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

and

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
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PART I

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

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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<tr>
<td>( a )</td>
<td>vortex core radius [fig. 5]</td>
</tr>
<tr>
<td>( \bar{a} )</td>
<td>mean vortex core size</td>
</tr>
<tr>
<td>( dP_T )</td>
<td>total pressure fluctuation</td>
</tr>
<tr>
<td>( dP_{T\text{rms}} )</td>
<td>root mean square total pressure fluctuation</td>
</tr>
<tr>
<td>( e )</td>
<td>exponential ( e^x )</td>
</tr>
<tr>
<td>erf</td>
<td>error function ( \text{erf}(x) )</td>
</tr>
<tr>
<td>( f )</td>
<td>root mean square data cutoff filter frequency</td>
</tr>
<tr>
<td>( k )</td>
<td>distortion factor</td>
</tr>
<tr>
<td>( \bar{k} )</td>
<td>mean instantaneous distortion factor</td>
</tr>
<tr>
<td>( k_{ss} )</td>
<td>steady-state distortion factor</td>
</tr>
<tr>
<td>( k_{\text{max}} )</td>
<td>maximum instantaneous distortion factor</td>
</tr>
<tr>
<td>( P )</td>
<td>pressure</td>
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<tr>
<td>( P_S )</td>
<td>static pressure</td>
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<td>( r )</td>
<td>radius from vortex centerline</td>
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<tr>
<td>( \text{rms} )</td>
<td>root mean square</td>
</tr>
<tr>
<td>( r_P )</td>
<td>radial location of probe</td>
</tr>
<tr>
<td>( r_v )</td>
<td>radial location of vortex core</td>
</tr>
<tr>
<td>( U, U_2 )</td>
<td>steady-state inlet flow velocity</td>
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</table>
\( V \)  
vortex induced velocity

\( V_T \)  
tangential swirl velocity about vortex

\( V_{T_{\text{max}}} \)  
vortex strength - maximum swirling velocity

Subscripts

\( f \)  
filtered

\( \text{inst} \)  
instantaneous

\( m \)  
measured

\( \text{max} \)  
maximum

\( \text{min} \)  
minimum

\( \text{p} \)  
predicted

\( \text{rad} \)  
radial

\( \text{rms} \)  
root mean square

\( T \)  
tangential

\( \text{ss} \)  
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 minimize 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 its 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 its 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. Therefore, 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 considered by definition negligible.

The next assumption involves the definition of the location of each of the vortex segments. It is assumed that the vortex segment is placed directly over the probe location 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 considerable 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):

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

(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:

\[ P_T = P_{T_{ss}} + dP_T \]  

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

From the incompressible Bernoulli equation:

\[ P_{T_{ss}} = P_S + \frac{1}{2} \rho f U^2 \]  \hspace{1cm} (3a)

\[ P_T = P_S + \frac{1}{2} \rho f (U + V_T)^2 \]  \hspace{1cm} (3b)

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

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

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

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

\[ = q \left[ \left( \frac{2V_T}{U} \right) + \left( \frac{V_T}{U} \right)^2 \right] = \frac{2qV_T}{U} \]  \hspace{1cm} (4)

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

$$dP_T = \frac{2\rho V}{U_{\text{max}}} r e^{-\frac{1}{2}[(r/a)^2 - 1]}$$  \hspace{1cm} (5)

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:

$$\left( \frac{dP_T_{\text{rms}(f)}}{dP_T_{\text{rms}}} \right)^2 = \text{erf} \left( 7.98 \frac{f}{U} \right)$$  \hspace{1cm} (6)

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, $\bar{a}$, 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, $\bar{k}$: (Reference 2)

$$\bar{k} = k_{ss} + f(\bar{a}, dP_T)$$  \hspace{1cm} (7)

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:

$$\bar{k} = f(P_{T_{ss}}, q, \bar{\alpha}, V_{T_{max}})$$  \hspace{1cm} (8)$$

where: $P_{T_{ss}}$, $q$, and $U$ are measured quantities

$\bar{\alpha}$ is computed from equation (6)

$V_{T_{max}}$ is then determined, using equation (6):

$$V_{T_{max}} = \frac{U \bar{\alpha} dP_T}{2qr} e^{\frac{q}{2}[(r/a)^2 - 1]}$$  \hspace{1cm} (9)$$

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

$$V_{T_{max}} = \frac{U}{q} \frac{dP_{T_{rms}}}{\bar{\alpha}}$$  \hspace{1cm} (10)$$

Equation (8) then becomes:

$$\bar{k} = f(P_{T_{ss}}, q, \bar{\alpha}, dP_{T_{rms}})$$  \hspace{1cm} (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):

$$k_{max} = f(\bar{k}, dP_{T_{rms}}, \text{statistical parameters})$$  \hspace{1cm} (12)$$

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

$$V_{T_{\text{max}}/pk} = V_{T_{\text{max}}} + f(k_{\text{max}} - \bar{k})$$ \hspace{1cm} (13)

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:

$$P_{T_{\text{pk}}} = P_{T_{\text{ss}}} + dP_{T_{\text{pk}}}$$ \hspace{1cm} (14)

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

$$dP_{T_{\text{pk}}} = \frac{2q}{U_s} \frac{V_{T_{\text{max}}/pk}}{r} e^{-\frac{1}{2}[(r/\bar{a})^2 - 1]}$$ \hspace{1cm} (15)

The only variable in equation (15) above is the radius, $r$. Using the simplifications and assumptions given in section 2.8., 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 $V = V_{T_{\text{max}}/pk}$):

$$P_{T_{\text{pk}}} = P_{T_{\text{ss}}} + \frac{2qV}{U_s} \frac{r(k,p)}{r_{\text{ss}}} e^{-\frac{1}{2}[(r(k,p)/\bar{a})^2 - 1]}$$ \hspace{1cm} (16)

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 $k$:

$$r(k,p) = r_p(k,p) - r_v(k)$$ \hspace{1cm} (17)
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 $P_{T_{pk}}$ 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).

8. 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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Figure 1. Determination of Steady-State Distortion

Dynamic Probe
Steady-State Instrumentation
Compressor Face

Original Page is of Poor Quality
ILLUSTRATION OF SOME FEATURES OF THE TIME VARIANT TOTAL PRESSURES AND DYNAMIC DISTORTION:

(a) Inlet Test Model:

(b) Total Pressure:

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

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

\[ \gamma \]

\[ \beta \]

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

b) Vortex Orientation

\[ H \]

\[ L \]

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)
normal distribution

$\sigma_0$ = "most probable" or 50% Confidence Level
$\sigma_2$ = 95% Confidence Level
$\sigma_3$ = 99.7% 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.

Note: NR = 7 = number of probe rings
NP = 8 = number of probe rakes
(a) Subsonic Full Scale Inlet Model:

(b) Test Conditions and Some Measured Results:

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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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Table 2. Subsonic Inlet Distortion Factor Comparison
Figure 11. Comparisons of the Predicted and Measured $\text{rms}$ 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
KHO2
IDC-MAX
IDR-MAX
KHA
KAP
OSPH
ID

DYNADEC peak

Melick model peak

segmented vortex peak

Figure 13a. Subsonic Inlet Map Comparisons (20, 40)
Figure 13b. Subsonic Inlet Map Comparison (54.30)
Figure 13c. Subsonic Inlet Map Comparisons (81.40)
percent from average pressure

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

steady-state

DYNADEC peak

percent from average pressure

Melick model peak
segmented vortex peak

Figure 13f. Subsonic Inlet Map Comparisons (137.50)
### Table 3: Transient Input Distortion Factor

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Figure 14. Comparisons of the Predicted and Measured 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)
Figure 16b. Transonic Inlet Map Comparison (465.11)
percent from average pressure

steady-state

DYNADEC peak

percent from average pressure

Melick model peak

segmented vortex peak

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

DYNADEC peak

percent from average pressure

Melick model peak

segmented vortex peak

Figure 16f. Transonic Inlet Map Comparisons (498.12)
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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 $K_2$ 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)
percent from average pressure

steady-state

DYNADEC peak

percent from average pressure

Melick model peak

segmented vortex peak

Figure 18a. Supersonic Inlet Map Comparison (182/1)
Figure 18b. Supersonic Inlet Map Comparisons (189/3)
percent from average pressure

steady-state

DYNADEC peak

percent from average pressure

Melick model peak

segmented vortex peak

Figure 18c. Supersonic Inlet Map Comparison (216/3)
Figure 18d. Supersonic Inter Map Comparative (243/3)

Segmented Vortex Peak

Melich Peak

Percent from Average Pressure

Dynamic Peak  Steady-State

Percent from Average Pressure
percent from average pressure

steady-state

K=THETA
K05
(KDC)=MAX
(KDR)=MAX
R1
GSPR
ID
.35305
.1082
.0340
.1021
.1687
.0456
.0175

DYNADEC peak

percent from average pressure

K=THETA
K05
(KDC)=MAX
(KDR)=MAX
R1
GSPR
ID
.43654
.1050
.0390
.1032
.1788
.0516
.0174

Melick peak

segmented vortex peak

Figure 18a. Supersonic Inlet Map Comparison (246/3)
percent from average pressure

steady-state  

DYNADEC peak  

percent from average pressure

Melick peak  

segmented vortex peak

Figure 18f. Supersonic Inlet Map Comparison (247/2)
percent from average pressure

steady-state

DYNADIC peak

percent from average pressure

Melick peak

segmented vortex peak

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)
percent from average pressure

steady-state

DYNADEC peak

percent from average pressure

Melick peak

segmented vortex peak

Figure 18j. Supersonic Inlet Map Comparisons (1334/2)
percent from average pressure

steady-state

DYNADEC peak

percent from average pressure

Melick peak

segmented vortex peak

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%
σ_{rms} = 15.2%

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

For peak distortion factor:
(with separated flow)
mean = -3.31%
σ_{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 to not only allow the user to select and control the quantity of dynamic data to be processed, but to also 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.
COMPUTER PROGRAM DOCUMENTATION
AND USERS MANUAL
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 UNSTODY

This subroutine is the primary subdriver responsible for the predictive evaluation of the peak instantaneous distortion. Called by the main driver of MAXIDYN, UNSTODY 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 UNSTODY 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 LNPOUT 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 UNSTODY. 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, UNSTODY.

UNSTODY 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, UNSTODY 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 func-
tion 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 solu-
tion. 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 MAXOP is called to compute the
most probable maximum instantaneous distortion levels.

MAXOP 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 LNP/OUT 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 ENOJOB 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 RAD-LOC 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. FO 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 deleted from the input data deck, without causing any real difficulties. Many of these are simply included for identification 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. **EFP** is a one-by-NR array with a value at each of the radial locations given 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 associated 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 KA2 (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 hub 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 $F_C$, 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>NR</th>
<th>NP</th>
</tr>
</thead>
<tbody>
<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>FO</td>
<td>FCQ</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(1,3)</td>
<td>PS(2,1)</td>
</tr>
<tr>
<td>PS(2,2)</td>
<td>PS(2,3)</td>
</tr>
<tr>
<td>PS(2,4)</td>
<td>PS(2,5)</td>
</tr>
<tr>
<td>PS(2,6)</td>
<td>PS(2,7)</td>
</tr>
<tr>
<td>PS(2,8)</td>
<td></td>
</tr>
<tr>
<td>PS(NR,1)</td>
<td>PS(NR,2)</td>
</tr>
<tr>
<td>PS(NR,3)</td>
<td>PS(NR,4)</td>
</tr>
<tr>
<td>PS(NR,5)</td>
<td>PS(NR,6)</td>
</tr>
<tr>
<td>PS(NR,7)</td>
<td>PS(NR,8)</td>
</tr>
<tr>
<td>ALPH</td>
<td>PSI</td>
</tr>
<tr>
<td>MO</td>
<td>U2</td>
</tr>
<tr>
<td>BF</td>
<td>CKP</td>
</tr>
<tr>
<td>FKP</td>
<td>MFR</td>
</tr>
<tr>
<td>NTUR</td>
<td>SPTRC</td>
</tr>
<tr>
<td>NPG</td>
<td>NPR1</td>
</tr>
<tr>
<td>RS</td>
<td>SIG</td>
</tr>
<tr>
<td>NPG</td>
<td>NPR2</td>
</tr>
<tr>
<td>RS</td>
<td>SIG</td>
</tr>
<tr>
<td>NPG</td>
<td>NPRn</td>
</tr>
<tr>
<td>RS</td>
<td>SIG</td>
</tr>
<tr>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>0.</td>
<td>0.</td>
</tr>
</tbody>
</table>

**Figure 3. Input Data File Formatting Arrangement**
Figure 4. Ring, Rake, and Probe Assignments for a typical instrument configuration

Boundary - centerbody hub radius

315°

270°

225°

135°

90°

45°

rake no.

90°

270°

180°

135°

225°

270°

315°

0°

probe no.

Note: NR = 7 = number of probe rings
NP = 8 = number of probe rakes

engine face

Outer inlet radius Boundary
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 TMIN) This is the minimum total pressure recovery value from the pressure array, P, exclusive of the static pressure data.

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

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

**PSAVG** (also SAVG) 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 available to the industry, and are intended as examples. The user is free to redefine the distortion factors within the program. 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:

\[
\begin{align*}
K-\text{THETA} & \text{ (also KTHETA, K8, and KITA) Pratt & Whitney} \\
K-D2 & \text{ Pratt & Whitney circumferential distortion factor [#1] - see Figure 9.} \\
(\text{IDC})-\text{MAX} & \text{ General Electric maximum circumferential distortion factor - see Figure 9.} \\
(\text{IDR})-\text{MAX} & \text{ General Electric maximum radial distortion factor - see Figure 9.} \\
KRA & \text{ Pratt & Whitney radial distortion factor - see Figure 9.}
\end{align*}
\]
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.

---

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.

- \( F_0 \) The engine filter frequency, in Hertz. \( F_0 \) is often associated with the engine rpm speed.

- \( R_T \) The outer radius of the inlet at the compressor face, or the location of the outermost static pressure probes - the maximum value of the RAOLC array.

- \( R_I \) The inner radius of the compressor face, the radius of the centerbody hub, or the minimum value of the RAOLC array.

- \( \text{ALPH (also ALPHA)} \) The inlet angle of attack, relative to the freestream, in degrees.

- \( \text{PSI} \) The sideslip or yaw angle of the inlet in degrees.

- \( \text{SPTRC} \) The total pressure recovery through the inlet shock
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.

M0 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. 
\[ QPT2 = \frac{QAVG}{PTAVG} \], 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 ft²/sec³.

**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.

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:

**KTTA** (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
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.

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.

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.
**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.

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

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

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

**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**.

**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.

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

**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.

**VBO** 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.

Page 6

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:

- \( T = 1.000 \)
- \( FO = 500 \text{ Hz} \)
- \( FCO = 1000 \text{ Hz} \)
- \( BF = 1.000 \)
- \( RS = 0.500 \)
- \( CKP \ (or \ KC) = 16.4 \)
- \( BRP = 1.000 \)
- \( MFR = 1.000 \)
- \( SPTRC = 1.000 \)
- \( VL = 999.999 \)
- \( \text{max RS} = 0.700 \)
- \( RKP \ (or \ KR) = 11.1 \)
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 8 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.
<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CASE 1</th>
<th>CASE 2</th>
<th>CASE 3</th>
<th>CASE 4</th>
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<td>5.000</td>
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<td>3 (IDC)</td>
<td>3 (IDC)</td>
<td>6 (KA2)</td>
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<td>500.0</td>
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<td>-</td>
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<tr>
<td>PSI (deg)</td>
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<td>-</td>
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<td>1</td>
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[A dash "-" indicates a defaulted entry, or zero. The program assigns default values in these cases.]

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.
Figure 7. Sample Problem Input Data
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<tr>
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**SAMPLE PROBLEM NO. 2**

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0.942 & 0.842 & 0.842 & 0.842 & 0.842 & 0.842 & 0.842 & 0.842 \\
0.905 & 0.805 & 0.805 & 0.805 & 0.805 & 0.805 & 0.805 & 0.805 \\
0.904 & 0.804 & 0.804 & 0.804 & 0.804 & 0.804 & 0.804 & 0.804 \\
0.893 & 0.793 & 0.793 & 0.793 & 0.793 & 0.793 & 0.793 & 0.793 \\
0.896 & 0.796 & 0.796 & 0.796 & 0.796 & 0.796 & 0.796 & 0.796 \\
0.880 & 0.780 & 0.780 & 0.780 & 0.780 & 0.780 & 0.780 & 0.780 \\
0.842 & 0.742 & 0.742 & 0.742 & 0.742 & 0.742 & 0.742 & 0.742 \\
0.500 & 0.25  & 0.25  & 0.25  & 0.25  & 0.25  & 0.25  & 0.25  \\
1184 & 1.400 & 0.079 &       &       &       &       &       \\
1184 & 0.490 & 0.019 &       &       &       &       &       \\
1184 & 0.463 & 0.027 &       &       &       &       &       \\
1184 & 0.394 & 0.008 &       &       &       &       &       \\
1184 & 0.361 & 0.078 &       &       &       &       &       \\
1184 & 0.342 & 0.010 &       &       &       &       &       \\
1184 & 0.424 & 0.026 &       &       &       &       &       \\
1184 & 0.667 & 0.019 &       &       &       &       &       \\
1184 & 0.517 & 0.020 &       &       &       &       &       \\
1184 & 0.416 & 0.007 &       &       &       &       &       \\
1184 & 0.472 & 0.022 &       &       &       &       &       \\
1184 & 0.321 & 0.019 &       &       &       &       &       \\
1184 & 0.499 & 0.009 &       &       &       &       &       \\
1184 & 0.494 & 0.007 &       &       &       &       &       \\
0     & 0     & 0     &       &       &       &       &       \\
\end{array}
\]

**END JOB**
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**SAMPLE PRUALFM #4 - USAF TRANSONIC INLET - 22 DEC 1983**

**PART-POINT = 464, 12**

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**ENDJOB**

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

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

**PRESSURE ARRAY**

<table>
<thead>
<tr>
<th>RADIUS</th>
<th>ANGULAR POSITION OF INPUT MEASUREMENTS, DEG</th>
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<tr>
<td>1.331</td>
<td>0.978 0.981 0.979 0.978 0.978 0.978 0.980 0.981</td>
</tr>
<tr>
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**BASE RADIAL PROFILE**

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<tr>
<td>5.169</td>
<td>1.000</td>
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</table>

**OVERALL FLOW DESCRIPTORS**

- \( PT_{MN} = 0.937 \quad (PT_{MN} = P_{MN}) \quad PT_{MX} = 0.0446 \)
- \( PT_{MAX} = 0.981 \quad (PT_{MAX} = P_{MAX}) \quad PT_{AVE} = 0.0332 \)
- \( PS_{AVE} = 0.860 \quad V_{AVE} = 0.1015 \)

**FLOW DISTORTION FACTORS**

- \( k = \theta \quad 0.0348 \)
- \( KD2 \quad 0.124 \)
- \( (TD_{C})_{MAX} \quad 0.0165 \)
- \( (TD_{R})_{MAX} \quad 0.0139 \)
- \( K_{RA} \quad 0.0474 \)
- \( K_{A2} \quad 0.1179 \)
- \( B_{FACTOR} \quad 0.7330 \)
- \( D_{SPR} \quad 0.0070 \)
- \( ID \quad 0.0181 \quad B_{SF} 0.2621 \quad KC 1.000 \quad KR 1.000 \)

**VORTEX PROPERTIES**

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<tr>
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</table>
--- SAMPLE PROBLEM #1 ---

**MU = 1.36**

**ALPHA = 4.0**

KEY IN MAPPING SYMBOLS

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<th>Symbol</th>
<th>Mapping</th>
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**IN NEWTONS**

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<tr>
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<td>18.0</td>
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</table>

**AVERAGE PRESSURE = 0.964**

---

Figure 8. (cont'd)

+ 360/0 DEGREES

270 +

+ 00

+ 180

<STADY-STATE DISTORTION>
Figure 8. (cont'd)

<table>
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<th>T</th>
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<th>RT</th>
<th>SPTRC</th>
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<th>MFR</th>
<th>H2</th>
<th>OPT2</th>
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RS AT FC = 1000.0

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<td>32</td>
<td>0.4330</td>
<td>0.0012</td>
<td>0.0646</td>
</tr>
<tr>
<td>33</td>
<td>0.3400</td>
<td>0.0023</td>
<td>0.0525</td>
</tr>
<tr>
<td>34</td>
<td>0.4520</td>
<td>0.0021</td>
<td>0.0664</td>
</tr>
<tr>
<td>35</td>
<td>0.4690</td>
<td>0.0012</td>
<td>0.0663</td>
</tr>
<tr>
<td>36</td>
<td>0.5600</td>
<td>0.0010</td>
<td>0.0817</td>
</tr>
<tr>
<td>37</td>
<td>0.4240</td>
<td>0.0026</td>
<td>0.0502</td>
</tr>
<tr>
<td>38</td>
<td>0.4240</td>
<td>0.0026</td>
<td>0.0502</td>
</tr>
<tr>
<td>39</td>
<td>0.4550</td>
<td>0.0028</td>
<td>0.0641</td>
</tr>
<tr>
<td>40</td>
<td>0.4430</td>
<td>0.0026</td>
<td>0.0625</td>
</tr>
</tbody>
</table>

FACE AVERAGE RMS (SP/PT2) = 0.00212

MEAN VORTEX STZF (AD/RT) = 0.06473
### SAMPLE PROBLEM #1

- **M0 = 1.36**
- **\( \alpha = 4.0 \)**

#### DISTORTION FACTOR \( F_{XTRFMF} \) VALUE

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>STEADY STATE ( F )</th>
<th>MEAN ( \mu )</th>
<th>SIGMA ( \sigma )</th>
<th>SIGMA ( \sigma_0 )</th>
<th>MAXIMUM INSTANTANEOUS ( 95.0% )</th>
<th>( 99.7% )</th>
</tr>
</thead>
<tbody>
<tr>
<td>KTA</td>
<td>0.0631</td>
<td>0.0634</td>
<td>0.0054</td>
<td>0.0028</td>
<td>0.0774</td>
<td>0.0788</td>
</tr>
<tr>
<td>KD2</td>
<td>1.182</td>
<td>1.794</td>
<td>0.174</td>
<td>0.073</td>
<td>1.750</td>
<td>1.797</td>
</tr>
<tr>
<td>ID2</td>
<td>0.0157</td>
<td>0.0190</td>
<td>0.0004</td>
<td>0.0002</td>
<td>0.0153</td>
<td>0.0167</td>
</tr>
<tr>
<td>IRA</td>
<td>0.0748</td>
<td>0.0748</td>
<td>0.0034</td>
<td>0.0018</td>
<td>0.0837</td>
<td>0.0846</td>
</tr>
<tr>
<td>K2</td>
<td>0.1179</td>
<td>0.1182</td>
<td>0.0050</td>
<td>0.0031</td>
<td>0.1343</td>
<td>0.1350</td>
</tr>
<tr>
<td>D2</td>
<td>0.0047</td>
<td>0.0047</td>
<td>0.0004</td>
<td>0.0002</td>
<td>0.0057</td>
<td>0.0058</td>
</tr>
<tr>
<td>ID</td>
<td>0.0182</td>
<td>0.0182</td>
<td>0.0005</td>
<td>0.0002</td>
<td>0.0194</td>
<td>0.0195</td>
</tr>
</tbody>
</table>

**Maximum instantaneous distortion factor**

\( F_{IDC} = 0.0183 \)

---

Figure 8. (cont'd)
--- SAMPLE PROBLEM #1 ---

**MO = 1.36**

**ALPHA = 4.0**

**PRESSURE ARRAY**

<table>
<thead>
<tr>
<th>RADIUS</th>
<th>ANGULAR POSITION OF INPUT MEASUREMENTS, DEG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.331</td>
<td>0.975 0.979 0.980 0.981 0.980 0.979 0.979 0.979</td>
</tr>
<tr>
<td>2.585</td>
<td>0.939 0.967 0.949 0.981 0.979 0.979 0.959 0.968</td>
</tr>
<tr>
<td>3.615</td>
<td>0.948 0.964 0.951 0.981 0.979 0.979 0.956 0.959</td>
</tr>
<tr>
<td>4.469</td>
<td>0.951 0.969 0.970 0.981 0.977 0.980 0.955 0.968</td>
</tr>
<tr>
<td>4.962</td>
<td>0.946 0.947 0.952 0.963 0.939 0.959 0.968 0.945</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**

<table>
<thead>
<tr>
<th>PTMIN = 0.939</th>
<th>PTMX/PTMN/PTMV = 0.0429</th>
<th>PTA = 0.0386</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTA = 0.946</td>
<td>PTAVG = 0.966</td>
<td>PAVR = 0.0279</td>
</tr>
<tr>
<td>PAVR = 0.894</td>
<td></td>
<td>PAVR = 0.1015</td>
</tr>
</tbody>
</table>

**FLOW DISTORTION FACTORS**

<table>
<thead>
<tr>
<th>A=THETA</th>
<th>0.07643</th>
</tr>
</thead>
<tbody>
<tr>
<td>K02</td>
<td>176.0</td>
</tr>
<tr>
<td>(TDC)-MAX</td>
<td>0.01857</td>
</tr>
<tr>
<td>(TDC)-MAX</td>
<td>0.01857</td>
</tr>
<tr>
<td>KRA</td>
<td>0.07876</td>
</tr>
<tr>
<td>KAP</td>
<td>0.13143</td>
</tr>
<tr>
<td>B=FACTOR</td>
<td>0.73300</td>
</tr>
<tr>
<td>DSFR</td>
<td>0.00624</td>
</tr>
<tr>
<td>ID</td>
<td>0.01428</td>
</tr>
</tbody>
</table>

**VORTEX LOCATION**

<table>
<thead>
<tr>
<th>VHAR</th>
<th>A/R</th>
<th>GAMMA</th>
<th>BETA</th>
<th>AY/RT</th>
<th>VI</th>
<th>R/RT</th>
<th>THETA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.013</td>
<td>1.178</td>
<td>90.0</td>
<td>0.0</td>
<td>1.178</td>
<td>999.999</td>
<td>0.597</td>
<td>67.50</td>
</tr>
<tr>
<td>VB/MX</td>
<td>VR0</td>
<td>A/R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.063</td>
<td>0.027</td>
<td>0.0687</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 8. Econt'd)
SAMPLE PROBLEM NO. 2  MAR. 14, 1981

\[ M_0 = 2.5 \quad \text{ALPHA} = 5.0 \]

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>0.0  45.0  90.0  135.0  180.0  225.0  270.0  315.0</td>
</tr>
<tr>
<td>2.669</td>
<td>0.0  0.908  0.885  0.883  0.881  0.889  0.874  0.879</td>
</tr>
<tr>
<td>3.218</td>
<td>0.0  0.804  0.890  0.894  0.870  0.849  0.859  0.866  0.879</td>
</tr>
<tr>
<td>3.721</td>
<td>0.0  0.894  0.886  0.882  0.847  0.842  0.851  0.854  0.870</td>
</tr>
<tr>
<td>4.151</td>
<td>0.0  0.836  0.869  0.857  0.835  0.837  0.850  0.858  0.877</td>
</tr>
</tbody>
</table>

BASE RADIAL PROFILE

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

- PTMIN = 0.835
- PTMAX = 0.898
- PTAVG = 0.875
- PSAVG = 0.842

FLOW DISTORTION FACTORS

- K = THETA
- KD2 = 0.59546
- (IDC) = MAX
- (IDR) = MAX
- KRA = 0.27757
- KA2 = 0.78942
- USPR = 0.1518
- ID = 0.02539

VORTEX PROPERTIES

- THMN 0.856
- RRKN 0.856
- THMX 0.896
- RRKM 1.80.00
- ZTH 0.80.00
- ZTHFA 1.571
- 90.00
**SAMPLE PROBLEM NO. 2  MAR. 14, 1981**

\[
\begin{array}{cccccc}
T & F_D & R_T & S_T & R_T & S_T \\
2.000 & 500.0 & 4.346 & 1.430 & 1.000 & 1.000 \\
\end{array}
\]

ALPH PSI MNO ETA MFR U2 UPT2
5.000 0.250 0.875 1.000 274.5 0.0370

RS AT FC = 400.0

PROBE RS SG/PT2 A/RT
1 0.4900 0.0079 0.1123
4 0.3800 0.0140 0.0869
6 0.4630 0.0127 0.1052
17 0.3940 0.0081 0.0879
18 0.3610 0.0078 0.0860
19 0.3420 0.0108 0.0754
20 0.4240 0.0265 0.0924
21 0.4670 0.0139 0.1650
22 0.5170 0.0129 0.1196
23 0.4160 0.0078 0.0933
24 0.4720 0.0128 0.1076
36 0.5210 0.0109 0.1206
37 0.4990 0.0098 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 EXTREMES VALUE**

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>STEADY</th>
<th>MEAN</th>
<th>SIGMA</th>
<th>SIGMA</th>
<th>MOST</th>
<th>INSTANTANEOUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>KT1A</td>
<td>0.5860</td>
<td>0.5999</td>
<td>0.1069</td>
<td>0.0801</td>
<td>0.9427</td>
<td>0.9996</td>
</tr>
<tr>
<td>K22</td>
<td>0.4627</td>
<td>0.4737</td>
<td>0.3477</td>
<td>0.2600</td>
<td>0.5077</td>
<td>0.6002</td>
</tr>
<tr>
<td>IDC</td>
<td>0.0298</td>
<td>0.0312</td>
<td>0.0025</td>
<td>0.0018</td>
<td>0.0388</td>
<td>0.0401</td>
</tr>
<tr>
<td>ITQ</td>
<td>0.0156</td>
<td>0.0157</td>
<td>0.0007</td>
<td>0.0005</td>
<td>0.0178</td>
<td>0.0181</td>
</tr>
<tr>
<td>RRA1</td>
<td>0.2776</td>
<td>0.2811</td>
<td>0.0541</td>
<td>0.0405</td>
<td>0.4563</td>
<td>0.0586</td>
</tr>
<tr>
<td>K22</td>
<td>0.7494</td>
<td>0.8600</td>
<td>0.1140</td>
<td>0.0854</td>
<td>1.1638</td>
<td>1.2276</td>
</tr>
<tr>
<td>DSPK</td>
<td>0.0152</td>
<td>0.0153</td>
<td>0.0023</td>
<td>0.0018</td>
<td>0.0377</td>
<td>0.0379</td>
</tr>
<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>
</tr>
</tbody>
</table>

MAXIMUM INSTANTANEOUS DISTORTION FACTOR

IDC = 0.01261
### 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 45.0 0.914 0.885 0.877 0.873 0.881 0.870 0.890</td>
</tr>
<tr>
<td>2.669</td>
<td>0.913 90.0 0.890 0.881 0.867 0.864 0.861 0.886</td>
</tr>
<tr>
<td>3.238</td>
<td>0.902 135.0 0.876 0.864 0.840 0.852 0.856 0.881</td>
</tr>
<tr>
<td>3.721</td>
<td>0.903 180.0 0.855 0.841 0.835 0.844 0.854 0.881</td>
</tr>
<tr>
<td>4.151</td>
<td>0.895 225.0 0.829 0.828 0.847 0.850 0.880</td>
</tr>
<tr>
<td>4.346</td>
<td>0.880 270.0 0.822 0.821 0.839 0.849 0.881</td>
</tr>
<tr>
<td>4.443</td>
<td>0.880 315.0 0.822 0.821 0.839 0.849 0.881</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>3.238</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>
<tr>
<td>4.443</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

### OVERALL FLOW DESCRIPTORS

- $P_{m\text{max}} = 0.878$ (PTRX/PTMN)/PTMN = 0.0937
- $P_{m\text{max}} = 0.914$ (PTRX/PTRM)/PTRAV = 0.0980
- $P_{TAV} = 0.874$ (PTRX/PTMN)/PTAV = 0.0520
- $P_{SAVG} = 0.842$ QAUX = 0.0720

### FLOW DISORTION FACTORS

- $KTHETA = 0.83940$
- $KD2 = 0.508.8$
- $(IDC)_{MAX} = 0.03786$
- $(IDR)_{MAX} = 0.01564$
- $KRA = 0.7757$
- $KAX = 1.04286$
- $BFACTR = 0.73300$
- $RDF = 0.32740$
- $KFC = 1.000$
- $KRA = 1.000$

### VORTEX LOCATION

- $VUX = 0.131$
- $A/RT = 1.571$
- $GAMMA = 90.0$
- $B/LTA = 1.571$
- $AV/RT = 999.999$
- $R/RT = 0.685$
- $THETA = 90.00$
- $WUX = 1.402$
- $WUX = 0.464$
- $A0/RT = 0.1078$
SAMPLE PROBLEM #3 - USAF SUBSONIC INLET - 22 DEC 1981 -
PART-POINT = 20.00
MD = SUBSONIC

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>0.902 0.861 0.846 0.935 0.992 0.985 0.940 0.920</td>
</tr>
<tr>
<td>0.599</td>
<td>0.866 0.790 0.817 0.936 0.992 0.980 0.930 0.900</td>
</tr>
<tr>
<td>0.737</td>
<td>0.857 0.783 0.814 0.952 0.996 0.962 0.946 0.871</td>
</tr>
<tr>
<td>0.852</td>
<td>0.835 0.786 0.785 0.944 0.920 0.985 0.962 0.963</td>
</tr>
<tr>
<td>0.953</td>
<td>0.825 0.786 0.758 0.830 0.820 0.882 0.881 0.852</td>
</tr>
</tbody>
</table>

BASE RADIAL PROFILE

| RADIUS | 0.283 0.419 0.599 0.777 0.852 0.953 1.000 |
| P/R/P/A | 1.000 1.000 1.000 1.000 1.000 1.000 1.000 |

OVERALL FLOW DESCRIPTIONS

| PTMN | 0.758 | (PTMX - PTMN) / PTM = 0.2382 |
| PTMX | 0.995 | (PTMX - PTMN) / PTN = 0.2672 |
| PTAV | 0.887 | (PTAV - PTMN) / PTMN = 0.1455 |
| PSAV | 0.804 | GAV = 0.0402 |

FLOW DISTORTION FACTORS

| K-THETA | 0.05777 |
| KD2 | 1.0000 |
| (IDC) | 0.10759 |
| (IDR) | 0.06516 |
| KRA | 0.30434 |
| KAP2 | 1.18065 |
| USPF | 0.05760 |
| LD | 1.26570 |

VORTEX PROPERTIES

| THMN | KRMN | THMX | KRNMX | DTH | THETA | A1 | C1 |
| 45.00 | 0.801 | 225.00 | 0.959 | 180.00 | 135.00 | 1.571 | 90.00 |
Figure 6. (cont'd)
SAMPLE PROBLEM #3 -- USAF SUBSONIC INLET -- 22 DEC 1983 --

PART-POINT = 20.40 WM = SUBSONIC

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>0.851, 0.798, 0.800, 0.935, 1.038, 1.048, 0.991, 0.948</td>
</tr>
<tr>
<td>0.599</td>
<td>0.835, 0.727, 0.771, 0.936, 1.041, 1.042, 0.981, 0.928</td>
</tr>
<tr>
<td>0.737</td>
<td>0.706, 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, 1.044, 1.013, 0.911</td>
</tr>
<tr>
<td>0.953</td>
<td>0.777, 0.723, 0.712, 0.830, 0.968, 0.945, 0.932, 0.880</td>
</tr>
</tbody>
</table>

BASE RADIUS PROFILE

<table>
<thead>
<tr>
<th>RADIUS</th>
<th>PTRA/PTR 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.283</td>
<td>0.419, 0.599, 0.737, 0.852, 0.953, 1.000</td>
</tr>
</tbody>
</table>

OVERALL FLOW DESCRIPTIONS

PTMN = 0.712 (PTAV + PTMN)/PTAV = 0.3210
PTMAX = 1.048 (PTAV + PTMN)/PTAV = 0.3779
PTAV = 0.891 (PTAV + PTMN)/PTAV = 0.2707
PSAVG = 0.804 QAFC = 0.0802

FLOW DISTORTION FACTORS

K=THETA 1.77307
Kg2 2.8204
(TLC)=MAX 0.1794
(TUR)=MAX 0.0649
KRA 0.30430
Kg2 1.99615
USPR 0.10752
ID 1.59735
R-FACTOR 0.73300
NSF 0.30742 KC 16.400 KR 11.100

VORTEX LOCATION

| VRHXR A/RI GAMMA BETA AY/RT V1 K/RT THETA |
|---------|--------|--------|--------|--------|--------|--------|
| 0.495   | 1.571  | 90.0   | 0.0    | 1.571  | 999.999 | 0.642  | 135.00 |
| VRMX    | VRH    | A/RI   |
| 1.461   | 0.598  | 0.3694 |
Figure 6. (cont'd)

<PEAK DISTORTION>
--- SAMPLE PROBLEM #4 = USAF TRANSONIC INLET = 22 DFC 1983 ---
PART=PUINT = 464.12 MO = TRANSONIC

### 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>
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### BASE RADIAL PROFILE

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### OVERALL FLOW DESCRIPTORS

- $P_{TMN} = 0.788$ ($P_{TMN}/P_{MAX} = 0.1644$)
- $P_{MAX} = 0.943$ ($P_{TMN}/P_{MAX} = 0.1802$)
- $P_{TAVG} = 0.860$ ($P_{TAVG}/P_{TMN} = 0.2084$)
- $P_{SAVG} = 0.721$ $Q_{AVG} = 0.1308$

### FLOW DISTORTION FACTORS

- $K_{HILTA} = 0.03551$
- $K_{T2} = 0.452.6$
- $(TDC)-MAX = 0.06052$
- $(TDR)-MAX = 0.03083$
- $K_{RA} = 0.10017$
- $K_{A2} = 0.11405$
- $K-FACTOR = 0.78400$
- $BSP = 0.00238$
- $ID = 0.67161$

### VORTEX PROPERTIES

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<th>THMN</th>
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<th>THMX</th>
<th>KRMX</th>
<th>DTH</th>
<th>THFIA</th>
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<th>C1</th>
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<td>V'</td>
<td>V''</td>
<td>V''/V'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>----------------------</td>
<td>----------------------</td>
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**TURBULENCE CALCULATIONS**

DIMENSIONLESS VELOCITY AT EACH PROBE LOCATION:

<table>
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<tr>
<th>TIME</th>
<th>V</th>
<th>V'</th>
<th>V''</th>
<th>V''/V'</th>
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<tr>
<td>27.97</td>
<td>24.37</td>
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<tr>
<td>27.97</td>
<td>24.37</td>
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<td>25.92</td>
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<td>27.97</td>
<td>24.37</td>
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<td>27.97</td>
<td>24.37</td>
<td>24.96</td>
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ERRORS IN K, E AND (K+e) OF EACH TYPHATT:

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<th>E</th>
<th>K+E</th>
<th>K+E/K+E</th>
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<tr>
<td>27.97</td>
<td>15.1694</td>
<td>52.56748</td>
<td>67.73246</td>
<td>15.2044</td>
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<tr>
<td>27.97</td>
<td>15.1694</td>
<td>52.56748</td>
<td>67.73246</td>
<td>15.2044</td>
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<tr>
<td>27.97</td>
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<td>27.97</td>
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<td>52.56748</td>
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### RESULTS OF TURBULENCE CALCULATIONS:

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**FACE AVERAGE RMS (SC/PT2) = 0.04209**

**MEAN VORTEX STRENGTH (AO/RT) = 0.16575**
**Sample Problem #4**  
**USAF Transonic Inlet - 22 Dec 1983**  
**PART-POINT = 464.12**  
**M0 = Transonic**

### Distortion Factor Extremes Value

<table>
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<th>Factor</th>
<th>Steady</th>
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<th>Sigma</th>
<th>Sigma</th>
<th>Most</th>
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<th>0.99%</th>
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<td>0.0066</td>
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### Maximum Instantaneous Distortion Factor

KRA2 = 0.3682
## Pressure Array

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<tr>
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<th>ANGULAR POSITION OF INPUT MEASUREMENTS, DEG</th>
</tr>
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<tbody>
<tr>
<td>2.225</td>
<td>0.840 0.851 0.865 0.880 0.893 0.918 0.943 0.970</td>
</tr>
<tr>
<td>3.070</td>
<td>0.843 0.856 0.870 0.884 0.898 0.912 0.926 0.953</td>
</tr>
<tr>
<td>3.725</td>
<td>0.850 0.864 0.879 0.893 0.907 0.921 0.935 0.962</td>
</tr>
<tr>
<td>4.280</td>
<td>0.858 0.872 0.886 0.900 0.914 0.928 0.942 0.969</td>
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<tr>
<td>4.775</td>
<td>0.866 0.880 0.894 0.908 0.922 0.936 0.950 0.977</td>
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</table>

## Base Radial Profile

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

## Overall Flow Descriptors

- $PTMIN = 0.731 \quad (PTMX-PTMIN)/PTMX = 0.2678$
- $PTMAX = 0.986 \quad (PTMX-PTMIN)/PTAVG = 0.3187$
- $PTAVG = 0.860 \quad (PTAVG-PTMIN)/PTAVG = 0.1505$
- $PSAVG = 0.721 \quad WAVG = 0.1308$

## Flow Distortion Factors

- $K-\Theta = 0.26719$
- $K\Theta = 1221.6$
- $(TDC)_{MAX} = 0.12698$
- $(TOR)_{MAX} = 0.03083$
- $KRA = 0.10017$
- $KA = 0.34573$
- $DSPR = 0.02846$
- $ID = 1.03333$

## Vortex Location

- $VBAR = 0.218 \quad \gamma/RT = 0.785 \quad \Gamma_{\beta} = 90.0 \quad \gamma/RT = 0.785 \quad \Gamma_{\beta} = 99.9\%$
- $K/RT = 1.100$
- $VBAR = 1.225 \quad \gamma/RT = 0.291 \quad \Gamma_{\beta} = 1.153$
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&lt;sub&gt;max&lt;/sub&gt;</td>
<td>IDC&lt;sub&gt;max&lt;/sub&gt; = max{2(IDC&lt;sub&gt;1&lt;/sub&gt; + IDC&lt;sub&gt;2&lt;/sub&gt;), 2(IDC&lt;sub&gt;4&lt;/sub&gt; + IDC&lt;sub&gt;5&lt;/sub&gt;)}</td>
<td>IDC&lt;sub&gt;j&lt;/sub&gt; = ( \frac{(\bar{p}_t)<em>j - (p</em>{t,min})_j}{\bar{p}_t} )</td>
<td>(( p_{t,j} )) = average total pressure for ring j</td>
</tr>
<tr>
<td>IDR&lt;sub&gt;max&lt;/sub&gt;</td>
<td>IDR&lt;sub&gt;max&lt;/sub&gt; = max(IDR&lt;sub&gt;1&lt;/sub&gt;, IDR&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>IDR&lt;sub&gt;j&lt;/sub&gt; = ( \frac{\bar{p}_t - (\bar{p}_t)_j}{\bar{p}_t} )</td>
<td>(( p_{t,min} )) = minimum total pressure reading in ring j</td>
</tr>
<tr>
<td>K&lt;sub&gt;r2&lt;/sub&gt;</td>
<td>K&lt;sub&gt;r2&lt;/sub&gt; = ( \frac{\sum_{j=1}^{NR} (\frac{\Delta p_t}{p_t}) (OD/D_j)}{\sum_{j=1}^{NR} (OD/D_j)} )</td>
<td>( (A_1)_j = \left( \frac{\sigma^2}{2} \right) \frac{h^2}{2} )</td>
<td>( \bar{p}_t ) = average total pressure at engine face</td>
</tr>
<tr>
<td>K&lt;sub&gt;r0&lt;/sub&gt;</td>
<td>K&lt;sub&gt;r0&lt;/sub&gt; = ( \frac{\sum_{j=1}^{NR} (A_1)<em>j (1/D_j)}{(q/p_t) \sum</em>{j=1}^{NR} (1/D_j)} )</td>
<td>( (a_1)<em>j = \frac{1}{M} \sum</em>{j=1}^{M} \left( \frac{p_{t,1}}{p_t} \cos(\theta_j) \right) )</td>
<td>( \bar{q} ) = average dynamic pressure at engine face</td>
</tr>
<tr>
<td>K&lt;sub&gt;rAD&lt;/sub&gt;</td>
<td>K&lt;sub&gt;rAD&lt;/sub&gt; = ( \sum_{j=1}^{NR} \left( \frac{\Delta p_t}{p_t} \right) \frac{1}{\bar{q} D_j} )</td>
<td>( (b_1)<em>j = \frac{1}{M} \sum</em>{j=1}^{M} \left( \frac{p_{t,1}}{p_t} \sin(\theta_j) \right) )</td>
<td>M = number of rakes</td>
</tr>
<tr>
<td>K&lt;sub&gt;A2&lt;/sub&gt;</td>
<td>K&lt;sub&gt;A2&lt;/sub&gt; = K&lt;sub&gt;r0&lt;/sub&gt; + 0.1K&lt;sub&gt;rAD&lt;/sub&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASPR</td>
<td>ASPR&lt;sub&gt;j&lt;/sub&gt; = ( \frac{p_{t,1}}{p_{t,base}} )</td>
<td>ASPR&lt;sub&gt;j&lt;/sub&gt; = f(k)</td>
<td></td>
</tr>
<tr>
<td>D&lt;sub&gt;St&lt;/sub&gt;</td>
<td>D&lt;sub&gt;St&lt;/sub&gt; = ( \frac{(p_{t} - p_{t,min})}{p_{t,min}} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IP</td>
<td>IP&lt;sub&gt;j&lt;/sub&gt; = K&lt;sub&gt;c&lt;/sub&gt; (IDC&lt;sub&gt;j&lt;/sub&gt;) + K&lt;sub&gt;r&lt;/sub&gt; (IDR&lt;sub&gt;j&lt;/sub&gt;)</td>
<td></td>
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</tbody>
</table>

**Figure 9. Distortion Factor Definitions**
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,AFLGCI(20),AUV,BETA2,TF,CDPOP3(10),CMAY6(10),FO,ISHFT,
& CMIN(10),DKKX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
& J1,J2,KX,KEY,LCNFIL,NN,NP,NN,P(11,20),PR(11,20),CPK,
& PSPEC(20),PV,AV,GD2,P,RADLOC(11),RANGE,RI,RMAY,RP(11),
& RT,SGDK(10),SGP(10),SIG,SMAV6,STATI,STATD,T,TDP1,TDP2,TMIN,
& TDP3,THETA,THTMN(10),TITLE1(20),TITLE2(20),TMAY6,TMAX6,RPK,U2

LOGICAL STATI,STATD,LCNFIL

LCNFIL=.FALSE.
STATI=.TRUE.
STATD=.TRUE.
DIMENSION DRT(11)

INPUT PROBE CONFIGURATION.
NR IS NUMBER OF RINGS; PLUS 2 TO INCLUDE CENTER BODY AND OUTER RADIUS
NP IS THE NUMBER OF RADIAL RAKES
RADLOC IS RADIAL LOCATION OF CENTER BODY; 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 (STATI) J2=NR-1
FACTOR=RADLOC(NR)/19.1

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

CALL HEPFD (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   READ (5,101) (BRP(J),J=1,NR)
0047    DO 25 J=1,11
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(7)-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  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 PFIX (.TRUE.)
0067    CALL DISTRT
0068c
0069c   CALL PFIX TO TRANSFORM INPUT MEASUREMENTS INTO MAPPING PARAMETERS.
0070c
0071    CALL PFIX (.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. UNSTDDY ALSO CONTROLS THE OUTPUT.
SUBROUTINE PFXL (AKS, DKS, ANT)

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

DKS = 0.0

IF (ANT.LE.1.0) GO TO 200

IF (AKS.LE.0.0) GO TO 200

X = AL0G6 (ANT)

A = 2.9564*AKS**0.8641

B = 0.0047 + 0.3865/AKS

X0 = 0.6909 + 0.1817/AKS

AN = 0.5625 + 0.58/AKS**0.707

DX = X - X0

IF (DX.LE.0.0) GO TO 200

DKS = A + (1.0 - EXP (-B * DX**2 * AN))

200 RETURN

END
0113 SUBROUTINE LINRUT(KY)

0115c THIS SUBROUTINE CONTROLS THE OUTPUT
0116c SOME OUTPUT IS CONTROLLED BY 'CARDAD' AND 'PFIX'.
0117c NF,RADLOC,ANGLOC AND F HAVE FIRST ARRAY DIMENSION EQUAL TO 11. TENTH OF
0118c THESE ARE AVAILABLE FOR USE. 11TH IS NEEDED FOR INTERNAL PROCESSING.

0120 COMMON AB, ANLOC(20), AOD, BETA2, BF, CDPOP3(10), CHAV6(10), FO, ISHT, 
0121$ CMIN(10), DNK(10), DKSS(10), FACE(39,65), FACTOR, FARC(39,65), BSF, 
0122$ J1, J2, KEY, KD, LCHTL, HH, HP, NR, PR(11, 20), PS(11, 20), CKP, 
0123$ P, PSC(20), PVBl, QAV, QF, RADLOC(11), RANGE, RI, RMAV, RP(11), 
0124$ RT, SGK(10), SGF(10), SIG, SMAV6, STAT, STATO, T, T0P1, T0P2, TMMIN, 
0125$ T0P3, ZET, THTMIN(10), TITLE1(20), TITLE2(20), TMAV6, TMMAX, RKP, U2 
0126c
0127 DIMENSION R0UT(19), FACP(65), FABC(65) 
0128 LOGICAL STATI, STATO, LCHTL 
0129 IF (KY - 2) 30, 20, 20 
0130 20 WRITE (6, 190) TITLE1, TITLE2 
0131 WRITE (6, 105) 
0132c
0133c OUTPUT SECTION FOR (FI - FAV6)/FAV6 MAP 
0134c
0135 DO 22 I = 1, 19 
0136 22 ROUT(I) = FLOAT(10 - I) * (RANGE / 20.0) 
0137 WRITE (6, 107) 
0138 WRITE (6, 110) ROUT(I), I = 1, 10 
0139 WRITE (6, 109) 
0140 WRITE (6, 107) 
0141 WRITE (6, 111) ROUT(I), I = 11, 19 
0142 WRITE (6, 128) TMAV6 
0143 WRITE (6, 120) 
0144 DO 10 I = 1, 39 
0145 DO 100 J = 1, 51 
0146 100 FACP(J) = FACE(1, J) 
0147 IF (I, HE, 20) WRITE (6, 101) (FACP(J), J = 1, 51) 
0148 10 IF (I, EQ, 20) WRITE (6, 121) (FACP(J), J = 1, 51) 
0149 WRITE (6, 122) 
0150 GO TO 16 
0151 30 WRITE (6, 219) TMMIN, T0P1, TMMAX, T0P2, TMAV6, T0P3, SMAV6, QAV
OUTPUT SECTION FOR USER-DEFINED DISTORTION PARAMETERS

WRITE (6,301) PSPEC(I), I=1,6, BF, PSPEC(7)
WRITE (6,302) PSPEC(8), BSF, K, RKP

FORMAT (14X,51A1)
FORMAT (37X,22HKEY TO MAPPING SYMBOLS)
FORMAT (2X,6HORDER,11X, 57H/= +/1 /< =/> #/)
$ $ 
FORMAT (2X,10HIN PERCENT)
FORMAT (2X,14H(P1-PAVG)/PAVG,20(1X,F5.1))
FORMAT (22X,10F6.1)
FORMAT (/39X,16H+ 360/0 DEGREES/)
FORMAT (6X,6H270 +2X,51A1,2X,5H+ 90)
FORMAT (/39X,6H+ 180)
FORMAT (32X,23H(P1-PAVG)/PAVG PROFILE32X,16H AVERAGE PRESSURE
$ 1H=,F7.3)
FORMAT (1H1,6X,20A4/6X,20A4)
FORMAT (33X,24H OVERALL FLOW DESCRIPTORS/
$ 25X,6HPTMIN=F7.3,3X,17H(PTMX-PTMN)/PTMN=F7.4/
$ 25X,6HPTMAX=F7.3,3X,17H(PTMAX-PTMIN)/PTAV=F7.4/
$ 25X,6HPTAVG=F7.3,3X,17H(PTAV-PTMN)/PTAV=F7.4/
$ 25X,6HPAVG=F7.3,15X,5HDAVG=F7.4)

SECTION FOR FORMATS FOR THE OUTPUT OF USER DEFINED DISTORTION FACTORS

FORMAT (/11X,23H FLOW DISTORTION FACTORS/
$ 3X,11H-FACr ,F11.5/11X,11HDFACR ,F11.5/
$ 51H/=+$ $ /51H/=+$ $ $ /51H/=+$ $ $ /51H/=+$ $ $ /
$ T/AD)
RETURN
END

ORIGINAL PAGE IS OF POOR QUALITY
SUBROUTINE RATK (RKFK,FABUD)

THIS IS THE FILTER ROUTINE.

RKFK=0.0
IF (FABUD.EQ.0.0) GO TO 40
B=11.76
RKFK=1.0
E=-B*FABUD
IF (ABS(E).GT.650.0) GO TO 40
RKFK=SQRT(1.0-EXP(E))
RETURN
END
SUBROUTINE SUMMER (X, ERF, KODE)

This subroutine solves the error function.

DIMENSION X(30)
DATA J/1/
IF (J.GT.3) 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) GO TO 40
ERF=1.0
GO TO 70
40 D=1.0
AN=1.0
DO 50 I=1,30
IF (X.LT.XT(I)) GO TO 60
N=I-1
AN=2.0*AN
IF (N.EQ.0.0) AN=1.0
ND=2*N+1
D=D*ND
XX=X**N
TERM=AN*X**D
IF (TERM.LT.CHECK) GO TO 60
SUM=SUM+TERM
F=TERM/SUM
IF (F.LT.CHECK) GO TO 60
CONTINUE
ERF=1.12838*EXP(-X**2)*SUM
IF (KODE=2) 90,80,80
ERF=1.0-ERF
90 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
REMAINING POSITION IS NEEDED FOR INTERNAL PROCESSING.

COMMON AR, ANGLOC(20), AVO, BETA2, BF, CDPD3P(10), CMAY(A10), FO, 1SHT,
$ CMIN(10), DMAX(10), DS2(10), FACE(99,65), FACTOR, FARCE(99,65), BSF,
$ J1, J2, KEY, KB, LCNTFL, NH, NP, NR, P(11,20), PR(11,20), PS(11,20), CKP,
$ PSPEC(20), PVVALUE, QAY, OPT2, T, RADLOC(11), RANGE, R1, RMAY, RRP(11),
$ RT, S6K(10), SGP(10), $16, SMAV6, STAPI, STATO, T, TOP1, TDP2, TM1N,
$ TDP3, THTP, THTMIN(10), TITLE1(20), TITLE2(20), TNAV6, TMAX, RKP, U1

DATA BLANK/*1H */PLUS/*1H*/

CALCULATION OF R AND THETA
APPROX. 1.0R(OUTER) (-- Y -->) APPROX. -1.0R(OUTER)
APPROX. -1.0R(OUTER) (-- X -->) APPROX. 1.0R(OUTER)
FACTOR%: SEE LINE 39 OF SUBROUTINE CARDRO

10 10 JD=1,51
Y=(FLOAT(20-10))*FACTOR
X=(FLOAT(10-26))/1.306*FACTOR
R=SQRT(X*X+Y*Y)
IF (X.E0.0) 60 TO 26
OMEGA=ATAN(ABS(Y/X))
60 TO 27
OMEGA=1.5708

CHANGING FROM CONVENTIONAL R-OMEGA SYSTEM TO THE
P-THETA SYSTEM USED IN THE INTERPOLATION PROCESS.
IF (X.E0.0.AND.Y.E0.0) THETA=1.5708-OMEGA
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 SYMNDER
0306 FACE(IO,JO)=PVALUE
0307 GO TO 10
0308 9 FACE(IO,JO)=BLANK
0309 10 CONTINUE
0310c
0311 RETURN
0312 END
0313c
0314c
SUBROUTINE DISIRF

SUBROUTINE WHICH CALCULATES SIMPLE DISTORTION PARAMETERS.

I, RANKLOC, 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), AUN, BETA2, BF, CDPOP3(10), CMAY6(10), F0, ISHFT,
& CMIN(10), DKMX(10), DKSS(10), FACE(39,65), FACTOR, FARCE(39,65), BSE,
& J1, J2, KEY, KD, LCHTLFL, INN, NP, NP, P(11,20), PR(10), PS(11,20), CKP,
& PSPEC(20), PVALUE, QAV, OPT2, R, RADLOC(11), RANGE, RI, RMAV, RRP(11),
& RT, SGOK(10), SGV(10), SIG, SMAY6, STAT, STAT, T, TDP1, TDP2, TMNIN,
& TDP3, THETA, TTHMIN(10), TITLE1(20), TITLE2(20), TMAY6, TMAX, RKP, U2

DIMENSION SEG(10), RADP(8,10), THTTOT(10), CMMAX(10)
LOGICAL STAT, STAT, LCHTLFL, LAID

CALCULATION OF SIMPLE CIRCUMFERENTIAL DISTORTION PARAMETERS.

DO 10 I=J1, J2

CALCULATION OF CMAY6, CMIN, AND CMAY6 FOR EACH RING

CMAXX(I)=0.0
CMAXX(I)=50000.0
CMAY6(I)=0.0
DO 11 J=1, NP
CMAXX(I)=AMAX1(P(I,J),CMAXX(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 TMAX AND TNMIN.
TMAX=0.0
0355  TMMIN=50000.0
0356  DO 7 I=J1, J2
0357  TMMAX=AMAX1(AMAX(I), TMMAX)
0358  7  TMMIN=AMIN1(AMIN(I), TMMIN)
0359c  CALCULATION OF THAVG
0360c
0361c  DIV=0.0
0362  PTSUM=0.0
0363  DO 33 I=J1, J2
0364  DO 33 J=1, NP
0365  PTSUM=PTSUM+P(I, J)
0366  33 DIV=DIV+1.0
0367  THAVG=PTSUM/DIV
0368c  CALCULATION OF TDF's
0369c
0370c  TDF1=(TMMAX-TMMIN)/TMMAX
0371c  TDF2=(TMMAX-TMMIN)/THAVG
0372c  TDF3=(THAVG-TMMIN)/THAVG
0373c  SECTION TO CALCULATE THDMIN FOR EACH RING.
0374c
0375c
0376c  DO 9 I=J1, J2
0377c  DO 13 LL=1, 10
0378  SEG(LL)=0.0
0379  IF (NP.EQ.1) GO TO 8
0380  L=1
0381  LAIND=.FALSE.
0382  DO 12 J=1, NP
0383  KO=J-1
0384  IF (KO.EQ.0) KO=NP
0385  K1=J
0386  A1=ANGLOC(K1)
0387  K2=J+1
0388  IF (K2.GT.NP) K2=K2-NP
0389  A2=ANGLOC(K2)
0390  IF ((J+1).GT.NP) A2=A2+360.0
0391  IF (L.GT.1) GO TO 14
0392  IF (P(I, K1).LT.(THAVG+1)) GO TO 21
0335 IF (P(I,K1).EQ.CMAVLG(I).AND.P(I,K2).GT.CMAVLG(I)) GO TO 22
0336 60 TO 14
0337 22 IF (P(I,KD).GE.CMAVLG(I)) GO TO 14
0338 21 LADD=.TRUE.
0339c LOGIC DETERMINES EACH SEGMENT'S CONTRIBUTION TO THTHIN ON EACH RING
0400c
0402 14 RINC=0
0403 IF (P(I,K2).LT.CMAVLG(I).AND.P(I,K1).LT.CMAVLG(I)) RINC=A2-A1
0406 IF (P(I,K2).GT.CMAVLG(I).AND.P(I,K1).LT.CMAVLG(I))
0407 % RINC=((A2-A1)/(P(I,K2)-P(I,K1)))*(CMAVLG(I)-P(I,K1))
0408 IF (P(I,K2).LT.CMAVLG(I).AND.P(I,K1).GT.CMAVLG(I))
0409 % RINC=((A2-A1)/(P(I,K1)-P(I,K2)))*(CMAVLG(I)-P(I,K2))

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.CMAVLG(I).AND.P(I,K1).GT.CMAVLG(I)) GO TO 23
0415 24 SEG(L)=SEG(L)+RINC
0416 60 TO 12
0417 23 IF (P(I,KD).GE.CMAVLG(I)) GO TO 24
0418 IF (J.EQ.1) GO TO 24
0419 L=L+1
0420 60 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$=0
0426 THTTOT(I)=0.0
0427 10 18 K=1,10
0428 IF (SEG(K).NE.0.0) K$=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

0433c SEARCH FOR LARGEST DEPRESSION BELOW AVERAGE ON EACH RING
0434c THIS WILL BECOME THTHIN FOR THAT RING
0435c 0436  THTMIN(I)=0.0
0437  DO 19 K=1,K3
0438  19  IF (SE6(K),G.T.,THTMIN(I)) THTMIN(I)=SE6(K)
0439  GO TO 9
0440  8  CALL PRNT(3)
0441  9  THTMIN(I)=0.0
0442  CONTINUE
0443c  CALCULATION OF AVERAGE STATIC PRESSURE.
0444c 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(1,I)
0451  DIV=DIV+FLOAT(NP)
0452  29  IF (.NOT.STATD) 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  $MAVG=STATSM/DIV
0458c  0459c  CALCULATION OF AVERAGE MACH NUMBER WHEN NO STATIC PRESSURES ARE INPUT
0460c  0461  AMACH=5.0*(ABS($MAVG/$MAVG)**.286-1.0)
0462  RMAVG=SORT(ABS(AMACH))
0463c  0464c  CALCULATION OF SIMPLE RADIAL DISTORTION PARAMETERS.
0465c  0466  DO 40 IR=1,NR
0467  40  ITHT=1,8
0468  R=RANLOC(IR)
0469  41  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
EXTREME 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 MAPPING PARAMETERS.
SUBROUTINE ALSO CONTROLS SOME OUTPUT

NP, RADLOC, ANSLOC, 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, ANSLOC(20), AVO, BETA2, BF, CDPOP3(10), CMAVG(10), FQ, ISHFT,
CMIN(10), DKANX(10), DKSS(10), FACE(39,65), FACTOR, FARC3(39,65), BSH,
J1, J2, KEY, K1, LSHFTFL, NH, NP, NR, P(11,20), PR(11,20), PS(11,20), CKP,
PSPEC(20), PVALUE, QAV, OPT2, R, RADLOC(11), RANGE, RI, RMAIN, BRP(11),
RT, SGDK(10), SGP(10), SIG, CMAVG, STAT, STATO, T, TDP1, TDP2, TMIN,
TDP3, THETA, THTMIN(10), TITLE1(20), TITLE2(20), TMAYG, TMAX, TMAX, RKP, U2

DIMENSION DPC(6)

LOGICAL STAT, STATO, LSHFTFL, 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. LSHFTLO) GO TO 50
IF (ISHFT.EQ.2) GO TO 50

DO 51 I=1, NR

NR1=NR+2-1

RADLOC(NR1)=RADLOC(NR1-1)

DO 546 K=2, ORIGINAL NO. OF POINTS ON THIS RING

SHIFT ANGULAR POSITIONS OUTWARD; SHIFT DATA OUTWARD

DO 51 J=1, NP

P(NR1,J)=P(NR1-1,J)

NR=NR+1

DO 550 51
SET UP 8-POINT DUMMY INNER RING AND FIND AVERAGE PRESSURE ON THE RING

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

DUMMY RING DATA AND POSITION SET-UP

0571   DO 53 I=1,8
0572       TH=(I-1)*45
0573   ANGLOC(I)=TH
0574   DO 53 J=1,NP
0575       P(J,I)=PSUM
0576   PCMN=0.0
0577   PCMX=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)/NMVG)-1.0)*100.0
0583   IF (PCMN.GT.P(I,J)) PCMN=P(I,J)
0584   IF (PCMX.LT.P(I,J)) PCMX=P(I,J)

SECTION TO WRITE OUT MAPPING PARAMETERS.

MAPPING PARAMETERS PUT INTO PROPER FORM FOR SYMBOL SUBROUTINE

0589   PCMN=-PCMN
0590   PCMX=AMAX1(PCMN,PCMX)
0591   DO 130 I=1,6
0592       IF (PCMX.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   CONVERT 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(1))/(RADLOC(NR)-
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 0630    RETURN
0631    END
0632c 0633c
SUBROUTINE FRF (RS, FAU)

SUBROUTINE TO EVALUATE FUNCTION OF AREA/VD 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)
FAUF = FAU
RETURN
END
SUBROUTINE SYMBLE

SUBROUTINE TO SUPPLY THE SYMBOLS FOR THE LINE PRINTER CONTOUR MAP

COMMON AB,ANGLOC(20),AUD,BETA2,BF,CDPOS3(10),CMAVG(10),F0,ISHFT,
       & CMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
       & J1,J2,KEY,KD,LCNTFL,ND,NEP(11,20),PR(10),PS(11,20),CRP,
       & PVALUE,QUAV,OPT2,R,RADLOC(11),RANGE,RI,RNAV,RP(11),R,
       & RT,SDK(10),SGP(10),S16SMG,STATI,STATP,T,TDB1,TDB2,THMIN,
       & TDP,TTH,THTMIN(10),TITLE1(20),TITLE2(20),TNAVG,TNMAX,RKP,US

DIMENSION OUTSYM(20),OUTSIM(20)

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

DATA OUTSYM/'H-1H-1H+1H+,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=-.00001
IF (PVALUE.LE.-20.0) PVALUE=-19.9999

SECTION TO DETERMINE THE PROPER SYMBOL FOR THE CONTOUR MAP.

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

RETURN
END
SUBROUTINE NEWPSD(KY)

SUBROUTINE TO EVALUATE RMS AND PSD FUNCTIONS FROM DYNAMIC PRESSURES.

COMMON AH,ANGLOC(20),AUO,BETA2,BF,CDPOP3(10),CMAVG(10),FO,ISHFT,

% CAMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,

% J1,J2,KEY,K1,LCNTFL,MM,NP,NR,P(11,20),PR(10),PS(11,20),CKP,

% FSPEC(20),PVALUE,QAV,OPT2,R,RADLOC(11),RANGE,R1,SMAVG,ERF(11),

% RT,SGMK(10),S6P(10),SIG,SMAVG,STATI,STAT1,T,TDP1,TDP2,TMIN,

% TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG,TMAX,RKP,U2

REAL M0,MFR

DIMENSION MOPRO(40),AVSIZ(40),FNOIL(40)

ON CALL FROM MAIN (KY=1) INPUT DISTORTION FACTOR KEY, TIME ON POINT,

AND FILTER FREQUENCIES. DISTORTION FACTORS ARE DEFINED BRIEFLY BELOW:

'1' KTHETA - FRATT & WHITNEY CIRCUMFERENTIAL DISTORTION FACTOR

'2' K02 - FRATT & WHITNEY CIRCUMFERENTIAL DISTORTION FACTOR

'3' IDG - GENERAL ELECTRIC CIRCUMFERENTIAL DISTORTION FACTOR

'4' IDR - GENERAL ELECTRIC RADIAL FLOW DISTORTION FACTOR

'5' KRA - FRATT & WHITNEY RADIAL FLOW DISTORTION FACTOR

'6' KRA - FRATT & WHITNEY COMBINED CIRCUMFERENTIAL/RADIAL DISTORTION

'7' DSFR - 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 UNSTAB, INPUT IDENTIFICATION AND CONTROL PARAMETERS

AND SET STEADY STATE DISTORTION FACTORS.
READ (5, 70) ALPH, PSI, MD, U2, BF, CKP, RKP, NFR, NTUR, SPTRC
IF (SPTRC = 1) SPTRC = 1.
IF (PSPEC(3)) 101, 102, 101
IF (RD = PSPEC(4) / PSPEC(3))
BSF = 0.24 + 0.76 / EXP(3.6 * RD * 0.79)
IF (CKP EQ 0.0) CKP = 16.4
IF (RKP EQ 0.0) RKP = 11.1
PSPEC(8) = BSF * CKP * PSPEC(3) + RKP * PSPEC(4)
102 IF (BF EQ 0.0) BF = 1.0
ETA = TMAVG
OPT2 = GAV / TMAVG
PSPEC(6) = PSPEC(1) + BF * PSPEC(5)
DO 241 I = 1, 10
241 D Blowup = PSPEC(1)
RETURN
ON 2ND CALL FROM UNSTUDY COMPUTE MAX INSTANTANEOUS DISTORTION FACTORS
NN = 0
IF (NFR EQ 0) NFR = 1
WRITE (6, 10) TITLE1, TITLE2
WRITE (6, 20) T, FD, RT, RI, SPTRC
WRITE (6, 30) ALPH, PSI, MD, ETA, NFR, U2, OPT2
WRITE (6, 120) FCO
ERANCH TO TURBULENCE MODELLING SUBROUTINE IF THERE IS NO DYNAMIC DATA
IF (NTUR EQ 1) GO TO 500
WRITE (6, 50)
DO 258 I = 1, 10
258 SIG(1) = 0.0
INPUT DYNAMIC DATA
NFR IS RUN CODE. IF ZERO IS ENTERED, THE INPUT SEQUENCE IS EXITED
NFR IS A DYNAMIC PRESSURE PROBE NUMBER
RS IS RATIO OF FILTERED/UNFILTERED MEAN SQUARE VALUE OF DYNAMIC
PRESSURE FLUCTUATIONS.
SIG IS RMS VALUE OF DYNAMIC PRESSURE FLUCTUATION.
0776 260 READ (5,90) NPF,NPR,RS,SIG
0777   IF (RS .EQ. 0) RS = 0.5
0778   IF (RS .GT. 0.7) RS = 0.7
0779   IF (NPF.NE.0) 60 TO 300
0780c
0781c CALL MAXDP TO COMPUTE MAXIMUM DISTORTION VALUES.
0782c
0783   CALL MAXDP
0784   DO 372 I=1,NN
0785   AVSIZ(I)=AVSIZ(I)/(AB)
0786   372    FNOPRO(I)=FLOAT(FOPRO(I))
0787   WRITE (7) (FNOPRO(I),I=1,NN),(AVSIZ(I),I=1,NN)
0788   RETURN
0789c
0790c COMPUTE MEAN VORTEX CORE SIZE FOR EACH FROE AND SUM AER AND SIG.
0791c NN IS COUNTER FOR NUMBER OF DYNAMIC PRESSURE FROES.
0792c
0793 300    CALL FRF (RS,FAUF)
0794   AO=FAUF/(7.376*FCO)
0795   AB=120*AO*U2
0796   AB=AB/PI
0797   WRITE (6,60) NPR,RS,SIG,AB
0798   SGF(1)=SGF(1)+SIG*SIG
0799   SGF(2)=SGF(2)+AB*AB
0800   NN=NN+1
0801   FOPRO(NN)=NPR
0802   AVSIZ(NN)=AB
0803   60 TO 260
0804 500    CONTINUE
0805c
0806c CALL TURBULENCE SUBPROGRAM TURBUL TO COMPUTE THE RMS LEVELS.
0807c SPTRC IS THE TOTAL PRESSURE RECOVER THROUGH INLET SHOCK SYSTEM
0808c (SPTRC=1. FOR SUBSONIC AND TRANSONIC SPEED).
0809c RS IS RATIO OF FILTERED/UNFILTERED MEAN SQUARE VALUE OF DYNAMIC
0810c PRESSURE FLUCTUATIONS.
0811c SIG IS RMS VALUE OF DYNAMIC PRESSURE FLUCTUATION.
0812c
0813   CALL TURBUL (RS,RAILOC,NR,HP,U2,OPT2,TVAG,ND,SPTRC,SIG)
0814   RS=0.5
0815   CALL FRF (RS,FAUF)
CALL MAKDP TO COMPUTE MAXIMUM DISTORTION VALUES.

CALL MAKDP
DO 375 I=1,NN
AVSIZ(I)=AVSIZ(I)/AB
ENDPRO(I)=FLOAT(ENDPRO(I))
CONTINUE
WRITE (7) (ENDPRO(I),I=1,NN), (AVSIZ(I),I=1,NN)
RETURN

FORMAT (IH1,19X,2AH4/19X,2AH4)
FORMAT (/14X,IHT,6X,2HF0,6X,2HR,6X,2HR1,5X,5HSPTRC/5X,F12.3,
8X,F8.1,3F8.3)
FORMAT (/13X,4HALPH,5X,5HPSI,4X,2HMO,5X,3HETA,4X,3HNFR,4X,2HUE,
5X,4HPT2/10X,F7.3,F8.3,3F7.3,F7.1,F8.4)
FORMAT (/10X,5HPROBE,3X,2HRS,3X,6HS/PT2,3X,4H/RT)
FORMAT (10X,13X,4F7.4)
FORMAT (5X,8F5.3,15,F5.3)
FORMAT (5X,8F5.3,11F5.2)
FORMAT (5X,215,F5.3,6.4)
FORMAT (/11X,10HRS AT FC =F8.1)
FORMAT (5X,15,F10.5)
SUBROUTINE MAXDP

COMMON AB, ANGLOC (20), AVO, BETA2, BF, CDPOR3 (10), CMAY6 (10), F0, ISHFT,
& CMIN (10), DMX (10), DKSS (10), FACCE (39, 65), FACTOR, FAUCE (39, 65), BSF,
& J1, J2, KEY, KD, LCHTFL, NH, NP, NF, P11, 20, PR (10), PS (11, 20), CKP,
& PSPEC (20), PVALUE, QAV, OPT2, R, RADLOC (11), RANGE, R1, RMAV, RRP (11),
& RT, S6DK (10), S6P (10), SIG, SMAX6, STAT1, STAT2, T, TDP1, TDP2, TMMIN,
& TDP3, THETA, THMIN (10), TITLE1 (20), TITLE2 (20), TMAV6, TMAX, TKP, U2

DIMENSION LAB (8), F0 (10), INBAR (10)

DATA LAB (1), LAB (2), LAB (3), LAB (4) /4HKTTA, 4H KD2, 4H IDC, 4H IDR/
DATA LAB (5), LAB (6), LAB (7), LAB (8) /4H KRA, 4H KA2, 4H DSRP, 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
RTUD = RT / U2 / 12.0

400 AN = NH

FIND MEAN VALUES OF SIGMA AND RGB

SIG = SORT (SGP (1) / AN)
AB = SORT (SGP (2) / AN)
SGP (1) = SIG / OPT2

FIND FLUX AND ENGINE FILTER EFFECTS

FL = AHRTU (AB) / RTUD
TFL = T + FL
FABUD = F0 + RTUD * AB
CALL RATEK (RKEF, FABUD)
VF = 0.949 * SGP (1) * RKEF / SORT (AB)
SIGF=SIG*RFK

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,RI,RK,AB,IKSS(J),NP,OPT2,YB,SGF)
SGP(I)=R1*SGP(I)*FQ(I)
GO TO 410

FORMULAS FOR KA2 AND ID SIGMAS

404 SGP(I)=SORT(SGP(3)**2+(BF*SGP(7)**2))
GO TO 410

406 SGP(I)=SORT((BF*CKP*SGP(5)**2+(RKP*SGP(6)**2))
GO TO 410

FILTERED RMS LEVEL (SGDK) OF DISTORTION FACTOR.

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

FILTERED MEAN INSTANTANEOUS VALUE (DKBEAR) OF DISTORTION FACTOR.

420 DKBEAR(J)=RK*SGDK(I)*IKSS(J)
GO TO 450

FORMULAS FOR KA2 AND ID DELTAS.

424 DKBEAR(6)=DKBEAR(1)+BF*DKBEAR(5)
GO TO 450

426 DKBEAR(8)=BSF*CKP*DKBEAR(3)+RKP*DKBEAR(4)

TO FIND MOST PROBABLE EXTREME VALUES.

CALL EXTRME (SGD(I), DKBAR(I), DKMH(I), T, FL)
WRITE (6,60) $16
WRITE (6,70) AB
IF (NN .LT. 2) GO TO 459
IF (NN .LT. 25) GO TO 460
WRITE (6,130) TITLE1, TITLE2
WRITE (6,100)
DO 500 I=1,8
J=1+8
IF (I.GT.1) GO TO 470
PP=1.0-EXP(-0.05193294/FIL)
IF (PP.EQ.0.) GO TO 999
FL1=1.0/(PP*T)
PP=1.0-EXP(-0.003004509/FIL)
IF (PP.EQ.0.) GO TO 996
FL2=1.0/(PP*T)
CONTINUE
FIND INSTANTANEOUS VALUES AT 95.0 AND 99.7 CONFIDENCE LEVELS
CALL EXTRME (SGD(J), DKBAR(J), DK950(J), TFL1)
CALL EXTRME (SGD(J), DKBAR(J), DK975(J), TFL2)
IF (J-2) 480,490,480
WRITE (6,110) LAB(J), DK93(J), DKBAR(J), SGD(J), DKBAR(J), DKMH(J), &
& DK950(J), DK997
60 TO 500
WRITE (6,120) LAB(J), DK93(J), DKBAR(J), SGD(J), DKBAR(J), DKMH(J), &
& DK950(J), DK997
CONTINUE
WRITE (6,75) LAB(KD), DKMH(KD)
FORMAT (/13X,"FACE-AVERAGE RMS (SG/PT2) =",F8.5)
FORMAT (/13X,"MEAN VORTEX $12E (AV/FT) =",F8.5)
FORMAT (/25X,3HMAXIMUM INSTANTANEOUS DISTORTION FACTOR/
& 30X,1A10.1H=F13.4)
FORMAT (/22X,3HDISTORTION FACTOR EXTREME VALUE//59X,21HMAXIMUM 1
$INSTANTANEOUS/12X,6HFACTOR,4X,6HSTEADY,3X,4HMEAN,5X,5HSTDMA,4X,
5HS16MA,5X,4HNSTD,4X,5H95,0X,4X,5H99,7X/22X,5HSTATE,4X,5HVALUE,5X,
$3HINF,7X,2HF0,6X,4HPR08,5X,4HPR0B,5X,4HPR0B)
FORMAT (10X,A4,6X,F7.4,F9.4)
FORMAT (10X,A4,6X,F7.1,F9.1)
FORMAT ('H1,19%,20R4/19%,20R4)
RETURN
PP=0.0000001
WRITE (6,998)
FORMAT ('//10%29HCONFIDENCE LEVEL IS INCORRECT)
GO TO 997
PP=0.0000001
WRITE (6,998)
GO TO 995
END
FUNCTION AMRTU (ART)

FUNCTION FOR FINDING VORTEX FLUX RATE.

AMRTU=1.0E+06

IF (ART.EQ.0.0) GO TO 100

AMRTU=0.254/(ART+ART)

100 RETURN

END
SUBROUTINE R SIGMA (J, R1, RK, AB, DK S, NP, OPT, VB, SIGF)

THIS ROUTINE IS USED NOW TO COMPUTE THE RATIO OF SIGMA KD
TO SIGMA OPT AND THE RATIO (KVAR-KSS)/SIGMA K.
SF IS RATIO OF SIGMA-OPT/R
FN IS NUMBER OF FREEZE PER RING
DT IS ANGULAR ARC PER FREEZE

SP = 1.0537 * SORT (AB)
PH = NP
DT = 6.28319 / PH
GO TO (10, 20, 30, 40, 50, 60, 70, J)

THIS BRANCH APPLIES TO KTHETA.

DKSS = DK S / VB
SDK I S = 1.65 * SORT (AB / PH) / EXP (40.0 * (AB / DT) ** 4.0)
SDK I L = 2.106 * (1.0 - 1.0 / EXP (1.1 * (AB ** 1.5)))
SDK I = SDK I S * SDK I S + SDK I L * SDK I L
DKTS = (1.403 * AB / EXP (76.67 * (AB / DT) ** 4.0)) / SORT (1.0 + 99.0 * DK SS * DK SS)
DKTL = (2.0 * (1.0 - 1.0 / EXP (1.05 * (AB ** 1.5)))) / SORT (1.0 + 5.25 * (0.9 * DK SS / AB) ** 2.3)
DKT = SORT (DKTS * DKTS + DKTL * DKTL)
SIGK = SORT (SDK I - 2.0 * DK SS * DKT - DKT * DKT)
R1 = SIGK / SP
RK = DKT / SIGK
IF (J, E, 0.7) GO TO 71
GO TO 90

THIS BRANCH APPLIES TO KID.

DKSS = DK S / (OPT / VB)
IF (AB - 0.45) 21: 21: 22
R1 = 10847.0 * (1.0 - 1.0 / EXP (4.0 * AB))
GO TO 23
R1 = 9054.0 + (AB - 0.45) * (1164.0 + 14052.0 * (1.0 - 1.0 / EXP (2.5 * DK SS / 97627.0)))
R1 = 25763.0 * (1.0 - 1.0 / EXP (4.82 * (125 * PH * AB) ** 1.4)) / EXP (DK SS / 17627.0)
1039 \quad RK=R1/R1
1040 \quad R1=R1*OPT/(0.1475*SP)
1041 \quad GO TO 90
1042c
1043c \quad THIS BRANCH APPLIES TO IRC.
1044c
1045 30 \quad DS=DS/(OPT*VB)
1046 \quad R1=1.01*AB+.063
1047 \quad R10=SQRT((0.5356*AB+.26)**2+(1.2271*SQRT(S.0*AB/PN)))/
1048 \quad \exp(5.42*(AB/DT)**2)**2
1049 \quad RS=SQRT(1.0-1.0/\exp(0.17*(DS/SGF)**2))
1050 \quad IF (R11-R10) 31,31,32
1051 31 \quad R1=R10-RS*(R10-R11)
1052 \quad GO TO 33
1053 32 \quad R1=R10+RS*(R11-R10)
1054 33 \quad RK=1.458*(1.0-1.0/\exp(9.0*(.125*PN*AB)**1.4)))/\exp((DS/1.424)
1055 \quad **0.75)
1056 \quad RK=R1/R1
1057 \quad R1=R1*OPT/(0.1475*SP)
1058 \quad GO TO 90
1059c
1060c \quad THIS BRANCH APPLIES TO IDA.
1061c
1062 40 \quad R1=0.1324*(1.0-1.0/\exp(4.0*(AB*1.4142)))
1063 \quad IF (AB.6T.03) 60 TO 45
1064 \quad RS=0.2713*SQRT(AB)-1.6528*AB*AB
1065 \quad R1=SQRT(RS*RS+R1*R1)
1066 45 \quad RK=0.0830*(1.0-1.0/\exp(4.0*AB*AB))
1067 \quad RK=R1/R1
1068 \quad R1=R1*OPT/(0.1397*SP)
1069 \quad GO TO 90
1070c
1071c \quad THIS BRANCH APPLIES TO IRB.
1072c
1073 50 \quad R1=0.0825*(1.0-1.0/\exp(6.0*AB*1.475))
1074 \quad IF (AB.6T.03) 60 TO 55
1075 \quad RS=0.192*SQRT(AB)-0.9253*AB*AB
1076 \quad R1=SQRT(RS*RS+R1*R1)
1077 55 \quad RK=0.0542*(1.0-1.0/\exp(3.75*(AB*1.6667)))
1078 \quad RK=R1/R1
1079 R1=R1/SP
1080 GO TO 90
1081c
1082c THIS BRANCH WHICH APPLIED TO KAZ HAS BEEN NULLED.
1083c
1084 60 GO TO 90
1085c
1086c THIS BRANCH APPLIES TO DSFR.
1087c
1088 70 DK5=1.4809*DK5/OP
1089 60 GO TO 10
1090 71 DK5=0.6753*DK5/OP
1091 DK5=DK5/VB
1092 IF (AB-0.6) 72,73,75
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=AP*AB**S
1099 60 GO TO 76
1100 74 S=(A-0.0996)/0.42
1101 RRK=0.0996-S*(AB-0.6)
1102 60 GO TO 76
1103 75 RR1=0.0996
1104 RRK=0.0996
1105 76 R1=R1*RR1/0.1475
1106 RRK=RRK*RRK/.1475
1107c
1108 90 RETURN
1109 END
1110c
1111c ----------------------------------------
SUBROUTINE SEARCH (AKS, DKS, ANT)

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

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

40 DKS = 2.6 + 0.283*(ALOG(ANT) - 4.60517)
SLOPP = 7.5
DKS N = 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
DKN = DKS + (ALOG(ANT) - ALOG(PX))/SLOPE
60 PX2 = PX
DKS2 = DKS
DKS = DKN
35 100 SLOPP = SLOPE
120 RETURN
END
SUBROUTINE FFX (AKS, KKS, PX)

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

UND = (-1) * (3.0 + ABS (AKS - 2.0))
UND1 = -5.0 * ABS (AKS - 2.5)
UND2 = -5.0 * ABS (AKS - 3.0)

IF (UND .LT. -38.0) UND1 = -38.0
IF (UND2 .LT. -38.0) UND2 = -38.0

AM = 1.16 - 15.5 * (AKS - 1.4) / (AKS + 4.0)**4

Y1 = -0.66 - 0.140 * (EXP (-3.0 * ABS (AKS - 6.5)))

A = +4.04 * (EXP (-0.99 * ABS (AKS - 2.0)))

B = -0.035 * (EXP (-1.2 * ABS (AKS - 4.7)))

C = -0.062 * (EXP (-0.7 * ABS (AKS - 16.0)))

A = 0.13 - 0.031 * (AKS - 2.7)**5 * (ABS (AKS - 2.7)**15) * (EXP ((AKS - 5.0) *

A = (-0.45) - 0.299 * (EXP (-0.08 * ABS (AKS - 16.0)))

A = +0.04 * (EXP (UND1)) - 0.177 * (EXP (-ABS (AKS - 4.0)))

A = -0.017 * (EXP (-ABS (AKS - 6.0))) - 0.034 * (EXP (UND))

A = -0.0817 * (EXP (UND2))

CH1 = AM * KKS + Y1 + A * (AKS - 2.0)**3

IF (CH1 .LT. 38.0) CH1 = 38.0

IF (CH1 .LT. -38.0) CH1 = -38.0

PX = 10.0 * 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), AUD, BETA2, BF, CIDOPP3(10), CMNAV6(10), FO, ISHFT,
& CMMIN(10), DKMX(10), DKSS(10), FACE(39, 65), FACTOR, FARCE(39, 65), BSC,
& J1, J2, KEY, KI, LCNTFL, NN, NP, PR(11), PS(11, 20), CKP,
& PSPEC(20), PVALUE, QAV, QPT2, R, RADLOC(11), RANGE, RI, RNAV, RP(11),
& RT, SGDK(10), SGK(10), SIG, SNAV6, STATI, STATO, T, TDP1, TDP2, TMMIN,
& TDP3, THTA, THTMIN(10), TITLE1(20), TITLE2(20), TNAV6, TMMAX, TKP, U2

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

DIMENSION PT(20), OD(10), DTHETA(20), RICO(5), RIIR(5)
LOGICAL STATI, STATO, LCNTFL
DATA IT/0/
IF (IT.EQ.1) GO TO 25

CALCULATION OF KD2

DINVS=0.0
DO 26 I=J1, J2
DINVS=DINVS+(1.0/RADLOC(I))
DO 27 I=J1, J2
OD(I)=(1.0/RADLOC(I))/DINVS
RKD2=0.0
DO 28 I=J1, J2
RKD2=RKD2+(CIDOPP3(I)*TMMIN(I)+OD(I)*100.0)

CALCULATION OF K-THETA.
IF (IT.EQ.1) GO TO 37
DO 36 J=1, NP
K1=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.NE.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 RTHT=0.0
1224 TTTT=DTHETA(1)
1225 DTHT=TTTT
1226 IF (ISHT.EQ.1) QAV=(SMAY6/PGAM)**((ABS(TMAV6/SMAY6)**(PGAM)-1.0)
1227 DO 35 I=J1, 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)/TMAV6)**SIN(PHI)*DTHETA(J))
1233 34 RICOS=RICOS+((P(I,J)/TMAV6)**COS(PHI)*DTHETA(J))
1234 35 RTHT=RTHT+R(J)**(SORT(ABS((ABS(RISIN)**2)+(ABS(RICOS)**2))))
1235 IF (QAV.EQ.0.0) QAV=1.0
1236 RTHT=(RTHT/(180.0*QAV))**TMAV6
1237c
1238c CALCULATION OF IDC-MAX AND IDR-MAX.
1239c
1240 NCHK=NP
1241 IF (STATI) NCHK=NCHK-1
1242 IF (STATO) NCHK=NCHK-1
1243 IF (NCHK.EQ.0.5) GO TO 39
1244 CALL PRNT(3)
1245 60 TO 39
1246 39 DO 41 J=J1, J2
1247 RDC(J)=(CMAV6(J)-CMIN(J))/TMAV6
1248 41 RDR(J)=(TMAV6-CMAV6(J))/TMAV6
1249 RDCX1=(RDC(J1)+RDC(J1+1))/2.0
1250 RDCX2=(RDC(J1+3)+RDC(J1+4))/2.0
1251 RDCMX=AMAX1(RDCX1,RDCX2)
1252 RDRMX=AMAX1(RDR(J1),RDR(J1+4))
1253c
1264c calculation of id
1266c pid=ridcmx*bsf*ckp+ridrnx*rkp
1267c
calculation of kra and ka2
1269c
1270c sptr=0.0
1271d do 100 i=j1,j2
1272d ptrv=cmav5(i)
1273d dptr=abs(ptrv/tmav6-brp(i))/brp(i)
1274d 100 sptr=sptr+dptr*odd(i)
1275d akra2=tmav6*sptr/ov
1276d akra2=rktht+akra2*bf
1277c
calculation of delta stall margin -dem
1278c first find the average radial pressure and minimum pressure
1279c
1280c ptrx=0.0
1281c ptrm=5.08000
1282c ak=hp
1283c amr=j2-j1+1
1284d do 300 j=1,np
1285d pt(j)=0.0
1286d do 200 i=j1,j2
1287d pt(j)=pt(j)+p(i,j)
1288d pt(j)=pt(j)/amr
1289d ptrx=ptrx+pt(j)
1290d ptrm=min(ptr(j),ptrm)
1291d ptrx=ptrx/ak
1292d risin=0.0
1293d ricos=0.0
1294d do 400 j=1,np
1295d phi=0.017453*angloc(j)
1296d risin=risin+(pt(j)/ptrx)*sin(phi)+dttht
1297d ricos=ricos+(pt(j)/ptrx)*cos(phi)+dttht
1298d 400 dem=0.675*sqrt(risin*risin+ricos*ricos)/180.0
1299c
cpecific distortion parameters stored in array 'fspec'
1300c in preparation to being transferred to 'lnfot'
1301c
SUBROUTINE PRNT (KP)
COMMON AB, ANGLOC (20), AOD, BETA2, BF, CDPOP3 (10), CMAVG (10), FO, ISHFT,
& CMIN (10), DMX (10), DKSS (10), FACE (39, 65), FACTOR, FARE (39, 65), BSF,
& J1, J2, KEY, KI, LCHTFL, NH, NP, NP, PR (11, 20), PS (11, 20), CKP,
& PSAF (20), PVALUE, QAY, OPT2, R, RADLOC (11), RANGG, RE, RMAV, BRP (11),
& RT, SGDK (10), SGF (10), S16, SNAV, STAT1, STAT2, T, TDP1, TDP2, TMIN,
& TDP3, THET, THMIN (10), TITLE1 (20), TITLE2 (20), TNAV, TMAX, RKP, U2
LOGICAL STAT1, STAT2, LCHTFL
GO TO (9, 2, 3, 9, 9, 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, NR)
WRITE (6, 105) (BRP (J), J=1, NR)
GO TO 1000
GO TO 1000
WRITE (6, 125) TITLE1, TITLE2
GO TO 1000
FORMAT (/10X, 4DHIC-MAX AND IDR-MAX CANNOT BE CALCULATED,
& 10X, 51THERE ARE NOT EXACTLY 5 RINGS OF TOTAL MEASUREMENTS)
FORMAT (/30X, 15SHAVE RADIAL PROFILE//10X, 8HRADI1 //8F8.3)
FORMAT (/10X, 8HRADI2 //8F8.4)
SUBROUTINE INTERP

INTERPOLATION SUBROUTINE

INPUT ARGUMENTS TO THE INTERPOLATION Routines MUST BE IN THE FIRST
10 VARIABLES OF THE ARRAY DIMENSION EQUAL TO 10. TEN OF THE
11 POSITIONS ARE AVAILABLE FOR USE. THE
12 REMAINING POSITION IS NEEDED FOR INTERNAL PROCESSING.

COMMON AR,ANGLOC(20),AUO,BETA2,BF,CDPOP3(10),CMAYG(10),FD,ISHFT,
13 CMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FAVE(39,65),BSF,
14 J1,J2,KEY,KD,LCNTFL,NH,NR,RP(11,20),PR(10),PS(11,20),OKP,
15 PSPEC(20),PVVALUE,OAY,OPT2,R,RAILC(11),RANGE,RMAY,BRP(11),
16 RT,SGDK(10),SGP(10),S16,SMAYG,STATI,STATO,T,TDP1,TDP2,TMAYG,
17 TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAYG,TMAX,RKP,U2
18
19 DIMENSION NFFIT(2),NRFIT(2),RADFIT(2),Z(2),F(2)
20 LOGICAL STATI,STATO,LCNTFL
21 IF (NR.LT.2) CALL PRTNT (3)
22 NR1=NR-1

Determine the correct two rings to use in the interpolation process.

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

Interpolation boundary ring nos.

NFIT(1)=II
15 NFIT(2)=II+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 11=1,2
K=MFIT(II)
IF (NP.NE.1) GO TO 21

IF ONLY ONE POINT ON RING, NO CIRCUMFERENTIAL INTERPOLATION
RAFIT(I1)=P(K,1)
GO TO 15

IF 0. < THETA < ANGLOC(K+1) REQUIRES SPECIAL INTERPOLATION
21 IF (THETA.LT.ANGLOC(1)) GO TO 19

SEARCH FOR ANGULAR BOUNDS
DO 16 J=1,NP
N2=J
IF (J.LE.NP) GO TO 20

IF ANGLOC(K+NP) < THETA < 360. REQUIRES SPECIAL INTERPOLATION
19 IF (THETA.GE.ANGLOC(J).AND.THETA.LT.ANGLOC(J+1)) GO TO 20
CONTINUE
GO TO 20
N2=NP

NUMBERS OF INTERPOLATION BOUNDARY ANGLES
M1=0
M1=1,N2+1
DO 18 I=1,2
IF (THETA.LT.ANGLOC(1)) GO TO 7
18 IF (N1.NE.L) GO TO 23
IF (N1.GT.NP) GO TO 24
L=N1
Z(I)=ANGLOC(L)
F(I)=P(I)L
GO TO 18
7 IF (N1.LE.NP) GO TO 6
L=N1-NP
Z(I)=ANGLOC(L)
F(I)=F(K+L)
60 TO 18

SET UP SPECIAL INTERPOLATION EXTERIOR POINT

L=NFFIT(I)
Z(I)=ANGLOC(L)-360.0
F(I)=F(K+L)
60 TO 18

L=NFFIT(I)+NP
Z(I)=ANGLOC(L)-360.0
F(I)=F(K+L)
60 TO 18

L=NFFIT(I)-NP
Z(I)=360.0+ANGLOC(L)
F(I)=F(K+L)
18 CONTINUE

LINEAR INTERPOLATION IN THE CIRCUMFERENTIAL DIRECTION.

RADFIT(I)=((F(2)-F(1))*(THETA-Z(I))/(Z(2)-Z(1)))+F(1)
15 CONTINUE

LINEAR INTERPOLATION IN THE RADIAL DIRECTION.

DO 30 I=1,2
L=NFFIT(I)
Z(I)=RADLOC(L)
F(I)=RADFIT(I)
30 CONTINUE

FINAL INTERPOLATED VALUE

PVVALUE=((F(2)-F(1))*(R-Z(I))/(Z(2)-Z(I)))+F(1)

RETURN
END
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),AUD,BETA2,BF,CIPDP3(10),CMAVG(10),F0,ISHFT,
& CMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARE(39,65),BSF,
& J1,J2,KEY,LD,LCNTFL,NN,NP,NR,PS(11,20),PR(10),PS(11,20),CRK,
& PSPEC(20),PVAC,PSYR,PADLOC(11),RANGE,RI,RMAX,BRP(11),
& RT,SGDK(10),SGP(10),S15,SMAVG,STAT1,STAT2,TIP1,TIP2,TMIN,
& TIP3,THETA,HTMIN(10),TITLE1(20),TITLE2(20),TMAYG,TMAX,RKP,U2

DIMENSION AR(1)

COH=1.0/S5.29577951

SET INITIAL AND/OR DEFAULT VALUES.

VL=999.999
XA=0.0
RI=0.0

CALL SUBROUTINE NEWPSD: INPUT IDENCTIFICATION AND CONTROL PARAMETERS

CALL NEWPSD2

DEFINE PROBE RADIAL LOCATION IN RATIO FORM.

NRG=0
DO 50 I=1,HR
IF (1.6E,J1,AAND I.LE.J2) NRG=NRG+1
50 AR(I)=RADLOC(I)/RADLOC(NR)

RBAR=0.5*(1.0+AR(I))
RRT=RBAR

OPT=0.7*RMAV*RMAY/(1.0+0.2*RMAV*RMAY)**3.5

COMPUTE AVERAGE AND MAXIMUM MACH NUMBER AND VELOCITY AT ENGINE FACE.
TMAYGG=TMAYG
AMA=SORT(5.+(<(TMAYG/SMAYG)**2.86)-1.0))
AMM=SORT(5.+(<(TMAX/SMAYG)**2.86)-1.0))
VBM=AMM+SORT(1.0+0.2*AMA+AMA)/SORT(1.0+0.2*AMM+AMM)/AMA
NY=2
DOK=P$SPEC(KD)
VBI=1.0

SEARCH FOR VORTEX LOCATION AND ORIENTATION.

RKX=TMX
RKX=TMMIN
DO 68 I=1,HP
RKAV=0.0
DO 66 J=J1,J2
RKAV=RKAV+PS(J,1)
RKAV=RKAV/NR6
IF (RKAV.LT.RKX) GO TO 67
RKX=RKAV
TMX=ANGLOC(I)
IF (RKAV.GT.RKMN) GO TO 68
RKMN=RKAV
TMX=ANGLOC(I)
CONTINUE
DTH=ABS(TMNN-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 (TMNN.GT.THE) GO TO 71
G1=90.0
IF (THE.GT.180.0) THE=THE-360.0
TV IS THE VORTEX CIRCUMFERENTIAL LOCATION
TV=THE
CALL LNPOUT(I)
WRITE (6,1996)
WRITE (6,1998) THMN,RKMN,THMX,RKMX,DTH,THE,ART,G1
CALL LMPOUT(2)
WRITE (6,1800)

CALL SUBROUTINE TO COMPUTE MAXIMUM INSTANTANEOUS DISTORTION FACTORS

CALL NEWPSD(3)
A0=AB
VB0=1.36*SIG/OPT2
VBAR=VB1

LOOP 600 IS THE VORTEX STRENGTH (VEAR) ITERATION.
VEAR VARIES FROM VE1 TO VE2 BY Die, NV TIMES.

VEAR=VB1
DO 600 IV=1,NV
IF (IV=2) 73,721,722
ONKD=PSPEC(KD)
676 722 VBAR=(OKMX(KD)-OKD)/(ONKD-OKD)
777c

WHEN A SPECIFIC PRESSURE CONTOUR IS NEEDED A/RT IS COMPUTED FROM VEAR

AYRT=ART
RAV=1.0/AYRT

VORTEX ORIENTATION ANGLES AND FUNCTIONS.

G=G1
COSG=\cos(CON+G)
SINGLE=\sin(CON+G)
G=B1
COSB=\cos(CON+B)
SINB=\sin(CON+B)
CBSG=COSB*SINGLE
SBSG=\sinB+SINGLE
CBSG=\sinB+COSG
SBCG=\sinB+COSG

1595c
1596c LOOP 90 IS THE PROBE RADIAL LOCATION ITERATION. FOR A GIVEN VORTEX
1597c THE PRESSURE FLOWFIELD IS FOUND AT EACH PROBE RADIUS AND THETA.
1598c THERE ARE NR RINGS AND NP PROBES PER RING.
1599c
1600 DO 90 J=1, NR
1601 IF (J-JID) 78, 65, 63
1602 63 IF (J-JID) 85, 65, 78
1603 65 ZA=AF(J-JID)/AYFT
1604 IF (ABS(ZA), GT, 100.0) ZA=SIGN(100.0, ZA)
1605 IF (ABS(TV), GT, 180.0) TV=SIGN(180.0, TV)
1606c LOOP 80 IS THE PROBE CIRCUMFERENTIAL LOCATION ITERATION.
1607c
1608c
1609 DO 80 I=1, NP
1610 PHI=ANGLOC(I)-TV
1611 IF (PHI.GT.180.0) PHI=PHI-360.0
1612 IF (PHI,LT.-180.) PHI=PHI+360.0
1613 Y=(CON*PHI)*RAY
1614 Y=-YA*SING+YA*COSG+ZA*SING
1615 IF (ABS(Y/VL), LT, 1.0) GO TO 70
1616 DPT1=0.0
1617 GO TO 75
1618 70 BASE=Y*A*SING-2A*COSG*COSB
1619 RAD=(Y*A*COSB+YA*SINB)+8+(-YA*SBSG+YA*CBSG-2A*COSG)*2-1.0
1620 IF (RAD.GT.670.0) RAD=670.0
1621c DPT1 IS THE PRESSURE FLUCTUATION AT PROBE AR(J) AND ANGLOC(J I).
1622c
1623c DPT1=2.0*VBAR*BASE/EXP(0.5*RAD)
1624 75 P(J, I)=PS(J, I)+DPT1*GPT1*TMAR66
1625 80 CONTINUE
1626 70 GO TO 90
1627 80 CONTINUE
1628c RESET STATIC PRESSURE RINGS TO STATIC PRESSURE.
1629c
1630c
1631 DO 79 I=1, NP
1632 79 P(J, I)=PS(J, I)
1633 90 CONTINUE
1634 IF (IY-1) 91,91,92
1635 91 CALL PFIX (.TRUE.,)
1636   CALL DISTRT
1637   GO TO 600
1638  92   CALL PRINT(2)
1639   CALL PFIXX(TRUE.)
1640   CALL DISTRT
1641   CALL PFIXX(FALSE.)
1642   CALL MAINLP
1643   CALL LNOUT(1)
1644   WRITE (6,1995)
1645   WRITE (6,2000) YBAR,ART,GB,HYRT,VL,RRT,TV
1646   WRITE (6,1999) VBM,VBC,A0
1647   CALL LNOUT(2)
1648   WRITE (6,1805)
1649  600   CONTINUE
1650c
1651   RETURN
1652c
1653  1800   FORMAT (/27X,"<STEADY-STATE DISTORTION>")
1654  1805   FORMAT (/31X,"<PEAK DISTORTION>")
1655  1995   FORMAT (/25X,1SHVORTEX LOCATION)
1656  1996   FORMAT (/25X,17HVGORTEX PROPERTIES)
1657  1998   FORMAT (/12X,4HTHNN,3X,4HRKNN,4X,4HTHMX,3X,4HRKMX,4X,3DTHX,3X,
1658       5X,2HA1,6X,2H61,8X,2H8F,2,4X,F7.2,F7.2,F7.2,F7.2,F7.2,F7.2,F7.2)
1659  1999   FORMAT (/11X,4HBVMX,4X,3HBV0,3X5HA0/RT/8X,2F7.3,F8.4)
1660  2000   FORMAT (/10X,4HVAR,4X,4RA/RT,1X,5H2AM6,2X,4H2BETA,3X,5HAY/RT,
1661       5X,2HA1,4X,4RHT/RT,4X,5HTHETA/6X,2F8.3,2F8.3,2F8.3,2F8.3)
1662c
1663   END
1664c
1665c   ----------------------------------
SUBROUTINE TURBUL (PT1, RS1, NR1, NP1, U2, O2, PT2, XM0, PINO, RMSAG)

TURBULENCE PROGRAM
BY: YEN-SEN CHEN
(MAY 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 (C6 AND GE RESPECTIVELY).
SUBROUTINE INLEVEL IS USED TO CALCULATE VELOCITY GRADIENTS.
SUBROUTINE CUBIC IS USED TO DO THE CUBIC SPLINE INTERPOLATIONS.
SUBROUTINE TRIDIAG 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), P1(11,20), U(11,20), W(20), WE(20), MUR(20),
% RS1(20)
COMM /CUB/ NGP, NGP, NPW, NWP, NPR, NPR, RS(20), THA(20), DR(20), C1(20),
% C2(20), C3(20), THG
COMM /VELGR/ URG(80,80), URG(80,80), UTRG(80,80), UTTG(80,80),
% UUG(80,80), UG(80,80)
COMM /INIKE/ G(K(80,80), 6E(80,80), G(R(80), 6T(80), ERRK, ERRE
COMM /PARA/ PMU, NPR, NFP, NRF, NFG, NSHT, FACT

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

NGP=4
NGP=4
NSHT=30
FACT=1.0
AMU=1.75E-4
PI=3.141592654
NP=NR1
NP=NP1
DO 18 I=2, NR
1706-18  RS(I)=RS(I)
1707  RS(1)=0.0
1708  WRITE(6,400)
1709  400  FORMAT(2/1X,"TURBULENCE CALCULATIONS:")
1710  DO 10  I=2,NR
1711  DO 12  J=1,NP
1712  12  PT(I,J)=PT(I,J)
1713  10  CONTINUE
1714c  COMPUTE RING AVERAGE Pressures FOR ESTIMATING BOUNDARY CONDITIONS.
1715c
1717  SUM=0.0
1718  SUM5=0.0
1719  SUM7=0.0
1720  SUM1=0.0
1721  DO 20  J=1,NP
1722  SUM=SUM+PT(2,J)
1723  SUM5=SUM5+(PT0-PT(6,J))
1724  SUM7=SUM7+PT(7,J)
1725  SUM1=SUM1+2.0-PT(NR-2,J)-PT(NP-1,J)
1726  20  CONTINUE
1727  AVG=SUM/NP
1728  AVG5=SUM5/NP
1729  AVG7=SUM7/NP
1730  AVG1=SUM1/2.0/NP
1731  DO 30  J=1,NP
1732  PT(1,J)=AVG
1733  30  CONTINUE
1734c  NONDIMENSIONALIZE RADIAL COORDINATE AND GENERATE GRID POINTS.
1735c
1737  DO 40  I=2,NR-1
1738  RS(I)=RS(I)/RS(NP)
1739  DR(I-1)=(RS(I)-RS(I-1))/NGR
1740  DO 40  II=1,NGR
1741  L=(1-2)*NGR+11
1742  GP(L)=RS(I-1)+(II-1)*DR(I-1)
1743  40  CONTINUE
1744  THF=2.*PI/NP
1745  THG=THE/NGR
1746  NEW = (NR - 2) * NGP + 1
1747  NF = NF * NGP
1748  GF(NF) = RS(NR - 1)
1749  DO 50 J = 1, NF
1750  THA(J) = (J - 1) * THE
1751  DO 50 JJ = 1, NGP
1752  L = (J - 1) * NGP + JJ
1753  G(L) = THA(J) + (JJ - 1) * TH5
1754 50 CONTINUE
1755c  ESTIMATE BOUNDARY RMS LEVEL AND CALCULATE VELOCITY DISTRIBUTIONS.
1756c
1758c  DA = RS(NR) / 6.
1759c  RS(NR) = 1.0
1760  CK = 0.115 * (PTT0 - PT2) * (-0.2587)
1761  RED = U2 * DA / AMU
1762  YELR = 0.1275 * (ALD610 * RED) * (-2.5)
1763  AMUR = SORT(YELR) * U2 * DA / AMU / 2.
1764  PMU = 1.0 / AMUR
1765  CENK = 10.0
1766  CENE = 0.164 * CENK ** 1.5 / 0.12
1767  WRMS = CK * AV65
1768  IF(WRMS .LT. 0.01) THEN FACT = 0.7
1769  DO 5 J = 1, NF
1770  SUMP = 0.0
1771  DO 15 I = 1, NR - 1
1772  DENR = (PT(I, J) / PT7A) ** 0.714286
1773  P1 = PT(I, J) / DENR / PT7A
1774  P1 = 3.5 * P1 / 0.2 * YELR / PT2
1775  U(I, J) = SORT(ABS(P1))
1776  IF(P1 .LT. 0.0) U(I, J) = -U(I, J)
1777  IF(I .LT. NR - 2) GO TO 15
1778  SUMP = SUMP + (1.0 - PT(I, J))
1779 15 CONTINUE
1780  P2 = CK * SUMP / 2.0 / AV65
1781  P1 = 1.0 / 3.0 * U(NR - 1, J) ** 2
1782  P2 = 1.75 * WRMS / 0.2 * YELR / DENR
1783  W(I, J) = P1 + SORT(P1 * P1 + P2 * P2)
1784  U(NR, J) = 0.0
1785  WUP = -2.0 * U(NR - 1, J) / (1.0 + 0.5 * RS(NR - 1, J))
1785 5 CONTINUE
1786 WRITE(6,300)
1787 300 FORMAT(5X,'DIMENSIONLESS VELOCITY AT EACH PROBE LOCATION: ')
1788 DO 35 J=1,MP
1789 WRITE(6,500) (U(J,J),J=1,MP)
1790 500 FORMAT(1X,12F10.2)
1791 35 CONTINUE
1792 C1(1)=0.
1793
1794c SET INITIAL VALUES FOR TURBULENCE KINETIC ENERGY, GK.
1795c
1796c CALL CUBIC(NP,WK,THA,C1,C2,C3)
1797 CALL INITL(CENK,WK,6K)
1798
1799c CALCULATE THE RADIAL AND CIRCUMFERENTIAL VELOCITY GRADIENTS.
1800c
1801c CALL INIVEL(U,RS,THA,DR,THG,MPW,NRW,GR,GR,NP,NGR,NGF)
1802 DO 65 J=1,MP
1803 JNP=(J-1)*N6P+1
1804 ME(J)=0.3*WK(J)*SORT(UUG(NRW,JNP))
1805 65 CONTINUE
1806 C1(1)=0.
1807
1808c SET INITIAL VALUES FOR TURBULENT KINETIC ENERGY DISSIPATION RATE, GE.
1809c
1810c CALL CUBIC(NP,ME,THA,C1,C2,C3)
1811c CALL INITL(CENL,ME,GE)
1812 600 FORMAT(13X,'-------------------------------------------------------------')
1813 WRITE(6,200)
1814 200 FORMAT(7/5X,'ERRORS IN K, E AND (K+E) OF EACH ITERATION: ')
1815 UUM=UUG(1,1)
1816 DO 45 J=2,MPW
1817 IF(UUG(1,J).GT. UUM) UUM=UUG(1,J)
1818 45 CONTINUE
1819 DO 55 J=1,MPW
1820 UUG(1,J)=UUM
1821 55 CONTINUE
1822 MPW=MPW
1826  NFP=NP
1827  NFP=NP
1828c
1829c CALL FINITE SUBROUTINE TO SOLVE FOR THE TURBULENCE MODEL USING
1830c FINITE DIFFERENCE FORMULATIONS.
1831c
1832  CALL FINITE(UUG,DR,TH,G,NPW,NFW)
1833  CALL PRNT (8)
1834  WRITE(6,100)
1835  100 FORMAT('RESULTS OF TURBULENCE CALCULATIONS:'))
1836  WRITE(6,800)
1837  800 FORMAT('PROBE',5X,'UUG',10X,'E',11X,'K',9X,'S6/PT2')
1838c
1839c COMPUTE RMS LEVEL AT EACH PROBE.
1840c
1841  SUMF=0.0
1842  DO 60 J=1,NP
1843       JK=(J-1)N5F+1
1844  DO 60 1=1,NER+2
1845       IL=I(1)*N5R+1
1846       TK=6E(11,J)
1847       TE=6E(11,J)
1848       TUU=UUG(11,J)
1849       TU=U(I+1,J)
1850  TR=R$(I+1)
1851  NT=(J-1+2)+I
1852  DERM=(PT(1)+J/PTZ)+0.714286
1853  PRO=0.09*TK*TK*TUU/TE
1854  P0=2.73
1855  P2=P0+TU*TU
1856  RMS=PI*SQRT(P2*TK*TK*TK)
1857  SUMF=SUMF+RMS**2
1858  WRITE(6,700) NT,TUU,TE,TK,RMS
1859  700 FORMAT(11X,'SUMF=NT')
1860  CONTINUE
1861  END
1862  RETURN
1863  END
SUBROUTINE INITL(CE, WA, GA)

THIS SUBROUTINE GIVES THE INITIAL VALUES OF Gk AND GE.

DIMENSION WA(20), GA(80,20)
COMMON /CUB/ NGR, NGP, NPW, NR, NP, RS(20), THA(20), DR(20), C1(20),
               C2(20), C3(20), TH6

DO 1 J=1, NP
DO 1 I=1, NGP
JJ= (J-1) * NGP + I
T1=THA(J) + (I-1) * TH6
P1=T1-THA(J)
GA(NPW,JJ)= (C1(J) * P1+C2(J)) * P1+C3(J) ) * P1+WA(J)
1 CONTINUE

DO 2 J=1, NP
DA= (GA(NPW,J) - CE) / RS(NR-1)
DO 2 I=1, NP-2
DO 2 K=1, NGR
KK= (I-1) * NGR + K
R1=RS(I) + (K-1) * DR(I)
GA(KK,J) = CE + R1 * DA
2 CONTINUE
RETURN
END
SUBROUTINE IMVEL (UR, T, TR, T5, NFW, NFW, MUR, GR, NR, NP, N6R, N6P)

THIS SUBROUTINE COMPUTES THE RADIAL AND CIRCUMFERENTIAL VELOCITY GRADIENTS AT EACH GRID POINT USING CUBIC SPLINE INTERPOLATIONS.

DIMENSION U(11,20), R(20), T(20), C1(60), C2(60), C3(60), A(60), DR(20),
MUR(20), MUR5(80), RA(60), GR(NRW)

COMMON /VELGR/, URG(80,80), URRG(80,80), UTRG(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)
1 CONTINUE
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 CONTINUE
DO 3 J=1, NP
DO 3 K=1, N6P
KK=(J-1)*N6P+K
UG1+KK)=U1+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=MFW/2
MP=MFW/NP-1
DO 5 J=1, MP
5 J=NP+J
<table>
<thead>
<tr>
<th>Line</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1934</td>
<td>DO 6 I=1,MR</td>
</tr>
<tr>
<td>1935</td>
<td>IF ( I &gt; NR ), GO TO 8</td>
</tr>
<tr>
<td>1936</td>
<td>IF ( I = 0 ), GO TO 7</td>
</tr>
<tr>
<td>1937</td>
<td>II = (NR-I) * NGR+1</td>
</tr>
<tr>
<td>1938</td>
<td>A(I) = U6(I, J)</td>
</tr>
<tr>
<td>1939</td>
<td>PA(I) = R(NR-I+1)</td>
</tr>
<tr>
<td>1940</td>
<td>GO TO 6</td>
</tr>
<tr>
<td>1941</td>
<td>7</td>
</tr>
<tr>
<td>1942</td>
<td>C1(I) = 999</td>
</tr>
<tr>
<td>1943</td>
<td>C1(I) = UGR6(J, D)</td>
</tr>
<tr>
<td>1944</td>
<td>A(I) = 0</td>
</tr>
<tr>
<td>1945</td>
<td>PA(I) = R(NR)</td>
</tr>
<tr>
<td>1946</td>
<td>GO TO 6</td>
</tr>
<tr>
<td>1947</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>1948</td>
<td>IF ( I = 0 ), GO TO 9</td>
</tr>
<tr>
<td>1949</td>
<td>II = (I-NR) * NGR+1</td>
</tr>
<tr>
<td>1950</td>
<td>A(I) = U6(I, J)</td>
</tr>
<tr>
<td>1951</td>
<td>PA(I) = R(I-NR+1)</td>
</tr>
<tr>
<td>1952</td>
<td>GO TO 6</td>
</tr>
<tr>
<td>1953</td>
<td>C1(I) = UGR6(J, D)</td>
</tr>
<tr>
<td>1954</td>
<td>A(I) = 0</td>
</tr>
<tr>
<td>1955</td>
<td>PA(I) = R(NR)</td>
</tr>
<tr>
<td>1956</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>1957</td>
<td>CALL CUBIC(MP, A, PA, C1, C2, C3)</td>
</tr>
<tr>
<td>1958</td>
<td>DO 11 1=2, MR-1</td>
</tr>
<tr>
<td>1959</td>
<td>IF ( I &gt; 6T ), GO TO 12</td>
</tr>
<tr>
<td>1960</td>
<td>DO 13 K=1, NGR</td>
</tr>
<tr>
<td>1961</td>
<td>II = (MR-I) * NGR+2-K</td>
</tr>
<tr>
<td>1962</td>
<td>K=NR-I</td>
</tr>
<tr>
<td>1963</td>
<td>F1 = -(K-1) * DR(1K)</td>
</tr>
<tr>
<td>1964</td>
<td>U6(I, J) = (C1(I) + R1 + C2(I)) * (R1 + C3(I)) * (R1 + A(I))</td>
</tr>
<tr>
<td>1966</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>1967</td>
<td>DO 11 11</td>
</tr>
<tr>
<td>1968</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>1969</td>
<td>DO 22 K=1, NGR</td>
</tr>
<tr>
<td>1970</td>
<td>II = (I-NR) * NGR+K</td>
</tr>
<tr>
<td>1971</td>
<td>K=I-NR+1</td>
</tr>
<tr>
<td>1972</td>
<td>F1 = -(K-1) * DR(1K)</td>
</tr>
<tr>
<td>1973</td>
<td>U6(I, J) = (C1(I) + R1 + C2(I)) * (R1 + C3(I)) * (R1 + A(I))</td>
</tr>
</tbody>
</table>
1974 \[ \text{URF}_6(i, j) = - (c_3 \cdot c_1(i) \cdot R1 + 2 \cdot c_2(i) \cdot R1 + c_3(i)) \]
1975 \[ \text{URF}_6(i, j) = 6 \cdot c_1(i) \cdot R1 + 2 \cdot c_2(i) \]
1976 22 CONTINUE
1977 11 CONTINUE
1978 \[ UG(1, 1) = UG(1, j) \]
1979 \[ URG(1, 1) = - URG(1, j) \]
1980 \[ UPRG(1, 1) = UPRG(1, j) \]
1981 5 CONTINUE
1982 DO 14 J = 1, NFW
1983 \[ UT6(i, j) = 0. \]
1984 \[ UTGT(i, j) = 0. \]
1985 DO 14 I = 2, NFW
1986 IF(J.EQ. 1) GO TO 15
1987 IF(J.EQ. NFW) GO TO 16
1988 \[ B = UG(i, j - 1) \]
1989 \[ D = UG(i, j + 1) \]
1990 GO TO 17
1991 15 B = UG(i, NFW)
1992 \[ D = UG(i, 2) \]
1993 GO TO 17
1994 16 B = UG(i, NFW - 1)
1995 \[ D = UG(i, 1) \]
1996 17 \[ UT6(i, j) = (D - B) / 2 \cdot TG6(i) \]
1997 \[ UTGT(i, j) = (D + B - 2 \cdot UG(i, j)) / TG6(i) \]
1998 14 CONTINUE
1999 DO 20 J = 1, NFW
2000 \[ D = 20 I = 1, NFW \]
2001 \[ UG(i, j) = URF6(i, j) \cdot \cdot \cdot 2 + UT6(i, j) \cdot \cdot \cdot 2 \]
2002 20 CONTINUE
2003 RETURN
2004 END
SUBROUTINE CUBIC(N,Y,X,C1,C2,C3)

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

DO 5 I=1,N-1

6(I)=Y(I+1)-Y(I)

H(I)=X(I+1)-X(I)

5 S(I)=SORT(G(I)/Y(3))**2+H(I)**2

H(N)=1.

IF(C1(I) .NE. 0.) 60 TO 7

6(N)=Y(1)-Y(N)

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=6*(I-1)*S(I)/H(I-1)

P2=6*I*S(I-1)/H(I)

R(I)=(P1+P2)/(S(I)+S(I-1))

60 TO 10

1 CONTINUE

P1=6*(N)*S(1)/H(N)

P2=6*N*S(N)/H(N)

B(N)=(P1+P2)/(S(1)+S(N))

IF(C1(1) .EQ. 999.) B(1)=C1(2)

60 TO 10

2 CONTINUE

P1=6*(N-1)*S(N)/H(N-1)

P2=6*(N-1)*S(N-1)/H(N-1)

B(N)=(P1+P2)/(S(N)+S(N-1))

IF(C1(N) .EQ. 999.) B(N)=C1(N)

10 CONTINUE

B(N+1)=B(1)

M=N-1

IF(C1(1) .EQ. 0.) M=N

M=0

50 DO 1=1,M

P1=H(1)*H(1)
C1(I) = (E(I)+E(I+1))/P1-2.*G(I)/P1/H(I)
C2(I) = -(2.*E(I)+E(I+1))/H(I)+3.*G(I)/P1
C3(I) = B(I)
CONTINUE
RETURN
END
--------------------
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

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

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

CONTINUE

RETURN

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

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),
X: (160), YKEFF (80, 80), DRG (80), AI (160), BI (160), CL (160), SL (160), F1 (160)

COMMON / PARA/ PMU, NFR, NPP, NPG, NG, NSHT, FACT
COMMON / INIKE/ G1, S0, S0, G0, G0, 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, NPP - 2
DO 2 J = 1, NPM

DRG (KK) = PDR
CONTINUE

DO 1 I = 1, NPP
DO 2 J = 1, NPM

YKEFF (I, J) = 0.09 * 6K (I, J) ** 2 / GE (I, J) + PMU
CONTINUE

MP = NPM / 2
MP = 8 * NPW - 1
NN = MP - 2

START ITERATIONS.

CONTINUE

ERPK = 0.0
ERPE = 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. NM-1) GO TO 5
II=NM-1
J=J
K=1
L1=0
L2=1
JP=JJ-1
JO=JJ+1
IF (J .EQ. 0) JP=NM
GO TO 6
5 CONTINUE
II=1-NM+2
JJ=J+MP
K=-1
L1=1
L2=0
JP=JJ-1
JO=JJ+1
IF (J .EQ. MP) JO=1
6 CONTINUE
10=II
GPA=6P(I1)
GB=6R(I1+K)
GPA=6P(I1-K)
TH50=TH6
IF (I .NE. NM-1) GO TO 12
GPA=1.0
GB=1.0
GPA=1.0
TH50=6P6(I1)
10=2
JP=JJ+MP+MP/2
JO=JJ+MP/2
IF (JP .GT. NM) JP=JP-NM
12 CONTINUE
P1=GPA*VMEFF(I1,JJ)+GB*VMEFF(I1+K,JJ)
P2=GPA*VMEFF(I1-K,JJ)+GB*VMEFF(I1,JJ)
P3=VMEFF(I1,JJ)+VMEFF(10,JP)
P4 = VMEFF(I0, J0) + VMEFF(I1, J0)
P5 = (P3 + P4) / PP
K = -6K(I0, J0) + P4 + 6K(I0, J0) + P3) / PP
C6 = -6E(I0, J0) + P4 + 6E(I0, J0) + P3) / PP
17 CONTINUE
OR1 = OR6(I1-L1)
OR2 = OR6(I1-L2)
IF(I1 .EQ. 0, NMW-1) OR2 = OR1
OR = (OR1 + OR2) * OR0
O1 = OR1 * OR
O2 = OR2 * OR
O3 = OR2 * OR
AP = P1 / O1
AH = -(OR1 * P2 + OR2 * P1) / (O2 + P5)
A0 = P2 / O3
FK = GE(I1, JJ) - VMEFF(I1, JJ) * UU(I1, JJ) / GK(I1, JJ)
FE = CE2 * GE(I1, JJ) - CE1 * VMEFF(I1, JJ) * UU(I1, JJ) / GK(I1, JJ)
B(I) = AP / SIGK
C(I) = AH / SIGK
D(I) = CK / SIGK
IF(I1, E0, 1) F(I) = F(I) - B(I) * G(EI+1, JJ)
IF(I1, E0, NM) F(I) = F(I) - C(I) * G(EI+1, JJ)
B(I) = AP / SIG6
C(I) = AH / SIG6
D(I) = CE / SIG6
IF(I1, E0, 1) F1(I) = F1(I) - B1(I) * G(EI+1, JJ)
IF(I1, E0, NM) F1(I) = F1(I) - C1(I) * G(EI+1, JJ)
7 CONTINUE
SOLVE FOR TRIDIAGONAL MATRIX EQUATIONS OF K AND E (XK AND XE),
CALL TRIDIA(NM, AH, B, C, F, XK)
CALL TRIDIA(NM, AH, B1, C1, F1, XE)
TO 8 I = 1, NM
IF(I .LT. NMW-1) GO TO 9
I = NMW-1
2199    JJ=J
2200    GO TO 10
2201 9   CONTINUE
2202    JJ=1-MF+4+2
2203    JJ=J+MP
2204 10   CONTINUE
2205c
2206c   COMPUTE RELATIVE ERRORS.
2207c
2208 ERRK=ERRK+ABS(XK(I)-6K(I,J,J)) * 100. / 6K(I,J,J)
2209 ERRF=ERRF+ABS(XE(I)-6E(I,J,J)) * 100. / 6E(I,J,J)
2210 IF(XK(I) .LT. 0.0001) XK(I)=0.0001
2211 IF(XE(I) .LT. 0.0001) XE(I)=0.0001
2212c
2213c   OBTAIN UP-DATED SOLUTIONS WITH RELAXATION FACTOR, FACT.
2214c
2215 6K(I,J,J)=6K(I,J,J)+FACT*XK(I)-6K(I,J,J)
2216 6E(I,J,J)=6E(I,J,J)+FACT*XE(I)-6E(I,J,J)
2217 VMEFF(I,J,J)=0.09*XK(I) * XE(I) + PMU
2218 8   CONTINUE
2219 100  FORMAT(9X,3F15.5)
2220 3   CONTINUE
2221 ERRK=ERRK/MM/MP
2222 ERRF=ERRF/MM/MP
2223 ERRT=ERRK+ERRF
2224 WRITE(6,100) ERRK,ERRF,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 ANGLOC(J,I)

DO(1=1,3,3)

P(J,I)=P(S(J,I)+DPT1*QPT+TMAVGG

CONTINUE

GO TO 90

RESET STATIC PRESSURE RINGS TO STATIC PRESSURE.

DU 79 I=1,MP

P(J,I)=P(S(J,I))

CONTINUE

*** NEW "SEGMENTED" VORTEX METHOD BY STEPHEN P. DF. NON ***

NEW

DO 125 I=1,MP

DOP(I)=0.

DU 110 J=1,lR

DP(J,I)=ABS(TMAVGG-P:S(J,I))

IF (DOP(J,I) .LE. DOP(I)) GO TO 100

GU TO 110

DU 100 DOP(I)=UP(J,I)

RADLOC(I)=RADLOC(J)

CONTINUE

120 CONTINUE

SOLVE FOR NEW PEAK INSTANTANEOUS PRESSURE APROX

DU 140 I=1,MP

DU 130 J=1,lR

IF (I .LT. J1 OR J .GT. J2) GU TO 125

DRR=ABS(RADLOC(I)-RADLOC(J))

RHA=DRR/RI/ARF

RAD=RAD**2-1.

DPT1=ABS(2.*VRAR*PHX*QPT*TMAVGG/EXP(.5*RAU))

IF (P(S(J,I) .LE. TMAVGG)) GO TO 121

P(J,I)=P(S(J,I))+DPT1

GO TO 130

121 P(J,I)=P(S(J,I))-DPT1

GO TO 130

125 P(J,I)=P(S(J,I))

CONTINUE

140 CONTINUE

150 CONTINUE

CALL PFIX(.TRUE.)

CALL DISTR

GU TO 800

CALL PRT(2)

CALL PFIX(.TRUE.)

CALL DISTR

CALL HFIX(.FALSE.)

CALL MAINLP

CALL LNPOT(I)

WRITE (9,1995)

WRITE (9,2000) VRAR,ART,G,B,AYRT,VL,RRT,TV

WRITE (9,1999) VRM,VR0,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 convec-
ting 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 main-
frame 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 pre-defined 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>RAOLOC</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>
<tr>
<td></td>
<td></td>
<td>KD = 1: KTHETA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: KD2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: IDC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4: IDR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5: KRA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6: KA2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7: DSPR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8: ID</td>
</tr>
</tbody>
</table>
Data * Format Definition

T  * F10.5  RMS fluctuation measurement time-on-point default = 1 sec.
FO  * 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
MO  * 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
RKP  * 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>
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<td>RADLOC(1)</td>
<td>RADLOC(2)</td>
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<td>ANGLOC(1)</td>
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<tr>
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</tr>
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<td></td>
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<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>
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<td>PS(1, 7)</td>
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<td>PS(NR, 4)</td>
<td>PS(NR, 7)</td>
</tr>
<tr>
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<td>PSI</td>
<td>MO</td>
</tr>
<tr>
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<td>NPAR1</td>
<td>RS</td>
</tr>
<tr>
<td>NPG</td>
<td>NPAR2</td>
<td>RS</td>
</tr>
<tr>
<td>O</td>
<td>O</td>
<td>O</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

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 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.

Page 4

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 dis-
tortion 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 DYNADEC. 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 desirable.

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 its 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 desirable 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


