
</tr>
<tr>
<td>IDK</td>
<td>0.5043</td>
<td>0.5184</td>
<td>0.2419</td>
<td>0.1566</td>
<td>1.6487</td>
</tr>
<tr>
<td>KA2</td>
<td>1.1809</td>
<td>1.2074</td>
<td>0.2105</td>
<td>0.1566</td>
<td>1.6487</td>
</tr>
<tr>
<td>DSPR</td>
<td>0.0576</td>
<td>0.0583</td>
<td>0.0126</td>
<td>0.0545</td>
<td>0.0985</td>
</tr>
<tr>
<td>Td</td>
<td>1.2657</td>
<td>1.3208</td>
<td>0.1074</td>
<td>0.0610</td>
<td>1.6452</td>
</tr>
</tbody>
</table>

Maximum Instantaneous Distortion Factor

\[ IDC = 0.1786 \]
### Sample Problem #3 - USAF Subsonic Inlet - 22 Dec 1983

**Pressure Array**

<table>
<thead>
<tr>
<th>RADIUS</th>
<th>ANGULAR POSITION OF INPUT MEASUREMENTS, DEG</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.419</td>
<td>45.0 0.798 0.800 0.935 1.038 1.048 0.991 0.948</td>
</tr>
<tr>
<td>0.599</td>
<td>1.077 0.771 0.936 1.041 1.042 0.981 0.928</td>
</tr>
<tr>
<td>0.737</td>
<td>0.806 0.720 0.768 0.955 1.011 1.025 0.997 0.999</td>
</tr>
<tr>
<td>0.852</td>
<td>0.754 0.723 0.739 0.940 0.966 1.048 1.013 0.91</td>
</tr>
<tr>
<td>0.953</td>
<td>0.774 0.723 0.712 0.838 0.864 0.945 0.932 0.888</td>
</tr>
</tbody>
</table>

**Base Radial Profile**

<table>
<thead>
<tr>
<th>RADIUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.283</td>
</tr>
<tr>
<td>0.419</td>
</tr>
<tr>
<td>0.599</td>
</tr>
<tr>
<td>0.737</td>
</tr>
<tr>
<td>0.852</td>
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**PT/R/PTA**

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**Overall Flow Descriptions**

- **PT MIN**: 0.712 (PT MIN)/(PT MAX) = 0.712
- **PT MAX**: 1.046 (PT MAX)/(PT AVG) = 0.577
- **PT AVG**: 0.891 (PT AVG)/(PT AVG) = 1.000
- **PS AVG**: 0.804 (PS AVG)/(PS AVG) = 1.000

**Flow Distortion Factors**

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<td>(TDR) - MAX</td>
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**Vortex Location**

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<th>GAMMA</th>
<th>BETA</th>
<th>AV/RT</th>
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<th>VI</th>
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**Figure 6. (cont'd)**
Figure 6. (cont'd)
-- SAMPLE PROBLEM #4 = USAF TRANSONIC INLET = 22 UFC 1983 --

PART=PUTNT = 464.12  MO = TRANSONIC

PRESSURE ARRAY

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BASE RADIAL PROFILE

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<td>5.000</td>
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OVERALL FLOW DESCRIPTORS

PTMIN = 0.788 (PTMX=PTMN)/PTMN = 0.1644
PTMAX = 0.943 (PTMN=PTMX)/PTAV = 0.1902
PTAVG = 0.860 (PTMV=PTMN)/PTAV = 0.0840
PSAVG = 0.721 QAVG = 0.1308

FLOW DISTORTION FACTORS

K-IHLTA  0.03551
K02     0.45226
(TUC)-MAX  0.06052
(TUR)-MAX  0.03033
KRA     0.10017
KRA2    0.11405 B-FACTOR  0.78400
USPR   0.00238
ID     0.67161 B5F 0.33185 KC 16.400 KR 11.100

VORTEX PROPERTIES

THMN THMX RKMX DTH THFLTA A1 C1
180.00 270.00 90.00 90.00 -185.00 0.785 90.00
**TURBULENCE CALCULATIONS:**

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**ERRORS IN K, E AND (K+E) OF EACH TYPHATTN:**

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*Note: The table and text are cropped and may not display all data accurately.*
TABLE 6. (cont'd)

RESULTS OF TURBULENCE CALCULATIONS:

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FACE AVERAGE RMS (SC/PT2) = 0.03209

MEAN VORT EX STZF (AO/RT) = 0.16575
**SAMPLE PROBLEM #4 **  |  **USAF TRANSONIC INLET = 22 DEC 1983**
**PART-POINT = 464.17**  |  **M0 = TRANSONIC**

**DISTORTION FACTOR EXTRUE VALUE**

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<th>SIGMA</th>
<th>MAXIMUM</th>
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<th>99%</th>
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**MAXIMUM INSTANTANEOUS DISTORTION FACTOR**

**K2A = 0.3682**

**Figure 6. (cont'd)**
**Pressure Array**

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<td>0.851</td>
<td>0.865</td>
<td>0.830</td>
<td>0.783</td>
<td>0.852</td>
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<tr>
<td>3.070</td>
<td>0.843</td>
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<td>0.779</td>
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<tr>
<td>3.725</td>
<td>0.856</td>
<td>0.890</td>
<td>0.940</td>
<td>0.847</td>
<td>0.768</td>
<td>0.873</td>
<td>0.998</td>
<td>0.898</td>
</tr>
<tr>
<td>4.280</td>
<td>0.828</td>
<td>0.858</td>
<td>0.929</td>
<td>0.827</td>
<td>0.750</td>
<td>0.854</td>
<td>0.990</td>
<td>0.887</td>
</tr>
<tr>
<td>4.775</td>
<td>0.814</td>
<td>0.830</td>
<td>0.874</td>
<td>0.793</td>
<td>0.731</td>
<td>0.818</td>
<td>0.949</td>
<td>0.861</td>
</tr>
</tbody>
</table>

**Base Radial Profile**

<table>
<thead>
<tr>
<th>Radii</th>
<th>1.645</th>
<th>2.225</th>
<th>3.070</th>
<th>3.725</th>
<th>4.280</th>
<th>4.775</th>
<th>5.000</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTR/PTA</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>

**Overall Flow Descriptors**

- PTMIN = 0.731
- (PTMX-PTMIN)/PTMX = 0.2678
- PTMAX = 0.998
- PTAVG = 0.860
- (PTAVG-PTMN)/PTAVG = 0.1505
- WAvg = 0.3498

**Flow Distortion Factors**

- K = 0.26719
- KD2 = 12.216
- (TD2)-MAX = 0.12698
- (TD2)-MAX = 0.03063
- K1 = 0.10017
- K2s = 0.34573
- DSFR = 0.02846
- ID = 1.03333
- BSF 0.33185

**Vortex Location**

- VBAR = 0.218
- A/RT = 0.785
- GAMMA = 90.0
- BETA = 0.785
- VI = 909.99
- K/RT = 0.664
- THETA = 159.00
- WBAR = 0.291
- VR = 1.225
- VR/RT = 0.1653
Figure 6. (cont'd)
<table>
<thead>
<tr>
<th>Factor</th>
<th>Equation</th>
<th>Supplemental equations</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>( IDC_{\text{max}} )</td>
<td>( IDC_{\text{max}} = \max \left{ \frac{1}{2} ( IDC_1 + IDC_2 ), \right. ) ( \frac{1}{2} ( IDC_4 + IDC_3 ) )</td>
<td>( IDC_j = \frac{\left( \bar{p}<em>{t,j} \right) - \left( p</em>{t,\text{min}},j \right)}{\bar{p}_{t,j}} )</td>
<td>( \left( \bar{p}_{t,j} \right) = \text{average total pressure for ring } j )</td>
</tr>
<tr>
<td>( IDR_{\text{max}} )</td>
<td>( IDR_{\text{max}} = \max \left( IDR_1, IDR_3 \right) )</td>
<td>( IDR_j = \frac{\bar{p}<em>{t,j} - \left( \bar{p}</em>{t,j} \right)}{\bar{p}_{t,j}} )</td>
<td>( \left( \bar{p}<em>{t,j} \right)</em>{\text{min}} = \text{minimum total pressure reading in ring } j )</td>
</tr>
<tr>
<td>( K_{D2} )</td>
<td>( K_{D2} = \frac{\sum_{j=1}^{NR} \frac{\bar{p}<em>{t,j} \left( \Delta p_j / \bar{p}</em>{t,j} \right) (OD/D_j)}{(q/\bar{p}<em>{t,j}) \sum</em>{j=1}^{NR} (1/D_j)}}{\sum_{j=1}^{NR} (OD/D_j)} )</td>
<td>( \Delta p_j = \left( \bar{p}<em>{t,j} \right) - \left( p</em>{t,\text{min}},j \right) \times 100 )</td>
<td>( \bar{p}<em>{t,j}, \left( \bar{p}</em>{t,j} \right)_{\text{min}}, D_j = \text{see above} )</td>
</tr>
<tr>
<td>( K_0 )</td>
<td>( K_0 = \frac{\sum_{j=1}^{NR} \left( \frac{A_1}{1/D_j} \right)}{(q/\bar{p}<em>{t,j}) \sum</em>{j=1}^{NR} (1/D_j)} )</td>
<td>( A_1,j = \left( \frac{\bar{p}<em>{t,j}}{\bar{p}</em>{t}} \right) \left( \frac{Hb_j}{1} \right) )</td>
<td>( \bar{p}<em>{t}, \left( \bar{p}</em>{t} \right)_{\text{min}}, D_j = \text{see above} )</td>
</tr>
<tr>
<td>( K_{\text{RAD}} )</td>
<td>( K_{\text{RAD}} = \frac{\sum_{j=1}^{NR} \frac{\Delta p_{t,j}}{\bar{p}<em>{t,j}} \frac{\bar{p}</em>{t,j}}{\bar{p}<em>{t,j}}}{\sum</em>{j=1}^{NR} \frac{\Delta p_{t,j}}{\bar{p}<em>{t,j}} \frac{\bar{p}</em>{t,j}}{\bar{p}_{t,j}}} )</td>
<td>( \Delta p_{t,j} = \left( \bar{p}<em>{t,j} \right) - \left( p</em>{t,\text{base}},j \right) )</td>
<td>( \bar{q} = \text{average dynamic pressure at engine face} )</td>
</tr>
<tr>
<td>( K_{A2} )</td>
<td>( K_{A2} = K_{D2} + K_{\text{RAD}} )</td>
<td>( \bar{p}<em>{t,j} = \frac{\bar{p}</em>{t,j}}{\bar{p}_{t,j}} )</td>
<td>( M = \text{number of rakes} )</td>
</tr>
<tr>
<td>( \Delta \text{ASPR} )</td>
<td>( \Delta \text{ASPR} = f(k) )</td>
<td>( \left( \bar{p}<em>{t,j} - p</em>{t,\text{min}},j \right) / \bar{p}_{t,j} = f(k) )</td>
<td>( (p_{t,\text{base}},j) = \text{base radial profile for ring } j; \text{ set } 1 ) for all ( j )</td>
</tr>
<tr>
<td>( \text{TD} )</td>
<td>( \text{TD} = k_c (\text{IDC}) b + k_r (\text{IDR}) )</td>
<td>( p_{t,\text{min}},j = \text{minimum total pressure at engine face} )</td>
<td>( k = \text{compressor reduced frequency} )</td>
</tr>
<tr>
<td>( k_c )</td>
<td>( k_c = \text{circumferential distortion sensitivity factor} )</td>
<td>( k_r = \text{radial distortion sensitivity factor} )</td>
<td>( b = \text{circumferential distortion weighting factor} )</td>
</tr>
</tbody>
</table>

**Figure 9. Distortion Factor Definitions**
Dynamic Probe

GAMMA = vortex orientation angle between y axis and the x'-y' plane

BETA = vortex orientation angle between x' and x axes, with the x axis in the x'-y' plane

Figure 10. Definition of Vortex Angles
APPENDIX A.

PROGRAM SOURCE CODE LISTING (FORTRAN)
MAXIDYN DISTORTION PROGRAM - MAIN DRIVER

PRELIMINARY DECLARATIONS AND DESIGNATIONS

COMMON AB, ANGLOC(20), AVO, BETA2, BF, CDPOP3(10), CNAV6(10), F0, ISHFT,
CMIN(10), DMNX(10), DKSS(10), FACE(39, 65), FACTOR, FARCE(39, 65), BSF,
J1, J2, KEY, KD, LCNFL, NN, NP, NR, P(11, 20), PR(11, 20), CP, NSPEC(20), PVALLUE, QAV, OPT2, R, RADLOC(11), RANGE, RI, RNAV, BRP(11),
RT, SGDK(10), SGP(10), SIG, SNAV6, STATI, STATO, T, TDP1, TDP2, TMNIN,
TDP3, THETA, THMIN(10), TITLE1(20), TITLE2(20), TNAV5, TMAX, RKP, U2

LOGICAL STATI, STATO, LCNFL

LCNFL=.FALSE.
STATI=.TRUE.
STATO=.TRUE.
DIMENSION DRT(11)

INPUT FRAME CONFIGURATION.
NR IS NUMBER OF RINGS, PLUS 2 TO INCLUDE CENTERBODY AND OUTER RADIUS
NP IS THE NUMBER OF RADIAL RAKES
RADLOC IS RADIAL LOCATION OF CENTERBODY, RINGS AND OUTER INLET RADIUS
ANGLOC IS ANGULAR LOCATION OF RAKES IN DEGREES, TOP RAKE IS '0'

READ (5, 100) NR, NP
READ (5, 101) (RADLOC(J), J=1, NR)
READ (5, 101) (ANGLOC(I), I=1, NP)
J1=1
IF (STATI) J1=2
J2=NR
IF (STATO) J2=NP-1
FACTOR=RADLOC(NR)/19.1

CALL NEWPSD TO INPUT DISTORTION KEY, DWELL TIME AND FILTER FREQUENCY.

CALL NEWPSD (1)
ISHFT=1

INPUT DATA TITLES AND COMMENTS, CHECKING FIRST FOR END OF FILE.
0041    READ(5,124,END=999) TITLE1
0042 20   READ (5,124) TITLE2
0043c
0044c   INPUT BASE RADIAL PROFILE
0045c
0046    DO 25 J=1,11
0047       READ (5,101) (BRP(J),J=1,NR)
0048 25   IF (BRP(J),EQ.0.0) BRP(J)=1.0
0049c
0050c   INPUT STEADY STATE PRESSURE AND PLACE INTO ARRAY 'P'
0051c
0052    DO 30 J=1,NR
0053       DRT(J)=(RADLOC(J)-RADLOC(1))/(RADLOC(NR)-RADLOC(1))
0054 30    READ (5,101) (PS(J,I), I=1,NP)
0055    DO 30 I=1,NP
0056 30    P(J,I)=PS(J,I)
0057    WRITE(7) (DRT(J),J=1,NR),(BRP(J),J=1,NR)
0058 20   BF=1.0
0059c
0060c   CALL PRNT TO PRINT STEADY STATE PRESSURE ARRAY.
0061c
0062    CALL PRNT (2)
0063c
0064c   CALL SUBROUTINES WHICH CALCULATE DISTORTION PARAMETERS.
0065c
0066    CALL PFX(.TRUE.)
0067    CALL DISTRT
0068c
0069c   CALL PFX TO TRANSFORM INPUT MEASUREMENTS INTO MAPPING PARAMETERS.
0070c
0071    CALL PFX(.FALSE.)
0072c
0073c   MAINLP CONTROLS INTERPOLATION PROCESS IN INPUT MEASUREMENT PLANE
0074c
0075    CALL MAINLP
0076    ISHFT=2
0077c
0078c   CALL SUBROUTINE TO COMPUTE MAXIMUM INSTANTANEOUS DISTORTION VALUES
0079c AND INSTANTANEOUS PRESSURE MAPS, UNSTADY ALSO CONTROLS THE OUTPUT.
CALL UNSTY
GO TO 10
0083
0083.5
0084 999 STOP
0085 100 FORMAT (215)
0086 101 FORMAT (SF10.5)
0087 124 FORMAT (20H4)
END
SUBROUTINE PXFL (AKS, DK$K, ANT)

THIS SUBROUTINE SOLVES (KMAX-KEAR)/SIGMA K FOR KEAR/SIGMA K LE. 2.0

0096    DK$K=0.0
0097    IF (ANT.LE.1.0) GO TO 200
0098    IF (AKS.LE.0.0) GO TO 200
0099    X=ALOG(AKT)
0100    A=2.9564*AKS**0.8641
0101    B=0.0047+0.3865/AKS
0102    X0=0.6909+0.1817/AKS
0103    AH=0.5625+0.58/AKS**0.707
0104    DX=X-X0
0105    IF (DX.LE.0.0) GO TO 200
0106    DK$K=A+(1.0-EXP(-B*DX**AH))
0107    200 RETURN
0108 END
SUBROUTINE LINOUT(KY)

THIS SUBROUTINE CONTROLS THE OUTPUT
SOME OUTPUT IS CONTROLLED BY 'CARDPD' AND 'FPIX'.
MF, RADLOC, ANGLOC, AND P HAVE FIRST ARRAY DIMENSION EQUAL TO 11. TEN OF
THESE ARE AVAILABLE FOR USE. 11TH IS NEEDED FOR INTERNAL PROCESSING.

COMMON AB, ANGLOC(20), AUC, BETA2, BF, DOPDP3(10), DAVG6(10), FO, ISHFT,
CMIN(10), DMIN(10), DMIN(10), FACTOR, FACTE(39,65), BSF,
J1, J2, KEY, KD, LCHTFL, NR, NP, NR, F(11, 20), PR(10), PS(11, 20), CKP,
PSPEC(20), PYVALU, QAV, OPT2, R, RADLOC(11), RANGE, RI, MAV, RP(11),
RT, S6K(10), S6P(10), SIG, SAVG6, STAT, STATO, TDP1, TDP2, TMIN,
TDP3, THETA, TTHMIN(10), TITLE1(20), TITLE2(20), TMAY6, TMAY6, TMAY6, RKP, U2

DIMENSION RDT(19), FACP(65), FACB(65)
LOGICAL STAT, STATO, LCHTFL
IF (KY-2) 30, 20, 20
WRITE (6, 190) TITLE1, TITLE2
WRITE (6, 105)

OUTPUT SECTION FOR (PI-FAVG)/FAVG MAP

DO 22 I=1, 19
22 ROUT(I)=FLOAT(10-I)*RANGE/20.0
WRITE (6, 107)
WRITE (6, 109)
WRITE (6, 407)
WRITE (6, 111) (ROUT(I), I=1, 11, 19)
WRITE (6, 128) TMAY6
WRITE (6, 129) TMAY6
DO 10 I=1, 139
10 DO 100 J=1, 51
FACP(J)=FACE(I, J)
100 IF (I, I.EQ. 20) WRITE (6, 101) (FACP(J), J=1, 51)
WRITE (6, 121) (FACP(J), J=1, 51)
WRITE (6, 122)
GO TO 10
WRITE (6, 219) TMMIN, TDP1, TMAY6, TDP2, TMAY6, TDP3, SAVG6, QAV
0152c
0153c OUTPUT SECTION FOR USER-DEFINED DISTORTION PARAMETERS.
0154c
0155    WRITE (6,301) (PSPEC(I), I=1,6), BF, PSPEC(7)
0156    WRITE (6,302) PSPEC(8), BSF, CKP, RKP
0157c
0158 101 FORMAT (14X,51A1)
0159 105 FORMAT (37X,22HKEY TO MAPPING SYMBOLS)
0160 107 FORMAT (2X,6HORDER,11X,57H/=+/ =+/ 1/ <# #/)
0161 $$/ $$ *+/ 0+/)
0162 109 FORMAT (2X,10HIN PERCENT)
0163 110 FORMAT (2X,14H(PI-PAY6)/PAY6,20(1X,F5.1))
0164 111 FORMAT (22X,10F6.1)
0165 120 FORMAT (/39X,16H+ 360/0 DEGREES/)  
0166 121 FORMAT (6X,6H270++,2X,51A1,2X,5H+ 90)
0167 122 FORMAT (/39X,6H+ 180)
0168 128 FORMAT (32X,23H(PI-PAY6)/PAY6 PROFILE 32X,16HAVERAGE PRESSURE
0169 +/- 1H=,F7.3)
0170 190 FORMAT (1H1,6X,20A4/6X,20A4)
0171 219 FORMAT (/33X,24OVERALL FLOW DESCRIPTORS/
0172 $$/ 25X,6HPMIN=F7.3,3X,17H(PTMX-PTMN)/PTMN=-F7.4/
0173 $$/ 25X,6HPMAX=F7.3,3X,17H(PTMAX-PTMN)/PTMN=F7.4/
0174 $$ 25X,6PTEV=F7.3,3X,17H(PTAV-PTMN)/PTMN=F7.4/
0175 $$ 25X,6PSAV=F7.3,15X,5H2AV=F7.4)
0176c
0177c SECTION FOR FORMATS FOR THE OUTPUT OF USER DEFINED DISTORTION FACTORS
0178c
0179 301 FORMAT (/11X,23HFLOW DISTORTION FACTORS/
0182 $$ 11X,11HKA2, F11.5/11X,11HKD2, F11.5/
0183 $$ 3X,11H-FAC'TOR, F11.5/11X,11HDP1, F11.5/
0184 302 FORMAT (11X,2HID,9X, F1L,10A4,2HBSF, F8.5,1H KCI/20.3)
0185 $$ 5H KR, F8.3)
0186 407 FORMAT (/25X, 51H/=+/ =+/ 1/ <# #/)
0187 $$/ $$ 5X T/A)
0188c
0189 16 RETURN
0190 END
0191c
SUBROUTINE RATK (RKFK,FABUD)

THIS IS THE FILTER ROUTINE.

RKFK=0.0
IF (FABUD.EQ.0.0) 60 TO 40
B=11.76
RKFK=1.0
E=-B*FABUD
IF (ABS(E).GT.650.0) 60 TO 40
RKFK=SQRT(1.0-EXP(E))

40 RETURN
END
SUBROUTINE SUMMER (X,ERF,KODE)

THIS SUBROUTINE SOLVES THE ERROR FUNCTION.

DIMENSION XT(30)
DATA J/-1/
IF (J>2) 10,30,30
DO 20 K=1,30
N=2*(K-1)+1
E=303.0/N
IF (E .GT. 38.) E=38.0
XT(K)=10.0**E
J=2
CHECK=0.00001
SUM=0.0
IF (X.LT.2.5) 60 TO 40
ERF=1.0
GO TO 70
D=1.0
AN=1.0
DO 50 I=1,30
IF (X.LT.XT(I)) 60 TO 60
H=I-1
AN=2.0*AN
IF (H.EQ.0.0) AN=1.0
ND=2*H+1
D=D*ND
XX=X**ND
TERM=AN*XX/D
IF (TERM.LT.CHECK) 60 TO 60
SUM=SUM+TERM
E=TERM/SUM
IF (R.LT.CHECK) 60 TO 60
CONTINUE
ERF=1.12838*EXP(-X**2)*SUM
IF (KODE=2) 90,80,80
ERF=1.0-ERF
RETURN
END
SUBROUTINE MAINLP

DRIVING SUBROUTINE WHICH INDEXES THROUGH THE GRID POINTS
IN THE INPUT MEASUREMENT PLANE.
NF, RADLOC, ANGLOC, AND P HAVE THE FIRST
ARRAY DIMENSION EQUAL TO 11, TEN OF THE
11 POSITIONS ARE AVAILABLE FOR USE. THE
REMAING POSITION IS NEEDED FOR INTERNAL PROCESSING.

COMMON AR, ANGLOC (20), AUD, BETA2, BF, CDPOP3 (10), CMAV6 (10), F0, 1SHFT,
CMIN (10), DKMAX (10), DKS (10), FACE (39, 65), FACTOR, FASC (39, 65), BSF,
J1, J2, KEY, KB, LCNTFL, NH, NP, NR, P (11, 20), PR (10), PS (11, 20), CKP,
PSPEC (20), PVVALUE, QAV, OPT2, R, RADLOC (11), RANGE, R1, R2, R3, BRP (11),
RT, S6DK (10), SGP (10), S16, SNAV6, STATI, STATD, T, TDP1, TDP2, TMNIN,
TDP3, THETA, THMIN (10), TITLE1 (20), TITLE2 (20), TNAV6, TMNMAX, RKP, U2

DATA BLANK /1H /PLUS/1H/+/

CALCULATION OF R AND THETA
APPROX. 1.0R (OUTER) <-- Y -- APPROX. -1.0R (OUTER)
APPROX. -1.0R (INNER) <-- X -- APPROX. 1.0R (INNER)
FACTOR: SEE LINE 39 OF SUBROUTINE CARD3D

FOR THE CONVENTIONAL R-OMEGA SYSTEM TO THE
R-THETA SYSTEM USED IN THE INTERPOLATION PROCESS.

CHANGING FROM CONVENTIONAL R-OMEGA SYSTEM TO THE
R-THETA SYSTEM USED IN THE INTERPOLATION PROCESS.
0291 IF (X.GE.0.0.AND.Y.LT.0.0) THETA=1.5708+OMEGA
0292 IF (X.LT.0.0.AND.Y.LT.0.0) THETA=4.71239-OMEGA
0293 IF (X.LT.0.0.AND.Y.GE.0.0) THETA=4.71239+OMEGA
0294 IF (THETA.GE.6.28318) THETA=6.28318
0295 IF (THETA.LT.0.0) THETA=0.0
0296 THETA=THETA+(360.0/6.28318)
0297c MAKE MAP ROUND OR ELSE
0298c
0300 IF (R.LT.RADLOC(1).OR.R.GT.RADLOC(NP)) GO TO 9
0301c
0302c CALLING INTERPOLATION AND SYMBOL SUBROUTINE.
0303c
0304 CALL INTERP
0305 CALL SYMME
0306 FACE(IO,JO)=PV
0307 GO TO 10
0308 9 FACE(IO,JO)=BLANK
0309 10 CONTINUE
0310c
0311 RETURN
0312 END
0313c
0314c
SUBROUTINE DISTRT

SUBROUTINE WHICH CALCULATES SIMPLE DISTORTION PARAMETERS.

NP, RADLOC, ANGLOC, AND P HAVE THE FIRST
ARRAY DIMENSION EQUAL TO 11. TEN OF THE
11 POSITIONS ARE AVAILABLE FOR USE. THE
REMAINING POSITION IS NEEDED FOR INTERNAL PROCESSING.

COMMON AB, ANGLOC(20), A00, BETA2, BF, CDPOP3(10), CNAY6(10), FO, ISHFT,
& CMIN(10), DMX(10), DSXX(10), FACE(39,65), FACTOR, FARCE(39,65), BSF,
& J1, J2, KEY, KD, LCHTLF, LN1, NP, NR, P(11,20), PR(10), PS(11,20), CKP,
& PSPEC(20), PVVALUE, QAV, OPT2, R, RADLOC(11), RANGE, RI, RMAY, ERP(11),
& RT, SGDY(10), SGF(10), SIG, SMAY6, STATI, STATO, T, TD1, TD2, TMMIN,
& TD3, THETA, TTHMIN(10), TITLE1(20), TITLE2(20), TMAY6, TMMAX, RKP, U2

DIMENSION SEG(10), RADP(8,10), TTHTOT(10), CMAX(10)
LOGICAL STATI, STATO, LCHTLF, LAID

CALCULATION OF SIMPLE CIRCUMFERENTIAL DISTORTION PARAMETERS.
DO 10 I=J1, J2

CALCULATION OF CMAX, CMIN, AND CMAY6 FOR EACH RING

CMAX(I)=0.0
CMIN(I)=50000.0
CMAY6(I)=0.0

DO 11 J=1, NP
CMAX(I)=AMAX1(P(I,J), CMAX(I))
CMIN(I)=AMIN1(P(I,J), CMIN(I))
CMAY6(I)=CMAY6(I)+(P(I,J)/FLOAT(NP))

CALCULATION OF CDPOP’S FOR EACH RING.

CDPOP3(I)=(CMAY6(I)-CMIN(I))/CMAY6(I)

CALCULATION OF TM MAX AND TM MIN.
TM MAX=0.0
0355 TMIN=50000.0
0356 DO 7 I=J1,J2
0357 TMMAX=MAX1(CMMAX(I),TMMAX)
0358 7 TMIN=MIN1(CMIN(I),TMIN)
0359c CALCULATION OF THAV
0360c
0361c DIV=0.0
0362 DO 33 J=1, NP
0363 PTSUM=PTSUM+F(I,J)
0364 DO 33 J=1, NP
0365 DIV=DIV+1.0
0366 THAVG=PTSUM/DIV
0366c CALCULATION OF TDP1'S
0370c
0371c TDP1=(TMMAX-TMIN)/TMMAX
0372 TDP2=(TMAX-TMIN)/THAVG
0373 TDP3=(CMAX-TMIN)/THAVG
0375c SECTION TO CALCULATE THMIN FOR EACH RING.
0376c
0377c DO 9 I=J1,J2
0378 DO 13 LL=1,10
0380 13 $E(I,LL)=0.0$
0381 IF (NP.EQ.1) GO TO 8
0382 L=1
0383 LMIN=.FALSE.
0384 DO 12 J=1, NP
0385 KD=J-1
0386 IF (KD.EQ.0) KD=NP
0387 K1=J
0388 A1=ANGLOC(K1)
0389 K2=J+1
0390 IF (K2.GT.NP) K2=K2-NP
0391 A2=ANGLOC(K2)
0392 IF (A1.GT.A2) A2=A2+360.0
0393 IF (I.GT.1) GO TO 14
0394 IF ($P(I,K1).LT.(THAVG(I)) GO TO 21
0355 IF (P(I,K1).EQ.CMAV6(I).AND.P(I,K2).LT.CMAV6(I)) GO TO 22
0366 GO TO 14
0377 22 IF (P(I,KD).GE.CMAV6(I)) GO TO 14
0388 21 LADD=.TRUE.
0399c LOGIC DETERMINES EACH SEGMENT'S CONTRIBUTION TO THTHIN ON EACH RING
0400c
0402 14 RINC=0.0
0403 IF (P(I,K2).LT.CMAV6(I).AND.P(I,K1).LT.CMAV6(I)) RINC=A2-A1
0404 IF (P(I,K2).LT.CMAV6(I).AND.P(I,K1).EQ.CMAV6(I)) RINC=A2-A1
0405 IF (P(I,K2).EQ.CMAV6(I).AND.P(I,K1).LT.CMAV6(I)) RINC=A2-A1
0406 IF (P(I,K2).GT.CMAV6(I).AND.P(I,K1).LT.CMAV6(I))
0407 & RINC=((A2-A1)/(P(I,K2)-P(I,K1)))*(CMAV6(I)-P(I,K1))
0408 IF (P(I,K2).LT.CMAV6(I).AND.P(I,K1).GT.CMAV6(I))
0411c LOGIC DETERMINES HOW TO ADD TOGETHER THE CONTRIBUTIONS OF EACH SECTION
0412c
0413 IF (RINC.EQ.0.0) GO TO 20
0414 IF (P(I,K2).LT.CMAV6(I).AND.P(I,K1).GT.CMAV6(I)) GO TO 23
0415 24 SEG(L)=SEG(L)+RINC
0416 GO TO 12
0417 23 IF (P(I,KD).GE.CMAV6(I)) GO TO 24
0418 IF (J.EQ.1) GO TO 24
0419 L=L+1
0420 GO TO 24
0421 20 IF (J.EQ.1) GO TO 12
0422 IF (SEG(L).EQ.0.0) GO TO 12
0423 L=L+1
0424 12 CONTINUE
0425 K$=0
0426 THTTOT(I)=0.0
0427 DD 18 K=1,10
0428 IF (SEG(K).NE.0.0) K$=K$+1
0429 18 THTTOT(I)=THTTOT(I)+SEG(K)
0430 IF (LADD) SEG(I)=SEG(I)+SEG(K$)
0431 IF (LADD) K$=K$-1
0432c SEARCH FOR LARGEST DEPRESSION BELOW AVERAGE ON EACH RING
0433c THIS WILL BECOME THTHIN FOR THAT RING
0435c
0436   THTMIN(I)=0.0
0437   DO 19 K=1,K3
0438 19   IF (SE6(K),GT,THTMIN(I)) THTMIN(I)=SE6(K)
0439   GO TO 9
0440 8    CALL PRINT(3)
0441 9    THTMIN(I)=0.0
0442    CONTINUE
0443c
0444c  CALCULATION OF AVERAGE STATIC PRESSURE.
0445c
0446    DIV=0.0
0447    STATSM=0.0
0448    IF (.NOT.STATI) GO TO 29
0449    DO 30 I=1,NP
0450 30    STATSM=STATSM+P(I,I)
0451    DIV=DIV+FLOAT(NP)
0452 29    IF (.NOT.STATI) GO TO 31
0453    DO 32 I=1,NP
0454 32    STATSM=STATSM+P(NR,I)
0455    DIV=DIV+FLOAT(NP)
0456 31    IF (DIV.EQ.0.0) DIV=1.0
0457    SMAXG=STATSM/DIV
0458c
0459c  CALCULATION OF AVERAGE MACH NUMBER WHEN NO STATIC Pressures ARE INPUT
0460c
0461    AMACH=5.0*(ABS(TMAXG/SMAXG)**.286-1.0)
0462    RMAV=SORT(ABS(AMACH))
0463c
0464c  CALCULATION OF SIMPLE RADIAL DISTORTION PARAMETERS.
0465c
0466    DO 40 IR=1,NR
0467    DO 40 ITHT=1,8
0468    R=RADLOC(IR)
0469    THETA=45*(ITHT-1)
0470c
0471c  CALL INTERPOLATION SUBROUTINE TO OBTAIN INTERPOLATED VALUES
0472c  OF MEASUREMENTS ON EACH RING AT DISCRETE THETA LOCATIONS.
0473c  NOTICE THAT SUBROUTINE 'INTERP' WILL GO THROUGH THE PROCESS OF RADIAL
0474c  INTERPOLATION EVEN THOUGH IT IS NOT NECESSARY. THIS REDUNDANCY IS NOT
EXTREMELY SINCE THE RADIAL INTERPOLATION IS NOT EXECUTED TOO MANY TIMES

CALL INTERP
RADP(ITHT,IR)=PVVALUE

CALL SUBROUTINE TO CALCULATE SPECIFIC DISTORTION PARAMETERS.

CALL DISPAR
RETURN
END
SUBROUTINE EXTREME (SGK,KSS,KMAX,T,FLUR)

SUBROUTINE WHICH MANAGES COMPUTATION OF EXTREME VALUES
SGKF IS DISTORTION FACTOR SIGMA
KSS IS MEAN VALUE
KMAX IS EXTREME VALUE
T IS TIME ON POINT, SECONDS
FLUR IS VORTEX FLUX RATE.

REAL KSS,KMAX
SGKF=SGK
AKS=KSS/SGKF
FLUX=T*FLUR
DKS=0.0
KMAX=0.0
IF (SGKF.EQ.0.0) GO TO 120
IF (AKS.GT.64.0) AKS=64.0
CALL SEARCH (AKS,DKS,FLUX)
KMAX=KSS+DKS*SGKF

RETURN
END

-----------------------------------------
SUBROUTINE PFIX(L0)

SUBROUTINE TO TRANSFORM INPUT MEASUREMENTS INTO HPPING PARAMETERS.
SUBROUTINE ALSO CONTROLS SOME OUTPUT

NP, RADLOC, ANGLAC, AND P HAVE THE FIRST
ARRAY DIMENSION EQUA TO 11, TEN OF THE
11 POSITIONS ARE AVAILABLE FOR USE. THE
REMAINING POSITION IS NEEDED FOR INTERNAL PROCESSING

COMMON AB, ANGLAC(20), AVO, BETA2, BF, CDPOP3(10), CMAY(10), F0, ISHFT,
CMIN(10), DKAX(10), DKSS(10), FACE(39,65), FACTOR, PACE(39,65), BSF,
J1, J2, KEY, KD, LCNTFL, NN, NP, NR, P(11,20), PR(11,20), PS(11,20), CKP,
PSPEC(20), PVALUE, QAV, OPT2, R, RADLOC(11), RANGE, R1, RMAY, RBP(11),
RT, SDK(10), SGP(10), SIG, SMAYG, STATI, STATO, T, TDP1, TDP2, TMIN,
TDP3, THETA, THIMIN(10), TITLE1(20), TITLE2(20), TMAYG, TMMAX, RKP, U2

DIMENSION DPC(6)

LOGICAL STATI, STATO, LCNTFL, LQ

DATA DPC(1), DPC(2), DPC(3)/10., 20., 25./
DATA DPC(4), DPC(5), DPC(6)/40., 50., 100./

IF (L0) GO TO 55

SECTION THAT ENABLES INTERPOLATION THROUGH THE CENTER OF THE CONTOUR MAP
SHIFT RADIAL LOCATIONS OUTWARD IF THE CENTER IS TO BE FILLED IN

IF (.NOT.LCNTFL) GO TO 50
IF (ISHFT.EQ.2) GO TO 50
DO 51 I=1, NR
543 NR1=NR+2-1
544 RADLOC(NR1)=RADLOC(NR1-1)

546c K --> ORIGINAL NO. OF POINTS ON THIS RING
547c SHIFT ANGULAR POSITIONS OUTWARD; SHIFT DATA OUTWARD
548c
549c
550c DO 51 J=1, HP
551c P(NR1,J)=P(NR1-1,J)
552c NR=NR+1
SET UP 8-POINT DUMMY INNER RING AND FIND AVERAGE PRESSURE ON THE RING

0555 49 PADLOC(I)=0.01
0556 PSUM=0.0
0557 DO 54 I=1,NP
0558 I1=I-1
0559 IF (I1.EQ.0) I1=NP
0560 A1=ANGLOC(I1)
0561 IF (I1.EQ.0) A1=A1-360.0
0562 I2=I+1
0563 IF (I1.GT.NP) I2=1
0564 A2=ANGLOC(I2)
0565 IF (I1.EQ.0) A2=A2+360.0
0566 DELTHT=(A2-A1)/2.0/360.0
0567 54 PSUM=PSUM+(DELTHT*P(2,I))

DUMMY RING DATA AND POSITION SET-UP

0571 DO 53 I=1,8
0572 TH=(I-1)*45
0573 ANGLOC(I)=TH
0574 53 P(I,D)=PSUM
0575 50 PCMNN=0.0
0576 PCMXX=0.0

MAPPING PARAMETERS GENERATED FROM INPUT MEASUREMENTS

0580 DO 12 I=1,NR
0581 DO 12 J=1,NP
0582 P(I,J)=((P(I,J)/TMAYC)-1.0)*100.0
0583 IF (PCMNN.GT.P(I,J)) PCMNN=P(I,J)
0584 12 IF (PCMXX.LT.P(I,J)) PCMXX=P(I,J)

SECTION TO WRITE OUT MAPPING PARAMETERS.

MAPPING PARAMETERS PUT INTO PROPER FORM FOR SYMBOL SUBROUTINE

0589 PCMNN=-PCMNN
0590 PCMXX=AMAX1(PCMNN,PCMXX)
0591 DO 130 I=1,6
0592 IF (PCMXX.LT.DPC(I)) GO TO 131
0593 130 CONTINUE
0594    I=6
0595 131 RANGE=2.0*DPC(I)
0596    DO 13 I=1,NR
0597    DO 13 J=1,NP
0598c  CONVET DELTA PERCENT TO DELTA RANGE INCREMENTS -10.0 TO +10.0
0599c
0600c 0601 13   P(I,J)=(P(I,J)/(RANGE/20.0))-10.0
0602c  RETURN
0603c 0604c 0605c  ENTRY POINT FOR CALCULATION OF BLOC.
0606c  0607 55   RMSUM=0.0
0608   KMSUM=0
0609    DO 30 I=J1,J2
0610    DO 30 J=1,NP
0611   PC=P(I,J)+(P(NP,J)-P(I,J))*(RADLOC(I)-RADLOC(NP))/RADLOC(NP)-
0612    & RADLOC(1))
0613c 0614c  MACH NUMBER IS CALCULATED FOR EACH INPUT MEASUREMENT LOCATION.
0615c  0616    GAM=0.286
0617    IF (PC.EQ.0.0) PC=0.00001
0618    AMACH=5.0*ABS(P(I,J)/PC)**GAM-1.0
0619    IF (AMACH) 610,630,620
0620 610   AMACH=-SORT(ABS(AMACH))
0621     GO TO 630
0622 620   AMACH=SORT(AMACH)
0623 630   RMSUM=RMSUM+AMACH
0624   30   KMSUM=KMSUM+1
0625c 0626c  CALCULATION OF AVERAGE MACH NUMBER.
0627c  0628    RMAY=RMSUM/FLOAT(KMSUM)
0629c  RETURN
0630c  END
0631c 0632c
0633c
SUBROUTINE FRF(RS, FAUL)

SUBROUTINE TO EVALUATE FUNCTION OF AER/UD VS SIGMA RATIO.
USES AN ITERATIVE SCHEME FOR INVERSE SOLUTION

TOL=0.0001
FAUL=0.5
RSL=.5205
FAU=0.5+.96061*(RS-.5205)
K=1
DO 100 J=1,100
CALL SUMMER (FAU, RSC, K)
ABE=ABS(RSC-RS)
IF (ABE.LT.TOL) GO TO 110
SLOPE=(FAU-FAUL)/(RSC-RSL)
FAUL=FAU
RSL=RSC
FAU=FAUL+SLOPE*(RS-RSL)
100 110 FAUF=FAU
RETURN
END

------------------------------------------------------------------
SUBROUTINE SYMBLE

SUBROUTINE TO SUPPLY THE SYMBOLS FOR THE LINE PRINTER CONTOUR MAP.

COMMON AB, ANGLOC (20), AUO, BETA2, BF, CDPDP3 (10), CMAYG (10), FO, ISHFT,
CMIN (10), DDMX (10), DKE1 (10), FACE (39, 65), FACTOR, FARCE (39, 65), BSE,
J1, J2, KEY, KD, LCNTFL, HH, NP, NR, P (11, 20), PR (10), PS (11, 20), CKP,
PSPEC (20), PVALUE, QAV, QPT2, R, RADLOC (11), RANGE, R1, RMAY, BRF (11),
RT, S6DK (10), SG (10), $1G, SNAVY, STATI, STATO, T, TDP1, TDP2, TMINT,
TIP3, THETA, THTMIN (10), TITLE1 (20), TITLE2 (20), TNAVY, TMAX, RKP, U2

DIMENSION OUTSYM (20), OUTSM (20)

TWO LISTS OF SYMBOLS COVER ALL POSSIBLE TYPES OF CONTOUR MAPS.

DATA OUTSYM /1H-, 1H-, 1H-, 1H-, 1H-, 1H-, 1H-, 1H-, 1H-, 1H-, 1H-, 1H-, 1H-, 1H-, 1H-,
1H-, 1H-, 1H-, 1H-, 1H-, 1H-, 1H-, 1H-/.

IF BETA EXCEEDS MAX OR MIN RANGE INCREMENTS, ASSIGN MAX OR MIN TO IT

IF (PVALUE .GE. 0.0) PVALUE = -.0001
IF (PVALUE .LE. -20.0) PVALUE = -19.9999

SECTION TO DETERMINE THE PROPER SYMBOL FOR THE CONTOUR MAP.

DO 10 I = 1, 20
UP = I - 1
DN = UP - 1.0
IF (PVALUE .LE. UP .AND. PVALUE .GT. DN) GO TO 11
10 CONTINUE
11 PVALUE = OUTSYM (I)

RETURN
END

SUBROUTINE NEWPSD(KY)

SUBROUTINE TO EVALUATE RMS AND PSD FUNCTIONS FROM DYNAMIC PRESSURES.

COMMON AB,ANGLOC(20),AUX,BETA2,BF,CPDP3(10),CMAVG(10),FO,ISHFT,
CMIN(10),DKHX(10),DKXS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
J1,J2,KEY,KD,LCNTFL,NN,NP,NRP(11,20),PR(11,20),PS(11,20),CKP,
PSPEC(20),PValeur,OAV,OPT2,RADLOC(11),RANGE,RI,RTAV,RRP(11),
RT,SGK(10),S6P(10),S1G,SMAVG,STATI,STAT0,T,TDP1,TDP2,TMIN,
TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG,TMAX,RKP,VE2

REAL MD,MFR

DIMENSION HDPRO(40),AVSIZ(40),FNPRO(40)

ON CALL FROM MAIN (KY=1) INPUT DISTORTION FACTOR KEY, TIME ON POINT,
AND FILTER FREQUENCIES. DISTORTION FACTORS ARE DEFINED BRIEFLY BELOW:

1. KTETA - FRATT & WHITNEY CIRCUMFERENTIAL DISTORTION FACTOR
2. KD2 - FRATT & WHITNEY CIRCUMFERENTIAL DISTORTION FACTOR
3. IDC - GENERAL ELECTRIC CIRCUMFERENTIAL DISTORTION FACTOR
4. IDR - GENERAL ELECTRIC RADIAL FLOW DISTORTION FACTOR
5. KRR - FRATT & WHITNEY RADIAL FLOW DISTORTION FACTOR
6. KRR2 - FRATT & WHITNEY COMBINED CIRCUMFERENTIAL/RADIAL DISTORTION
7. DFR - DELTA (LOSS IN) STALL PRESSURE RATIO
8. ID - GENERAL ELECTRIC COMBINED CIRCUMFERENTIAL/RADIAL DISTORTION

IF (KY=2) 100,250,255

READ (5,130) KD,T,FO,FCO

IF (T.EQ.0) T = 1.

IF (FO.LT.1) FO = 500.

IF (FCO.LT.1) FCO = 1000.

RT=RADLOC(NR)

PI=RADLOC(1)

RETURN

ON 1ST CALL FROM UNSTDY, INPUT IDENTIFICATION AND CONTROL PARAMETERS
AND SET STEADY STATE DISTORTION FACTORS.
0736 250 READ (5,70) ALPH,PSI,MD,U2,BF,CKP,RKP,MFR,NTUR,SPTRC
0737    IF (SPTRC .EQ. 0) SPTRC = 1.
0738    IF (PSPEC(3)) 101,102,101
0739 101 RD=PSPEC(4)/PSPEC(3)
0740    BSF=0.24+0.76*EXP(3.6*RD**0.79)
0741    IF (CKP.EQ.0.0) CKP=16.4
0742    IF (RKP.EQ.0.0) RKP=11.1
0743    PSPEC(8)=BSF*CKP*PSPEC(3)+RKP*PSPEC(4)
0744 102 IF (BF.EQ.0.0) BF=1.0
0745    ETA=TMAG6
0746    OPT2=0AV/TMAG6
0747    PSPEC(6)=PSPEC(1)+BF*PSPEC(5)
0748    DO 241 I=1,10
0749 241 DKSS(I)=PSPEC(I)
0750c            RETURN
0752c   ON 2ND CALL FROM UNSTDY COMPUTE MAX INSTANTANEOUS DISTORTION FACTORS
0754c
0755 255 NN=0
0756    IF (MFR .EQ. 0) MFR = 1
0757    WRITE (6,10) TITLE1,TITLE2
0758    WRITE (6,20) T,FD,RT,RI,SPTRC
0759    WRITE (6,30) ALPH,PSI,MD,ETA,MFR,U2,OPT2
0760    WRITE (6,120) FCD
0761c
0762c   IF (NTUR .EQ. 1) GO TO 500
0763c
0764    WRITE (6,50)
0765    DO 258 I=1,10
0766 258 SGP(I)=0.0
0768c
0769c   INPUT DYNAMIC DATA
0770c   MFR IS RUN CODE, IF ZERO IS ENTERED, THE INPUT SEQUENCE IS EXITED
0771c   MFR IS A DYNAMIC PRESSURE PROBE NUMBER
0772c   RS IS RATIO OF FILTERED/UNFILTERED MEAN SQUARE VALUE OF DYNAMIC
0773c   PRESSURE FLUCTUATIONS.
0774c   SIG IS RMS VALUE OF DYNAMIC PRESSURE FLUCTUATION.
0776 260 READ (5,90) NFG,NPR,RS,SIG
0777  IF (RS .EQ. 0) RS = 0.5
0778  IF (RS .GT. 0.7) RS = 0.7
0779  IF (NFG.NE.0) GO TO 300
0780c  CALL MAXDP TO COMPUTE MAXIMUM DISTORTION VALUES.
0782c  CALL MAXDP
0783   DO 372 I=1,NN
0784   AVSIZ(I)=AVSIZ(I)/(AB)
0785   372  FNOPRO(I)=FLOAT(FNOPRO(I))
0787   WRITE (7) (FNOPRO(I),I=1,NN),(AVSIZ(I),I=1,NN)
0788   RETURN
0790c  COMPUTE MEAN VORTEX CORE SIZE FOR EACH FROEZ AND SUM AERR AND SIG.
0791c  NN IS COUNTER FOR NUMBER OF DYNAMIC PRESSURE FROEZ.
0792c  300  CALL FRF (RS,FAUF)
0793   AUO=FAUF/(7.376*FD)
0795   AB=12.0*AUO*U2
0796   AB=AB/PI
0797   WRITE (6,60) NPR,RS,SIG,AB
0798   SGP(1)=SGP(1)+SIG*SIG
0799   SGP(2)=SGP(2)+AB*AB
0800   NN=NN+1
0801   FNOPRO(NN)=NPR
0802   AVSIZ(NN)=AB
0803   GO TO 260
0804  500  CONTINUE
0805c  CALL TURBULENCE SUBPROGRAM TURBUL; TO COMPUTE THE RMS LEVELS.
0806c  SPTRC IS THE TOTAL PRESSURE RECOVER THROUGH INLET SHOCK SYSTEM.
0807c  (SPTRC=1. FOR SUBSONIC AND TRANSONIC SPEED).
0808c  RS IS RATIO OF FILTERED/UNFILTERED MEAN SQUARE VALUE OF DYNAMIC
0809c  PRESSURE FLUCTUATIONS.
0810c  SIG IS RMS VALUE OF DYNAMIC PRESSURE FLUCTUATION.
0811c  60  CALL TURBUL (RS,RAILOC,NR,NP,U2,OPT2,TMAY6,ND,SPTRC,SIG)
0813  RS=0.5
0815  CALL FRF (RS,FAUF)
CALL MAXDP TO COMPUTE MAXIMUM DISTORTION VALUES.

CALL MAXDP
DO 375 I=1,NN
AVSIZ(I)=AVSIZ(I)/AB
ENDO=N.DP(I)=FLOAT(ENDO(I))
CONTINUE
WRITE (7) (ENDO(I),I=1,NN),AVSIZ(I),I=1,NN
RETURN
FORMAT (1HI,13X,2H4/13X,2H4)
FORMAT (1I5,1HT,6X,2HFO,6X,2HR,T,6X,2HRI,5X,5HSPTRC/5X,F12.3,
&     F8.1,F8.3)
FORMAT (13X,4HALPH,5X,3HPSI,4X,2HMO,5X,3HETA,4X,3HFR,4X,2H,U2,
&     5X,4HPTZ/10X,F7.3,F8.3,3F7.3,F7.1,F8.4)
FORMAT (10X,5HPROBE,3X,2HRS,3X,6HS6/PTZ,3X,4HA/RT)
FORMAT (10X,13X,4F7.4)
FORMAT (5X,8F5.3,15,F5.3)
FORMAT (5X,11F5.2)
FORMAT (5X,15,F5.3,F6.4)
FORMAT (/1I5,10HRS AT FC =F8.1)
FORMAT (5X,15,F10.5)
END
SUBROUTINE MAXDP

COMMON AB, ANLOC (20), AVO, BETAL2, BF, CDPOP3 (10), CMAYG (10), FO, ISHFT,
       CMIN (10), DMX (10), DK (10), FACE (39, 65), FACTOR, FAPCE (39, 65), BSF,
       J1, J2, KEY, KD, LCHFL, LH, LN, NP, NP1, PR (10), PS (11, 20), CP,  
       PSPEC (20), QVALUE, QAY, OPT2, PR, RADLOC (11), RANGE, RI, RMAV, BF (11),
       RT, SGDK (10), SGF (10), SIG, SMAYG, STAI1, STAT2, T, TDF1, TDF2, TMNII,
       TDF3, THETA, THMIN (10), TITLE1 (20), TITLE2 (20), TMAYG, TMAX, RPM, U2

DIMENSION LAB (8), FO (10), INBAR (10)

DATA LAB (1), LAB (2), LAB (3), LAB (4), 4HKT12, 4H KD2, 4H IDC, 4H IDR/
       DATA LAB (5), LAB (6), LAB (7), LAB (8), 4H KRA, 4H KRB, 4H DSPR, 4H ID/

F0 (1) = 1.0
F0 (2) = 1.0
F0 (3) = 1.0
F0 (4) = OPT2
F0 (5) = OPT2
F0 (6) = OPT2
F0 (7) = 1.0
F0 (8) = 1.0
F0 (9) = OPT2
F0 (10) = 1.0
RTU = RT / U2 / 12.0
AH = HH

FIND MEAN VALUES OF SIGMA AND ABAR

SIG = SORT (SGF (1) / AH)
AB = SORT (SGF (2) / AH)
SGF (1) = SIG / OPT2

FIND FLUX AND ENGINE FILTER EFFECTS

FL = AH * RTU (AB) / RTU
TFL = T + FL
FABUD = FO * RTU * AB
CALL RATEK (RFK, FABUD)
VE = 0.949 * SGF (1) * RFK / SORT (AB)
SIGF = SIG * RKFK

FIND MAXIMUM VALUES FOR EACH DISTORTION FACTOR.

DO 450 I = 3, 10
J = 1 - 2

GET SIGMA RATIOS AND DELTAS FOR ALL FACTORS EXCEPT KA2 AND ID

IF (1.E0, 8) GO TO 404
IF (1.E0, 10) GO TO 406
CALL RSIGMA (J, R1, RK, KB, DKS (J), NP, OPT2, VB, SIGF)
SGP (I) = R1 * SGP (I) * FQ (I)
GO TO 410

FORMULAS FOR KA2 AND ID SIGMAS

SGP (I) = SQRT (SGP (3) ** 2 + (BF * SGP (7)) ** 2)
GO TO 410
SGP (I) = SQRT ((BSF * CKP * SGP (5)) ** 2 + (RKP * SGP (6)) ** 2)

FILTERED RMS LEVEL (SGDK) OF DISTORTION FACTOR.

SGDK (I) = SGP (I) * RKFK
IF (1.E0, 8) GO TO 424
IF (1.E0, 10) GO TO 426

COMPUTE MEAN INSTANTANEOUS VALUE (DKEAR) OF DISTORTION FACTOR.

DKEAR (J) = RK * SGDK (I) * DKS (J)
GO TO 450

FORMULAS FOR KA2 AND ID DELTAS.

DKEAR (6) = DKEAR (1) + BF * DKEAR (5)
GO TO 450
DKEAR (8) = BSF * CKP * DKEAR (3) + RKP * DKEAR (4)

TO FIND MOST PROBABLE EXTREME VALUES.
CALL EXTRME (SGDK(J), DKBAR(I), DKNX(J), T, FL)
WRITE (6,60) $16
WRITE (6,70) AB
IF (NN .LT. 2) 60 TO 459
IF (NN .LT. 25) 60 TO 460
WRITE (6,130) TITLE1, TITLE2
WRITE (6,100)
DO 500 I=1,8
J=I+2
IF (I.GT.1) 60 TO 470
PP=1.0-EXP(-0.051289394/FL)
IF (PP.EQ.0.0.) 60 TO 999
FL1=1.0/(PP+T)
PP=1.0-EXP(-0.003004509/FL)
IF (PP.EQ.0.0.) 60 TO 996
FL2=1.0/(PP+T)
C FIND INSTANTANEOUS VALUES AT 95.0 AND 99.7 CONFIDENCE LEVELS
C
CALL EXTRME (SGDK(J), DKBAR(I), DKNX(J), T, FL1)
CALL EXTRME (SGDK(J), DKBAR(I), DKNX(J), T, FL2)
IF (1-2) 480,490,480
WRITE (6,110) LAB(I), DKS(I), DKBAR(I), SGF(J), SGDK(J), DKNX(I),
& DK950, DK997
60 TO 500
WRITE (6,120) LAB(I), DKS(I), DKBAR(I), SGF(J), SGDK(J), DKNX(I),
& DK950, DK997
CONTINUE
WRITE (6,75) LAB(KI), DKNX(KI)
FORMAT (/13X,"FACE-AVERAGE RMS (SG/PT2) =",F8.5)
FORMAT (/13X,"MEAN VORTEX $12E (A0/FT) =",F8.5)
FORMAT (/13X,"399MAXIMUM INSTANTANEOUS DISTORTION FACTOR/
& 30X,1A10,1H=F13.4)
FORMAT (/22X,31HDI STORTION FACTOR EXTREME VALUE/,59X,21HMAXIMUM 1
$INSTANTANEOUS/12X,6HFACTOR,4E,6HST EADY,3E,4HHEAN,5X,5HSTEMA,4X,
5HSTEMA,5X,4HINSTANT,4E,5H95,0E,4X,5H99,7E/22X,5HSTATE,4E,5HVALUE,5X,
3HSTATE,7X,2HFACTOR,6E,4HPRDB,5X,4HPRDB,5X,4HPRDB)
FORMAT (10X,A4,6X,F7.4,6F9.4)
FORMAT (10X,A4,6X,F7.1,6F9.1)
0971 130 FORMAT (1H1, 19X, 20A4/19X, 20A4)
0972c
0973 RETURN
0974c
0975 999 PP=.00000001
0976 WRITE (6, 998)
0977 998 FORMAT ("/10X, 29HCONFIDENCE LEVEL IS INCORRECT")
0978 GO TO 997
0979 996 PP=.00000001
0980 WRITE (6, 998)
0981 GO TO 995
0982c
0983 END
0984c
0985c -----------------------------------------------
FUNCTION ANRTU (ART)

FUNCTION FOR FINDING VORTEX FLUX RATE.

ANRTU = 1.0E+06
IF (ART .EQ. 0.0) GO TO 100
ANRTU = 0.254 / (ART * ART)
100 RETURN
END
SUBROUTINE RSIGMA (J,R1,RK,AB,DKS,NP,OPT,VB,SGF)

THIS ROUTINE IS USED NOW TO COMPUTE THE RATIO OF SIGMA KD TO SIGMA IQ AND THE RATIO (KQARP-KSS)/SIGMA K.

SF IS RATIO OF SIGMA-QP/R

FN IS NUMBER OF FRAEEES PER RING

DT IS ANGULAR ARC PER FRAEE

IF = 1.0537*SORT(AB)

PH=NP

DT=6.28319/PN

GO TO (10,20,30,40,60,70), J

THIS BRANCH APPLIES TO KTHETA.

DKSS=DKS/VB

SDKIS=1.65*SORT(AB/PN)/EXP(40.0*(AB/DT)**4.0)

SDKIL=2.106*(1.0-1.0/EXP(1.1*(AB**1.5)))

SDKI=SDKIS+SDKIL+SDKIL

DKTS=(1.408*AB/EXP(76.67*(AB/DT)**4))/SORT(1.0+99.0*DKSS*DKSS)

DKTL=(2.0*(1.0-1.0/EXP(1.05*(AB**1.5))))/SORT(1.0+5.25*(0.9*DKSS/AB)**(2.3))

DKT=SORT(DKTS+DKTS+DKT+DKTL)

SIGK=SORT(SK2-2.0+DKSS+DKT-DKT+DKT)

RI=SIGK/IF

K=DKT/SIGK

IF (J,LE,70) GO TO 71

GO TO 90

THIS BRANCH APPLIES TO KD2.

DKSS=DKS/(OPT+VB)

IF (AB-0.45) 21:21:22

RI=10847.0*(1.0-1.0/EXP(4.0*AB))

GO TO 23

RI=9054.0*(AB-0.45)*(1164.0+14052.0*(1.0-1.0/EXP(2.5*DKSS/8)*97627.0))

RI=25763.0*(1.0-1.0/EXP(4.82*(0.125*PN*AB)**1.4)) /EXP(DKSS/8)

RI=17627.0
1039  RF=RF/F1
1040  R1=R1+OPT/(0.1475*SP)
1041  GO TO 90
1042c
1043c  THIS BRANCH APPLIES TO I1C.
1044c
1045  30  DKSS=DKS/(OPT*VB)
1046     R11=1.01*AB+0.63
1047     R10=SORT(0.5358*AB+0.26)**2+(1.2271*SORT(8.0*AB/PN)/
1048       EXP(5.42*(AB/DT)**2))**2
1049     RS=SORT(1.0-1.0/EXP(0.17*(DKS/SGF)**2))
1050     IF (R11-R10) 31,31,32
1051  31  R1=R10-RS*(R10-R11)
1052  32  GO TO 33
1053  33  R1=R10+RS*(R11-R10)
1054  33  RF=1.458*(1.0-1.0/EXP(9.0+(.125*PN+AB)**1.4))**EXP((DKSS/1.424)
1055     * *0.75)
1056  RF=RF/F1
1057     R1=R1+OPT/(0.1475*SP)
1058  30  GO TO 90
1059c
1060c  THIS BRANCH APPLIES TO I1D.
1061c
1062  40  R1=0.1324*(1.0-1.0/EXP(4.0*(AB+1.4142)))
1063     IF (AB.6T.0.3) GO TO 45
1064     RS=0.6739*SORT(AB)-1.6528*AB+AB
1065     R1=SORT(RS*RS+R1*R1)
1066  45  RF=0.0630*(1.0-1.0/EXP(4.0*AB*AB))
1067     RF=RF/F1
1068     R1=R1+OPT/(0.1397*SP)
1069  40  GO TO 90
1070c
1071c  THIS BRANCH APPLIES TO K1A
1072c
1073  50  R1=0.0825*(1.0-1.0/EXP(6.0*AB+1.475))
1074     IF (AB.6T.0.35) GO TO 55
1075     RS=0.192*SORT(AB)-0.9253*AB+AB
1076     R1=SORT(RS*RS+R1*R1)
1077  55  RF=0.0542*(1.0-1.0/EXP(3.75*(AB+1.6667)))
1078     RF=RF/F1
1079  R1=R1/SP
1080  60 TO 90
1081c
1082c  THIS BRANCH WHICH APPLIED TO KAZ HAS BEEN NULLED.
1083c
1084  60 60 TO 90
1085c
1086c  THIS BRANCH APPLIES TO DSFR.
1087c
1088  70  DK$=1.4809*DK$/OPT
1089  50 TO 10
1090  71  DK$=0.6753*DK$/OPT
1091  DKSS=DK$/VB
1092  IF (AB-0.6) 72,72,75
1093  72  RR1=0.0996+(0.047/EXP(8.0*DKSS*0.8)-0.008)*(AB-0.6)
1094  A=0.0992+1.15*(1.0-1.0/EXP(4.0*DKSS**3))
1095  IF (AB-0.28) 73,73,74
1096  73  S=0.5+DKSS
1097  HP=A/(0.28**S)
1098  RRK=HP*AB**S
1099  60 TO 76
1100  74  S=(A-0.0996)/0.42
1101  RRK=0.0996-S*(AB-0.6)
1102  60 TO 76
1103  75  RR1=0.0996
1104  RR1=0.0996
1105  76  R1=R1+RR1/0.1475
1106  RRK=RRK+RR1/.1475
1107c
1108  90 RETURN
1109  END
1110c
1111c
SUBROUTINE SEARCH (AKS, DKS, ANT)

THIS SUBROUTINE CONTROLS SOLUTION OF (KMAX - KMIN) / SIGMA K

IF (AKS.GE.2.0) GO TO 40
CALL PFXL (AKS, DKS, ANT)
GO TO 120

DKS = 2.6 + 0.233 * (ALOG(ANT) - 4.60517)
SLOPP = 7.5
DKSN = DKS + 0.25
DO 100 J = 1, 100

IF (DKS.LT.2.3) GO TO 120
CALL PFX (AKS, DKS, PX)
ERR = ABS (PX - ANT) / ANT
IF (ERR.LT.0.001) RETURN
IF (J.EQ.1) GO TO 60

DDK = ABS (DKS2 - DKS)
IF (DDK.LT.0.00001) RETURN
SLOPE = (ALOG(PX2) - ALOG(PX)) / (DKS2 - DKS)
IF (SLOPE.EQ.0.0) SLOPE = SLOPP

DKSN = DKS + (ALOG(ANT) - ALOG(PX)) / SLOPE

PX2 = PX
DKS2 = DKS
DKS = DKSN
100 SLOPP = SLOPE

120 RETURN

END
SUBROUTINE FFX (AKS,DKS,PK)

THIS SUBROUTINE SOLVES (KMAX-KEAR)/SIGMA K FOR KEAR/SIGMA K.GT.

UND=(-1)*(3.0*ABS(AKS-2.0))
UND1=-5.*ABS(AKS-2.5)
UND2=-5.*ABS(AKS-3.)
IF (UND .LT. -38.) UND1=-38.
IF (UND2 .LT. -38.) UND2=-38.
IF (UND .LT. -38.) UND=-38.
B=((AKS+15.)*.023)/((ABS(AKS-1.5))**1.2)+2.4
AM=1.16-(15.5*(ABS(1.4)/((AKS+.4)**4))
Y1=-.66-.140*(EXP(-.30*ABS(AKS-6.5)))
S+ .440*(EXP(-.99*ABS(AKS-2.0)))
S- .035*(EXP(-1.2*ABS(AKS-4.7)))
S- .062*(EXP(-0.7*ABS(AKS-16.)))
A=1.13-.031*(AKS-2.7)**.5*(ABS(AKS-2.7)**15)*EXP((-AKS-5.)*
(-.45))- .0299*(EXP(-2.8*ABS(AKS-16.)))
S+ .04*(EXP(UND))+ .0177*(EXP(-ABS(AKS-4.)))
S- .0172*(EXP(-ABS(AKS-6.0)))- .0534*(EXP(UND))
S- -.0817*(EXP(UND2))
CH1=AN+DKS+Y1+A*(DKS-2.3)**3
IF (CH1 .GT. 38.) CH1=38.0
IF (CH1 .LT. -38.) CH1=-38.0
PK=10.**CH1

RETURN

END
SUBROUTINE DISPAR

SUBROUTINE TO CALCULATE SPECIFIC DISTORTION PARAMETERS,

NF, RADLOC, ANGLOC, AND P HAVE THE FIRST ARRAY DIMENSION EQUAL TO 11.

TEN OF THE 11 POSITIONS ARE AVAILABLE FOR USE. THE
REMAINING POSITION IS NEEDED FOR INTERNAL PROCESSING.

COMMON AB, ANGLOC (20), AUO, BETA2, BF, CDPOP3 (10), CMAV6 (10), FO, ISHFT,
CMIN (10), DKMX (10), DKSS (10), FACE (39, 65), FACTOR, FARCE (39, 65), BSF,
J1, J2, KEY, KI, LCNTFL, NH, NP, NR, P (11, 20), PR (10), PS (11, 20), CKP,
PSPEC (20), PVALUE, QAV, QPT2, R, RADLOC (11), RANGE, RI, RMAV, RRNP (11),
RTP, SGDK (10), SGP (10), SIG, SNAV6, STATI, STATO, T, TDP1, TDP2, TMIN,
TDP3, THETA, THTMIN (10), TITLE1 (20), TITLE2 (20), TMAX, TMAX, RKP, U2

COMMON BLOCK FOR TRANSFERRING SPECIFIC DISTORTION
PARAMETERS TO THE OUTPUT SUBROUTINE ‘LNFDOUT’

DIMENSION PT (20), QD (10), DTHETA (20), RIOD (5), RIIM (5)
LOGICAL STATI, STATO, LCNTFL

DATA IT/0/

IF (IT.EQ.1) GO TO 25

CALCULATION OF K2

DINV = 0.0

DO 26 I = J1, J2
   DINV = DINV + (1.0/RADLOC(I))

DO 27 I = J1, J2
   QD(I) = (1.0/RADLOC(I))/DINV

RD2 = 0.0

DO 28 I = J1, J2
   RD2 = RD2 + (CDPOP3(I)*THTMIN(I) + QD(I)*100.0)

CALCULATION OF K-THETA.

IF (IT.EQ.1) GO TO 37

DO 36 J = 1, NP
   KI = J - 1
1214 IF (K1.EQ.0.0) K1=NP
1215 A1=ANGLOC(K1)
1216 IF ((J-1).EQ.0.0) A1=A1-360.0
1217 K2=J+1
1218 IF (K2.GT.NP) K2=1
1219 A2=ANGLOC(K2)
1220 IF ((J+1).GT.NP) A2=A2+360.0
1221 36 DTHETA(J)=(A2-A1)/2.0
1222 PGAM=.285714
1223 37 RKHT=0.0
1224 TTTT=DTHETA(1)
1225 DTHT=TTTT
1226 IF (ISHFT.EQ.1) QAV=(SMAY6/PGAM)+((ABS(TMAY6/SMAY6))**PGAM)-1.0
1227 DO 35 J=1,J2
1228 RISIN=0.0
1229 RICOS=0.0
1230 DO 34 J=1,NP
1231 PHI=0.017453*ANGLOC(J)
1232 RISIN=RISIN+((P(I,J)/TMAY6)*SIN(PHI)*DTHETA(J))
1233 34 RICOS=RICOS+((P(I,J)/TMAY6)*COS(PHI)*DTHETA(J))
1234 35 RKHT=RKHT+QD(J)*((SORT(ABS(((ABS(RISIN))**2)+((ABS(RICOS))**2))))
1235 IF (QAV.EQ.0.0) QAV=1.0
1236 RKHT=(RKHT/(180.0*QAV))*TMAY6
1237c
1238c CALCULATION OF IDC-MAX AND IDR-MAX.
1239c
1240 NCJH=NP
1241 IF (STATI) NCJH=NCJH-1
1242 IF (STATD) NCJH=NCJH-1
1243 IF (NCJH.EQ.0.5) GO TO 39
1244 CALL PRNT(3)
1245 GO TO 39
1246 39 DO 41 J=1,J2
1247 RIC((J)=CMAY6((J)-CMNIN(J))/TMAY6
1248 41 RIDC((J)=TMAY6-CMAY6((J))/TMAY6
1249 RIDCX1=(RIDC(J1)+RIDC(J1+1))/2.0
1250 RIDCX2=(RIDC(J1+3)+RIDC(J1+4))/2.0
1251 RIDC=ANAX1(RIDCX1,RIDCX2)
1252 RIDF=ANAX1(RIDC(J1),RIDC(J1+4))
1253c
1254c CALCULATION OF ID
1255c
1256 \[ \text{P1D} = \text{R1DCMX} \times \text{BSF} \times \text{CKP} + \text{R1DMX} \times \text{RKP} \]
1257c
1258c CALCULATION OF KRA2 AND KA2
1259c
1260 \[ \text{SPTR} = 0.0 \]
1261 DO 100 I = 1, J2
1262 PTAVR = CMAVG(I)
1263 \[ \text{DFTR} = \text{ABS}(\text{PTAVR} - \text{TMAYG} - \text{BRP}(I)) / \text{BRP}(I) \]
1264 DO 100 \[ \text{SPTR} = \text{SPTR} + \text{DFTR} \times \text{ORD}(I) \]
1265 \[ \text{AKRA2} = \text{TMAYG} + \text{SPTR} / \text{OAV} \]
1266 \[ \text{AKRA2} = \text{RKTHT} + \text{AKRA2} \times \text{BF} \]
1267c
1268c CALCULATION OF DELTA STALL MARGIN - DSM
1269c FIRST FIND THE AVERAGE RADIAL PRESSURE AND MINIMUM PRESSURE
1270c
1271 \[ \text{PTRA} = 0.0 \]
1272 \[ \text{PTRM} = 50000. \]
1273 \[ \text{AK} = \text{NP} \]
1274 \[ \text{ANR} = \text{J2} - \text{J1} + 1 \]
1275 DO 300 J = 1, NP
1276 \[ \text{PT}(J) = 0.0 \]
1277 DO 200 I = 1, J2
1278 DO 200 \[ \text{PT}(J) = \text{PT}(J) + \text{P}(I, J) \]
1279 \[ \text{PT}(J) = \text{PT}(J) / \text{ANR} \]
1280 \[ \text{PTRA} = \text{PTRA} + \text{PT}(J) \]
1281 DO 300 \[ \text{PTRM} = \text{AMIN}(\text{PT}(J), \text{PTRM}) \]
1282 \[ \text{PTRA} = \text{PTRA} / \text{AK} \]
1283 \[ \text{RISIN} = 0.0 \]
1284 \[ \text{RICOS} = 0.0 \]
1285 DO 400 J = 1, NP
1286 \[ \text{PHI} = 0.017453 \times \text{ANGLOC}(J) \]
1287 \[ \text{RISIN} = \text{RISIN} + \text{CT}(J) / \text{PTRA} \times \text{SIN}(\text{PHI}) + \text{DTHT} \]
1288 DO 400 \[ \text{RICOS} = \text{RICOS} + \text{CT}(J) / \text{PTRA} \times \text{COS}(\text{PHI}) + \text{DTHT} \]
1289 \[ \text{DSM} = 0.675 \times \text{SPRT}(\text{RISIN} + \text{RISIN} + \text{RICOS} + \text{RICOS}) / 180.0 \]
1290c
1291c SPECIFIC DISTOCTION PARAMETERS STORED IN ARRAY 'FSPEC'
1292c IN PREPARATION TO BEING TRANSFERRED TO 'LMFOUT',
1293c
PSPEC(1) = PKTHT
PSPEC(2) = PK02
PSPEC(3) = PIDCNX
PSPEC(4) = PIDPMX
PSPEC(5) = AKRA2
PSPEC(6) = AKAR2
PSPEC(7) = DSM
PSPEC(8) = RID
RETURN
END
SUBROUTINE PRNT (KP)
COMMON AB, ANGLOC (20), A0U, BETA2, BF, CIDP13 (10), CMAYG (10), FO, ISHFT,
& CMIN (10), DMX (10), DMIN (10), FACE (39, 65), FACTOR, FARC (39, 65), BFS,
& J1, J2, KEY, KID, LCNTFL, MN, NP, NP, NP, P (11, 20), PR (10), PS (11, 20), CKP,
& PSPEC (20), PYVALU, OW, OPT2, R, RADLOC (11), RANGE, R, RMAY, BPR (11),
& R, SBDK (10), SGF (10), SIGE, CMAY6, STA1, STATO, T, TDP1, TDP2, TMIN,
& TDP3, THERA, THMIN (10), TITLE1 (10), TITLE2 (10), TMAYG, TMAX, RKP, U2
LOGICAL STA1, STATO, LCNTFL
GO TO (9, 2, 3, 9, 9, 9, 8, 9, KP
WRITE (6, 125) TITLE1, TITLE2,
SECTION THAT WRITES THE ANGULAR POSITIONS OF THE INPUT MEASUREMENTS
WRITE (6, 113)
WRITE (6, 121)
WRITE (6, 123) (ANGLOC (I), I=1, NP)
WRITE (6, 109)
SECTION THAT WRITES THE INPUT MEASUREMENTS
DO 40 J=1, J2
WRITE (6, 110) RADLOC (J), (P (J, I), I=1, NP)
SECTION THAT WRITES THE BASE RADIAL PROFILES.
WRITE (6, 104) (RADLOC (J), J=1, NP)
WRITE (6, 105) (BPR (J), J=1, NP)
GO TO 1000
WRITE (6, 100)
GO TO 1000
WRITE (6, 125) TITLE1, TITLE2
GO TO 1000
FORMAT ('/10X, 44HANGLOC-MAX AND IDP-MAX CANNOT BE CALCULATED/
10X, 51HTHERE ARE NOT EXACTLY 5 RINGS OF TOTAL MEASUREMENTS/)
104 FORMAT ('/30X, 1SHBASE RADIAL PROFILE//10X, 8HRADI11, 8F8.3)
105 FORMAT ('/10X, 8HRADPI, 8F8.4)
SUBROUTINE INTERP
INTERPOLATION SUBROUTINE
NP, RADLOC, ANGLOC, AND P HAVE THE FIRST
ARRAY DIMENSION EQUAL TO 11. TEN OF THE
11 POSITIONS ARE AVAILABLE FOR USE. THE
REMAINING POSITION IS NEEDED FOR INTERNAL PROCESSING.

COMMON AR, ANGLOC(20), AVO, BETA2, BF, CDPDP3(10), CMAY6(10), FO, ISHFT,
CMIN(10), DMX(10), DKSS(10), FACE(39,65), FACTOR, FARCE(39,65), BSF,
J1, J2, KEY, KD, LCNTFL, NH, NP, NR, P(11,20), PR(10), PS(11,20), CKP,
PSPEC(20), PVVALUE, DAY, OPT2, R, RADLOC(11), RANGE, RI, RMAY5, BMF(11),
RT, SGOK(10), SGP(10), SIG, SMAY6, STATI, STATO, T, TDP1, TDP2, TMAY6,
TDP3, THT(10), TITLE1(20), TITLE2(20), TMAY6, TMAX, RKP, U2

DIMENSION NFIT(2), NRFIT(2), RADFIT(2), Z(2), F(2)
LOGICAL STATI, STATO, LCNTFL
IF (NR.LT.2) CALL PRNT (3)
NR1=NR-1

DETERMINE THE CORRECT TWO RINGS TO USE IN THE INTERPOLATION PROCESS.

DO 11 I=1,NR1
   11 I=1
IF (R.GE.RADLOC(I1).AND.R.LT.RADLOC(I1+1)) GO TO 12
CONTINUE

INTERPOLATION BOUNDARY RING NO.

NFIT(1)=11
NFIT(2)=11+1

SET-UP FOR CIRCUMFERENTIAL INTERPOLATION
DETERMINE THE TWO MEASUREMENTS ON EACH RING TO USE
IN THE CIRCUMFERENTIAL INTERPOLATION PROCESS.
INTERPOLATION RING ONE TO INTERPOLATION RING TWO
DO 15 J=1,NP
N2=J
IF (J.EQ.NP) GO TO 20
13
IF ANGLOC(J+1) < THETA < 360. REQUIRES SPECIAL INTERPOLATION
14 CONTINUE
15 GO TO 20
16 NP=N2
17 NUMBERS OF INTERPOLATION BOUNDARY ANGLES
18 DO 20 I=1,N2
19 IF (THETA.LT.ANGLC(I)) GO TO 7
20 IF (ANGLOC(I).LT.LT.1) GO TO 23
21 IF (ANGLOC(I).LT.LT.NP) GO TO 24
22 L=ANGLOC(I)
23 Z(I)=ANGLOC(I)
24 P(I)=P(I)+L
25 GO TO 18
26 IF (ANGLOC(I).LE.NP) GO TO 27
27 L=ANGLOC(I)-NP
1438  Z(I)=ANGLOC(L)
1439  F(I)=F(K+L)
1440  GO TO 18
1441c  SET UP SPECIAL INTERPOLATION EXTERIOR POINT
1443c  L=NFFIT(I)
1444  Z(I)=ANGLOC(L)-360.0
1445  F(I)=F(K+L)
1446  GO TO 18
1448  L=NFFIT(I)+NP
1449  Z(I)=ANGLOC(L)-360.0
1450  F(I)=F(K+L)
1451  GO TO 18
1452  L=NFFIT(I)-NP
1453  Z(I)=360.0+ANGLOC(L)
1454  F(I)=F(K+L)
1455  CONTINUE
1456c
1457c  LINEAR INTERPOLATION IN THE CIRCUMFERENTIAL DIRECTION.
1458c  RADFIT(I)=((F(2)-F(1))^((THETA-Z(1))/(Z(2)-Z(1))))+F(1)
1460  CONTINUE
1461c
1462c  LINEAR INTERPOLATION IN THE RADIAL DIRECTION.
1463c  DO 30 I=1,2
1464  L=NFFIT(I)
1465  Z(I)=RADLOC(L)
1466  F(I)=RADFIT(I)
1468c
1469c  FINAL INTERPOLATED VALUE
1470c  PVALUE=((F(2)-F(1))^((R-Z(1))/(Z(2)-Z(1))))+F(1)
1472c
1473  RETURN
1474  END
1475c
1476c
SUBROUTINE UNITDY

THIS SUBROUTINE PERFORMS THE TOTAL PRESSURE FLUCTUATION COMPUTATIONS.

THE DELTA Pressures are added to the Steady State Pressures, then the
Distortion Factor Routines and the Contour Map Routines are called.

COMMON AR, ANGLOC(20), AUDIO, BE, E, R, BF, CDFEOP3(10), CMAY6(10), F0, ISHFT,
& CMIN1(10), DMX(10), DISS(10), FACE(39,65), FACT, FARD(39,65), BSF,
& J1, J2, KEY, KD, LINTFL, NN, NP, NR, P(11,20), PR(10), PS(11,20), CKD,
& PSEG(20), PMAX, QAY, OPE2, R, RMEG(11), RANG, RI, RMAY6, BRP(11),
& RT, SGD(10), SGF(10), S15, SMAY6, STAT, STATD, T, TIP1, TIP2, TMIN,
& TIP3, THET, THTM(10), TITLE1(20), TITLE2(20), TMAY6, TMMAX, RKP, U2

DIMENSION AR(11)
COMMON COH=1.0/57.29577951

SET INITIAL AND/OR DEFAULT VALUES.

VL=999.999
X=0.0
R1=0.0

CALL SUBROUTINE NEWPSD: INPUT IDENTIFICATION AND CONTROL PARAMETERS

CALL NEWPSD(2)

DEFINE PROBE RADIAL LOCATION IN RATIO FORM.

NRG=0
DO 50 I=1, NR
IF (1.0E, J1, AND. I.LE. J2) NRG=NRG+1
50 AR(I)=RADLOC(I)/RADLOC(NR)

RMAY=0.5*(1.0+AR(I))
PR=PRAM
COP=0.7*RMAY*RMAY/(1.0+0.7*RMAY*RMAY)**3.5

COMPUTE AVERAGE AND MAXIMUM Mach NUMBER AND VELOCITY AT ENGINE FACE.
TMAYGG=TMAYG
AMX=SORT(5.0*(<TMAYG/SMAVG>**.286)-1.0))
AMN=SORT(5.0*(<TMAYG/SMAVG>**.286)-1.0))
YBM=AMM*SORT((1.0+0.2*AMM*AMM)/SORT((1.0+0.2*AMM*AMM))/AMA
NY=2
OKD=PSPEC(KD)
YBI=1.0

SEARCH FOR VORTEX LOCATION AND ORIENTATION.

RKMX=TMXMIN
RKMN=TMXMAX
DO 68 I=1,HP
RKAV=0.0
DO 66 J=J1,J2
RKAV=RKAV+PS(J,I)
RKAV=RKAV/NPG
IF (RKAV,LT,RKMX) GO TO 67
RKMX=RKAV
THMX=ANGLOC(I)
IF (RKAV,GT,RKMN) GO TO 68
RKMN=RKAV
THMN=ANGLOC(I)
GO 68 CONTINUE
DTH=ABS(THMN-THMX)
THE=0.5*(THMN+THMX)
IF (DTH,LE,180.0) GO TO 69
DTH=360.0-DTH
THE=THE+180.0
IF (THE,GE,360.0) THE=THE-360.0
ART=DTH/114.592
G1=-90.0
IF (THMN,GT,THE) GO TO 71
G1=90.0
IF (THE,GT,180.0) THE=THE-180.0
TV=THE
CALL LNPOT(I)
1557   WRITE (6,1996)
1558   WRITE (6,1998) THMN,RKMN,THMX,RKMX,DTH,THE,ART,G1
1559   CALL LMPD (2)
1560   WRITE (6,1800)
1561c  CALL SUBROUTINE TO COMPUTE MAXIMUM INSTANTANEOUS DISTORTION FACTORS
1562c
1564   CALL NEWPSD(3)
1565   A0=AB
1566   VB0=1.36*SIG/OPT2
1567   VBAR=VB1
1568c ,
1569c  LOOP 600 IS THE VORTEX STRENGTH (VEAR) ITERATION.
1570c  VEAR VARY FROM VB1 TO VB2 BY DVE, NV TIMES.
1571c
1572   VBAR=VB1
1573   DO 600 IV=1,NV
1574   IF (IV-2) .GE. 73,721,722
1575   721 QNKD=PSPEC(KD)
1576   722 VEAR=(DKMX(KD)-OKD)/(QNKD-OKD)
1577c
1578c  WHEN A SPECIFIC PRESSURE CONTOUR IS NEEDED A/RT IS COMPUTED FROM VEAR
1579c
1580   73   AYRT=ART
1581   RAV=1.0/AYRT
1582c
1583c  VORTEX ORIENTATION ANGLES AND FUNCTIONS.
1584c
1585   G=G1
1586   COSG=COS(CON+G)
1587   SING=SIN(CON+G)
1588   B=B1
1589   COSB=COS(CON+B)
1590   SINB=SIN(CON+B)
1591   CBSG=COSB*SING
1592   SBSG=SINB*SING
1593   CBCG=COSB*COSG
1594   SBCG=SINB*COSG
1595c
LOOP 90 IS THE PROBE RADIAL LOCATION ITERATION. FOR A GIVEN VORTEX
THE PRESSURE FLOWFIELD IS FOUND AT EACH PROBE RADIUS AND THETA.
THERE ARE NR RINGS AND NP PROBES PER RING.

DO 90 J=1, NR
IF (J-J1) 78, 65, 63
IF (J-J2) 65, 65, 78
ZR=AR(J)-RPT)/AYPT
IF (ABS(ZA).GT.100.0) ZA=SIGN(100.0, ZA)
IF (ABS(TV).GT.180.0) TV=SIGN(180.0, TV)

LOOP 80 IS THE PROBE CIRCUMFERENTIAL LOCATION ITERATION.

DO 80 I=1, NP
PHI=ANGLOC(I)-TV
IF (PHI.GT.180.0) PHI=PHI-360.0
IF (PHI.LT.-180.) PHI=PHI+360.0
YA=CON*PHI*PAV
Y=-XA*BCG+YA*BCG+2A*SING
IF (ABS(Y/VL).LT.1.0) GO TO 70
DPT1=0, 0
GO TO 75
70 BASE=YA*SING-2A*COSG*COSB
RAD=XA*COSB+YA*SINB+.2+(-XA*SA+YA*CBS-2A*COSG)**2-1.0
IF (RAD.GT.670.0) RAD=670.0

DPT1 IS THE PRESSURE FLUCTUATION AT PROBE AR(J) AND ANGLOC(J, I)

DPT1=2.0+VBAR*BASE/EXP(0.5*RAD)
P(J, I)=PS(J, I)+DPT1*O.DPL*TMAY66
CONTINUE

GO TO 90

RESET STATIC PRESSURE RINGS TO STATIC PRESSURE.

DO 79 I=1, NP
P(J, I)=PS(J, I)
CONTINUE

IF (IV-1) 91, 91, 92
CALL PFIX (.TRUE.)
CALL DISTRT
GO TO 600
CALL PRINT (2)
CALL PFIIX(.TRUE.)
CALL DISTRT
CALL PFIIX(.FALSE.)
CALL MAINLP
CALL LNPOT(1)
WRITE (6,1995)
WRITE (6,2000) VBAR,ART6,B,HYRT,VL,RR,T,Y
WRITE (6,1999) VBM,VB0,A0
CALL LNPOT(2)
WRITE (6,1805)
600 CONTINUE
RETURN
1800 FORMAT (/27X,"<STEADY-STATE DISTORTION>")
1805 FORMAT (/31X,"<PEAK DISTORTION>")
1995 FORMAT (/25X,1SHVORTEX LOCATION)
1996 FORMAT (/25X,17HVORTEX PROPERTIES)
1998 FORMAT (/12X,4HTHNN,3X,4HRKNN,4X,4HTHMX,3X,4HRKMX,4X,3DTH,3X,
% 5THETA,5X,2HA1,6X,2H61/8X,2(F8.2,F7.3),F7.2,F8.2,F8.3,F7.2)
1999 FORMAT (/11X,4HVBMX,4X,3HVBO,3X5HA0/RT/8X,2F7.3,F8.4)
2000 FORMAT (/10X,4HVBAR,4X,4HA/RT,1X,5HGMMA,2X,4HBETA,3X,5HAY/RT,
% 5X,2HV,4X,4HR/RT,4X,5THETHA/6X,2F8.3,2F6.1,3F8.3,F8.2)
END
SUBROUTINE TURBUL (PT1, RS1, NR1, NP1, U2, O2, PT2, XM0, PT0, RMSAG)

TURBULENCE PROGRAM

BY: YEN-SEN CHEN
(MAR. 17, 1984)

THIS SUBROUTINE IS A SUBDRIVER FOR THE COMPUTATION OF RMS LEVELS
AT THE COMPRESSOR FACE BY SOLVING THE K-E TURBULENCE MODEL.

SUBROUTINE INITL IS Used TO SET INITIAL VALUES OF K AND E AT EACH
GRID POINT (GK AND GE RESPECTIVELY).

SUBROUTINE INIVEL IS Used TO CALCULATE VELOCITY GRADIENTS.

SUBROUTINE CUBIC IS Used TO DO THE CUBIC SPLINE INTERPOLATIONS.
SUBROUTINE TRIDIA IS USED TO SOLVE THE TRIDIAGONAL MATRIX EQUATION.
SUBROUTINE FINITE SOLVES FOR THE K-E TURBULENCE MODEL USING A FINITE
DIFFERENCE FORMULATION.

DIMENSION PT(11,20), PT1(11,20), U(11,20), WK(20), WE(20), MUR(20),

%  RS1(20)

COMMON /CUB/ NGP, NGF, NW, NR, NP, RS(20), THA(20), DR(20), C(20),
%  C2(20), C3(20), THG

COMMON /VELGR/ URG(80,80), URG(80,80), URG(80,80), URG(80,80),
%  URG(80,80), URG(80,80)

COMMON /INIKE/ GK(80,80), GE(80,80), GR(80,80), GT(80), ERRK, ERRF
COMMON /PARA/ PMU, NPM, NPP, NPG, NSHT, FACT

SET GRID SIZE PARAMETERS (NGP & NGF), ITERATION LIMITER (NSHT),
RELAXATION FACTOR (FACT) AND OTHER CONSTANTS.

N6R=4
N6F=4
NSHT=30
FACT=1.0
AMU=1.75E-4
PI=3.141592654
NP=NR1
NP=NP1
DO 18 I=2, NP
RS(I)=RS(I-1)/NR
DR(I-1)=(RS(I)-RS(I-1))/NGR
DO 40 I=1,NGR
L=(I-2)*NGR+1
GR(L)=RS(I-1)+(I-1)*DR(I-1)
DO 40 CONTINUE
THF=2.*F1/NP
TH6=THE+NP
1746  NEW=(NR-2)*NGR+1
1747  NF=NF*NGP
1748  GP(NF)=(NR-1)
1749  DO 50 J=1,NGP
1750  THA(J)=(J-1)*THE
1751  DO 50 JJ=1,NGP
1752  L=(J-1)*NGP+JJ
1753  GT(L)=THA(J)+(JJ-1)*TH5
1754  50 CONTINUE
1755c  ESTIMATE BOUNDARY RMS LEVEL AND CALCULATE VELOCITY DISTRIBUTIONS.
1755c
1756c  DA=RS(NR)/6.
1757c  RS(NR)=1.0
1758c  CK=0.115*(PTT0-PT2)**(-0.2587)
1759c  RED=U2*DA/AMU
1760c  YELR=0.1275*(ALD510-RED)**(-2.5)
1761c  AMUR=90/VELR)*U2*DA/AMU/2.
1762c  PMU=1./AMUP
1763c  CENK=10.0
1764c  CENE=0.164*CENK**1.5/0.12
1765c  WRMS=CK*AVG5
1766c  IF(WRMS .LT. 0.01) FACT=0.7
1767c  DO 5 J=1,NGP
1768c  SUMP=0.0
1769c  DO 15 I=1,NR-1
1770c  DENR=(PT(I-1,0)/PT7A)**0.714286
1771c  P1=PT(I,J)/DENR-PT7A
1772c  P1=3.5*P1/0.2*VELR/PT2
1773c  U(I,J)=SORT(ABS(P1))
1774c  IF(P1 .LT. 0.) U(I,J)=-U(I,J)
1775c  IF(I .LT. NR-2) 60 TO 15
1776c  SUMP=SUMP+(1.-PT(I,J))
1777c  15 CONTINUE
1778c  P1=CK*SUMP/2,0./AVG5
1779c  P1=1./3.*U(NR-1,J)**2
1780c  P2=1.75*WRMS/0.2*VELR/DENR
1781c  W(I,J)=P1*SORT(P1*P1+P2)
1782c  U(I,J)=0.0
1783c  WDR(J)=2.0*U(NR-1,J)/1.0-RS*(NP-1)
1785 5 CONTINUE
1787 WRITE(*,300)
1788 300 FORMAT(5X:"DIMENSIONLESS VELOCITY AT EACH PROBE LOCATION:")
1789 DO 35 J=1,NP
1790 WRITE(*,500) (U(J),J=1,NP)
1791 500 FORMAT(1X,12F10.2)
1792 35 CONTINUE
1793 C1(1)=0.
1794c SET INITIAL VALUES FOR TURBULENCE KINETIC ENERGY, Gk.
1796c
1797 CALL CUBIC(NP,MK,THA,C1,C2,C3)
1798 CALL INITL(CENK,MK,GK)
1799c CALCULATE THE RADIAL AND CIRCUMFERENTIAL VELOCITY GRADIENTS.
1800c
1802 CALL INIVEL(U,RS,THA,IR,TH6,NPW,NRM,WR,G,R,NP,NGR,NGP)
1803 DO 65 J=1,NP
1804 JNP=(J-1)*NGP+1
1805 WR(J)=0.3*WK(J)*SORT(UUG(NPW,JNP))
1806 65 CONTINUE
1807 C1(1)=0.
1808c
1809c SET INITIAL VALUES FOR TURBULENT KINETIC ENERGY DISSIPATION RATE, GE.
1811c
1812 CALL CUBIC(NP,ME,THA,C1,C2,C3)
1813 CALL INITL(CENL,ME,GE)
1814 600 FORMAT(13X:"""
1815 WRITE(*,6200)
1816 200 FORMAT(1X,5X,"ERRORS IN K, E AND (K+E) OF EACH ITERATION:")
1817 UUM=UUG(1,1)
1818 DO 45 J=2,NPW
1819 IF(UUG(1,J).GT. UUM) UUM=UUG(1,J)
1820 45 CONTINUE
1821 DO 55 J=1,NP
1822 UUG(1,J)=UUM
1823 55 CONTINUE
1824 NP5=NP6
1825 NP6=NP5
CALL FINITE SUITRALOINE TO SOLVRE FOR THE TURBULENCE MODEL USING
FINITE DIFFERENCE FORMULATIONS.
CALL FINITE(UU6,DR,TH6,NPW,NRF)
CALL PRINT (8)
WRITE (6,100)
100 FORMAT (/4X,"RESULTS OF TURBULENCE CALCULATIONS:\)
WRITE (6,800)
COMPUTE RMS LEVEL AT EACH PROBE.
SUMF=0.0
DO 60 J=1,NP
   J0=(J-1)*NRF+1
DO 60 I=1,NR-2
   I1=I*NRF+1
   TK=6K(I1,J0)
   TE=6E(I1,J0)
   TUU=UU6(I1,J0)
   TU=U(I+1,J)
   TR=RS(I+1)
   NT=(J-1)*(NP-2)+1
   DENR=(PT(I+1,J)/PT7A)**0.714286
   PRD=0.09*TK*TK*TUU/TE/TE
   P0=2.*3.
   P1=2.*02*DENR*VELR/3.5
   P2=P0*TU*TU
   RMS=P1*SORT(P2*TK*TK*TK)
   SUMF=SUMF+RMS**2
60   WRITE (6,700) NT,TUU,TE,TK,RMS
700 FORMAT (11X,4F12.4,F12.4)
CONTINUE
END
SUBROUTINE INITL(CE, WA, GA)

THIS SUBROUTINE GIVES THE INITIAL VALUES OF GK AND GE.

DIMENSION WA(20), GA(80), THA

COMMON /CUB/ NGR, NPG, NPM, NRW, NR, NP, RS(20), THA(20), DR(20), C1(20),
          C2(20), C3(20), THG

DO 1 J=1, NP
DO 1 I=1, NPG
JJ=(J-1)*NGP+I
T1=THA(J)+(I-1)*THG
P1=T1-THA(J)
GA(NRW, JJ)=(C1(J)*P1+C2(J))*P1+C3(J)*P1+WA(J)
CONTINUE
DO 2 J=1, NP
DA=(GA(NRW, J)-CE)/RS(NR-1)
DO 2 I=1, NP-2
DO 2 K=1, NGR
KK=(I-1)*NGR+K
R1=RS(1)+(K-1)*DR(I)
GA(KK, J)=CE+R1*DA
CONTINUE
RETURN
END
SUBROUTINE INIVEL (U, R, T, DP, T6, HPW, MUR, GR, NP, NR, N6R, N6P)

This subroutine computes the radial and circumferential velocity gradients at each grid point using cubic spline interpolations.

DIMENSION U(11,20,10), R(20), T(20), C1(60), C2(60), C3(60), H(60), DP(20),
MUR(20), MURG(80, 80), RA(60), GR(NP)
COMMON /VELGR/ URG(80, 80), URRG(80, 80), UTG(80, 80), UTTG(80, 80),
UG(80, 80), UG(80, 80)

DO 1 I=2, NP-1
DO 2 J=1, NP
A(J)=U(I,J)
2 CONUUE
C1(1)=0.
CALL CUBIC(NP, A, T, C1, C2, C3)
II=(I-1)·N6R+1
DO 1 J=1, NP
DO 1 K=1, N6P
KK=(J-1)·N6P+K
T1=(K-1)·T6
U5(II,KK)=((C1(J)·T1+C2(J)·T1+C3(J)·T1+U(I,J)
1 CONTIUE
DO 3 J=1, NP
DO 3 K=1, N6P
KK=(J-1)·N6P+K
UG(1,KK)=U(1,J)
3 CONTINUE
C1(1)=0.
CALL CUBIC(NP, MUR, T, C1, C2, C3)
DO 4 J=1, NP
DO 4 K=1, N6P
KK=(J-1)·N6P+K
T1=(K-1)·T6
MURG(KK)=((C1(J)·T1+C2(J)·T1+C3(J)·T1+MUR(J)
4 CONTINUE
MP=RPW/2
MP=MP+1
DO 5 J=1, MP
10 J=NP+1
DO 6 I=1,NR
1935 IF I .LT. NR, GO TO 8
1936 IF (I .EQ. 1) GO TO 7
1937 II = NR-I+1+NR+1
1938 A(I) = U6(I1,J)
1939 PA(I) = R(NR-I-1)
1940 GO TO 6
1941 CONTINUE
1942 CONTINUE
1943 CONTINUE
1944 CONTINUE
1945 CONTINUE
1946 CONTINUE
1947 IF (I .EQ. NR) GO TO 9
1948 II = (I-NR) + NR+1
1949 A(I) = U6(I1,J)
1950 PA(I) = -R(NR-I-1)
1951 GO TO 6
1952 CONTINUE
1953 CONTINUE
1954 CONTINUE
1955 CONTINUE
1956 CALL CUBIC(NR,A,PA,C1,C2,C3)
1957 DO 11 I=2,NR-1
1958 IF (I .GT. NR-I) GO TO 12
1959 DO 13 K=1,NR
1960 II = (NR-I)*NR+2-K
1961 IL = NR+1
1962 P1 = -(K-1)*P1(I)
1963 U6(I1,J) = (C1(I)+P1+R1+C2(I))*R1+C3(I)*R1-A(I)
1964 URP5(I1,J) = (C1(I)+P1+R1+C2(I))*R1+C3(I)
1965 URP5(I1,J) = C1(I)+P1+R1+C2(I)
1966 CONTINUE
1967 GO TO 11
1968 CONTINUE
1969 DO 22 K=1,NR
1970 II = (I-NR)*NR+K
1971 IF (I-NR+1
1972 P1 = -(K-1)*P1(I)
1973 U6(I1,J) = (C1(I)+P1+R1+C2(I))*R1+C3(I)*R1-A(I)
1974 URG(1I,JJ) = -(C3+G1(I)+R1+2+G2(I)+R1+G3(I))
1975 URRG(1I,JJ) = 6*(G1(I)+R1+2+G2(I))
1976 22 CONTINUE
1977 11 CONTINUE
1978 UG(I,J) = UG(I,J)
1979 URG(I,J) = URG(I,J)
1980 URRG(I,J) = URRG(I,J)
1981 5 CONTINUE
1982 DO 14 J = 1, NFW
1983 UTG(I,J) = 0.
1984 UTTG(I,J) = 0.
1985 DO 14 J = 2, NFW
1986 IF(J .LT. J) GO TO 15
1987 IF(J .LT. J) GO TO 16
1988 B = UG(I,J-1)
1989 D = UG(I,J+1)
1990 60 TO 17
1991 15 B = UG(I,NFW)
1992 D = UG(I,2)
1993 60 TO 17
1994 16 B = UG(I,NFW-1)
1995 D = UG(I,1)
1996 17 UTG(I,J) = (D-B)/2+GT/G6R(I)
1997 UTTG(I,J) = (D+B-2+UG(I,J))/GT/G6R(I)/G6R(I)
1998 14 CONTINUE
1999 DO 20 J = 1, NFW
2000 DO 20 J = 1, NFW
2001 UG(I,J) = UG(I,J)**2+UG(I,J)**2
2002 20 CONTINUE
2003 RETURN
2004 END
2005c ------------------------
SUBROUTINE CUBIC(N,Y,X,C1,C2,C3)

This subroutine performs cubic spline interpolations (slope-based).

DIMENSION Y(N),X(N),C1(N),C2(N),C3(N),S(N),H(N),S60,B(N)

DO 5 I=1,N-1
5 G(I)=Y(I+1)-Y(I)
H(I)=X(I+1)-X(I)
S(I)=SORT(G(I)/Y(I)+H(I)**2)**2
H(N)=1.
IF(C1(I).NE.0.) 60 TO 7
G(N)=Y(N)-Y(N-1)
H(N)=X(N)-X(N-1)
S(N)=SORT(G(N)**2+H(N)**2)
7 CONTINUE
DO 10 I=1,N
IF(I.EQ.1) 60 TO 1
IF(I.EQ.N) 60 TO 2
P1=G(I-1)*S(I)/H(I-1)
P2=G(I)*S(I)/H(I)
B(I)=(P1+P2)/(S(I)+S(I-1))
60 TO 10
1 CONTINUE
P1=G(N)*S(N)/H(N)
P2=G(N)*S(N)/H(N)
B(N)=(P1+P2)/(S(N)+S(N-1))
IF(C1(N).EQ.999.) B(N)=C1(N)
60 TO 10
2 CONTINUE
P1=G(N-1)*S(N)/H(N-1)
P2=G(N)*S(N)/H(N)
B(N)=(P1+P2)/(S(N)+S(N-1))
IF(C1(N).EQ.999.) B(N)=C1(N)
60 TO 10
3 CONTINUE
B(N+1)=B(N)
M=N-1
IF(C1(N).EQ.0.) M=N
DO 50 I=1,M
B(I)=H(I)**2+B(I)
50 CONTINUE
2047   C1(D) = (B(D) + B(D+1))/P1 - 2.6(D)/P1/H(D)
2048   C2(D) = -(2.6(D) + B(D+1))/H(D) + 3.6(D)/P1
2049   C3(D) = B(D)
2050  50  CONTINUE
2051    RETURN
2052    END
2053c
2054c  ---------------------------------------------
SUBROUTINE TRIDIA(N,A,B,C,F,X)

THIS SUBROUTINE SOLVES THE TRIDIAGONAL MATRIX EQUATION.

DIMENSION A(N),B(N),C(N),F(N),X(N)

DO 10 I=1,N

10 IF(I.EQ.1) GO TO 5

A(I)=A(I)-B(I)*C(I-1)
C(I)=C(I)/A(I)
F(I)=F(I)-B(I)*F(I-1)/A(I)

GO TO 10

C(I)=C(I)/A(I)
F(I)=F(I)/A(I)

CONTINUE

X(N)=F(N)

DO 20 I=1,N-1

J=N-I

X(J)=F(J)-C(J)*X(J+1)

CONTINUE

RETURN

END
SUBROUTINE FINITE(UU, DP, THG, NPW, NRW)

THIS SUBROUTINE SOLVES FOR THE FINITE DIFFERENCE SCHEME USING
IMPLICIT TRIDIAGONAL MATRIX FORMULATIONS.

DIMENSION DP(20), UU(20, 20), A(160), B(160), C(160), F(160), XK(160),
VE(160), VMEFF(20, 20), DRG(80), AL(160), BL(160), CL(160), FL(160)
COMMON / PARA / PMU, NRW, NPW, NPG, NSHT, FACT
COMMON / INIKE / G0(80, 80), GE(80, 80), GP(80), GT(80), ERRK, ERRE

SET INITIAL PARAMETER AND CONSTANTS.

NSH=1
SIGK=1.0
SIGE=1.3
CE1=1.45
CE2=2.0
DO 1 I=1, NPW-1
1 CONTINUE
DO 2 I=1, NPW
2 CONTINUE
DO 2 J=1, NPW
2 CONTINUE
VMEFF(I, J)=0.09*6K(I, J)*GE(I, J)+PMU
MP=NPW/2
MP=2*NPW-1
MM=MP-2

START ITERATIONS.

CONTINUE
ERFKE=0.0
ERFPE=0.0

COMPUTE ELEMENTS OF TRIDIAGONAL MATRIX EQUATIONS OF K AND E.
DO 3 J=1,MP
DO 7 I=1,NM
IF (I .GT. NW-1) GO TO 5
II=NW-1
JJ=J
K=1
L1=0
L2=1
JP=JJ-1
JO=JJ+1
IF (J .EQ. 1) JP=NPW
GO TO 6
CONTINUE
II=I-NW+2
JJ=J+MP
K=-1
L1=1
L2=0
JP=JJ-1
JO=JJ+1
IF (J .EQ. MP) JO=1
CONTINUE
II=II
GP0=GP (II)
GPB=GP (II+K)
GPA=GP (II-K)
TH60=TH6
IF (I .NE. NW-1) GO TO 12
GP0=1.0
GPB=1.0
GPA=1.0
TH60=TH6 (II)
II=II
JP=JJ+MP+MP/2
JO=JJ+MP/2
IF (JP .GT. NPW) JP=JP-NPW
CONTINUE
P1=GP0*VMEFF (II, JJ)+GPB*VMEFF (II+K, JJ)
P2=GPA*VMEFF (II-K, JJ)+GP0*VMEFF (II, JJ)
P3=VMEFF (II, JJ)+VMEFF (10, JP)
P4 = VMEFF(I0,J0) + VMEFF(I1,J0)
PP = 2.0P0.012/1H60/0.2
IF(I ,E0, NM=1) GO TO 17
P5 = (P3+P4)/PP
CK = -6K(I0,J0) + PP4 + 6K(I0,JP)*P3)/PP
CE = -6E(I0,J0) + PP4 + 6E(I0,JP)*P3)/PP
17 CONTINUE
OR1 = OR6(II-L1)
OR2 = OR6(II-L2)
IF(I ,E0, NM=1) OR2 = OR1
OR = (OR1+OR2)*OR0
O1 = OR1*OR
O2 = OR2*OR
O3 = OR2*OR
AP = P1/O1
AH = -(0R1+P2+OR2+P1)/O2+P5
A0 = P2/03
FK = 6E(II,J0)-VMEFF(I1,J0)*UU(I1,J0)/GK(II,J0)
FE = CE2*6E(II,J0)-CE1*VMEFF(I1,J0)*UU(I1,J0)/GK(II,J0)
B(I) = AP/SIG
Ah(I) = AH/SIG-FK/2.
C(I) = AH/SIG
F(I) = CK/SIG
IF(I ,E0, 1) F(I) = F(I) - B(I) * 6K(II+1,J0)
IF(I ,E0, NM) F(I) = F(I) - C(I) * 6K(II+1,J0)
B(I) = AP/SIGE
Ah(I) = AH/SIGE-FE/2.
C(I) = AH/SIGE
F(I) = CE/SIGE
IF(I ,E0, 1) F1(I) = F1(I) - B1(I) * 6E(II+1,J0)
IF(I ,E0, NM) F1(I) = F1(I) - C1(I) * 6E(II+1,J0)
7 CONTINUE
17c SOLVE FOR TRIDIAGONAL MATRIX EQUATIONS OF K AND E(K AND XE).
193c CALL TRIDIA(NM,A0,B0,C0,F0)
195c CALL TRIDIA(NM,A1,B1,C1,F1,xe)
196 TO 8 I=1,NM
197 IF(I ,E0, NM=1) GO TO 9
198 II = NM-1
2194  J,J = J
2200  GO TO 10
2201  9  CONTINUE
2202  II = I - MP + 2
2203  J,J = J + MP
2204  10  CONTINUE
2205c  COMPUTE RELATIVE ERRORS.
2206c
2207c
2208  ERRK = ERRK + ABS(XK(I)) -6GK(I,J,J) *100, /GK(I,J,J)
2209  ERR = ERR + ABS(XE(I)) -6GE(I,J,J) *100, /GE(I,J,J)
2210  IF ERRK(I,J,J) .LT. 0.0001  XK(I,J,J) = 0.0001
2211  IF ERR(I,J,J) .LT. 0.0001  XE(I,J,J) = 0.0001
2212c
2213c  OBTAIN UP-DATED SOLUTIONS WITH RELAXATION FACTOR, FACT.
2214c
2215  6GK(I,J,J) = 6GK(I,J,J) + FACT * (XK(I,J,J) -6GK(I,J,J))
2216  6GE(I,J,J) = 6GE(I,J,J) + FACT * (XE(I,J,J) -6GE(I,J,J))
2217  VMEF(I,J,J) = 0.09 * XK(I,J,J) *2/XE(I,J,J) + PMU
2218  8  CONTINUE
2219  100  FORMAT(9X, 3F15.5)
2220  3  CONTINUE
2221  ERRK = ERRK / MM/MP
2222  ERR = ERR / MM/MP
2223  ERR = ERRK + ERR
2224  WRITE (6, 100) ERRK, ERR, ERRT
2225  IF (NSH .GE. NSHT) GO TO 20
2226  NSH = NSH + 1
2227  GO TO 4
2228  20  CONTINUE
2229  RETURN
2230  END
APPENDIX B.

OPTIONAL "SEGMENTED VORTEX" ADDITION

An addition to the source code given in Appendix B includes the Segmented Vortex approach described in Ref. 8. In this approach, the vortex model derived in the standard Melick approach is divided into eight segments. This process allows for simulation of a nonlinear vortex, or a vortex ring. Theoretically, this should allow for more accurate modelling of the inlet flow distortion, for better results. The segmented vortex approach showed some improvement of the predicted peak instantaneous distortion contour map in certain cases (Reference 8). The User is free to experiment with this addition to the source code. The following page lists the addition, showing where it is to be inserted in the original code.
IF (RAD.GT.670.0) RAD=670.0
DO 1 IS THE PRESSURE FLUCTUATION AT PROBE AR(J) AND ANGLUC(J,I)

POPT=2.*VRAR*BASE/EXP(0.5*RAU)
P(J,I)=PS(J,I)+POPT*TMAGGC
CONTINUE
GO TO 90

RESET STATIC PRESSURE RINGS TO STATIC PRESSURE.

P(J1=1,MP
P(J,I)=PS(J,I)
CONTINUE

*** NEW "SEGMENTED" VORTEX METHOD BY STEPHEN P. DEFUNI ***

FIND PROBE LOCATION (RADLOC) NEAREST TO MEAN LINE

DU 120 1=1,MP
DO(J1=1,MP
IF (J1.GT. J2) GO TO 125
DU 110 J=1,MR
DU 130 J=1,MR
P(J1=1,MP
IF (DP(J1,J1).LE. DP(J1)) GO TO 100
GU TO 110
100 GO TO 125

125 RADLOC(I)=RADLOC(J)
CONTINUE

120 CONTINUE

SOLVE FOR JTH PEAK INSTANTANEOUS PRESSURE AT PAY

DU 140 I=1,IP
DU 140 I=1,IP
IF (J1.LT. J1) UR(I,J1,J1,J1,J2) GO TO 125

SOLVE FOR JTH PEAK INSTANTANEOUS PRESSURE AT PAY

RAD=ABS(RADLOC(I)-RADLOC(J))
IF (DP(J1,J1).LE. TMAGGC) GO TO 121
P(J1,J1)=PS(J1,J1)+POPT
GO TO 130

130 CONTINUE

125 IF (P(J1,J1).GT.0) GO TO 130

130 CONTINUE

110 CONTINUE

IF (J1=1) 91,91,92
CALL PFX(J,TRUE)
CALL DISTR
GO TO 140
91 CALL PFX(J,TRUE)
CALL DISTR
92 CALL PFX(J,FALSE)
CALL MAINPL
CALL LNPOUT(1)
WHITE (0,1995)
WRITE (5,2000) VRAR,ART,G,AYRT,VL,RRT,TV
WRITE (5,1999) VRM,VRM,A0

150
APPENDIX C.

QUICK REFERENCE GUIDE

1. MAXIDYN Program Description
2. Input Data Description
3. Output Data Description
1. MAXIDYN Program Description

The MAXIDYN dynamic distortion program computes the most probable peak instantaneous distortion level given the steady-state distortion conditions, and generates a peak distortion map based on the predictions. The Melick convecting vortex model and statistical approach is used in this predictive analysis, with some modifications and improvements to enhance program flexibility. The complete FORTRAN program requires sufficient computer memory capacity for approximately 100,000 words, plus typically 5000 words per data set. Run time varies from system, but is generally limited only by the online printer output capacity on most mainframe systems.

Input data requirements include the rake and probe configuration used in the test, the steady-state static and total (stagnation) pressure measurements in the rake plane, some basic inlet flow parameters, and optionally the root mean square pressure fluctuation level measurements. The input data are described briefly in the next section, and formatting requirements are shown in the figure. Some of the input data are optional, that is they may be deleted from the input file. The program automatically assigns predefined default values, or as in the case of the rms levels, the data are computed based on other input data.

The printed output of the MAXIDYN program includes several pages of steady-state and dynamic distortion data. The input data are organized in groups printed in the first few pages, along with steady-state distortion computations, Melick vortex model parameters, and the steady-state map. The rms fluctuation levels and/or turbulence modelling data are printed in the next few pages, along with the statistical
predictions of the most probable peak instantaneous distortion levels. Finally, a dynamic distortion map is generated based on the peak instantaneous prediction. A brief description of the output data is given in the third part of this Appendix.

2. Input Data Description

The table below briefly defines the variables in the input data. Certain data may be deleted from the input file because they are considered optional and generally are not part of the computational procedure. Some of these data are assigned default values as needed within the program. All optional data are indicated with a "*" in the second column of the table below. In the Format column, "F" indicates a real number, "I" indicates an integer, and "A" indicates an alphanumeric array, according to standard FORTRAN rules. The arrangement of the input data is illustrated in Figure A1.

<table>
<thead>
<tr>
<th>Data</th>
<th>Format</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>I5</td>
<td>Number of pressure tap radial locations</td>
</tr>
<tr>
<td>NP</td>
<td>I5</td>
<td>Number of rakes</td>
</tr>
<tr>
<td>RADOLOC</td>
<td>F10.5</td>
<td>Radial location of pressure taps</td>
</tr>
<tr>
<td>ANGLOC</td>
<td>F10.5</td>
<td>Angular location of rakes in degrees</td>
</tr>
<tr>
<td>KD</td>
<td>I5</td>
<td>Distortion factor selection index</td>
</tr>
</tbody>
</table>

KD = 1: KTHETA
2: KD2
3: IDC
4: IDR
5: KRA
6: KA2
7: DSPR
8: ID
Data * Format Definition

T  * F10.5  RMS fluctuation measurement time-on-point
default = 1 sec.
F0 * F10.5  Engine filter frequency, default = 500 Hz
FCO * F10.5  RMS cut-off filter frequency, 1000 Hz def.
TITLE * A80  Title block
BRP * F10.5  Base radial profile array, default = 1.0
PS  F10.5  Steady-state pressure array
ALPH * F5.3  Inlet angle of attack in degrees
PSI * F5.3  Inlet yaw angle (crosswind) in degrees
M0  * F5.3  Freestream Mach number
U2  F5.3  Inlet flow velocity in fps
BF  * F5.3  B-factor for weighting in KA2 computation
default = 1.0
CKP * F5.3  Circumferential ID weighting factor,
default = 16.4
AKP * F5.3  Radial ID weighting factor, default = 11.1
MFR * F5.3  Inlet mass flow ratio, default = 1.0
NTUR * I5  Dynamic data selection index
NTUR = 0: Dynamic data (rms levels) input
1: Dynamic data synthesized
SPTRC * F5.3  Supersonic inlet pressure recovery,
default = 1.0

The following data is required if NTUR = 0:

NPG I5  Data run number
NPR I5  Dynamic probe location number
RS * F5.3  Filtered rms level ÷ unfiltered rms level
default = 0.5
SIG F6.4  Unfiltered rms fluctuation level
<table>
<thead>
<tr>
<th>STATEMENT NUMBER</th>
<th>FORTRAN STATEMENT</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>NP</td>
<td></td>
</tr>
<tr>
<td>RADLOC(1)</td>
<td>RADLOC(2)</td>
<td>RADLOC(3)</td>
</tr>
<tr>
<td>ANGLOC(1)</td>
<td>ANGLOC(2)</td>
<td>ANGLOC(3)</td>
</tr>
<tr>
<td>KO</td>
<td>T</td>
<td>FD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TITLE1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TITLE2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BAP(1)</td>
<td>BAP(2)</td>
<td>BAP(3)</td>
</tr>
<tr>
<td>PS(1, 1)</td>
<td>PS(1, 3)</td>
<td>PS(1, 4)</td>
</tr>
<tr>
<td>PS(2, 1)</td>
<td>PS(2, 3)</td>
<td>PS(2, 4)</td>
</tr>
<tr>
<td>PS(NR, 1)</td>
<td>PS(NR, 2)</td>
<td>PS(NR, 3)</td>
</tr>
<tr>
<td>ALPH</td>
<td>PSI</td>
<td>MO</td>
</tr>
<tr>
<td>NPG</td>
<td>NPH1</td>
<td>RS</td>
</tr>
<tr>
<td>NPG</td>
<td>NPH2</td>
<td>RS</td>
</tr>
<tr>
<td>NPG</td>
<td>NPH3</td>
<td>RS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TITLE1 (For next run)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure A1. Input Data File Formatting Arrangement
3. Output Data Description

The printed output of the MAXIDYN program consists of several pages of data and computations. The first two pages are related to the steady-state distortion and some Melick vortex model parameters, the middle page or pages are related to the dynamic data and the statistical determination of the most probable peak instantaneous distortion, and the last two pages are related to the generation of the peak instantaneous distortion map. The contents of each of the pages of output are briefly defined below.

Page 1

At the top of the first page, immediately below the title blocks supplied by the user, is the steady-state PRESSURE ARRAY. This array is identical to the pressure array of the input data, except the static pressures have been deleted. Each column of the array represents a rake, while the rows represent probe locations of probes along the rake. Immediately below the pressure array is the BASE RADIAL PROFILE, also from the input file. The next table, the OVERALL FLOW DESCRIPTORS, provides some simple distortion parameters:

- PTMIN is the minimum measured local pressure from the steady-state PRESSURE ARRAY.
- PTMAX is the maximum pressure from the PRESSURE ARRAY.
- PTAVG is the average pressure from the PRESSURE ARRAY.
- PSAVG is the average static pressure.
- QAVG is the average dynamic pressure.

The next table is a listing of the eight FLOW DISTORTION FACTORS and their values, along with weighting factors.
At the bottom of the first page, some of the Melick VORTEX PROPERTIES are given. These properties are:

- **THMN**: The rake showing minimum average pressure
- **RKMN**: The average pressure along rake THMN
- **THMX**: The rake with maximum average pressure
- **RKMX**: The average pressure along rake THMX
- **DTH**: The angular difference between THMX and THMN
- **THETA**: The angular location of the center of arc DTH
- **A1**: The radius of the steady-state Melick vortex
- **G1**: The orientation angle of the steady-state vortex

Page 2

The next page of printed output is a distortion contour map for the steady-state case. Relatively high and low pressure regions are indicated by symbols, which represent the percent difference from the average pressure, as indicated by the KEY TO MAPPING SYMBOLS immediately above the map. The average pressure is printed to the right of the map.

Page 3

Page three of the output includes a listing of some of the input data, including flow parameters, and the dynamic data, assuming dynamic data was included in the input file. If dynamic data was not included in the input file, the third page would include some data from internal turbulence calculations. The data on this page includes:

- **T**: The dynamic data time-on-point, in seconds
- **FO**: The engine filter frequency, in Hz.
- **RT**: The outer rake diameter at the static tap
- **RI**: The centerbody hub radius
- **SPTRC**: The supersonic inlet shock pressure recovery
- **ALPH**: The inlet angle of attack
- **PSI**: The inlet yaw/crosswind angle
MO - The freestream Mach number
ETA - The average pressure at the measurement plane
MFR - The inlet mass flow ratio
U2 - The inlet flow velocity at the measurement plane
QPT2 - The ratio of the dynamic to total pressure
FC - The rms filter cutoff frequency

If dynamic data is included in the input data file, these data are printed in a table. The terms in this table are:
PROBE - The dynamic probe location index
RS - The ratio of filtered-to-unfiltered rms level
SG/PT2 - The unfiltered rms fluctuation level
A/RT - The vortex radius resulting from the rms level

The rms fluctuation level and vortex size are given below the dynamic data table.

If dynamic data are excluded from the input file, these data must be synthesized by the turbulence modelling scheme. In this case, the dynamic data table is replaced by a table of DIMENSIONLESS VELOCITIES occurring at each of the probe locations, and a table of iterations of turbulent kinetic energies. These are provided for the convenience of the user and are not directly involved in the distortion analysis.

The fourth page of output includes a listing of the DISTORTION FACTOR EXTREME VALUE computations. For each of the eight distortion factors, values of the most probable peak instantaneous distortion are presented. This table includes the STEADY STATE, MEAN INSTANTANEOUS, and peak instantaneous distortion at various statistical confidence levels. In addition, the filtered and unfiltered rms distortion levels are indicated; INF referring to the unfiltered case and FO representing the filtered case.
In the case where the turbulence modelling scheme is used to generate the dynamic data, the fourth page includes further results of the TURBULENCE CALCULATIONS. This table is similar to the dynamic data table as described in the third page of output, with the exception that the term RS is deleted, and velocity gradients (UU) and turbulent kinetic energy terms (K and E) are added. The unfiltered rms levels are presented in the last column. The DISTORTION FACTOR EXTREME VALUE table is moved to the fifth page in this case.

Page 5

The fifth page is arranged exactly like the first page, but with notable differences. All of the terms in the PRESSURE ARRAY, OVERALL FLOW DESCRIPTORS, and FLOW DISTORTION FACTORS tables refer to the peak instantaneous case rather than the steady-state case. In addition, the VORTEX properties table contains additional terms:

- VBAR - The vortex "strength", or maximum swirling velocity
- A/RT - The radius of the Melick vortex
- GAMMA - One of the vortex orientation angles
- BETA - The second vortex orientation angle
- AY/RT - (The same as A/RT)
- VL - The vortex length limit (generally "infinity")
- R/RT - The radial location of the vortex core
- VBMX - The maximum instantaneous vortex "strength"
- VBO - The approximated mean vortex strength found in an iteration of strengths and distortion factors.
- AO/RT - The vortex size indicated from the rms data.

Page 6

The sixth page is similar to the second page except the distortion map is for the peak instantaneous case.
VI. CONCLUSIONS & RECOMMENDATIONS

The subject computer program can be used to aid the prediction of maximum instantaneous distortion levels, and the peak instantaneous contour map, given the steady-state distortion data and, optionally, the dynamic rms pressure fluctuation data. There are some improvements which can be added to the program, at User's discretion.

One improvement currently being researched at the University of Kansas is the replacement of the single steady-state vortex model with a series of vortices whose axes lie approximately along the "mean line" of pressure recoveries at the compressor face. This effort is intended to improve the predicted peak distortion contour map to more closely resemble the experimental map produced by DYNABEG. Other methods of improving the accuracy of both the peak distortion level, and the corresponding contour map, with respect to experimental results, would be highly desireable.

The accuracy of the present analysis is discussed in References 5 and 6, along with the basic derivations in the theoretical analysis. In general, the Melick technique is reasonably accurate for preliminary design and analysis. The major benefit of the Melick method is it's efficiency, and the general tendency to over-estimate the experimental or true peak distortion level, rather than under-estimate it. One of the primary difficulties with the Melick analysis is in predicting the distortion levels for inlets with separated flows. It would be desireable to try to improve the accuracy of the peak prediction for this extreme case, which can occur especially often in highly maneuverable aircraft, which operate at high angles of attack and yaw angles, and also tend to have complicated inlet duct shapes.
VII. REFERENCES


