(NASA-CR-176765) REVIEW AND EVALUATION OF RECENT DEVELOPMENTS IN MELIC INLET DYNAMIC FLOW DISTORTION PREDICTION AND COMPUTER PROGRAM DOCUMENTATION AND USER'S MANUAL (Kansas Univ. Center for Research, Inc.)

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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.

TABLE OF CONTENTS

LIST OF SYMBOLS

Symbols	Description
a	vortex core radius (fig. 5)
$\bar{a}$	mean vortex core size
dP_T	total pressure fluctuation
$dP_{T_{rms}}$	root mean square total pressure fluctuation
e	exponential e^x
erf	error function erf(x)
f	root mean square data cutoff filter frequency
k	distortion factor
$\bar{k}$	mean instantaneous distortion factor
k_{ss}	steady-state distortion factor
k_{max}	maximum instantaneous distortion factor
P	pressure
P_S	static pressure
P_T	total pressure
$P_{T_{ss}}$	steady-state total pressure
q	dynamic pressure, steady-state
r	radius from vortex centerline
rms	root mean square
r_p	radial location of probe
r_v	radial location of vortex core
U, U_2	steady-state inlet flow velocity

V	vortex induced velocity
V_T	tangential swirl velocity about vortex
$V_{T_{max}}$	vortex strength - maximum swirling velocity

Subscripts

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

Superscripts

-	mean value $\bar{x}$

Greek Symbols

β, γ	vortex orientation angles
α, β	angle of attack, sideslip angle
ρ	density
σ	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 accomodate 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).

B. The Minimum Dynamic Measurement Approach

One of the benefits of the Melick approach to dynamic distortion prediction is it's 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 desireable to minimise the number of dynamic probes used while retaining the accuracy of the results. Proper placement of a minimum number of dynamic probes is necessary in order to obtain an accurate representation of the average rms level, and the resulting peak dynamic distortion prediction.

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

Since it is preferred to remain on the conservative side in dynamic distortion prediction, that is it would be more desireable 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 desireable 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 desireable 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 useable 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 contributer to the pressure disturbances occurring on the rake associated with that vortex segment. It is assumed that each vortex segment affects the pressure only on the rake associated with it. The position of the vortex segment relative to it's associated rake is assumed to be at the probe nearest to the mean pressure line where it crosses the rake. The orientation of each vortex segment is assumed to be perpendicular to it's associated rake, and coplaner with the measurement plane. Each of these simplifying assumptions are illustrated in figure 4, and are discussed separately.

The first assumption involves the division of the nonlinear vortex into eight linear sub-vortices, or vortex segments. Traditionally, there are eight rakes mounted at 45 degree intervals around the measurement plane (fig. 7). Since all probes on a rake are affected by the induced flow velocity caused by the local vorticity, it makes sense to divide the probes into rake-groups, and to determine the dominant vortex activity associated with that group. 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 it's 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 distict sections: 1) the development of the most probable peak instantaneous distortion level; and 2) the generation of the peak instantaneous map. Since the present analysis is concerned primarily with the latter of these two sections, the first section will be presented only in summary form. Details on the derivation of the peak instantaneous distortion level may be found in reference 2.

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

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

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 independant 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:

$$P_T = P_{T_{ss}} + dP_T \qquad (2)$$

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:

$$P_{T_{ss}} = P_S + \tfrac{1}{2}\rho U^2 \qquad (3a)$$

$$P_T = P_S + \tfrac{1}{2}\rho(U + V_T)^2 \qquad (3b)$$

where: P_S is the static pressure

ρ is the flow density

U is the steady-state flow velocity

V_T is the vortex-induced velocity

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

$$dP_T = P_T - P_{T_{ss}} = \tfrac{1}{2}\rho(U + V_T)^2 - \tfrac{1}{2}\rho U^2$$

$$= \tfrac{1}{2}\rho(U^2 + 2UV_T + V_T^2 - U^2)$$

$$= q\left[\left(\frac{2V_T}{U}\right) + \left(\frac{V_T}{U}\right)^2\right] \doteq \frac{2qV_T}{U} \qquad (4)$$

Second order terms have been neglected for V_T much less than U.

Substituting (1) into (4), we obtain:

$$dP_T = \frac{2q}{Ua} V_{T_{max}} \, r \, e^{-\frac{1}{2}[(r/a)^2 - 1]} \tag{5}$$

Equation (5) represents the total pressure fluctuation level produced by the convection of an arbitrary vortex through the inlet duct in terms 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:

$$\left(\frac{dP_{T_{rms(f)}}}{dP_{T_{rms}}} \right)^2 = \text{erf}\left(7.98 \frac{f\bar{a}}{U}\right) \tag{6}$$

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)

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

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 be determined from them:

$$\bar{k} = f(P_{T_{ss}}, q, U, \bar{a}, V_{T_{max}}) \qquad (8)$$

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

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

$V_{T_{max}}$ is then determined, using equation (5):

$$V_{T_{max}} = \frac{U\bar{a}dPT}{2qr} e^{½[(r/a)^2 - 1]} \qquad (9)$$

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

$$V_{T_{max}} = ½ \frac{U}{q} dP_{T_{rms}} \qquad (10)$$

Equation (8) then becomes:

$$\bar{k} = f(P_{T_{ss}}, q, U, \bar{a}, dP_{T_{rms}}) \qquad (11)$$

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):

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

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

$$V_{T_{max/pk}} = V_{T_{max}} + f(k_{max} - \bar{k}) \qquad (13)$$

Once the most probable peak instantaneous distortion level and the value of VTmax has been determined, the value for the peak instantaneous total pressure can be determined:

$$P_{T_{pk}} = P_{T_{ss}} + dP_{T_{pk}} \qquad (14)$$

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

$$dP_{T_{pk}} = \frac{2q}{U\bar{a}} V_{T_{max/pk}} \; r \; e^{-\frac{1}{2}[(r/\bar{a})^2 - 1]} \qquad (15)$$

The only variable in equation (15) above is the radius, r. Using the simplifications and assumptions given in section 2.B., 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 $V = V_{T_{max/pk}}$):

$$P_{T_{pk}}(k,p) = P_{T_{ss}}(k,p) + \frac{2qV}{U\bar{a}} \, r(k,p) \; e^{-\frac{1}{2}[(r(k,p)/\bar{a})^2 - 1]} \qquad (16)$$

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:

$$r(k,p) = r_p(k,p) - r_v(k) \qquad (17)$$

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

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

A. Subsonic Inlet

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

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

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

B. Transonic Inlet

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

Comparisons of predicted and measured peak instantaneous distortion levels are given in Table 3 and Figures 14 and 15. Figure 16 shows mapping comparisons for steady-state, DYNADEC measured peak, Melick predicted peak, and the Modified Vortex predicted peak instantaneous distortion patterns. Good accuracy in predicting peak dynamic distortion levels is indicated for these test cases. The Melick method slightly overpredicts the peak distortion level, which is the desired affect.

The Modified Vortex approach again compares favorably with the Melick linear vortex approach. In examples where the original Melick approach yields poor predictions of the peak instantaneous distortion pattern, the modified approach produces superior results (fig. 16). In cases where the Melick approach produces good peak distortion maps, the modified approach produces comparable results.

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

C. Supersonic Inlet

Configurations for four 25% scale supersonic inlet ducts are shown in Figure 10. These inlet models include data for a variety of supersonic freestream Mach numbers, and angles of attack and yaw. There are thirteen test cases availabe 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 DYNADEC 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 disortion 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.

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6. Dennon, Stephen R., 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, University of Kansas Center for Research, Inc., 1986.

Table 1. Distortion Factor Definitions (Ref. 2)

Factor	Equation	Supplemental equations	Definitions
IDC_{max}	$IDC_{max} = \max\left[\frac{1}{2}(IDC_1+IDC_2),\ \frac{1}{2}(IDC_4+IDC_5)\right]$	$IDC_j = \dfrac{(\bar{p}_t)_j-(p_{t,min})_j}{\bar{p}_t}$	$(\bar{p}_t)_j$ = average total pressure for ring j $(p_{t,min})_j$ = minimum total pressure reading in ring j $\bar{p}_t$ = average total pressure at engine face
IDR_{max}	$IDR_{max} = \max(IDR_1, IDR_5)$	$IDR_j = \dfrac{\bar{p}_t - (\bar{p}_t)_j}{\bar{p}_t}$	
K_{D2}	$K_{D2} = \dfrac{\sum_{j=1}^{NR} \bar{\theta}_j(\Delta p_t/p_t)(OD/D_j)}{\sum_{j=1}^{NR}(OD/D_j)}$	$\dfrac{\Delta p_t}{p_t} = \dfrac{(\bar{p}_t)_j-(p_{t,min})_j}{(\bar{p}_t)_j} * 100$	$(\bar{p}_t)_j, (p_{t,min})_j$ = see above $\bar{\theta}_j$ = circumferential extent of largest continuous total pressure depression below $(\bar{p}_t)_j$, degrees D_j = diameter of ring j; NR = number of ring OD = outer duct diameter
K_θ	$K_\theta = \dfrac{\sum_{j=1}^{NR}(A1)_j(1/D_j)}{(\bar{q}/\bar{p}_t)\sum_{j=1}^{NR}(1/D_j)}$	$(A_1)_j = \left(\sqrt{a_1^2+b_1^2}\right)_j$ $(a_1)_j = \frac{1}{M}\left[\sum_{i=1}^{M}\frac{p_{ti}}{\bar{p}_t}\cos(\theta_i)\right]_j$ $(b_1)_j = \frac{1}{M}\left[\sum_{i=1}^{M}\frac{p_{ti}}{\bar{p}_t}\sin(\theta_i)\right]_j$ $\dfrac{\Delta p_{tj}}{\bar{p}_t} = \dfrac{(\bar{p}_t)_j}{\bar{p}_t} - \dfrac{(p_{t,base})_j}{\bar{p}_t}$	$\bar{p}_t, (\bar{p}_t)_j, D_j$ = see above $\bar{q}$ = average dynamic pressure at engine face M = number of rakes $(p_{ti})_j$ = individual total pressure; rake i, ring j θ = angular position of p_{ti} $\dfrac{(p_{t,base})_j}{\bar{p}_t}$ = base radial profile for ring j; set = 1 for all j b = radial distortion weighting factor=1.0
K_{RAD}	$K_{RAD} = \sum_{j=1}^{NR}\left\lvert\dfrac{\Delta p_{tj}}{\bar{p}_t}\right\rvert \dfrac{\bar{p}_t}{\bar{q}}\dfrac{1}{D_j}$		
K_{A2}	$K_{A2} = K_\theta + bK_{RAD}$		
$\frac{\Delta SPR}{Dist}$	$\dfrac{\Delta SPR}{Dist} = \dfrac{\Delta SPR}{\left[(\bar{p}_t - p_{t,min})/\bar{p}_t\right]} = f(k)$		$\bar{p}_t$ = see above $p_{t,min}$ = minimum total pressure at engine face k = compressor reduced frequency
ID	$ID = k_c(IDC)b + k_r(IDR)$		k_c = circumferential distortion sensitivity factor k_r = radial distortion sensitivity factor b = circumferential distortion weighting factor

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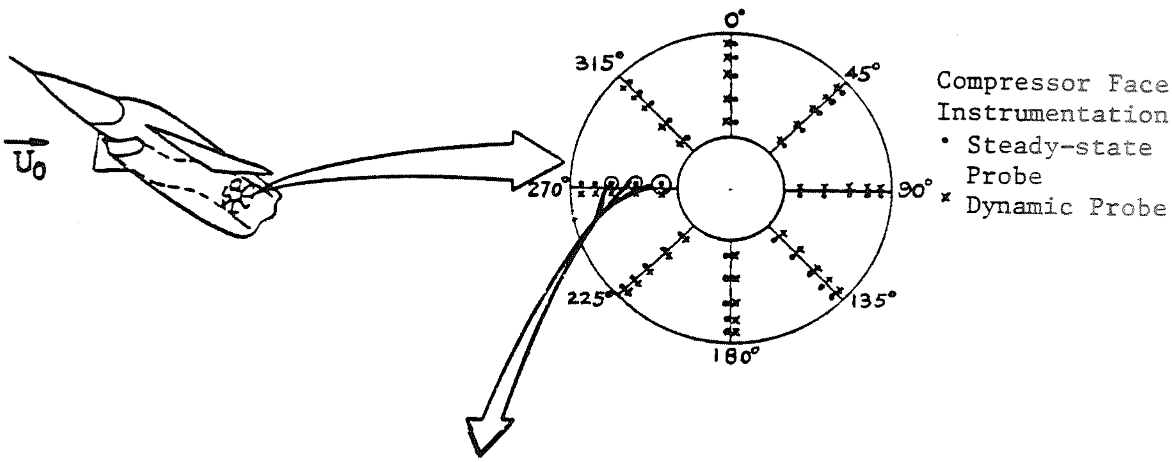


PRESSURE ARRAY

RADIUS	ANGULAR POSITION OF INPUT MEASUREMENTS, DEG 0.	45.0	90.0	135.0	180.0	225.0	270.0	315.0
2.225	0.841	0.851	0.864	0.827	0.774	0.852	0.927	0.876
3.070	0.844	0.867	0.913	0.843	0.770	0.869	0.977	0.894
3.725	0.837	0.869	0.939	0.844	0.759	0.873	1.007	0.901
4.280	0.829	0.858	0.928	0.824	0.741	0.854	0.999	0.890
4.775	0.815	0.830	0.873	0.790	0.722	0.818	0.958	0.864

DISTORTION FACTOR	STEADY STATE
KTTA	0.7298
KD2	856.3
IDC	0.0462
IDR	0.0120
KRA	0.1078
KA2	0.8088
DSPR	0.0324
ID	0.0320

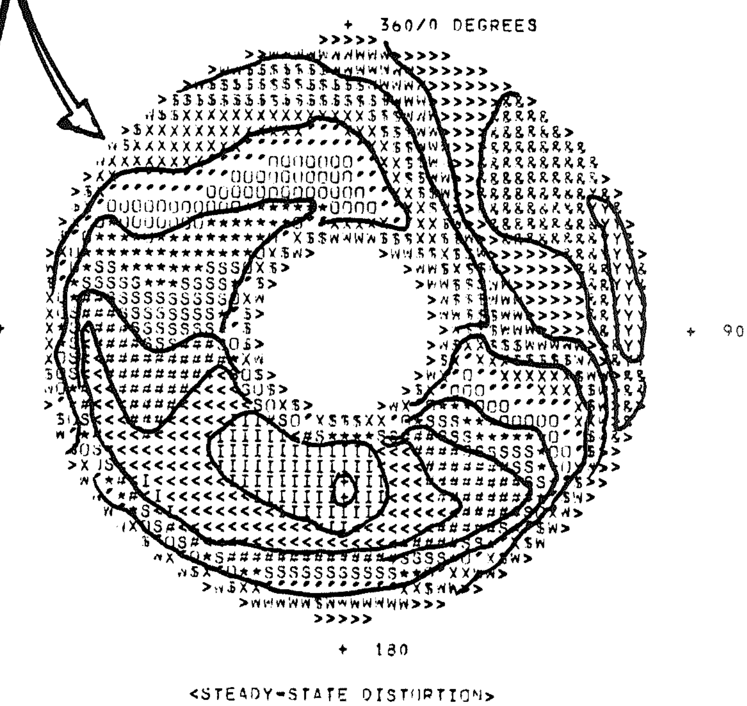


Figure 1. Determination of Steady-State Distortion

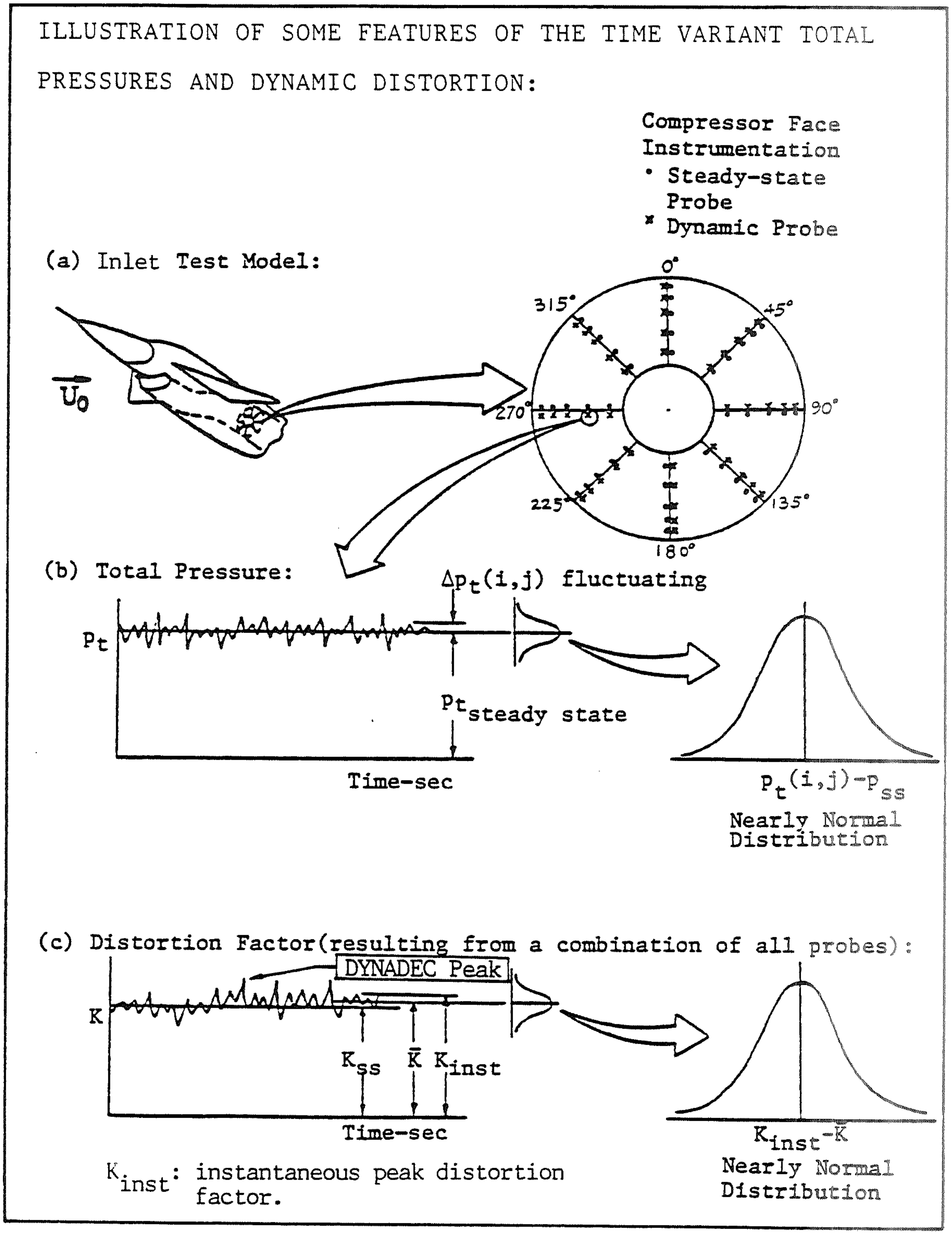
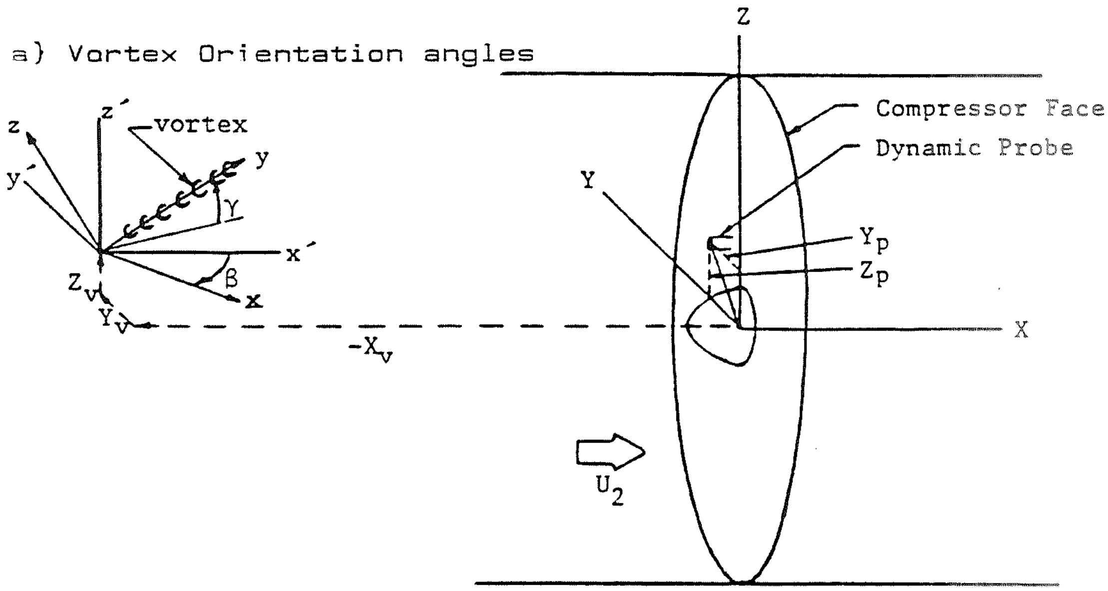


Figure 2. Illustration of a Typical Inlet Test Model and Peak Distortion Factor Measurement

a) Vortex Orientation angles



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

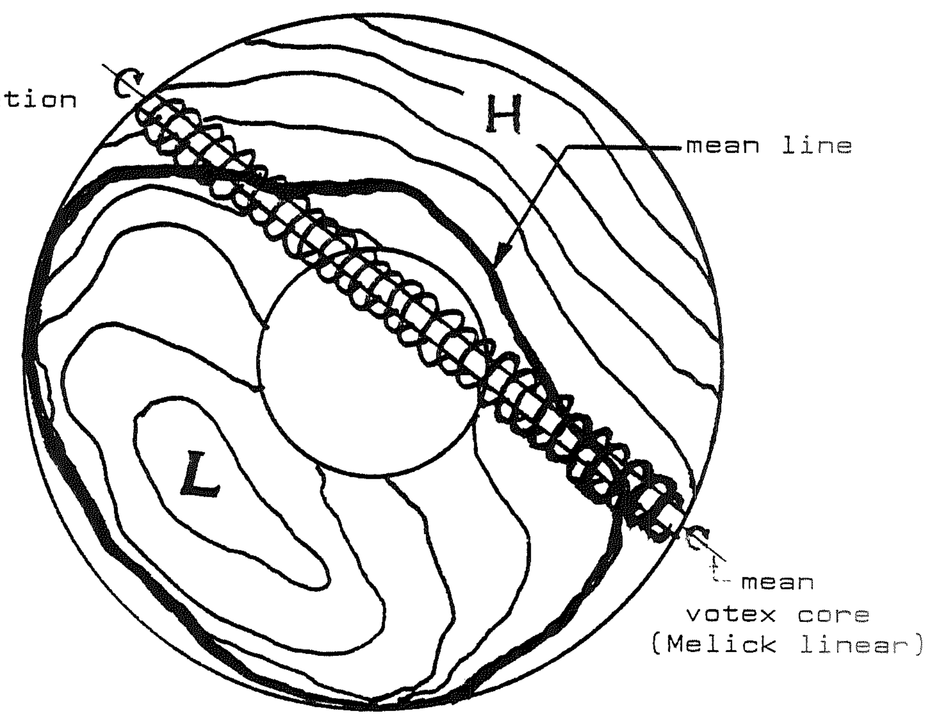


Figure 3. Melick Linear Vortex Model

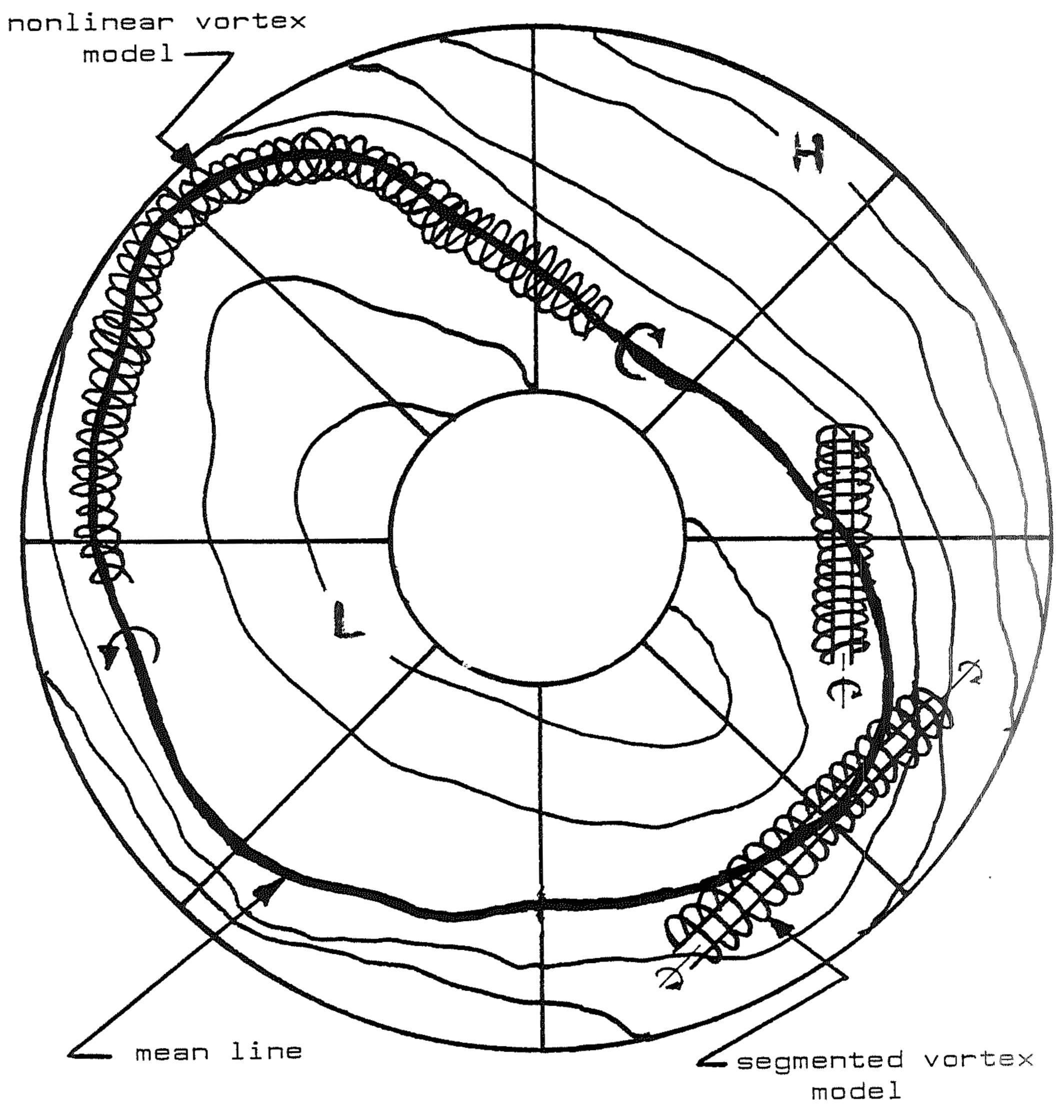


Figure 4. Nonlinear/Segmented Vortex Models

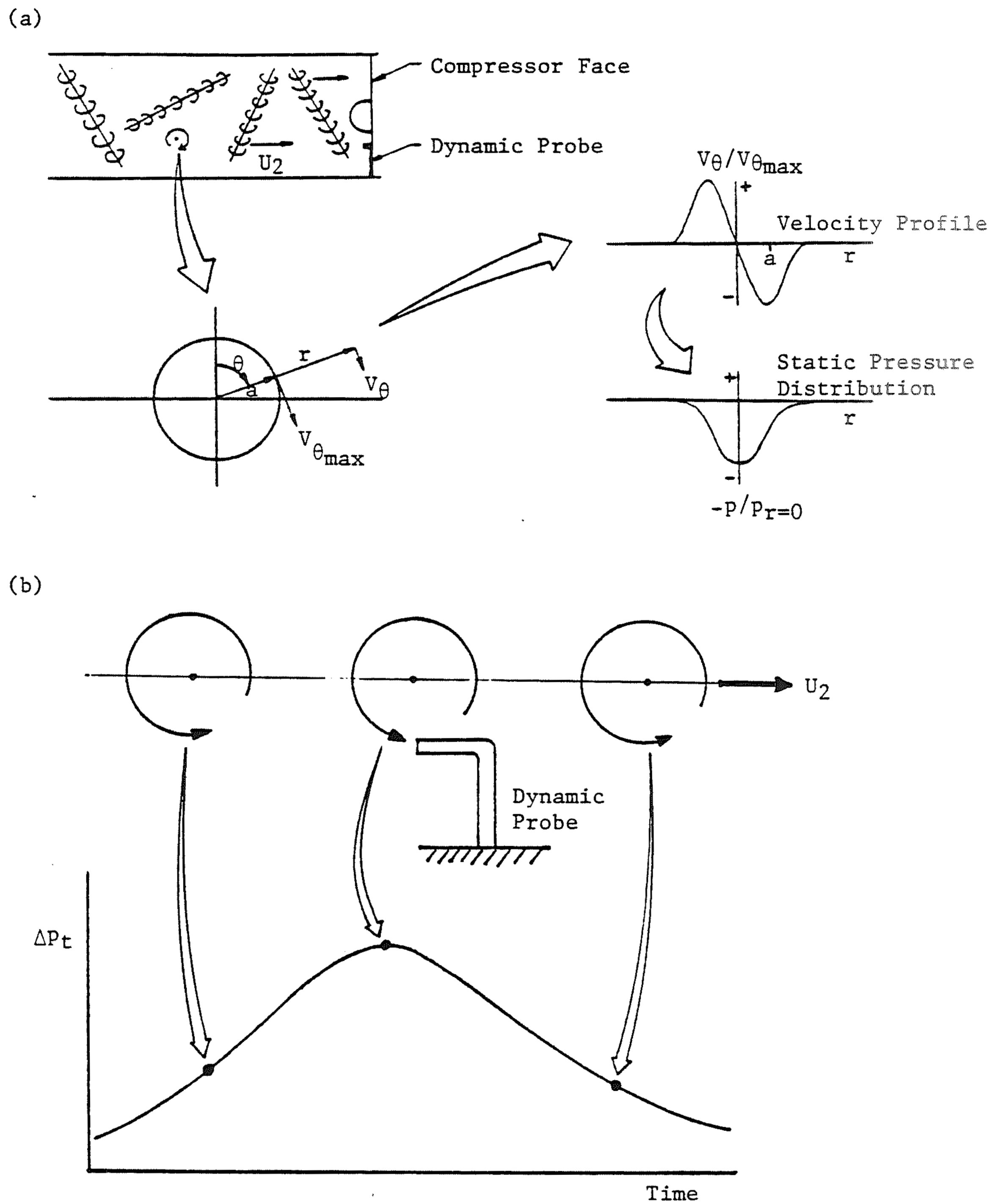


Figure 5. Inlet vortex flow model and perturbation of velocity and static pressure and the time variant total pressure fluctuation caused by a single 1-D vortex (Ref. 2)

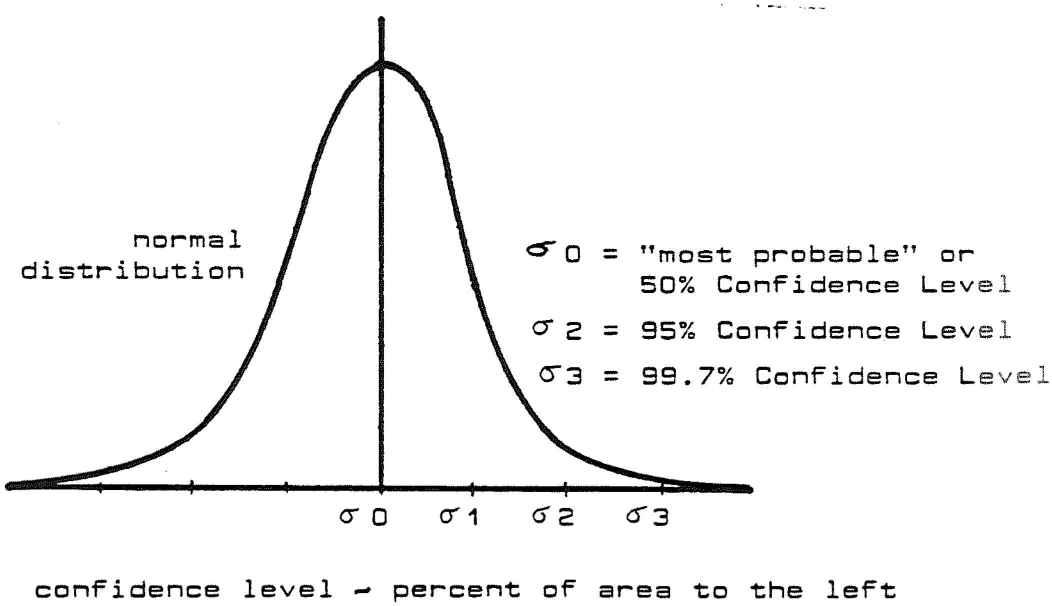
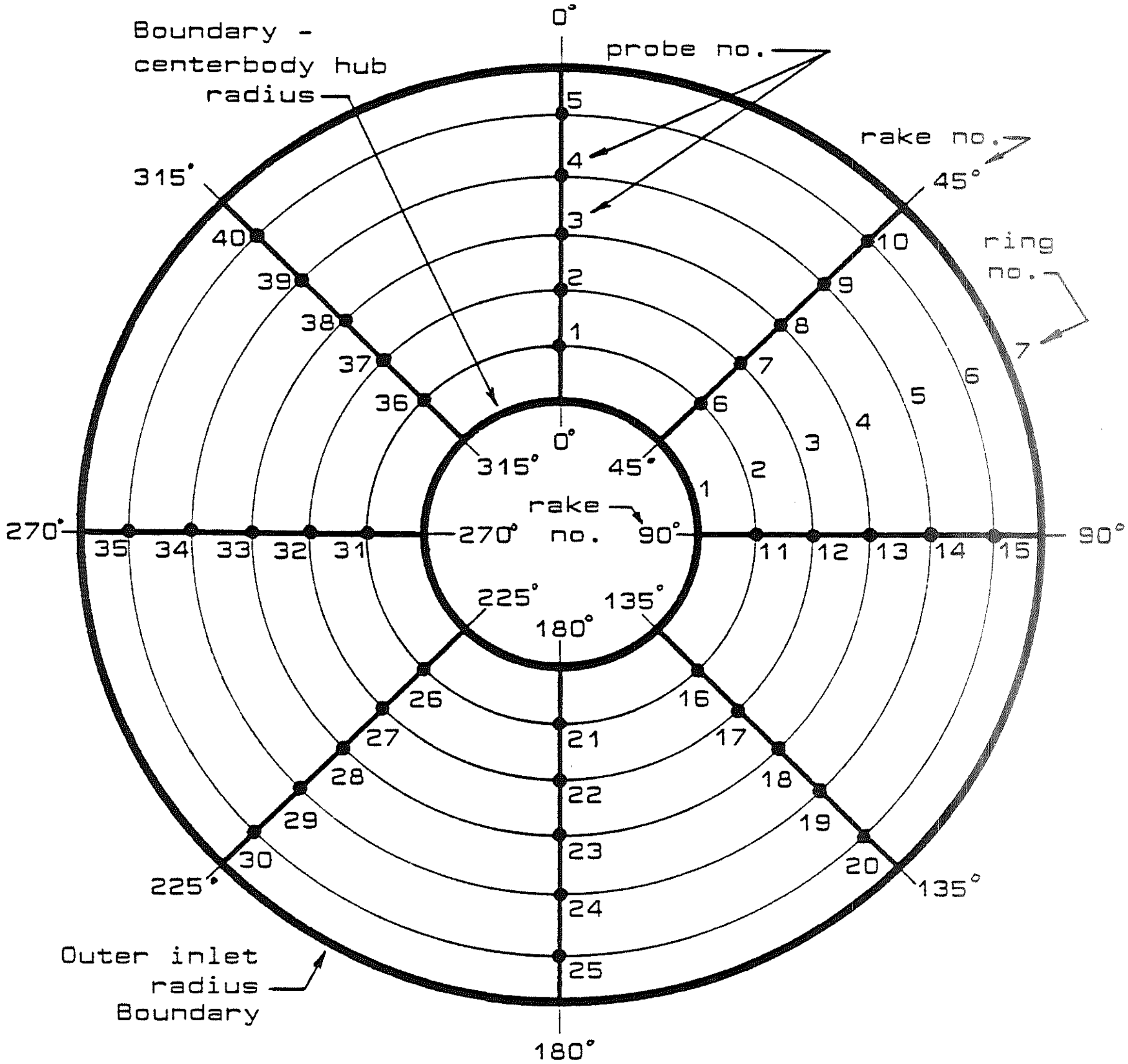
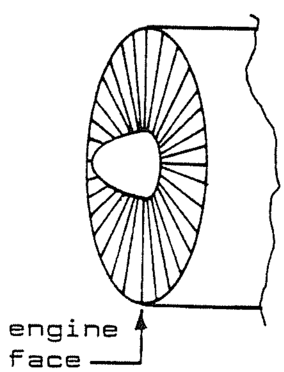


Figure 6. Definition of Confidence Levels

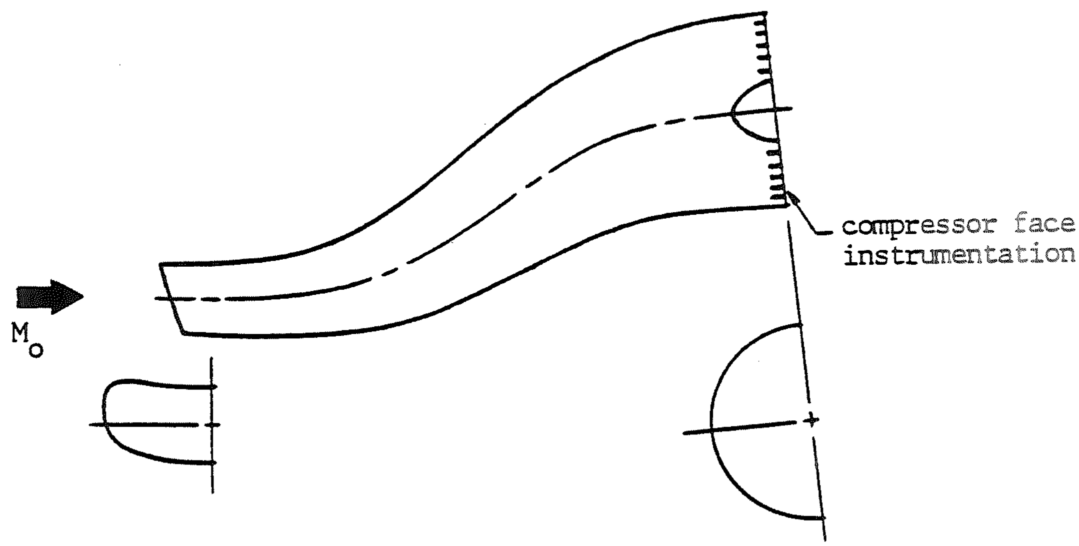




Note: NR = 7 = number of probe rings
NP = 8 = number of probe rakes

Figure 7. Ring, Rake, and Probe Assignments for a typical instrument configuration

(a) Subsonic Full Scale Inlet Model:

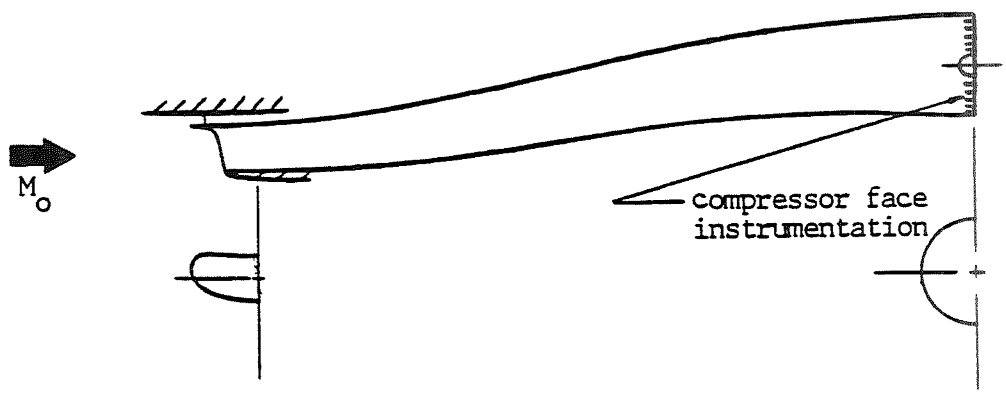


(b) Test Conditions and Some Measured Results:

Data pt.	Mach No.	P_{t2}	$\overline{rms}_m$	$IDC_{max, peak}$
20.40	subsonic	.887	.0336	.225
54.30	subsonic	.853	.0478	.326
81.40	subsonic	.925	.0337	.127
111.30	subsonic	.868	.0537	.319
112.30	subsonic	.873	.0475	.329
137.50	subsonic	.926	.0360	.144

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:

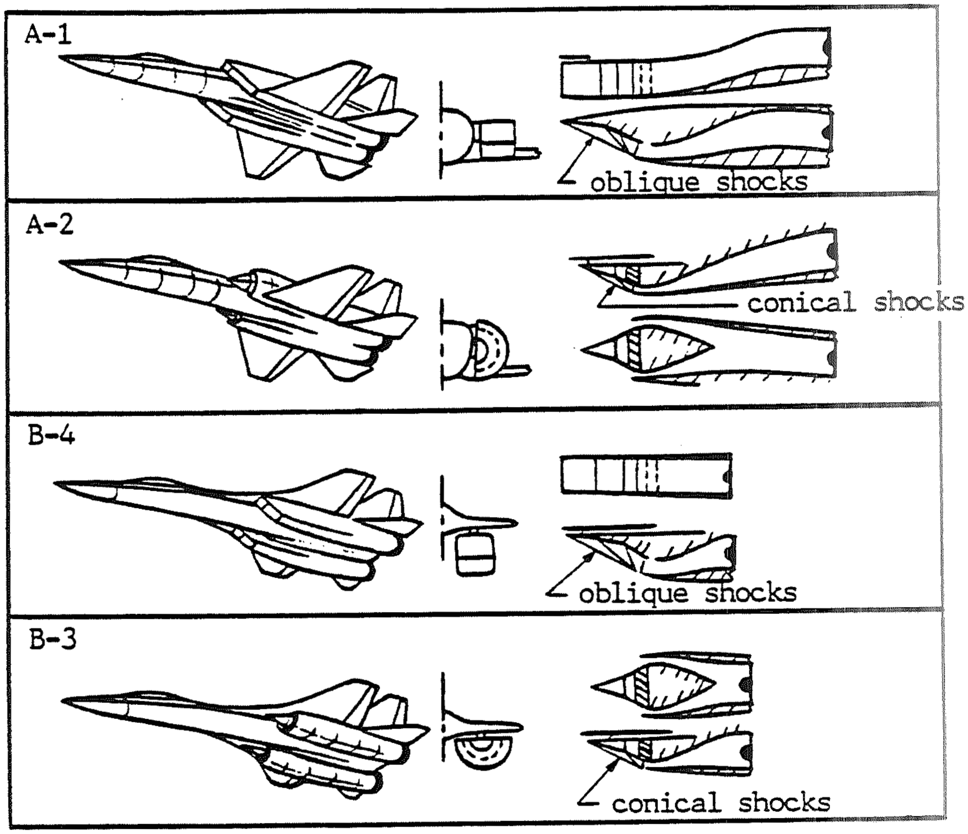


(b) Test Conditions and Some Measured Results:

Data pt.	Mach No.	P_{t2}	$\overline{rms}_m$	$K_{A2, peak}$
464.12	transonic	.860	.0422	.303
465.11	transonic	.912	.0281	.522
473.12	transonic	.928	.0217	.565
485.10	transonic	.891	.0414	.819
487.80	transonic	.857	.0493	1.025
498.12	transonic	.913	.0299	.777

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:



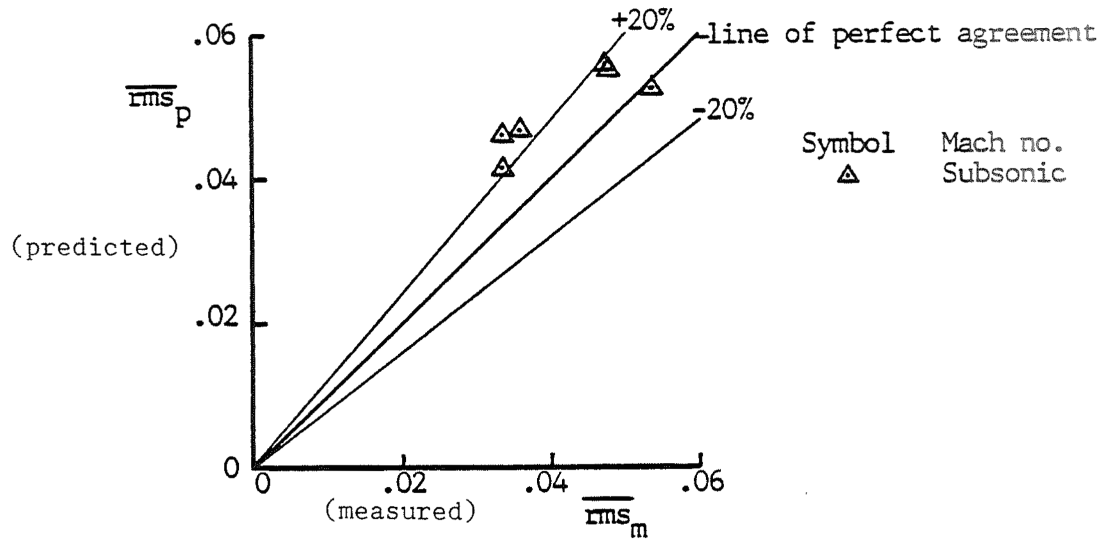
(b) Test Conditions and Some Measured Results:

Inlet	Data pt.	Mach No.	α	β	P_{t2}	IDC_{max}	$K_{A2,peak}$
A-1	182/1	2.2	5	4	.833	.150	1.384
	189/3	2.2	15	0	.829	.076	1.020
	216/3	1.6	10	4	.894	.086	.900
A-2	243/3	2.2	5	4	.768	.078	1.123
	246/3	2.2	15	0	.666	.111	1.446
	247/2	2.2	15	4	.579	.163	1.572
B-4	433/3	2.2	0	0	.814	.090	1.254
	437/3	2.2	5	0	.872	.125	1.511
	1554/4	0.9	20	8	.918	.074	.597
B-3	640/2	2.2	5	-4	.945	.092	.887
	643/3	2.2	15	0	.935	.078	.738
	695/1	1.65	0	-8	.845	.136	1.271
	1334/2	0.9	25	4	.933	.121	.649

Figure 10. Illustration of four Supersonic Inlet Test Model and some Test Results (ref. 3)

DISTORTION FACTOR	STEADY-STATE	DYNADEC PEAK	MELICK PREDICTED PEAK dynamic data input: FULL	MIN.	NONE
CASE# 20.40					
K-THETA	0.95777	1.48828	1.8486	2.0279	1.9826
KD2	1801.4	3534.1	2712.4	2840.9	2950.7
(IDC)-MAX	0.10759	0.22481	0.1728	0.1813	0.1893
(IDR)-MAX	0.06516	0.06645	0.0761	0.0773	0.0784
KRA	0.30434	0.30659	0.4362	0.4489	0.4689
KA2	1.18085	1.71301	2.0781	2.2580	2.2134
DSPR	0.05760	0.09058	0.1114	0.1221	0.1193
ID	1.26570	2.33132	1.6204	1.6600	1.7002
54.30					
K-THETA	1.19444	2.57046	2.2807	2.5317	2.6086
KD2	2740.2	3937.6	4258.7	4398.5	4620.5
(IDC)-MAX	0.23592	0.32522	0.3381	0.3393	0.3618
(IDR)-MAX	0.09032	0.09262	0.1083	0.1066	0.1117
KRA	0.35968	0.70330	0.5131	0.4885	0.5371
KA2	1.45809	3.08598	2.5518	2.8003	2.8848
DSPR	0.08654	0.11821	0.1644	0.1820	0.1875
ID	2.47579	3.37518	3.1583	3.1545	3.3007
81.40					
K-THETA	0.36337	0.72753	1.1293	1.3249	1.3619
KD2	819.7	1385.4	1864.3	2172.3	2325.0
(IDC)-MAX	0.09355	0.12868	0.1606	0.1787	0.1867
(IDR)-MAX	0.07916	0.08334	0.0901	0.0930	0.0942
KRA	0.40766	0.47655	0.5365	0.5692	0.5852
KA2	0.66219	1.07684	1.4626	1.6637	1.7047
DSPR	0.02406	0.04890	0.0703	0.0816	0.0835
ID	1.29662	1.55624	1.6183	1.7053	1.7424
111.30					
K-THETA	1.06535	1.46101	2.2481	2.0422	2.2327
KD2	2401.7	3728.9	4184.6	3862.5	4146.2
(IDC)-MAX	0.21749	0.31896	0.3373	0.3154	0.3345
(IDR)-MAX	0.08970	0.08782	0.1103	0.1069	0.1098
KRA	0.37629	0.39444	0.5505	0.5224	0.5464
KA2	1.34117	1.75014	2.5291	2.3261	2.5135
DSPR	0.07771	0.10564	0.1628	0.1483	0.1618
ID	2.30509	3.31415	3.0653	2.9376	3.0487
112.30					
K-THETA	0.98200	1.57512	2.0663	2.1201	2.2161
KD2	2142.5	3925.5	3719.7	3749.1	4014.4
(IDC)-MAX	0.18026	0.32641	0.2876	0.2899	0.3090
(IDR)-MAX	0.10505	0.09182	0.1232	0.1235	0.1263
KRA	0.47993	0.41299	0.6332	0.6340	0.6604
KA2	1.33379	1.87784	2.4178	2.4742	2.5783
DSPR	0.07275	0.11616	0.1505	0.1543	0.1610
ID	2.08990	3.41034	2.6794	2.6894	2.7835
137.50					
K-THETA	0.44035	0.72466	1.3124	1.5762	1.4732
KD2	946.7	1999.1	2083.2	2388.4	2444.1
(IDC)-MAX	0.09824	0.14375	0.1725	0.1908	0.1927
(IDR)-MAX	0.08502	0.10058	0.0971	0.1002	0.1002
KRA	0.46385	0.55000	0.6040	0.6355	0.6412
KA2	0.78035	1.12781	1.6853	1.9575	1.5590
DSPR	0.03022	0.04565	0.0838	0.0996	0.0929
ID	1.37968	1.80079	1.7336	1.8218	1.8296

Table 2. Subsonic Inlet Distortion Factor Comparison



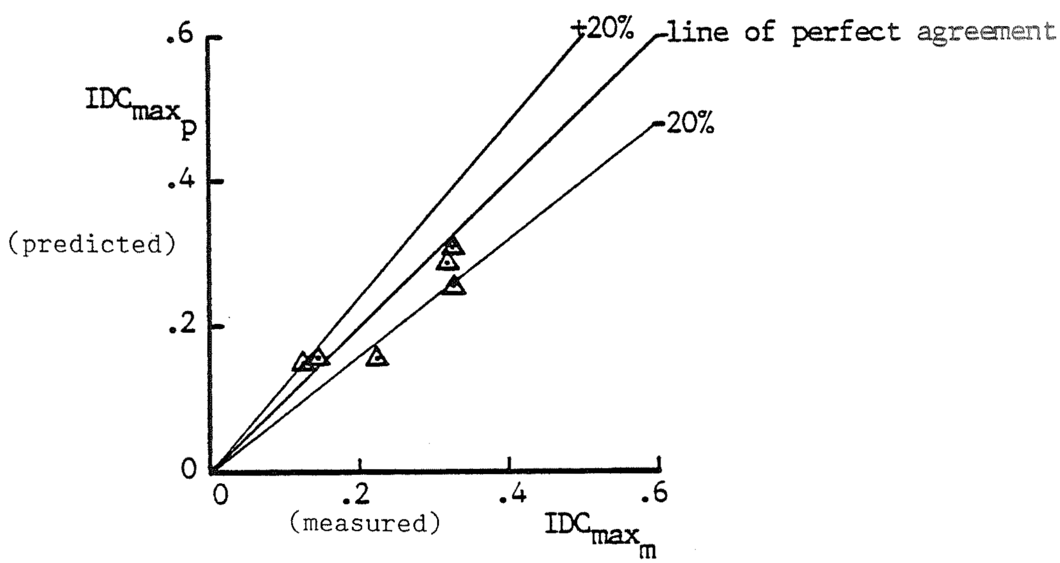


Figure 11. Comparisons of the Predicted and Measured rms Level and Peak Distortion Factor for the Subsonic Inlet Model shown in Figure 8. (unpublished data)

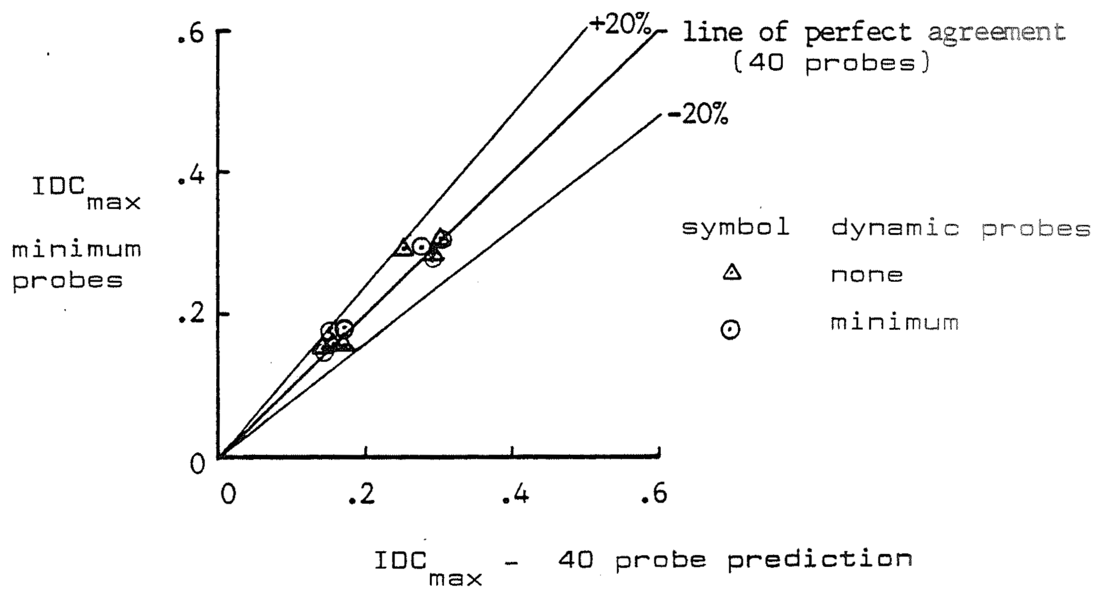
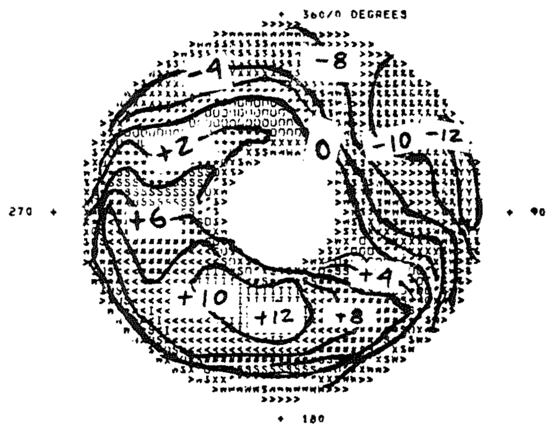


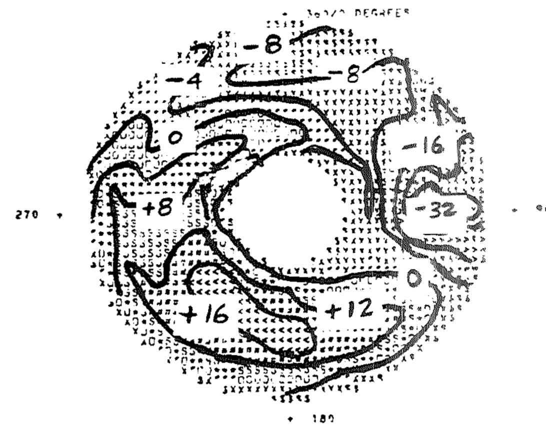
Figure 12. Comparisons of peak distortion factors predicted by the present analyses and the Melick method based on the total pressure rms measurements for the subsonic inlet data set (unpublished data)

(percent from average pressure)



K-THETA	0.95777
KD2	1801.4
(IDC)-MAX	0.10759
(IDR)-MAX	0.06516
KRA	0.30434
KA2	1.18085
DSPR	0.05760
ID	1.26570

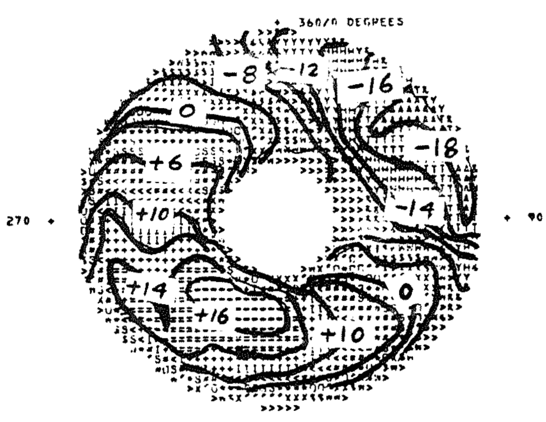
steady-state



K-THETA	1.48828
KD2	3534.1
(IDC)-MAX	0.22481
(IDR)-MAX	0.06645
KRA	0.30659
KA2	1.71301
DSPR	0.09058
ID	2.33132

DYNADEC peak

(percent from average pressure)



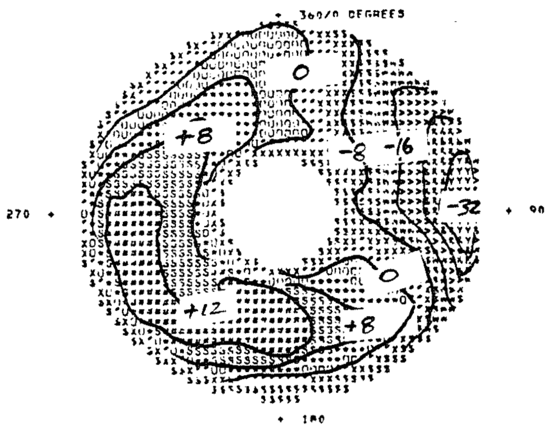
K-THETA	1.70557
KD2	2727.4
(IDC)-MAX	0.16782
(IDR)-MAX	0.06492
KRA	0.30434
KA2	1.92865
DSPR	0.10343
ID	1.56671

Melick model peak

K-THETA	1.59725
KD2	2920.7
(IDC)-MAX	0.16147
(IDR)-MAX	0.12464
KRA	0.65704
KA2	2.07886
DSPR	0.09611
ID	2.19760

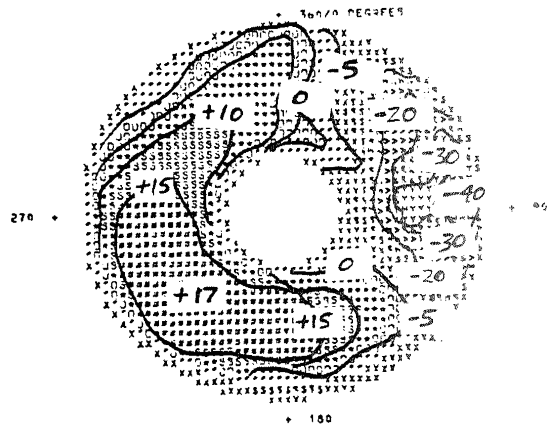
segmented vortex peak

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



K-THETA	1.19444
KD2	2740.2
(IDC)-MAX	0.23592
(IDR)-MAX	0.09032
KRA	0.35968
KA2	1.45809
DSPR	0.08654
ID	2.47579

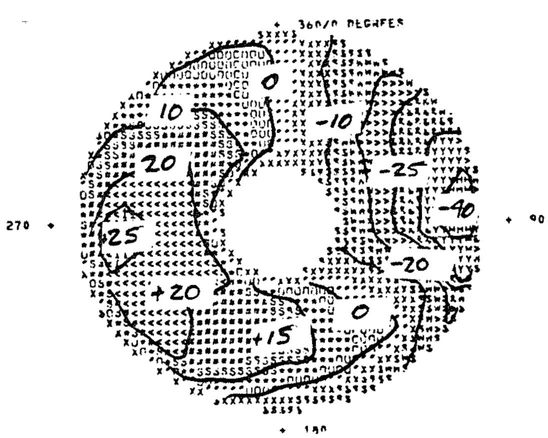
steady-state



K-THETA	2.57046
KD2	3937.6
(IDC)-MAX	0.325[illegible]
(IDR)-MAX	0.092[illegible]
KRA	0.7[illegible]
KA2	3.0[illegible]
DSPR	0.11821
ID	3.3751[illegible]

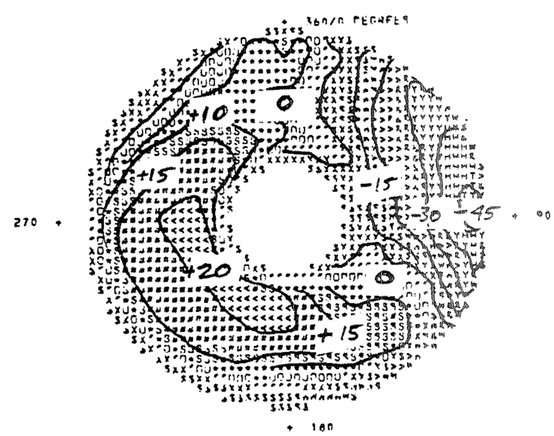
DYNADEC peak

(percent from average pressure)



K-THETA	2.27609
KD2	4933.2
(IDC)-MAX	0.34644
(IDR)-MAX	0.09090
KRA	0.35968
KA2	2.53974
DSPR	0.16734
ID	3.17246

Melick model peak

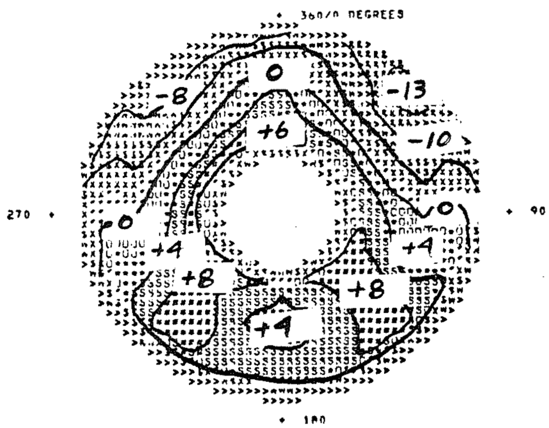


K-THETA	1.88601
KD2	3894.9
(IDC)-MAX	0.33781
(IDR)-MAX	0.15206
KRA	0.67127
KA2	2.37806
DSPR	0.13047
ID	3.79736

segmented vortex peak

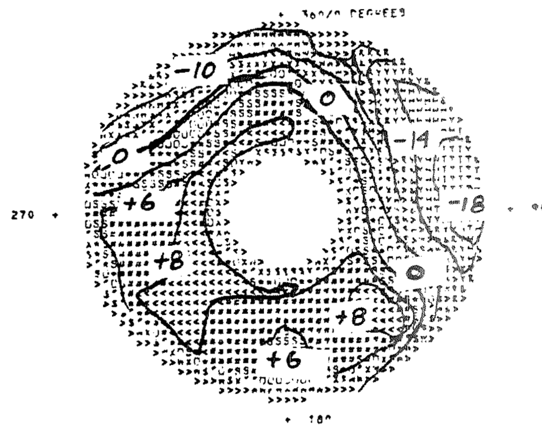
Figure 13b. Subsonic Inlet Map Comparison (54.30)

percent from average pressure



K-THETA	0.36337
KD2	819.7
(IDC)-MAX	0.09355
(IDR)-MAX	0.07916
KRA	0.40766
KA2	0.66219
DSPR	0.02406
ID	1.29662

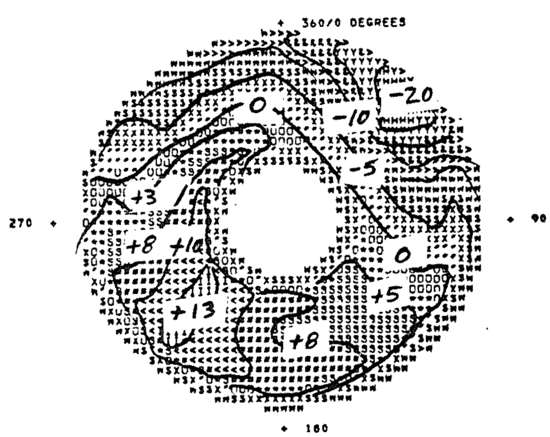
steady-state



K-THETA	0.72753
KD2	1365.4
(IDC)-MAX	0.12868
(IDR)-MAX	0.06354
KRA	0.47655
KA2	1.07664
DSPR	0.04890
ID	1.55624

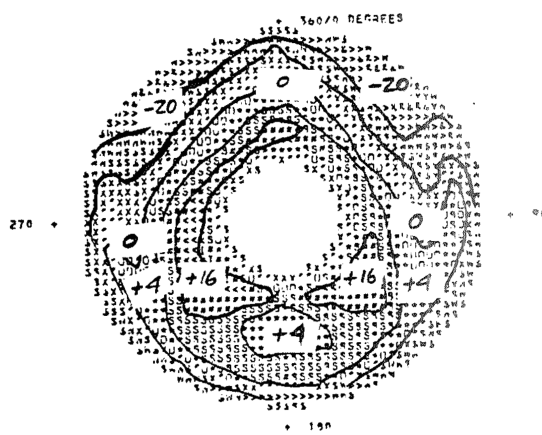
DYNADEC peak

percent from average pressure



K-THETA	1.03546
KD2	2223.2
(IDC)-MAX	0.16101
(IDR)-MAX	0.07888
KRA	0.40766
KA2	1.33427
DSPR	0.06540
ID	1.59487

Melick model peak



K-THETA	0.74868
KD2	1315.7
(IDC)-MAX	0.15364
(IDR)-MAX	0.17138
KRA	0.99184
KA2	1.47570
DSPR	0.04671
ID	2.58862

segmented vortex peak

Figure 13c. Subsonic Inlet Map Comparisons (81.40)

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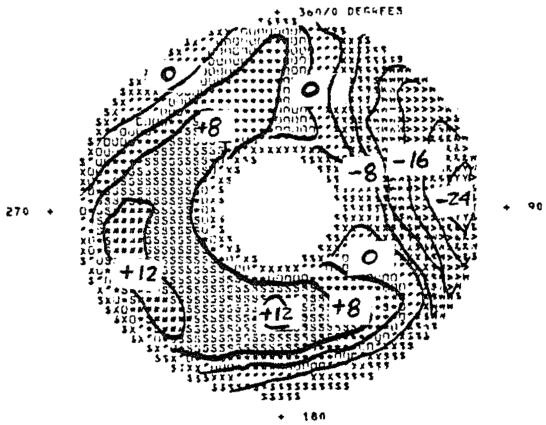
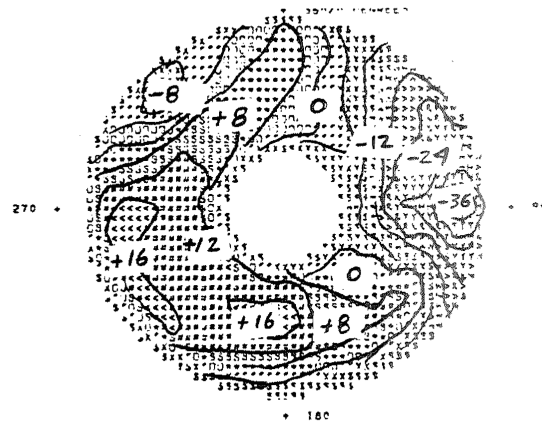
percent from average pressure



K-THETA	1.06535
KD2	2401.7
(IDC)-MAX	0.21749
(IDR)-MAX	0.08970
KRA	0.37629
KA2	1.34117
DSPR	0.07771
ID	2.30509

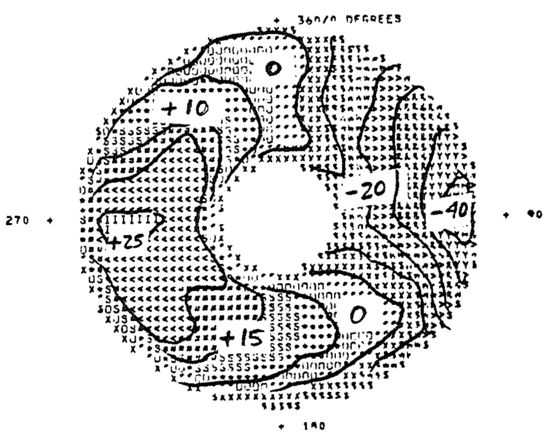
steady-state



K-THETA	1.06101
KD2	3728.9
(IDC)-MAX	0.31896
(IDR)-MAX	0.06782
KRA	0.39444
KA2	1.75014
DSPR	0.10564
ID	3.31415

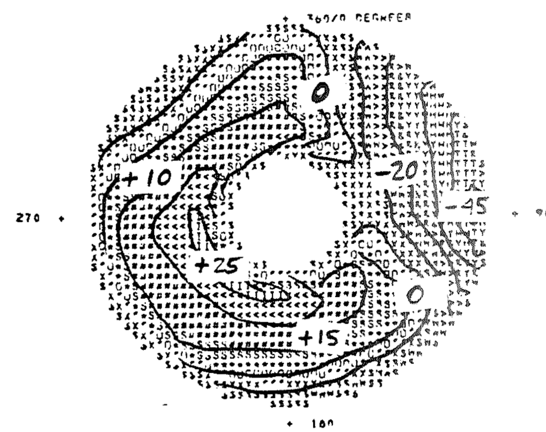
DYNADEC peak

percent from average pressure



K-THETA	2.23398
KD2	4782.5
(IDC)-MAX	0.33669
(IDR)-MAX	0.09033
KRA	0.37629
KA2	2.50980
DSPR	0.16529
ID	3.02967

Melick model peak

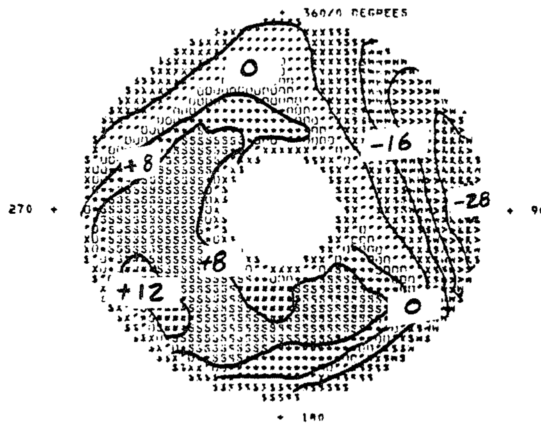


K-THETA	1.81969
KD2	3467.6
(IDC)-MAX	0.33634
(IDR)-MAX	0.17413
KRA	0.93912
KA2	2.50807
DSPR	0.15081
ID	3.95781

segmented vortex peak

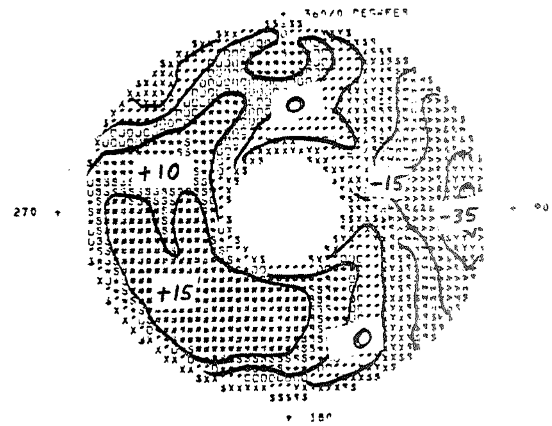
Figure 13d. Subsonic Inlet Map Comparisons (111.30)

percent from average pressure



K-THETA	0.98200
KD2	2142.5
(IDC)-MAX	0.18026
(IDR)-MAX	0.10505
KRA	0.47993
KA2	1.33379
DSPR	0.07275
ID	2.06990

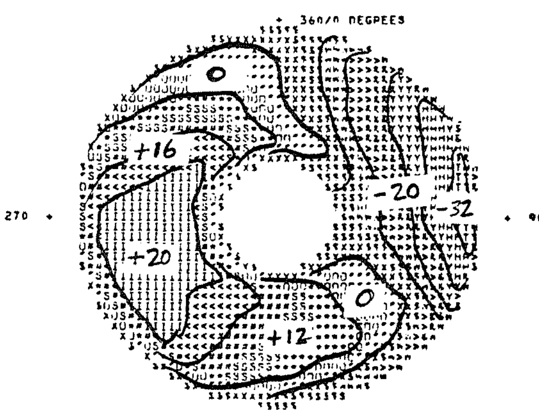
steady-state



K-THETA	1.57512
KD2	3925.5
(IDC)-MAX	0.32841
(IDR)-MAX	0.09162
KRA	0.41290
KA2	1.87764
DSPR	0.11616
ID	3.41034

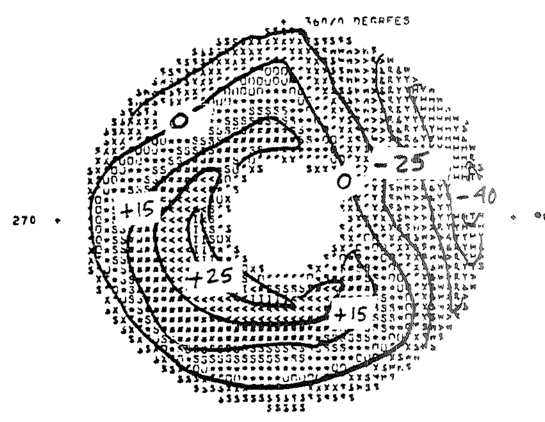
DYNADEC peak

percent from average pressure



K-THETA	2.01448
KD2	4095.7
(IDC)-MAX	0.28694
(IDR)-MAX	0.10571
KRA	0.47993
KA2	2.36627
DSPR	0.14946
ID	2.64388

Melick model peak



K-THETA	1.69529
KD2	3057.6
(IDC)-MAX	0.28465
(IDR)-MAX	0.18153
KRA	0.98845
KA2	2.41982
DSPR	0.12353
ID	3.47378

segmented vortex peak

Figure 13e. Subsonic Inlet Map Comparisons (112.30)

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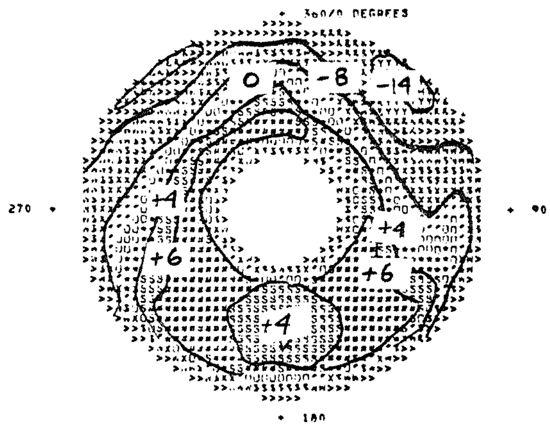
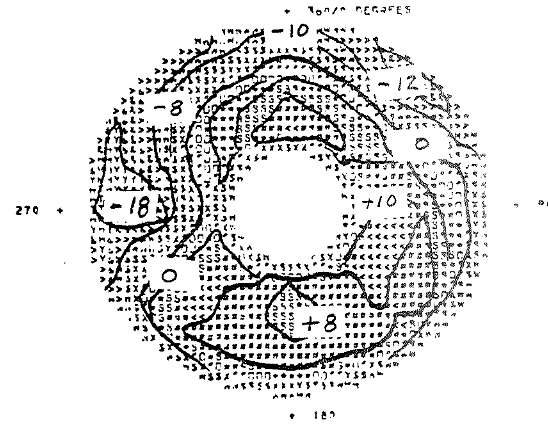
percent from average pressure



K-THETA	0.44035
KD2	946.7
(IDC)-MAX	0.09824
(IDR)-MAX	0.08502
KRA	0.46385
KA2	0.78035
DSPR	0.03022
ID	1.37968

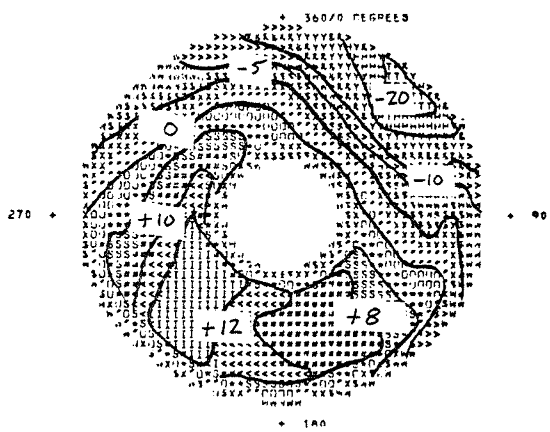
steady-state



K-THETA	0.72466
KD2	1090.1
(IDC)-MAX	0.14375
(IDR)-MAX	0.10056
KRA	0.55000
KA2	1.12761
DSPR	0.04555
ID	1.60079

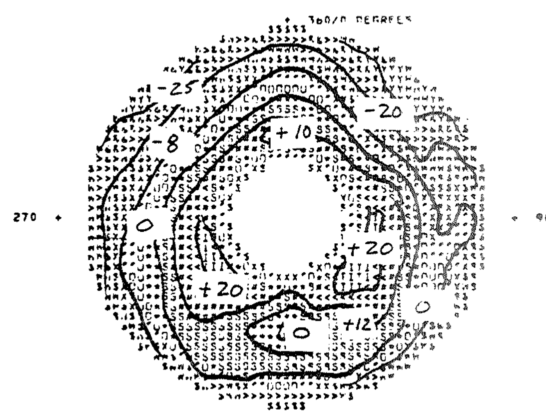
DYNADEC peak

percent from average pressure



K-THETA	1.19054
KD2	2510.5
(IDC)-MAX	0.17302
(IDR)-MAX	0.08468
KRA	0.46385
KA2	1.53054
DSPR	0.07607
ID	1.70783

Melick model peak



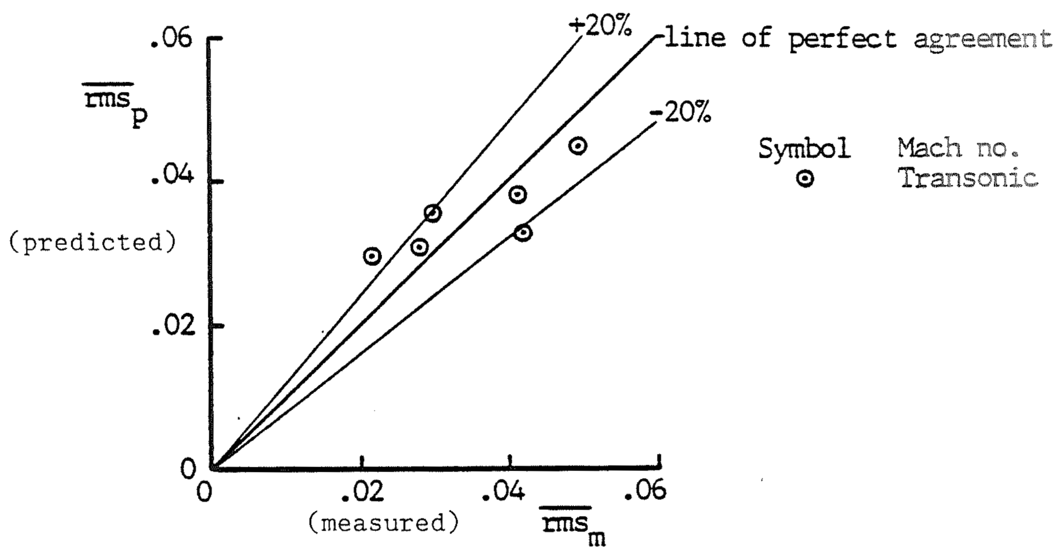
K-THETA	0.81925
KD2	1494.3
(IDC)-MAX	0.16596
(IDR)-MAX	0.19362
KRA	1.23565
KA2	1.72498
DSPR	0.05655
ID	2.88571

segmented vortex peak

Figure 13f. Subsonic Inlet Map Comparisons (137.50)

DISTORTION FACTOR CASE#	STEADY-STATE	DYNADEC PEAK	MELICK PREDICTED PEAK dynamic data input: FULL	MIN.	NONE
464.12					
K-THETA	0.03551	0.41514	0.2903	0.2857	0.2129
KD2	452.6	1199.5	1811.6	1791.5	1451.1
(IDC)-MAX	0.06052	0.07391	0.1757	0.1731	0.1343
(IDR)-MAX	0.03083	0.01520	0.0592	0.0568	0.0509
KRA	0.10017	0.07157	0.2283	0.2264	0.1924
KA2	0.11405	0.47126	0.4059	0.4006	0.3190
DSPR	0.00238	0.04257	0.0165	0.0164	0.0137
ID	0.67161	0.78789	1.3818	1.3666	1.1240
465.11					
K-THETA	0.26071	0.37914	0.3868	0.4001	0.3997
KD2	834.1	1306.1	1710.6	1805.2	1801.9
(IDC)-MAX	0.05798	0.08741	0.1235	0.1320	0.1317
(IDR)-MAX	0.04863	0.03776	0.0661	0.0679	0.0678
KRA	0.15727	0.10265	0.2279	0.2352	0.2349
KA2	0.38400	0.45962	0.5211	0.5349	0.5345
DSPR	0.02852	0.04038	0.0414	0.0427	0.0426
ID	0.79950	0.93361	1.1459	1.1877	1.1862
473.12					
K-THETA	0.27191	0.41032	0.3659	0.4073	0.4021
KD2	748.8	1157.7	1432.5	1748.0	1709.0
(IDC)-MAX	0.04194	0.06200	0.0947	0.1264	0.1224
(IDR)-MAX	0.05092	0.05070	0.0647	0.0703	0.0696
KRA	0.17237	0.16923	0.2253	0.2476	0.2448
KA2	0.40705	0.54299	0.5099	0.5539	0.5465
DSPR	0.03074	0.04502	0.0409	0.0449	0.0444
ID	0.73817	0.84266	1.0000	1.1435	1.1245
485.10					
K-THETA	0.51255	0.72939	0.6984	0.7173	0.6822
KD2	1520.8	2181.6	2746.1	2890.8	2620.4
(IDC)-MAX	0.08008	0.13863	0.1766	0.1897	0.1660
(IDR)-MAX	0.06062	0.01941	0.0861	0.0887	0.0839
KRA	0.19793	0.09619	0.3059	0.3175	0.2960
KA2	0.66773	0.89460	0.8726	0.6925	0.8552
DSPR	0.05478	0.07504	0.0739	0.0757	0.0720
ID	1.04356	1.56775	1.5644	1.6303	1.5101
487.80					
K-THETA	0.75539	1.05180	0.9839	1.0251	0.9622
KD2	1983.4	3194.0	3335.9	3632.7	3187.9
(IDC)-MAX	0.10555	0.17707	0.2122	0.2376	0.1987
(IDR)-MAX	0.06503	0.03807	0.0944	0.1000	0.0915
KRA	0.21478	0.16612	0.3512	0.3795	0.3371
KA2	0.92378	1.18204	1.1757	1.2212	1.1502
DSPR	0.07803	0.10784	0.1008	0.1046	0.0988
ID	1.25020	1.87747	1.8630	2.0057	1.7945
498.12					
K-THETA	0.41709	0.64972	0.5484	0.5764	0.5745
KD2	1258.9	1902.7	2143.2	2386.1	2354.3
(IDC)-MAX	0.06621	0.11275	0.1348	0.1555	0.1526
(IDR)-MAX	0.06127	0.03643	0.0799	0.0841	0.0835
KRA	0.21888	0.08764	0.2933	0.3102	0.3080
KA2	0.58869	0.71843	0.7322	0.7662	0.7622
DSPR	0.04733	0.06939	0.0614	0.0643	0.0639
ID	0.96861	1.16976	1.3266	1.4252	1.4118

Table 3. Transonic Inlet Distortion Factor Comparison



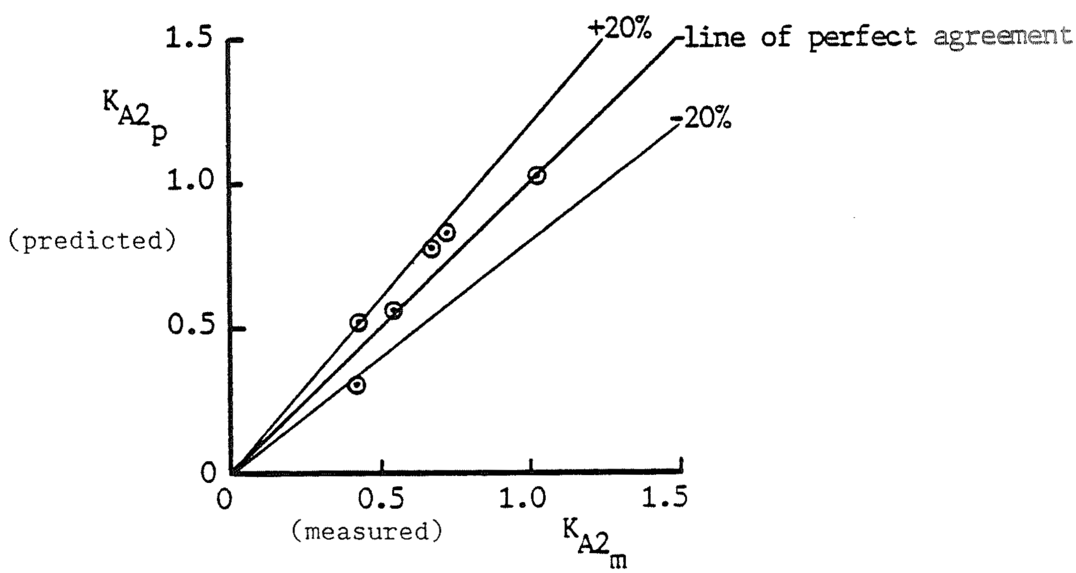


Figure 14. Comparisons of the Predicted and Measured rms Level and Peak Distortion Factor for the Transonic Inlet Model shown in Figure 9. (unpublished data)

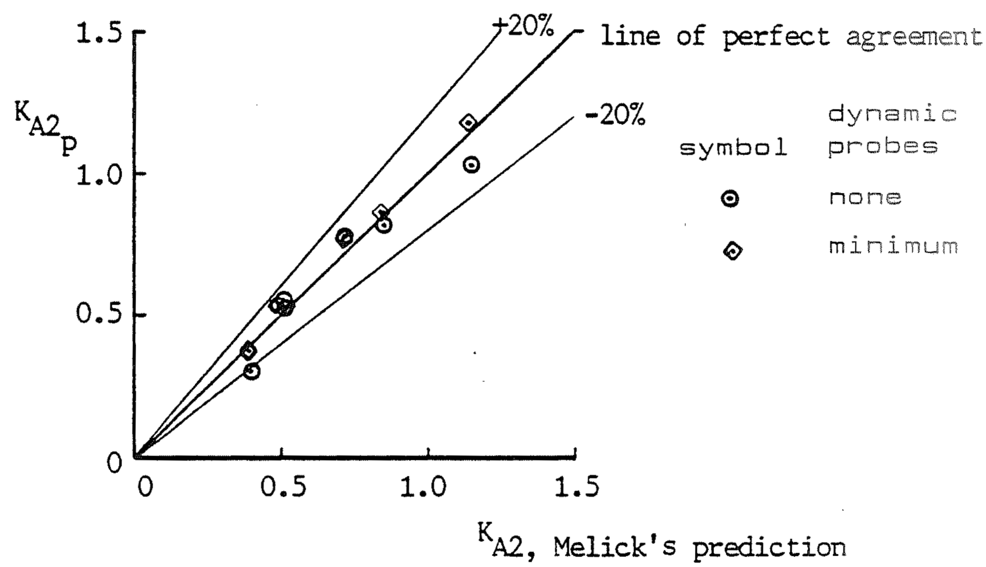
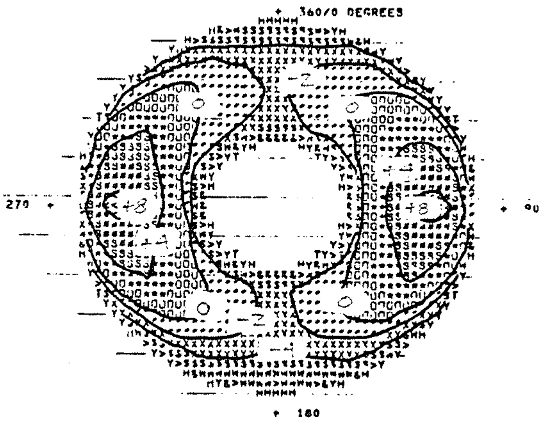


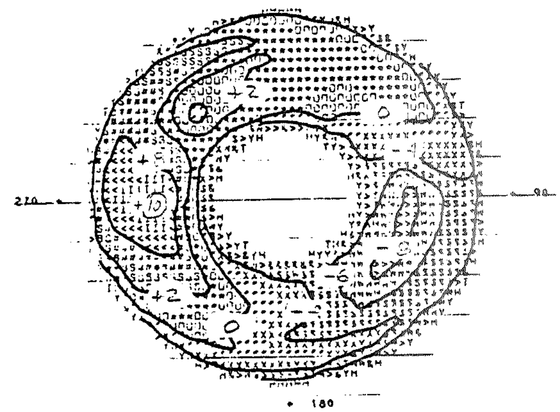
Figure 15. Comparisons of peak distortion factors predicted by the present analysis and the Melick method based on the total pressure rms measurements for the transonic inlet data set (unpublished data)

percent from average pressure



K-THETA	0.03551
KD2	452.6
(IDC)-MAX	0.06052
(IDR)-MAX	0.03083
KRA	0.10017
KA2	0.11405
DSPR	0.00238
ID	0.67161

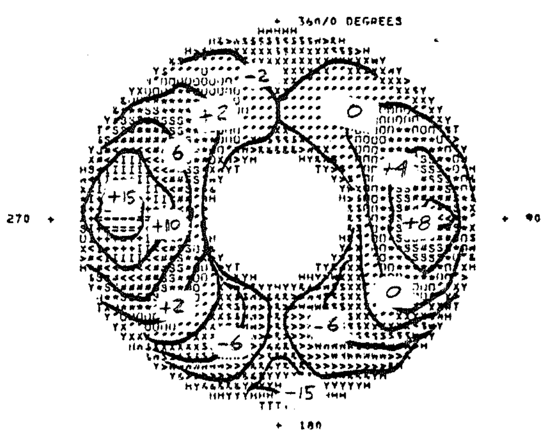
steady-state



K-THETA	0.41518
KD2	1199.5
(IDC)-MAX	0.07391
(IDR)-MAX	0.01520
KRA	0.07157
KA2	0.47126
DSPR	0.04257
ID	0.78769

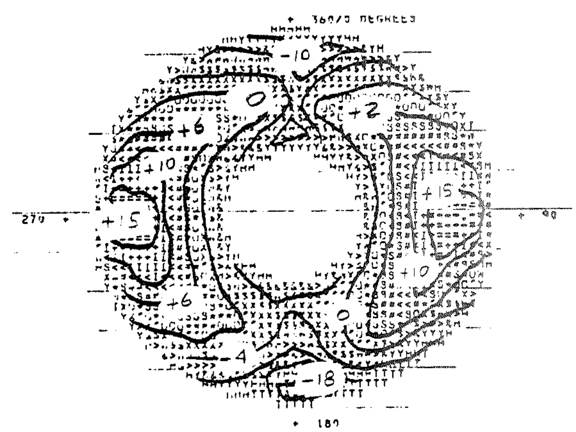
DYNADEC peak

percent from average pressure



K-THETA	0.30575
KD2	1348.5
(IDC)-MAX	0.13683
(IDR)-MAX	0.03083
KRA	0.10017
KA2	0.38428
DSPR	0.03241
ID	1.08694

Melick model peak



K-THETA	0.18022
KD2	1226.0
(IDC)-MAX	0.15058
(IDR)-MAX	0.05004
KRA	0.27536
KA2	0.39610
DSPR	0.00733
ID	1.37496

segmented vortex peak

Fig. 16a. Transonic Inlet Map Comparison (464.12)

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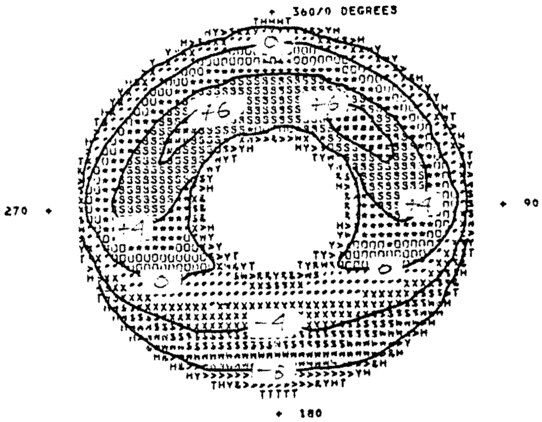
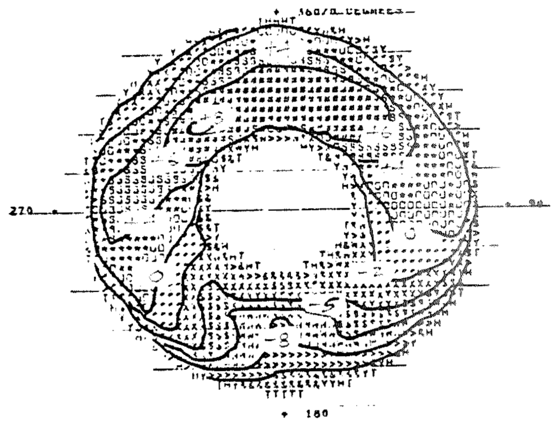
percent from average pressure



K-THETA	0.26071
KD2	834.1
(IDC)-MAX	0.05798
(IDR)-MAX	0.04863
KRA	0.15727
KA2	0.38400
DSPR	0.02852
ID	0.79950

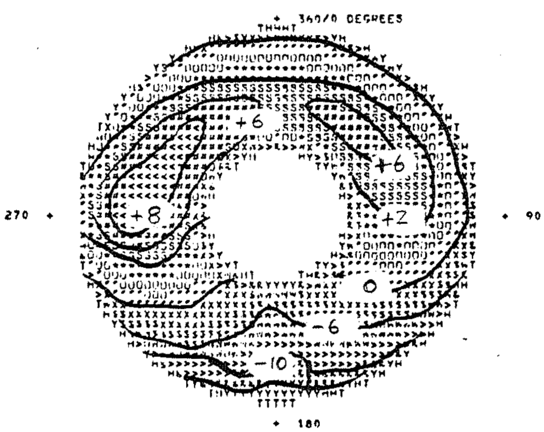
steady-state



K-THETA	0.37914
KD2	1306.1
(IDC)-MAX	0.08741
(IDR)-MAX	0.03776
KRA	0.13205
KA2	0.45962
DSPR	0.04038
ID	0.95301

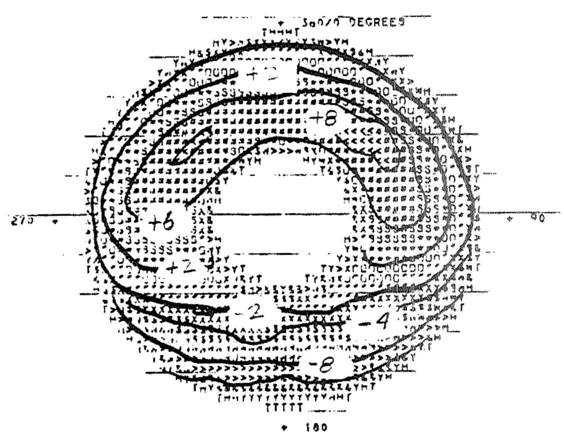
DYNADEC peak

percent from average pressure



K-THETA	0.38011
KD2	1337.1
(IDC)-MAX	0.09678
(IDR)-MAX	0.04863
KRA	0.15727
KA2	0.50341
DSPR	0.04164
ID	0.97331

Melick model peak

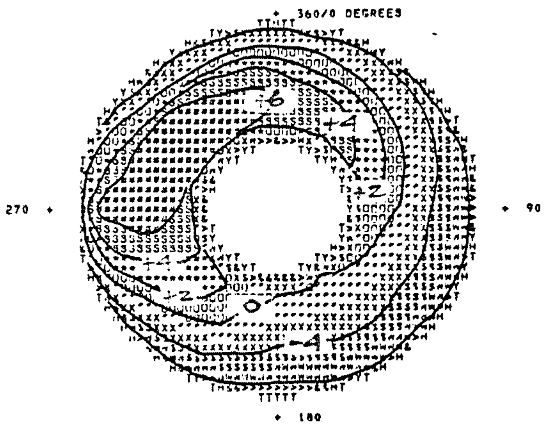


K-THETA	0.35300
KD2	1056.7
(IDC)-MAX	0.07294
(IDR)-MAX	0.06197
KRA	0.21387
KA2	0.52067
DSPR	0.03859
ID	1.01451

segmented vortex peak

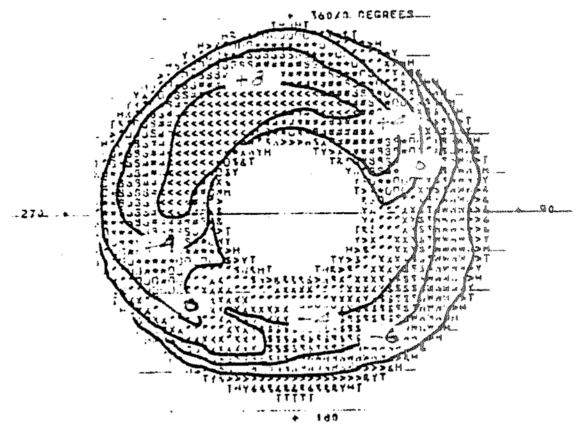
Figure 16b. Transonic Inlet Map Comparison (465.11)

percent from average pressure



K-THETA	0.27191
KD2	748.8
(IDC)-MAX	0.04194
(IDR)-MAX	0.05092
KRA	0.17237
KA2	0.40705
DSPR	0.03074
ID	0.73817

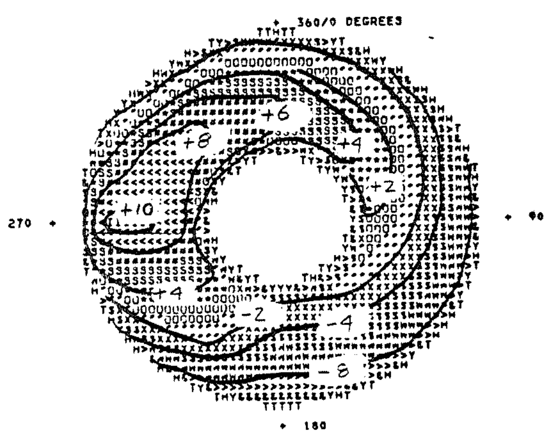
steady-state



K-THETA	0.41032
KD2	1157.7
(IDC)-MAX	0.06260
(IDR)-MAX	0.05370
KRA	0.16923
KA2	0.54299
DSPR	0.04502
ID	0.84266

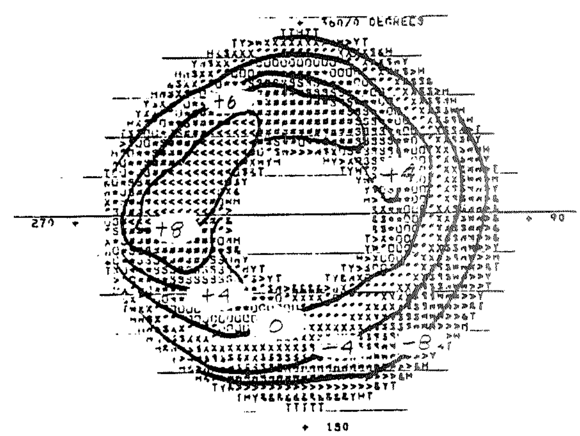
DYNADEC peak

percent from average pressure



K-THETA	0.37410
KD2	1230.5
(IDC)-MAX	0.06921
(IDR)-MAX	0.05092
KRA	0.17237
KA2	0.50924
DSPR	0.04214
ID	0.85062

Melick model peak

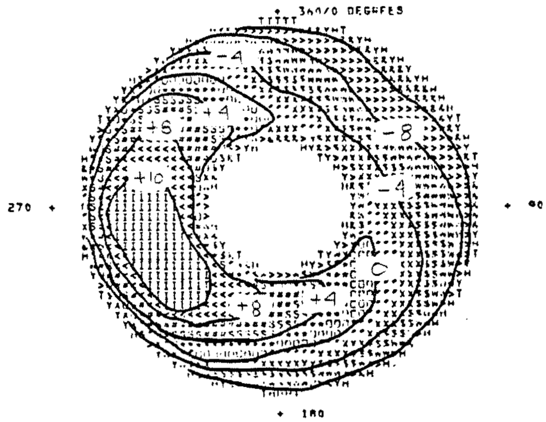


K-THETA	0.33852
KD2	945.7
(IDC)-MAX	0.05469
(IDR)-MAX	0.06169
KRA	0.21720
KA2	0.50880
DSPR	0.03816
ID	0.91022

segmented vortex peak

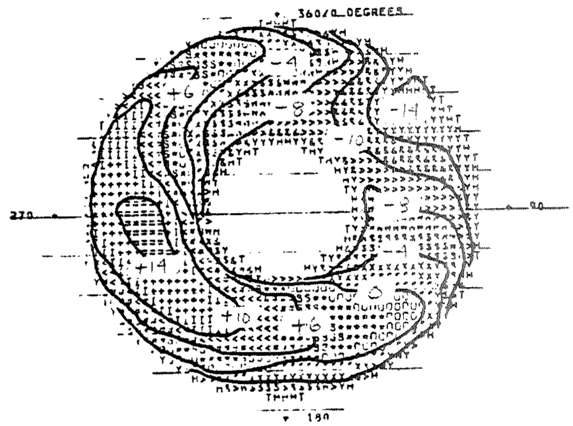
Figure 16c. Transonic Inlet Map Comparison (473.12)

percent from average pressure



K-THETA	0.51255
KD2	1520.8
(IDC)-MAX	0.08006
(IDR)-MAX	0.06062
KRA	0.19793
KA2	0.66773
DSPR	0.05478
ID	1.04356

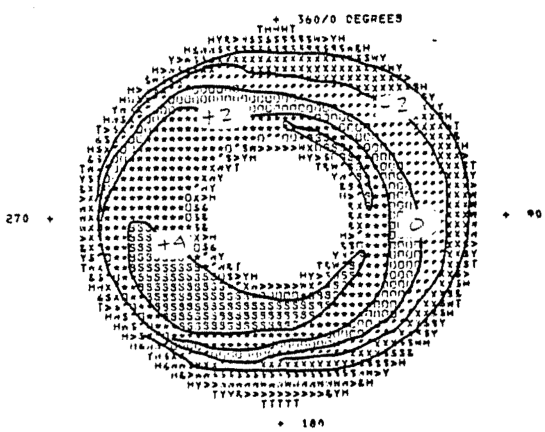
steady-state



K-THETA	0.72939
KD2	2131.6
(IDC)-MAX	0.13863
(IDR)-MAX	0.01941
KRA	0.09619
KA2	0.80480
DSPR	0.07504
ID	1.56775

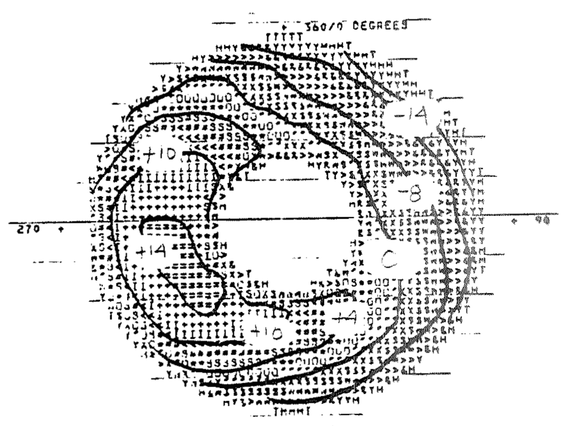
DYNADEC peak

percent from average pressure



K-THETA	0.13204
KD2	517.5
(IDC)-MAX	0.03954
(IDR)-MAX	0.06062
KRA	0.19793
KA2	0.28722
DSPR	0.00625
ID	0.85587

Melick model peak

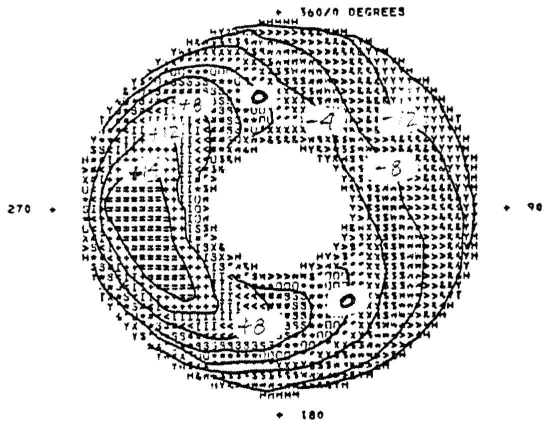


K-THETA	0.65597
KD2	1864.6
(IDC)-MAX	0.04936
(IDR)-MAX	0.07884
KRA	0.27597
KA2	0.87233
DSPR	0.07032
ID	1.33515

segmented vortex peak

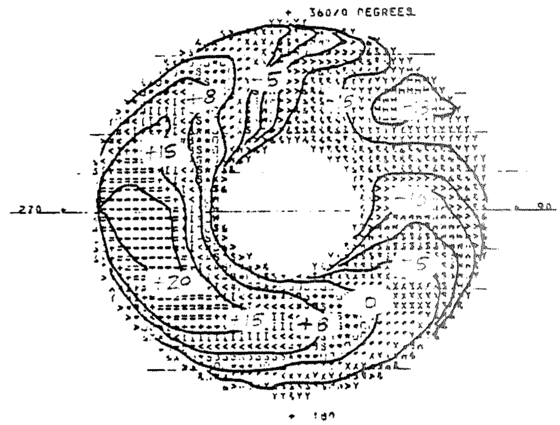
Figure 16d. Transonic Inlet Map Comparison (485.10)

percent from average pressure



K-THETA	0.75539
KD2	1983.4
(IDC)-MAX	0.10555
(IDR)-MAX	0.06503
KRA	0.21478
KA2	0.92378
DSPR	0.07803
ID	1.25020

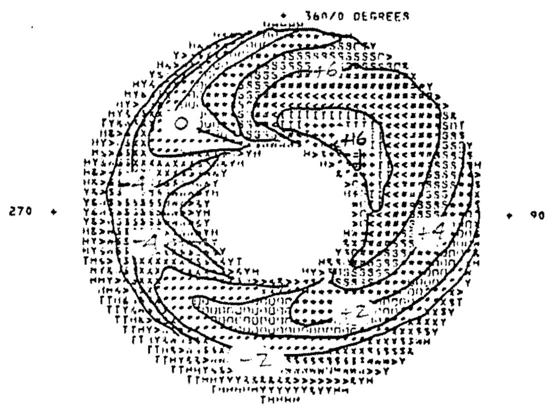
steady-state



K-THETA	1.05180
KD2	3194.0
(IDC)-MAX	0.17707
(IDR)-MAX	0.03807
KRA	0.16612
KA2	1.18204
DSPR	0.10784
ID	1.67747

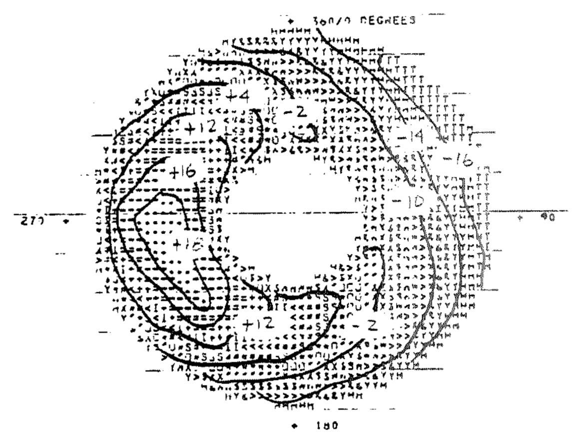
DYNADEC peak

percent from average pressure



K-THETA	0.56445
KD2	1862.0
(IDC)-MAX	0.10969
(IDR)-MAX	0.06503
KRA	0.21478
KA2	0.73284
DSPR	0.05632
ID	1.27092

Melick model peak

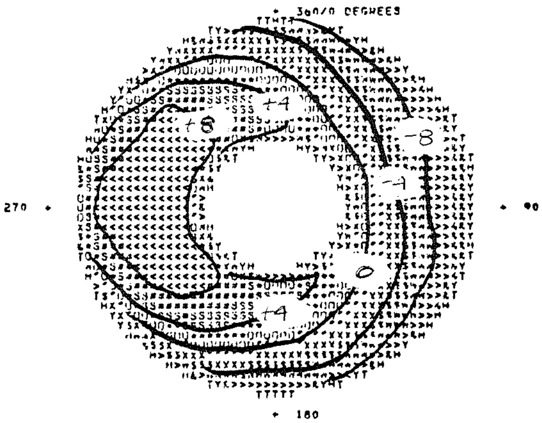


K-THETA	0.93733
KD2	2364.0
(IDC)-MAX	0.12610
(IDR)-MAX	0.06590
KRA	0.30362
KA2	1.17536
DSPR	0.09710
ID	1.57472

segmented vortex peak

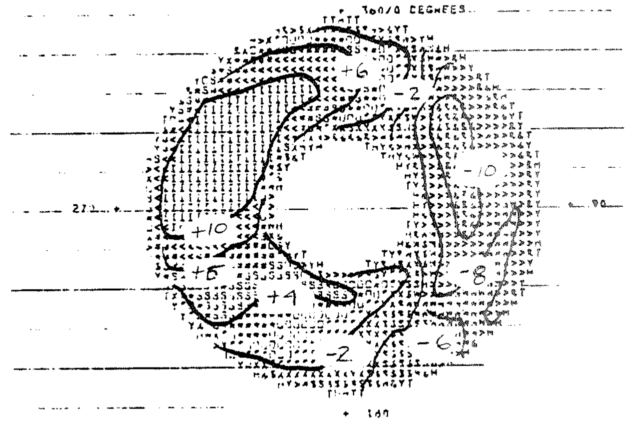
Figure 16e. Transonic Inlet Map Comparison (487.80)

percent from average pressure



K-THETA	0.41709
KD2	1258.9
(IDC)-MAX	0.06621
(IDR)-MAX	0.06127
KRA	0.21888
KA2	0.58869
DSPR	0.04733
ID	0.96861

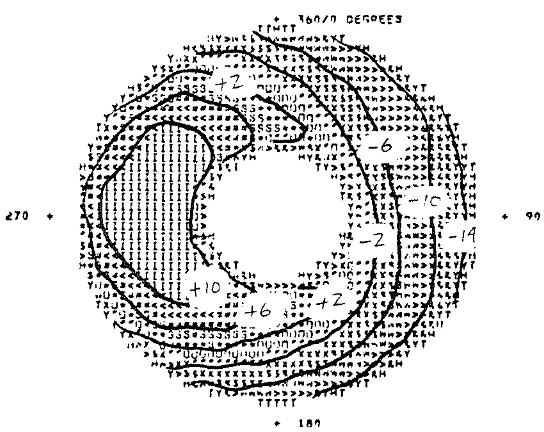
steady-state



K-THETA	0.64972
KD2	1902.7
(IDC)-MAX	0.11275
(IDR)-MAX	0.03643
KRA	0.08704
KA2	0.71843
DSPR	0.06939
ID	1.10976

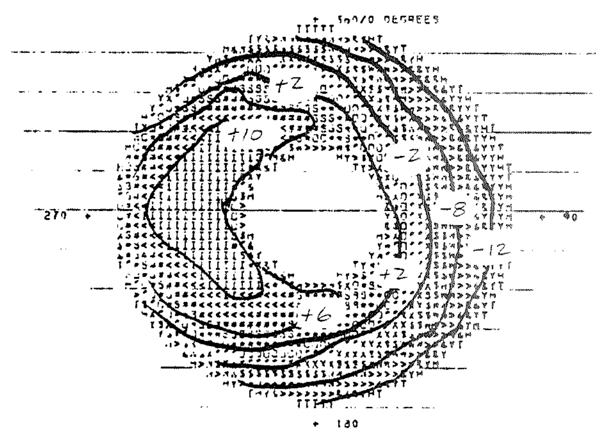
DYNADEC peak

percent from average pressure



K-THETA	0.55988
KD2	1667.4
(IDC)-MAX	0.08721
(IDR)-MAX	0.06134
KRA	0.21888
KA2	0.73148
DSPR	0.06296
ID	1.06094

Melick model peak



K-THETA	0.51359
KD2	1540.2
(IDC)-MAX	0.08236
(IDR)-MAX	0.07514
KRA	0.27740
KA2	0.73107
DSPR	0.05738
ID	1.19303

segmented vortex peak

Figure 16f. Transonic Inlet Map Comparisons (498.12)

DISTORTION FACTOR CASE#	STEADY-STATE	DYNADEC PEAK	PREDICTED PEAK
182/1			
K-THETA	1.19729	1.91726	1.5817
KD2	1496.6	2083.6	1836.5
(IDC)-MAX	0.08776	0.14950	0.1161
(IDR)-MAX	0.02568	0.00833	0.0355
KRA	0.26171	0.15219	0.5381
KA2	1.38912	2.02882	1.8198
DSPR	0.05196	0.07252	0.0660
ID	0.06158	0.11603	0.0767
189/3			
K-THETA	0.72977	0.99604	1.0647
KD2	856.3	1317.8	1191.6
(IDC)-MAX	0.04623	0.07602	0.0798
(IDR)-MAX	0.01200	0.01652	0.0218
KRA	0.10781	0.17564	0.3284
KA2	0.80860	1.12478	1.1831
DSPR	0.03236	0.04402	0.0448
ID	0.03198	0.05215	0.0493
216/3			
K-THETA	0.42371	0.77572	0.5765
KD2	1004.2	1550.8	1572.0
(IDC)-MAX	0.05599	0.08590	0.1017
(IDR)-MAX	0.02829	0.02949	0.0416
KRA	0.10789	0.18070	0.2067
KA2	0.50279	0.90817	0.6708
DSPR	0.03187	0.05105	0.0435
ID	0.04657	0.06335	0.0667
243/3			
K-THETA	0.17562	0.29504	0.2777
KD2	840.1	1363.5	2391.7
(IDC)-MAX	0.05782	0.07996	0.1954
(IDR)-MAX	0.02114	0.04603	0.0597
KRA	0.04418	0.09339	0.1126
KA2	0.20800	0.36349	0.3211
DSPR	0.03047	0.05070	0.0461
ID	0.04276	0.07010	0.1114
246/3			
K-THETA	0.35780	0.62345	0.5511
KD2	1089.1	1768.8	2251.2
(IDC)-MAX	0.08957	0.11079	0.1877
(IDR)-MAX	0.03598	0.02923	0.0682
KRA	0.14713	0.12632	0.2814
KA2	0.46565	0.71604	0.6797
DSPR	0.04060	0.06559	0.0587
ID	0.06795	0.07777	0.1150
247/2			
K-THETA	1.43627	1.85223	2.2478
KD2	1163.7	2054.6	1530.2
(IDC)-MAX	0.09133	0.16269	0.1261
(IDR)-MAX	0.03498	0.02560	0.0459
KRA	0.46954	0.35946	1.0524
KA2	1.78044	2.10106	2.6853
DSPR	0.04587	0.06944	0.0657
ID	0.06836	0.11450	0.0853

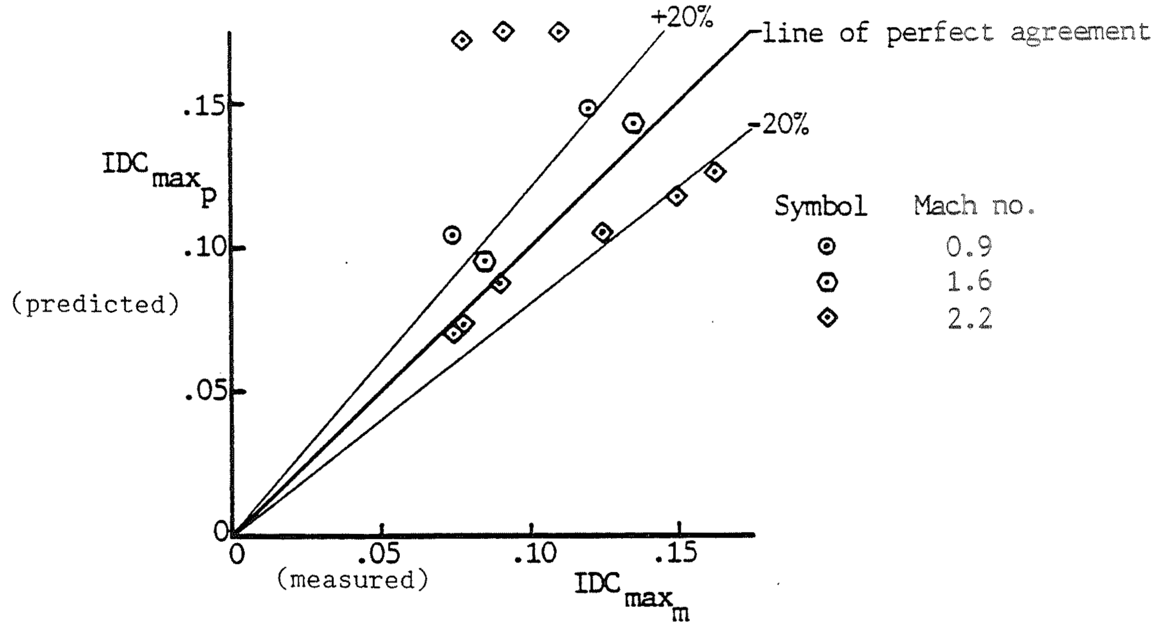
Table 4. Supersonic Inlet Distortion Comparison

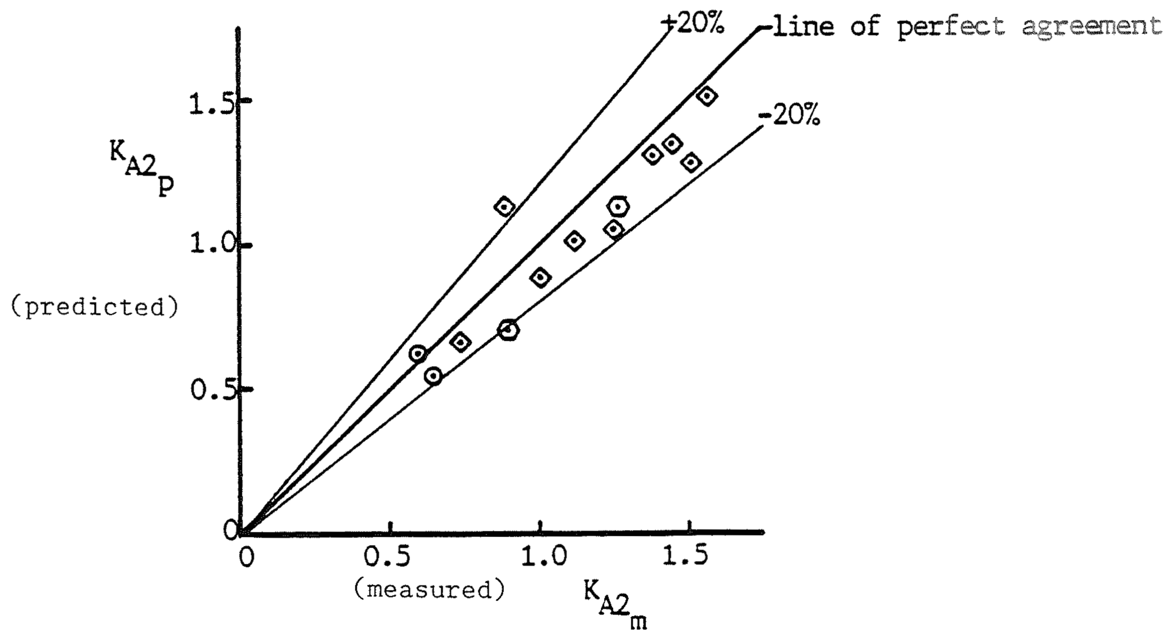
DISTORTION FACTOR CASE#	STEADY-STATE	DYNADEC PEAK	PREDICTED PEAK
640/2			
K-THETA	0.52739	0.90844	0.7798
KD2	867.7	1087.8	1164.9
(IDC)-MAX	0.08143	0.08115	0.1045
(IDR)-MAX	0.01611	0.02199	0.0243
KRA	0.13391	0.16460	0.3099
KA2	0.62555	1.03275	0.9061
DSPR	0.02388	0.03569	0.0342
ID	0.05671	0.05709	0.0709
643/3			
K-THETA	0.52601	0.87416	0.7126
KD2	745.5	860.2	894.5
(IDC)-MAX	0.06654	0.07828	0.0780
(IDR)-MAX	0.01427	0.02301	0.0184
KRA	0.19070	0.32695	0.3188
KA2	0.66580	1.11381	0.8743
DSPR	0.01783	0.03004	0.0242
ID	0.04631	0.05556	0.0533
695/1			
K-THETA	0.43841	0.72044	0.6187
KD2	987.1	1820.2	1521.4
(IDC)-MAX	0.10020	0.13615	0.1385
(IDR)-MAX	0.05052	0.06602	0.0631
KRA	0.22436	0.20931	0.3362
KA2	0.60287	0.91784	0.8010
DSPR	0.03245	0.05711	0.0445
ID	0.08377	0.11203	0.1019
1334/2			
K-THETA	0.40639	0.52556	0.5013
KD2	1288.8	1415.1	1821.6
(IDC)-MAX	0.10599	0.12034	0.1437
(IDR)-MAX	0.02163	0.02770	0.0341
KRA	0.05386	0.09191	0.1134
KA2	0.44587	0.59292	0.5493
DSPR	0.04740	0.05650	0.0570
ID	0.07595	0.08618	0.0991
433/3			
K-THETA	0.80102	1.81271	1.2175
KD2	852.5	1520.4	1224.7
(IDC)-MAX	0.06253	0.08995	0.0966
(IDR)-MAX	0.02028	0.03254	0.0306
KRA	0.17272	0.41549	0.4572
KA2	0.92762	2.11727	1.3919
DSPR	0.03509	0.05849	0.0495
ID	0.04456	0.06565	0.0615
437/3			
K-THETA	1.20829	2.43519	1.5203
KD2	1379.8	2031.3	1658.9
(IDC)-MAX	0.08946	0.12952	0.1121
(IDR)-MAX	0.02007	0.01109	0.0282
KRA	0.17141	0.15082	0.3996
KA2	1.33393	2.54574	1.6840
DSPR	0.05169	0.07392	0.0633
ID	0.06141	0.09560	0.0748

Table 4. Supersonic Inlet Distortion Comparison (cont'd)

DISTORTION FACTOR	STEADY-STATE	DYNADEC PEAK	PREDICTED PEAK
CASE# 1554/4			
K-THETA	0.43895	0.50648	0.5268
KD2	1278.3	1365.6	1725.3
(IDC)-MAX	0.07057	0.07372	0.1036
(IDR)-MAX	0.00489	0.03012	0.0154
KRA	0.03103	0.10038	0.0858
KA2	0.46170	0.58006	0.5599
DSPR	0.04183	0.04993	0.0505
ID	0.05647	0.05731	0.0830

Table 4. Supersonic Inlet Distortion Comparison (cont'd)

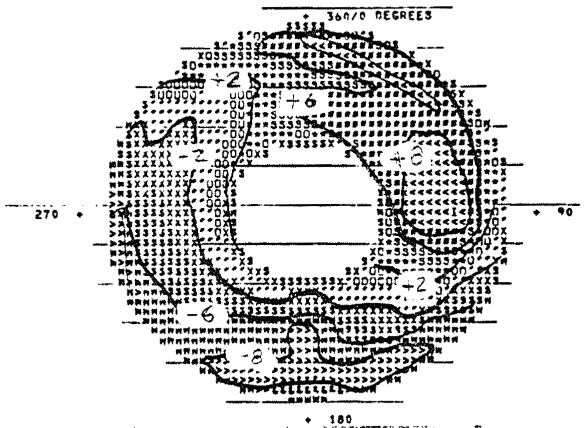




Note: The measured data was screened on K_{A2} for peak distortion

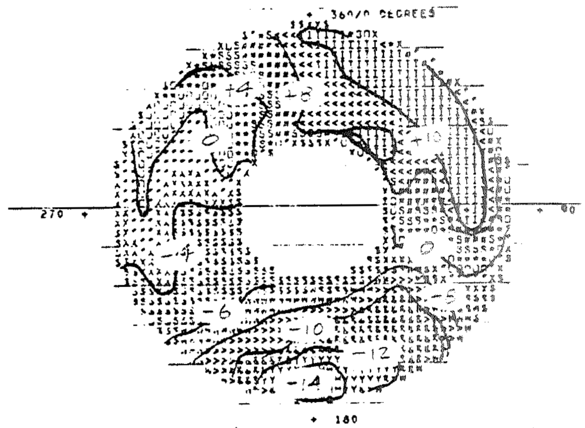
Figure 17. Comparisons of the Predicted and Measured Peak Distortion Factors for four Tailor-Mate Supersonic Inlet Models (ref. 3; see Figure 10)

percent from average pressure



K-THETA	1.19729
KD2	1496.6
(IDC)-MAX	0.08776
(IDR)-MAX	0.02588
KRA	0.26171
KA2	1.38912
DSPR	0.05196
ID	0.06158

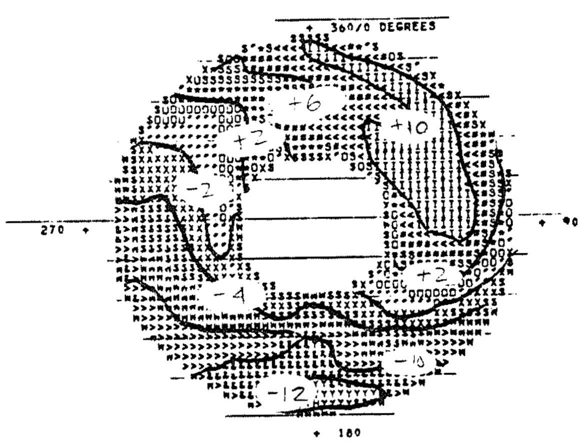
steady-state



K-THETA	1.91726
KD2	2083.6
(IDC)-MAX	0.14957
(IDR)-MAX	0.00833
KRA	0.15219
KA2	2.02862
DSPR	0.07252
ID	0.11600

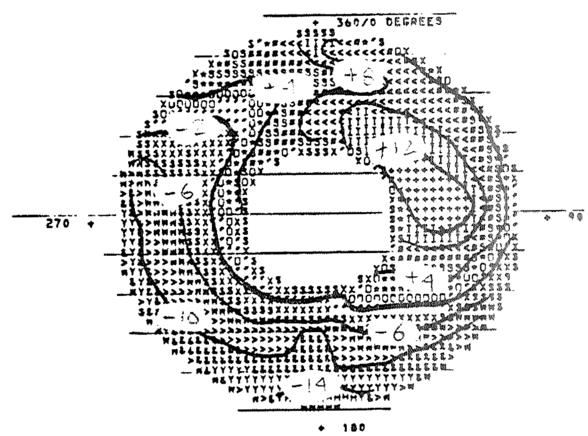
DYNADEC peak

percent from average pressure



K-THETA	1.62048
KD2	2029.7
(IDC)-MAX	0.11688
(IDR)-MAX	0.02588
KRA	0.26171
KA2	1.81232
DSPR	0.06990
ID	0.07343

Melick model peak

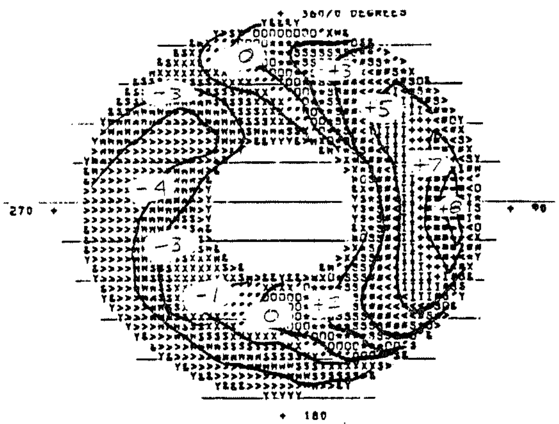


K-THETA	1.66406
KD2	1910.2
(IDC)-MAX	0.11607
(IDR)-MAX	0.04077
KRA	0.48391
KA2	2.01877
DSPR	0.07160
ID	0.08799

segmented vortex peak

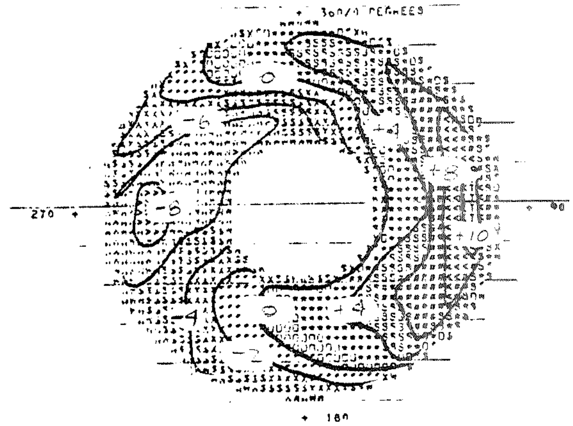
Figure 18a. Supersonic Inlet Map Comparison (182/1)

percent from average pressure



K-THETA	0.72977
KD2	856.3
(IDC)-MAX	0.04623
(IDR)-MAX	0.01200
KRA	0.10781
KA2	0.80880
DSPR	0.03236
ID	0.03198

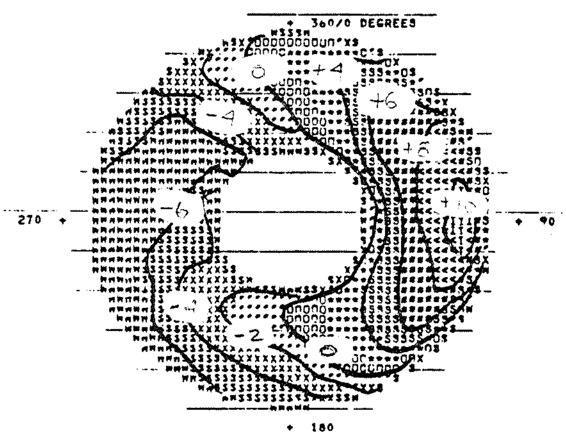
steady-state



K-THETA	0.99604
KD2	1317.8
(IDC)-MAX	0.07602
(IDR)-MAX	0.01652
KRA	0.17554
KA2	1.12478
DSPR	0.04402
ID	0.05215

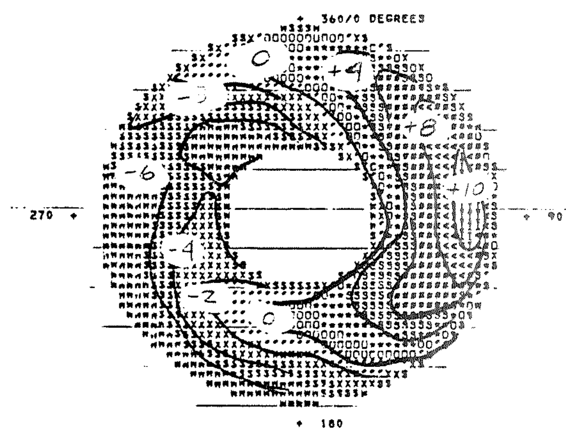
DYNADEC peak

percent from average pressure



K-THETA	1.09591
KD2	1235.5
(IDC)-MAX	0.06907
(IDR)-MAX	0.01199
KRA	0.10781
KA2	1.17494
DSPR	0.04886
ID	0.04184

Melick model peak

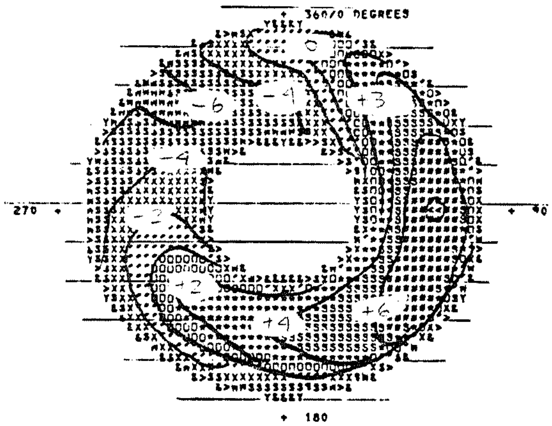


K-THETA	1.08016
KD2	1343.9
(IDC)-MAX	0.07370
(IDR)-MAX	0.01259
KRA	0.13339
KA2	1.17793
DSPR	0.04572
ID	0.04444

segemnted vortex peak

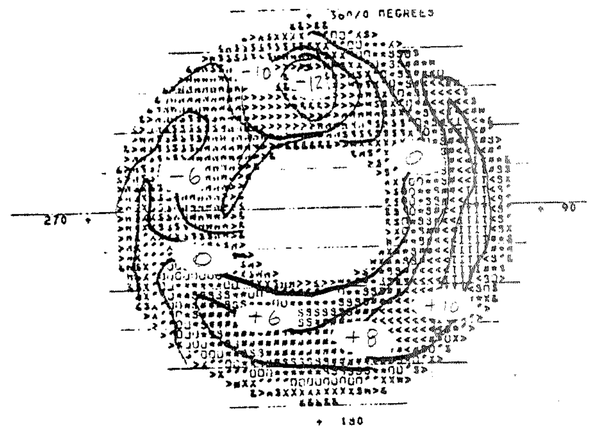
Figure 18b. Supersonic Inlet Map Comparisons (189/3)

percent from average pressure



K-THETA	0.42371
KD2	1004.2
(IDC)-MAX	0.05599
(IDR)-MAX	0.02829
KRA	0.10789
KA2	0.50279
DSPR	0.03187
ID	0.04657

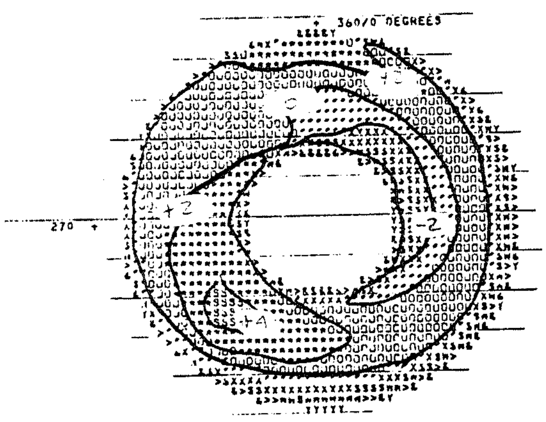
steady-state



K-THETA	0.77572
KD2	1550.8
(IDC)-MAX	0.08596
(IDR)-MAX	0.02949
KRA	0.18070
KA2	0.90817
DSPR	0.05105
ID	0.06335

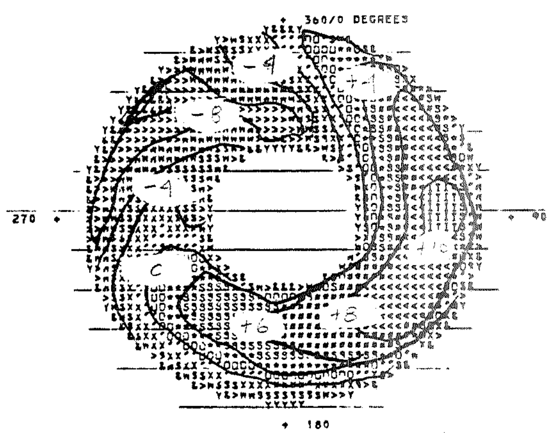
DYNADEC peak

percent from average pressure



K-THETA	0.25112
KD2	573.8
(IDC)-MAX	0.04649
(IDR)-MAX	0.02829
KRA	0.10789
KA2	0.33020
DSPR	0.01412
ID	0.04347

Melick model peak

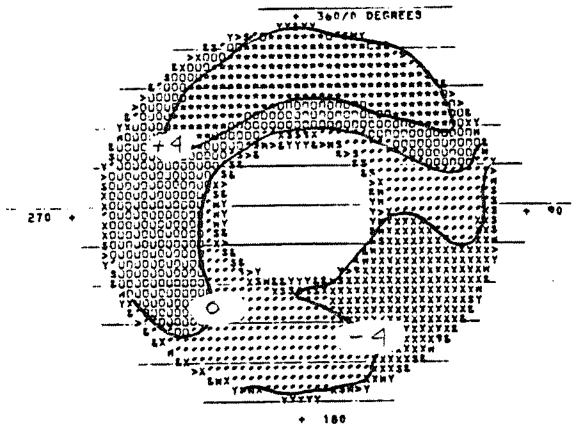


K-THETA	0.66511
KD2	1687.5
(IDC)-MAX	0.09537
(IDR)-MAX	0.04306
KRA	0.12620
KA2	0.75762
DSPR	0.04737
ID	0.07419

segmented vortex peak

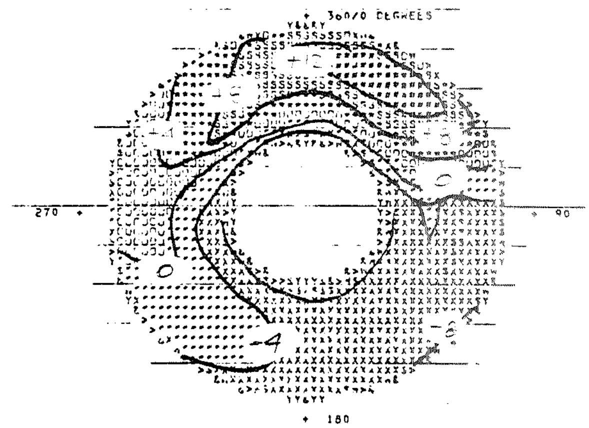
Figure 18c. Supersonic Inlet Map Comparison (216/3)

percent from average pressure



K-THETA	0.17562
KD2	840.1
(IDC)-MAX	0.05782
(IDR)-MAX	0.02114
KRA	0.04415
KA2	0.20800
DSPR	0.03047
ID	0.04276

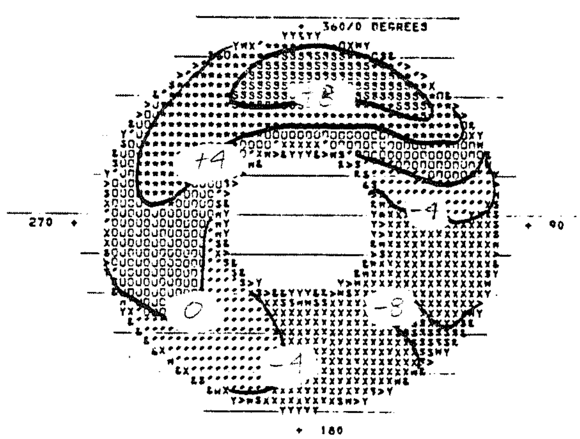
steady-state



K-THETA	0.29504
KD2	1303.5
(IDC)-MAX	0.07986
(IDR)-MAX	0.04603
KRA	0.09339
KA2	0.30349
DSPR	0.05070
ID	0.07010

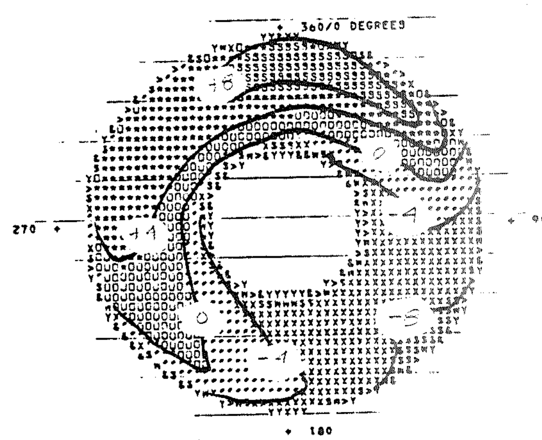
DYNADEC peak

percent from average pressure



K-THETA	0.28657
KD2	1379.5
(IDC)-MAX	0.08788
(IDR)-MAX	0.02114
KRA	0.04418
KA2	0.31895
DSPR	0.04920
ID	0.05400

Melick peak

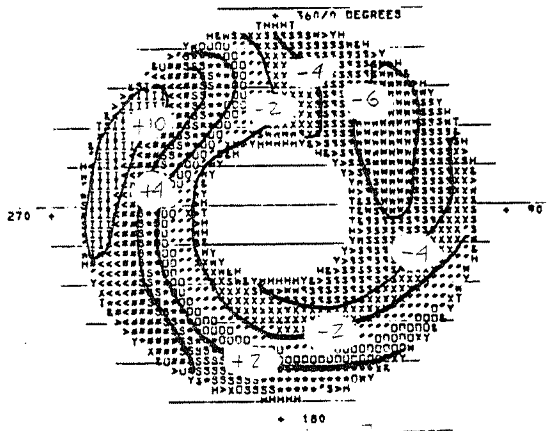


K-THETA	0.26380
KD2	1286.6
(IDC)-MAX	0.10405
(IDR)-MAX	0.03535
KRA	0.07128
KA2	0.31605
DSPR	0.04691
ID	0.07448

segmented vortex peak

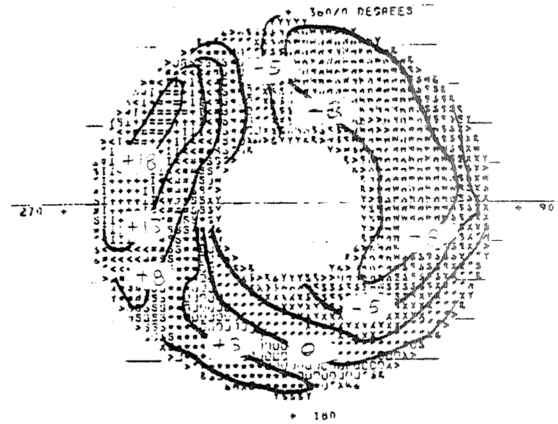
Figure 18d. Supersonic Inlet Map Comparisons (243/3)

percent from average pressure



K-THETA	0.35780
KD2	1089.1
(IDC)-MAX	0.08957
(IDR)-MAX	0.03598
KRA	0.14713
KA2	0.46565
DSPR	0.04060
ID	0.06795

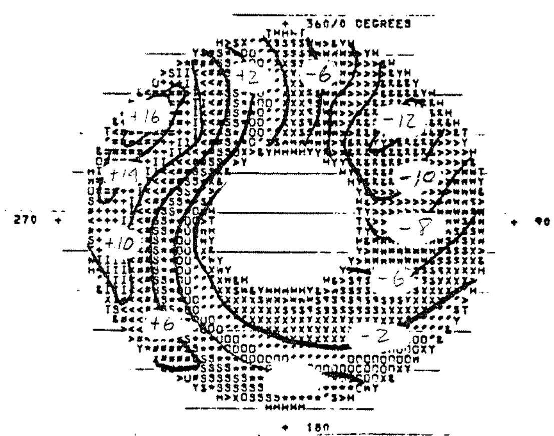
steady-state



K-THETA	0.62345
KD2	1708.8
(IDC)-MAX	0.11079
(IDR)-MAX	0.02923
KRA	0.12632
KA2	0.71604
DSPR	0.06509
ID	0.07777

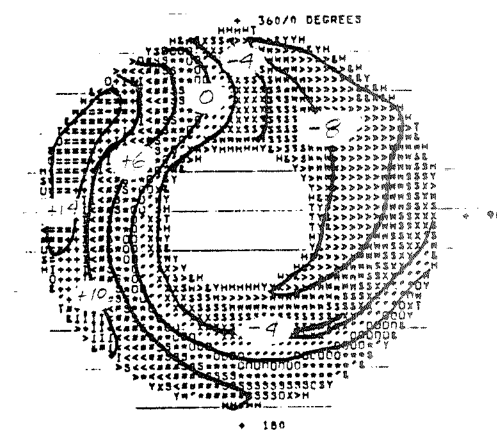
DYNADEC peak

percent from average pressure



K-THETA	0.56888
KD2	2114.2
(IDC)-MAX	0.14587
(IDR)-MAX	0.03598
KRA	0.14713
KA2	0.67673
DSPR	0.06311
ID	0.08806

Melick peak

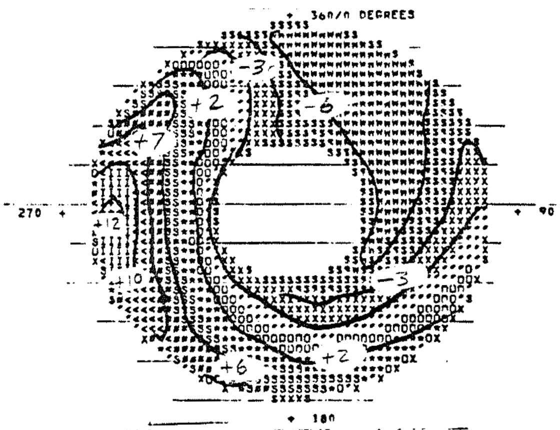


K-THETA	0.52763
KD2	1637.3
(IDC)-MAX	0.13837
(IDR)-MAX	0.05231
KRA	0.20498
KA2	0.67788
DSPR	0.05801
ID	0.10171

segmented vortex peak

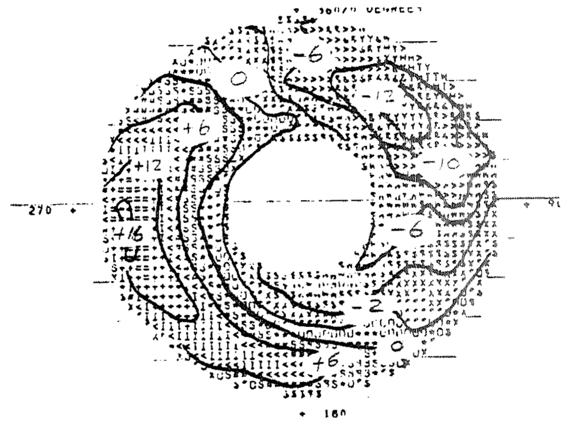
Figure 18e. Supersonic Inlet Map Comparison (246/3)

percent from average pressure



K-THETA	1.43627
KD2	1163.7
(IDC)-MAX	0.09133
(IDR)-MAX	0.03498
KRA	0.46954
KA2	1.78044
DSPR	0.04587
ID	0.06836

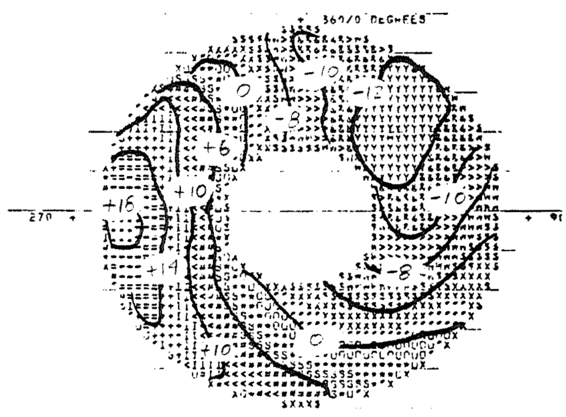
steady-state



K-THETA	1.85223
KD2	2054.6
(IDC)-MAX	0.16269
(IDR)-MAX	0.02580
KRA	0.33946
KA2	2.10106
DSPR	0.06944
ID	0.11450

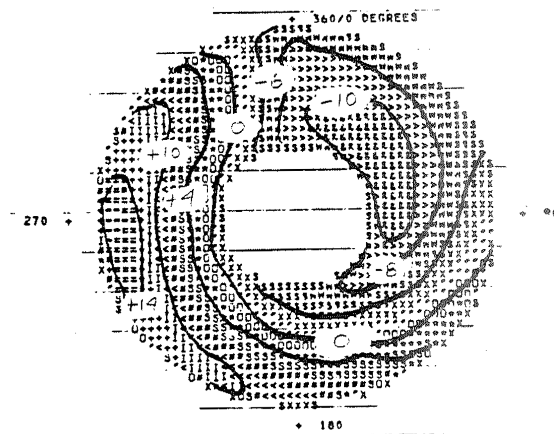
DYNADEC peak

percent from average pressure



K-THETA	2.78589
KD2	2357.3
(IDC)-MAX	0.15209
(IDR)-MAX	0.03498
KRA	0.46954
KA2	3.13006
DSPR	0.08760
ID	0.09055

Melick peak

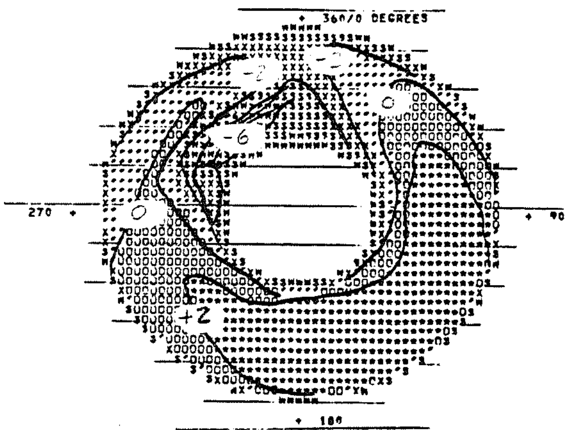


K-THETA	2.08610
KD2	1654.1
(IDC)-MAX	0.11963
(IDR)-MAX	0.06101
KRA	0.81582
KA2	2.68410
DSPR	0.06606
ID	0.10473

segmented vortex peak

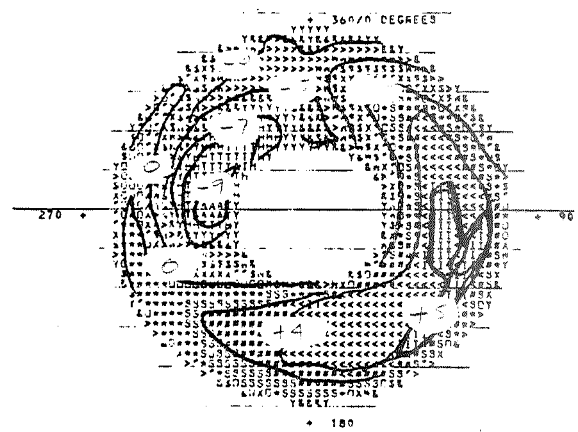
Figure 18f. Supersonic Inlet Map Comparison (247/2)

percent from average pressure



K-THETA	0.52739
KD2	867.7
(IDC)-MAX	0.08143
(IDR)-MAX	0.01611
KRA	0.13391
KA2	0.62555
DSPR	0.02388
ID	0.05671

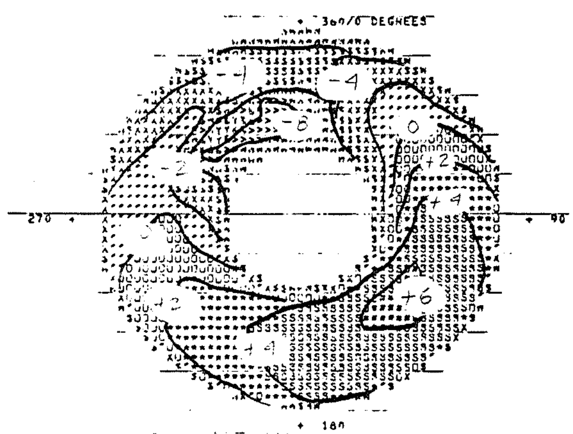
steady-state



K-THETA	0.90844
KD2	1089.8
(IDC)-MAX	0.08115
(IDR)-MAX	0.02199
KRA	0.16960
KA2	1.03275
DSPR	0.03569
ID	0.05709

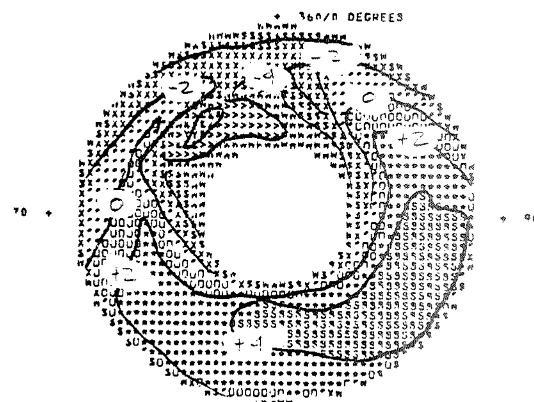
DYNADEC peak

percent from average pressure



K-THETA	0.88273
KD2	1346.6
(IDC)-MAX	0.10450
(IDR)-MAX	0.01611
KRA	0.13391
KA2	0.98068
DSPR	0.04099
ID	0.06821

Melick peak

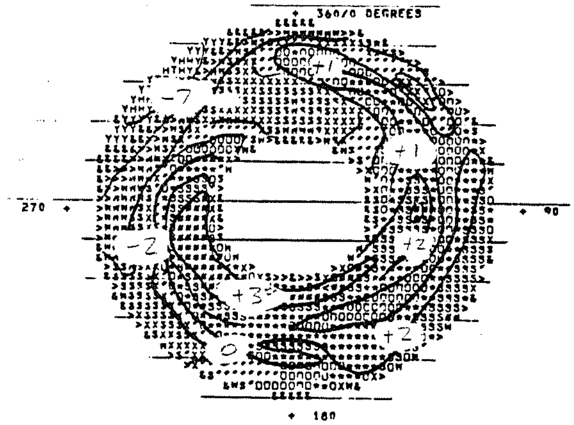


K-THETA	0.74948
KD2	1113.2
(IDC)-MAX	0.09714
(IDR)-MAX	0.02882
KRA	0.20313
KA2	0.89837
DSPR	0.03395
ID	0.07725

segmented vortex peak

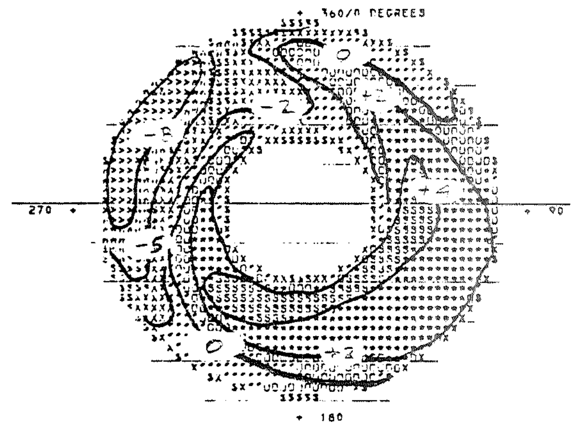
Figure 18g. Supersonic Inlet Map Comparison (640/2)

percent from average pressure



K-THETA	0.52601
KD2	745.5
(IDC)-MAX	0.06654
(IDR)-MAX	0.01427
KRA	0.19070
KA2	0.66580
DSPR	0.01783
ID	0.04631

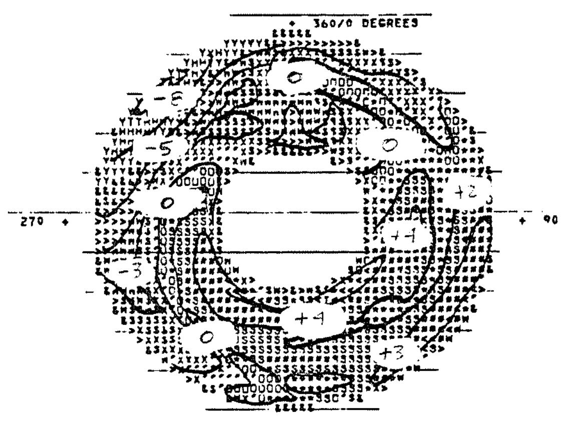
steady-state



K-THETA	0.87416
KD2	860.2
(IDC)-MAX	0.07828
(IDR)-MAX	0.02301
KRA	0.32695
KA2	1.11381
DSPR	0.03004
ID	0.05558

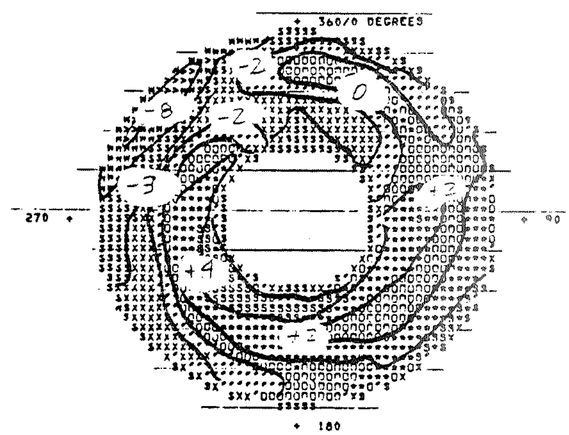
DYNADEC peak

percent from average pressure



K-THETA	0.70806
KD2	916.2
(IDC)-MAX	0.07811
(IDR)-MAX	0.01428
KRA	0.19070
KA2	0.84784
DSPR	0.02647
ID	0.05189

Melick peak

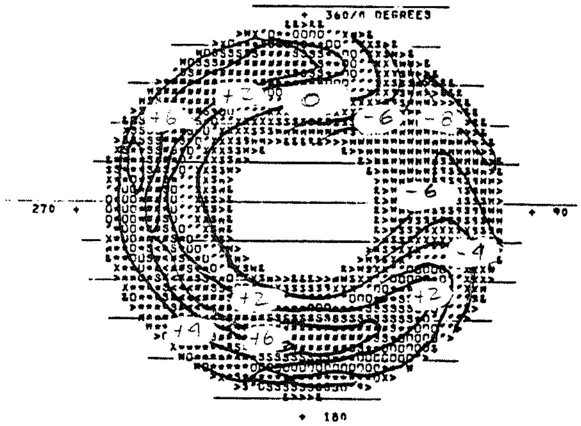


K-THETA	0.71497
KD2	901.3
(IDC)-MAX	0.07801
(IDR)-MAX	0.01718
KRA	0.22314
KA2	0.87853
DSPR	0.02317
ID	0.05474

segmented vortex peak

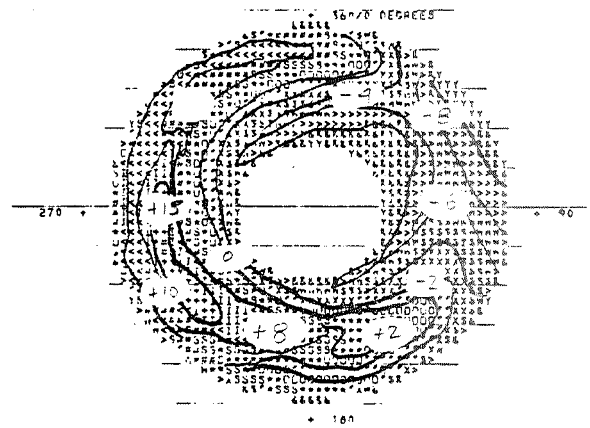
Figure 18h. Supersonic Inlet Map Comparison (643/3)

percent from average pressure



K-THETA	0.43841
KD2	987.1
(IDC)-MAX	0.10020
(IDR)-MAX	0.05052
KRA	0.22436
KA2	0.60287
DSPR	0.03245
ID	0.08377

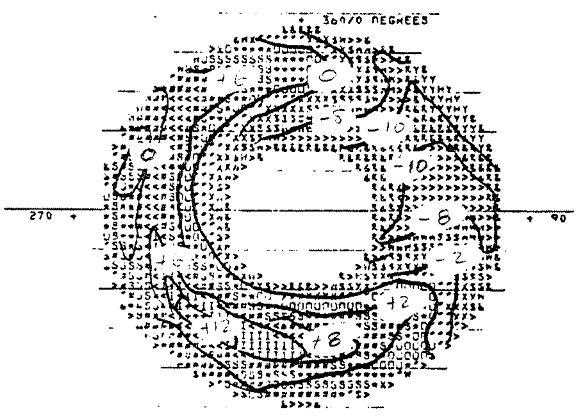
steady-state



K-THETA	0.72044
KD2	1820.2
(IDC)-MAX	0.13615
(IDR)-MAX	0.06602
KRA	0.26931
KA2	0.91784
DSPR	0.05711
ID	0.11203

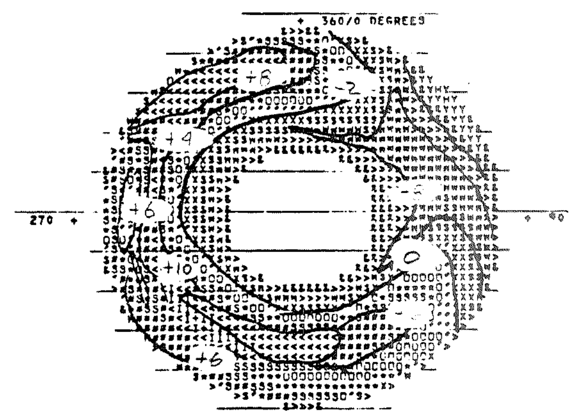
DYNADEC peak

percent from average pressure



K-THETA	0.77891
KD2	1603.7
(IDC)-MAX	0.13891
(IDR)-MAX	0.05042
KRA	0.22436
KA2	0.94336
DSPR	0.05823
ID	0.09651

Melick peak

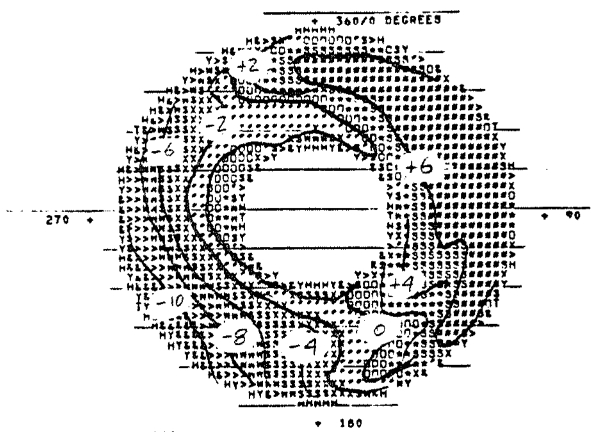


K-THETA	0.55825
KD2	1414.5
(IDC)-MAX	0.13864
(IDR)-MAX	0.07556
KRA	0.33345
KA2	0.80267
DSPR	0.04192
ID	0.12156

segmented vortex peak

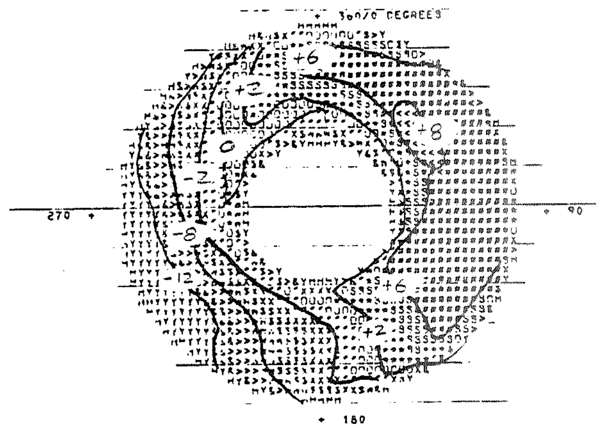
Figure 18i. Supersonic Inlet Map Comparisons (695/1)

percent from average pressure



K-THETA	0.40639
KD2	1288.8
(IDC)-MAX	0.10599
(IDR)-MAX	0.02163
KRA	0.05386
KA2	0.44587
DSPR	0.04740
ID	0.07595

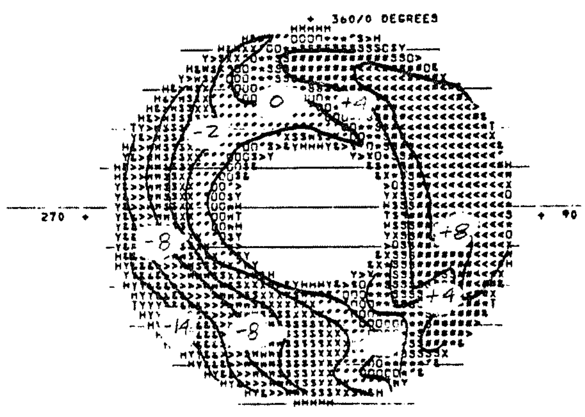
steady-state



K-THETA	0.52556
KD2	1415.1
(IDC)-MAX	0.12034
(IDR)-MAX	0.02770
KRA	0.04191
KA2	0.59292
DSPR	0.05650
ID	0.08618

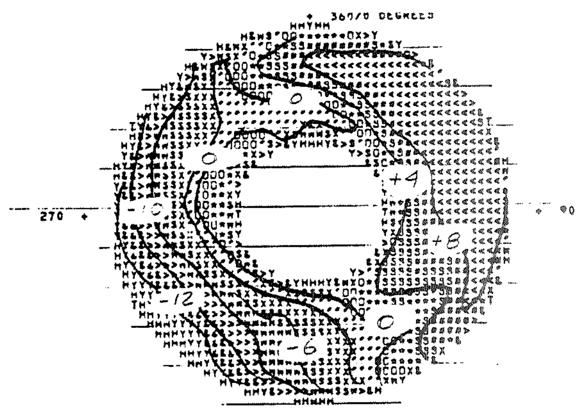
DYNADEC peak

percent from average pressure



K-THETA	0.50521
KD2	1511.8
(IDC)-MAX	0.12294
(IDR)-MAX	0.02163
KRA	0.05386
KA2	0.54469
DSPR	0.05800
ID	0.08464

Melick peak



K-THETA	0.49907
KD2	1582.8
(IDC)-MAX	0.13074
(IDR)-MAX	0.02285
KRA	0.05938
KA2	0.54260
DSPR	0.05818
ID	0.08986

segmented vortex peak

Figure 18j. Supersonic Inlet Map Comparisons (1334/2)

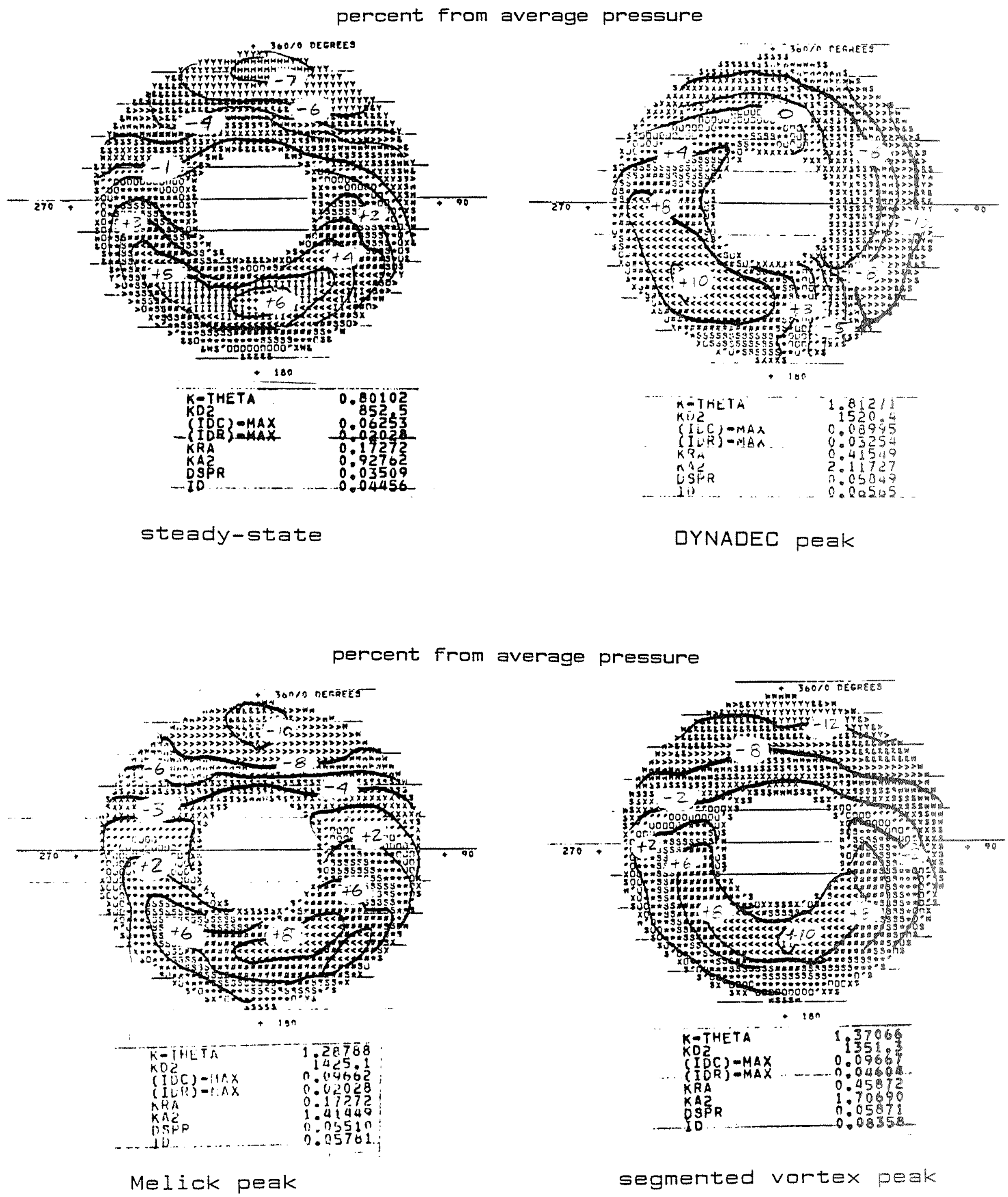
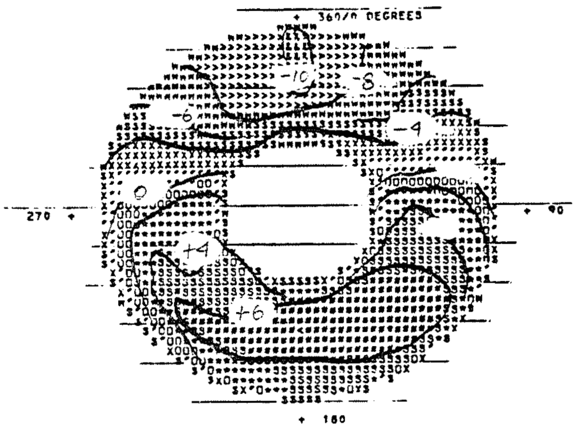


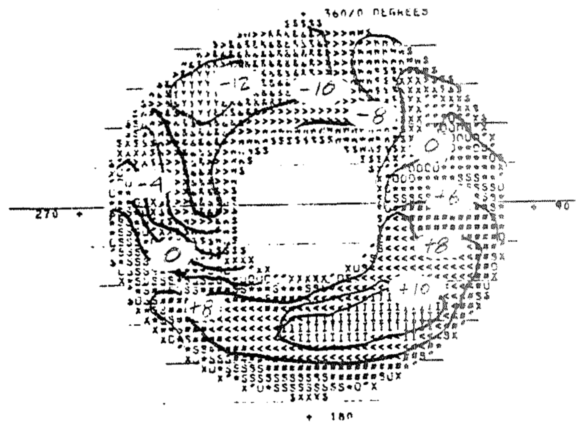
Figure 18k. Supersonic Inlet Map Comparison (433/3)

percent from average pressure



K-THETA	1.20829
KD2	1379.8
(IDC)-MAX	0.08946
(IDR)-MAX	0.02007
KRA	0.17141
KA2	1.33393
DSPR	0.05169
ID	0.06141

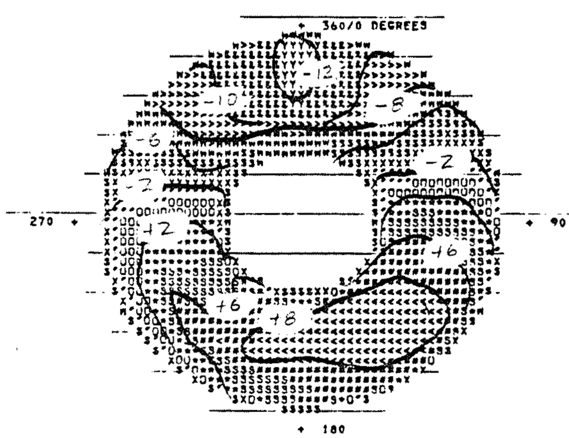
steady-state



K-THETA	2.43519
KD2	2031.3
(IDC)-MAX	0.12952
(IDR)-MAX	0.01100
KRA	0.15082
KA2	2.54574
DSPR	0.07392
ID	0.09560

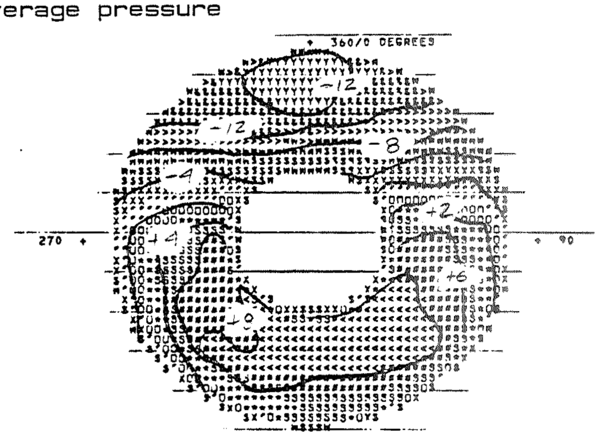
DYNADEC peak

percent from average pressure



K-THETA	1.55301
KD2	1773.6
(IDC)-MAX	0.11328
(IDR)-MAX	0.02007
KRA	0.17141
KA2	1.67865
DSPR	0.06616
ID	0.07242

Melick peak

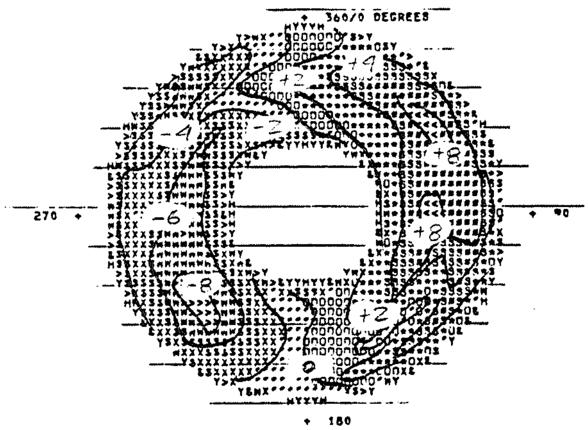


K-THETA	1.54909
KD2	1688.3
(IDC)-MAX	0.11220
(IDR)-MAX	0.03504
KRA	0.34601
KA2	1.80271
DSPR	0.06595
ID	0.08689

segmented vortex peak

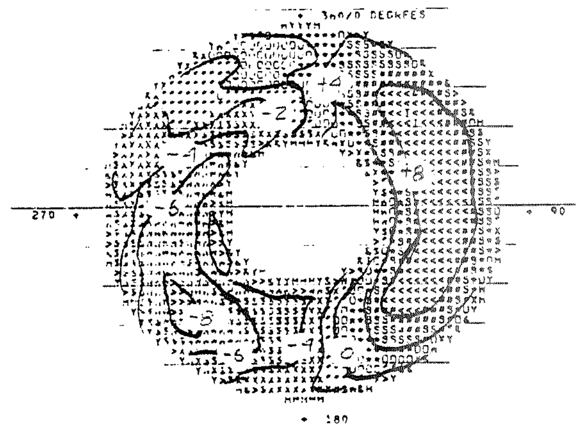
Figure 181. Supersonic Inlet Map Comparison (473/3)

percent from average pressure



K-THETA	0.43895
KD2	1278.3
(IDC)-MAX	0.07057
(IDR)-MAX	0.00489
KRA	0.03103
KA2	0.46170
DSPR	0.04183
ID	0.05647

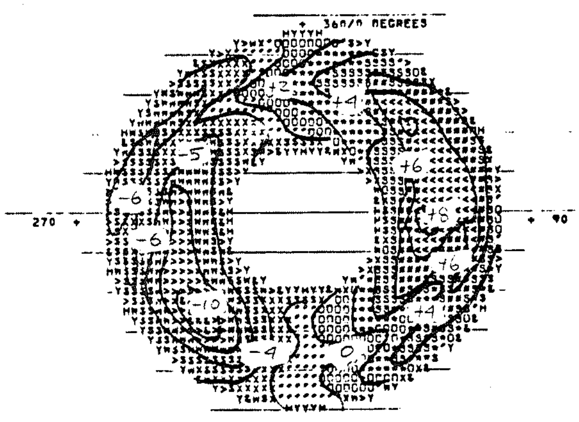
steady-state



K-THETA	0.50648
KD2	1365.0
(IDC)-MAX	0.07372
(IDR)-MAX	0.03012
KRA	0.10038
KA2	0.58006
DSPR	0.04993
ID	0.05731

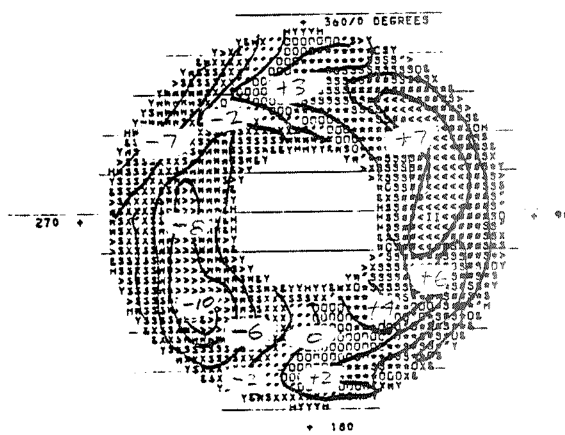
DYNADEC peak

percent from average pressure



K-THETA	0.53327
KD2	1489.4
(IDC)-MAX	0.07773
(IDR)-MAX	0.00489
KRA	0.03103
KA2	0.55602
DSPR	0.05117
ID	0.06170

Melick peak



K-THETA	0.52143
KD2	1375.0
(IDC)-MAX	0.07670
(IDR)-MAX	0.00797
KRA	0.05022
KA2	0.55824
DSPR	0.04856
ID	0.06403

segmented vortex peak

Figure 18m. Supersonic Inlet Map Comparison (1554/4)

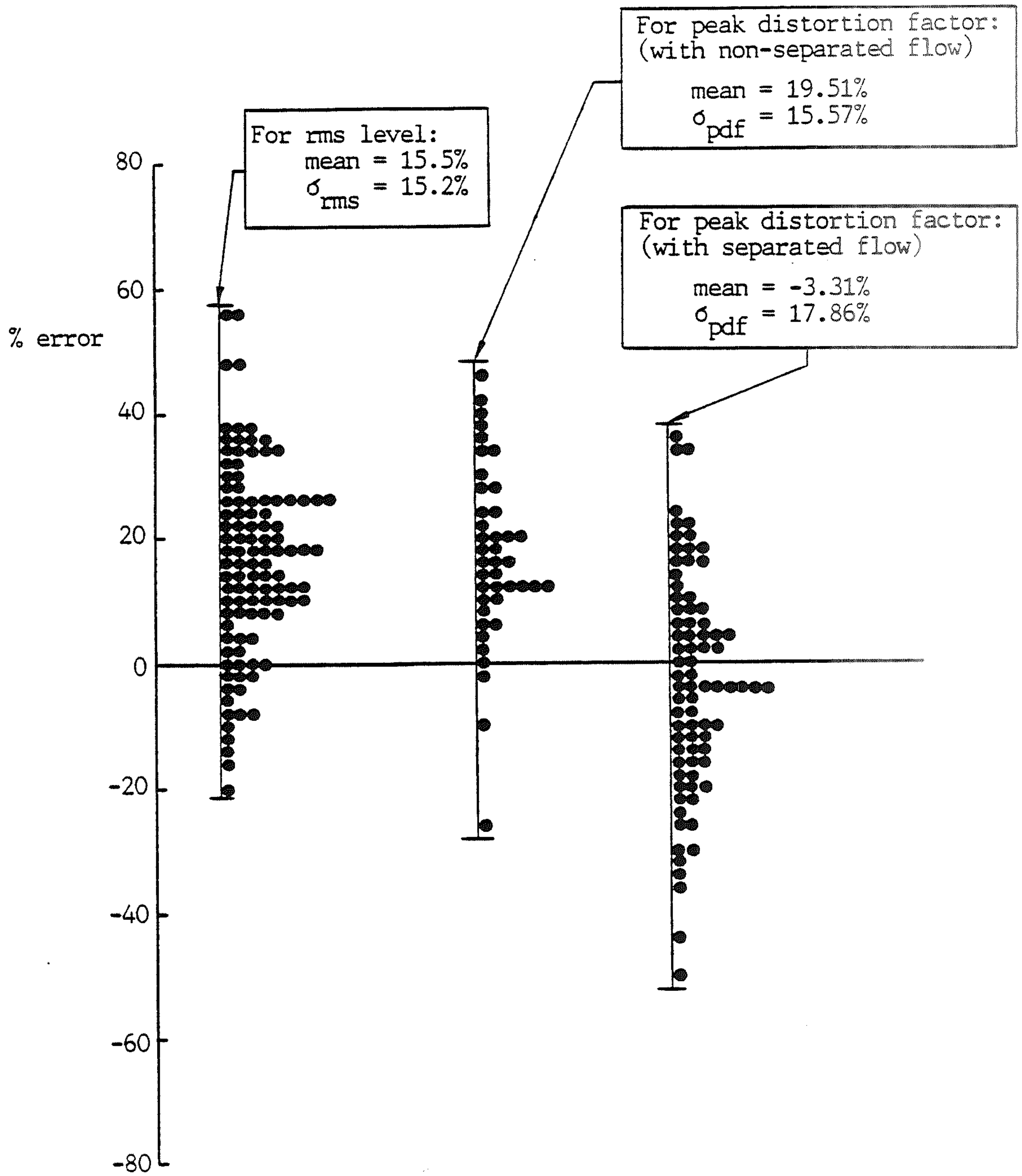


Figure 19. Accuracy of the Present Method in Predicting rms Levels and Dynamic Peak Distortion Factors

PART II

COMPUTER PROGRAM DOCUMENTATION AND USER'S MANUAL

ESTIMATING MAXIMUM INSTANTANEOUS INLET FLOW DISTORTION FORM 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 modelling, 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.

TABLE OF CONTENTS

NOMENCLATURE

SYMBOL	OTHER NAMES	DESCRIPTION	PAGE
A		Vortex core radius at point of maximum angular velocity, inches	49
A		Tridiagonal matrix	142
AB	ABAR, $\bar{a}$	Mean vortex core radius, inches	43
ALPH	alpha	Aircraft/inlet angle of attack, in degrees	29
ANGLOC		Angular position of rakes, deg.	26
ART	A/RT, AYRT, AY/RT	Nondimensionalized vortex core radius (divided by inlet radius)	49
AO		Vortex core size computed from power spectral density function	50
AO/RT		Nondimensionalized PSD vortex radius (divided by inlet radius)	50
A1		Radius of steady-state vortex, inches	40
B	BETA	Vortex orientation angle, deg.	49
BF	B-factor	Radial weighting factor for KA2	29
BRP		Base radial profile	29
BSF		Intermediate weighting factor for ID distortion solution	39
CKP	KC	Circumferential weighting factor for ID distortion solution	29
CUBIC		Subroutine - executes cubic spline interpolations	8

SYMBOL	OTHER NAMES	DESCRIPTION	PAGE
DISPAR		Subroutine - computes primary distortion factors	8
DISTRT		Subroutine - computes simple distortion parameters	8
DK	K , KD	General distortion factor designator	26
DKBAR		Mean distortion level	46
DKMX	DKMAX	Most probable peak distortion level - 50% probable	46
DKSS		Steady-state distortion level	46
DK950		95% probable distortion level - estimated peak distortion	48
DK997		99.7% probable peak distortion level	48
DRT		Nondimensionalized radial locations of rings	25
DSPR	ΔSPR	Delta stall pressure ratio distortion factor	81
DTH	DTHETA	Angular difference between the pressure rakes with minimum and maximum average total pressure	40
E	TE	Turbulent kinetic energy dissipation rate in ft^2/sec^3	45
ERRE		Error in E in iteration, ft^2/sec^3	44
ERRK		Error in K in iteration, ft^2/sec^2	44
ERRT		Total error in E and K	44
ETA		Face average steady-state total pressure recovery	42
EXTRME		Subroutine - manages distortion factor extreme-value computation	9

SYMBOL	OTHER NAMES	DESCRIPTION	PAGE
FACE	FACP	Element used in discrete point analysis in face contour map	88
FCO	FC	Low-pass cut-off filter frequency in rms fluctuation data	27
FINITE		Subroutine - solves finite difference equations	9
FO	F	Engine rpm filter frequency in hertz	27
FRF		Subroutine - computes by iteration the mean vortex core size	9
G	GAMMA	Vortex orientation angle , deg.	40
GE		Turbulent kinetic energy dissipation rate at each finite element grid point , ft^2/sec^3	44
GK		Turbulent kinetic energy at each grid point , ft^2/sec^2	44
G1		Steady-state GAMMA orientation angle of the vortex , degrees	40
ID		General Electric combined radial/circumferential distortion factor	39
IDC		GE circumferential distortion factor	38
IDC-MAX		Maximum GE circumferential distortion factor	30
IDR		GE radial distortion factor	30
IDR-MAX		Maximum GE radial distortion factor	30
INITL		Subroutine - sets initial values for GE and GK (energies)	10
INIVEL		Subroutine - computes velocity gradiants in steady-state data	10

SYMBOL	OTHER NAMES	DESCRIPTION	PAGE
INTERP		Subroutine - interpolates pressure recoveries at discrete element points at engine face	10
K	KD, DK	General distortion factor	26
K	TK	Turbulent kinetic energy in ft^2/sec^2	45
KA2		Pratt & Whitney combined radial and circumferential distortion	39
KD2		P & W circumferential distortion factor	38
KRA		P & W radial distortion factor	38
KTHETA	KTTA	P & W circumferential distortion factor (alternate)	38
LAB	LABEL	Distortion factor name or label	111
LNPOUT		Subroutine - prints pressure distortion contour map and distortion factor tables	11
MAINLP		Subroutine - controls computation of discrete point pressure data for contour mapping	11
MAXDP		Subroutine - calculates projected extreme values of distortion factors	11
MAXIDYN		Main driver computer program	7
MFR		Inlet mass flow ratio - $\dot{m}_2/\dot{m}_0$	30
MO		Freestream Mach number	29
$\dot{m}_0$		Mass flow rate in front of inlet	30
$\dot{m}_2$		Mass flow rate at compressor face measurement plane	30
NEWPSD		Subroutine - inputs dynamic data and evaluates PSD functions	12

SYMBOL	OTHER NAMES	DESCRIPTION	PAGE
NP		Total number of radial rakes	25
NPR	NT, PROBE	Numerical designation of probe	31
NR		Total number of rings, including static pressure rings at hub and outer radius	25
NTUR		Control parameter for selection of dynamic data input or turbulence modelling subroutines	30
P	PI	Local instantaneous total pressure recovery	28
PAVG	PAVE	Average pressure recovery at compressor face measurement plane	37
PFIX		Subroutine - transforms input data into mapping parameters	13
PFX	PFXL	Subroutine - computes vortex flux rate	13
PRNT		Subroutine - prints pressure arrays and other output	13
PROBE	NPR, NT	Numerical designation of probe	31
PS		Local steady-state total pressure recovery	28
PSAVG	SMAVG	Average steady-state total pressure recovery at engine face	37
PSD		Power spectral density function	-
PSI		Aicraft/inlet yaw angle, degrees	29
PSPEC	K, KD, DK	General flow distortion factor designator	26
PT	PT2	Local total pressure recovery at compressor face	37
PTAVG	PTAV, TMAVG	Face average total pressure recovery	37

SYMBOL	OTHER NAMES	DESCRIPTION	PAGE
PTMAX	PTMX, TMMAX	Maximum indicated local total pressure recovery	37
PTMIN	PTMN, TMMIN	Minimum indicated local total pressure recovery	37
QAVG	QAV	Face average dynamic pressure	38
QPT2	Q/PT2	Ratio of dynamic-to-total pressure at engine face	42
RADLOC		Radial position of rings, deg.	25
RATK		Subroutine determines the effect of filter frequencies on distortion factor values	14
RI		Inlet centerbody hub radius in inches (typical units)	41
RKMN		Average total pressure recovery along rake with minimum average pressure	39
RKMX		Average total pressure recovery along rake with maximum average pressure	40
RKP	KR	Radial weighting factor for solution of ID distortion	30
RMS		Root mean square	-
ROUT		Percent difference between the indicated local probe, rake, or ring pressure and the face average pressure	88
RRT	R/RT	Radial location of vortex core (nondimensional)	49
RS		Ratio of filtered-to-unfiltered rms total pressure fluctuations	32
RSIGMA		Subroutine - computes rms value of distortion factors	14

SYMBOL	OTHER NAMES	DESCRIPTION	PAGE
RT		Outer inlet radius (tip) at the compressor face, in	41
SEARCH		Subroutine - controls solution of peak distortion factors	14
SG	SIG	Unfiltered rms total pressure fluctuations	32
SGDK		Filtered rms distortion level	46
SGP		Unfiltered rms distortion level	46
SG/PT2		Ratio of unfiltered rms total pressure fluctuations to average total pressure recovery at engine face	45
SMAVG	PSAVG	Face average static pressure recovery	37
SPTRC		Total pressure recovery through supersonic inlet shock system	30
SUMMER		Subroutine - evaluates error function in vortex core size iterative computations	14
SYMBLE		Subroutine - supplies symbols for distortion contour map generation	15
T	TOP	Time-on-point or data point dwell time - duration of rms pressure fluctuation data measurement , seconds	27
TDP1		Simple distortion parameter: (PTMAX-PTMIN)/PTMAX	95
TDP2		Simple distortion parameter: (PTMAX-PTMIN)/PTAVG	95
TDP3		Simple distortion parameter: (PTAVG-PTMIN)/PTAVG	95
TE	E	Turbulent kinetic energy dissipation rate - ft^2/sec^3	45

SYMBOL	OTHER NAMES	DESCRIPTION	PAGE
THE	THETA	Angular location of the center of the arc DTH, in degrees	40
THMN		Angular location of the rake with minimum rake-average total pressure recovery, degrees	39
THMX		Angular location of the rake with maximum rake-average total pressure recovery, degrees	39
TITLE1		Identification block, also serves to execute end of file	28
TITLE2		Identification title block #2	28
TMAVG	PTAVG	Average total pressure recovery	37
TMMAX	PTMAX	Maximum local total pressure recovery	37
TMMIN	PTMIN	Minimum local total pressure recovery	37
TRIDIA		Subroutine - solves tridiagonal matrix equations	15
TURBUL		Subroutine - manages turbulence modelling predictions and other computations as a subdriver	16
TV	THETA	Angular location of vortex core in degrees	49
UNSTDY		Subroutine - manages dynamic data and peak distortion prediction as a subdriver	15
UU	TUU	Sum of squares of radial and circumferential velocity gradiants	45
U		Dimensionless velocity at each probe location	76
U2		Face average flow velocity , fps	29

SYMBOL	OTHER NAMES	DESCRIPTION	PAGE
VBAR		Average vortex strength, in^2/sec	49
VBM	VBMX	Maximum vortex strength, in^2/sec	50
VBO		Approximated vortex strength	50
VL		Vortex core length limit	49

(Nomenclature Addendum)

SYMBOL	OTHER NAMES	DESCRIPTION	PAGE
ANRTU		Function subprogram - computes vortex flux rate	7
KD		Input variable - user selected primary distortion factor	26
NPG		Data run identification code, or "part-point"	31

LIST OF FIGURES

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 develope 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 it's 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 it's 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 tubulent 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 and engine filters, via subroutine RATK. Subroutine RSIGMA is called to compute the filtered and unfiltered rms level of the distortion factors. Subroutine EXTRME 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 messeges 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 UNSTDY

This subroutine is the primary subdriver responsible for the predictive evaluation of the peak instantaneous distortion. Called by the main driver of MAXIDYN, UNSTDY 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 UNSTDY 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 dy- dynamic data or select the turbulence modelling routines if there is no dynamic data in the input file.

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

26. Subroutine TURBUL

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

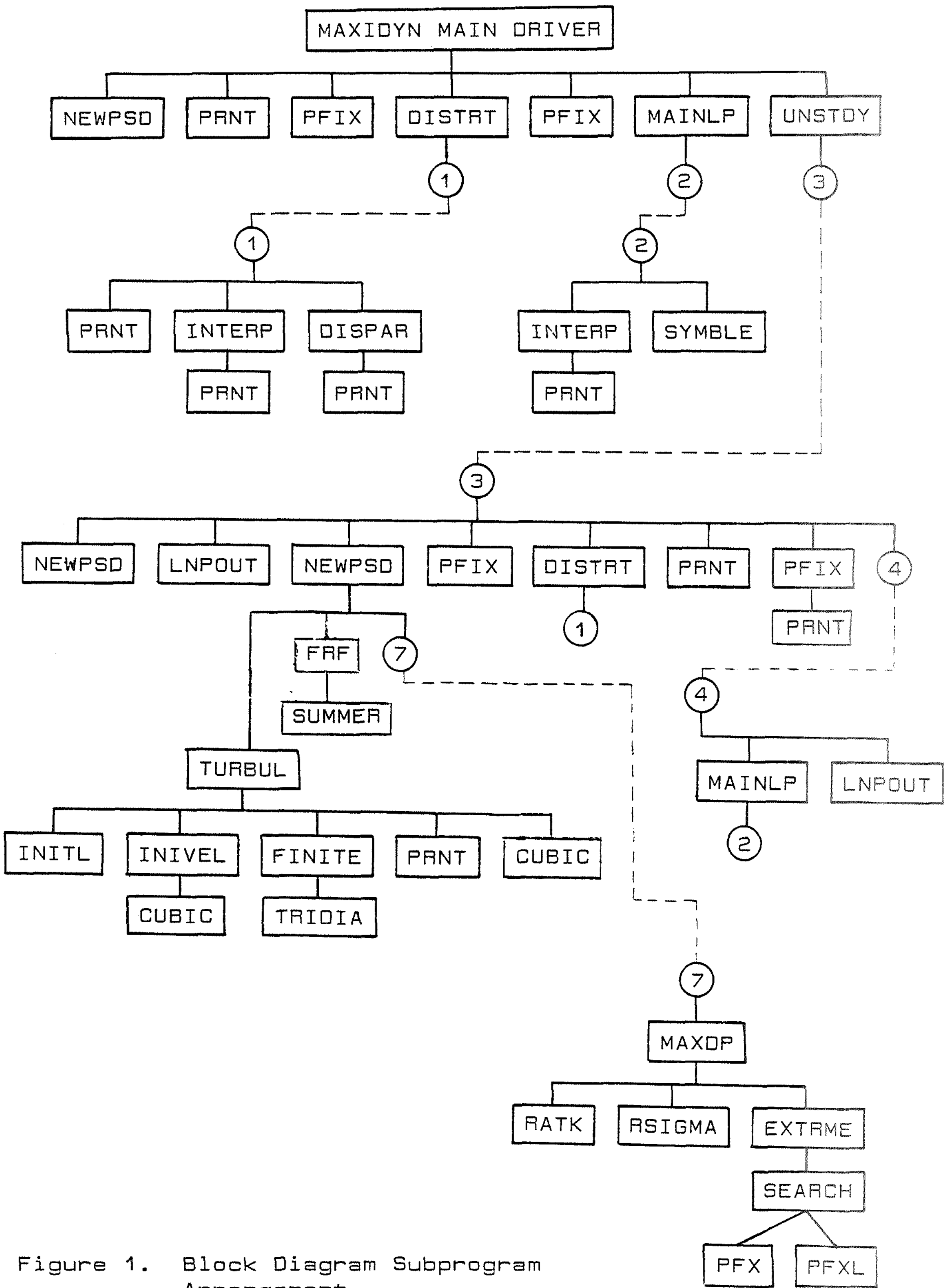


Figure 1. Block Diagram Subprogram Arrangement

II.B. TYPICAL DATA RUN SEQUENCE DESCRIPTION

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

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

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

Subroutine PRNT is then called to print the table of steady-state pressures and the base radial profile. These items are included on the first page of the output. Subroutine PFIX 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 tranforms the input pressure measurements into parameters used by the map-generating subdriver routine MAINLP. MAINLP controls subroutines INTERP and SYMBLE which generate the symbols in the distortion map. INTERP interpolates the pressure at the discrete locations on the engine face based on the steady-state input data, while SYMBLE assigns a character based on the interpolated value at each of the discrete points. After all interpolations and symbol assignments have been completed, MAINLP returns program control to the main driver. At this point the steady-state distortion has been completely defined and the dynamic distortion evaluations are commenced with the calling of the main subdriver, UNSTDY.

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

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

After printing out the identification and control parameters, NEWPSD branches according to the dynamic data option selected by the user. If the no-dynamic-data option has been selected, NEWPSD calls the tubulence 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 tridiagonal 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 funtion of the filtered-to-unfiltered rms pressure fluctuation level ratio using an iterative scheme. FRF calls subroutine SUMMER to evaluate the error function of the inverse solution. After the vortex core size is found, the results are printed by NEWPSD. When all of the dynamic probe data have been read in, subroutine MAXDP is called to compute the most probable maximum instantaneous distortion levels.

MAXDP is the subdriver which controls the computation of the most probable maximum peak in the distortion level. After determining the mean values for the vortex core size and filtered-to-unfiltered rms pressure fluctuation ratio, and the effects of engine filters and vortex flux rates via subroutines RSIGMA and RATK, the rms and mean instantaneous levels are computed by adding a "delta" distortion value to the steady-state value. Subroutine EXTRME is then called to evaluate the most probable (50% confidence level) extreme value of the peak instantaneous distortion. EXTRME utilizes subroutine SEARCH which controls the twin subroutines PFXL and PFX in the determination of the "delta" distortion used to find the maximum instantaneous distortion. EXTRME is also used to determine the distortion factor extreme values for the 95% and 99.7% confidence levels, using the same plan as for the 50% confidence level. After printing the results of these computations, program control is returned to NEWPSD, and then back to UNSTDY.

After re-evaluating the vortex properties for the maximum instantaneous case, UNSTDY finds the pressure recoveries at each of the probe locations based on the predicted maximum instantaneous distortion and the steady-state data. Subroutine PRNT is called to print some output, then PFIX is called to compute flow velocities and Mach number at each of the probe locations. The face-average Mach number for the peak instantaneous case is also determined by PFIX. In the same manner as with the steady-state case, subroutine DISTRT manages the computation of the distortion factors given the total pressure recoveries found by UNSTDY for the maximum instantaneous distortion case. Subroutine MAINLP controls the printing of the pressure distortion contour map for the peak instantaneous case as for the steady-state case, and LNPOUT is again called to assist with the printing of output of the peak instantaneous data. After all the output for the test run has been printed, UNSTDY returns to the main driver. The main driver checks for additional sets of data or new test cases. If there data, then program execution begins with the reading in of data titles and the steady-state pressure data for the new case. If an END OF FILE or ENDJOB 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 frequecies, 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 RADLOC 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. FO and FCO 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:

<u>NR</u> 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.

<u>NP</u> 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.

<u>RADLOC</u> 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: IDC (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.

T * 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.

FO * 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.

FCO * 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

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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.

BRP is the compressor face base radial profile. This is defined as the ratio of the average pressure around a ring to the face-average pressure. BRP is a one-by-NR array with a value at each of the radial locations given by RADLOC. BRP 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 reatio, 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 hilite 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.

<u>NPG</u> 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 the the next phase of computations.

<u>NPR</u> is the numeral designation for the location of the dynamic probe. This identification code can be found with the aid of Figure 4, which is given as an example for the convenience of the user. Other inlet probe and instrumentation configurations may result in a different numeration scheme, so Figure 4 should be used as a guideline.

RS is the ratio of filtered to unfiltered mean square pressure fluctuations. RS is found by squaring the ratio of the rms pressure fluctuation level filtered at the cut-off filter frequency FCO, to the unfiltered level. This ratio is used in the prediction of the maximum instantaneous distortion level, and a default value of 0.50 has been included in the program. In addition, a maximum value of 0.70 has been set to avoid errors in certain computations. These values are easily modified, if necessary, by the user.

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

Sample problems have been included in this manual to illustrate the arrangement of the input data, and to further clarify the utility of the various capabilities of the program. Figures 2 and 3 show formatting rules and the general arrangement scheme of the input data.

CARD 1

FIELD	1-5	6-10
FORMAT	I5	I5
PARAMETER	NR	NP

CARD 2

FIELD	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
FORMAT	F10.5	F10.5	F10.5	F10.5	F10.5	F10.5	F10.5	F10.5
PARAMETER	RADLOC(1)	(2)	(3)	(4)	(5)	---	---	RADLOC(NR)

CARD 3

FIELD	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
FORMAT	F10.5	F10.5	F10.5	F10.5	F10.5	F10.5	F10.5	F10.5
PARAMETER	ANGLOC(1)	(2)	(3)	(4)	(5)	---	---	ANGLOC(NR)

CARD 4

FIELD	6-10	11-20	21-30	31-40
FORMAT	I5	F10.5	F10.5	F10.5
PARAMETER	KD	T	FO	FCO

CARD 5,6

FIELD	1-80
FORMAT	20A4
PARAMETER	TITLE1 and TITLE2

CARD 7.1

FIELD	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
FORMAT	F10.5	F10.5	F10.5	F10.5	F10.5	F10.5	F10.5	F10.5
PARAMETER	BRP(1)	(2)	(3)	(4)	(5)	(6)	(7)	BRP(NR)

⋮

CARD 7.NR

FIELD	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
FORMAT	F10.5	F10.5	F10.5	F10.5	F10.5	F10.5	F10.5	F10.5
PARAMETER	PS(NR,1)	(NR,2)	(NR,3)	(NR,4)	(NR,5)	---	---	PS(NR,NP)

CARD 8

FIELD	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55
FORMAT	F5.3	F5.3	F5.3	F5.3	F5.3	F5.3	F5.3	F5.3	I5	F5.3
PARAMETER	ALPH	PSI	MO	U2	BF	CKP	RKP	MFR	NTUR	SPTRC

CARD 9

FIELD	6-10	11-15	16-20	21-26
FORMAT	I5	I5	F5.3	F6.4
PARAMETER	NPG	NPR	RS	SIG

CARD 10

FIELD	
FORMAT	(BLANK)
PARAMETER	

CARD 11

FIELD	1-80
FORMAT	20A4
PARAMETER	TITLE1 - for new data point set, or END OF FILE card

Figure 2. Batch Input Data Deck Formatting Arrangement

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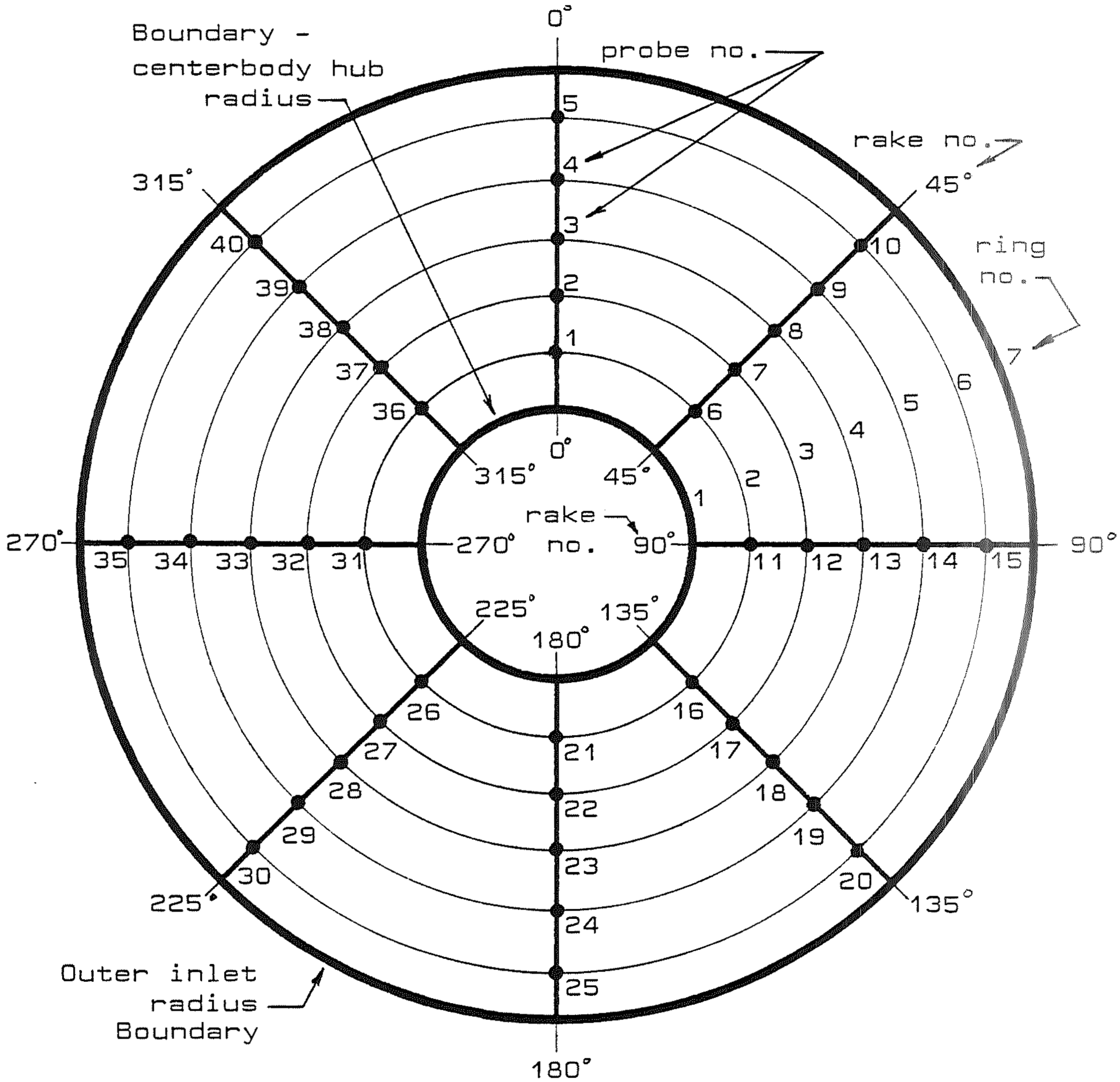
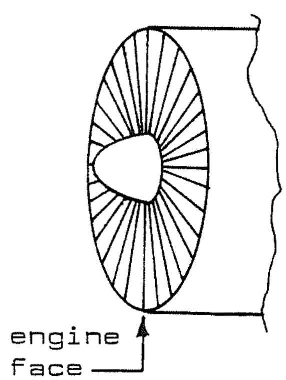
FORTRAN STATEMENT

NR	NP								
RADLOC(1)	RADLOC(2)	RADLOC(3)	RADLOC(4)	RADLOC(5)	RADLOC(6)	RADLOC(7)	RADLOC(8)		
ANGLOC(1)	ANGLOC(2)	ANGLOC(3)	ANGLOC(4)	ANGLOC(5)	ANGLOC(6)	ANGLOC(7)	ANGLOC(8)		
KD	T	FO	FCO						
TITLE1									
TITLE2									
BRP(1)	BRP(2)	BRP(3)	BRP(4)	BRP(5)	BRP(6)	BRP(7)	BRP(8)		
PS(1,1)	PS(1,2)	PS(1,3)	PS(1,4)	PS(1,5)	PS(1,6)	PS(1,7)	PS(1,8)		
PS(2,1)	PS(2,2)	PS(2,3)	PS(2,4)	PS(2,5)	PS(2,6)	PS(2,7)	PS(2,8)		
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮		
PS(NR,1)	PS(NR,2)	PS(NR,3)	PS(NR,4)	PS(NR,5)	PS(NR,6)	PS(NR,7)	PS(NR,8)		
ALPH	PSI	MO	U2	BF	CKP	RKP	MFR	NTUR	SPTRC
NPG	NPR1	RS	SIG						
NPG	NPR2	RS	SIG						
⋮	⋮	⋮	⋮						
NPG	NPRn	RS	SIG						
0.	0.	0.	0.						
TITLE1 (for next run)									

Figure 3. Input Data File Formatting Arrangement





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

Figure 4. Ring, Rake, and Probe Assignments for a typical instrument configuration

IV. PRINTED OUTPUT DATA DESCRIPTION

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

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

Page 1

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

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

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

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

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

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

PSAVG (also SMAVG) This is the average value of static pressure from the static pressure data in the pressure array, PS. The two static pressure rings at the centerbody hub and outer radius of the inlet supply these data.

QAVG (also QAV) This is the face-average dynamic pressure recovery, computed as the difference between the average total pressure recovery and the static pressure. Mathematically stated, QAVG = PTAVG - PSAVG.

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

Following the overall flow descriptors table is a table of flow distortion factors. The eight distortion factors listed in this table are representative of a variety available to the industry, and are intented 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:

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

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

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

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

KRA Pratt & Whitney radial distortion factor - see Figure 9.

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

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

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

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

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

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

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

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

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

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

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

RKMX The average total pressure recovery along the rake designated by THMX.

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

THETA (also THE) The angular location of the rake midway between the rakes designated by THMX and THMN. THETA = ½(THMX + THMN).

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

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

Page 2

The second page of the printed output is the pressure distortion contour map for the steady-state case. A representation of the high and low pressure regions at the compressor face of the enging, 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.

Page 3

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.

FO The engine filter frequency, in Hertz. FO is often associated with the engine rpm speed.

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

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

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

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

SPTRC The total pressure recovery through the inlet shock

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

MO The freestream Mach number.

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

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

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

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

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

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

PROBE The numerical designation for the location of a dynamic probe. See Figure 4

RS The ratio of the filtered to unfiltered mean square total pressure fluctuation level.

SG/PT2 (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 minimised 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 synthisized 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 gradiants in $(ft/sec)^2$.

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

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

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

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

Page 4

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

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 factor (see Fig. 9).

<u>IDR</u> The General Electric radial distortion factor (see Fig. 9).

<u>KRA</u> The Pratt & Whitney radial distortion factor (see Fig. 9).

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

<u>DSPR</u> The loss in stall pressure ratio (see Fig. 9).

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

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

<u>MEAN VALUE</u> The mean instantaneous distortion level, computed by adding the mean instantaneous rms fluctuation level to the steady-state distortion.

<u>SIGMA INF</u> The unfiltered rms distortion fluctuation level.

<u>SIGMA FO</u> The rms distortion fluctuation level, filtered at the engine filter frequency, FO.

<u>MOST PROB</u> 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.

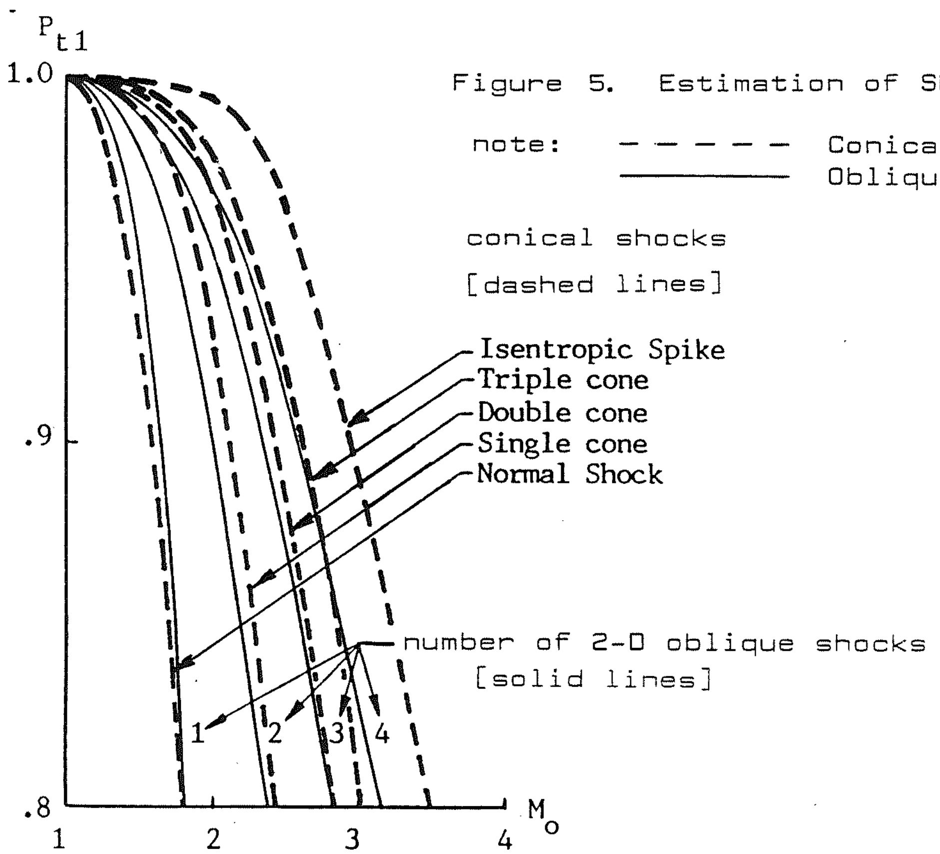


Figure 5. Estimation of SPTRC

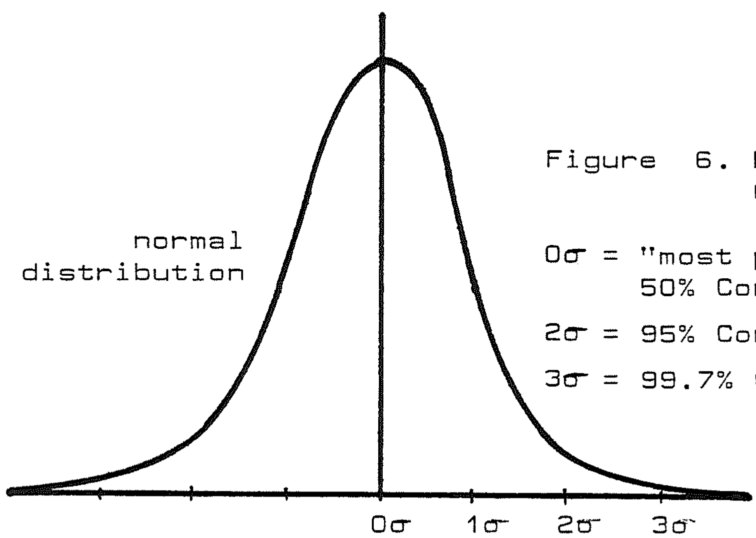


Figure 6. Definition of Confidence Levels

0σ = "most probable" or 50% Confidence Level

2σ = 95% Confidence Level

3σ = 99.7% Confidence Level

confidence level ~ percent of area under curve to left

95% PROB The peak instantaneous distortion level at a 95% confidence level. This is interpreted as meaning there is a 95% chance the actual peak instantaneous distortion level will be less than the indicated level. The likelyhood that the actual peak will reach this level is small.

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

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

Page 5

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

A major difference between the fifth page and the first page is that the vortex properties table has been replaced by a vortex location table, with some new terms. These are defined on the following page. Many of the terms are similar to some of the steady-state vortex properties, though they apply to the peak instantaneous vortex.

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	BRP = 1.000
FO = 500 Hz	MFR = 1.000
FCO = 1000 Hz	SPTRC = 1.000
BF = 1.000	VL = 999.999
RS = 0.500	max RS = 0.700
CKP (or KC) = 16.4	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.

PARAMETER	CASE 1	CASE 2	CASE 3	CASE 4
NR	7	7	7	7
NP	8	8	8	8
RI	1.000	1.430	0.283	1.645
RT	5.169	4.346	1.000	5.000
KD	3 (IDC)	3 (IDC)	3 (IDC)	6 (KA2)
T (sec)	30.0	2.0	2.0	2.0
FO (Hz)	500.0	500.0	1000.0	1000.0
FCO (Hz)	1000.0	400.0	500.0	500.0
ALPH (deg)	4.0	5.0	-	-
PSI (deg)	0.0	0.0	-	-
MO	1.36	2.5	-	-
U2 (fps)	514.3	278.5	432.4	575.8
BF	0.733	0.733	0.733	0.784
CKP/KC	1.0	1.0	-	-
RKP/KR	1.0	1.0	-	-
MFR	-	1.0	-	-
NTUR	-	0	-	1
SPTRC	-	1.0	-	-
probes	40	14	2	0

[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 over-flows, 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.

```
 7      8
1.00000    1.33100   2.58500   3.61500   4.46900   4.96200   5.16900
0.        45.00000  90.00000 135.00000 180.00000 225.00000 270.00000 315.00000
      3   30.00000 500.000001000.00000
          ---          SAMPLE  PROBLEM  #1              ---
                 MU = 1.36            ALPHA = 4.0
1.00000    1.00000   1.00000   1.00000   1.00000   1.00000   1.00000   1.00000
0.86267    0.86144   0.85925   0.85842   0.85609   0.85897   0.85966   0.86322
0.97789    0.98064   0.97899   0.97803   0.97776   0.97831   0.97982   0.98078
0.94175    0.96841   0.94766   0.97789   0.97693   0.97789   0.95962   0.96965
0.95068    0.96498   0.94917   0.97803   0.97652   0.97845   0.95659   0.96044
0.95357    0.97061   0.96855   0.97831   0.97556   0.97886   0.95522   0.96731
0.94862    0.94821   0.95110   0.96030   0.93708   0.95811   0.96882   0.94656
0.86267    0.86144   0.85925   0.85842   0.85609   0.85897   0.85966   0.86322
    4.0   0.0 1.30514.3 .733  1.0  1.0
   1815    10.3380.0022
   1815    20.4030.0027
   1815    30.4460.0026
   1815    40.4600.0032
   1815    50.5380.0032
   1815    60.4880.0012
   1815    70.4110.0028
   1815    80.3890.0029
   1815    90.4180.0026
   1815   100.4380.0023
   1815   110.3630.0015
   1815   120.3820.0029
   1815   130.4300.0035
   1815   140.4510.0022
   1815   150.4580.0031
   1815   160.5370.0010
   1815   170.5200.0010
   1815   180.4950.0011
   1815   190.4790.0011
   1815   200.4180.0021
   1815   210.5170.0010
   1815   220.4110.0011
   1815   230.4690.0003
   1815   240.5100.0012
   1815   250.4480.0020
   1815   260.5880.0010
   1815   270.5310.0010
   1815   280.4240.0003
   1815   290.4970.0011
   1815   300.4040.0021
   1815   310.4970.0011
   1815   320.4030.0022
   1815   330.3800.0023
   1815   340.4320.0021
   1815   350.4690.0021
   1815   360.5600.0010
   1815   370.4250.0026
   1815   380.4240.0025
   1815   390.4550.0028
   1815   400.4450.0026
      0
  ENDJOB
```

Figure 7. Sample Problem Input Data

```
7     8
1.430     1.934     2.669     3.238     3.721     4.151     4.346
   0.       45.       90.      135.      180.      225.      270.      315.
   3       2.0      500.      400.
--    SAMPLE   PROBLEM  NO. 2       MAR. 14, 1981    --
             MO = 2.5        ALPHA = 5.0
1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
 .842      .842      .842      .842      .842      .842      .842      .842
 .905      .908      .885      .883      .881      .888      .874      .883
 .904      .894      .890      .887      .871      .871      .865      .879
 .893      .890      .896      .870      .849      .859      .860      .874
 .894      .896      .882      .847      .842      .851      .858      .874
 .886      .889      .857      .835      .837      .850      .858      .877
 .842      .842      .842      .842      .842      .842      .842      .842
  5.0    0 2.5 278.5  .733   1.0   1.0   1.0   0 1.0
 1184    1 .490.0079
 1184    4 .390.0140
 1184    6 .463.0127
 1184   17 .394.0081
 1184   18 .361.0078
 1184   19 .342.0108
 1184   20 .422.0265
 1184   21 .667.0139
 1184   22 .517.0129
 1184   23 .416.0078
 1184   24 .472.0128
 1184   36 .521.0109
 1184   37 .499.0098
 1184   38 .499.0079
    0    0   0.    0.
 ENDJOB
```

Figure 7. (cont'd)

```
7    8
0.283     0.419     0.599     0.737     0.852     0.953     1.000
    0.       45.       90.      135.      180.      225.      270.      315.
    3       2.0     1000.      500.
  --   SAMPLE PROBLEM #3   -  USAF SUBSONIC INLET - 22 DEC 1983  --
               PART-POINT = 20.40          MO = SUBSONIC
1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
 .804      .804      .804      .804      .804      .804      .804      .804
 .902      .861      .846      .935      .992      .985      .940      .920
 .886      .790      .817      .936      .995      .980      .930      .900
 .857      .783      .814      .955      .965      .962      .946      .871
 .835      .786      .785      .944      .920      .985      .962      .863
 .825      .786      .758      .830      .820      .882      .881      .852
 .804      .804      .804      .804      .804      .804      .804      .804
  0.0      0 0.0 432.4 .733   0.0   0.0
 2040     12 .384 .050
 2040     34 .210 .024
    0      0    0.    0.
  ENDJOB
```

Figure 7. (cont'd)

```
 7    8
 1.645     2.225     3.070     3.725     4.280     4.775     5.000
    0.       45.       90.      135.      180.      225.      270.      315.
    6       2.0     1000.      500.
--  SAMPLE PROBLEM #4  -  USAF TRANSONIC INLET - 22 DEC 1983  --
          PART-POINT = 464.12          M0 = TRANSONIC
 1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
  .721      .721      .721      .721      .721      .721      .721      .721
0.83700   0.85100   0.86800   0.85600   0.84000   0.85200   0.86100   0.84700
0.84000   0.86700   0.91700   0.87200   0.83600   0.86900   0.91100   0.86500
0.83300   0.86900   0.94300   0.87300   0.82500   0.87300   0.94100   0.87200
0.82500   0.85800   0.93200   0.85300   0.80700   0.85400   0.93300   0.86100
0.81100   0.83000   0.87700   0.81900   0.78800   0.81800   0.89200   0.83500
0.72060   0.72060   0.72060   0.72060   0.72060   0.72060   0.72060   0.72060
    0.0      0 0.9 575.8 .784   0.0  0.0   0.0     1
    ENDJOB
```

Figure 7. (cont'd)

\--- SAMPLE PROBLEM #1 ---

MU = 1.36 ALPHA = 4.0

PRESSURE ARRAY

RADIUS	ANGULAR POSITION OF INPUT MEASUREMENTS, DEG							
	0.	45.0	90.0	135.0	180.0	225.0	270.0	315.0
1.331	0.978	0.981	0.979	0.978	0.978	0.978	0.980	0.981
2.585	0.942	0.968	0.948	0.978	0.977	0.978	0.960	0.970
3.615	0.951	0.965	0.949	0.978	0.977	0.978	0.957	0.960
4.469	0.954	0.971	0.969	0.978	0.976	0.979	0.955	0.967
4.962	0.949	0.948	0.951	0.960	0.937	0.958	0.969	0.947

BASE RADIAL PROFILE

RADIT	1.000	1.331	2.585	3.615	4.469	4.962	5.169
PTR/PTA	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

OVERALL FLOW DESCRIPTORS

PTMIN=	0.937	(PTMX-PTMN)/PTMX=	0.0446
PTMAX=	0.981	(PTMX-PTMN)/PTAV=	0.0452
PTAVG=	0.966	(PTAV-PTMN)/PTAV=	0.0298
PSAVG=	0.860	QAVG=	0.1015

FLOW DISTORTION FACTORS

K-THETA	0.06314						
KD2	138.2						
(IDC)-MAX	0.01563						
(IDR)-MAX	0.01397						
KRA	0.07476						
KA2	0.11794	B-FACTOR	0.73300				
DSPR	0.00470						
ID	0.01816	BSF	0.26821	KC	1.000	KR	1.000

VORTEX PROPERTIES

THMN	RKMN	THMX	RKMX	DTH	THETA	A1	G1
0.	0.955	135.00	0.975	135.00	67.50	1.178	90.00

ORIGINAL PAGE IS OF POOR QUALITY

Figure 8. Sample Problem Output

--- SAMPLE PROBLEM #1 ---

MU = 1.36 ALPHA = 4.0

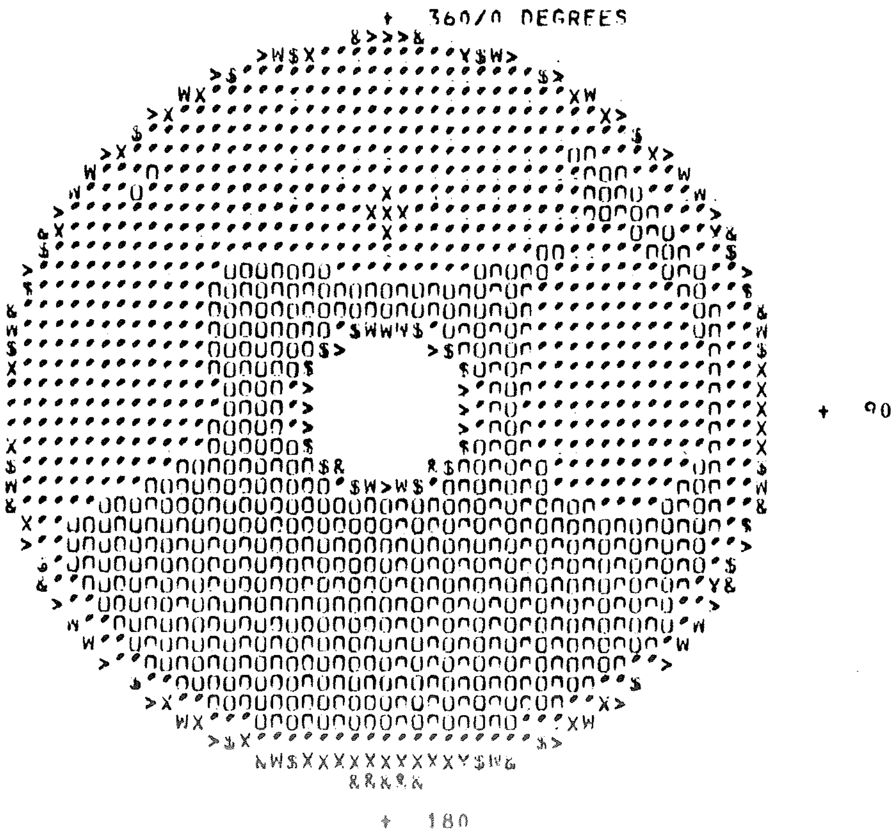
KEY TO MAPPING SYMBOLS

BORDER	./-	-/=	=/+	+/I	I/<	</#	#/S	S/*	*/0	0/'
(PI-PAVG)/PAVG IN PERCENT	18.0	16.0	14.0	12.0	10.0	8.0	6.0	4.0	2.0	0.

BORDER	'/X	X/$	$/W	W/>	>/&	&/Y	Y/H	H/T	T/A
(PI-PAVG)/PAVG	-2.0	-4.0	-6.0	-8.0	-10.0	-12.0	-14.0	-16.0	-18.0

(PI-PAVG)/PAVG PROFILE

AVERAGE PRESSURE= 0.966



<STEADY-STATE DISTORTION>

Figure 8. (cont'd)

--- SAMPLE PROBLEM #1 ---

MO = 1.36 ALPHA = 4.0

T	FO	RT	RT	SPTRC
30.000	500.0	5.169	1.000	1.000

ALPH	PST	MO	ETA	MFR	U2	QPT2
4.000	0.	1.360	0.966	1.000	514.3	0.1051

RS AT FC = 1000.0

PROBE	RS	SG/PT2	A/RT
1	0.3380	0.0022	0.0463
2	0.4030	0.0027	0.0560
3	0.4460	0.0026	0.0626
4	0.4600	0.0032	0.0649
5	0.5380	0.0032	0.0779
6	0.4880	0.0012	0.0694
7	0.4110	0.0028	0.0572
8	0.3890	0.0029	0.0538
9	0.4180	0.0026	0.0583
10	0.4380	0.0023	0.0614
11	0.3630	0.0015	0.0500
12	0.3820	0.0029	0.0528
13	0.4300	0.0035	0.0601
14	0.4510	0.0022	0.0634
15	0.4580	0.0031	0.0645
16	0.5370	0.0010	0.0777
17	0.5200	0.0010	0.0748
18	0.4950	0.0011	0.0706
19	0.4790	0.0011	0.0679
20	0.4180	0.0021	0.0583
21	0.5170	0.0010	0.0743
22	0.4110	0.0011	0.0572
23	0.4690	0.0003	0.0663
24	0.5100	0.0012	0.0731
25	0.4480	0.0020	0.0630
26	0.5880	0.0010	0.0868
27	0.5310	0.0010	0.0766
28	0.4240	0.0003	0.0592
29	0.4970	0.0011	0.0709
30	0.4040	0.0021	0.0561
31	0.4970	0.0011	0.0709
32	0.4030	0.0022	0.0560
33	0.3800	0.0023	0.0525
34	0.4320	0.0021	0.0604
35	0.4690	0.0021	0.0663
36	0.5600	0.0010	0.0817
37	0.4250	0.0026	0.0594
38	0.4240	0.0025	0.0592
39	0.4550	0.0028	0.0641
40	0.4450	0.0026	0.0625

FACE-AVERAGE RMS (SG/PT2) = 0.00212

MEAN VORTEX SIZE (A0/RT) = 0.06473

Figure 8. (cont'd)

--- SAMPLE PROBLEM #1 ---
MO = 1.36 ALPHA = 4.0

DISTORTION FACTOR EXTREME VALUE

FACTOR	STEADY STATE	MEAN VALUE	SIGMA INF	SIGMA FO	MAXIMUM INSTANTANEOUS MOST PROB	MAXIMUM INSTANTANEOUS 95.0% PROB	MAXIMUM INSTANTANEOUS 99.7% PROB
KTTA	0.0631	0.0634	0.0054	0.0028	0.0773	0.0788	0.0795
KD2	138.2	139.4	13.9	7.3	175.9	179.7	181.6
IDC	0.0156	0.0157	0.0010	0.0005	0.0183	0.0186	0.0188
IDR	0.0140	0.0140	0.0004	0.0002	0.0149	0.0150	0.0151
KRA	0.0748	0.0748	0.0034	0.0018	0.0837	0.0846	0.0850
KA2	0.1179	0.1182	0.0059	0.0031	0.1335	0.1350	0.1358
DSPR	0.0047	0.0047	0.0004	0.0002	0.0057	0.0058	0.0058
ID	0.0182	0.0182	0.0005	0.0002	0.0194	0.0195	0.0196

MAXIMUM INSTANTANEOUS DISTORTION FACTOR

IDC = 0.0183

Figure 8. (cont'd)

--- SAMPLE PROBLEM #1 ---

MO = 1.36 ALPHA = 4.0

PRESSURE ARRAY

ANGULAR POSITION OF INPUT MEASUREMENTS, DEG

RADIUS	0.	45.0	90.0	135.0	180.0	225.0	270.0	315.0
1.331	0.975	0.979	0.980	0.981	0.980	0.979	0.979	0.979
2.585	0.939	0.967	0.949	0.981	0.979	0.979	0.959	0.968
3.615	0.948	0.964	0.951	0.981	0.978	0.979	0.956	0.959
4.469	0.951	0.969	0.970	0.981	0.977	0.980	0.955	0.965
4.962	0.946	0.947	0.952	0.963	0.939	0.959	0.968	0.945

BASE RADIAL PROFILE

RADII	1.000	1.331	2.585	3.615	4.469	4.962	5.169
PTR/PTA	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

OVERALL FLOW DESCRIPTORS

PTMIN=	0.939	(PTMX-PTMN)/PTMX=	0.0429
PTMAX=	0.981	(PTMX-PTMN)/PTAV=	0.0436
PTAVG=	0.966	(PTAV-PTMN)/PTAV=	0.0279
PSAVG=	0.860	QAVG=	0.1015

FLOW DISTORTION FACTORS

K-THETA	0.07663						
KD2	176.0						
(TDC)-MAX	0.01607						
(TDR)-MAX	0.01397						
KRA	0.07476						
KA2	0.13143	B-FACTOR	0.73300				
D3PR	0.00624						
ID	0.01828	BSF	0.26821	KC	1.000	KR	1.000

VORTEX LOCATION

VBAR	A/RT	GAMMA	BETA	AY/RT	VI	R/RT	THETA
0.013	1.178	90.0	0.	1.178	999.999	0.597	67.50

VBMX	VRO	A0/RT
1.063	0.027	0.0647

Figure 8. (cont'd)

--- SAMPLE PROBLEM #1 ---

MU = 1.36 ALPHA = 4.0

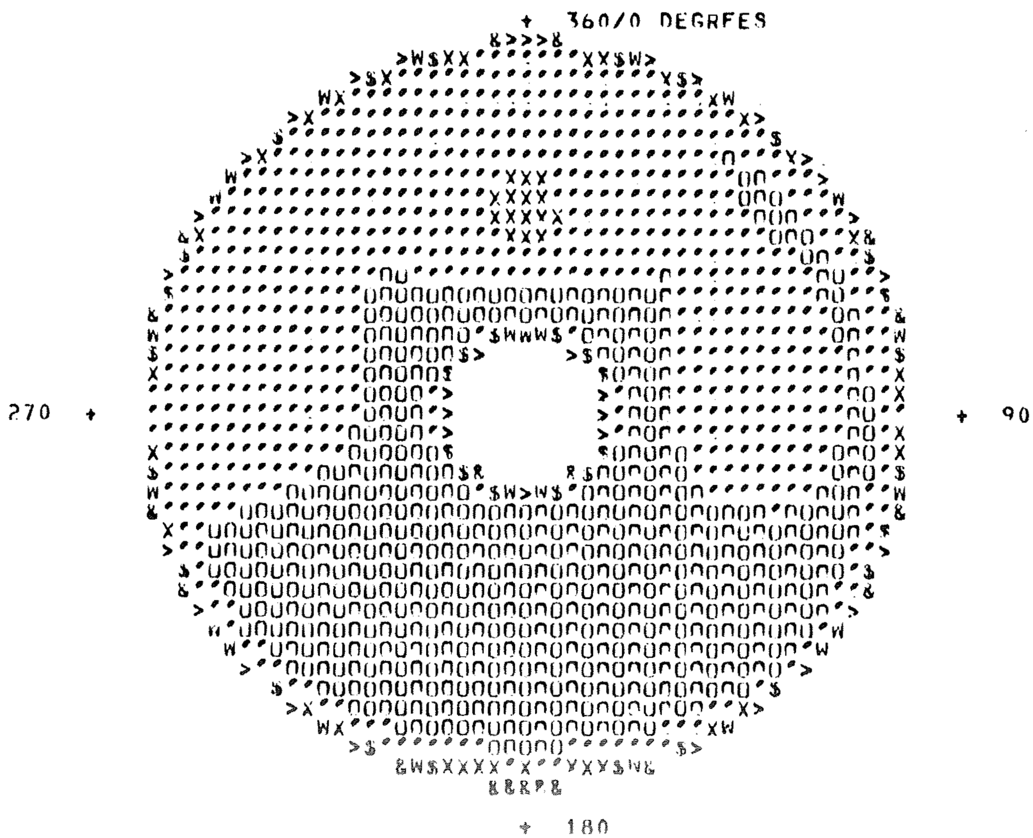
KEY TO MAPPING SYMBOLS

BORDER	./-	-/=	=/+	+/I	I/<	</#	#/S	S/*	*/O	O/'
(PI-PAVG)/PAVG IN PERCENT	18.0	16.0	14.0	12.0	10.0	8.0	6.0	4.0	2.0	0.

'/X	X/$	$/W	W/>	>/&	&/Y	Y/H	H/T	T/A
-2.0	-4.0	-6.0	-8.0	-10.0	-12.0	-14.0	-16.0	-18.0

(PI-PAVG)/PAVG PROFILE

AVERAGE PRESSURE= 0.966



<PEAK DISTORTION>

Figure 8. (cont'd)

-- SAMPLE PROBLEM NO. 2 MAR. 14, 1981 --
MO = 2.5 ALPHA = 5.0

PRESSURE ARRAY

RADIUS	ANGULAR POSITION OF INPUT MEASUREMENTS, DEG							
	0.	45.0	90.0	135.0	180.0	225.0	270.0	315.0
1.934	0.905	0.908	0.885	0.883	0.881	0.888	0.874	0.883
2.669	0.904	0.894	0.890	0.887	0.871	0.871	0.865	0.879
3.238	0.893	0.890	0.896	0.870	0.849	0.859	0.860	0.879
3.721	0.894	0.896	0.882	0.847	0.842	0.851	0.858	0.874
4.151	0.886	0.889	0.857	0.835	0.837	0.850	0.858	0.877

BASE RADIAL PROFILE

RADII	1.430	1.934	2.669	3.238	3.721	4.151	4.346
PTR/PTA	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

OVERALL FLOW DESCRIPTORS

PTMIN=	0.835	(PTMX-PTMN)/PTMX=	0.0804
PTMAX=	0.908	(PTMX-PTMN)/PTAV=	0.0834
PTAVG=	0.875	(PTAV-PTMN)/PTAV=	0.0455
PSAVG=	0.842	QAVG=	0.0324

FLOW DISTORTION FACTORS

K-THETA	0.58596						
KD2	462.7						
(IDC)-MAX	0.02979						
(IDR)-MAX	0.01563						
KRA	0.27757						
KA2	0.78942	B-FACTOR	0.73300				
DSPR	0.01518						
ID	0.02539	BSF	0.32740	KC	1.000	KR	1.000

VORTEX PROPERTIES

THMN	RKMN	THMX	RKMX	DTH	THETA	A1	C1
180.00	0.856	0.	0.896	180.00	90.00	1.571	-90.00

Figure 8. (cont'd)

-- SAMPLE PROBLEM NO. 2 MAR. 14, 1981 --

M0 = 2.5 ALPHA = 5.0

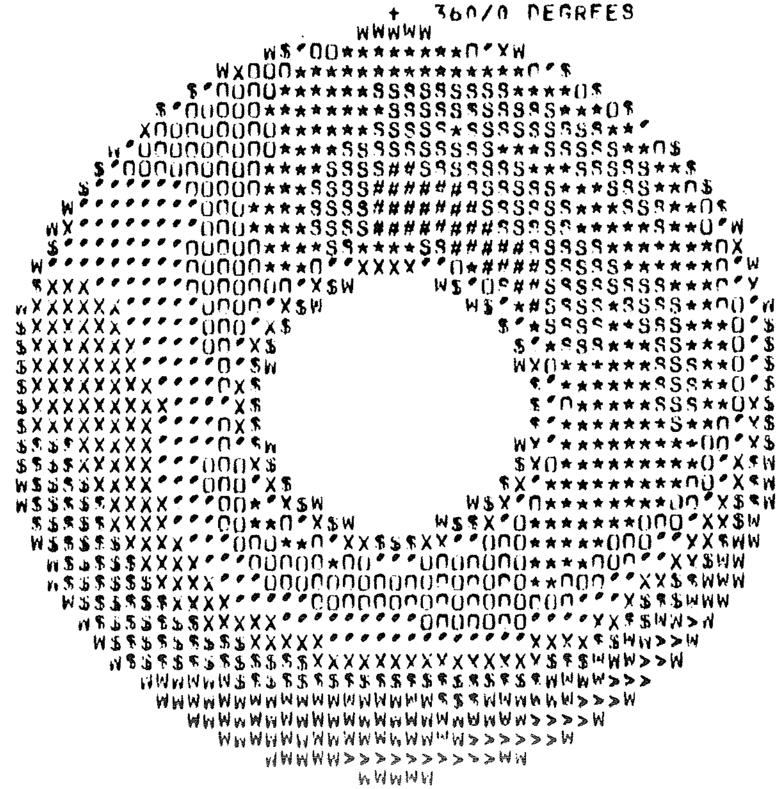
KEY TO MAPPING SYMBOLS

BORDER	./=	=/=	=/+	+/I	1/<	</#	#/S	S/*	*/O	O/'
(PT-PAVG)/PAVG IN PERCENT	9.0	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.

'/X	X/$	$/W	W/>	>/&	&/Y	Y/H	H/T	T/A
-1.0	-2.0	-3.0	-4.0	-5.0	-6.0	-7.0	-8.0	-9.0

(PT-PAVG)/PAVG PROFILE

AVERAGE PRESSURE= 0.875



<STEADY-STATE DISTORTION>

Figure 8. (cont'd)

** SAMPLE PROBLEM NO. 2 MAR. 14, 1981 **
MO = 2.5 ALPHA = 5.0

T	FO	RT	RT	SPTRC
2.000	500.0	4.346	1.430	1.000

ALPH	PSI	MO	ETA	MFR	U2	WPT2
5.000	0.	2.500	0.875	1.000	279.5	0.0370

RS AT FC = 400.0

PROBE	RS	SG/PT2	A/RT
1	0.4900	0.0079	0.1123
4	0.3900	0.0140	0.0869
6	0.4630	0.0127	0.1052
17	0.3940	0.0081	0.0879
18	0.3610	0.0078	0.0800
19	0.3420	0.0108	0.0754
20	0.4220	0.0265	0.0948
21	0.6670	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 (AO/RT) = 0.10779

DISTORTION FACTOR EXTREME VALUE

FACTOR	STEADY STATE	MEAN VALUE	SIGMA INF	SIGMA FO	MAXIMUM INSTANTANEOUS MOST PROB	95.0% PROB	99.7% PROB
KTTA	0.5860	0.5999	0.1069	0.0801	0.9427	0.9996	1.0459
KD2	462.7	475.7	34.7	26.0	582.7	600.2	614.4
IDC	0.0298	0.0312	0.0025	0.0018	0.0389	0.0401	0.0412
IDR	0.0156	0.0157	0.0007	0.0005	0.0178	0.0181	0.0184
KRA	0.2776	0.2811	0.0541	0.0405	0.4563	0.4856	0.5095
KA2	0.7894	0.8060	0.1140	0.0854	1.1638	1.2226	1.2701
DSPR	0.0152	0.0153	0.0023	0.0018	0.0227	0.0239	0.0249
TD	0.0254	0.0259	0.0011	0.0008	0.0291	0.0297	0.0301

MAXIMUM INSTANTANEOUS DISTORTION FACTOR

IDC = 0.0389

Figure 8. (cont'd)

```
--   SAMPLE  PROBLEM  NO. 2      MAR. 14, 1981   --
             M0 = 2.5      ALPHA = 5.0

                 PRESSURE ARRAY

RADIUS              ANGULAR POSITION OF INPUT MEASUREMENTS, DEG
             0.     45.0    90.0    135.0   180.0   225.0   270.0   315.0

 1.934      0.914   0.914   0.885   0.877   0.872   0.881   0.870   0.890
 2.669      0.913   0.900   0.890   0.881   0.862   0.864   0.861   0.886
 3.238      0.902   0.896   0.896   0.864   0.840   0.852   0.856   0.881
 3.721      0.903   0.902   0.882   0.841   0.833   0.844   0.854   0.881
 4.151      0.895   0.895   0.857   0.829   0.828   0.843   0.854   0.884

                 BASE RADIAL PROFILE

   RADII      1.430   1.934   2.669   3.238   3.721   4.151   4.346

   PTR/PTA   1.0000  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000

                   OVERALL FLOW DESCRIPTORS

             PTMIN=  0.878   (PTMX-PTMN)/PTMX=  0.0937
             PTMAX=  0.914   (PTMX-PTMN)/PTAV=  0.0980
             PTAVG=  0.874   (PTAV-PTMN)/PTAV=  0.0524
             PSAVG=  0.842               QAVG=  0.0324

   FLOW DISTORTION FACTORS

   K-THETA          0.83940
   KD2                568.8
   (IDC)-MAX        0.03786
   (IDR)-MAX        0.01564
   KRA              0.27757
   KA2              1.04286   B-FACTOR       0.73300
   DSPR             0.02184
   ID               0.02803   BSF 0.32740  KC    1.000   KR   1.000

                 VORTEX LOCATION

  VBAR    A/RT  GAMMA   BETA    AY/RT     VL     R/RT    THETA
 0.131   1.571  -90.0    0.     1.571  999.999   0.665   90.00

  VBMX    VBU    A0/RT
 1.402   0.464  0.1078
```

Figure 8. (cont'd)

-- SAMPLE PROBLEM NO. 2 MAR. 14, 1981 --
MO = 2.5 ALPHA = 5.0

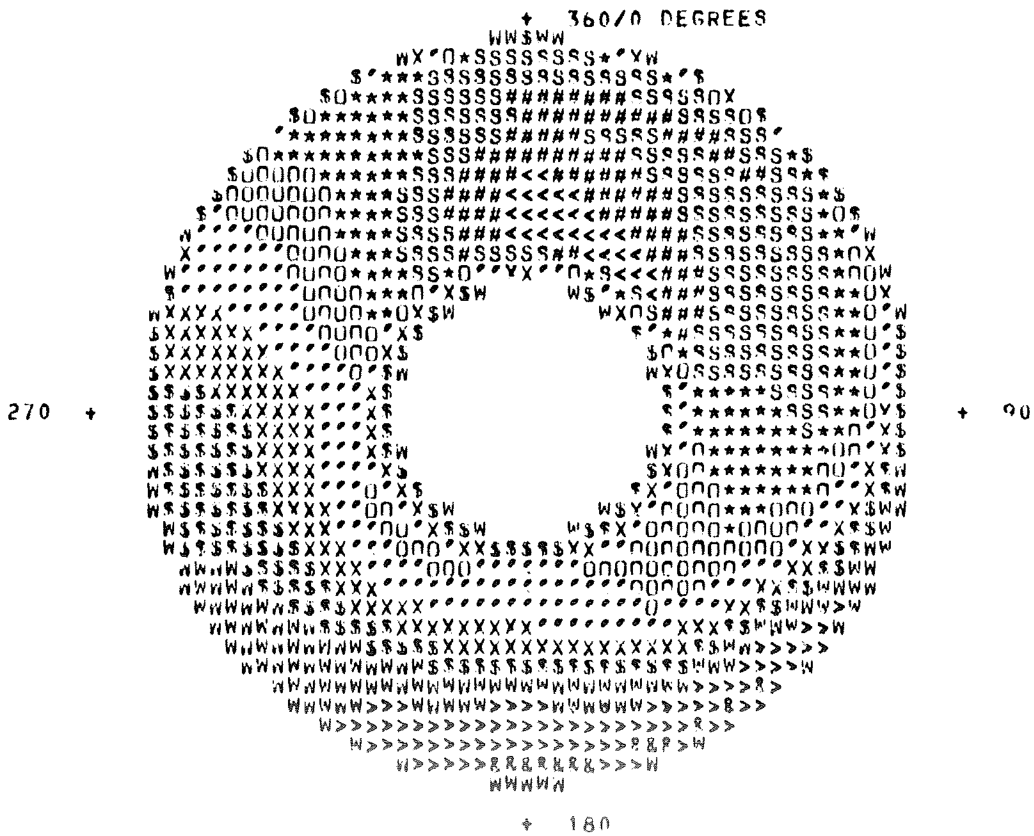
KEY TO MAPPING SYMBOLS

BORDER	./-	-/=	=/+	+/I	I/<	</#	#/S	S/*	*/O	O/'
(PI-PAVG)/PAVG IN PERCENT	9.0	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.

'/X	X/$	$/W	W/>	>/&	&/Y	Y/H	H/T	T/A
-1.0	-2.0	-3.0	-4.0	-5.0	-6.0	-7.0	-8.0	-9.0

(PI-PAVG)/PAVG PROFILE

AVERAGE PRESSURE= 0.874



<PEAK DISTORTION>

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Figure 8. (cont'd)

-- SAMPLE PROBLEM #3 - USAF SUBSONIC INLET - 22 DEC 1983 --
PART-POINT = 20.40 MO = SUBSONIC

PRESSURE ARRAY

RADIUS	ANGULAR POSITION OF INPUT MEASUREMENTS, DEG 0.	45.0	90.0	135.0	180.0	225.0	270.0	315.0
0.419	0.902	0.861	0.846	0.935	0.992	0.985	0.940	0.920
0.599	0.886	0.790	0.817	0.936	0.995	0.980	0.930	0.900
0.737	0.857	0.783	0.814	0.955	0.965	0.962	0.946	0.871
0.852	0.835	0.786	0.785	0.944	0.920	0.985	0.962	0.863
0.953	0.825	0.786	0.758	0.830	0.820	0.882	0.881	0.852

BASE RADIAL PROFILE

RADII	0.283	0.419	0.599	0.737	0.852	0.953	1.000
PTR/PTA	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

OVERALL FLOW DESCRIPTORS

PTMIN=	0.758	(PTMX-PTMN)/PTMX=	0.2382
PTMAX=	0.995	(PTMX-PTMN)/PTAV=	0.2672
PTAVG=	0.897	(PTAV-PTMN)/PTAV=	0.1455
PSAVG=	0.804	QAVG=	0.0802

FLOW DISTORTION FACTORS

K-THETA	0.95777						
KD2	1801.4						
(IDC)-MAX	0.10759						
(IDR)-MAX	0.06516						
KRA	0.30434						
KA2	1.18085	B-FACTOR		0.73300			
DSPR	0.05760						
ID	1.26570	BSF	0.30742	KC	16.400	KR	11.100

VORTEX PROPERTIES

THMN	RKMN	THMX	RKMX	DTH	THETA	A1	G1
45.00	0.801	225.00	0.959	180.00	135.00	1.571	90.00

Figure 8. (cont'd)

-- SAMPLE PROBLEM #3 -. USAF SUBSONIC INLET - 22 DEC 1983 --
PART-POINT = 20.40 MO = SUBSONIC

KEY TO MAPPING SYMBOLS

BORDER (PI-PAVG)/PAVG IN PERCENT	./-	-/=	=/+	+/I	I/<	</#	#/S	S/*	*/0	0/'
	18.0	16.0	14.0	12.0	10.0	8.0	6.0	4.0	2.0	0.

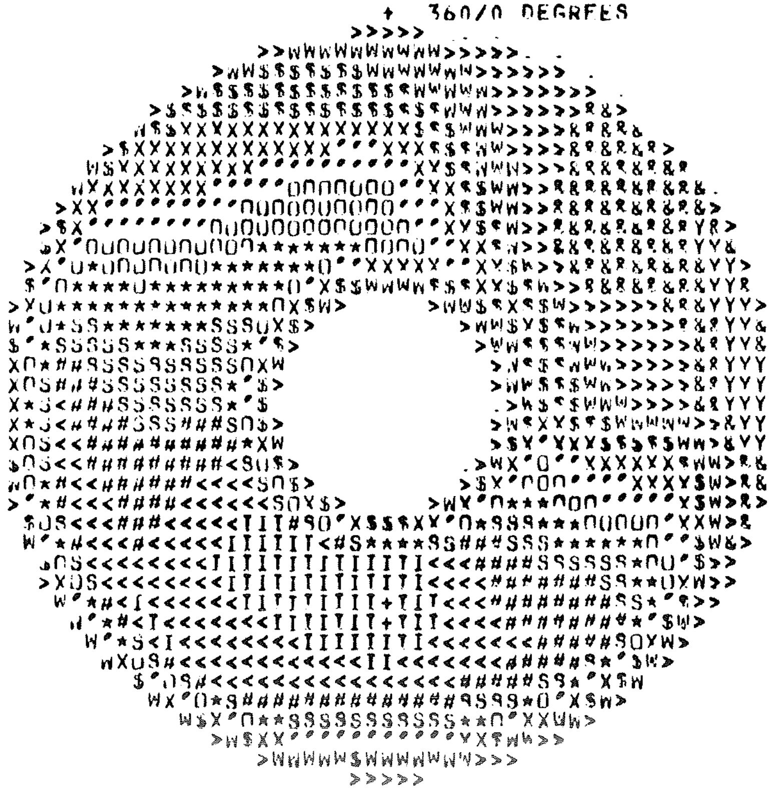
'/X	X/$	$/W	W/>	>/&	&/Y	Y/H	H/T	T/A
-2.0	-4.0	-6.0	-8.0	-10.0	-12.0	-14.0	-16.0	-18.0

(PI-PAVG)/PAVG PROFILE

AVERAGE PRESSURE= 0.887

+ 360/0 DEGREES

270 +



+ 90

+ 180

<STEADY-STATE DISTORTION>

Figure 6. (cont'd)

-- SAMPLE PROBLEM #3 -. USAF SUBSONIC INLET - 22 DEC 1983 --
PART-POINT = 20.40 MO = SUBSONIC

T	FO	RT	RI	SPTRC
2.000	1000.0	1.000	0.283	1.000

ALPH	PSI	MO	FTA	MFR	U2	QPT2
0.	0.	0.	0.887	1.000	432.4	0.0904

RS AT FC = 500.0

PROBE	RS	SG/PT2	A/RT
12	0.3840	0.0500	0.4614
34	0.2100	0.0240	0.2450

FACE-AVERAGE RMS (SG/PT2) = 0.03922

MEAN VORTEX SIZE (AO/RT) = 0.36942

DISTORTION FACTOR EXTREME VALUE

FACTOR	STEADY STATE	MEAN VALUE	SIGMA INF	SIGMA FO	MAXIMUM INSTANTANEOUS MOST PROB	95.0% PROB	99.7% PROB
KTTA	0.9578	0.9740	0.2082	0.1568	1.6387	1.7605	1.8604
KD2	1801.4	1856.8	314.1	236.5	2829.3	3001.3	3140.7
IDC	0.1076	0.1162	0.0201	0.0151	0.1786	0.1896	0.1986
IDR	0.0652	0.0662	0.0033	0.0025	0.0759	0.0776	0.0789
KRA	0.3043	0.3184	0.0419	0.0315	0.4455	0.4678	0.4857
KA2	1.1809	1.2074	0.2105	0.1585	1.8610	1.9772	2.0712
DSPR	0.0576	0.0583	0.0126	0.0095	0.0985	0.1059	0.1120
ID	1.2657	1.3208	0.1076	0.0810	1.6458	1.7028	1.7488

MAXIMUM INSTANTANEOUS DISTORTION FACTOR

IDC = 0.1786

Figure 6. (cont'd)

-- SAMPLE PROBLEM #3 -. USAF SUBSONIC INLET - 22 DEC 1983 --
PART-POINT = 20.40 MO = SUBSONIC

PRESSURE ARRAY

ANGULAR POSITION OF INPUT MEASUREMENTS, DEG

RADIUS	0.	45.0	90.0	135.0	180.0	225.0	270.0	315.0
0.419	0.851	0.798	0.800	0.935	1.038	1.048	0.991	0.948
0.599	0.835	0.727	0.771	0.936	1.041	1.043	0.981	0.928
0.737	0.806	0.720	0.768	0.955	1.011	1.025	0.997	0.899
0.852	0.784	0.723	0.739	0.944	0.966	1.048	1.013	0.891
0.953	0.774	0.723	0.712	0.830	0.866	0.945	0.932	0.880

BASE RADIAL PROFILE

RADII	0.283	0.419	0.599	0.737	0.852	0.953	1.000
PTR/PTA	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

OVERALL FLOW DESCRIPTORS

PTMIN=	0.712	(PTMX-PTMN)/PTMX=	0.3210
PTMAX=	1.048	(PTMX-PTMN)/PTAV=	0.3779
PTAVG=	0.891	(PTAV-PTMN)/PTAV=	0.2007
PSAVG=	0.804	QAVG=	0.0802

FLOW DISTORTION FACTORS

K-THETA	1.77307						
KD2	2820.4						
(TDC)-MAX	0.17394						
(TDR)-MAX	0.06490						
KRA	0.30434						
KA2	1.99615	B-FACTOR		0.73300			
DSPR	0.10752						
ID	1.59735	BSF	0.30742	KC	16.400	KR	11.100

VORTEX LOCATION

VBAR	A/RT	GAMMA	BETA	AY/RT	VI	R/RT	THETA
0.395	1.571	90.0	0.	1.571	999.999	0.642	135.00

VRMX	VRU	A0/RT
1.461	0.590	0.3694

Figure 6. (cont'd)

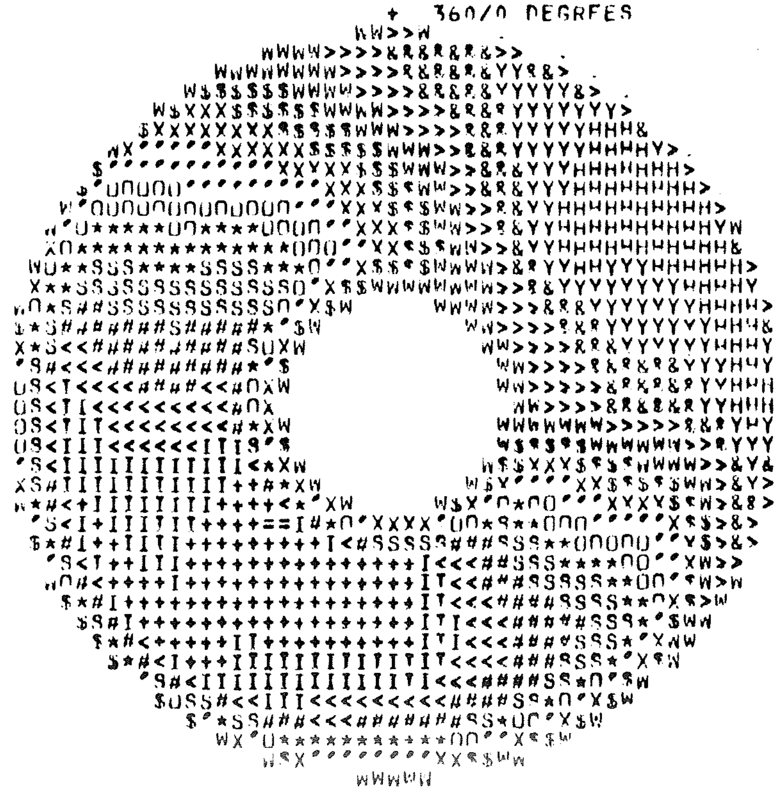
```
--  SAMPLE PROBLEM #3  -  USAF SUBSONIC INLET - 22 DEC 1983  --
          PART-POINT = 20.40          MO = SUBSONIC
                    KEY TO MAPPING SYMBOLS
BORDER            ./=    -/=    =/+    +/I    I/<    </#    #/S    S/*    */O    O/'
(PI-PAVG)/PAVG   22.5   20.0   17.5   15.0   12.5   10.0    7.5    5.0    2.5    0.
IN PERCENT

                         '/X    X/$    $/W    W/>    >/&    &/Y    Y/H    H/T    T/A
                        -2.5   -5.0   -7.5  -10.0  -12.5  -15.0  -17.5  -20.0  -22.5
                              (PI-PAVG)/PAVG  PROFILE
```

AVERAGE PRESSURE= 0.891

+ 360/0 DEGREES

270 +



+ 90

+ 180

<PEAK DISTORTION>

Figure 6. (cont'd)

-- SAMPLE PROBLEM #4 - USAF TRANSONIC INLET - 22 DEC 1983 --
PART-POINT = 464.12 MO = TRANSONIC

PRESSURE ARRAY

RADIUS	ANGULAR POSITION OF INPUT MEASUREMENTS, DEG							
	0.	45.0	90.0	135.0	180.0	225.0	270.0	315.0
2.225	0.837	0.851	0.868	0.856	0.840	0.852	0.861	0.847
3.070	0.840	0.867	0.917	0.872	0.836	0.869	0.911	0.865
3.725	0.833	0.869	0.943	0.873	0.825	0.873	0.941	0.872
4.280	0.825	0.858	0.932	0.853	0.807	0.854	0.933	0.861
4.775	0.811	0.830	0.877	0.819	0.788	0.818	0.892	0.835

BASE RADIAL PROFILE

RADII	1.645	2.225	3.070	3.725	4.280	4.775	5.000
PTR/PTA	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

OVERALL FLOW DESCRIPTORS

PTMIN=	0.788	(PTMX-PTMN)/PTMX=	0.1644
PTMAX=	0.943	(PTMX-PTMN)/PTAV=	0.1802
PTAVG=	0.860	(PTAV-PTMN)/PTAV=	0.0840
PSAVG=	0.721	QAVG=	0.1308

FLOW DISTORTION FACTORS

K-THETA	0.03551						
KD2	452.6						
(IDC)-MAX	0.06052						
(IDR)-MAX	0.03083						
KRA	0.10017						
KA2	0.11405	B-FACTOR	0.78400				
DSPR	0.00238						
ID	0.67161	BSF 0.33185	KC	16.400	KR	11.100	

VORTEX PROPERTIES

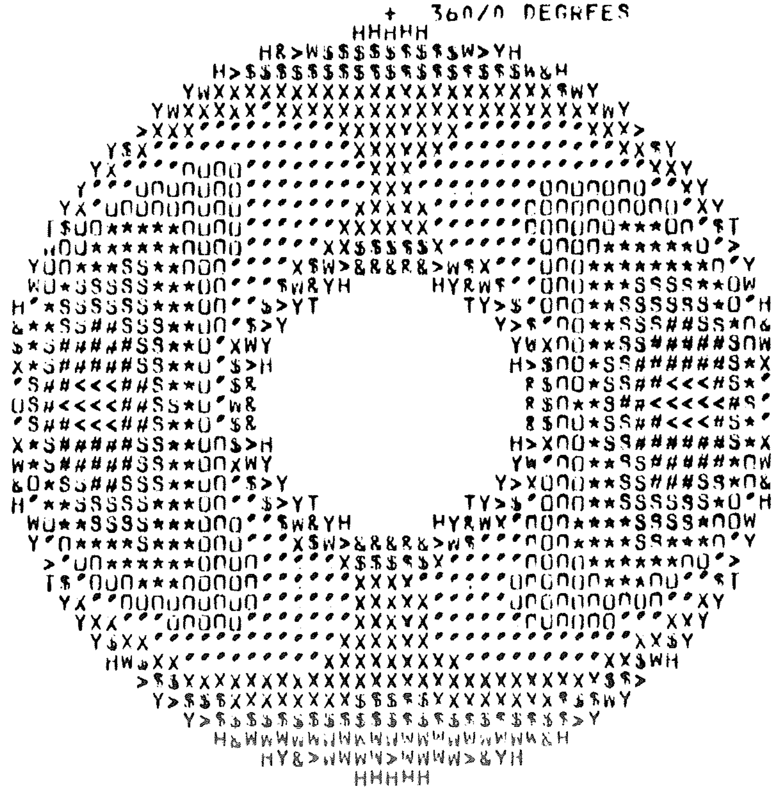
THMN	RKMN	THMX	RKMX	DTH	THETA	A1	C1
180.00	0.819	270.00	0.908	90.00	-135.00	0.785	90.00

Figure 6. (cont'd)

```
--  SAMPLE PROBLEM #4  -  USAF TRANSONIC INLET - 22 DEC 1983  --
         PART-POINT = 464.12              MO = TRANSONIC
                         KEY TO MAPPING SYMBOLS
BORDER           ./-   -/=   =/+   +/I   I/<   </#   #/S   S/*   */O   O/'
(PI-PAVG)/PAVG  18.0  16.0  14.0  12.0  10.0   8.0   6.0   4.0   2.0   0.
IN PERCENT

                 '/X   X/$   $/W   W/>   >/&   &/Y   Y/H   H/T   T/A
                -2.0  -4.0  -6.0  -8.0 -10.0 -12.0 -14.0 -16.0 -18.0
                      (PI-PAVG)/PAVG  PROFILE
```

AVERAGE PRESSURE= 0.860



<STEADY-STATE DISTORTION>

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Figure 6. (cont'd)

```
--  SAMPLE PROBLEM #4  -  USAF TRANSONIC INLET - 22 DEC 1983  --
            PART-POINT = 464.12              MO = TRANSONIC

    T        FO        RT        RI      SPTRC
  2.000   1000.0     5.000     1.645     1.000

  ALPH      PSI        MO       ETA       MFR       U2      QPT2
  0.        0.       0.900     0.860     1.000    575.8    0.1520

 RS AT FC =    500.0

TURBULENCE CALCULATIONS :

 DIMENSIONLESS VELOCITY AT EACH PROBE LOCATION:
  27.87    26.37    26.69    25.93    25.04    23.37    0.
  27.87    27.82    29.38    29.57    28.52    25.60    0.
  27.87    29.47    33.68    35.65    34.83    30.30    0.
  27.87    28.32    29.85    29.94    28.02    24.34    0.
  27.87    26.69    26.26    25.04    22.87    20.29    0.
  27.87    27.92    29.57    29.94    28.12    24.22    0.
  27.87    28.81    33.20    35.50    34.91    31.62    0.
  27.87    27.42    29.19    29.85    28.81    26.15    0.

 ERRORS IN K, E AND (K+E) OF EACH ITERATION:
         15.36497         52.56748         67.93246
          8.17813          8.42651         16.60464
          3.96146          3.57977          7.54123
          2.55916          2.31696          4.87612
          1.83772          1.64211          3.47984
          1.40335          1.24322          2.64657
          1.10800          0.97559          2.08359
          0.89188          0.78194          1.67382
          0.72644          0.63496          1.36140
          0.59620          0.51999          1.11619
          0.49182          0.42829          0.92011
          0.40719          0.35419          0.76138
          0.33801          0.29379          0.63179
          0.28112          0.24422          0.52534
          0.23415          0.20336          0.43751
          0.19525          0.16955          0.36480
          0.16296          0.14150          0.30446
          0.13610          0.11819          0.25429
          0.11373          0.09877          0.21249
          0.09507          0.08258          0.17765
          0.07950          0.06907          0.14857
          0.06649          0.05778          0.12426
          0.05563          0.04835          0.10398
          0.04654          0.04046          0.08700
          0.03894          0.03387          0.07281
          0.03259          0.02835          0.06094
          0.02727          0.02373          0.05101
          0.02283          0.01986          0.04270
          0.01911          0.01664          0.03575
          0.01600          0.01392          0.02992
```

Figure 6. (cont'd)

-- SAMPLE PROBLEM #4 - USAF TRANSONIC INLET - 22 DEC 1983 --
PART-POINT = 464.12 MO = TRANSONIC

RESULTS OF TURBULENCE CALCULATIONS:

PROBE	UU	E	K	SG/PT2
1	1.4448	2236.3714	120.9109	0.031157
2	9.2138	2486.2515	128.6876	0.032748
3	53.8775	2745.8098	135.8546	0.032908
4	157.1748	3020.2345	142.8482	0.032833
5	5434.5535	3315.1465	149.8993	0.031811
6	68.5994	2093.5900	98.7376	0.029223
7	90.7128	2476.5374	105.5357	0.032221
8	107.7526	2923.0317	113.1623	0.033786
9	411.0606	3447.4029	121.6877	0.033907
10	10674.3311	4066.7809	131.2077	0.031811
11	328.9029	1603.3533	71.0785	0.025860
12	363.1044	1933.9231	73.2679	0.030837
13	6.8060	2435.1411	78.3018	0.034355
14	532.8087	3170.0668	86.2044	0.035154
15	20992.1580	4222.9423	97.1550	0.031811
16	67.8584	2407.4271	104.5073	0.030784
17	101.5759	2888.2705	111.9544	0.033925
18	185.2175	3464.3006	120.5637	0.035539
19	790.1339	4157.7780	130.4113	0.034695
20	13829.8063	4995.9947	141.6096	0.031811
21	6.9353	2893.2974	135.3699	0.033772
22	39.2705	3342.0105	146.9025	0.034959
23	207.7453	3794.7266	157.3540	0.034903
24	519.1988	4269.7131	167.4694	0.033573
25	8048.2910	4780.7404	177.6324	0.031811
26	62.4443	2409.1980	103.2728	0.030112
27	107.1068	2930.1115	111.1357	0.033433
28	160.3528	3554.2982	120.2175	0.035479
29	802.5839	4311.6639	130.6648	0.034863
30	14972.7083	5235.0960	142.6111	0.031811
31	335.7476	1476.2798	70.4834	0.025077
32	442.0766	1707.2749	71.8314	0.029971
33	21.0620	2052.2888	75.4039	0.033483
34	320.6582	2543.4345	81.1118	0.034095
35	14572.3846	3223.6260	89.0140	0.031811
36	69.7910	2023.5076	99.0392	0.028819
37	130.0550	2348.8047	104.6667	0.031841
38	120.1257	2734.4349	111.1492	0.033783
39	396.8805	3189.9798	118.5119	0.033746
40	9608.6600	3729.7290	126.8308	0.031811

FACE-AVERAGE RMS (SG/PT2) = 0.03249

MEAN VORTEX SIZE (AO/RT) = 0.16525

Figure 6. (cont'd)

-- SAMPLE PROBLEM #4 - USAF TRANSONIC INLET - 22 DEC 1983 --
PART-POINT = 464.12 MO = TRANSONIC

DISTORTION FACTOR EXTREME VALUE

FACTOR	STEADY STATE	MEAN VALUE	SIGMA INF	SIGMA FO	MAXIMUM INSTANTANEOUS MOST PROB	MAXIMUM INSTANTANEOUS 95.0% PROB	MAXIMUM INSTANTANEOUS 99.7% PROB
KTTA	0.0355	0.1158	0.0385	0.0335	0.2627	0.2853	0.3031
KD2	452.6	833.5	410.1	356.4	2341.7	2509.5	2636.1
IDC	0.0605	0.0854	0.0293	0.0255	0.1971	0.2139	0.2271
IDR	0.0308	0.0314	0.0061	0.0053	0.0546	0.0587	0.0621
KRA	0.1002	0.1042	0.0299	0.0260	0.2189	0.2382	0.2538
KA2	0.1140	0.1974	0.0451	0.0392	0.3682	0.3978	0.4220
DSPK	0.0024	0.0066	0.0021	0.0018	0.0147	0.0159	0.0169
ID	0.6716	0.8136	0.1736	0.1508	1.4685	1.5834	1.6777

MAXIMUM INSTANTANEOUS DISTORTION FACTOR

KA2 = 0.3682

Figure 6. (cont'd)

** SAMPLE PROBLEM #4 - USAF TRANSONIC INLET - 22 DEC 1983 **
PART-POINT = 464.12 MO = TRANSONIC

PRESSURE ARRAY

RADIUS	ANGULAR POSITION OF INPUT MEASUREMENTS, DEG 0.	45.0	90.0	135.0	180.0	225.0	270.0	315.0
2.225	0.840	0.851	0.865	0.830	0.783	0.852	0.918	0.873
3.070	0.843	0.867	0.914	0.846	0.779	0.869	0.968	0.891
3.725	0.836	0.869	0.940	0.847	0.768	0.873	0.998	0.898
4.280	0.828	0.858	0.929	0.827	0.750	0.854	0.990	0.887
4.775	0.814	0.830	0.874	0.793	0.731	0.818	0.949	0.861

BASE RADIAL PROFILE

RADII	1.645	2.225	3.070	3.725	4.280	4.775	5.000
PTR/PTA	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

OVERALL FLOW DESCRIPTORS

PTMIN=	0.731	(PTMX-PTMN)/PTMX=	0.2678
PTMAX=	0.998	(PTMX-PTMN)/PTAV=	0.3107
PTAVG=	0.860	(PTAV-PTMN)/PTAV=	0.1505
PSAVG=	0.721	QAVG=	0.1308

FLOW DISTORTION FACTORS

K-THETA	0.26719						
KD2	1221.6						
(TDC)-MAX	0.12698						
(TDR)-MAX	0.03083						
KRA	0.10017						
KA2	0.34573	B-FACTOR	0.78400				
DSPR	0.02846						
ID	1.03333	BSF	0.33185	KC	16.400	KR	11.100

VORTEX LOCATION

VBAR	A/RT	GAMMA	BETA	AY/RT	VI	R/RT	THETA
0.218	0.785	90.0	0.	0.785	999.999	0.664	-135.00

VBRX	VBU	A0/RT
1.225	0.291	0.1653

Figure 6. (cont'd)

-- SAMPLE PROBLEM #4 - USAF TRANSONIC INLET - 22 DEC 1983 --

PART-POINT = 464.12 MO = TRANSONIC

KEY TO MAPPING SYMBOLS

BORDER	./-	-/=	=/+	+/I	I/<	</#	#/S	S/*	*/O	O/'
(PI-PAVG)/PAVG IN PERCENT	18.0	16.0	14.0	12.0	10.0	8.0	6.0	4.0	2.0	0.

'/X	X/$	$/W	W/>	>/&	&/Y	Y/H	H/T	T/A
-2.0	-4.0	-6.0	-8.0	-10.0	-12.0	-14.0	-16.0	-18.0

(PI-PAVG)/PAVG PROFILE

AVERAGE PRESSURE= 0.860

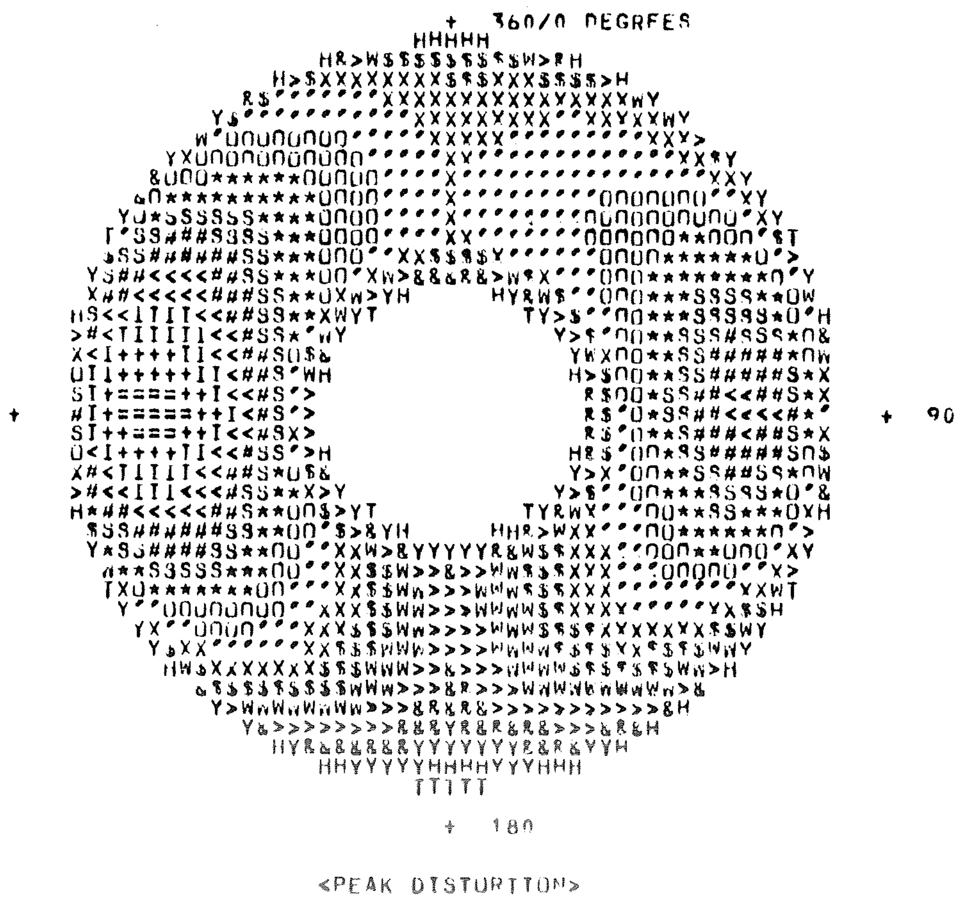
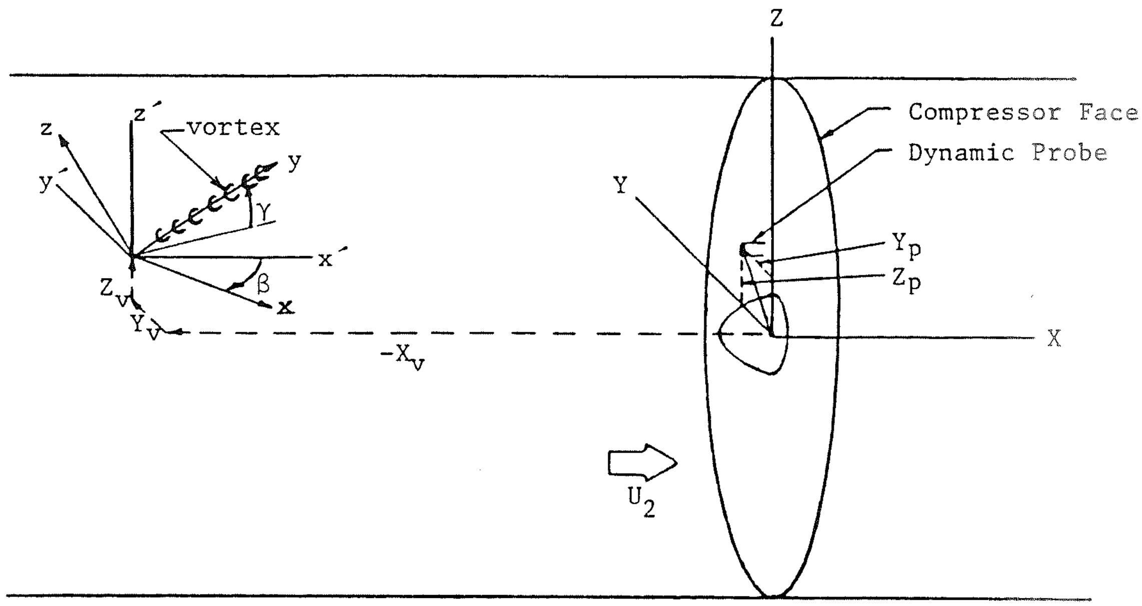


Figure 6. (cont'd)

Factor	Equation	Supplemental equations	Definitions
IDC_{max}	$IDC_{max}=\max\left[\tfrac{1}{2}(IDC_1+IDC_2),\ \tfrac{1}{2}(IDC_4+IDC_5)\right]$	$IDC_j=\dfrac{(\bar{p}_t)_j-(p_{t,min})_j}{\bar{p}_t}$	$(\bar{p}_t)_j$ = average total pressure for ring j $(p_{t,min})_j$ = minimum total pressure reading in ring j $\bar{p}_t$ = average total pressure at engine face
IDR_{max}	$IDR_{max}=\max(IDR_1, IDR_5)$	$IDR_j=\dfrac{\bar{p}_t-(\bar{p}_t)_j}{\bar{p}_t}$	
K_{D2}	$K_{D2}=\dfrac{\sum_{j=1}^{NR}\bar{\theta}_j(\Delta p_t/p_t)(OD/D_j)}{\sum_{j=1}^{NR}(OD/D_j)}$	$\dfrac{\Delta p_t}{p_t}=\dfrac{(\bar{p}_t)_j-(p_{t,min})_j}{(\bar{p}_t)_j}*100$	$(\bar{p}_t)_j, (p_{t,min})_j$ = see above $\bar{\theta}_j$ = circumferential extent of largest continuous total pressure depression below $(\bar{p}_t)_j$, degrees D_j = diameter of ring j; NR = number of ring OD = outer duct diameter
K_θ	$K_\theta=\dfrac{\sum_{j=1}^{NR}(A_1)_j(1/D_j)}{(\bar{q}/\bar{p}_t)\sum_{j=1}^{NR}(1/D_j)}$	$(A_1)_j=\left(\sqrt{a_1^2+b_1^2}\right)_j$ $(a_1)_j=\dfrac{1}{M}\left[\sum_{i=1}^{M}\dfrac{p_{t_i}}{\bar{p}_t}\cos(\theta_i)\right]_j$ $(b_1)_j=\dfrac{1}{M}\left[\sum_{i=1}^{M}\dfrac{p_{t_i}}{\bar{p}_t}\sin(\theta_i)\right]_j$	$\bar{p}_t, (\bar{p}_t)_j, D_j$ = see above $\bar{q}$ = average dynamic pressure at engine face M = number of rakes $(p_{t_i})_j$ = individual total pressure; rake i, ring j θ = angular position of p_{t_i}
K_{RAD}	$K_{RAD}=\sum_{j=1}^{NR}\left\lvert\dfrac{\Delta p_{t_j}}{\bar{p}_t}\right\rvert\dfrac{\bar{p}_t}{\bar{q}}\dfrac{1}{D_j}$	$\dfrac{\Delta p_{t_j}}{\bar{p}_t}=\dfrac{(\bar{p}_t)_j}{\bar{p}_t}-\dfrac{(p_{t,base})_j}{\bar{p}_t}$	$\dfrac{(p_{t,base})_j}{\bar{p}_t}$ = base radial profile for ring j; set = 1 for all j
K_{A2}	$K_{A2}=K_\theta+bK_{RAD}$		b = radial distortion weighting factor=1.0
$\dfrac{\Delta SPR}{Dist}$	$\dfrac{\Delta SPR}{Dist}=\dfrac{\Delta SPR}{\left[(\bar{p}_t-p_{t,min})/\bar{p}_t\right]}=f(k)$		$\bar{p}_t$ = see above $p_{t,min}$ = minimum total pressure at engine face k = compressor reduced frequency
ID	$ID=k_c(IDC)b+k_r(IDR)$		k_c = circumferential distortion sensitivity factor k_r = radial distortion sensitivity factor b = circumferential distortion weighting factor

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)

```
c    MAXIDYN DISTORTION PROGRAM - MAIN DRIVER
c
c
c    PRELIMINARY DECLARATIONS AND DESIGNATIONS
c
         COMMON  AB,ANGLOC(20),AUD,BETA2,BF,CDPOP3(10),CMAVG(10),FO,ISHFT,
        & CMMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
        & J1,J2,KEY,KD,LCNTFL,NN,NP,NR,P(11,20),PR(10),PS(11,20),CKP,
        & PSPEC(20),PVALUE,QAV,QPT2,R,RADLOC(11),RANGE,RI,RMAV,BRP(11),
        & RT,SGDK(10),SGP(10),SIG,SMAVG,STATI,STATO,T,TDP1,TDP2,TMMIN,
        & TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG,TMMAX,RKP,U2
c
         LOGICAL STATI,STATO,LCNTFL
         LCNTFL=.FALSE.
         STATI=.TRUE.
         STATO=.TRUE.
         DIMENSION DRT(11)
c
c    INPUT PROBE CONFIGURATION.
c    NR IS NUMBER OF RINGS, PLUS 2 TO INCLUDE CENTERBODY AND OUTER RADIUS
c    NP IS THE NUMBER OF RADIAL RAKES
c    RADLOC IS RADIAL LOCATION OF CENTERBODY, RINGS AND OUTER INLET RADIUS
c    ANGLOC IS ANGULAR LOCATION OF RAKES IN DEGREES. TOP RAKE IS '0'
c
         READ (5,100) NR,NP
         READ (5,101) (RADLOC(J), J=1,NR)
         READ (5,101) (ANGLOC(I), I=1,NP)
         J1=1
         IF (STATI) J1=2
         J2=NR
         IF (STATO) J2=NR-1
         FACTOR=RADLOC(NR)/19.1
c
c    CALL NEWPSD TO INPUT DISTORTION KEY, DWELL TIME AND FILTER FREQUENC.
c
         CALL NEWPSD (1)
   10    ISHFT=1
c
c    INPUT DATA TITLES AND COMMENTS, CHECKING FIRST FOR END OF FILE.
c
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      READ(5,124,END=999) TITLE1
 20   READ (5,124) TITLE2
c
c  INPUT BASE RADIAL PROFILE
c
      READ (5,101) (BRP(J),J=1,NR)
      DO 25 J=1,11
 25   IF (BRP(J).EQ.0.0) BRP(J)=1.0
c
c  INPUT STEADY STATE PRESSURE AND PLACE INTO ARRAY 'P'
c
      DO 30 J=1,NR
      DRT(J)=(RADLOC(J)-RADLOC(1))/(RADLOC(7)-RADLOC(1))
      READ (5,101) (PS(J,I), I=1,NP)
      DO 30 I=1,NP
 30   P(J,I)=PS(J,I)
      WRITE (7) (DRT(J),J=1,NR),(BRP(J),J=1,NR)
      BF=1.0
c
c  CALL PRNT TO PRINT STEADY STATE PRESSURE ARRAY.
c
      CALL PRNT (2)
c
c  CALL SUBROUTINES WHICH CALCULATE DISTORTION PARAMETERS.
c
      CALL PFIX (.TRUE.)
      CALL DISTRT
c
c  CALL PFIX TO TRANSFORM INPUT MEASUREMENTS INTO MAPPING PARAMETERS.
c
      CALL PFIX(.FALSE.)
c
c  MAINLP CONTROLS INTERPOLATION PROCESS IN INPUT MEASUREMENT PLANE
c
      CALL MAINLP
      ISHFT=2
c
c  CALL SUBROUTINE TO COMPUTE MAXIMUM INSTANTANEOUS DISTORTION VALUES
c  AND INSTANTANEOUS PRESSURE MAPS. UNSTDY ALSO CONTROLS THE OUTPUT.
c
```

```
      CALL UNSTDY
      GO TO 10
C
  999 STOP
  100 FORMAT(2I5)
  101 FORMAT (8F10.5)
  124 FORMAT (20A4)
      END
C
C
```

```
c
      SUBROUTINE PFXL (AKS,DKS,ANT)
c
c THIS SUBROUTINE SOLVES (KMAX-KBAR)/SIGMA K FOR KBAR/SIGMA K.LE. 2.0
c
      DKS=0.0
      IF (ANT.LE.1.0) GO TO 200
      IF (AKS.LE.0.0) GO TO 200
      X=ALOG(ANT)
      A=2.9564*AKS**0.8641
      B=0.0047+0.3865/AKS
      XO=0.6909+0.1817/AKS
      AN=0.5625+0.58/AKS**0.707
      DX=X-XO
      IF (DX.LE.0.0) GO TO 200
      DKS=A*(1.0-EXP(-B*DX**AN))
c
  200 RETURN
      END
c
c ----------------------------------------------------------------------
```

```
C
      SUBROUTINE LNPOUT(KY)
C
C  THIS SUBROUTINE CONTROLS THE OUTPUT
C  SOME OUTPUT IS CONTROLLED BY 'CARDRD' AND 'PFIX'.
C  NP,RADLOC,ANGLOC,AND P HAVE FIRST ARRAY DIMENSION EQUAL TO 11. TEN OF
C  THESE ARE AVAILABLE FOR USE. 11TH IS NEEDED FOR INTERNAL PROCESSING.
C
      COMMON  AB,ANGLOC(20),AUD,BETA2,BF,CDPOP3(10),CMAVG(10),FD,ISHFT,
     & CMMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
     & J1,J2,KEY,KD,LCNTFL,NN,NP,NR,P(11,20),PR(10),PS(11,20),CKP,
     & PSPEC(20),PVALUE,QAV,QPT2,R,RADLOC(11),RANGE,RI,RMAV,BRP(11),
     & RT,SGDK(10),SGP(10),SIG,SMAVG,STATI,STATO,T,TDP1,TDP2,TMMIN,
     & TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG,TMMAX,RKP,U2
C
      DIMENSION ROUT(19),FACP(65),FACB(65)
      LOGICAL STATI,STATO,LCNTFL
      IF (KY-2) 30,20,20
 20   WRITE (6,190) TITLE1,TITLE2
      WRITE (6,105)
C
C  OUTPUT SECTION FOR (PI-PAVG)/PAVG MAP
C
      DO 22 I=1,19
 22   ROUT(I)=FLOAT(10-I)*(RANGE/20.0)
      WRITE (6,107)
      WRITE (6,110) (ROUT(I),I=1,10)
      WRITE (6,109)
      WRITE (6,407)
      WRITE (6,111) (ROUT(I),I=11,19)
      WRITE (6,128) TMAVG
      WRITE (6,120)
      DO 10 I=1,39
      DO 100 J=1,51
 100  FACP(J)=FACE(I,J)
      IF (I.NE.20)   WRITE (6,101) (FACP(J), J=1,51)
 10   IF (I.EQ.20)   WRITE (6,121) (FACP(J), J=1,51)
      WRITE (6,122)
      GO TO 16
 30   WRITE (6,219)  TMMIN,TDP1,TMMAX,TDP2,TMAVG,TDP3,SMAVG,QAV
```

```
C
C  OUTPUT SECTION FOR USER-DEFINED DISTORTION PARAMETERS.
C
      WRITE (6,301)  (PSPEC(I), I=1,6), BF, PSPEC(7)
      WRITE (6,302) PSPEC(8),BSF,CKP,RKP
C
 101  FORMAT (14X,51A1)
 105  FORMAT(37X,22HKEY TO MAPPING SYMBOLS)
 107  FORMAT (2X,6HBORDER,11X, 57H./-    -/=    =/+    +/I    I/<    </#    #/
    &S    S/♦    ♦/O    O/')
 109  FORMAT (2X,10HIN PERCENT)
 110  FORMAT (2X,14H(PI-PAVG)/PAVG,20(1X,F5.1))
 111  FORMAT (22X,10F6.1)
 120  FORMAT (//39X,16H+  360/0 DEGREES/)
 121  FORMAT (  6X,6H270  +,2X,51A1,2X,5H+  90)
 122  FORMAT (  /39X,6H+  180)
 128  FORMAT (32X,23H(PI-PAVG)/PAVG  PROFILE32X,16HAVERAGE PRESSURE
    & 1H=,F7.3)
 190  FORMAT (1H1,6X,20A4/6X,20A4)
 219  FORMAT (//33X,24HOVERALL FLOW DESCRIPTORS//
    &                    25X,6HPTMIN=,F7.3,3X,17H(PTMX-PTMN)/PTMX=,F7.4/
    &                    25X,6HPTMAX=,F7.3,3X,17H(PTMX-PTMN)/PTAV=,F7.4/
    &                    25X,6HPTAVG=,F7.3,3X,17H(PTAV-PTMN)/PTAV=,F7.4/
    &                    25X,6HPSAVG=,F7.3,15X,5HQAVG=,F7.4)
C
C  SECTION FOR FORMATS FOR THE OUTPUT OF USER DEFINED DISTORTION FACTORS
C
 301  FORMAT (//11X,23HFLOW DISTORTION FACTORS//
    &     11X,11HK-THETA     ,F11.5/11X,11HKD2         ,F11.1/
    &     11X,11H(IDC)-MAX   ,F11.5/11X,11H(IDR)-MAX   ,F11.5/
    &     11X,11HKRA         ,F11.5/11X,11HKA2         ,F11.5,
    &      3X,11HB-FACTOR    ,F11.5/11X,11HDSPR        ,F11.5)
 302  FORMAT (11X,2HID,9X   ,F11.5,3X,3HBSF,F8.3,5H    KC,F8.3
    &  5H   KR,F8.3)
 407  FORMAT (/25X,     51H'/X   X/$   $/W   W/>   >/&   &/Y   Y/H   H/
    &T   T/A)
C
  16  RETURN
      END
C
```

```
c ------------------------------------------------------------------------
c
      SUBROUTINE RATK (RKFK,FABUD)
c
c THIS IS THE FILTER ROUTINE.
c
      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))
c
   40 RETURN
      END
c
c ------------------------------------------------------------------------
```

```
c
      SUBROUTINE SUMMER (X,ERF,KODE)
c
c THIS SUBROUTINE SOLVES THE ERROR FUNCTION.
c
      DIMENSION XT( 30)
      DATAJ/1/
      IF (J-2) 10,30,30
   10 DO 20 K=1,30
      N=2*(K-1)+1
      E=303.0/N
      IF (E .GT. 38.) E=38.0
   20 XT(K)=10.0**E
      J=2
      CHECK=0.00001
   30 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.GT.XT(I)) GO TO 60
      N=I-1
      AN=2.0*AN
      IF (N.EQ.0) AN=1.0
      ND=2*N+1
      D=D*ND
      XX=X**ND
      TERM=AN*XX/D
      IF (TERM.LT.CHECK) GO TO 60
      SUM=SUM+TERM
      R=TERM/SUM
      IF (R.LT.CHECK) GO TO 60
   50 CONTINUE
   60 ERF=1.12838*EXP(-X*X)*SUM
   70 IF (KODE-2) 90,80,80
   80 ERF=1.0-ERF
c
   90 RETURN
      END
```

```
C
C -----------------------------------------------------------------------
C
      SUBROUTINE MAINLP
C
C  DRIVING SUBROUTINE WHICH INDEXES THROUGH THE GRID POINTS
C  IN THE INPUT MEASUREMENT PLANE.
C  NP, RADLOC, ANGLOC, AND P HAVE THE FIRST
C  ARRAY DIMENSION EQUAL TO 11.  TEN OF THE
C  11 POSITIONS ARE AVAILABLE FOR USE.  THE
C  REMAINING POSITION IS NEEDED FOR INTERNAL PROCESSING.
C
      COMMON  AB,ANGLOC(20),AUO,BETA2,BF,CDPOP3(10),CMAVG(10),FO,ISHFT,
     & CMMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
     & J1,J2,KEY,KD,LCNTFL,NN,NP,NR,P(11,20),PR(10),PS(11,20),CKP,
     & PSPEC(20),PVALUE,QAV,QPT2,R,RADLOC(11),RANGE,RI,RMAV,BRP(11),
     & RT,SGDK(10),SGP(10),SIG,SMAVG,STATI,STATO,T,TDP1,TDP2,TMMIN,
     & TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG,TMMAX,RKP,U2
C
      DATA BLANK/1H /,PLUS/1H+/
C
C  CALCULATION OF R AND THETA
C  APPROX. 1.0R(OUTER) <-- Y --> APPROX. -1.0R(OUTER)
C  APPROX. -1.0R(OUTER) <-- X --> APPROX. 1.0R(OUTER)
C  FACTOR%  SEE LINE 39 OF SUBROUTINE CARDRD
C
      DO 10 IO=1,39
      DO 10 JO=1,51
      Y=(FLOAT(20-IO))*FACTOR
      X=((FLOAT(JO-26))/1.306)*FACTOR
      R=SQRT(X*X+Y*Y)
      IF (X.EQ.0.0) GO TO 26
      OMEGA=ATAN(ABS(Y/X))
      GO TO 27
   26 OMEGA=1.5708
C
C  CHANGING FROM CONVENTIONAL R-OMEGA SYSTEM TO THE
C  R-THETA SYSTEM USED IN THE INTEPOLATION PROCESS.
C
   27 IF (X.GE.0.0.AND.Y.GE.0.0) THETA=1.5708-OMEGA
```

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```
      IF (X.GE.0.0.AND.Y.LT.0.0) THETA=1.5708+OMEGA
      IF (X.LT.0.0.AND.Y.LT.0.0) THETA=4.71239-OMEGA
      IF (X.LT.0.0.AND.Y.GE.0.0) THETA=4.71239+OMEGA
      IF (THETA.GE.6.28318) THETA=6.28318
      IF (THETA.LT.0.0) THETA=0.0
      THETA=THETA*(360.0/6.28318)
c
c   MAKE MAP ROUND OR ELSE
c
      IF (R.LT.RADLOC(1).OR.R.GT.RADLOC(NR)) GO TO 9
c
c   CALLING INTERPOLATION AND SYMBOL SUBROUTINE.
c
      CALL INTERP
      CALL SYMBLE
      FACE(ID,JD)=PVALUE
      GO TO 10
9     FACE(ID,JD)=BLANK
10    CONTINUE
c
      RETURN
      END
c
c ---------------------------------------------------------------
```

```
C
      SUBROUTINE DISTRT
C
C     SUBROUTINE WHICH CALCULATES SIMPLE DISTORTION PARAMETERS.
C     NP, RADLOC, ANGLOC, AND P HAVE THE FIRST
C     ARRAY DIMENSION EQUAL TO 11.  TEN OF THE
C     11 POSITIONS ARE AVAILABLE FOR USE.  THE
C     REMAINING POSITION IS NEEDED FOR INTERNAL PROCESSING.
C
      COMMON  AB,ANGLOC(20),AUD,BETA2,BF,CDPOP3(10),CMAVG(10),FO,ISHFT,
     & CMMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
     & J1,J2,KEY,KD,LCNTFL,NN,NP,NR,P(11,20),PR(10),PS(11,20),CKP,
     & PSPEC(20),PVALUE,QAV,QPT2,R,RADLOC(11),RANGE,RI,RMAV,BRP(11),
     & RT,SGDK(10),SGP(10),SIG,SMAVG,STATI,STATO,T,TDP1,TDP2,TMMIN,
     & TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG,TMMAX,RKP,U2
C
      DIMENSION SEG(10), RADP(8,10), THTTOT(10), CMMAX(10)
      LOGICAL STATI,STATO,LCNTFL,LADD
C
C     CALCULATION OF SIMPLE CIRCUMFERENTIAL DISTORTION PARAMETERS.
C
      DO 10 I=J1,J2
C
C     CALCULATION OF CMMAX,CMMIN, AND CMAVG FOR EACH RING
C
      CMMAX(I)=0.0
      CMMIN(I)=50000.0
      CMAVG(I)=0.0
      DO 11 J=1,NP
      CMMAX(I)=AMAX1(P(I,J),CMMAX(I))
      CMMIN(I)=AMIN1(P(I,J),CMMIN(I))
 11   CMAVG(I)=CMAVG(I)+(P(I,J)/FLOAT(NP))
C
C     CALCULATION OF CDPOP'S FOR EACH RING.
C
 10   CDPOP3(I)=(CMAVG(I)-CMMIN(I))/CMAVG(I)
C
C     CALCULATION OF TMMAX AND TMMIN.
C
      TMMAX=0.0
```

```
      TMMIN=50000.0
      DO 7 I=J1,J2
      TMMAX=AMAX1(CMMAX(I),TMMAX)
    7 TMMIN=AMIN1(CMMIN(I),TMMIN)
c
c  CALCULATION OF TMAVG
c
      DIV=0.0
      PTSUM=0.0
      DO 33 I=J1,J2
      DO 33 J=1,NP
      PTSUM=PTSUM+P(I,J)
   33 DIV=DIV+1.0
      TMAVG=PTSUM/DIV
c
c  CALCULATION OF TDF'S
c
      TDF1=(TMMAX-TMMIN)/TMMAX
      TDF2=(TMMAX-TMMIN)/TMAVG
      TDF3=(TMAVG-TMMIN)/TMAVG
c
c  SECTION TO CALCULATE THTMIN FOR EACH RING.
c
      DO 9 I=J1,J2
      DO 13 LL=1,10
   13 SEG(LL)=0.0
      IF (NP.EQ.1) GO TO 8
      L=1
      LADD=.FALSE.
      DO 12 J=1,NP
      K0=J-1
      IF (K0.EQ.0) K0=NP
      K1=J
      A1=ANGLOC(K1)
      K2=J+1
      IF (K2.GT.NP) K2=K2-NP
      A2=ANGLOC(K2)
      IF ((J+1).GT.NP) A2=A2+360.0
      IF (J.GT.1) GO TO 14
      IF (P(I,K1).LT.CMAVG(I)) GO TO 21
```

```
      IF (P(I,K1).EQ.CMAVG(I).AND.P(I,K2).LT.CMAVG(I)) GO TO 22
      GO TO 14
22    IF (P(I,K0).GE.CMAVG(I)) GO TO 14
21    LADD=.TRUE.
c
c  LOGIC DETERMINES EACH SEGMENT'S CONTRIBUTION TO THTMIN ON EACH RING
c
14    RINC=0.0
      IF (P(I,K2).LT.CMAVG(I).AND.P(I,K1).LT.CMAVG(I)) RINC=A2-A1
      IF (P(I,K2).LT.CMAVG(I).AND.P(I,K1).EQ.CMAVG(I)) RINC=A2-A1
      IF (P(I,K2).EQ.CMAVG(I).AND.P(I,K1).LT.CMAVG(I)) RINC=A2-A1
      IF (P(I,K2).GT.CMAVG(I).AND.P(I,K1).LT.CMAVG(I))
     &      RINC=((A2-A1)/(P(I,K2)-P(I,K1)))*(CMAVG(I)-P(I,K1))
      IF (P(I,K2).LT.CMAVG(I).AND.P(I,K1).GT.CMAVG(I))
     &      RINC=((A2-A1)/(P(I,K1)-P(I,K2)))*(CMAVG(I)-P(I,K2))
c
c  LOGIC DETERMINES HOW TO ADD TOGETHER THE CONTRIBUTIONS OF EACH SECTION
c
      IF (RINC.EQ.0.0) GO TO 20
      IF (P(I,K2).LT.CMAVG(I).AND.P(I,K1).GT.CMAVG(I)) GO TO 23
24    SEG(L)=SEG(L)+RINC
      GO TO 12
23    IF (P(I,K0).GE.CMAVG(I)) GO TO 24
      IF (J.EQ.1) GO TO 24
      L=L+1
      GO TO 24
20    IF (J.EQ.1) GO TO 12
      IF (SEG(L).EQ.0.0) GO TO 12
      L=L+1
12    CONTINUE
      KS=0
      THTTOT(I)=0.0
      DO 18 K=1,10
      IF (SEG(K).NE.0.0) KS=KS+1
18    THTTOT(I)=THTTOT(I)+SEG(K)
      IF (LADD) SEG(1)=SEG(1)+SEG(KS)
      IF (LADD) KS=KS-1
c
c  SEARCH FOR LARGEST DEPRESSION BELOW AVERAGE ON EACH RING
c  THIS WILL BECOME THTMIN FOR THAT RING
```

```
C
      THTMIN(I)=0.0
      DO 19 K=1,KS
   19 IF (SEG(K).GT.THTMIN(I)) THTMIN(I)=SEG(K)
      GO TO 9
    8 CALL PRNT(3)
      THTMIN(I)=0.0
    9 CONTINUE
C
C  CALCULATION OF AVERAGE STATIC PRESSURE.
C
      DIV=0.0
      STATSM=0.0
      IF (.NOT.STATI) GO TO 29
      DO 30 I=1,NP
   30 STATSM=STATSM+P(1,I)
      DIV=DIV+FLOAT(NP)
   29 IF (.NOT.STATO) GO TO 31
      DO 32 I=1,NP
   32 STATSM=STATSM+P(NR,I)
      DIV=DIV+FLOAT(NP)
   31 IF (DIV.EQ.0.0) DIV=1.0
      SMAVG=STATSM/DIV
C
C  CALCULATION OF AVARAGE MACH NUMBER WHEN NO STATIC PRESSURES ARE INPUT
C
      AMACH=5.0*((ABS(TMAVG/SMAVG))**.286-1.0)
      RMAV=SQRT(ABS(AMACH))
C
C  CALCULATION OF SIMPLE RADIAL DISTORTION PARAMETERS.
C
      DO 40 IR=1,NR
      DO 40 ITHT=1,8
      R=RADLOC(IR)
      THETA=45*(ITHT-1)
C
C  CALL INTERPOLATION SUBROUTINE TO OBTAIN INTERPOLATED VALUES
C  OF MEASUREMENTS ON EACH RING AT DISCRETE THETA LOCATIONS.
C  NOTICE THAT SUBROUTINE 'INTERP' WILL GO THROUGH THE PROCESS OF RADIAL
C  INTERPOLATION EVEN THOUGH IT IS NOT NECESSARY. THIS REDUNDANCY IS NOT
```

```
c  EXTREME SINCE THE RADIAL INTERPOLATION IS NOT EXECUTED TOO MANY TIMES
c
      CALL INTERP
   40 RADP(ITHT,IR)=PVALUE
c
c  CALL SUBROUTINE TO CALCULATE SPECIFIC DISTORTION PARAMETERS.
c
      CALL DISPAR
c
      RETURN
      END
c
c -----------------------------------------------------------------------
```

```
C
      SUBROUTINE EXTRME (SGK,KSS,KMAX,T,FLUR)
C
C  SUBROUTINE WHICH MANAGES COMPUTATION OF EXTREME VALUES
C  SGKF IS DISTORTION FACTOR SIGMA
C  KSS IS MEAN VALUE
C  KMAX IS EXTREME VALUE
C  T IS TIME ON POINT;SECONDS
C  FLUR  IS VORTEX FLUX RATE.
C
      REAL KSS,KMAX
      SGKF=SGK
 110  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
C
 120  RETURN
      END
C
C ----------------------------------------------------------------------
```

```
c
      SUBROUTINE PFIX(LQ)
c
c  SUBROUTINE TO TRANSFORM INPUT MEASUREMENTS INTO MAPPING PARAMETERS.
c  SUBROUTINE ALSO CONTROLS SOME OUTPUT
c
c  NP, RADLOC, ANGLOC,AND  P HAVE THE FIRST
c  ARRAY DIMENSION EQUAL TO 11.  TEN OF THE
c  11 POSITIONS ARE AVAILABLE FOR USE.  THE
c  REMAINING POSITION IS NEEDED FOR INTERNAL PROCESSING
c
      COMMON  AB,ANGLOC(20),AUO,BETA2,BF,CDPOP3(10),CMAVG(10),FO,ISHFT,
     & CMMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
     & J1,J2,KEY,KD,LCNTFL,NN,NP,NR,P(11,20),PR(10),PS(11,20),CKP,
     & PSPEC(20),PVALUE,QAV,QPT2,R,RADLOC(11),RANGE,RI,RMAV,BRP(11),
     & RT,SGDK(10),SGP(10),SIG,SMAVG,STATI,STATO,T,TDP1,TDP2,TMMIN,
     & TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG,TMMAX,RKP,U2
c
      DIMENSION DPC(6)
      LOGICAL STATI,STATO,LCNTFL,LQ
      DATA DPC(1),DPC(2),DPC(3)/10.,20.,25./
      DATA DPC(4),DPC(5),DPC(6)/40.,50.,100./
      IF (LQ) GO TO 55
c
c  SECTION THAT ENABLES INTERPOLATION THROUGH THE CENTER OF THE CONTOUR MAP
c  SHIFT RADIAL LOCATIONS OUTWARD IF THE CENTER IS TO BE FILLED IN
c
      IF (.NOT.LCNTFL) GO TO 50
      IF (ISHFT.EQ.2) GO TO 50
      DO 51 I=1,NR
      NR1=NR+2-I
      RADLOC(NR1)=RADLOC(NR1-1)
c
c  K --> ORIGINAL NO. OF POINTS ON THIS RING
c  SHIFT ANGULAR POSITIONS OUTWARD, SHIFT DATA OUTWARD
c
      DO 51 J=1,NP
   51 P(NR1,J)=P(NR1-1,J)
      NR=NR+1
c
```


C-3

```
c   SET UP 8-POINT DUMMY INNER RING, AND FIND AVERAGE PRESSURE ON THE RING
c
 49     RADLOC(1)=0.01
        PSUM=0.0
        DO 54 I=1,NP
        I1=I-1
        IF (I1.EQ.0) I1=NP
        A1=ANGLOC(I1)
        IF ((I-1).EQ.0) A1=A1-360.0
        I2=I+1
        IF (I1.GT.NP) I2=1
        A2=ANGLOC(I2)
        IF ((I+1).GT.NP) A2=A2+360.0
        DELTHT=((A2-A1)/2.0)/360.0
 54     PSUM=PSUM+(DELTHT*P(2,I))
c
c   DUMMY RING DATA AND POSITION SET-UP
c
        DO 53 I=1,8
        TH=(I-1)*45
        ANGLOC(I)=TH
 53     P(1,I)=PSUM
 50     PCMN=0.0
        PCMX=0.0
c
c   MAPPING PARAMETERS GENERATED FROM INPUT MEASUREMENTS
c
        DO 12 I=1,NR
        DO 12 J=1,NP
        P(I,J)=(((P(I,J)/TMAVG)-1.0)*100.0)
        IF (PCMN.GT.P(I,J)) PCMN=P(I,J)
 12     IF (PCMX.LT.P(I,J)) PCMX=P(I,J)
c
c   SECTION TO WRITE OUT MAPPING PARAMETERS.
c   MAPPING PARAMETERS PUT INTO PROPER FORM FOR SYMBOL SUBROUTINE
c
        PCMN=-PCMN
        PMX=AMAX1(PCMN,PCMX)
        DO 130 I=1,6
        IF (PMX.LT.DPC(I)) GO TO 131
```

```
 130  CONTINUE
      I=6
 131  RANGE=2.0*DPC(I)
      DO 13 I=1,NR
      DO 13 J=1,NP
c
c  CONVERT DELTA PERCENT TO DELTA RANGE INCREMENTS  -10.0 TO +10.0
c
 13   P(I,J)=(P(I,J)/(RANGE/20.0))-10.0
c
      RETURN
c
c  ENTRY POINT FOR CALCULATION OF QLOC.
c
 55   RMSUM=0.0
      KMSUM=0
      DO 30 I=J1,J2
      DO 30 J=1,NP
      PC=P(1,J)+(P(NR,J)-P(1,J))*(RADLOC(I)-RADLOC(1))/(RADLOC(NR)-
     &   RADLOC(1))
c
c  MACH NUMBER IS CALCULATED FOR EACH INPUT MEASUREMENT LOCATION.
c
      GAM=0.286
      IF (PC.EQ.0.0) PC=0.00001
      AMACH=5.0*((ABS(P(I,J)/PC))**GAM-1.0)
      IF (AMACH) 610,630,620
 610  AMACH=-SQRT(ABS(AMACH))
      GO TO 630
 620  AMACH=SQRT(AMACH)
 630  RMSUM=RMSUM+AMACH
 30   KMSUM=KMSUM+1
c
c  CALCULATION OF AVERAGE MACH NUMBER.
c
      RMAV=RMSUM/FLOAT(KMSUM)
c
      RETURN
      END
c
c  -----------------------------------------------------------------------
```

```
c
      SUBROUTINE FRF(RS,FAUF)
c
c SUBROUTINE TO EVALUATE FUNCTION OF ABAR/UD VS SIGMA RATIO,
c USES AN ITERATIVE SCHEME FOR INVERSE SOLUTION
c
      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
  100 FAU=FAUL+SLOPE*(RS-RSL)
  110 FAUF=FAU
c
      RETURN
      END
c
c ------------------------------------------------------------------
```

```
      SUBROUTINE SYMBLE

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

      COMMON  AB,ANGLOC(20),AUD,BETA2,BF,CDPOP3(10),CMAVG(10),FD,ISHFT,
     & CMMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
     & J1,J2,KEY,KD,LCNTFL,NN,NP,NR,P(11,20),PR(10),PS(11,20),CKP,
     & PSPEC(20),PVALUE,QAV,QPT2,R,RADLOC(11),RANGE,RI,RMAV,BRP(11),
     & RT,SGDK(10),SGP(10),SIG,SMAVG,STATI,STATO,T,TDP1,TDP2,TMMIN,
     & TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG,TMMAX,RKP,U2

      DIMENSION OUTSYM(20),OUTSIM(20)

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

      DATA OUTSYM/1H.,1H-,1H=,1H+,1HI,1H<,1H*,1HS,1H*,1HO,1H',1HX,1H$,
     & 1HW,1H>,1H&,1HY,1HH,1HT,1HA/

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

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

C SECTION TO DETERMINE THE PROPER SYMBOL FOR THE CONTOUR MAP.

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

      RETURN
      END

C ------------------------------------------------------------------
```

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```
      SUBROUTINE NEWPSD(KY)

 SUBROUTINE TO EVALUATE RMS AND PSD FUNCTIONS FROM DYNAMIC PRESSURES.

      COMMON  AB,ANGLOC(20),AUO,BETA2,BF,CDPOP3(10),CMAVG(10),FO,ISHFT,
     & CMMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
     & J1,J2,KEY,KD,LCNTFL,NN,NP,NR,P(11,20),PR(10),PS(11,20),CKP,
     & PSPEC(20),PVALUE,QAV,QPT2,R,RADLOC(11),RANGE,RI,RMAV,BRP(11),
     & RT,SGDK(10),SGP(10),SIG,SMAVG,STATI,STATO,T,TDP1,TDP2,TMMIN,
     & TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG,TMMAX,RKP,U2

      REAL MO,MFR
      DIMENSION NOPRO(40),AVSIZ(40),FNOPRO(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 - PRATT & WHITNEY CIRCUMFERENTIAL DISTORTION FACTOR
 '2' KD2 - PRATT & WHITNEY CIRCUMFERENTIAL DISTORTION FACTOR
 '3' IDC - GENERAL ELECTRIC CIRCUMFERENTIAL DISTORTION FACTOR
 '4' IDR - GENERAL ELECTRIC RADIAL FLOW DISTORTION FACTOR
 '5' KRA - PRATT & WHITNEY RADIAL FLOW DISTORTION FACTOR
 '6' KA2 - PRATT & WHITNEY COMBINED CIRCUMFERENTIAL/RADIAL DISTORTION
 '7' DSPR - DELTA (LOSS IN) STALL PRESSURE RATIO
 '8' ID - GENERAL ELECTRIC COMBINED CIRCUMFERENTIAL/RADIAL DISTORTION

      IF (KY-2) 100,250,255
 100  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)
      RI=RADLOC(1)

      RETURN

 ON 1ST CALL FROM UNSTDY, INPUT IDENTIFICATION AND CONTROL PARAMETERS
 AND SET STEADY STATE DISTORTION FACTORS.
```

```
250   READ (5,70) ALPH,PSI,MD,U2,BF,CKP,RKP,MFR,NTUR,SPTRC
      IF (SPTRC .EQ. 0) SPTRC = 1.
      IF (PSPEC(3)) 101,102,101
101   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
      QPT2=QAV/TMAVG
      PSPEC(6)=PSPEC(1)+BF*PSPEC(5)
      DO 241 I=1,10
241   DKSS(I)=PSPEC(I)
c
      RETURN
c
c  ON 2ND CALL FROM UNSTDY COMPUTE MAX INSTANTANEOUS DISTORTION FACTORS
c
255   NN=0
      IF (MFR .EQ. 0) MFR = 1
      WRITE (6,10) TITLE1,TITLE2
      WRITE (6,20) T,FO,RT,RI,SPTRC
      WRITE (6,30) ALPH,PSI,MD,ETA,MFR,U2,QPT2
      WRITE (6,120) FCD
c
c BRANCH TO TURBULENCE MODELLING SUBROUTINE IF THERE IS NO DYNAMIC DATA
c
      IF (NTUR .EQ. 1) GO TO 500
      WRITE (6,50)
      DO 258 I=1,10
258   SGP(I)=0.0
c
c  INPUT DYNAMIC DATA
c   NFG IS RUN CODE. IF ZERO IS ENTERED, THE INPUT SEQUENCE IS EXITED
c   NFR IS A DYNAMIC PRESSURE PROBE NUMBER
c   RS IS RATIO OF FILTERED/UNFILTERED MEAN SQUARE VALUE OF DYNAMIC
c   PRESSURE FLUCTUATIONS.
c   SIG IS RMS VALUE OF DYNAMIC PRESSURE FLUCTUATION.
c
```

```
 260  READ (5,90) NPG,NPR,RS,SIG
      IF (RS .EQ. 0) RS = 0.5
      IF (RS .GT. 0.7) RS = 0.7
      IF (NPG.NE.0) GO TO 300
c
c  CALL MAXDP TO COMPUTE MAXIMUM DISTORTION VALUES.
c
      CALL MAXDP
      DO 372 I=1,NN
      AVSIZ(I)=AVSIZ(I)/(AB)
 372  FNOPRO(I)=FLOAT(NOPRO(I))
      WRITE (7) (FNOPRO(I),I=1,NN),(AVSIZ(I),I=1,NN)
      RETURN
c
c  COMPUTE MEAN VORTEX CORE SIZE FOR EACH PROBE AND SUM ABAR AND SIG.
c  NN IS COUNTER FOR NUMBER OF DYNAMIC PRESSURE PROBES.
c
 300  CALL FRF (RS,FAUF)
      AUO=FAUF/(7.976*FCO)
      AB=12.0*AUO*U2
      AB=AB/RT
      WRITE (6,60) NPR,RS,SIG,AB
      SGP(1)=SGP(1)+SIG*SIG
      SGP(2)=SGP(2)+AB*AB
      NN=NN+1
      NOPRO(NN)=NPR
      AVSIZ(NN)=AB
      GO TO 260
 500  CONTINUE
c
c  CALL TURBULENCE SUBPROGRAM, TURBUL, TO COMPUTE THE RMS LEVELS.
c  SPTRC IS THE TOTAL PRESSURE RECOVER THROUGH INLET SHOCK SYSTEM,
c        (SPTRC=1. FOR SUBSONIC AND TRANSONIC SPEED).
c  RS IS RATIO OF FILTERED/UNFILTERED MEAN SQUARE VALUE OF DYNAMIC
c  PRESSURE FLUCTUATIONS.
c  SIG  IS RMS VALUE OF DYNAMIC PRESSURE FLUCTUATION.
c
      CALL TURBUL(PS,RADLOC,NR,NP,U2,OPT2,TNAVG,MO,SPTRC,SIG)
      RS=0.5
      CALL FRF (RS,FAUF)
```

```
      AUD=FAUF/(7.976*FCD)
      AB=12.0*AUD*U2/RT
      NN=1
      AVSIZ(NN)=AB
      NOPRO(NN)=1
      SGP(1)=SIG
      SGP(2)=AB*AB

 CALL MAXDP TO COMPUTE MAXIMUM DISTORTION VALUES.

      CALL MAXDP
      DO 375 I=1,NN
      AVSIZ(I)=AVSIZ(I)/(AB)
      FNOPRO(I)=FLOAT(NOPRO(I))
  375 CONTINUE
      WRITE (7)  (FNOPRO(I),I=1,NN),(AVSIZ(I),I=1,NN)

      RETURN

   10 FORMAT  (1H1,19X,20A4/19X,20A4)
   20 FORMAT  (/14X,1HT,6X,2HFD,6X,2HRT,6X,2HRI,5X,5HSPTRC/5X,F12.3,
     &        F8.1,3F8.3)
   30 FORMAT  (/13X,4HALPH,5X,3HPSI,4X,2HMD,5X,3HETA,4X,3HMFR,4X,2HU2,
     &  5X,4HOPT2/10X,F7.3,F8.3,3F7.3,F7.1,F8.4)
   50 FORMAT  (/10X,5HPROBE,3X,2HRS,3X,6HSG/PT2,3X,4HA/RT)
   60 FORMAT  (10X,I3,1X,4F7.4)
   70 FORMAT  (5X,8F5.3,I5,F5.3)
   80 FORMAT  (5X,2I5,2F5.3,11F5.2)
   90 FORMAT  (5X,2I5,F5.3,F6.4)
  120 FORMAT  (/11X,10HRS AT FC =,F8.1)
  130 FORMAT  (5X,I5,7F10.5)

      END

 ----------------------------------------------------------------------------
```

```fortran
c
      SUBROUTINE MAXDP
c
      COMMON  AB,ANGLOC(20),AUD,BETA2,BF,CDPOP3(10),CMAVG(10),FD,ISHFT,
     & CMMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
     & J1,J2,KEY,KD,LCNTFL,NN,NP,NR,P(11,20),PR(10),PS(11,20),CKP,
     & PSPEC(20),PVALUE,QAV,QPT2,R,RADLOC(11),RANGE,RI,RMAV,BRP(11),
     & RT,SGDK(10),SGP(10),SIG,SMAVG,STATI,STATO,T,TDP1,TDP2,TMMIN,
     & TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG;TMMAX,RKP,U2
c
      DIMENSION LAB(8), FQ(10), DKBAR(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 KA2,4HDSPR,4H  ID/
c
      FQ(1)=1.0
      FQ(2)=1.0
      FQ(3)=1.0
      FQ(4)=QPT2
      FQ(5)=QPT2
      FQ(6)=QPT2
      FQ(7)=1.0
      FQ(8)=1.0
      FQ(9)=QPT2
      FQ(10)=1.0
      RTUD=RT/U2/12.0
  400 AN=NN
c
c  FIND MEAN VALUES OF SIGMA AND ABAR
c
      SIG=SQRT(SGP(1)/AN)
      AB=SQRT(SGP(2)/AN)
      SGP(1)=SIG/QPT2
c
c  FIND FLUX AND ENGINE FILTER EFFECTS
c
      FL=ANRTU(AB)/RTUD
      TFL=T*FL
      FABUD=FD*RTUD*AB
      CALL RATK (RKFK,FABUD)
      VB=0.949*SGP(1)*RKFK/SQRT(AB)
```

```
      SIGF=SIG*RKFK

 FIND MAXIMUM VALUES FOR EACH DISTORTION FACTOR.

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

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

      IF (I.EQ.8) GO TO 404
      IF (I.EQ.10) GO TO 406
      CALL RSIGMA (J,R1,RK,AB,DKSS(J),NP,QPT2,VB,SIGF)
      SGP(I)=R1*SGP(1)*FQ(I)
      GO TO 410

 FORMULAS FOR KA2 AND ID SIGMAS

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

 FILTERED RMS LEVEL (SGDK) OF DISTORTION FACTOR.

410   SGDK(I)=SGP(I)*RKFK
      IF (I.EQ.8) GO TO 424
      IF (I.EQ.10) GO TO 426

 COMPUTE MEAN INSTATANEOUS VALUE (DKBAR) OF DISTORTION FACTOR.

      DKBAR(J)=RK*SGDK(I)+DKSS(J)
      GO TO 450

 FORMULAS FOR KA2 AND ID DELTAS.

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

 TO FIND MOST PROBABLE EXTREME VALUES.

```

```
 450  CALL EXTRME (SGDK(I),DKBAR(J),DKMX(J),T,FL)
      WRITE (6,60) SIG
      WRITE (6,70) AB
      IF (NN .LT. 2) GO TO 459
      IF (NN .LT.25) GO TO 460
 459  WRITE (6,130) TITLE1,TITLE2
 460  WRITE (6,100)
      DO 500 I=1,8
      J=I+2
      IF (I.GT.1) GO TO 470
      PP=1.0-EXP(-0.051293294/TFL)
      IF (PP.EQ.0.)  GO TO 999
 997  FL1=1.0/(PP*T)
      PP=1.0-EXP(-0.003004509/TFL)
      IF (PP.EQ.0.)   GO TO 996
 995  FL2=1.0/(PP*T)
C
C  FIND INSTANTANEOUS VALUES AT 95.0 AND 99.7 CONFIDENCE LEVELS
C
 470  CALL EXTRME (SGDK(J),DKBAR(I),DK950,T,FL1)
      CALL EXTRME (SGDK(J),DKBAR(I),DK997,T,FL2)
      IF (I-2) 480,490,480
 480  WRITE (6,110) LAB(I),DKSS(I),DKBAR(I),SGP(J),SGDK(J),DKMX(I),
     & DK950,DK997
      GO TO 500
 490  WRITE (6,120) LAB(I),DKSS(I),DKBAR(I),SGP(J),SGDK(J),DKMX(I),
     & DK950,DK997
 500  CONTINUE
      WRITE (6,75) LAB(KD), DKMX(KD)
C
 60   FORMAT (/13X,"FACE-AVERAGE RMS (SG/PT2) =",F8.5)
 70   FORMAT (/13X,"MEAN VORTEX SIZE (A0/RT)  =",F8.5)
 75   FORMAT (//25X,39HMAXIMUM INSTANTANEOUS DISTORTION FACTOR//
     &          30X,1A10,1H=F13.4)
 100  FORMAT (//22X,31HDISTORTION FACTOR EXTREME VALUE//59X,21HMAXIMUM I
     &NSTANTANEOUS/12X,6HFACTOR,4X,6HSTEADY,3X,4HMEAN,5X,5HSIGMA,4X,
     &5HSIGMA,5X,4HMOST,4X,5H95.0%,4X,5H99.7%/22X,5HSTATE,4X,5HVALUE,5X,
     &3HINF,7X,2HFD,6X,4HPROB,5X,4HPROB,5X,4HPROB)
 110  FORMAT (10X,A4,6X,F7.4,6F9.4)
 120  FORMAT (10X,A4,6X,F7.1,6F9.1)
```

```
 130  FORMAT (1H1,19X,20A4/19X,20A4)
c
      RETURN
c
 999  PP=.0000001
      WRITE (6,998)
 998  FORMAT (//10X,29HCONFIDENCE LEVEL IS INCORRECT)
      GO TO 997
 996  PP=.0000001
      WRITE (6,998)
      GO TO 995
c
      END
c
c ---------------------------------------------------------------------
```

```
c
      FUNCTION ANRTU (ART)
c
c  FUNCTION FOR FINDING VORTEX FLUX RATE.
c
      ANRTU=1.0E+06
      IF (ART.EQ.0.0) GO TO 100
      ANRTU=0.254/(ART*ART)
c
  100 RETURN
      END
c
c ---------------------------------------------------------------------
```

```
C
      SUBROUTINE RSIGMA (J,R1,RK,AB,DKS,NP,QPT,VB,SGF)
C
C  THIS ROUTINE IS USED NOW TO COMPUTE THE RATIO OF SIGMA KD
C  TO SIGMA DPT AND THE RATIO (KBAR-KSS)/SIGMA K.
C   SF IS RATIO OF SIGMA-DPT/B
C   PN IS NUMBER OF PROBES PER RING
C   DT IS ANGULAR ARC PER PROBE
C
      SP=1.0537*SQRT(AB)
      PN=NP
      DT=6.28319/PN
      GO TO (10,20,30,40,50,60,70), J
C
C  THIS BRANCH APPLIES TO KTHETA.
C
 10   DKSS=DKS/VB
      SDKIS=1.65*SQRT(AB/PN)/EXP(40.0*(AB/DT)**4.0)
      SDKIL=2.106*(1.0-1.0/EXP(1.1*(AB**1.5)))
      SDKI=SDKIS*SDKIS+SDKIL*SDKIL
      DKTS=(1.408*AB/EXP(76.67*(AB/DT)**4))/SQRT(1.0+99.0*DKSS*DKSS)
      DKTL=(2.0*(1.0-1.0/EXP(1.05*(AB**1.5))))/SQRT(1.0+5.25*(0.9*DKSS/
     &        AB)**2.3)
      DKT=SQRT(DKTS*DKTS+DKTL*DKTL)
      SIGK=SQRT(SDKI-2.0*DKSS*DKT-DKT*DKT)
      R1=SIGK/SP
      RK=DKT/SIGK
      IF (J.EQ.7) GO TO 71
      GO TO 90
C
C  THIS BRANCH APLLIES TO KD2.
C
 20   DKSS=DKS/(QPT*VB)
      IF (AB-0.45) 21,21,22
 21   R1=10847.0*(1.0-1.0/EXP(4.0*AB))
      GO TO 23
 22   R1=9054.0+(AB-0.45)*(1164.0+14052.0*(1.0-1.0/EXP(2.5*DKSS/
     &      97627.0)))
 23   RK=25763.0*(1.0-1.0/EXP(4.82*(.125*PN*AB)**1.4)) /EXP(DKSS/
     &       17627.0)
```

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OF POOR QUALITY

```
      RK=RK/R1
      R1=R1*QPT/(0.1475*SP)
      GO TO 90
c
c  THIS BRANCH APLLIES TO IDC.
c
 30   DKSS=DKS/(QPT*VB)
      R1I=1.01*AB**0.63
      R1D=SQRT((0.5356*AB**0.26)**2+(1.2271*SQRT(8.0*AB/FN)/
     &      EXP(5.42*(AB/DT)**2))**2)
      RS=SQRT(1.0-1.0/EXP(0.17*(DKS/SGF)**2))
      IF (R1I-R1D) 31,31,32
 31   R1=R1D-RS*(R1D-R1I)
      GO TO 33
 32   R1=R1D+RS*(R1I-R1D)
 33   RK=1.458*(1.0-1.0/EXP(9.0*(.125*FN*AB)**1.4))/EXP((DKSS/1.424)
     &      **0.75)
      RK=RK/R1
      R1=R1*QPT/(0.1475*SP)
      GO TO 90
c
c  THIS BRANCH APPLIES TO IDR.
c
 40   R1=0.1324*(1.0-1.0/EXP(4.0*(AB**1.4142)))
      IF (AB.GT.0.3) GO TO 45
      RS=0.2713*SQRT(AB)-1.6528*AB*AB
      R1=SQRT(RS*RS+R1*R1)
 45   RK=0.0830*(1.0-1.0/EXP(4.0*AB*AB))
      RK=RK/R1
      R1=R1*QPT/(0.1397*SP)
      GO TO 90
c
c  THIS BRANCH APPLIES TO KRA
c
 50   R1=0.0825*(1.0-1.0/EXP(6.0*AB**1.475))
      IF (AB.GT.0.35) GO TO 55
      RS=0.192*SQRT(AB)-0.9253*AB*AB
      R1=SQRT(RS*RS+R1*R1)
 55   RK=0.0542*(1.0-1.0/EXP(3.75*(AB**1.6667)))
      RK=RK/R1
```

```
          R1=R1/SP
          GO TO 90
c
c   THIS BRANCH WHICH APPLIED TO KA2 HAS BEEN NULLED.
c
   60     GO TO 90
c
c   THIS BRANCH APPLIES TO DSFR.
c
   70     DKS=1.4809*DKS/QPT
          GO TO 10
   71     DKS=0.6753*DKS*QPT
          DKSS=DKS/VB
          IF (AB-0.6) 72,72,75
   72     RR1=0.0996+(0.047/EXP(8.0*DKSS**0.8)-0.008)*(AB-0.6)
          A=0.0992+1.15*(1.0-1.0/EXP(4.0*DKSS**3))
          IF (AB-0.28) 73,73,74
   73     S=0.5+DKSS
          AP=A/(0.28**S)
          RRK=AP*AB**S
          GO TO 76
   74     S=(A-0.0996)/0.42
          RRK=0.0996-S*(AB-0.6)
          GO TO 76
   75     RR1=0.0996
          RRK=0.0996
   76     R1=R1*RR1/0.1475
          RK=RK*RRK/.1475
c
   90     RETURN
          END
c
c ---------------------------------------------------------------------
```

```
c
      SUBROUTINE SEARCH (AKS,DKS,ANT)
c
c THIS SUBROUTINE CONTROLS SOLUTION  OF (KMAX-KBAR)/SIGMA K.
c
      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
      DKSN=DKS+0.25
      DO 100 J=1,100
      IF (DKS.LT.2.3) GO TO 120
      CALL PFX (AKS,DKS,PX)
      ERR =ABS(PX-ANT)/ANT
      IF (ERR.LT.0.001) RETURN
      IF (J.EQ.1) GO TO 60
      DDK=ABS(DKS2-DKS)
      IF (DDK.LT.0.00001) RETURN
      SLOPE=(ALOG(PX2)-ALOG(PX))/(DKS2-DKS)
      IF (SLOPE.EQ.0.0) SLOPE=SLOPP
      DKSN=DKS+(ALOG(ANT)-ALOG(PX))/SLOPE
   60 PX2=PX
      DKS2=DKS
      DKS=DKSN
  100 SLOPP=SLOPE
c
  120 RETURN
      END
c
c ----------------------------------------------------------------------
```

```
      SUBROUTINE PFX (AKS,DKS,PX)

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

      UND=(-1)*(8.0*ABS(AKS-2.0))
      UND1=-5.*ABS(AKS-2.5)
      UND2=-5.*ABS(AKS-3.)
      IF (UND1 .LT. -38.) UND1=-38.
      IF (UND2 .LT. -38.) UND2=-38.
      IF (UND .LT. -38.) UND=-38.
      B=((AKS+15.)*.023)/((ABS(AKS-1.5))**1.2))+2.4
      AM=1.16-(15.5*(AKS-1.4)/((AKS+.4)**4))
      YI=-.66-.140*(EXP(-.30*ABS(AKS-6.5)))
     &  +.440*(EXP(-.99*ABS(AKS-2.0)))
     &  -.035*(EXP(-1.2*ABS(AKS-4.7)))
     &  -.062*(EXP(-0.7*ABS(AKS-16.)))
      A=.13-(.031*(AKS-2.7)*.5*((ABS(AKS-2.7)**.15))*EXP((AKS-5.)*
     &     (-.45)))-.0299*(EXP(-.08*ABS(AKS-16.)))
     &     +.04*(EXP(UND1))-.0177*(EXP(-ABS(AKS-4.)))
     &     -.0172*(EXP(-ABS(AKS-6.0)))-.0534*(EXP(UND))
     &       -.0017*(EXP(UND2))
      CH1=AM*DKS+YI+A*((DKS-2.3)**B)
      IF (CH1 .GT. 38.) CH1=38.0
      IF (CH1 .LT. -38.) CH1=-38.0
      PX=10.**CH1

      RETURN
      END

 ------------------------------------------------------------------
```

```
c
      SUBROUTINE DISPAR
c
c  SUBROUTINE TO CALCULATE SPECIFIC DISTORTION PARAMETERS.
c
c  NP, RADLOC, ANGLOC, AND P HAVE THE FIRST ARRAY DIMENSION EQUAL TO 11.
c  TEN OF THE 11 POSITIONS ARE AVAILABLE FOR USE. THE
c  REMAINING POSITION IS NEEDED FOR INTERNAL PROCESSING.
c
       COMMON  AB,ANGLOC(20),AUO,BETA2,BF,CDPOP3(10),CMAVG(10),FO,ISHFT,
     & CMMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
     & J1,J2,KEY,KD,LCNTFL,NN,NP,NR,P(11,20),PR(10),PS(11,20),CKP,
     & PSPEC(20),PVALUE,QAV,QPT2,R,RADLOC(11),RANGE,RI,RMAV,BRP(11),
     & RT,SGDK(10),SGP(10),SIG,SMAVG,STATI,STATO,T,TDP1,TDP2,TMMIN,
     & TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG,TMMAX,RKP,U2
c
c  COMMON BLOCK FOR TRANSFERRING SPECIFIC DISTORTION
c  PARAMETERS TO THE OUTPUT SUBROUTINE 'LNFOUT'
c
      DIMENSION PT(20), QD(10), DTHETA(20), RIDC(5), RIDR(5)
      LOGICAL STATI,STATO,LCNTFL
      DATA IT/0/
      IF (IT.EQ.1) GO TO 25
c
c  CALCULATION OF KD2
c
      DINVS=0.0
      DO 26 I=J1,J2
   26 DINVS=DINVS+(1.0/RADLOC(I))
      DO 27 I=J1,J2
   27 QD(I)=(1.0/RADLOC(I))/DINVS
   25 RKD2=0.0
      DO 28 I=J1,J2
   28 RKD2=RKD2+(CDPOP3(I)*THTMIN(I)*QD(I)*100.0)
c
c  CALCULATION OF K-THETA.
c
      IF (IT.EQ.1) GO TO 37
      DO 36 J=1,NP
      K1=J-1
```

```
      IF (K1.EQ.0) K1=NP
      A1=ANGLOC(K1)
      IF ((J-1).EQ.0) A1=A1-360.0
      K2=J+1
      IF (K2.GT.NP) K2=1
      A2=ANGLOC(K2)
      IF ((J+1).GT.NP) A2=A2+360.0
   36 DTHETA(J)=(A2-A1)/2.0
      RGAM=.285714
   37 RKTHT=0.0
      TTTT=DTHETA(1)
      DTHT=TTTT
      IF (ISHFT.EQ.1) QAV=(SMAVG/RGAM)*(((ABS(TMAVG/SMAVG))**RGAM)-1.0)
      DO 35 I=J1,J2
      RISIN=0.0
      RICOS=0.0
      DO 34 J=1,NP
      PHI=0.017453*ANGLOC(J)
      RISIN=RISIN+((P(I,J)/TMAVG)*SIN(PHI)*DTHETA(J))
   34 RICOS=RICOS+((P(I,J)/TMAVG)*COS(PHI)*DTHETA(J))
   35 RKTHT=RKTHT+OD(I)*(SQRT(ABS(((ABS(RISIN))**2)+((ABS(RICOS))**2))))
      IF (QAV.EQ.0.0) QAV=1.0
      RKTHT=(RKTHT/(180.0*QAV))*TMAVG
C
C  CALCULATION OF IDC-MAX AND IDR-MAX.
C
      NCHK=NR
      IF (STATI) NCHK=NCHK-1
      IF (STATO) NCHK=NCHK-1
      IF (NCHK.EQ.5) GO TO 39
      CALL PRNT(3)
      GO TO 39
   39 DO 41 J=J1,J2
      RIDC(J)=(CMAVG(J)-CMMIN(J))/TMAVG
   41 RIDR(J)=(TMAVG -CMAVG(J))/TMAVG
      RIDCX1=(RIDC(J1)+RIDC(J1+1))/2.0
      RIDCX2=(RIDC(J1+3)+RIDC(J1+4))/2.0
      RIDCMX=AMAX1(RIDCX1,RIDCX2)
      RIDRMX=AMAX1(RIDR(J1),RIDR(J1+4))
C
```

```
c   CALCULATION OF ID
c
          RID=RIDCMX*BSF*CKP+RIDRMX*RKP
c
c   CALCULATION OF KRA2 AND KA2
c
          SPTR=0.0
          DO 100 I=J1,J2
          PTAVR=CMAVG(I)
          DPTR=ABS(PTAVR/TMAVG-BRP(I))/BRP(I)
     100  SPTR=SPTR+DPTR*QD(I)
          AKRA2=TMAVG*SPTR/QAV
          AKA2=RKTHT+AKRA2*BF
c
c   CALCULATION OF DELTA STALL MARGIN -DSM
c   FIRST FIND THE AVERAGE RADIAL PRESSURE AND MINIMUM PRESSURE
c
          PTRA=0.0
          PTRM=50000.
          AK=NP
          ANR=J2-J1+1
          DO 300 J=1,NP
          PT(J)=0.0
          DO 200 I=J1,J2
     200  PT(J)=PT(J)+P(I,J)
          PT(J)=PT(J)/ANR
          PTRA=PTRA+PT(J)
     300  PTRM=AMIN1(PT(J),PTRM)
          PTRA=PTRA/AK
          RISIN=0.0
          RICOS=0.0
          DO 400 J=1,NP
          PHI=0.017453*ANGLOC(J)
          RISIN=RISIN+((PT(J)/PTRA)*SIN(PHI)*DTHT)
     400  RICOS=RICOS+((PT(J)/PTRA)*COS(PHI)*DTHT)
          DSM=0.675*SQRT(RISIN*RISIN+RICOS*RICOS)/180.0
c
c   SPECIFIC DISTORTION PARAMETERS STORED IN ARRAY 'PSPEC'
c   IN PREPARATION TO BEING TRANSFERRED TO 'LNFOUT'.
c
```

```
      PSPEC(1)=PKTHT
      PSPEC(2)=RKD2
      PSPEC(3)=RIDCMX
      PSPEC(4)=RIDRMX
      PSPEC(5)=AKRA2
      PSPEC(6)=AKA2
      PSPEC(7)=DSM
      PSPEC(8)=RID
c
      RETURN
      END
c
c ------------------------------------------------------------------
```

```
C
      SUBROUTINE PRNT (KP)
C
      COMMON   AB,ANGLOC(20),AUD,BETA2,BF,CDPOP3(10),CMAVG(10),FD,ISHFT,
     & CMMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
     & J1,J2,KEY,KD,LCNTFL,NN,NP,NR,P(11,20),PR(10),PS(11,20),CKP,
     & PSPEC(20),PVALUE,QAV,OPT2,R,RADLOC(11),RANGE,RI,RMAV,BRP(11),
     & RT,SGDK(10),SGP(10),SIG,SMAVG,STATI,STATO,T,TDP1,TDP2,TMMIN,
     & TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG,TMMAX,RKP,U2
C
      LOGICAL STATI,STATO,LCNTFL
      GO TO (9,2,3,9,9,9,9,8,9), KP
    2 WRITE (6,125) TITLE1,TITLE2
C
C  SECTION THAT WRITES THE ANGULAR POSITIONS OF THE INPUT MEASUREMENTS
C
      WRITE (6,113)
      WRITE (6,121)
      WRITE (6,123) (ANGLOC(I), I=1,NP)
      WRITE (6,109)
C
C  SECTION THAT WRITES THE  INPUT MEASUREMENTS
C
      DO 40 J=J1,J2
   40 WRITE (6,110) RADLOC(J), (P(J,I), I=1,NP)
C
C  SECTION THAT WRITES THE BASE RADIAL PROFILES.
C
      WRITE (6,104) (RADLOC(J),J=1,NR)
      WRITE (6,105) (BRP(J),J=1,NR)
      GO TO 1000
    3 WRITE (6,100)
    9 GO TO 1000
    8 WRITE (6,125) TITLE1,TITLE2
      GO TO 1000
C
  100 FORMAT (/10X,40HIDC-MAX AND IDR-MAX CANNOT BE CALCULATED,
     &         10X,51HTHERE ARE NOT EXACTLY 5 RINGS OF TOTAL MEASUREMENTS)
  104 FORMAT (//30X,19HBASE RADIAL PROFILE//10X,8HRADII    ,8F8.3)
  105 FORMAT (/10X,8HPTR/PTA ,8F8.4)
```

```
 109  FORMAT (1H )
 110  FORMAT (5X,F6.3,4X,10F8.3/15X,10F8.3)
 113  FORMAT (/30X,14HPRESSURE ARRAY)
 121  FORMAT (1X/4X,6HRADIUS,15X,43HANGULAR POSITION OF INPUT MEASUREMEN
     &TS, DEG)
 123  FORMAT (15X,10F8.1)
 125  FORMAT (1H1,6X,20A4/6X,20A4)
c
 1000 RETURN
      END
c
c -------------------------------------------------------------------
```

```
      SUBROUTINE INTERP

INTERPOLATION SUBROUTINE

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

      COMMON  AB,ANGLOC(20),AUO,BETA2,BF,CDPOP3(10),CMAVG(10),FO,ISHFT,
     & CMMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARÇE(39,65),BSF,
     & J1,J2,KEY,KD,LCNTFL,NN,NP,NR,P(11,20),PR(10),PS(11,20),CKP,
     & PSPEC(20),PVALUE,QAV,QPT2,R,RADLOC(11),RANGE,RI,RMAV,BRP(11),
     & RT,SGDK(10),SGP(10),SIG,SMAVG,STATI,STATO,T,TDP1,TDP2,TMMIN,
     & TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG,TMMAX,RKP,U2

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

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

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

INTERPOLATION BOUNDARY RING NOS.

 12   NFIT(1)=I1
      NFIT(2)=I1+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 II=1,2
      K=NFIT(II)
      IF (NP.NE.1) GO TO 21
c
c  IF ONLY ONE POINT ON RING, NO CIRCUMFERENTIAL INTERPOLATION
c
      RADFIT(II)=P(K,1)
      GO TO 15
c
c  IF 0. < THETA < ANGLOC(K,1) REQUIRES SPECIAL INTERPOLATION
c
 21   IF (THETA.LT.ANGLOC(1)) GO TO 19
c
c  SEARCH FOR ANGULAR BOUNDS
c
      DO 16 J=1,NP
      N2=J
      IF (J.EQ.NP) GO TO 20
c
c  IF  ANGLOC(K,NP) < THETA < 360. REQUIRES SPECIAL INTERPOLATION
c
      IF (THETA.GE.ANGLOC(J).AND.THETA.LT.ANGLOC(J+1)) GO TO 20
 16   CONTINUE
      GO TO 20
 19   N2=NP
c
c  NUMBERS OF INTERPOLATION BOUNDARY  ANGLES
c
 20   NRFIT(1)=N2
      NRFIT(2)=N2+1
      DO 18 I=1,2
      IF (THETA.LT.ANGLOC(1)) GO TO 7
      IF (NRFIT(I).LT.1) GO TO 23
      IF (NRFIT(I).GT.NP) GO TO 24
      L=NRFIT(I)
      Z(I)=ANGLOC(L)
      F(I)=P(K,L)
      GO TO 18
 7    IF (NRFIT(I).LE.NP) GO TO 6
      L=NRFIT(I)-NP
```

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

```

      SUBROUTINE UNSTDY

 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  AB,ANGLOC(20),AUD,BETA2,BF,CDPOP3(10),CMAVG(10),FO,ISHFT,
     & CMMIN(10),DKMX(10),DKSS(10),FACE(39,65),FACTOR,FARCE(39,65),BSF,
     & J1,J2,KEY,KD,LCNTFL,NN,NP,NR,P(11,20),PR(10),PS(11,20),CKP,
     & PSPEC(20),PVALUE,QAV,QPT2,R,RADLOC(11),RANGE,RI,RMAV,BRP(11),
     & RT,SGDK(10),SGP(10),SIG,SMAVG,STATI,STATO,T,TDP1,TDP2,TMMIN,
     & TDP3,THETA,THTMIN(10),TITLE1(20),TITLE2(20),TMAVG,TMMAX,RKP,U2

      DIMENSION AR(11)
      CON=1.0/57.29577951

 SET INITIAL AND/OR DEFAULT VALUES.

      VL=999.999
      XA=0.0
      R1=0.0

 CALL SUBROUTINE NEWPSD: INPUT INDENTIFICATOON AND: CONTROL PARAMETERS

      CALL NEWPSD(2)

 DEFINE PROBE RADIAL LOCATION IN RATIO FORM.

      NRG=0
      DO 50 I=1,NR
      IF (I.GE.J1.AND.I.LE.J2) NRG=NRG+1
   50 AR(I)=RADLOC(I)/RADLOC(NR)
      RBAR=0.5*(1.0+AR(1))
      RRT=RBAR
      QOPT=0.7*RMAV*RMAV/(1.0+0.2*RMAV*RMAV)**3.5

 COMPUTE AVERAGE AND MAXIMUM MACH NUMBER AND VELOCITY AT ENGINE FACE.

```

```
      TMAVGG=TMAVG
      AMA=SQRT(5.*(((TMAVG/SMAVG)**.286)-1.0))
      AMM=SQRT(5.*(((TMMAX/SMAVG)**.286)-1.0))
      VBM=AMM*SQRT(1.0+0.2*AMA*AMA)/SQRT(1.0+0.2*AMM*AMM)/AMA
      NV=2
      DKD=PSPEC(KD)
      VB1=1.0
c
c SEARCH FOR VORTEX LOCATION AND ORIENTATION.
c
      RKMX=TMMIN
      RKMN=TMMAX
      DO 68 I=1,NP
      RKAV=0.0
      DO 66 J=J1,J2
66    RKAV=RKAV+PS(J,I)
      RKAV=RKAV/NRG
      IF (RKAV.LT.RKMX) GO TO 67
      RKMX=RKAV
      THMX=ANGLOC(I)
67    IF (RKAV.GT.RKMN) GO TO 68
      RKMN=RKAV
      THMN=ANGLOC(I)
68    CONTINUE
      DTH=ABS(THMN-THMX)
      THE=0.5*(THMN+THMX)
      IF (DTH.LE.180.0) GO TO 69
      DTH=360.0-DTH
      THE=THE+180.0
69    IF (THE.GE.360.0) THE=THE-360.0
      ART=DTH/114.592
      G1=-90.0
      IF (THMN.GT.THE) GO TO 71
      G1=90.0
71    IF (THE.GT.180.0) THE=THE-360.0
c
c TV IS THE VORTEX CICUMFERENTIAL LOCATION
c
      TV=THE
      CALL LNPOUT(1)
```

```
      WRITE (6,1996)
      WRITE (6,1998) THMN,RKMN,THMX,RKMX,DTH,THE,ART,G1
      CALL LNPOUT(2)
      WRITE (6,1800)
c
c   CALL SUBROUTINE TO COMPUTE MAXIMUM INSTANTANEOUS DISTORTION FACTORS
c
      CALL NEWPSD(3)
      A0=AB
      VB0=1.36*SIG/QPT2
 72   VBAR=VB1
c
c   LOOP 600 IS THE VORTEX STRENGTH (VBAR) ITERATION.
c   VBAR VARIES FROM VB1 TO VB2 BY DVB, NV TIMES.
c
      VBAR=VB1
      DO 600 IV=1,NV
      IF (IV-2) 73,721,722
 721  DNKD=PSPEC(KD)
 722  VBAR=(DKMX(KD)-DKD)/(DNKD-DKD)
c
c   WHEN A SPECIFIC PRESSURE CONTOUR IS NEEDED A/RT IS COMPUTED FROM VBAR
c
 73   AYRT=ART
      RAV=1.0/AYRT
c
c   VORTEX ORIENTATION ANGLES AND FUNCTIONS.
c
      G=G1
      COSG=COS(CON*G)
      SING=SIN(CON*G)
      B=B1
      COSB=COS(CON*B)
      SINB=SIN(CON*B)
      CBSG=COSB*SING
      SBSG=SINB*SING
      CBCG=COSB*COSG
      SBCG=SINB*COSG
c
```

```
C   LOOP 90 IS THE PROBE RADIAL LOCATION ITERATION.  FOR A GIVEN VORTEX
C   THE PRESSURE FLOWFIELD IS FOUND AT EACH PROBE RADIUS AND THETA.
C   THERE ARE NR RINGS AND NP PROBES PER RING.
C
       DO 90 J=1,NR
       IF (J-J1) 78,65,63
63     IF (J-J2) 65,65,78
65     ZA=(AR(J)-RRT)/AYRT
       IF (ABS(ZA).GT.100.0) ZA=SIGN(100.0,ZA)
       IF (ABS(TV).GT.180.0) TV=SIGN(180.0,TV)
C
C   LOOP 80 IS THE PROBE CIRCUMFERENTIAL LOCATION ITERATION.
C
       DO 80 I=1,NP
       PHI=ANGLOC(I)-TV
       IF (PHI.GT.180.0) PHI=PHI-360.0
       IF (PHI.LT.-180.) PHI=PHI+360.0
       YA=CON*PHI*RAV
       Y=-XA*SBCG+YA*CBCG+ZA*SING
       IF (ABS(Y/VL).LT.1.0) GO TO 70
       DPT1=0.0
       GO TO 75
70     BASE=YA*SING-ZA*COSG*COSB
       RAD=(XA*COSB+YA*SINB)**2+(-XA*SBSG+YA*CBSG-ZA*COSG)**2-1.0
       IF (RAD.GT.670.0) RAD=670.0
C
C   DPT1 IS THE PRESSURE FLUCTUATION AT PROBE AR(J) AND ANGLOC(J,I)
C
       DPT1=2.0*VBAR*BASE/EXP(0.5*RAD)
75     P(J,I)=PS(J,I)+DPT1*ODPT*TMAVGG
80     CONTINUE
       GO TO 90
C
C   RESET STATIC PRESSURE RINGS TO STATIC PRESSURE.
C
78     DO 79 I=1,NP
79     P(J,I)=PS(J,I)
90     CONTINUE
       IF (IV-1) 91,91,92
91     CALL PFIX (.TRUE.)
```

```
      CALL DISTRT
      GO TO 600
92    CALL PRNT (2)
      CALL PFIX(.TRUE.)
      CALL DISTRT
      CALL PFIX(.FALSE.)
      CALL MAINLP
      CALL LNPOUT(1)
      WRITE (6,1995)
      WRITE (6,2000) VBAR,ART,G,B,AYRT,VL,RRT,TV
      WRITE (6,1999) VBM,VB0,A0
      CALL LNPOUT(2)
      WRITE (6,1805)
600   CONTINUE
c
      RETURN
c
1800 FORMAT (//27X,"<STEADY-STATE DISTORTION>")
1805 FORMAT (//31X,"<PEAK DISTORTION>")
1995 FORMAT (//25X,15HVORTEX LOCATION)
1996 FORMAT (//25X,17HVORTEX PROPERTIES)
1998 FORMAT (/12X,4HTHMN,3X,4HRKMN,4X,4HTHMX,3X,4HRKMX,4X,3HDTH,3X,
   &    5HTHETA,5X,2HA1,6X,2HG1/8X,2(F8.2,F7.3),F7.2,F8.2,F8.3,F7.2)
1999 FORMAT (/11X,4HVBMX,4X,3HVB0,3X5HA0/RT/8X,2F7.3,F8.4)
2000 FORMAT (/10X,4HVBAR,4X,4HA/RT,1X,5HGAMMA,2X,4HBETA,3X,5HAY/RT,
   &  5X,2HVL,4X,4HR/RT,4X,5HTHETA/6X,2F8.3,2F6.1,3F8.3,F8.2)
c
      END
c
c ----------------------------------------------------------------------
```

```
c
      SUBROUTINE TURBUL (PT1,RS1,NR1,NP1,U2,Q2,PT2,XM0,PTT0,RMSAG)
c
c TURBULENCE PROGRAM
c BY: YEN-SEN CHEN
c     (MAR. 17, 1984)
c
c THIS SUBROUTINE IS A SUBDRIVER FOR THE COMPUTATION OF RMS LEVELS
c AT THE COMPRESSOR FACE BY SOLVING THE K-E TURBULENCE MODEL.
c
c SUBROUTINE INITL IS USED TO SET INITIAL VALUES OF K AND E AT EACH
c GRID POINT (GK AND GE RESPECTIVELY).
c SUBROUTINE INIVEL IS USED TO CALCULATE VELOCITY GRADIENTS.
c SUBROUTINE CUBIC IS USED TO DO THE CUBIC SPLINE INTERPOLATIONS.
c SUBROUTINE TRIDIA IS USED TO SOLVE THE TRIDIAGONAL MATRIX EQUATION.
c SUBROUTINE FINITE SOLVES FOR THE K-E TURBULENCE MODEL USING A FINITE
c DIFFERENCE FORMULATION.
c
c
      DIMENSION PT(11,20),PT1(11,20),U(11,20),WK(20),WE(20),WUR(20),
     &          RS1(20)
      COMMON /CUB/ NGR,NGP,NPW,NRW,NR,NP,RS(20),THA(20),DR(20),C1(20),
     &             C2(20),C3(20),THG
      COMMON /VELGR/ URG(80,80),URRG(80,80),UTG(80,80),UTTG(80,80),
     &               UUG(80,80),UG(80,80)
      COMMON /INIKE/ GK(80,80),GE(80,80),GR(80),GT(80),ERRK,ERRE
      COMMON /PARA/ PMU,NRR,NPP,NRG,NPG,NSHT,FACT
c
c SET GRID SIZE PARAMETERS (NGR & NGP), ITERATION LIMITER (NSHT),
c RELAXATION FACTOR (FACT) AND OTHER CONSTANTS.
c
      NGR=4
      NGP=4
      NSHT=30
      FACT=1.0
      AMU=1.75E-4
      PI=3.141592654
      NR=NR1
      NP=NP1
      DO 18 I=2,NR
```

```
18    RS(I)=RS1(I)
      RS(1)=0.0
      WRITE(6,400)
400   FORMAT(//1X,"TURBULENCE CALCULATIONS :")
      DO 10 I=2,NR
      DO 12 J=1,NP
12    PT(I,J)=PT1(I,J)
10    CONTINUE
C
C  COMPUTE RING AVERAGE PRESSURES FOR ESTIMATING BOUNDARY CONDITIONS.
C
      SUM=0.0
      SUM5=0.0
      SUM7=0.0
      SUM1=0.0
      DO 20  J=1,NP
      SUM=SUM+PT(2,J)
      SUM5=SUM5+(PTT0-PT(6,J))
      SUM7=SUM7+PT(7,J)
      SUM1=SUM1+2.-PT(NR-2,J)-PT(NR-1,J)
20    CONTINUE
      AVG=SUM/NP
      AVG5=SUM5/NP
      PT7A=SUM7/NP
      AVGP=SUM1/2.0/NP
      DO 30 J=1,NP
      PT(1,J)=AVG
30    CONTINUE
C
C  NONDIMENSIONALIZE RADIAL COORDINATE AND GENERATE GRID POINTS.
C
      DO 40 I=2,NR-1
      RS(I)=RS(I)/RS(NR)
      DR(I-1)=(RS(I)-RS(I-1))/NGR
      DO 40 II=1,NGR
      L=(I-2)*NGR+II
      GR(L)=RS(I-1)+(II-1)*DR(I-1)
40    CONTINUE
      THP=2.*PI/NP
      THG=THE/NGP
```

```
      NPW=(NR-2)*NGR+1
      NPW=NP*NGP
      GR(NRW)=RS(NR-1)
      DO 50 J=1,NP
      THA(J)=(J-1)*THE
      DO 50 JJ=1,NGP
      L=(J-1)*NGP+JJ
      GT(L)=THA(J)+(JJ-1)*THG
50    CONTINUE
C
C  ESTIMATE BOUNDARY RMS LEVEL AND CALCULATE VELOCITY DISTRIBUTIONS.
C
      DA=RS(NR)/6.
      RS(NR)=1.0
      CK=0.115*(PTT0-PT2)**(-0.2587)
      RED=U2*DA/AMU
      VELR=0.1275*(ALOG10(RED))**(-2.5)
      AWUR=SQRT(VELR)*U2*DA/AMU/2.
      PMU=1./AWUR
      CENK=10.0
      CENE=0.164*CENK**1.5/0.12
      WRMS=CK*AVGS
      IF(WRMS .LT. 0.01) FACT=0.7
      DO 5 J=1,NP
      SUMP=0.0
      DO 15 I=1,NR-1
      DENR=(PT(I,J)/PT7A)**0.714286
      P1=PT(I,J)/DENR-PT7A
      P1=3.5*P1/Q2/VELR/PT2
      U(I,J)=SQRT(ABS(P1))
      IF(P1 .LT. 0.) U(I,J)=-U(I,J)
      IF(I .LT. NR-2) GO TO 15
      SUMP=SUMP+(1.-PT(I,J))
15    CONTINUE
      P0=CK*SUMP/2.0/AVGP
      P1=1./3.*U(NR-1,J)**2
      P2=1.75*WRMS/Q2/VELR/DENR
      WR(J)=-P1+SQRT(P1*P1+P2*P2)
      U(NR,J)=0.0
      WUR(J)=-2.0*U(NR-1,J)/(1.0-RS(NR-1))
```

```
5     CONTINUE
      WRITE(6,300)
300   FORMAT(/5X,"DIMENSIONLESS VELOCITY AT EACH PROBE LOCATION:")
      DO 35 J=1,NP
      WRITE(6,500) (U(I,J),I=1,NR)
500   FORMAT(1X,12F10.2)
35    CONTINUE
      C1(1)=0.
c
c  SET INITIAL VALUES FOR TURBULENCE KINETIC ENERGY, GK.
c
      CALL CUBIC(NP,WK,THA,C1,C2,C3)
      CALL INITL(CENK,WK,GK)
c
c  CALCULATE THE RADIAL AND CIRCUMFERENTIAL VELOCITY GRADIENTS.
c
      CALL INIVEL(U,RS,THA,DR,THG,NPW,NRW,WUR,GR,NR,NP,NGR,NGP)
      DO 65 J=1,NP
      JNP=(J-1)*NGP+1
      WE(J)=0.3*WK(J)*SQRT(UUG(NRW,JNP))
65    CONTINUE
      C1(1)=0.
c
c  SET INITIAL VALUES FOR TURBULENT KINETIC ENERGY DISSIPATION RATE,
c  GE.
c
      CALL CUBIC(NP,WE,THA,C1,C2,C3)
      CALL INITL(CENE,WE,GE)
600   FORMAT(13X,"****************************************")
      WRITE(6,200)
200   FORMAT(//5X,"ERRORS IN K, E AND (K+E) OF EACH ITERATION:")
      UUM=UUG(1,1)
      DO 45 J=2,NPW
      IF(UUG(1,J) .GT. UUM) UUM=UUG(1,J)
45    CONTINUE
      DO 55 J=1,NPW
      UUG(1,J)=UUM
55    CONTINUE
      NPG=NGP
      NPG=NGP
```


ORIGINAL PAGE IS
OF POOR QUALITY

```
      NRP=NR
      NPP=NP
C
C  CALL FINITE SUBROUTINE TO SOLVE FOR THE TURBULENCE MODEL USING
C  FINITE DIFFERENCE FORMULATIONS.
C
      CALL FINITE(UUG,DR,THG,NPW,NRW)
      CALL PRNT (8)
      WRITE(6,100)
  100 FORMAT(//4X,"RESULTS OF TURBULENCE CALCULATIONS:")
      WRITE(6,800)
  800 FORMAT(/13X,"PROBE",5X,"UU",10X,"E",11X,"K",9X,"SG/PT2")
C
C  COMPUTE RMS LEVEL AT EACH PROBE.
C
      SUMF=0.0
      DO 60 J=1,NP
      JJ=(J-1)*NGP+1
      DO 60 I=1,NR-2
      II=I*NGR+1
      TK=GK(II,JJ)
      TE=GE(II,JJ)
      TUU=UUG(II,JJ)
      TU=U(I+1,J)
      TR=RS(I+1)
      NT=(J-1)*(NR-2)+I
      DENR=(PT(I+1,J)/PT7A)**0.714286
      PRO=0.09*TK*TK*TUU/TE/TE
      P0=2./3.
      P1=2.*Q2*DENR*VELR/3.5
      P2=P0*TU*TU
      RMS=P1*SQRT(P2*TK+TK*TK)
      SUMF=SUMF+RMS**2
      WRITE(6,700) NT,TUU,TE,TK,RMS
  700 FORMAT(11X,I5,3F12.4,F12.6)
   60 CONTINUE
      RMSAG=SUMF/NT
      RETURN
      END
C
```

```
c --------------------------------------------------------------------------------
c
      SUBROUTINE INITL(CE,WA,GA)
c
c  THIS SUBROUTINE GIVES THE INITIAL VALUES OF GK AND GE.
c
      DIMENSION WA(20),GA(80,80)
      COMMON /CUB/ NGR,NGP,NPW,NRW,NR,NP,RS(20),THA(20),DR(20),C1(20),
     &             C2(20),C3(20),THG
      DO 1 J=1,NP
      DO 1 I=1,NGP
      JJ=(J-1)*NGP+I
      T1=THA(J)+(I-1)*THG
      P1=T1-THA(J)
      GA(NRW,JJ)=((C1(J)*P1+C2(J))*P1+C3(J))*P1+WA(J)
 1    CONTINUE
      DO 2 J=1,NPW
      DA=(GA(NRW,J)-CE)/RS(NR-1)
      DO 2 I=1,NR-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
c
c --------------------------------------------------------------------------------
```

```
c
      SUBROUTINE INIVEL(U,R,T,DR,TG,NPW,NRW,WUR,GR,NR,NP,NGR,NGP)
c
c THIS SUBROUTINE COMPUTES THE RADIAL AND CIRCUMFERENTIAL VELOCITY
c GRADIENTS AT EACH GRID POINT USING CUBIC SPLINE INTERPOLATIONS.
c
      DIMENSION U(11,20),R(20),T(20),C1(60),C2(60),C3(60),A(60),DR(20),
     &          WUR(20),WURG(80),RA(60),GR(NRW)
      COMMON /VELGR/ URG(80,80),URRG(80,80),UTG(80,80),UTTG(80,80),
     &               UUG(80,80),UG(80,80)
      DO 1 I=2,NR-1
      DO 2 J=1,NP
      A(J)=U(I,J)
2     CONTINUE
      C1(1)=0.
      CALL CUBIC(NP,A,T,C1,C2,C3)
      II=(I-1)*NGR+1
      DO 1 J=1,NP
      DO 1 K=1,NGP
      KK=(J-1)*NGP+K
      T1=(K-1)*TG
      UG(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,NGP
      KK=(J-1)*NGP+K
      UG(1,KK)=U(1,J)
3     CONTINUE
      C1(1)=0.
      CALL CUBIC(NP,WUR,T,C1,C2,C3)
      DO 4 J=1,NP
      DO 4 K=1,NGP
      KK=(J-1)*NGP+K
      T1=(K-1)*TG
      WURG(KK)=((C1(J)*T1+C2(J))*T1+C3(J))*T1+WUR(J)
4     CONTINUE
      MP=NPW/2
      MR=2*NR-1
      DO 5 J=1,MP
      JJ=MP+J
```

```
      DO 6 I=1,MR
      IF(I .GT. MR) GO TO 8
      IF(I .EQ. 1) GO TO 7
      II=(MR-I)*NGR+1
      A(I)=UG(II,J)
      RA(I)=R(MR-I+1)
      GO TO 6
 7    C1(1)=999.
      C1(2)=WURG(J)
      A(I)=0.
      RA(I)=R(MR)
      GO TO 6
 8    CONTINUE
      IF(I .EQ. MR) GO TO 9
      II=(I-MR)*NGR+1
      A(I)=UG(II,JJ)
      RA(I)=-R(I-MR+1)
      GO TO 6
 9    C1(3)=-WURG(JJ)
      A(I)=0.
      RA(I)=-R(MR)
 6    CONTINUE
      CALL CUBIC(MR,A,RA,C1,C2,C3)
      DO 11 I=2,MR-1
      IF(I .GT. MR-1) GO TO 12
      DO 13 K=1,NGR
      II=(MR-I)*NGR+2-K
      IK=MR-I
      R1=-(K-1)*DR(IK)
      UG(II,J)=((C1(I)*R1+C2(I))*R1+C3(I))*R1+A(I)
      URG(II,J)=(3.*C1(I)*R1+2.*C2(I))*R1+C3(I)
      URRG(II,J)=6.*C1(I)*R1+2.*C2(I)
 13   CONTINUE
      GO TO 11
 12   CONTINUE
      DO 22 K=1,NGR
      II=(I-MR)*NGR+K
      IK=I-MR+1
      R1=-(K-1)*DR(IK)
      UG(II,JJ)=((C1(I)*R1+C2(I))*R1+C3(I))*R1+A(I)
```

```
      URG(II,JJ)=-((3.*C1(I)*R1+2.*C2(I))*R1+C3(I))
      URRG(II,JJ)=6.*C1(I)*R1+2.*C2(I)
22    CONTINUE
11    CONTINUE
      UG(1,J)=UG(1,JJ)
      URG(1,J)=-URG(1,JJ)
      URRG(1,J)=URRG(1,JJ)
5     CONTINUE
      DO 14 J=1,NPW
      UTG(1,J)=0.
      UTTG(1,J)=0.
      DO 14 I=2,NRW
      IF(J .EQ. 1) GO TO 15
      IF(J .EQ. NPW) GO TO 16
      B=UG(I,J-1)
      D=UG(I,J+1)
      GO TO 17
15    B=UG(I,NPW)
      D=UG(I,2)
      GO TO 17
16    B=UG(I,NPW-1)
      D=UG(I,1)
17    UTG(I,J)=(D-B)/2./TG/GR(I)
      UTTG(I,J)=(D+B-2.*UG(I,J))/TG/TG/GR(I)/GR(I)
14    CONTINUE
      DO 20 J=1,NPW
      DO 20 I=1,NRW
      UUG(I,J)=URG(I,J)**2+UTG(I,J)**2
20    CONTINUE
      RETURN
      END
c
c -----------------------------------------------------------------------
```

```
C
      SUBROUTINE CUBIC(N,Y,X,C1,C2,C3)
C
C THIS SUBROUTINE PERFORMS CUBIC SPLINE INTERPOLATIONS (SLOPE-BASED).
C
      DIMENSION Y(N),X(N),C1(N),C2(N),C3(N),G(60),H(60),S(60),B(60)
      DO 5 I=1,N-1
      G(I)=Y(I+1)-Y(I)
      H(I)=X(I+1)-X(I)
    5 S(I)=SQRT((G(I)/Y(3))**2+H(I)**2)
      H(N)=1.
      IF(C1(1) .NE. 0.) GO TO 7
      G(N)=Y(1)-Y(N)
      H(N)=X(N)-X(N-1)
      S(N)=SQRT(G(N)**2+H(N)**2)
    7 CONTINUE
      DO 10 I=1,N
      IF(I .EQ. 1) GO TO 1
      IF(I .EQ. N) GO TO 2
      P1=G(I-1)*S(I)/H(I-1)
      P2=G(I)*S(I-1)/H(I)
      B(I)=(P1+P2)/(S(I)+S(I-1))
      GO TO 10
    1 CONTINUE
      P1=G(N)*S(1)/H(N)
      P2=G(1)*S(N)/H(1)
      B(1)=(P1+P2)/(S(1)+S(N))
      IF(C1(1) .EQ. 999.) B(1)=C1(2)
      GO TO 10
    2 CONTINUE
      P1=G(N-1)*S(N)/H(N-1)
      P2=G(N)*S(N-1)/H(N)
      B(N)=(P1+P2)/(S(N)+S(N-1))
      IF(C1(1) .EQ. 999.) B(N)=C1(3)
   10 CONTINUE
      B(N+1)=B(1)
      M=N-1
      IF(C1(1) .EQ. 0.) M=N
      DO 50 I=1,M
      P1=H(I)*H(I)
```

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

```
C
      SUBROUTINE TRIDIA(N,A,B,C,F,X)
C
C THIS SUBROUTINE SOLVES THE TRIDIAGONAL MATRIX EQUATION.
C
      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)
   10 CONTINUE
      X(N)=F(N)
      DO 20 I=1,N-1
      J=N-I
      X(J)=F(J)-C(J)*X(J+1)
   20 CONTINUE
      RETURN
      END
C
C ------------------------------------------------------------------------
```

```
c
      SUBROUTINE FINITE(UU,DR,THG,NPW,NRW)
c
c THIS SUBROUTINE SOLVES FOR THE FINITE DIFFERENCE SCHEME USING
c IMPLICIT TRIDIAGONAL MATRIX FORMULATIONS.
c
      DIMENSION DR(20),UU(80,80),A(160),B(160),C(160),F(160),XK(160),
     &    XE(160),VMEFF(80,80),DRG(80),A1(160),B1(160),C1(160),F1(160)
      COMMON /PARA/ PMU,NRR,NPP,NRG,NPG,NSHT,FACT
      COMMON /INIKE/ GK(80,80),GE(80,80),GR(80),GT(80),ERRK,ERRE
c
c SET INITIAL PARAMETER AND CONSTANTS.
c
      NSH=1
      SIGK=1.0
      SIGE=1.3
      CE1=1.45
      CE2=2.0
      DO 1 I=1,NRR-2
      PDR=DR(I)/NRG
      DO 1 K=1,NRG
      KK=(I-1)*NRG+K
      DRG(KK)=PDR
 1    CONTINUE
      DO 2 I=1,NRW
      DO 2 J=1,NPW
      VMEFF(I,J)=0.09*GK(I,J)**2/GE(I,J)+PMU
 2    CONTINUE
      MP=NPW/2
      MR=2*NRW-1
      NM=MR-2
c
c START ITERATIONS.
c
 4    CONTINUE
      ERRK=0.0
      ERRE=0.0
c
c COMPUTE ELEMENTS OF TRIDIAGONAL MATRIX EQUATIONS OF K AND E.
c
```

```
      DO 3 J=1,MP
      DO 7 I=1,NM
      IF(I .GT. NRW-1) GO TO 5
      II=NRW-I
      JJ=J
      K=1
      L1=0
      L2=1
      JP=JJ-1
      JQ=JJ+1
      IF(J .EQ. 1) JP=NPW
      GO TO 6
 5    CONTINUE
      II=I-NRW+2
      JJ=J+MP
      K=-1
      L1=1
      L2=0
      JP=JJ-1
      JQ=JJ+1
      IF(J .EQ. MP) JQ=1
 6    CONTINUE
      I0=II
      GR0=GR(II)
      GRB=GR(II+K)
      GRA=GR(II-K)
      THG0=THG
      IF(I .NE. NRW-1) GO TO 12
      GR0=1.0
      GRB=1.0
      GRA=1.0
      THG0=DRG(II)
      I0=2
      JP=JJ+MP+MP/2
      JQ=JJ+MP/2
      IF(JP .GT. NPW) JP=JP-NPW
 12   CONTINUE
      P1=GR0*VMEFF(II,JJ)+GRB*VMEFF(II+K,JJ)
      P2=GRA*VMEFF(II-K,JJ)+GR0*VMEFF(II,JJ)
      P3=VMEFF(II,JJ)+VMEFF(I0,JP)
```

```
      P4=VMEFF(I0,J0)+VMEFF(II,JJ)
      PP=2.*GR0**2*THG0**2
      IF(I .EQ. NRW-1) GO TO 17
      P5=(P3+P4)/PP
      CK=-(GK(I0,J0)*P4+GK(I0,JP)*P3)/PP
      CE=-(GE(I0,J0)*P4+GE(I0,JP)*P3)/PP
17    CONTINUE
      QR1=DRG(II-L1)
      QR2=DRG(II-L2)
      IF(I .EQ. NRW-1) QR2=QR1
      QR=(QR1+QR2)*GR0
      Q1=QR1*QR
      Q2=QR2*Q1
      Q3=QR2*QR
      AP=P1/Q1
      AA=-((QR1*P2+QR2*P1)/Q2+P5)
      AQ=P2/Q3
      FK=(GE(II,JJ)-VMEFF(II,JJ)*UU(II,JJ))/GK(II,JJ)
      FE=(CE2*GE(II,JJ)-CE1*VMEFF(II,JJ)*UU(II,JJ))/GK(II,JJ)
      B(I)=AP/SIGK
      A(I)=AA/SIGK-FK/2.
      C(I)=AQ/SIGK
      F(I)=CK/SIGK
      IF(I .EQ. 1) F(I)=F(I)-B(I)*GK(II+1,JJ)
      IF(I .EQ. NM) F(I)=F(I)-C(I)*GK(II+1,JJ)
      B1(I)=AP/SIGE
      A1(I)=AA/SIGE-FE/2.
      C1(I)=AQ/SIGE
      F1(I)=CE/SIGE
      IF(I .EQ. 1) F1(I)=F1(I)-B1(I)*GE(II+1,JJ)
      IF(I .EQ. NM) F1(I)=F1(I)-C1(I)*GE(II+1,JJ)
7     CONTINUE
c
c  SOLVE FOR TRIDIAGONAL MATRIX EQUATIONS OF K AND E (XK AND XE).
c
      CALL TRIDIA(NM,A,B,C,F,XK)
      CALL TRIDIA(NM,A1,B1,C1,F1,XE)
      DO 8 I=1,NM
      IF(I .GT. NRW-1) GO TO 9
      II=NRW-I
```

```
      JJ=J
      GO TO 10
9     CONTINUE
      II=I-NRW+2
      JJ=J+MP
10    CONTINUE
c
c     COMPUTE RELATIVE ERRORS.
c
      ERRK=ERRK+ABS(XK(I)-GK(II,JJ))*100./GK(II,JJ)
      ERRE=ERRE+ABS(XE(I)-GE(II,JJ))*100./GE(II,JJ)
      IF(XK(I) .LT. 0.0001) XK(I)=0.0001
      IF(XE(I) .LT. 0.0001) XE(I)=0.0001
c
c     OBTAIN UP-DATED SOLUTIONS WITH RELAXATION FACTOR, FACT.
c
      GK(II,JJ)=GK(II,JJ)+FACT*(XK(I)-GK(II,JJ))
      GE(II,JJ)=GE(II,JJ)+FACT*(XE(I)-GE(II,JJ))
      VMEFF(II,JJ)=0.09*XK(I)**2/XE(I)+PMU
8     CONTINUE
100   FORMAT(9X,3F15.5)
3     CONTINUE
      ERRK=ERRK/NM/MP
      ERRE=ERRE/NM/MP
      ERRT=ERRK+ERRE
      WRITE(6,100) ERRK,ERRE,ERRT
      IF(NSH .GE. NSHT) GO TO 20
      NSH=NSH+1
      GO TO 4
20    CONTINUE
      RETURN
      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
C
C  DPT1 IS THE PRESSURE FLUCTUATION AT PROBE AR(J) AND ANGLUC(J,I)
C
      DPT1=2.0*VBAR*BASE/EXP(0.5*RAD)
 75   P(J,I)=PS(J,I)+DPT1*QUPT*TMAVGG
 80   CONTINUE
      GO TO 90
C
C  RESET STATIC PRESSURE RINGS TO STATIC PRESSURE.
C
 78   DO 79 I=1,NP
 79   P(J,I)=PS(J,I)
 90   CONTINUE
```

original code

---

new addition

```
C
C  *** NEW "SEGMENTED" VORTEX METHOD BY STEPHEN R. DENNON ***
C  FIND PROBE LOCATION (RADLOC) NEAREST TO MEAN LINE
C
      DO 120 I=1,NP
      DDP(I) = 10.
      DO 110 J=1,NR
      DP(J,I) = ABS(TMAVGG - PS(J,I))
      IF (DP(J,I) .LE. DDP(I)) GO TO 100
      GO TO 110
 100  DDP(I) = DP(J,I)
      RADLOM(I) = RADLOC(J)
 110  CONTINUE
 120  CONTINUE
C
C  SOLVE FOR NEW PEAK INSTANTANEOUS PRESSURE ARRAY
C
      DO 140 I=1,NP
      DO 130 J=1,NR
      IF (J .LT. J1 .OR. J .GT. J2) GO TO 125
      DRR = ABS(RADLOM(I) - RADLOC(J))
      RRA = DRR/RT/ART
      RAD = RRA**2-1.
      DPT1 = ABS(2*VBAR*RRA*QOPT*TMAVGG/EXP(.5*RAD))
      IF (PS(J,I) .LE. TMAVGG) GO TO 121
      P(J,I) = PS(J,I) + DPT1
      GO TO 130
 121  P(J,I) = PS(J,I) - DPT1
      GO TO 130
 125  P(J,I) = PS(J,I)
 130  CONTINUE
 140  CONTINUE
```

---

original code

```
C
      IF (IV=1) 91,91,92
 91   CALL PFIX (.TRUE.)
      CALL DISTRT
      GO TO 600
 92   CALL PRNT (2)
      CALL PFIX(.TRUE.)
      CALL DISTRT
      CALL PFIX(.FALSE.)
      CALL MAINLP
      CALL LNPOUT(1)
      WRITE (6,1995)
      WRITE (6,2000) VBAR,ART,G,B,AYRT,VL,RRT,TV
      WRITE (6,1999) VBM,VB0,A0
```

APPENDIX C.

QUICK REFERENCE GUIDE

1. MAXIDYN Program Description

2. Input Data Description

3. Output Data Description

1. MAXIDYN Program Description

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

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

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

2. Input Data Description

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

Data	*	Format	Definition
NR		I5	Number of pressure tap radial locations
NP		I5	Number of rakes
RADLOC		F10.5	Radial location of pressure taps
ANGLOC		F10.5	Angular location of rakes in degrees
KD		I5	Distortion factor selection index KD = 1: KTHETA 2: KD2 3: IDC 4: IDR 5: KRA 6: KA2 7: DSPR 8: ID

Data	*	Format	Definition
T	*	F10.5	RMS fluctuation measurement time-on-point default = 1 sec.
F0	*	F10.5	Engine filter frequency, default = 500 Hz
FC0	*	F10.5	RMS cut-off filter frequency, 1000 Hz def.
TITLE	*	A80	Title block
BRP	*	F10.5	Base radial profile array, default = 1.0
PS		F10.5	Steady-state pressure array
ALPH	*	F5.3	Inlet angle of attack in degrees
PSI	*	F5.3	Inlet yaw angle (crosswind) in degrees
M0	*	F5.3	Freestream Mach number
U2		F5.3	Inlet flow velocity in fps
BF	*	F5.3	B-factor for weighting in KA2 computation default = 1.0
CKP	*	F5.3	Circumferential ID weighting factor, default = 16.4
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

NR	NP						
RADLOC(1)	RADLOC(2)	RADLOC(3)	RADLOC(4)	RADLOC(5)	RADLOC(6)	RADLOC(7)	RADLOC(8)
ANGLOC(1)	ANGLOC(2)	ANGLOC(3)	ANGLOC(4)	ANGLOC(5)	ANGLOC(6)	ANGLOC(7)	ANGLOC(8)
KD	T	FO	FCO				
TITLE1							
TITLE2							
BRP(1)	BRP(2)	BRP(3)	BRP(4)	BRP(5)	BRP(6)	BRP(7)	BRP(8)
PS(1,1)	PS(1,2)	PS(1,3)	PS(1,4)	PS(1,5)	PS(1,6)	PS(1,7)	PS(1,8)
PS(2,1)	PS(2,2)	PS(2,3)	PS(2,4)	PS(2,5)	PS(2,6)	PS(2,7)	PS(2,8)
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
PS(NR,1)	PS(NR,2)	PS(NR,3)	PS(NR,4)	PS(NR,5)	PS(NR,6)	PS(NR,7)	PS(NR,8)
ALPH	PSI	MO	U2	BF	CKR	AKR	MFR
NTUR	SPTRC						
NPG	NPR1	RS	SIG				
NPG	NPR2	RS	SIG				
⋮	⋮	⋮	⋮				
NPG	NPRn	RS	SIG				
0.	0.	0.	0.				
TITLE1 (for next run)							

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.

<u>Page 1</u>

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

<u>Page 2</u>

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.

<u>Page 3</u>

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 distortion levels are indicated; INF referring to the unfiltered case and FO representing the filtered case.

In the case where the turbulence modelling scheme is used to generate the dynamic data, the fourth page includes further results of the TURBULENCE CALCULATIONS. This table is similar to the dynamic data table as described in the third page of output, with the exception that the term RS is deleted, and velocity gradiants (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 desireable.

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

VII. REFERENCES

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