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Part VIII

ROTOR-BEARING DYNAMICS TECHNOLOGY DESIGN GUIDE

Part VIII A Computerized Retrieval System for Fluid Film Bearings

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This report describes a computerized data storage retrieval system for the static and dynamic characteristics of fluid film bearings. The procedure combines asymptotic power law extrapolation outside the stored data range with smooth interpolation within the data table. Thirty-one data tables given in ~~AFAPL-TR-78-6, Part VI~~ have been prepared and installed in the system. The procedure allows addition of new data tables in the future. The retrieval software allows the user to list the data content in either

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) the dimensional or the dimensionless form or to generate data lines in the sequence and format directly usable as input to the rotordynamics software described~~, in AFAPL-TR-78-6, Part I.~~ Inertia, compliance and damping effects of the pedestal can be included in the retrieval dynamic characteristics of each bearing.

PREFACE

The work reported herein is for a partial fulfillment of USAF Contract No. AF33615-76-C-2038. Dr. Coda H. T. Pan, the Principal Investigator of the contract, was directly involved in the execution of the technical effort with the assistance of Mr. B. F. Geren, Ms. J. A. Bartlett, and Mr. S. Fiedler. The contract was initiated under Project 3048, "Fuels, Lubrication and Fire Protection," Task 304806, "Aerospace Lubrication," Work Unit 30480685, "Rotor-Bearing Dynamics Design."

The work reported herein was performed during the period March 1979 to March 1980 under the direction of John B. Schrand (AFWAL/POSL) and Dr. James F. Dill (AFWAL/POSL), Project Engineers. The report was released by Shaker Research Corporation in April 1980.

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NOMENCLATURE

a_o	near field constant
b_o	effective damping constant (lb-sec/in); far field constant
B_{xx}, B_{xy}, etc.	damping coefficients (lb-sec/in)
[B]	damping matrix (lb-sec/in)
$\overline{B}_{xx}$, $\overline{B}_{xy}$, etc.	$2\pi C\{\mu LD(R/C)^2\}^{-1}$ X (B_{xx}, B_{xy}, etc.)
$[\overline{B}]$	$2\pi C\{\mu LD(R/C)^2\}^{-1}$ [B]
C	radial arc clearance (in)
C_b	radial bearing clearance (in)
D	journal diameter (in)
e	eccentricity (in)
f	vibrational frequency (Hz)
F_x, F_y	components of bearing reaction force (lb)
F'_x, F'_y	components of perturbation bearing reaction (lb)
$\tilde{F}_x$, $\tilde{F}_y$	complex amplitudes of F'_x and F'_y for simple harmonic motion (lb)
G_x, G_y	complex coefficients in the governing equation for the eigenvector
J_p	pitching mass moment of inertia of a tilting pad
$\overline{J}$	$J_p N_s[\mu(R/C)^2(LD)R]$
k_o	effective stiffness constant (lb/in)
K_{xx}, K_{xy}, etc.	stiffness coefficients (lb/in)
[K]	stiffness matrix (lb/in)
$\overline{K}_{xx}$, $\overline{K}_{xy}$, etc.	$C\{\mu N_s LD(R/C)^2\}^{-1}$ X (K_{xx}, K_{xy}, etc.)
$[\overline{K}]$	$C\{\mu N_s LD(R/C)^2\}^{-1}$ [K]
L	bearing length (in)

[M]	inertia matrix (lb-sec^2/in)
m	preload, 1-C_b/C
m_o	consistent mass (lb-sec^{2}in)
N_s	rotor speed (rev/sec)
Q_{loss}	volume flow rate of lubricant lost by end leakage (in^3/sec)
$Q_{required}$	volume flow rate of lubricant (in^3/sec)
$\bar{Q}_{loss}$, $\bar{Q}_{required}$	$(N_s LDC)^{-1}$ $(Q_{loss}, Q_{required})$
R	journal radius, D/2 (in)
S	Sommerfeld number, $\mu N_s LD(R/C)^2/W$
T	bearing friction torque (in-lb)
$\bar{T}$	$4TC/(\mu N_s D^3 L)$
u_o	amplitude of $\tilde{\delta}_{xo}$
U_x, U_y	real parts of G_x and G_y, respectively
V_x, V_y	imaginary parts of G_x and G_y, respectively
$\underline{w}$	vector symbol for (δ_x, δ_y)
$\underline{w}_o$	vector symbol for $(\tilde{\delta}_{xo}, \tilde{\delta}_{yo})$
W	static load magnitude (lbs)
$\bar{W}$	1/S, static equilibrium load parameter
x, y	Cartesian coordinates of the journal bearing in the radial plane; x is along the direction of load, rotation is counterclockwise
X, Y	global Cartesian coordinates of the rotor in the radial plane
[Z]	[K] = i [B]

α	load scaling parameter for L/D variation
γ_o	argument of $\tilde{\delta}_{xo}$
δ_{xo}, δ_{yo}	components of static displacement (in)
δ'_x, δ'_y	components of perturbation displacement (in)
$\dot{\delta}_x$, $\dot{\delta}_y$	components of perturbation velocity (in/sec)
$\tilde{\delta}_x$, $\tilde{\delta}_y$	complex amplitudes of δ_x and δ_y for simple harmonic motion (in)
ε	e/C, eccentricity ratio of bearing arc
ε	e/C_b, eccentricity ratio of assembled bearing
μ	viscosity coefficient of lubricant (Reyns)
ν	frequency of oscillation (radians/sec)
ω	rotational speed (radians/sec)
ψ	attitude angle (deg)
τ	$\frac{2}{\pi}\tan^{-1}(\overline{W})$, load parameter function
θ_p	angular location of pivot or preload line measured from the leading edge of a bearing pad arc angle of bearing pad
χ	arc angle of bearing pad (deg)

<u>Subscripts</u>

Arg { }	Argument of the complex quantity { }
b	rigidly mounted bearing
o	natural orbit
p	pedestal
$(\dot{\ })$	time derivative

SECTION I

INTRODUCTION

Reliable prediction of the dynamic behavior of a rotor system supported by fluid film bearings (e.g., critical speeds and resonant frequencies, damped response to mass imbalance and other forms of dynamic excitation, and threshold of self-excited instability) depends on an accurate knowledge of the dynamic restraining characteristics of each bearing, which are represented by a set of eight dynamic perturbation coefficients (stiffness and damping coefficients with cross-coupling effects). Given the details of the bearing design (e.g., diameter, length, nominal operating clearance, gap geometry), lubricant viscosity and its temperature dependance, operating speed, and the lubricant film temperature, one can in principle compute steady state performance parameters (e.g., minimum gap, bearing friction, lubricant flow rate) and the dynamic perturbation coefficients. Typically, it is necessary to resort to some numerical technique in such computations. In the previous issue of the Rotor-Bearing Dynamics Technology Design Guide, one volume dealt with the calculation of performance parameters and perturbation coefficients for circular arc journal bearings operating with an incompressible lubricant [1]. Since then, other sources for such computations have also become available either as software furnished in its entirety or by allowing the user to access installed software at a computer center [2]. Some of the software have the capability of accommodating special features in the gap geometry. The proliferation efforts of such software has not yet reached a well-defined trend. Even with the availability of such software, the computation of a set of data needed as input for a rotor-bearing dynamic analysis is not a totally trivial matter. The storage memory requirement is typically quite large. Accuracy of computed data is often sensitive to details in the input preparation which may be quite obscure to an inexperienced user. For these two reasons, it was decided not to link up the bearing computer software with the rotor dynamics software. Instead, as a part of the present effort to update the Rotor-Bearing Dynamics

Technology Design Guide, it was decided that the immediate attention should be directed toward the establishment of a procedure for the convenient extraction of the dynamic perturbation coefficients from a prepared data table. A basic data bank consisting of thirty-one tables for various incompressible fluid film bearings is described in another part of the new Design Guide [3]. The data bank can be readily appended with additional tables if so desired. The required procedures for extracting the desired dynamic perturbation coefficients and for installing additional data tables are described herein.

Gas lubricated fluid film bearings are also of interest in advanced aircraft turbo-propulsion systems. Recent technological efforts in this area are primarily concerned with gas bearings of the "foil" variety. Another part in the new Design Guide will be exclusively devoted to gas bearings for machinery applications [4].

SECTION II

DYNAMIC CHARACTERISTICS OF A JOURNAL BEARING

2.1 Static Equilibrium Condition

The dynamic perturbation coefficients of a journal bearing contains the information regarding the mutual interactions between the rotor and the bearing. The perturbation analysis of a dynamic system presumes the existence of a static equilibrium condition, and deals with the response to a dynamics excitation and/or whether the equilibrium condition is stable. Typically, the dynamic perturbation coefficients are dependent on the static equilibrium state. Parameters which define the static equilibrium condition of a journal bearing are illustrated in Fig. 1, which depicts the cross-sectional view of the space between the journal, the portion of shaft which passes through the bearing bushing, and the bushing inner surface, which is shown as a circle for the present purpose.

In the lateral plane, the x-axis of a two-dimensional right-handed Cartesian coordinate system is oriented along the direction of the static load W. Sense of rotation is by convention required to be counterclockwise. Under load, the journal center is displaced from the bearing center. The amplitude of the displacement is called bearing eccentricity e. It is a peculiarity of the fluid film bearing that the displacement vector is not necessarily parallel to the load vector. The angle measured from the load vector to the displacement vector (in the counterclockwise direction) is called the attitude angle ψ.

The overall geometry of the journal bearing is described by three dimensions; namely, the length L, the diameter D, and the clearance C. There is some variance in the literature regarding the connotation of the clearance. In the present document, it represents the radial distance between the journal surface and the bushing surface (or a portion thereof) when the centers of curvature of the two surfaces are made coincident. The operating condition of the journal bearing

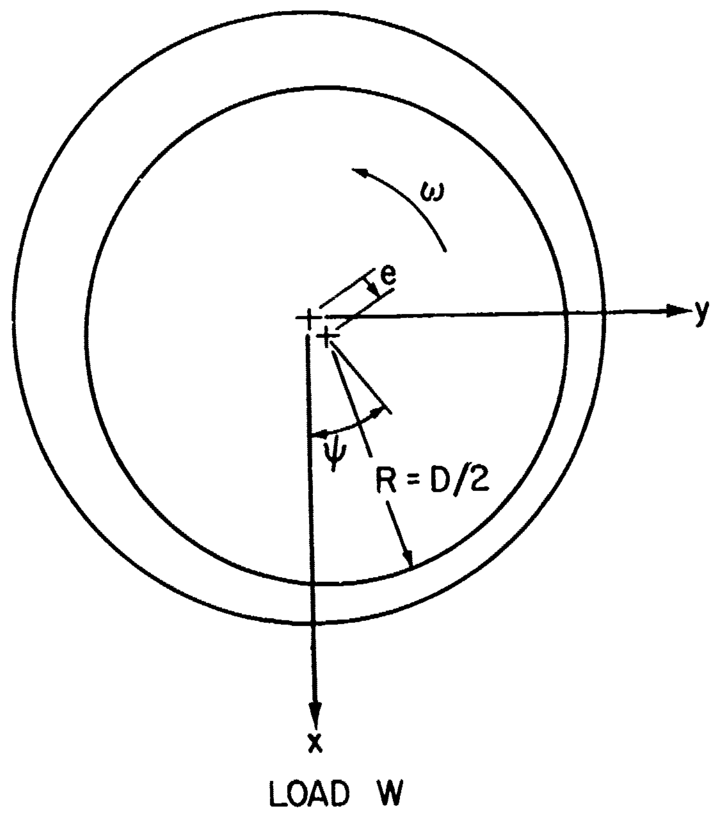

Figure 1 Static Equilibrium Condition of a Journal Bearing

is defined in terms of the rotational speed N_s (in units of revolution per sec) and the lateral load W (in pounds).

It is also necessary to specify the lubricant viscosity, which in turn is temperature dependent. Actually the lubricant temperature varies not only across the film thickness, but also along the passage through the bearing gap. Since it is impractical to allow for actual temperature dependance of viscosity in the computation of bearing operation characteristics, it is necessary to exer ise a judicious judgment in specifying the effective temperature level. In principle, a heat balance can be performed among friction heat generation, convection cooling by the lubricant flow, and conduction cooling through journal and bushing surfaces. However, uncertainty in the operating temperature level itself is typically sufficient to obscure other considerations. Therefore, for the present purpose, it is recommended that high-low estimates of the operating temperature be used for the determination of the effective lubricant viscosity in lieu of a more thorough treatment of the thermal problem.

In order to allow general applicability to bearings possessing geometrical similarity irrespective of size, clearance to radius ratio, lubricant viscosity, and rotor speed, a data table is compiled in terms of dimensionless variables. Such dimensionless representation lends the data naturally to scaling in accordance with first principles. Among the parameters which represent the static equilibrium condition, specification of the load vector is sufficient. Other parameters are unique functions of the load vector (in the dimensionless representation). The directional parameter of the load vector relates to a reference axis which is peculiar to the bearing geometry. A plain circular bearing does not have such a reference axis due to its rotational symmetry; therefore, the load parameter is complete in terms of amplitude only. For other bearings (e.g., the two-lobe configuration) the direction of the load vector measured from a suitable reference axis of the particular configuration is also a relevant parameter. The Sommerfeld number

$$S = \frac{\mu N_s LD(R/C)^2}{W} \quad (1)$$

which is a natural parameter in any solution of the lubrication equation for a journal bearing, can be directly utilized to represent the amplitude of the static load. The latter appears in the right-hand side of Eq. (1), while all other quantities are presumably known for a specific problem. Note that the journal diameter D is customarily represented in conjunction with the bearing length L to describe the projected area; at the same time, the journal radius R also appears in a ratio with the clearance C. In fact a bearing engineer often thinks of (LD) and (C/R) as independent design parameters. The reciprocal of the Sommerfeld number is customarily accepted as the dimensionless representation of the static load (amplitude) and is sometimes referred to as the load parameter:

$$\overline{W} = 1/S = \frac{W}{\mu N_s LD(R/C)^2} \quad (2)$$

A brief comment on the applicable units is in order in view of the common addiction to "English units" of American and British engineers amidst the worldwide movement toward standardization via the SI units. In the "English" convention, W would be in lbs. while the consistent unit for μ is Reyns = lb-sec/in^2. If SI units are to be adhered to, then W should be in Newtons (1 N = 0.22482 lb) and μ in Pascal-sec (1 Pa = 1 N/m^2 = 1.45038×10^{-4} lb/in^2). For the reader who is more used to cgs units, it may be of interest to note

$$1 \text{ centipoise} = 1.45038 \times 10^{-7} \text{ Reyns}$$
$$= 0.001 \text{ Pa-sec}$$

$$1 \text{ centipoise} = 0.001 \text{ Pa-sec} = 1.45038 \times 10^{-7} \text{ Reyns}$$

Other operating parameters for the static equilibrium condition are unique functions of S or $\overline{W}$. Although they do not directly contribute to the dynamic perturbation problems, they are included in the data table for completeness. They are defined in the dimensionless representation as follows without further elaboration.

Eccentricity

Pad Eccentricity Ratio $\varepsilon = e/C$ (3a)

Bearing Eccentricity Ratio $\varepsilon_b = e/C_b$ (3b)

C_b is the largest radius which the journal center can circumscribe in an assembled bearing.

Attitude Angle

ψ (customarily given in deg)

Torque

$$\overline{T} = \frac{4TC}{\mu N_s D^3 L} \tag{4}$$

T is the frictional torque experienced by the bearing.

Lubricant Flow Rate

$$\overline{Q}_{required} = \frac{Q_{required}}{N_s LDC} \tag{5}$$

$$\overline{Q}_{loss} = \frac{Q_{loss}}{N_s LDC}$$

$Q_{required}$ is the volume flow rate which passes through the bearing inlet edge. Q_{loss} is the volume flow rate leaving the bearing gap through its ends. The excess of $Q_{required}$ over Q_{loss} is the recirculation flow rate.

2.2 Dynamic Perturbations

The perturbation point of view requires that the deviation of the force of interaction between the rotor and the bearing from the equilibrium value be sufficiently small to permit use of the method of linear superposition in the dynamic analysis. The measure of "smallness" is that the amplitude of the perturbation displacement at any instant be a small fraction of the minimum film thickness. Dynamic analysis requires allowance for time-dependence. In the case of incompressible fluid film bearings, time-dependence is associated with squeeze film effects which correspond to velocity perturbations. Combined displacement and velocity perturbations are illustrated in Fig. 2. Displacement components (δ_x', δ_y') and velocity components $(\dot{\delta}_x, \dot{\delta}_y)$ form a complete set of perturbation parameters. The instantaneous bearing reaction has the components

$$F_x = -W + F_x'$$

$$F_y = F_y'$$

While the static equilibrium displacement is determined by $e = C\varepsilon$ and ψ, both ε and ψ being unique functions of $\bar{W} = W(C/R)^2/(\mu N_s LD)$, the perturbation hypothesis allows one to express the perturbation reaction components to be

$$F_x' = - K_{xx}\,\delta_x' - B_{xx}\,\dot{\delta}_x - K_{xy}\,\delta_y' - B_{xy}\,\dot{\delta}_y \qquad (7a)$$

$$F_y' = - K_{yx}\,\delta_x' - B_{yx}\,\dot{\delta}_x - K_{yy}\,\delta_y' - B_{yy}\,\dot{\delta}_y \qquad (7b)$$

The complete set of perturbation coefficients includes the stiffness coefficients $(K_{xx}, K_{xy}, K_{yx}, K_{yy})$ and the damping coefficients

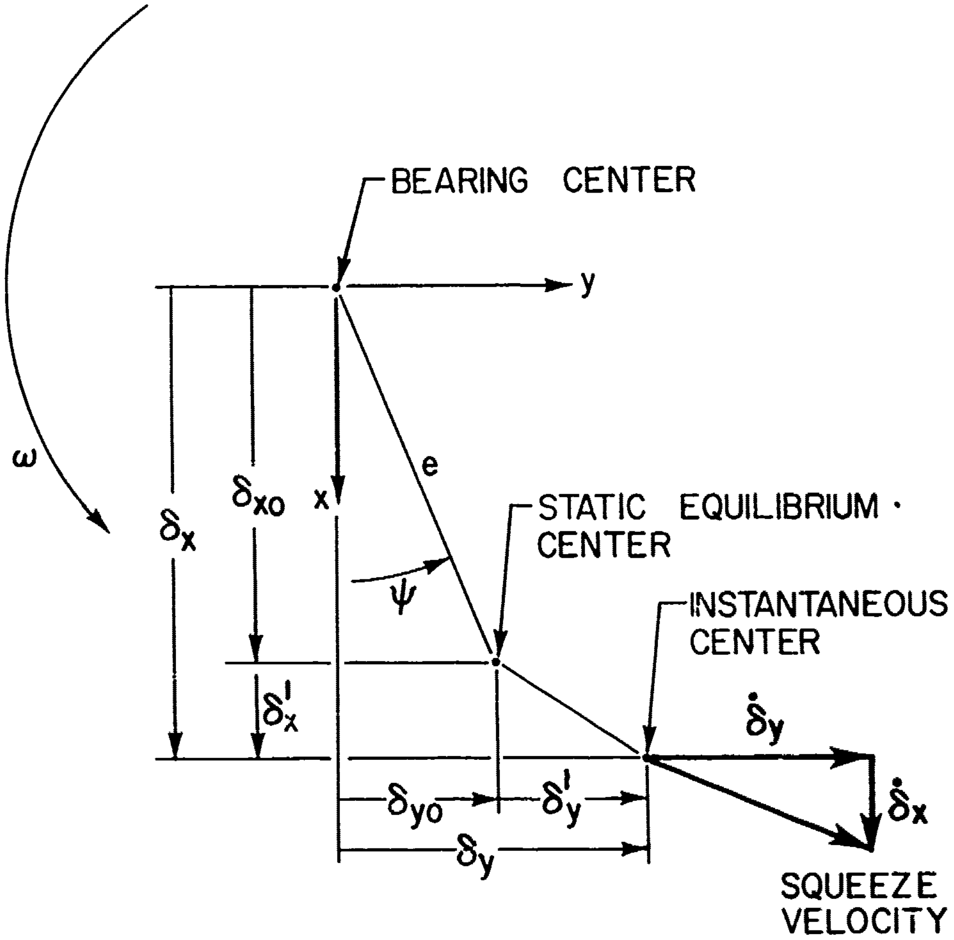

Figure 2 Displacement and Kinematic Perturbation Vectors

(B_{xx}, B_{xy}, B_{yx}, B_{yy}). Double subscripts are necessary because the perturbation reaction is not necessarily co-linear with either the perturbation displacement or the perturbation velocity. The first subscript denotes the direction of the reaction, and the second subscript represents the direction of the perturbation parameter. The stiffness coefficients are associated with displacement perturbations while the damping coefficients are associated with kinematic (velocity) perturbations. It is customary to employ the notations of matrix algebra to write

$$[K] = \begin{bmatrix} K_{xx} & K_{xy} \\ K_{yx} & K_{yy} \end{bmatrix} ; \quad [B] = \begin{bmatrix} B_{xx} & B_{xy} \\ B_{yx} & B_{yy} \end{bmatrix} \tag{8}$$

The perturbation coefficients are obtained by solving the lubrication equation which is linearized with respect to each of the eight perturbation parameters one at a time, then integrating the film pressure with the appropriate projection of bearing surface.

The perturbation coefficients can also be represented in the dimensionless form to allow dynamic scaling for geometrically similar bearings. Thus,

$$[\bar{K}] = \left[\frac{\mu N_s LD(R/C)^2}{C}\right]^{-1} [K] \tag{9a}$$

$$[\bar{B}] = \left[\frac{\mu LD(R/C)^2}{2\pi C}\right]^{-1} [B] \tag{9b}$$

From Eq. (2) one can write

$$\mu N_s LD(R/C)^2 = WS$$

Therefore, it may also be written

$$[\bar{K}] = \left(\frac{C}{WS}\right) [K] ; \quad [\bar{B}] = \left(\frac{\omega C}{WS}\right) [B] \tag{10}$$

$[\bar{K}]$ and $[\bar{B}]$ clearly are dependent on the static equilibrium parameter $\bar{W}$.

2.3 Symmetry Law for the Damping Matrix

It has been shown that the damping matrix is symmetrical provided the boundary conditions of the perturbation problem are time invariant [5]; that is

$$\bar{B}_{yx} = \bar{B}_{xy} \tag{11}$$

Bearings with fixed film boundaries or with a cavitation break up boundary determined by the Swift-Stieber condition [6, 7] inherently obey this symmetry relationship. Some approximate computation schemes may not conform to this requirement but otherwise yield fairly suitable results [3]. For this reason, the data retrieval system enforces this symmetry condition by substituting

$$(\bar{B}_{xy})_{adj} = (\bar{B}_{yx})_{adj} = \frac{1}{2}(\bar{B}_{xy} + \bar{B}_{yx}) \tag{12}$$

in place of $(\bar{B}_{xy}, \bar{B}_{yx})$ which are directly extracted from a data table and may not have identical values. Clearly, a data table which already satisfies Eq. (11) is not affected by this adjustement.

2.4 Natural Orbits and Effective Stiffness/Damping Constants

2.4.1 General Case: $Z_{xy} Z_{yx} \neq 0$

Suppose the perturbation motion is simple harmonic so that

$$(\delta_x', \delta_y') = \mathrm{Re}\,\{(\tilde{\delta}_x, \tilde{\delta}_y)e^{i\nu t}\} \tag{13}$$

The corresponding perturbation reactions are

$$(F_x', F_y') = \mathrm{Re}\,\{(\tilde{F}_x, \tilde{F}_y)e^{i\nu t}\} \tag{14}$$

To make use of matrix notation, write

$$\underline{w} = \begin{Bmatrix} \tilde{\delta}_x \\ \tilde{\delta}_y \end{Bmatrix} ; \quad \underline{P} \begin{Bmatrix} \tilde{F}_x \\ \tilde{F}_y \end{Bmatrix} \tag{15}$$

Given the stiffness and damping matrices, the perturbation reaction can be computed as

$$\underline{P} = - \left[K + i\nu B \right] \underline{w} \tag{16}$$

One can seek the condition of diagonalization of the above equation; i.e. provided the components of $\underline{w}$ assume a special relative amplitude and phase relationship, one can write

$$\underline{P}_o = -(k_o + i\nu b_o) \, \underline{w}_o \tag{17}$$

Subscript "o" designates the special relationship which describes a natural orbit. The physical interpretation of Eq. (17) is that the bearing behaves like a spring-dashpot restraint if the perturbed motion is a natural orbit, the spring and dashpot constants being respectively k_o and b_o.

Given [K] and [B] of a bearing, k_o and b_o can be found at any frequency ν as roots of a complex eigenvalue problem. Accordingly, $\underline{w}_o$ can be determined as the corresponding eigenvector. Upon first identifying $\underline{P}$ and $\underline{w}$ in Eq. (16) with $\underline{P}_o$ and $\underline{w}_o$ respectively, and then eliminating $\underline{P}_o$ between Eqs. (16) and (17), one obtains the homogeneous equation

$$\left[K + i\nu B - (k_o + i\nu b_o) \, I \right] \underline{w}_o = \underline{0} \tag{18}$$

[I] is the identity matrix with unity as its diagonal elements and null elements elsewhere. Disregarding the possibility that $\underline{w}_o$ may be a null vector, the characteristic determinant should vanish. k_o and b_o are roots of the characteristic determinant and are found as sets which are consistent with the null condition of both real and imaginary parts of the characteristic determinant. The characteristic determinant is

$$\{Z_{xx} - (k_o + i\nu b_o)\}\{Z_{yy} - (k_o + i\nu b_o)\} - Z_{xy}Z_{yx} = 0 \qquad (19)$$

where, $Z_{xx} = K_{xx} + i\nu B_{xx}$, etc.; and an explicit solution can be found as

$$k_o + i\nu b_o = \frac{1}{2}(Z_{xx} + Z_{yy}) \mp Z_o \qquad (20)$$

where

$$Z_o = \frac{1}{2}\sqrt{(Z_{xx} - Z_{yy})^2 + 4\, Z_{xy}Z_{yx}} \qquad (21)$$

By convention, Z_o has a non-negative real part. The alternate signs in Eq. (20) yield two independent sets of $(k_o, \nu b_o)$. One may observe that the imaginary part of the right-hand side of Eq. (20) may not vanish with ν. Thus, it is more appropriate to keep ν and b together as a product. It is sometimes useful to define $\beta_o = (\nu b_o)/(2k_o)$ as the critical damping ratio of the natural orbit, which is related to the amplitude decrement factor of an unrestrained natural motion per cycle.

Corresponding to the two sets of $(k_o, \nu b_o)$, there are two eigenvectors, which are defined by

$$\{\frac{1}{2}(Z_{xx} - Z_{yy}) \pm Z_o\}\, \tilde{\delta}_{xo} + Z_{xy}\tilde{\delta}_{yo} = 0 \qquad (22a)$$

or, alternately,

$$Z_{yx}\tilde{\delta}_{xo} - \left[\frac{1}{2}(Z_{xx} - Z_{yy}) \pm Z_o\right]\tilde{\delta}_{yo} = 0 \qquad (22b)$$

These two equations are equivalent by virtue of Eq. (19). Only in the case of very special conditions, e.g., $Z_{xy}Z_{yx} = 0$ and/or $Z_{xx}-Z_{yy} = 0$, is it necessary to treat both of them to compute the eigenvector. The eigenvector is indeterminant by an arbitrary complex factor. Therefore, one is at liberty to invoke some ad hoc scaling and phasing rules; such as

$$|\tilde{\delta}_{xo}| + |\tilde{\delta}_{yo}| = 1 \tag{23}$$

$$\mathrm{Arg}\{\tilde{\delta}_{xo}\} + \mathrm{Arg}\{\tilde{\delta}_{yo}\} = 0 \tag{24}$$

which sets the eigenvector to be

$$\underline{w}_o = \begin{Bmatrix} u_o e^{i\gamma_o} \\ (1-u_o)e^{-i\gamma_o} \end{Bmatrix} \tag{25}$$

u_o (which has a non-negative value bounded by unity) and γ_o (which is one-half the relative phase between the two degrees of freedom) remain to be found. In order to avoid writing lengthy algebraic expressions, in place of Eq. (22a) or Eq. (22b), let the governing equation for the eigenvector be

$$G_x \tilde{\delta}_{xo} + G_y \tilde{\delta}_{yo} = 0 \tag{26}$$

where

$$G_x = U_x + iV_x \; ; \quad G_y = U_y + iV_y \tag{27}$$

are complex quantities. Substitution of Eq. (25) into Eq. (26) then sets real and imaginary parts separately to zero, and one finds

$$\{U_x u_o + U_y(1-u_o)\} \cos\gamma_o - \{V_x u_o - V_y(1 - u_o)\} \sin\gamma_o = 0$$

$$\{V_x u_o + V_y(1-u_o)\} \cos\gamma_o + \{U_x u_o - U_y(1-u_o)\} \sin\gamma_o = 0$$

They yield, after some straightforward algebraic manipulations

$$u_o = \frac{|G_y|}{|G_x|+|G_y|} \quad ; \quad 1-u_o = \frac{|G_x|}{|G_x|+|G_y|} \tag{28}$$

$$\gamma_o = \tan^{-1} \frac{(U_x|G_y|+U_y|G_x|)}{(V_x|G_y|-V_y|G_x|)} \tag{29}$$

The principal value of Eq. (29) would be used. The eigenvector as defined by Eq. (25, 28, 29) is thus far presented in terms of a Cartesian coordinate system. It describes an elliptical orbit with the sense of whirl governed by γ_o. The sense of whirl is positive; i.e., same as the sense of shaft rotation, if γ_o is in either the first or the third quadrant; and the sense of whirl is negative or opposite to that of shaft rotation if γ_o is in either the second or the fourth quadrant. In other words, the sense of whirl has the same sign as

$$\tan\gamma_o = \frac{U_x|G_y| + U_y|G_x|}{V_x|G_y| - V_y|G_x|}$$

If either Z_{xy} or Z_{yx} or both should vanish, the formulations presented above are not workable because both G_x and G_y would also vanish, rendering Eqs. (28) and (29) indeterminate. These are special cases and require separate attention.

2.4.2 No Cross-coupling: $Z_{xy} = 0$, $Z_{yx} = 0$

The homogeneous system of Eq. (18) becomes

$$\begin{Bmatrix} Z_{xx} - (k_o + i\nu b_o) & 0 \\ 0 & Z_{yy} - (k_o + i\nu b_o) \end{Bmatrix} \begin{Bmatrix} \tilde{\delta}_{xo} \\ \tilde{\delta}_{yo} \end{Bmatrix} = 0$$

Since the two degrees of freedom are totally uncoupled, the desired eigenvalue/vector sets are simply

$$k_o + i\nu b_o = Z_{xx}; \quad \tilde{\delta}_{xo} = 1, \quad \tilde{\delta}_{yo} = 0 \tag{31a}$$

and

$$k_o + i\nu b_o = Z_{yy}; \quad \tilde{\delta}_{xo} = 0, \quad \tilde{\delta}_{yo} = 1 \tag{31b}$$

2.4.3 Pseudo Uncoupled Case

One of Z_{xy} and Z_{yx} is zero, the other one is not. Write

$$Z_{jk} = 0; \quad Z_{kj} \neq 0 \tag{32}$$

The indices j or k may denote either x or y. They are always distinct. (Repeated indices designate a diagonal term; the implicit summation convention of indicial contraction is not used here.)

Eq. (18) is reduced to

$$\{Z_{jj} - (k_o + i\nu b_o)\} \tilde{\delta}_{jo} = 0 \tag{33}$$

$$Z_{kj} \tilde{\delta}_{jo} + \{Z_{kk} - (k_o + i\nu b_o)\} \tilde{\delta}_{ko} = 0 \tag{34}$$

Eq. (33) can be satisfied by two conditions. The first one is

$$k_o + i\nu b_o = Z_{jj} \tag{35}$$

Consequently, substituting into Eq. (34)

$$Z_{kj} \tilde{\delta}_{jo} + (Z_{kk} - Z_{jj}) \tilde{\delta}_{ko} = 0 \tag{36a}$$

Following steps previously used to describe Eqs. (28) and (29), from Eq. (26), one finds

$$|\tilde{\delta}_{jo}| = \frac{|Z_{kk}-Z_{jj}|}{|Z_{kj}|+|Z_{kk}-Z_{jj}|} \quad ; \quad |\tilde{\delta}_{ko}| = \frac{|Z_{kj}|}{|Z_{kj}|+|Z_{kk}-Z_{jj}|} \tag{37a}$$

$$\mathrm{Arg}\{\tilde{\delta}_{jo}\} = -\mathrm{Arg}\{\tilde{\delta}_{ko}\}$$

$$= \tan^{-1}\left[\frac{K_{kj}|Z_{kk}-Z_{jj}|+ (K_{kk}-K_{jj})|Z_{kj}|}{\nu(B_{kj}|Z_{kk}-Z_{jj}|- (B_{kk}-B_{jj})|Z_{kj}|)}\right] \tag{38a}$$

If Z_{kk} and Z_{jj} should happen to be equal, Eq. (38a) becomes indeterminate, at the same time $\tilde{\delta}_{jo}$ vanishes while $|\tilde{\delta}_{ko}|$ becomes unity. Actually, with $\tilde{\delta}_{jo}$ being zero, the argument of $\tilde{\delta}_{ko}$ has no physical significance and can be set to zero as an accepted convention.

The second condition which satisfies Eq. (33) is

$$\tilde{\delta}_{jo} = 0 \qquad (37b)$$

Consequently, one can set

$$\tilde{\delta}_{ko} = 1 \qquad (38b)$$

Then, upon substitution into Eq. (34), one obtains

$$k_o + i\nu b_o = Z_{kk} \qquad (35b)$$

Note that the second eigenvalue/vector set is indistinguishable from the first set under the conditions of ($Z_{jk} = 0$, $Z_{kj} \neq 0$, $Z_{jj} = Z_{kk}$) which represent a truly degenerate state since only <u>one</u> eigenvalue/vector set can be found for a <u>two</u>-degrees-of-freedom system.

The parameters ($\tilde{\delta}_{xo}$, $\tilde{\delta}_{yo}$) are Cartesian components of the natural orbit. Since every simple harmonic orbit takes on the shape of an ellipse, the natural orbit can be represented by:

- ratio of minor/major radii of the orbit, and
- inclination of the major axis from the x-axis

The relationships between the Cartesian components and the geometric parameters are derived in another part of the Rotor-Bearing Dynamics Technology Design Guide [9].

SECTION III

RETRIEVAL SYSTEM

3.1 Contents of the Bearing Data Bank

There are presently thirty-one (31) data tables in the collection of the data bank. Each data table represents one combination of configurations, geometrical parameters, and preload setting (if applicable). A summary of the contents of the data bank is contained in Table 1.

For bearings made up of partial arc pads, there is a setup parameter called preload, which measures the distance between the arc center and the bearing center as a fraction of the nominal clearance (pad clearance). As shown in Fig. 3, the bearing clearance C_b is smaller than the original arc clearance by the amount of preload mC. In this particular illustration, the preload is centrally directed, i.e., the line of centers bisect the pad arc. All data tables thus far collected have centrally preloaded pads.

For partial arc configurations, rotational symmetry is disrupted. The direction of the load vector is to be defined with reference to the arc geometry. A lobed bearing is made up of equally spaced arcs. The direction of the load vector is specified relative to the loaded arc. A two-lobe bearing is usually parted in a horizontal plane. Thus the gravity load is commonly directed along the bi-sector of the bottom arc. Such an arrangement is said to have a load "on pad." With an odd number of lobes, the usual practice is to place one more arc on the bottom than the top. Thus the load is directed between pads for the three-lobe bearing.

The tilting shoe bearing is described similarly as the lobed bearing. The preload parameter deals with the radial displacement of the pivot point. The angular location of the pivot is equivalent to the preload direction relative to the arc. It is known what the optimum pivot location is about 55% from the leading edge. However, if the pads should be erroneously in-

TABLE 1

CONTENTS OF DATA BANK

Bearing Type	Arc Angle	L/D	Notes	Preload	Data Table Number
Plain	360	0.50			PJ-05-1
2 Lobe	160	0.50	(1),(5)	0.00	ML2-05-1
				0.25	ML2-05-2
				0.50	ML2-05-3
3 Lobe	100	0.50	(2),(5)	0.00	ML3-05-1
				0.25	ML3-05-2
				0.50	ML3-05-3
4 Shoe Tilting Pad	80	0.25	(2),(3),(4)	0.00	TP4-02-1
				0.20	TP4-02-2
				0.30	TP4-02-3
				0.50	TP4-02-4
		0.50		0.00	TP4-05-1
				0.20	TP4-05-2
				0.30	TP4-05-3
				0.50	TP4-05-4
		1.00		0.00	TP4-10-1
				0.20	TP4-10-2
				0.30	TP4-10-3
				0.50	TP4-10-4

LEGEND:

(1) Load on pad

(2) Load between pads

(3) Centrally pivoted

(4) Synchronous frequency only, and shoe inertia is neglected

(5) Centrally preloaded

TABLE 1 - CONTENTS OF DATA BANK (continued)

Bearing Type	Arc Angle	L/D	Notes	Preload	Data Table Number
5 Shoe Tilting Pad	55	0.25	(1),(3),(4)	0.00	TP5-02-1
				0.20	TP5-02-2
				0.30	TP5-02-3
				0.50	TP5-02-4
		0.50		0.00	TP5-05-1
				0.20	TP5-05-2
				0.30	TP5-05-3
				0.50	TP5-05-4
		1.00		0.00	TP5-10-1
				0.20	TP5-10-2
				0.30	TP5-10-3
				0.50	TP5-10-4

LEGEND:

(1) Load on pad

(2) Load between pads

(3) Centrally pivoted

(4) Synchronous frequency only, and shoe inertia is neglected

(5) Centrally preloaded

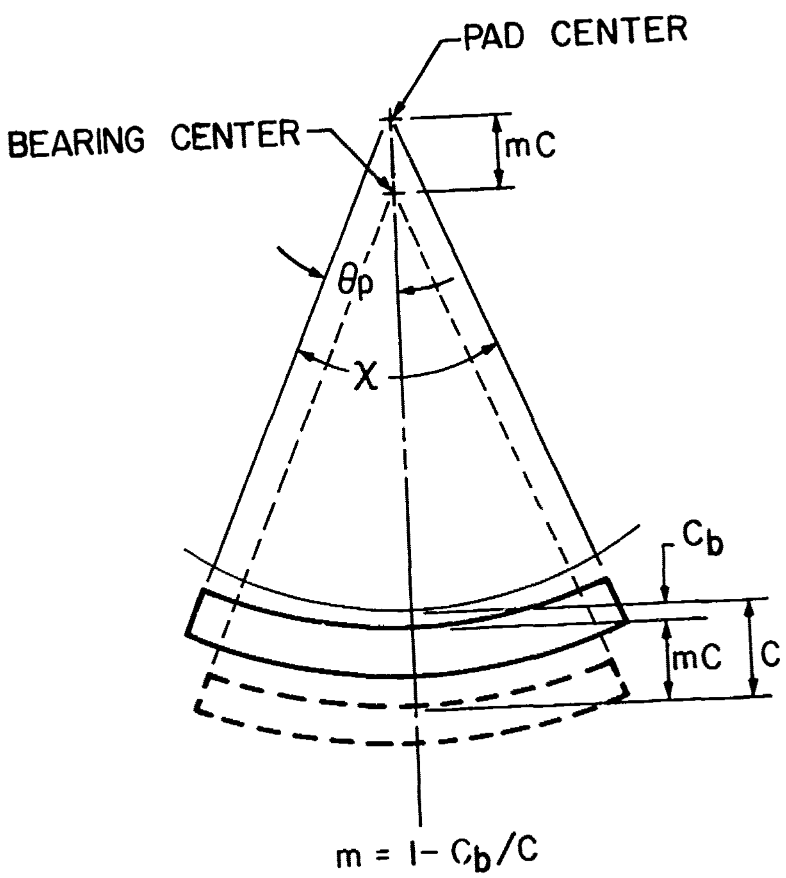

Figure 3 Centrally Preloaded Partial Arc ($\theta_p = \chi/2$)

stalled backwards, the load capacity of the bearing would be drastically smaller. The centrally pivoted arrangement is error safe since it acts identically if reversed. The tilting shoe bearings in the present data bank are all centrally pivoted.

An ideal pivot is incapable of exerting moment to the bearing pad. This condition adds two additional parameters for a complete definition of the dynamic data; namely,

$$\bar{J} = \frac{J_p N_s}{\mu (R/C)^2 (LD) R} \tag{39}$$

$$\bar{\nu} = f/N_s \tag{40}$$

which relate to the pitch moment of inertia of a bearing pad and the ratio of the vibrational frequency to the rotation frequency, respectively. In the present data, ($\bar{J}$ = 0 and $\bar{\nu}$ = 1) are imposed. The inertialess assumption is usually adequate since the inertia of each pad should be quite small in comparison with the rotor inertia. An exception is the unloaded shoe, which would become vulnerable to the pathological condition of shoe fluttering. For this reason, tilting shoe bearings should always be preloaded. The data tables for the unloaded tilting shoe bearings are included mainly for reference. The nature of frequency dependance of the perturbation coefficients of tilting shoe bearings in effect reflects the phase relationships between the rotor motion and the pitching motions of the shoes. Fortunately, the total resultant of all shoes does not significantly vary with frequency. Therefore, the synchronous data ($\bar{\nu}$ = 1) can be used for nonsynchronous rotor dynamic studies with fair accuracy. If the precise data with allowance for shoe inertias and frequency dependance should be desired, the dynamic assembly procedure should be followed to synthesize the bearing characteristics from single pad characteristics [3].

All data tables in the present collection concern journal bearings which influence dynamics of the rotor system by reacting to lineal motions of the rotor. Some bearing support systems can react to angular motions of the rotor. A long journal bearing and a large thrust bearing runner are two such examples. In reacting to an angular motion of the rotor (in the radial plane), the bearing can provide a restraining moment. The required data parameters for such bearings are angular stiffness and angular damping coefficients which react to angular displacements and angular velocities, respectively. These coefficients also may induce anisotropic and cross-coupling features. The storage and retrieval methodologies described in this document can be readily adapted to handle angular bearings.

3.2 Interfacing Bearing Data with Rotor Dynamics Software

Each bearing data table is necessarily restricted to the following two conditions:

1. The bearing data is presented in a coordinate system which is peculiar to static load vector acting on the particular bearing.
2. The pedestal of the bearing is assumed to be rigid.

The bearing data retrieval system incorporates an interfacing procedure which removes these restrictions.

The static load vectors of all bearings in a rotor system may not share the same direction. The following circumstances require that individual load directions be assigned to each bearing:

1. For an overhung rotor, if its center of gravity is outboard, the load vectors at the two bearings would have opposite directions.

2. Gyroscopic loads which occur during rapid maneuvers of a military aircraft, usually are oppositely directed at the two main support bearings.

3. Laterally coupled rotors (e.g., in a transmission box) exert force on each other and tend to cause load vectors at various bearings to assume distinct directions.

4. Misalignment loads (for rotors supported by three or more bearings) generally may not be co-planar with the gravity load.

For these reasons, it is necessary to allow a deviation of the static bearing load vector from an axis of the global coordinates of the rotor: Let (X, Y) and (x, y), respectively, be global (rotor) and local (bearing) coordinate axes in the Cartesian representation, with the x-axis directed along the static load. Let ϕ be the angle measured from X to x as illustrated in Fig. 4. The transformation of a vector represented in the bearing coordinates to that represented in the rotor coordinates is given by the relation

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \tag{41}$$

Transformation of the stiffness and damping matrices is achieved by the following formula

$$\begin{bmatrix} K, B \end{bmatrix}_{Rotor} = \begin{bmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} K, B \end{bmatrix}_{Bearing} \begin{bmatrix} \cos\phi & \sin\phi \\ -\sin\phi & \cos\phi \end{bmatrix} \tag{42}$$

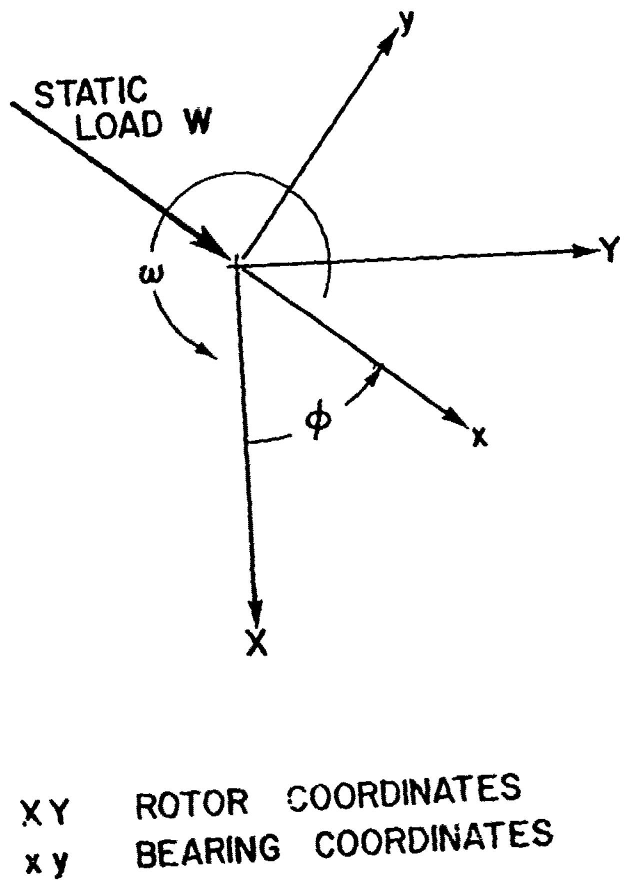

Figure 4 Rotor and Bearing Coordinate Systems

Pedestal compliance and/or damping can contribute significantly to the rotor behavior. Pedestal compliance can be modelled in terms of lumped parameters.

$$[Z]_p = [K]_p + [M]_p \frac{d^2}{dt^2} + [B]_p \frac{d}{dt} \tag{43}$$

This is regarded as an operator for the displacement of the pedestal. The subscript "p" labels the pedestal effects. For a simple harmonic motion with the time dependence factor exp{iνt}, Eq. (43) is reduced to

$$[Z]_p = [K]_p - \nu^2 [M]_p + i\nu [B]_p \tag{44}$$

Since the bearing reaction is directly transmitted to the pedestal

$$\underline{P} = -[Z]_b [\underline{w}_b - \underline{w}_p] \tag{45a}$$

$$= -[Z]_p \underline{w}_p \tag{45b}$$

$[Z]_b$ is the impedance matrix of the (rigidly mounted) bearing. $\underline{w}_b$ and $\underline{w}_p$ are displacement vectors of the bearing and of the pedestal in the matrix notation, respectively. Eliminating $\underline{P}$ between Eqs. (45a) and (45b), one finds

$$-[Z]_b \underline{w}_b + [[Z]_p + [Z]_b] \underline{w}_p = 0$$

Solving for $\underline{w}_p$ then substituting back into Eq. (45b), one obtains

$$\underline{P} = -\left[Z\right]_p \left[\left[Z\right]_p + \left[Z\right]_b\right]^{-1} \left[Z\right]_b \underline{w}_b \tag{46}$$

which in essence defines the effective support impedance as

$$\left[Z\right]_{effective} = \left[Z\right]_p \left[\left[Z\right]_p + \left[Z\right]_b\right]^{-1} \left[Z\right]_b \tag{47}$$

The retrieval software provides the user with an option to allow for pedestal compliance. Upon selecting this option, the user can furnish data consisting of up to ten numbers which define the elements of the three matrices $\left[K\right]_p$, $\left[B\right]_p$, and $\left[M\right]_p$. Upon extracting $\left[Z\right]_b$ from the data bank, Eq. (47) is executed by the interfacing software.

Aside from performing required coordinate transformations and incorporating pedestal compliance effects, the bearing data retrieval system also organizes the results in a tabular form consistent with the input format of the rotor dynamics software [9].

3.3 The Retrieval Procedure

The Fluid Film Bearing Data Bank is designed to furnish numerical information of bearing support characteristics needed in the performance of a variety of rotordynamic studies. The software for data retrieval requires the user to furnish the following input:

1. Location of Data Table -- The user has the choice of selecting a data table from the index of the available data bank or submitting the data bank to the file management system of the computer center in advance of the retrieval run. In either case, the data table is a result of preparation for full range interpolation according to the method to be described in Section IV.

2. Design Parameters of the Bearing.

   - o lubricant viscosity (centipoise)
   - o bearing diameter (in)
   - o bearing length (in)
   - o clearance (in)

3. Operating Parameters of the Bearing.

   - o load magnitude (lbs)
   - o load direction defined by the angle measured from the vertical axis in the sense of shaft rotation (deg)
   - o shaft rotational speed (rpm)
   - o vibration frequency as may be needed in certain bearing support systems (Hz)

4. Pedestal Compliance Characteristics -- The user can elect to furnish lumped parameter data of the pedestal which define stiffness, damping, and mass matrices.

   - o pedestal weight (lbs)
   - o pedestal c.g. offsets in three directions (in)
   - o pedestal angular weight moment of inertia in two planes ($lb\text{-}in^2$)
   - o pedestal stiffness constants in two planes (lbs/in or in-lb/rad)
   - o pedestal damping constants in two planes (lbs-sec/in or in-lb-sec/rad)

The output of the retrieval software includes in tabular forms

1. Data sets compatible with the input format of the rotor-dynamics software [9],

2. Tabulation of the static bearing characteristics,

3. Tabulation of the dynamic bearing coefficients, and

4. Effective stiffness/damping constants and natural orbit parameters as described in Section 2.4.

Additional information pertaining to the use of the retrieval software is given in Appendix A.

3.4 Description of the Retrieval Table

The retrieval table of each bearing is furnished as a sequential FORTRAN file. Its contents include the following:

1. Alphanumeric Index - This contains the file designation, the file size or number of data points (including near- and far-field limits), L/D of the bearing, and the load scaling factor which is presently defaulted as 1.125.

2. Array of Working Parameters - This is stored as groups of seven floating point numbers, each occupying a field of eleven spaces.

3. Retrieval Data of Each of Thirteen Data Variables - The thirteen variables appear in the following order: eccentricity ratio, attitude angle, friction, required flow, lost flow, $\bar{K}_{xx}$, $\bar{B}_{xx}$, $\bar{K}_{xy}$, $\bar{B}_{xy}$, $\bar{K}_{yx}$, $\bar{B}_{yx}$, $\bar{K}_{yy}$, and $\bar{B}_{yy}$.

   The retrieval data of each variable consists of numbers which are also stored in succession in groups of seven floating point numbers each occupying a field of eleven spaces. They are stored without interruption for each variable and include: near-field exponent s_1, far-field exponent s_2, near-field constant a_o, far-field constant b_o, then for each data interval a set of spline coefficients for each of the data intervals corresponding to the array of working parameters (the comparison function and its three derivatives with respect to the working parameter), and the comparison function for the far-field limit which should always be unity.

Table 2 shows the contents of a typical retrieval file. Table 3 is a printout of the contents with appropriate headings. The load is computed from the working parameter (TAU) according to Eq. (62) described in the next section.

A complete listing of all retrieval files of the present data bank is given in Appendix D.

TABLE 2

TYPICAL RETRIEVAL FILE

```
RETRIEVAL FILE NO  ML3-05-1
      FILE SIZE =   17
      L/D       =    0.5000
      ALFA      =    1.1250
 0.0000D-01 3.5768D-02 5.8456D-02 8.0138D-02 1.2718D-01 2 0721D-01 2.8602D-01
 4.4623D-01 5.7427D-01 6.5943D-01 7.6051D-01 8.1662D-01 8.4578D-01 8.7580D-01
 9.0640D-01 9.3739D-01 1.0000D 00
 1.0000D 00 0.0000D-01 1.0001D 00 1.0000D 00 1.0000D 00-1 6502D 00 0.0000D-01
 1.9803D 02 9.4249D-01-1.5236D 00 7.0830D 00-1.3293D 02 9.0948D-01-1.3971D 00
 4.0671D 00-6.6448D 01 8.8003D-01-1.3245D 00 2.6264D 00 1 2060D 01 8 2085D-01
-1.1876D 00 3.1937D 00 1.3868D-02 7.3602D-01-9.3197D-01 3.1948D 00-1 7265D 00
 6.7236D-01-6.8557D-01 3.0587D 00-3.4465D 00 5.9942D-01-2.3977D-01 2.5066D 00
 6.8959D-01 5.8950D-01 8.6833D-02 2.5949D 00 5.2071D 00 6.0685D-01 3.2671D-01
 3.0383D 00 1.0659D 01 6.5722D-01 6.8826D-01 4.1157D 00 2 4396D 01 7 0303D-01
 9.5757D-01 5.4845D 00 2.6015D 01 7.3340D-01 1.1286D 00 6.2432D 00 3.4971D 01
 7.7026D-01 1.3318D 00 7.2931D 00 6.2869D 01 8.1471D-01 1 5843D 00 9.2165D 00
 3.4883D 01 8.6841D-01 1.8867D 00 1.0298D 01-1.6446D 02 1.0000D 00
 0.0000D-01-5.0000D-01 9.0000D 01 1.0007D 02 1.0000D 00-2.2698D 00 0.0000D-01
 5.0412D 02 9.2266D-01-1.9473D 00 1.8031D 01-4.9054D 02 8.8216D-01-1.6645D 00
 6.9020D 00 4.2378D 01 8.4777D-01-1.5049D 00 7.8208D 00-4.8412D 01 7 8479D-01
-1.1905D 00 5.5436D 00-2.1033D 01 7.0546D-01-8.1422D-01 3 8601D 00-1 5182D 01
 6.5205D-01-5.5717D-01 2.6638D 00-6.8634D 00 5.9227D-01-2.1849D-01 1 5642D 00
 9.3216D-01 5.7744D-01-1.0573D-02 1.6835D 00 4.1808D 00 5 8307D-01 1 4796D-01
 2.0396D 00 1.5715D 01 6 1115D-01 4.3440D-01 3.6280D 00 4 4005D 01 6 4253D-01
 7.0720D-01 6.0969D 00 5.9916D 01 6.6600D-01 9.1050D-01 7.8443D 00 1.3540D 02
 6.9748D-01 1.2070D 00 1.1909D 01 1.6682D 02 7.4078D-01 1.6494D 00 1.7013D 01
 5.4840D 02 8.0278D-01 2.4400D 00 3.4008C 01-5.4315D 02 1.0000D 00
 0.0000D-01 5.0000D-01 1.6463D 01 1.7306D 01 1.0000D 00 1 2603D 00 0 0000D-01
-3.1207D 02 1.0427D 00 1.0607D 00-1.1162D C1 3.5255D 02 1 0646D 00 8 9819D-01
-3.1636D 00-1.9538D 01 1.0933D 00 8.2500D-01-3.5872D 00 2.1639D 01 1 1185D 00
 6.8020D-01-2.5694D 00 7.0205D 00 1.1653D 00 4.9704D-01-2 0075D 00 5.1224D 00
 1.1987D 00 3.5475D-01-1.6038D 00-9.9900D-01 1 2342D 00 8 4981D-02-1 7639D 00
-9.9638D-01 1.2303D 00-1.4904D-01-1.8914D 00-3.7706D 00 1 2104D 00-3 2379D-01
-2.2126D 00-6.9700D 00 1.1651D 00-5.8304D-01-2.9171D 00 5.6679D 00 1.1280D 00
-7.3778D-01-2.5991D 00 4.7046D 01 1.1056D 00-7.9358D-01-1 2270D 00-9 1263D 01
 1.0808D 00-8.7155D-01-3.9670D 00 4.5428D 02 1.0544D 00-7 8032D-01 9.9308D 00
-2.4352D 02 1.0338D 00-5.8950D-01 2.3839D 00-3.8074D 01 1 0000D 00
 0.0000D-01 0.0000D-01 4.7133D 00 4.0711D 00 1.0000D 00 7 7286D-02 0.0000D-01
-2.9511D 01 1.0025D 00 5.8409D-02-1.0555D 00 1.0540D 01 1 0036D 00 3.7173D-02
-8.1640D-01 2.6434D 01 1.0043D 00 2.5686D-02-2.4323D-01-2 2245D 00 1.0052D 00
 1.1783D-02-3.4787D-01 2.5114D 00 1.0052D 00-8.0156D-03-1.4687D-01 2 7507D 00
 1.0044D 00-1.1048D-02 6.9898D-02-2 5357D-01 1 0033D 00-3 1042D-03 2 9274D-02
 4.7336D-01 1.0033D 00 4.5244D-03 8 9884D-02-9.1681D-01 1 0039D 00 8.8545D-03
 1.1804D-02 3 8665D-01 1.0050D 00 1.2023D-02 5.0886D-02 3 5435D-01 1 0057D 00
 1.5435D-02 7.07660-02-2.0676D 01 1.0061D 00 8.7061D-03-5 3224D-01 1 7294D 01
 1.0062D 00 5.2080D-04-1.3025D-02-3.9162D 01 1 0060D 00-1 8204D-02-1 2111D 00
 2.4203D 00 1.0049C 00-5.4574D-02-1.1361D 00 1 8145D 01 1 0000D 00
 1.0000D 00 0.0000D-01 1.4902D 00 1.6170D 00 1 0000D 00-1 5480D 00 0 0000D-01
 1.2753D 02 9.4560D-01-1.4665D 00 4.5616D 00-1.1867D 02 9.1327D-01-1 3935D 00
 1.8691D 00 7.3618D 01 8.8362D-01-1.3357D 00 3 4653D 00-1 6203D 01 8.2435D-01
-1.1906D 00 2.7032D 00 7.5566D 00 7.3836D-01-9 5004D-01 3 3080D 00-4.6527D 00
 6.7339D-01-7.0381D-01 2.9413D 00-2.4167D 00 5.9672D-01-2 6360D-01 2 5541D 00
 7.0220D-01 5 8415D-01 6.9196D-02 2.6441D 00 4 6007D 00 6 0011D-01 3 1106D-01
 3.0359D 00 1.1362D 01 6.4901D-01 6 7596D-01 4 1843D 00 3 1211D 01 6 9444D-01
```

Table 2 - Typical Retrieval File (continued)

```
 9.5984D-01 5.9354D 00-7.6498D 00 7.2493D-01 1.1297[illegible] 5 7123D 00 5.4438D 01
 7.6166D-01 1.3257D 00 7.3467D 00 1.2255D 01 8.057[illegible] 1 5562D 00 7.7216D 00
 2.6260D 02 8.5896D-01 1.9216D 00 1.5860D 01-2.533[illegible] 1 0000D 00
 1 0000D 00 2.5000D 00-5.5102D-01 9.0173D-01-1.00[illegible] 2.4323D 00 0.0000D-01
 7.1487D 02-9.0755D-01 2.8896D 00 2.5569D 01-9.14[illegible]-8.3719D-01 3.2344D 00
 4.8283D 00 5.0437D 02-7.6507D-01 3.4576D 00 1.57[illegible] 01-2.2806D 02-5.8893D-01
 3.9469D 00 5.0357D 00-2.7454D 00-2.5717D-01 4.7[illegible]11D 00 4.8160D 00-2.0724D 02
 8.3000D-02 4.0770D 00-1.1517D 01 5.9633D 01 6.[illegible]25D-01 2.9972D 00-1.9630D 00
-1.1046D 02 9.5828D-01 1.8404D 00-1.6106D 01 1.0971D 02 1 0679D 00 8.6662D-01
-6.7639D 00-6.0643D 00 1.1199D 00 1.5194D-01-7.3769D 00-4.4883D-01 1.1168D 00
-2.6268D-01-7.4020D 00 4.8558D 02 1.1080D 00-2.7207D-01 6 7576D 00-6.3813D 02
 1.1000D 00-3.5675D-01-1.2399D 01 3.6049D 02 1 0850D 00-5 6738D-01-1.3678D 00
-3.5481D 02 1.0650D 00-7.8015D-01-1.2363D 01 1.9747D 02 1 0000D 00
 0.0000D-01 1.5000D 00 2.0058D 00 1.4450D 01 1.0000D 00-1 8609D 00 0.0000D-01
-9.6880D 02 9.2605D-01-2.4806D 00-3.4652D 01 2.2807D 03 8 6529D-01-2.6798D 00
 1.7092D 01-1.9040D 02 8.1088D-01-2.3540D 00 1.2964D 01 2 1440D 01 7.1486D-01
-1.7204D 00 1.3973D 01-7.1428D 01 6.1582D-01-8.3091D-01 8 2564D 00-7.3256D 01
 5.7000D-01-4.0772D-01 2.4831D 00-1.1667D 01 5.2855D-01-1 5964D-01 6.1388D-01
 1.0713D 01 5.1689D-01 6.7780D-03 1.9855D 00-1.7847D 01 5.2283D-01 1.1115D-01
 4.6571D-01 3.7505D 01 5.4290D-01 3.4982D-01 4.2567D 00-4 0585D 00 5.6911D-01
 5.8228D-01 4.0290D 00 5.2698D 02 5.8998D-01 9.2381D-01 1 9396D 01 1.2142D 02
 6.2700D-01 1.5608D 00 2.3041D 01 3.0426D 02 6.8700D-01 2.4083D 00 3.2351D 01
-4.3686D 02 7.7500D-01 3.2011D 00 1.8813D 01-3.0047D 02 1 0000D 00
 0 0000D-01 2.0000D 00 1.0028D 00 2.4336D 00 1.0000D 00 2 5245D-01 0.0000D-01
 6.9107D 02 1.0143D 00 6.9450D-01 2.4718D 01-3.6921D 02 1 0357D 00 1.1603D 00
 1.6341D 01-1.1674D 02 1.0645D 00 1 4872D 00 1.3810D 01-1 4059) 02 1 1473D 00
 1.9813D 00 7.1964D 00-1.6511D 02 1.3148D 00 2.0284D 00-6.0173D 00-7.0334D 00
 1.4554D 00 1.5324D 00-6.5716D 00-2.4457D 01 1 5998D 00 1.6564D-01-1.0490D 01
 3 9955D 01 1.5490D 00-8.4997D-01-5.3741D 00 1.6620D 00 1 4573D 00-1 3016D 00
-5.2326D 00 5.4599D 01 1.3084D 00-1.5516D 00 2.8626D-01-3 7039D 01 1.2207D 00
-1.5938D 00-1.7920D 00 8.1851D 01 1 1738D 00-1.6113D 00 5.9479D-01 2.8899D 02
 1.1270D 00-1.4632D 00 9.2704D 00-1.1846D 02 1.0860D 00-1.2350D 00 5.6455D 00
 1 1328D 02 1.0510D 00-1.0057D 00 9.1561D 00-1 4624D 02 1 0000D 00
 1 0000D 00 1.5000D 00 5.0960D 00 4 3765D 00 1.0000D 00 5 0622D-01 0 0000D-01
 2 4828D 02 1.0200D 00 6.6504D-01 8.8804D 00-6.0311D 02 1 0362D 00 7 1129D-01
-4.8030D 00 2.9832D 02 1.0510D 00 6.7727D-01 1 6652D 00-4 6267D 01 1 0839D 00
 7.0441D-01-5.1129D-01-2.1501D 01 1.1368D 00 5.9464D-01-2.2320D 00 3.2866D 00
 1.1770D 00 4.2894D-01 1.9730D 00-5.9810D 00 1.2163D 00 3 6082D-02-2.9312D 00
 6 0249D 00 1.1990D 00-2.8985D-01-2.1598D 00 2.2492D 01 1 1688D 00-3.9222D-01
-2.4440D-01 5.4648D-01 1.1280D 00-4 1413D-01-1.8916D-01-2 9390D 01 1.1036D 00
-4.7101D-01-1.8382D 00 1.0071D 02 1.0895D 00-4.8179D-01 1 0986D 00-3.3966D 02
 1 0740D 00-6.0187D-01-9.0980D 00 5.6050D 02 1.0540D 00-6 1785D-01 8 0533D 00
-3 4674D 02 1.0370D 00-5 3478D-01-2.6920D 00 4 2997D 01 1 0000D 00
 0 0000D-01 2 5000D 00-2 2799D 00 2 2460D-01-1 0000D 00 8 0513D-01 0.0000D-01
-3 2357D 02-9 7367D-01 5 9815D-01-1.1573D 01-1 7063D 02-9 6341D-01 2.9166D-01
-1 5445D 01 1.4284D 03-9.5829D-01 2 9254D-01 1.5526D 01-6 0409D 02-9.3787D-01
 3 5451D-01-1 2892D 01 2 3308D 02-9 3083D-01 6 9231D-02 5 7622D 00-1.0444D 02
-9 1600D-01 1 9900D-01-2.4689D 00 9 5282D 01-8.5050D-01 1 0263D 00 1.2796D 01
-2 4658D 01-6.2283D-01 2.4626D 00 9 6391D 00 2.2912D 02-3 5458D-01 4.1143D 00
 2.9151D 01-8.5809D 01 1.9544D-01 6.6225D 00 2.0477D 01 1 0861D 02 6.0246D-01
 7.9424D 00 2.6572D 01-7.5738D 03 8 1406D-01 5.4972D 00-1 9428D 02 5 2019D 03
 9.1500D-01 2.0089D 00-3.8119D 01 2.8757D 02 9.6000D-01 9 7712D-01-2 9319D 01
 7 6561D 02 9.8000D-01 4.3616D-01-5 5929D 00 8 9329D 01 1 0000D 00
 1.0000D 00 1.5000D 00 5.0960D 00 4 3765D 00 1.0000D 00 5 0622D-01 0 0000D-01
```

(Sheet 2 of 3)

Table 2 - Typical Retrieval File (continued)

```
 2.4828D 02 1.0200D 00 6.6504D-01 8.8804D 00-6.0311D 02 1 0362D 00 7 1129D-01
-4.8030D 00 2.9832D 02 1.0510D 00 6 7727D-01 1 6652D 00-4 6261D 01 1 0839D 00
 7.0441D-01-5.1129D-01-2.1501D 01 1 1368D 00 5 9464D-01-2 2320D 00 3 2866D 00
 1.1770D 00 4.2894D-01-1.9730D 00-5 9810D 00 1.2163D 00 3 6082D-02-2 9312D 00
 6.0249D 00 1.1990D 00-2.8985D-01-2 1598D 00 2.2492D 01 1 1688D 00-3 9222D-01
-2.4440D-01 5.4648D-01 1.1280D 00-4.1413D-01-1 8916D-01-2 9390D 01 1 1036D 00
-4.7101D-01-1.8382D 00 1.0071D 02 1.0895D 00-4 8179D-01 1 0986D 00-3 3966D 02
 1.0740D 00-6.0187D-01-9.0980D 00 5 6050D 02 1 0540D 00-6 1785D-01 8 0533D 00
-3.4674D 02 1.0370D 00-5.3478D-01-2 6920D 00 4 2997D 01 1 0000D 00
 1.0000D 00 1.5000D 00 4.7203D 00 3.4007D 00 1 0000D 00 5 9625D-01 0 0000D-01
 1.1453D 02 1.0222D 00 6 6951D-01 4 0965D 00-7 9332D 02 1 0369D 00 5 5827D-01
-1.3902D 01 7.4367D 02 1.0470D 00 4 3164D-01 2 2220D 00-1 3049D 02 1 0675D 00
 3.9179D-01-3.9165D 00 2.9114D 01 1.0888D 00 1.7159D-01-1 5865D 00 7 4008D 00
 1.0980D 00 6.9544D-02-1.0032D 00-6.2259D 00 1 0920D 00-1 7108D-01-2.0007D 00
 1.7163D 01 1.0597D 00-2.8655D-01 1.9695D-01-2.5369D 01 1 0334D 00-3 6177D-01
-1.9635D 00-4.6567D 00 9.8600D-01-5 8403D-01-2.4342D 00 1 2063D 02 9 5295D-01
-5 3072D-01 4.3345D 00 2.0153D 02 9.4015D-01-3.1864D-01 1 0211D 01-2 6295D 02
 9.3400D-01-1.3058D-01 2.3174D 00 4.0015D 02 9 3300D-01 1 2767D-01 1 4562D 01
 1.0265D 01 9.4400D-01 5.8388D-01 1.4880D 01-2 3766D 02 1 0000D 00
 0.0000D-01 1.0000D 00 4.5143D 00 7 0281D 00 1 0000D 00-2 7314D 00 0 0000D-01
 6.6960D 02 9.0741D-01-2.3031D 00 2 3950D 01-4 6342D 02 8 6042D-01-1 8790D 00
 1.3436D 01-1.5225D 02 8.2258D-01-1 6234D 00 1.0135D 01-1 9908D 01 7 5708D-01
-1.1687D 00 9.1987D 00-7.0346D 01 6 8700D-01-6 5777D-01 3 5690D 00-8 1482D 00
 6.4558D-01-4.0180D-01 2.9268D 00-9 8761D 00 6 1200D-01-5 9646D-02 1 3445D 00
-4.3785D 00 6.1387D-01 7 7029D-02 7.9033D-01-9.4781D 00 6 2232D-01 1 0996D-01
-1 6820D-02 4.7353D 01 6.4150D-01 3 5017D-01 4 7696D 00-1 0745D 01 6 6834D-01
 6.0088D-01 4.1667D 00 3.5252D 02 6.8909D-01 8 7226D-01 1 4446D 01-3 9581D 02
 7.2000D-01 1.1276D 00 2 5641D 00-3.5695D 02 7.5400D-01 1 0389D 00-8 3584D 00
 2.3823D 03 7.9400D-01 1.9239D 00 6.5469D 01-1 0457D 03 1 0000D 00
```

TABLE 3

CONTENTS OF RETRIEVAL FILE WITH HEADING

(Sheet 1 of 7)

VERIFICATION OF DATA TABLE

RETRIEVAL FILE NO ML3-05-1
FILE SIZE = 17
L/D = 0.5000
ALFA = 1.1250

ECC RATIO	CONSTANT	EXPONENT
NEAR FIELD	1.000100000D 00	1.000000000D 00
FAR FIELD	1.000000000D 00	0.000000000D-01

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.000000000D-01	0.000000000D-01	1.000000000D 00	-1.650200000D 00	0.000000000D-01	1.980300000D 02
2	5.624343611D-02	3.576800000D-02	9.424900000D-01	-1.523600000D 00	7.083000000D 00	-1.329300000D 02
3	9.208140634D-02	5.845600000D-02	9.094800000D-01	-1.397100000D 00	4.067100000D 00	-6.644800000D 01
4	1.265496138D-01	8.013800000D-02	8.800300000D-01	-1.324500000D 00	2.626400000D 00	1.206000000D 01
5	2.024746314D-01	1.271800000D-01	8.208500000D-01	-1.187600000D 00	3.193700000D 00	1.386800000D-02
6	3.374875818D-01	2.072100000D-01	7.360200000D-01	-9.319700000D-01	3.194800000D 00	-1.726500000D 00
7	4.821663392D-01	2.860200000D-01	6.723600000D-01	-6.855700000D-01	3.058700000D 00	-3.446500000D 00
8	8.438904501D-01	4.462300000D-01	5.994200000D-01	-2.397700000D-01	2.506600000D 00	6.895900000D-01
9	1.265506517D 00	5.742700000D-01	5.895000000D-01	8.683300000D-02	2.594900000D 00	5.207100000D 00
10	1.687457556D 00	6.594300000D-01	6.068500000D-01	3.267100000D-01	3.038300000D 00	1.065900000D 01
11	2.531635214D 00	7.605100000D-01	6.572200000D-01	6.882600000D-01	4.115700000D 00	2.439600000D 01
12	3.375034900D 00	8.166200000D-01	7.030300000D-01	9.575700000D-01	5.484500000D 00	2.601500000D 01
13	4.046930393D 00	8.457800000D-01	7.334000000D-01	1.128600000D 00	6.243200000D 00	3.497100000D 01
14	5.060566484D 00	8.758000000D-01	7.702600000D-01	1.331800000D 00	7.293100000D 00	6.286900000D 01
15	6.752413676D 00	9.064000000D-01	8.147100000D-01	1.584300000D 00	9.216500000D 00	3.488300000D 01
16	1.013521696D 01	9.373900000D-01	8.684100000D-01	1.886700000D 00	1.029800000D 01	-1.644600000D 02
17	INFINITE	1.000000000D 00	1.000000000D 00			

Table 3 - Contents of Retrieval File . . . (continued)

ATT ANGLE	CONSTANT	EXPONENT
NEAR FIELD	9.0000000000D 01	0.0000000000D-01
FAR FIELD	1.0007000000D 02	-5.0000000000D-01

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.0000000000D-01	0.0000000000D-01	1.0000000000D 00	-2.2698000000D 00	0.0000000000D-01	5.0412000000D 02
2	5.6243436110D-02	3.5768000000D-02	9.2266000000D-01	-1.9473000000D 00	1.8031000000D 01	-4.9054000000D 02
3	9.2081406340D-02	5.8456000000D-02	8.8216000000D-01	-1.6645000000D 00	6.9020000000D 00	4.2378000000D 01
4	1.2654961380D-01	8.0138000000D-02	8.4777000000D-01	-1.5049000000D 00	7.8208000000D 00	-4.8412000000D 01
5	2.0247463140D-01	1.2718000000D-01	7.6479000000D-01	-1.1905000000D 00	5.5436000000D 00	-2.1033000000D 01
6	3.3748759180D-01	2.0721000000D-01	7.0546000000D-01	-8.1422000000D-01	3.8601000000D 00	-1.5182000000D 01
7	4.8216633920D-01	2.8602000000D-01	6.5205000000D-01	-5.5717000000D-01	2.6638000000D 00	-6.8634000000D 00
8	8.4389045010D-01	4.4623000000D-01	5.9227000000D-01	-2.1849000000D-01	1.5642000000D 00	9.3216000000D-01
9	1.2655065170D 00	5.7427000000D-01	5.7744000000D-01	-1.0573000000D-02	1.6835000000D 00	4.1808000000D 00
10	1.6874575560D 00	6.5943000000D-01	5.8307000000D-01	1.4796000000D-01	2.0396000000D 00	1.5715000000D 01
11	2.5316352140D 00	7.6051000000D-01	6.1115000000D-01	4.3440000000D-01	3.6280000000D 00	4.4005000000D 01
12	3.3750349000D 00	8.1662000000D-01	6.4253000000D-01	7.0720000000D-01	6.0969000000D 00	5.9916000000D 01
13	4.0469303930D 00	8.4578000000D-01	6.6600000000D-01	9.1050000000D-01	7.9443000000D 00	1.3540000000D 02
14	5.0605664840D 00	8.7580000000D-01	6.9748000000D-01	1.2070000000D 00	1.1909000000D 01	1.6682000000D 02
15	6.7524136760D 00	9.0640000000D-01	7.4078000000D-01	1.6494000000D 00	1.7013000000D 01	5.4840000000D 02
16	1.0135216960D 01	9.3739000000D-01	8.0278000000D-01	2.4400000000D 00	3.4008000000D 01	-5.4315000000D 02
17	INFINITE	1.0000000000D 00	1.0000000000D 00			

TORQUE	CONSTANT	EXPONENT
NEAR FIELD	1.6463000000D 01	0.0000000000D-01
FAR FIELD	1.7306000000D 01	5.0000000000D-01

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.0000000000D-01	0.0000000000D-01	1.0000000000D 00	1.2603000000D 00	0.0000000000D-01	-3.1207000000D 02
2	5.6243436110D-02	3.5768000000D-02	1.0427000000D 00	1.0607000000D 00	-1.1162000000D 01	3.5255000000D 02
3	9.2081406340D-02	5.8456000000D-02	1.0646000000D 00	8.9819000000D-01	-3.1636000000D 00	-1.9538000000D 01
4	1.2654961380D-01	8.0138000000D-02	1.0833000000D 00	8.2500000000D-01	-3.5872000000D 00	2.1639000000D 01
5	2.0247463140D-01	1.2718000000D-01	1.1185000000D 00	6.8020000000D-01	-2.5694000000D 00	7.0205000000D 00
6	3.3748758180D-01	2.0721000000D-01	1.1653000000D 00	4.9704000000D-01	-2.0075000000D 00	5.1224000000D 00
7	4.8216633920D-01	2.8602000000D-01	1.1987000000D 00	3.5475000000D-01	-1.6038000000D 00	-9.9900000000D-01
8	8.4389045010D-01	4.4623000000D-01	1.2342000000D 00	8.4981000000D-02	-1.7639000000D 00	-9.9638000000D-01
9	1.2655065170D 00	5.7427000000D-01	1.2303000000D 00	-1.4904000000D-01	-1.8914000000D 00	-3.7706000000D 00
10	1.6874575560D 00	6.5943000000D-01	1.2104000000D 00	-3.2379000000D-01	-2.2126000000D 00	-6.9700000000D 00
11	2.5316352140D 00	7.6051000000D-01	1.1651000000D 00	-5.8304000000D-01	-2.9171000000D 00	5.6679000000D 00
12	3.3750349000D 00	8.1662000000D-01	1.1280000000D 00	-7.3778000000D-01	-2.5991000000D 00	4.7046000000D 01
13	4.0469303930D 00	8.4578000000D-01	1.1056000000D 00	-7.9358000000D-01	-1.2270000000D 00	-9.1263000000D 01
14	5.0605664840D 00	8.7580000000D-01	1.0808000000D 00	-8.7155000000D-01	-3.9670000000D 00	4.5428000000D 02
15	6.7524136760D 00	9.0640000000D-01	1.0544000000D 00	-7.8032000000D-01	9.9308000000D 00	-2.4352000000D 02
16	1.0135216960D 01	9.3739000000D-01	1.0338000000D 00	-5.8950000000D-01	2.3839000000D 00	-3.8074000000D 01
17	INFINITE	1.0000000000D 00	1.0000000000D 00			

(Sheet 2 of 7)

Table 3 - Contents of Retrieval File . . . (continued)

REQ FLOW

	CONSTANT	EXPONENT
NEAR FIELD	4.7133000000D 00	0.0000000000D-01
FAR FIELD	4.0711000000D 00	0.0000000000D-01

POINT	LOAD	TAU	COMPARISON FCN	DERIVPTIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.0000000000D-01	0.0000000000D-01	1.0000000000D 00	7.7286000000D-02	0.0000000000D-01	-2.9511000000D 01
2	5.6243436110D-02	3.5768000000D-02	1.0025000000D 00	5.8409000000D-02	-1.0555000000D 00	1.0540000000D 01
3	9.2081406340D-02	5.8456000000D-02	1.0036000000D 00	3.7173000000D-02	-8.1640000000D-01	2.6434000000D 01
4	1.2654961380D-01	8.0138000000D-02	1.0043000000D 00	2.5686000000D-02	-2.4323000000D-01	-2.2245000000D 00
5	2.0247463140D-01	1.2718000000D-01	1.0052000000D 00	1.1783000000D-02	-3.4787000000D-01	2.5114000000D 00
6	3.3748758180D-01	2.0721000000D-01	1.0052000000D 00	-8.0156000000D-03	-1.4687000000D-01	2.7507000000D 00
7	4.8216633920D-01	2.8602000000D-01	1.0044000000D 00	-1.1048000000D-02	6.9898000000D-02	-2.5357000000D-01
8	8.4389045010D-01	4.4623000000D-01	1.0033000000D 00	-3.1042000000D-03	2.9274000000D-02	4.7336000000D-01
9	1.2655065170D 00	5.7427000000D-01	1.0033000000D 00	4.5244000000D-03	8.9884000000D-02	-9.1681000000D-01
10	1.6874575560D 00	6.5943000000D-01	1.0039000000D 00	8.8545000000D-03	1.1804000000D-02	3.8665000000D-01
11	2.5316352140D 00	7.6051000000D-01	1.0050000000D 00	1.2023000000D-02	5.0886000000D-02	3.5435000000D-01
12	3.3750349000D 00	8.1662000000D-01	1.0057000000D 00	1.5435000000D-02	7.0766000000D-02	-2.0676000000D 01
13	4.0469303930D 00	8.4578000000D-01	1.0061000000D 00	8.7061000000D-03	-5.3224000000D-01	1.7294000000D 01
14	5.0605664840D 00	8.7580000000D-01	1.0062000000D 00	5.2080000000D-04	-1.3025000000D-02	-3.9162000000D 01
15	6.7524136760D 00	9.0640000000D-01	1.0060000000D 00	-1.8204000000D-02	-1.2111000000D 00	2.4203000000D 00
16	1.0135216960D 01	9.3739000000D-01	1.0049000000D 00	-5.4574000000D-02	-1.1361000000D 00	1.8145000000D 01
17	INFINITE	1.0000000000D 00	1.0000000000D 00			

FLOW LOSS

	CONSTANT	EXPONENT
NEAR FIELD	1.4902000000D 00	1.0000000000D 00
FAR FIELD	1.6170000000D 00	0.0000000000D-01

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.0000000000D-01	0.0000000000D-01	1.0000000000D 00	-1.5480000000D 00	0.0000000000D-01	1.2753000000D 02
2	5.6243436110D-02	3.5768000000D-02	9.4560000000D-01	-1.4665000000D 00	4.5616000000D 00	-1.1867000000D 02
3	9.2081406340D-02	5.8456000000D-02	9.1327000000D-01	-1.3935000000D 00	1.8691000000D 00	7.361[illegible]000000D 01
4	1.2654961380D-01	8.0138000000D-02	8.8362000000D-01	-1.3357000000D 00	3.4653000000D 00	-1.6203000000D 01
5	2.0247463140D-01	1.2718000000D-01	8.2435000000D-01	-1.1906000000D 00	2.7032000000D 00	7.5566000000D 00
6	3.3748758180D-01	2.0721000000D-01	7.3836000000D-01	-9.5004000000D-01	3.3080000000D 00	-4.6527000000D 00
7	4.8216633920D-01	2.8602000000D-01	6.7339000000D-01	-7.0381000000D-01	2.9413000000D 00	-2.4167000000D 00
8	8.4389045010D-01	4.4623000000D-01	5.9672000000D-01	-2.6360000000D-01	2.5541000000D 00	7.0220000000D-01
9	1.2655065170D 00	5.7427000000D-01	5.8415000000D-01	6.9196000000D-02	2.6441000000D 00	4.6007000000D 00
10	1.6874575560D 00	6.5943000000D-01	6.0011000000D-01	3.1106000000D-01	3.0359000000D 00	1.1362000000D 01
11	2.5316352140D 00	7.6051000000D-01	6.4901000000D-01	6.7596000000D-01	4.1843000000D 00	3.1211000000D 01
12	3.3750349000D 00	8.1662000000D-01	6.9444000000D-01	9.5984000000D-01	5.9354000000D 00	-7.64[illegible]8000000D 00
13	4.0469303930D 00	8.4578000000D-01	7.2493000000D-01	1.1297000000D 00	5.7123000000D 00	5.44[illegible]8000000D 01
14	5.0605664840D 00	8.7580000000D-01	7.6166000000D-01	1.3257000000D 00	7.3467000000D 00	1.2255000000D 01
15	6.7524136760D 00	9.0640000000D-01	8.0572000000D-01	1.5562000000D 00	7.7216000000D 00	2.6260000000D 02
16	1.0135216960D 01	9.3739000000D-01	8.5896000000D-01	1.9216000000D 00	1.5860000000D 01	-2.5330000000D 02
17	INFINITE	1.0000000000D 00	1.0000000000D 00			

(Sheet 3 of 7)

Table 3 - Contents of Retrieval File . . . (continued)

K-XX

	CONSTANT	EXPONENT
NEAR FIELD	-5.510200000D-01	1.000000000D 00
FAR FIELD	9.017300000D-01	2.500000000D 00

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.000000000D-01	0.000000000D-01	-1.000000000D 00	2.432300000D 00	0.000000000D-01	7.148700000D 02
2	5.624343611D-02	3.576800000D-02	-9.075500000D-01	2.889600000D 00	2.556900000D 01	-9.141900000D 02
3	9.208140634D-02	5.845600000D-02	-8.371900000D-01	3.234400000D 00	4.828300000D 00	5.043700000D 02
4	1.265496138D-01	8.013800000D-02	-7.650700000D-01	3.457600000D 00	1.576400000D 01	-2.280600000D 02
5	2.024746314D-01	1.271800000D-01	-5.889300000D-01	3.946900000D 00	5.035700000D 00	-2.745400000D 00
6	3.374875818D-01	2.072100000D-01	-2.571700000D-01	4.341100000D 00	4.816000000D 00	-2.072400000D 02
7	4.821663392D-01	2.860200000D-01	8.300000000D-02	4.077000000D 00	-1.151700000D 01	5.963300000D 01
8	8.438904501D-01	4.462300000D-01	6.292500000D-01	2.997200000D 00	-1.963000000D 00	-1.104600000D 02
9	1.265506517D 00	5.742700000D-01	9.582800000D-01	1.840400000D 00	-1.610600000D 01	1.097100000D 02
10	1.687457556D 00	6.594300000D-01	1.067900000D 00	8.666200000D-01	-6.763900000D 00	-6.064300000D 00
11	2.531635214D 00	7.605100000D-01	1.119900000D 00	1.519400000D-01	-7.376900000D 00	-4.488300000D-01
12	3.375034900D 00	8.166200000D-01	1.116800000D 00	-2.626800000D-01	-7.402000000D 00	4.855800000D 02
13	4.046930393D 00	8.457800000D-01	1.108000000D 00	-2.720700000D-01	6.757600000D 00	-6.381300000D 02
14	5.060566484D 00	8.758000000D-01	1.100000000D 00	-3.567500000D-01	-1.239900000D 01	3.604900000D 02
15	6.752413676D 00	9.064000000D-01	1.085000000D 00	-5.673800000D-01	-1.367800000D 00	-3.548100000D 02
16	1.013521696D 01	9.373900000D-01	1.065000000D 00	-7.801500000D-01	-1.236300000D 01	1.974700000D 02
17	INFINITE	1.000000000D 00	1.000000000D 00			

B-XX

	CONSTANT	EXPONENT
NEAR FIELD	2.005800000D 00	0.000000000D-01
FAR FIELD	1.445000000D 01	1.500000000D 00

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.000000000D-01	0.000000000D-01	1.000000000D 00	-1.860900000D 00	0.000000000D-01	-9.688000000D 02
2	5.624343611D-02	3.576800000D-02	9.260500000D-01	-2.480600000D 00	-3.465200000D 01	2.280700000D 03
3	9.208140634D-02	5.845600000D-02	8.652900000D-01	-2.679800000D 00	1.709200000D 01	-1.904000000D 02
4	1.265496138D-01	8.013800000D-02	8.108800000D-01	-2.354000000D 00	1.296400000D 01	2.144000000D 01
5	2.024746314D-01	1.271800000D-01	7.148600000D-01	-1.720400000D 00	1.397300000D 01	-7.142800000D 01
6	3.374875818D-01	2.072100000D-01	6.158200000D-01	-8.309100000D-01	8.256400000D 00	-7.325600000D 01
7	4.821663392D-01	2.860200000D-01	5.700000000D-01	-4.077200000D-01	2.483100000D 00	-1.166700000D 01
8	8.438904501D-01	4.462300000D-01	5.285500000D-01	-1.596400000D-01	6.138800000D-01	1.071300000D 01
9	1.265506517D 00	5.742700000D-01	5.168900000D-01	6.778000000D-03	1.985500000D 00	-1.784700000D 01
10	1.687457556D 00	6.594300000D-01	5.228300000D-01	1.111500000D-01	4.657100000D-01	3.750500000D 01
11	2.531635214D 00	7.605100000D-01	5.429000000D-01	3.498200000D-01	4.256700000D 00	-4.058500000D 00
12	3.375034900D 00	8.166200000D-01	5.691100000D-01	5.822800000D-01	4.029000000D 00	5.269800000D 02
13	4.046930393D 00	8.457800000D-01	5.699800000D-01	9.238100000D-01	1.939600000D 01	1.214200000D 02
14	5.060566484D 00	8.758000000D-01	6.270000000D-01	1.560800000D 00	2.304100000D 01	3.042600000D 02
15	6.752413676D 00	9.064000000D-01	6.870000000D-01	2.408300000D 00	3.235100000D 01	-4.368600000D 02
16	1.013521696D 01	9.373900000D-01	7.750000000D-01	3.201100000D 00	1.881300000D 01	-3.004700000D 02
17	INFINITE	1.000000000D 00	1.000000000D 00			

(Sheet 4 of 7)

Table 3 - Contents of Retrieval File . . . (continued)

K-X'

	CONSTANT	EXPONENT
NEAR FIELD	1.0028000000D 00	0.0000000000D-01
FAR FIELD	2.4336000000D 00	2.0000000000D 00

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.0000000000D-01	0.0000000000D-01	1.0000000000D 00	2.5245000000D-01	0.0000000000D-01	6.9107000000D 02
2	5.6243436110D-02	3.5768000000D-02	1.0143000000D 00	6.9450000000D-01	2.4718000000D 01	-3.6921000000D 02
3	9.2081406340D-02	5.8456000000D-02	1.0357000000D 00	1.1603000000D 00	1.6341000000D 01	-1.1674000000D 02
4	1.2654961380D-01	8.0138000000D-02	1.0645000000D 00	1.4872000000D 00	1.3810000000D 01	-1.4059000000D 02
5	2.0247463140D-01	1.2718000000D-01	1.1473000000D 00	1.9813000000D 00	7.1964000000D 00	-1.6511000000D 02
6	3.3748758180D-01	2.0721000000D-01	1.3148000000D 00	2.0284000000D 00	-6.0173000000D 00	-7.0334000000D 00
7	4.8216633920D-01	2.8602000000D-01	1.4554000000D 00	1.5324000000D 00	-6.5716000000D 00	-2.4457000000D 01
8	8.4389045010D-01	4.4623000000D-01	1.5998000000D 00	1.6564000000D-01	-1.0490000000D 01	3.9955000000D 01
9	1.2655065170D 00	5.7427000000D-01	1.5490000000D 00	-8.4997000000D-01	-5.3741000000D 00	1.6620000000D 00
10	1.6874575560D 00	6.5943000000D-01	1.4573000000D 00	-1.3016000000D 00	-5.2326000000D 00	5.4599000000D 01
11	2.5316352140D 00	7.6051000000D-01	1.3084000000D 00	-1.5516000000D 00	2.8626000000D-01	-3.7039000000D 01
12	3.3750349000D 00	8.1662000000D-01	1.2207000000D 00	-1.5938000000D 00	-1.7920000000D 00	8.1851000000D 01
13	4.0469303930D 00	8.4578000000D-01	1.1738000000D 00	-1.6113000000D 00	5.9479000000D-01	2.8899000000D 02
14	5.0605664840D 00	8.7580000000D-01	1.1270000000D 00	-1.4632000000D 00	9.2704000000D 00	-1.1846000000D 02
15	6.7524136760D 00	9.0640000000D-01	1.0860000000D 00	-1.2350000000D 00	5.6455000000D 00	1.1328000000D 02
16	1.0135216960D 01	9.3739000000D-01	1.0510000000D 00	-1.0057000000D 00	9.1561000000D 00	-1.4624000000D 02
17	INFINITE	1.0000000000D 00	1.0000000000D 00			

B-XY

	CONSTANT	EXPONENT
NEAR FIELD	5.0960000000D 00	1.0000000000D 00
FAR FIELD	4.3765000000D 00	1.5000000000D 00

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.0000000000D-01	0.0000000000D-01	1.0000000000D 00	5.0622000000D-01	0.0000000000D-01	2.4828000000D 02
2	5.6243436110D-02	3.5768000000D-02	1.0200000000D 00	6.6504000000D-01	8.8804000000D 00	-6.0311000000D 02
3	9.2081406340D-02	5.8456000000D-02	1.0362000000D 00	7.1129000000D-01	-4.8030000000D 00	2.9832000000D 02
4	1.2654961380D-01	8.0138000000D-02	1.0510000000D 00	6.7727000000D-01	1.6652000000D 00	-4.6267000000D 01
5	2.0247463140D-01	1.2718000000D-01	1.0839000000D 00	7.0441000000D-01	-5.1129000000D-01	-2.1501000000D 01
6	3.3748758180D-01	2.0721000000D-01	1.1368000000D 00	5.9464000000D-01	-2.2320000000D 00	3.2866000000D 00
7	4.8216633920D-01	2.8602000000D-01	1.1770000000D 00	4.2894000000D-01	-1.9730000000D 00	-5.9810000000D 00
8	8.4389045010D-01	4.4623000000D-01	1.2163000000D 00	3.6082000000D-02	-2.9312000000D 00	6.0249000000D 00
9	1.2655065170D 00	5.7427000000D-01	1.1990000000D 00	-2.8985000000D-01	-2.1598000000D 00	2.2492000000D 01
10	1.6874575560D 00	6.5943000000D-01	1.1688000000D 00	-3.9222000000D-01	-2.4440000000D-01	5.4648000000D-01
11	2.5316352140D 00	7.6051000000D-01	1.1280000000D 00	-4.1413000000D-01	-1.8916000000D-01	-2.9390000000D 01
12	3.3750349000D 00	8.1662000000D-01	1.1036000000D 00	-4.7101000000D-01	-1.8382000000D 00	1.0071000000D 02
13	4.0469303930D 00	8.4578000000D-01	1.0895000000D 00	-4.8179000000D-01	1.0986000000D 00	-3.3966000000D 02
14	5.0605664840D 00	8.7580000000D-01	1.0740000000D 00	-6.0187000000D-01	-9.0980000000D 00	5.6050000000D 02
15	6.7524136760D 00	9.0640000000D-01	1.0540000000D 00	-6.1785000000D-01	8.0533000000D 00	-3.4674000000D 02
16	1.0135216960D 01	9.3739000000D-01	1.0370000000D 00	-5.3478000000D-01	-2.6920000000D 00	4.2997000000D 01
17	INFINITE	1.0000000000D 00	1.0000000000D 00			

(Sheet 5 of 7)

Table 3 - Contents of Retrieval File . . . (continued)

K-YX

	CONSTANT	EXPONENT
NEAR FIELD	-2.2799000000D 00	0.0000000000D-01
FAR FIELD	2.2460000000D-01	2.5000000000D 00

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.0000000000D-01	0.0000000000D-01	-1.0000000000D 00	8.0513000000D-01	0.0000000000D-01	-3.2357000000D 02
2	5.6243436110D-02	3.5768000000D-02	-9.7367000000D-01	5.9815000000D-01	-1.1573000000D 01	-1.7063000000D 02
3	9.2081406340D-02	5.8456000000D-02	-9.6341000000D-01	2.9166000000D-01	-1.5445000000D 01	1.4284000000D 03
4	1.2654961380D-01	8.0138000000D-02	-9.5829000000D-01	2.9254000000D-01	1.5526000000D 01	-6.0409000000D 02
5	2.0247463140D-01	1.2718000000D-01	-9.3783000000D-01	3.5451000000D-01	-1.2892000000D 01	2.3308000000D 02
6	3.3749758180D-01	2.0721000000D-01	-9.3083000000D-01	6.9231000000D-02	5.7622000000D 00	-1.0444000000D 02
7	4.8216633920D-01	2.8602000000D-01	-9.1600000000D-01	1.9900000000D-01	-2.4689000000D 00	9.5282000000D 01
8	8.4389045010D-01	4.4623000000D-01	-8.5050000000D-01	1.0263000000D 00	1.2796000000D 01	-2.4658000000D 01
9	1.2655065170D 00	5.7427000000D-01	-6.2283000000D-01	2.4626000000D 00	9.6391000000D 00	2.2912000000D 02
10	1.6874575560D 00	6.5943000000D-01	-3.5458000000D-01	4.1143000000D 00	2.9151000000D 01	-8.5809000000D 01
11	2.5316352140D 00	7.6051000000D-01	1.9544000000D-01	6.6225000000D 00	2.0477000000D 01	1.0861000000D 02
12	3.3750349000D 00	8.1662000000D-01	6.0246000000D-01	7.9424000000D 00	2.6572000000D 01	-7.5738000000D 03
13	4.0469303930D 00	8.4578000000D-01	8.1406000000D-01	5.4972000000D 00	-1.9428000000D 02	5.2019000000D 03
14	5.0605664340D 00	8.7580000000D-01	9.1500000000D-01	2.0089000000D 00	-3.8119000000D 01	2.8757000000D 02
15	6.7524136760D 00	9.0640000000D-01	9.6000000000D-01	9.7712000000D-01	-2.9319000000D 01	7.6561000000D 02
16	1.0135216960D 01	9.3739000000D-01	9.8000000000D-01	4.3616000000D-01	-5.5929000000D 00	8.9329000000D 01
17	INFINITE	1.0000000000D 00	1.0000000000D 00			

B-YX

	CONSTANT	EXPONENT
NEAR FIELD	5.0960000000D 00	1.0000000000D 00
FAR FIELD	4.3765000000D 00	1.5000000000D 00

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.0000000000D-01	0.0000000000D-01	1.0000000000D 00	5.0622000000D-01	0.0000000000D-01	2.4828000000D 02
2	5.6243436110D-02	3.5768000000D-02	1.0200000000D 00	6.6504000000D-01	8.8804000000D 00	-6.0311000000D 02
3	9.2081406340D-02	5.8456000000D-02	1.0362000000D 00	7.1129000000D-01	-4.8030000000D 00	2.9832000000D 02
4	1.2654961380D-01	8.0138000000D-02	1.0510000000D 00	6.7727000000D-01	1.6652000000D 00	-4.6267000000D 01
5	2.0247463140D-01	1.2718000000D-01	1.0839000000D 00	7.0441000000D-01	-5.1129000000D-01	-2.1501000000D 01
6	3.3749758180D-01	2.0721000000D-01	1.1368000000D 00	5.9464000000D-01	-2.2320000000D 00	3.2866000000D 00
7	4.8216633920D-01	2.8602000000D-01	1.1770000000D 00	4.2894000000D-01	-1.9730000000D 00	-5.9810000000D 00
8	8.4389045010D-01	4.4623000000D-01	1.2163000000D 00	3.6082000000D-02	-2.9312000000D 00	6.0249000000D 00
9	1.2655065170D 00	5.7427000000D-01	1.1990000000D 00	-2.8985000000D-01	-2.1598000000D 00	2.2492000000D 01
10	1.6874575560D 00	6.5943000000D-01	1.1688000000D 00	-3.9222000000D-01	-2.4440000000D-01	5.4648000000D-01
11	2.5316352140D 00	7.6051000000D-01	1.1280000000D 00	-4.1413000000D-01	-1.8916000000D-01	-2.9390000000D 01
12	3.3750349000D 00	8.1662000000D-01	1.1036000000D 00	-4.7101000000D-01	-1.8382000000D 00	1.0071000000D 02
13	4.0469303930D 00	8.4578000000D-01	1.0895000000D 00	-4.8179000000D-01	1.0986000000D 00	-3.3966000000D 02
14	5.0605664840D 00	8.7580000000D-01	1.0740000000D 00	-6.0187000000D-01	-9.0980000000D 00	5.6050000000D 02
15	6.7524136760D 00	9.0640000000D-01	1.0540000000D 00	-6.1785000000D-01	8.0533000000D 00	-3.4674000000D 02
16	1.0135216960D 01	9.3739000000D-01	1.0370000000D 00	-5.3478000000D-01	-2.6920000000D 00	4.2997000000D 01
17	INFINITE	1.0000000000D 00	1.0000000000D 00			

(Sheet 6 of 7)

Table 3 - Contents of Retrieval File . . . (continued)

K-YY

	CONSTANT	EXPONENT
NEAR FIELD	4.7203000000D 00	1.0000000000D 00
FAR FIELD	3.4007000000D 00	1.5000000000D 00

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.0000000000D-01	0.0000000000D-01	1.0000000000D 00	5.9625000000D-01	0.0000000000D-01	1.1453000000D 02
2	5.6243436110D-02	3.5768000000D-02	1.0222000000D 00	6.6951000000D-01	4.0965000000D 00	-7.9330000000D 02
3	9.2081406340D-02	5.8456000000D-02	1.0369000000D 00	5.5827000000D-01	-1.3902000000D 01	7.4359000000D 02
4	1.2654961380D-01	8.0138000000D-02	1.0470000000D 00	4.3164000000D-01	2.2205000000D 00	-1.3037000000D 02
5	2.0247463140D-01	1.2718000000D-01	1.0675000000D 00	3.9184000000D-01	-3.9123000000D 00	2.8910000000D 01
6	3.3748758180D-01	2.0721000000D-01	1.0888000000D 00	1.7132000000D-01	-1.5987000000D 00	8.1280000000D 00
7	4.8216633920D-01	2.8602000000D-01	1.0980000000D 00	7.0568000000D-02	-9.5811000000D-01	-7.3096000000D 00
8	8.4389045010D-01	4.4623000000D-01	1.0920000000D 00	-1.7674000000D-01	-2.1292000000D 00	2.2246000000D 01
9	1.2655065170D 00	5.7427000000D-01	1.0597000000D 00	-2.6701000000D-01	7.1921000000D-01	-5.9939000000D 01
10	1.6874575560D 00	6.5943000000D-01	1.0334000000D 00	-4.2310000000D-01	-4.3852000000D 00	6.8378000000D 01
11	2.5316352140D 00	7.6051000000D-01	9.8000000000D-01	-5.1705000000D-01	2.5265000000D 00	-6.8461000000D 01
12	3.3750349000D 00	8.1662000000D-01	9.5295000000D-01	-4.8305000000D-01	-1.3149000000D 00	4.4644000000D 02
13	4.0469303930D 00	8.4578000000D-01	9.4015000000D-01	-3.3159000000D-01	1.1703000000D 01	-3.2582000000D 02
14	5.0605664840D 00	8.7580000000D-01	9.3400000000D-01	-1.2707000000D-01	1.9221000000D 00	4.1642000000D 02
15	6.7524136760D 00	9.0640000000D-01	9.3300000000D-01	1.2670000000D-01	1.4664000000D 01	6.4106000000D 00
16	1.0135216960D 01	9.3739000000D-01	9.4400000000D-01	5.8423000000D-01	1.4863000000D 01	-2.3739000000D 02
17	INFINITE	1.0000000000D 00	1.0000000000D 00			

B-YY

	CONSTANT	EXPONENT
NEAR FIELD	4.5143000000D 00	0.0000000000D-01
FAR FIELD	7.0281000000D 00	1.0000000000D 00

POINT	LOAD	TAU	COMPARISON FCN	DERIVATIVE 1	DERIVATIVE 2	DERIVATIVE 3
1	0.0000000000D-01	0.0000000000D-01	1.0000000000D 00	-2.7314000000D 00	0.0000000000D-01	6.6960000000D 02
2	5.6243436110D-02	3.5768000000D-02	9.0741000000D-01	-2.3031000000D 00	2.3950000000D 01	-4.6342000000D 02
3	9.2081406340D-02	5.8456000000D-02	8.6042000000D-01	-1.8790000000D 00	1.3436000000D 01	-1.5225000000D 02
4	1.2654961380D-01	8.0138000000D-02	8.2258000000D-01	-1.6234000000D 00	1.0135000000D 01	-1.9908000000D 01
5	2.0247463140D-01	1.2718000000D-01	7.5708000000D-01	-1.1687000000D 00	9.1987000000D 00	-7.0346000000D 01
6	3.3748758180D-01	2.0721000000D-01	6.8700000000D-01	-6.5777000000D-01	3.5690000000D 00	-8.1482000000D 00
7	4.8216633920D-01	2.8602000000D-01	6.4558000000D-01	-4.0180000000D-01	2.9268000000D 00	-9.8761000000D 00
8	8.4389045010D-01	4.4623000000D-01	6.1200000000D-01	-5.9646000000D-02	1.3445000000D 00	-4.3285000000D 00
9	1.2655065170D 00	5.7427000000D-01	6.1387000000D-01	7.7029000000D-02	7.9033000000D-01	-9.4781000000D 00
10	1.6874575560D 00	6.5943000000D-01	6.2232000000D-01	1.0996000000D-01	-1.6820000000D-02	4.7353000000D 01
11	2.5316352140D 00	7.6051000000D-01	6.4150000000D-01	3.5017000000D-01	4.7696000000D 00	-1.0745000000D 01
12	3.3750349000D 00	8.1662000000D-01	6.6834000000D-01	6.0088000000D-01	4.1667000000D 00	3.5252000000D 02
13	4.0469303930D 00	8.4578000000D-01	6.8909000000D-01	8.7226000000D-01	1.4446000000D 01	-3.9581000000D 02
14	5.0605664840D 00	8.7580000000D-01	7.2000000000D-01	1.1276000000D 00	2.5641000000D 00	-3.5695000000D 02
15	6.7524136760D 00	9.0640000000D-01	7.5400000000D-01	1.0389000000D 00	-8.3584000000D 00	2.3823000000D 03
16	1.0135216960D 01	9.3739000000D-01	7.9400000000D-01	1.9239000000D 00	6.5469000000D 01	-1.0457000000D 03
17	INFINITE	1.0000000000D 00	1.0000000000D 00			

(Sheet 7 of 7)

SECTION IV

FOUNDATIONS OF THE STORAGE RETRIEVAL METHOD

4.1 Choice of the Operating Parameter

The state of static equilibrium of a fluid film journal bearing may be specified either in terms of a static load vector or a static displacement vector. Traditionally, the bearing designer tends to work with the displacement vector not only because the eccentricity ratio is an easy to use design parameter in bearing analysis but also because the bearing designer is concerned with the minimum film thickness which is directly related to the eccentricity ratio. A rotor dynamicist, on the other hand, starts with a known bearing design. Furthermore, the static load condition is usually known.* Therefore; the load parameter, as readily computed according to Eq. (2), is the natural choice to define the data point in the table.

The complete range of the load parameter should span from zero to infinity. Obviously it is not possible to treat unbounded numbers in a data table. As a practical matter, some arbitrary cutoff point is accepted when a table is being prepared. At the time of data retrieval, if the requested data point should lie outside the available data range, a judicial extrapolation procedure must be used. The most commonly used extrapolation procedure is the power law, which amounts to a straight line extension of a log-log plot. The desired retrieval method requires the inclusion of such an extrapolation procedure which also retains overall smoothness within the data range.

The graphical extrapolation process can be emulated by a computer program. The power law extrapolation for an infinitesimal load can be expressed as

*The new rotor dynamics software [9] has a feature to calculate the load vector of each bearing.

$$\bar{Z} = a\bar{W}^{s_1} \qquad \text{for} \qquad \bar{W} \ll 1 \qquad (48)$$

Its log differential form is

$$\frac{d\bar{Z}}{\bar{Z}} = s_1 \frac{d\bar{W}}{\bar{W}}$$

Or,

$$s_1 = \frac{d\bar{Z}}{d\bar{W}} \frac{\bar{W}}{\bar{Z}} \qquad \text{for} \qquad \bar{W} \ll 1 \qquad (49)$$

With the differentials replaced by finite differences and $(\bar{W}, \bar{Z})$ approximated by average values, Eq. (49) can be used to calculate s_1 from two data points corresponding to the smallest values of $\bar{W}$ in the data table.

Similarly, the power law extrapolation for the load parameter tending to infinity is

$$\bar{Z} = b\bar{W}^{s_2} \qquad \text{for} \qquad \bar{W} \gg 1 \qquad (50)$$

Or,

$$s_2 = \frac{d\bar{Z}}{d\bar{W}} \frac{\bar{W}}{\bar{Z}} \qquad \text{for} \qquad \bar{W} \gg 1 \qquad (51)$$

s_2 can thus be calculated with the two data points which represent the largest values of $\bar{W}$ in the data table.

The values of s_1 and s_2 as computed numerically can have either sign and certainly may not always be integers. As illustrated in the π-film short bearing analysis, the factor $(1-\varepsilon^2)^{-1/2}$ shows up prominently in various coefficients. Therefore, the values of s_1 and s_2 are rounded off to the nearest half-integer.

Upon fixing s_1 and s_2, the near-field and far-field data behavior can be more accurately represented by

$$\lim_{\overline{W}\to 0} \overline{Z} = \overline{W}^{s_1}\{a_o + a_1\overline{W} + a_2\overline{W}^2\} \tag{52}$$

$$\lim_{\overline{W}\to\infty} \overline{Z} = \overline{W}^{s_1}\{b_o + b_1\overline{W}^{-1} + b_2\overline{W}^{-2}\} \tag{53}$$

and the coefficients a_o and b_o, respectively, can be determined numerically from three consecutive data points in each end of the data table. The other coefficients (a_1, a_2, b_1, b_2) are not explicitly required to define the extreme field asymptotes which are

$$\lim_{\overline{W}\to 0} \overline{Z} = a_o\overline{W}^{s_1}; \quad \lim_{\overline{W}\to\infty} \overline{Z} = b_o\overline{W}^{s_2} \tag{54}$$

4.2 Full Range Interpolation

An important requirement for a foolproof full range interpolation procedure is to conform to the asymptotic properties uniformly in both the near field and in the far field. This very stringent requirement is satisfied by comparing the data point with a reference function $\overline{Z}_o$ which has the following properties:

(1) $$\lim_{\overline{W}\to 0} \frac{|\overline{Z}|}{\overline{Z}_o} = 1 \tag{55}$$

(2) $$\lim_{\overline{W}\to\infty} \frac{|\overline{Z}|}{\overline{Z}_o} = 1 \tag{56}$$

(3) $\overline{Z}_o\ (0<\overline{W}<\infty)>0$ and is bounded. (57)

Many simple functions can be concocted to satisfy these conditions for a specific combination of s_1 and s_2. After some experimentation, the reference function is chosen to have one of three forms depending on the relative values of s_1 and s_2:

(a) $s_1 > s_2$ then

$$\bar{Z}_o = \frac{|a_o b_o| \bar{W}^{s_1 + s_2} (1 + \bar{W})}{|a_o| \bar{W}^{s_1 + 1} + |b_o| \bar{W}^{s_2}} \tag{58a}$$

(b) $s_2 - 1 < s_1 \leq s_2$ then

$$\bar{Z}_o = \frac{|a_o| \bar{W}^{s_1} + |b_o| \bar{W}^{s_2 + 1}}{1 + \bar{W}} \tag{58b}$$

(c) $s_2 - 1 \geq s_1$ then

$$\bar{Z}_o = |a_o| \bar{W}^{s_1} + |b_o| \bar{W}^{s_2} \tag{58c}$$

The interpolation operation is then to be performed on the comparison function, which is simply the ratio between the data point and the reference function at the same value of the load parameter; i.e.

$$\bar{Z}_c(\bar{W}) = \bar{Z}(W)/\bar{Z}_o(\bar{W}) \tag{59}$$

The near-field and far-field values of the comparison function are simply

$$Z_c(W \to 0) = sg\{a_o\}; \qquad Z_c(W \to \infty) = sg\{b_o\} \tag{60}$$

$\bar{Z}_c$ is bounded for all values of $\bar{W}$. Since $\bar{Z}_o$ is everywhere smooth, smoothness, or the lack of it, in the data would be directly reflected by the comparison function. Because $\overline{Z}_c$ has a limited range, its maximum magnitude is usually near unity; its smoothness can be readily verified. Examination of $\overline{Z}_c$ is thus a very effective way to discover inaccuracy in the data table. Furthe. discussion of this question will be pursued in Section 4.4.

Obtaining a $\overline{Z}_c$ ($\overline{W}$) at discrete points of $\overline{W}$, interpolation can still be problematic if the desired value of $\overline{W}$ exceeds the largest data point. This difficulty is overcome by mapping the semi-infinite range of the load parameter into a finite domain of a working parameter. To assure one-to-one transformation between the load parameter and the working parameter, a monotonic differential relationship is desired. The selected transformation is

$$\tau = \frac{2}{\pi} \tan^{-1}(\overline{W}) \tag{61}$$

The inverse transformation is

$$\overline{W} = \tan(\frac{\pi}{2} \tau) \tag{62}$$

Differentiation of Eq. (61) yields

$$\frac{d\tau}{d\overline{W}} = \frac{(2/\pi)}{1 + (\overline{W})^2} \tag{63}$$

which is always positive and bounded. One may again note the near-field and far-field asymptotes of Eq. (61)

$$\lim_{\overline{W}\to 0} \tau = \frac{2}{\pi} \overline{W} \; ; \qquad \lim_{\overline{W}\to\infty} \tau = 1 - \frac{1}{(\pi/2)\overline{W}} \tag{64}$$

These simple relationships allow one to examine the data points in <u>all</u> ranges of $\overline{W}$.

With the aic of Eq. (62), the comparison function can now be described in the domain $0 \leq \tau \leq 1$. $\overline{Z}_c(\tau)$ is in fact assured to be bounded and smooth. Established numerical interpolation schemes can be readily implemented on it. The selected approach is the third order spline function [9], which represents $\overline{Z}_c(\tau_i \leq \tau \leq \tau_{i+1})$ as

$$\overline{Z}_c = \overline{Z}_c(\tau_i) + a_i(\tau - \tau_i) + \frac{1}{2} b_i(\tau - \tau_i)^2 + \frac{1}{6} c_i(\tau - \tau_i)^3$$

i spans 1 to N if the full range is divided into N intervals (which may not be uniform). There is some flexibility in the choice of the coefficients at each of the end points where one free condition can be specified. The common convention is to let the outboard second derivative vanish at each end; i.e.

$$b_1 = 0; \quad \text{and } b_N + (\tau_{N+1} - \tau_N)c_N = 0$$

Sometimes, if justified by other arguments, one can elect to null the first derivative at either end; i.e.,

$$a_1 = 0; \text{ or } a_N + (\tau_{N+1} - \tau_N)b_N + \frac{1}{2}(\tau_{N+1} - \tau_N)^2 c_N = 0$$

4.3 Correction for L/D Variation

The length to diameter ratio is a major configuration parameter in the design of a fluid film bearing. Typically, in industrial practice, it is in the range of 0.4 - 0.75; occasionally it may be less than 0.25. Unfortunately, there is no standardization of its value. If the data bank were to include a range of L/D, its total storage requirement would be very large indeed. It is, therefore, useful to develop an approach to correct any deviation in the value of (L/D) from that of an available data table.

The short bearing analysis described in Appendix B contains a scaling law which is applicable to the dimensionless load as well as the dimensionless dynamic coefficients:

$$\overline{W}; \quad \overline{K}_{xx}, \text{ etc.}; \quad \overline{B}_{xx}, \text{ etc.} \sim (\frac{L}{D})^2 \tag{66}$$

For the plain journal bearing, Lund [12] showed that this scaling yields reasonable results even for L/D = 1.0 for modest eccentricity ratios (up to about 0.3). It is also clear that such a scaling law would become increasingly unsatisfactory as L/D becomes very large since all such coefficients remain finite for an infinitely long bearing. To improve the situation one requires the scaling factor to assume a finite asymptote as $L/D \to \infty$ and that a load level dependence be suitably included. A scaling factor which possesses these two properties can be derived by comparing the "half Sommerfeld" solution with the short bearing solution. The "half Sommerfeld" solution is described in Appendix C.

Suppose the scaling factor is defined as

$$\Sigma = \overline{W}/\overline{W}_{sh} \tag{67}$$

$\overline{W}$ is the dimensionless load of any L/D and

$$\overline{W}_{sh} = \lim_{L/D \to 0} \frac{\overline{W}}{(L/D)^2} \tag{68}$$

The requirements indicated previously are satisfied if Σ is to be dependent on both L/D and $\overline{W}$. Thus

$$\Sigma = \Sigma\ (L/D, \overline{W});$$

and

$$\lim_{L/D \to 0} \Sigma = (L/D)^2$$

$$\lim_{L/D \to \infty} \Sigma = \Sigma_\infty < \infty \tag{69}$$

An empirical formula which is consistent with these conditions is

$$\Sigma = \frac{3}{\alpha^2}\left[1 - \frac{\tanh(\alpha L/D)}{\alpha(L/D)}\right] \tag{70}$$

It is seen that

$$\lim_{L/D\to\infty} \Sigma = \Sigma_\infty = \frac{3}{\alpha^2} \tag{71}$$

One can compute, with the aid of $\overline{W}_{sh}$ and $\overline{W}_\infty$ derived in Appendices B and C,

$$\alpha = \sqrt{\frac{3\overline{W}_{sh}}{\overline{W}_\infty}}$$

$$= \sqrt{\frac{(2+\varepsilon^2)}{2(1-\varepsilon^2)}\sqrt{\frac{1 - \{1 - (4/\pi)^2\}\varepsilon^2}{1 - \{1 - (2/\pi)^2\}\varepsilon^2}}} \tag{72}$$

ε, in turn can be regarded as a function of $\overline{W}_\infty$. Since Eq. (70) is intended to exclude the effect of L/D, Eq. (72) can be construed to define the load scaling factor

$$\alpha(\overline{W}) = \alpha(\varepsilon(\overline{W}_\infty = \overline{W})) \tag{73}$$

as shown in Fig. 5. It is seen that for a wide range of the load parameter, $\overline{W}$, α is hardly distinguishable from unity. Consequently, the value of $\alpha = 1.125$ (at $\overline{W} = 10.0$) should be quite satisfactory; thus

$$\Sigma = \frac{\overline{W}}{\overline{W}_{sh}} \simeq 2.3704\left[1 - \frac{\tanh(1.125\ L/D)}{1.125\ (L/D)}\right] \tag{74}$$

which would be used to scale the load parameter as well as the dimensionless dynamic coefficients.

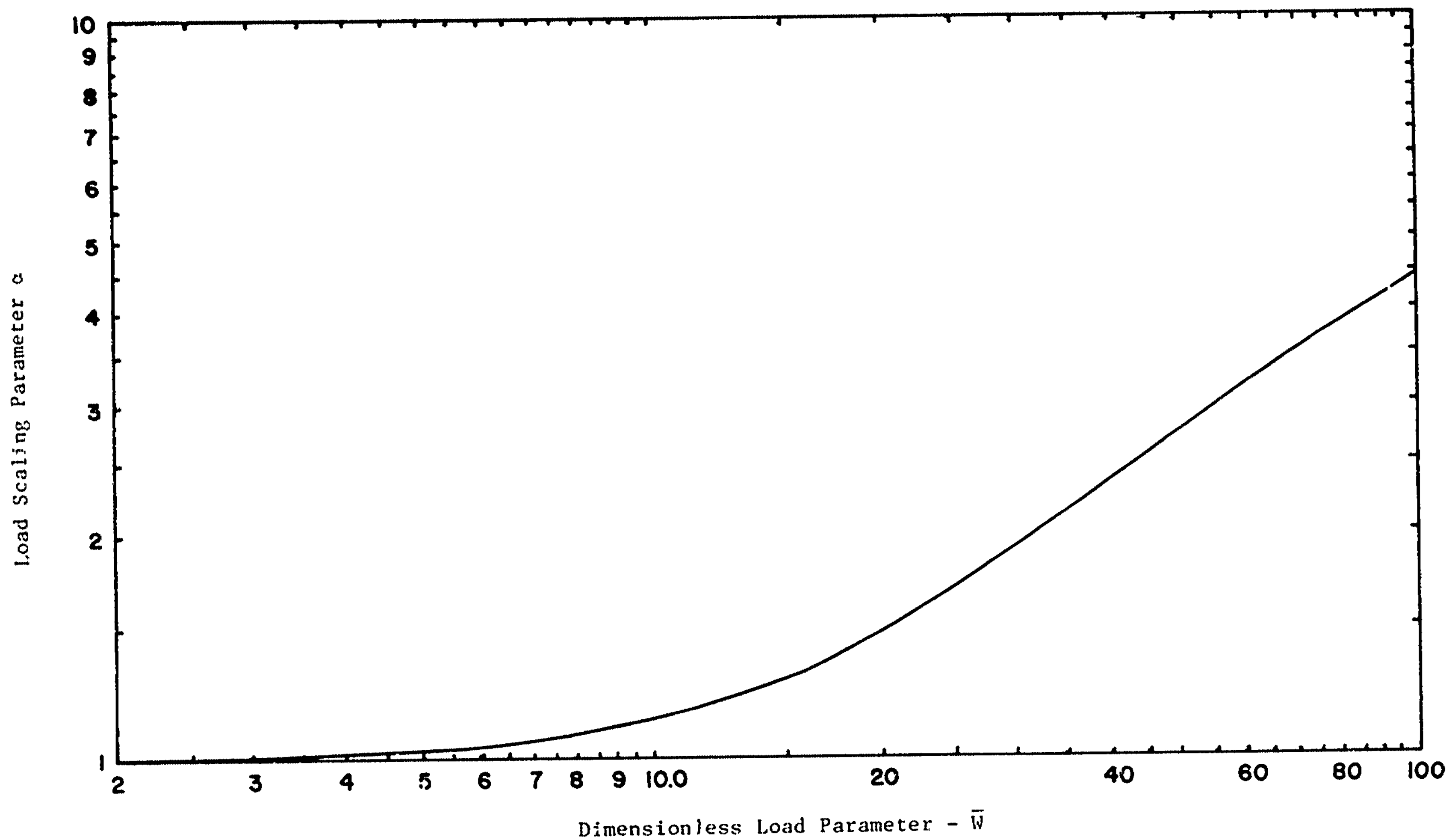

Figure 5 Load Scaling Parameter

For instance, if a data table for L/D = 0.5 is available, then

$$(\Sigma)_{table} = 0.22195$$

If the design under consideration is for L/D = 1.0, i.e.,

$$(\Sigma)_{design} = 0.66518$$

the effective load for the available table should be

$$(\overline{W})_{table} = \frac{0.22195}{0.66518}\ (\overline{W})_{design} = 0.3367\ (\overline{W})_{design}$$

which would be used to interpolate in the data table to obtain

$$(\overline{K}_{xx},\ \text{etc.};\ \ B_{xx},\ \text{etc.})_{table}$$

Finally,

$$(\overline{K}_{xx},\ \text{etc};\ \ \overline{B}_{xx},\ \text{etc.})_{design}$$

$$= \frac{0.66518}{0.22195}\ (\overline{K}_{xx},\ \text{etc.};\ \ \overline{B}_{xx},\ \text{etc.})_{table}$$

$$= 2.9970\ (\overline{K}_{xx},\ \text{etc.};\ \ \overline{B}_{xx},\ \text{etc.})_{table}$$

In this manner, a data table of a particular value of L/D can be reasonably used for designs of somewhat different L/D. This scaling procedure should not be used if there is significant preloading.

4.4 Data Smoothing

The full range interpolation procedure is sensitive to the presence of inaccurate data points. Numerically computed data points can be inaccurate for a variety of reasons; the most common ones are:

- faulty algorithm
- improper mesh (or function) setup, and
- inadequate convergence control

Unfortunately, such inaccuracies often show up even with "proven" softwares as run by an "experienced" user. Because the full range interpolation procedure is sensitive to inaccuracies in the data table, it can be used as the tool to uncover bad data points which should be adjusted.

Upon compiling a retrieval table, the comparison function and its spline interpolation coefficients (first, second, and third derivatives with respect to the working parameter) in each data interval are printed out. Lack of smoothness can be recognized at a glance by inspection of the sign of the first derivative. An isolated change of sign or a succession of sign reversals prominently mark the presence of bad data points.

Very often the inaccuracy associated with each data point is quite modest. But the error may be of alternate signs for a group of such data points in close range. In this case, the table is readily "fixed" by omitting some of the original data points. In some other instances, neighboring groups of data points depict an abrupt change. This is most likely caused by the necessity of employing a different input setup to obtain the data points of the two groups. It is then necessary to adjust one or more data points to permit smooth interpolation over the full range.

Fig. 6(a) shows an example of how "ripples" would be generated by the full range interpolation procedure. In this particular case, a number of data points of questionable accuracy were contained in the original data table as furnished [3] . "Data clutter" in a range of moderately high load level is probably due to loss of accuracy associated with the use of finite difference operation on "trajectory" points to compute the impedance

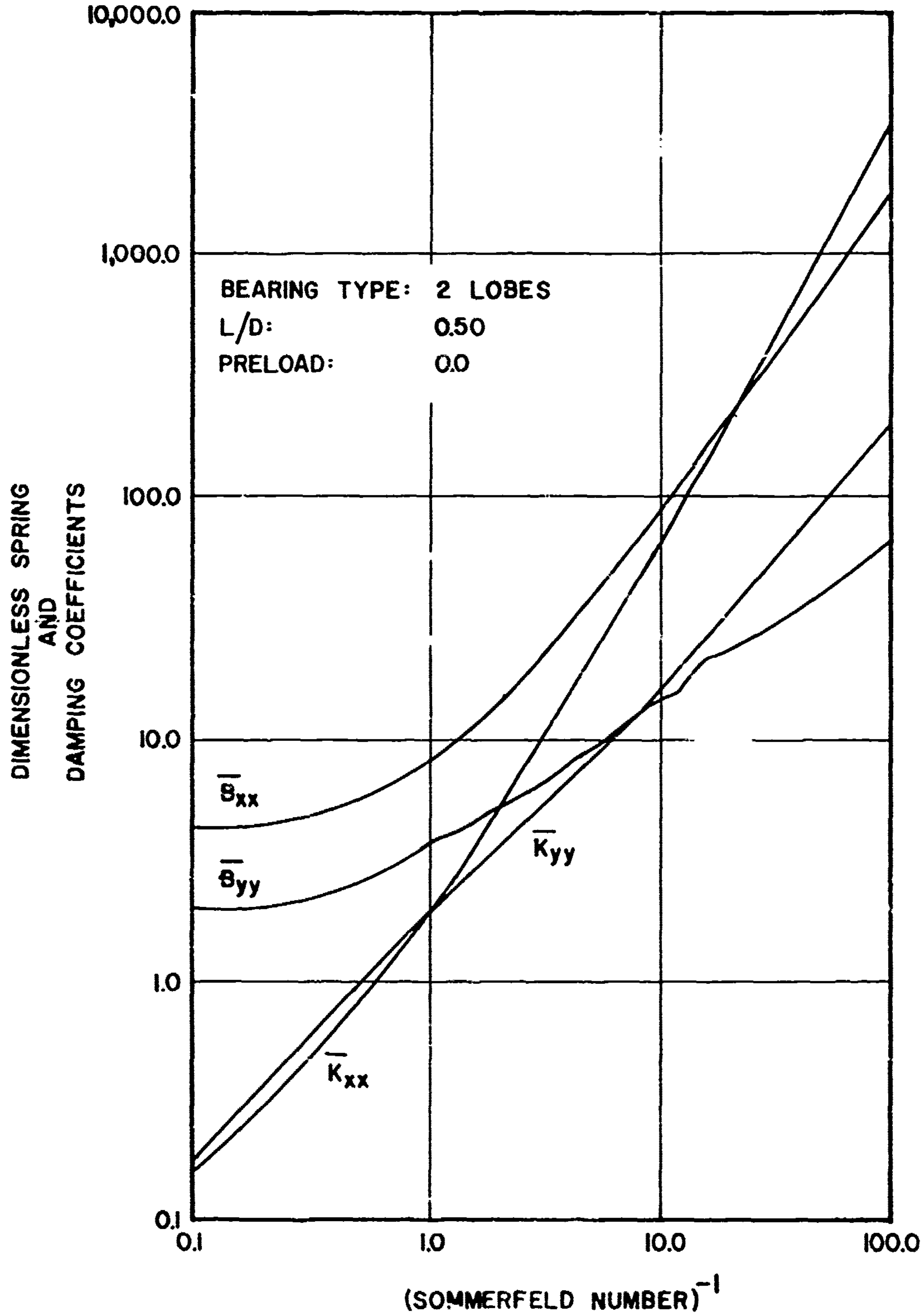

Figure 6(a) Ripples in Original Data

coefficients. Removal of "data clutter" by omitting six of the original seventeen data points permits smooth graphing by interpolation as shown in Fig. 6(b).

A thorough screening of each data table was performed. Adjustments and/or omissions are made where necessary. Therefore, the retrieval files as listed in Appendix D no longer correspond fully to the original data tables.

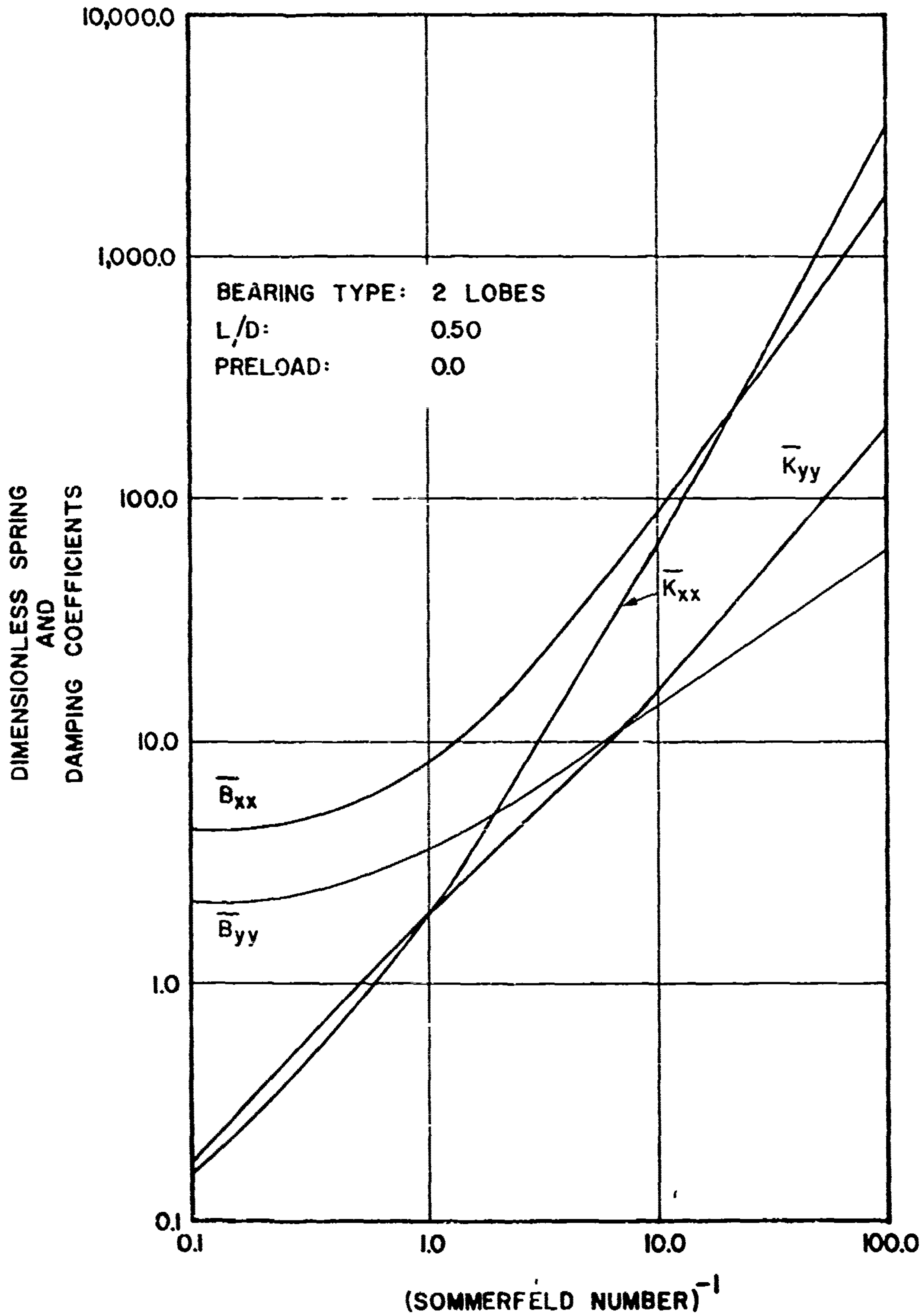

Figure 6(b) Smooth Curves upon Removal of Data Clutter

APPENDIX A

SAMPLE RUNS

The data retrieval software is designed primarily to prepare dynamic data of fluid film bearings for use as part of the input for running the Rotor System Vibrations Program (RSVP) [9]. In addition to extracting the necessary information from a stored data table, at user's command, it performs the supplementary functions of

- shifting the direction of load vector,
- adjusting the data for any deviation of L/D from that of the data table, and
- incorporation of foundation compliance with allowance for inertia and dissipation effects.

It may also be used simply to prepare a listing of the data table in either the dimensional or the dimensionless form in a load range specified by the user.

The software is coded in FORTRAN and is written in the interactive mode. It can thus be run on any computer system which provides the FORTRAN option and can be commanded from an interactive terminal. The bank of data tables may be located on either tape or disk type mass storage device. Thirty-one data tables are listed in Appendix D. The user may install additional data tables according to the procedure described in Section IV. The format of the data table is described in Section 3.4. The source listing of the software is given in Appendix E.

Several sample runs are shown on the following pages. Each sample includes:

- a record of the interactive session with the prompting messages enclosed in boxes;
- a complete output of bearing data for the applicable operating condition(s), including file identification, static characteristics, table of dynamic characteristics, effective stiffness/damping representation with descriptive headings; and

- as required, a listing of the data lines suitable for incorporation into the input setup for running the Rotor System Vibration Program.

The last listing can be punched out into data cards.

Brief descriptions of these sample runs with commentary on notable features are given below:

<u>Sample 1</u> — <u>Synchronous Data with Anisotropic Foundation Compliance in Two Speed Groups, L/D Adjustment Accepted, Inclined Load</u>

L/D of specified bearing (0.6667) is different from that of data table (0.50).

Load vector of bearing is inclined to the vertical direction by 30 degrees.

Foundation data includes inertia (weight) stiffness, and damping coefficients; the latter have distinct values in vertical and horizontal planes.

<u>Sample 2</u> — <u>Synchronous Data with Rigid Foundation in Two Speed Groups, No L/D Adjustment</u>

Same bearing as Sample I, but L/D adjustment is suppressed. Load direction coincides with vertical direction. Same speed points in two groups as Sample I.

<u>Sample 3</u> — <u>Synchronous Data with Rigid Foundation in Two Speed Groups, L/D Adjustment Accepted</u>

By comparison with Sample II, this sample shows the effect of L/D adjustment.

Sample 4 — Synchronous Data with Rigid Foundation in Three Speed Groups, L/D Adjustment Accepted, Inclined Load.

By comparison with Sample III, this sample shows that the dynamic coefficients vary with the load direction, but the static characteristics as well as the stiffness/damping representation are independent of the load direction.

This run also shows the capability of generating data for a third speed group.

Sample 5 — Asynchronous Data with Rigid Foundation, Two Frequency Groups at the Same Speed, L/D Matched with Data Table

A single data line of dynamic characteristics is shown for each frequency group because such data for the bearing on rigid foundation is independent of frequency.

Sample 6 — Asynchronous Data with Isotropic Foundation Compliance

Foundation has an isotropic elastic compliance, (reciprocal of stiffness) but no inertia and damping effects. The overall dynamic coefficients become frequency dependent and are thus generated at each frequency.

SAMPLE 1

RECORD OF INTERACTIVE SESSION

```
ENTER DATA TABLE NAME: PJ-05-1
ENTER OUTPUT FILE NAME: OUTPUT

SELECT:   (1) PREPARE DATA FOR RSVP INPUT
          (2) DIMENSIONAL TABLE
          (3) DIMENSIONLESS TABLE
          (4) QUIT
1

SELECT:   (1) SYNCH FREQ, OR
          (2) ASYNCH FREQ?
1
ENTER BEARING LENGTH (IN)
1.0
ENTER BEARING DIAMETER (IN)
1.5
ENTER BEARING CLEARANCE (IN)
0.001
ENTER VISCOSITY (CENTI-POISE)
40.0
ENTER BEARING LOAD (LBS)
750.0
ENTER BEARING COEFS FILE NAME: RSVP
SELECT:   (1) USE DEFAULT L/D =        0.5000
          (2) ADJUST DATA FOR L/D =    0.6667
2

SELECT:   (1) LOAD VECTOR IN VERTICAL PLANE, OR
          (2) INCLINED LOAD VECTOR?
2
     ENTER LOAD INCLINATION ANGLE (DEG)?
30.0

SELECT:  (1) RIGID FOUNDATION
         (2) ISOTROPIC FOUNDATION COMPLIANCE, OR
         (3) ANISOTROPIC FOUNDATION COMPLIANCE?
3

SELECT:  (1) RADIAL BEARING, OR
         (2) ANGULAR BEARING?
1
     ENTER PEDESTAL WEIGHT (LB)?
120.0
     ENTER PEDESTAL STIFFNESS IN VERTICAL PLANE?
     (LB/IN) FOR RADIAL BRG, OR (IN-LB/RAD) FOR ANG BRG
2.50+04
     ENTER PEDESTAL STIFFNESS IN HORIZONTAL PLANE?
     (LB/IN) FOR RADIAL BRG, OR (IN-LB/RAD) FOR ANG BRG
1.00+04
     ENTER PEDESTAL DAMPING IN VERTICAL PLANE?
     (LB-SEC/IN) FOR RAD BRG, OR (IN-LB-SEC/RAD) FOR ANG BRG
10.0
```

Sample 1 - Record of Interactive Session (continued)

```
        ENTER PEDESTAL DAMPING IN HORIZONTAL PLANE?
        (LB-SEC/IN) FOR RAD BRG, OR (IN-LB-SEC/RAD) FOR ANG BRG
25.0
ENTER LOWEST SPEED (RPM)
6000.0
ENTER HIGHEST SPEED (RPM)
9000.0
ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)
11

 SELECT - (1) ANOTHER SPEED GROUP
          (2) QUIT
1
ENTER LOWEST SPEED (RPM)
9000.0
ENTER HIGHEST SPEED (RPM)
12000.0
ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)
11

 SELECT - (1) ANOTHER SPEED GROUP
          (2) QUIT
2
```

RETRIEVAL FILE NO PJ-05-1
FILE SIZE = 17
L/D = 0 5000
ALFA = 1 1250

SAMPLE 1

TABULATION OF BEARING DATA

L (IN)	DIA (IN)	C (IN)	VISC (CP)	W (LBS)	SPEED RANGE (RPM)	
1 0000	1 5000	0 001000	4.0000 01	750 00	6000.00 TO 9000.00	11 PTS

LOAD PARAMETER IS ADJUSTED FOR L/D = 0.6667

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)	Q-LOST(GPM)
6 0000D 03	3.4171D-04	6.8805D 01	8.6080D-04	8.0048D-02	3.8200D-02
6 2483D 03	3.3232D-04	6.9402D 01	9.3257D-04	8.2827D-02	3.8685D-02
6.5068D 03	3.2302D-04	6.9994D 01	1.0105D-03	8.5705D-02	3 9156D-02
6 7761D 03	3.1383D-04	7.0582D 01	1.0951D-03	8.8686D-02	3.9614D-02
7.0565D 03	3.0476D-04	7.1164D 01	1.1871D-03	9.1775D-02	4.0059D-02
7.3485D 03	2.9581D-04	7.1741D 01	1.2869D-03	9.4976D-02	4.0489D-02
7.6525D 03	2.8698D-04	7.2312D 01	1 3953D-03	9.8294D-02	4.0905D-02
7.9692D 03	2.7829D-04	7.2873D 01	1.5130D-03	1.0173D-01	4.1305D-02
8 2990D 03	2 6972D-04	7.3425D 01	1.6410D-03	1.0530D-01	4.1688D-02
8 6424D 03	2.6128D-04	7.3966D 01	1.7799D-03	1.0899D-01	4.2054D-02
9 0000D 03	2.5298D-04	7.4494D 01	1.9309D-03	1.1283D-01	4.2402D-02

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0.6667

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
6.000D 03	-9.863D 04	1.593D 01	-1.036D 03	-3.021D 00	1.982D 03	-3.488D-01	-1.134D 05	2.970D 01
6.248D 03	-1.092D 05	1.678D 01	-1.259D 03	-3.342D 00	2.341D 03	-3.758D-01	-1.239D 05	3.029D 01
6 507D 03	-1.206D 05	1.773D 01	-1.526D 03	-3.683D 00	2.757D 03	-4.081D-01	-1.352D 05	3.094D 01
6.776D 03	-1.330D 05	1.877D 01	-1.844D 03	-4.044D 00	3.239D 03	-4.473D-01	-1.476D 05	3.167D 01
7.056D 03	-1.464D 05	1.992D 01	-2.222D 03	-4 427D 00	3.795D 03	-4 956D-01	-1 609D 05	3.249D 01
7 348D 03	-1.609D 05	2.118D 01	-2.670D 03	-4.832D 00	4.437D 03	-5.542D-01	-1.754D 05	3.339D 01
7 653D 03	-1.767D 05	2.257D 01	-3.200D 03	-5.258D 00	5.177D 03	-6.259D-01	-1.912D 05	3.439D 01
7.969D 03	-1.938D 05	2.410D 01	-3.824D 03	-5 704D 00	6.028D 03	-7 137D-01	-2 082D 05	3.551D 01
8 299D 03	-2.124D 05	2.577D 01	-4.559D 03	-6 170D 00	7 005D 03	-8.208D-01	-2.268D 05	3.674D 01
8 642D 03	-2.325D 05	2.759D 01	-5.421D 03	-6 653D 00	8.124D 03	-9.509D-01	-2.468D 05	3.810D 01
9.000D 03	-2 542D 05	2.959D 01	-6.430D 03	-7.154D 00	9 405D 03	-1.108D 00	-2.686D 05	3.961D 01

(Page 1 of 3)

Sample 1 - Tabulation of Bearing Data (continued)

*****************SYNCH BRG CHARACTERISTICS*****************   STABILITY   PARAMETERS

6 00000 03	-1 1337D 05	6 3400D-02	-9 8650D 04	4 9455D-02	UNCONDITIONALLY STABLE
6 2483D 03	-1 2384D 05	8 1392D-02	-1 0918D 05	4 8717D-02	UNCONDITIONALLY STABLE
6 5068D 03	-1 .3520D 05	7 9697D-02	-1 2061D 05	4 8142D-02	UNCONDITIONALLY STABLE
6 7761D 03	-1 4752D 05	7.8316D-02	-1 3300D 05	4 7697D-02	UNCONDITIONALLY STABLE
7 0565D 03	-1 6087D 05	7 7252D-02	-1 4645D 05	4 7351D-02	UNCONDITIONALLY STABLE
7 3485D 03	-1 7535D 05	7.6513D-02	-1 6103D 05	4 7078D-02	UNCONDITIONALLY STABLE
7.6525D 03	-1 9104D 05	7.6107D-02	-1 7686D 05	4 6851D-02	UNCONDITIONALLY STABLE
7 9692D 03	-2 0806D 05	7 6041D-02	-1.9401D 05	4 6646D-02	UNCONDITIONALLY STABLE
8 2990D 03	-2 2650D 05	7.6323D-02	-2 1262D 05	4 6443D-02	UNCONDITIONALLY STABLE
8 6424D 03	-2 4649D 05	7 6953D-02	-2 3278D 05	4 6229D-02	UNCONDITIONALLY STABLE
9 00000 03	-2 6816D 05	7 7926D-02	-2 5463D 05	4 5999D-02	UNCONDITIONALLY STABLE

LOAD PARAMETER IS ADJUSTED FOR L/D = 0 6667

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)	Q-LOST(GPM)
9 00000 03	2.5298D-04	7.4494D 01	1 9309D-03	1 1283D-01	4.2402D-02
9 2627D 03	2 4718D-04	7.4860D 01	2.0459D-03	1 1563D-01	4.2638D-02
9 5330D 03	2.4145D-04	7.5219D 01	2 1679D-03	1.1851D-01	4.2864D-02
9 8112D 03	2.3580D-04	7.5570D 01	2 2973D-03	1 2146D-01	4.3081D-02
1 0098D 04	2.3022D-04	7.5914D 01	2 4345D-03	1 2449D-01	4.3288D-02
1 0392D 04	2 2472D-04	7 6249D 01	2 5801D-03	1 2760D-01	4 3486D-02
1 0696D 04	2.1930D-04	7 6575D 01	2.7346D-03	1 3079D-01	4.3674D-02
1 1008D 04	2 1396D-04	7.6893D 01	2 8985D-03	1 3407D-01	4.3853D-02
1 1329D 04	2.0870D-04	7 7202D 01	3 0723D-03	1 3743D-01	4.4022D-02
1 1660D 04	2.0352D-04	7 7502D 01	3 2567D-03	1 4088D-01	4.4183D-02
1 2000D 04	1.9843D-04	7.7793D 01	3 4524D-03	1 4442D-01	4.4334D-02

Sample 1 - Tabulation of Bearing Data (continued)

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0 6667

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
9.000D 03	-2.542D 05	2.959D 01	-6.430D 03	-7.154D 00	9.405D 03	-1.108D 00	-2.686D 05	3.961D 01
9.263D 03	-2.708D 05	3.111D 01	-7.247D 03	-7.517D 00	1.042D 04	-1.239D 00	-2.851D 05	4.077D 01
9.533D 03	-2.883D 05	3.273D 01	-8.158D 03	-7.886D 00	1.154D 04	-1.388D 00	-3.026D 05	4.202D 01
9.811D 03	-3.068D 05	3.445D 01	-9.172D 03	-8.260D 00	1.277D 04	-1.556D 00	-3.211D 05	4.335D 01
1.010D 04	-3.264D 05	3.628D 01	-1.030D 04	-8.638D 00	1.411D 04	-1.746D 00	-3.407D 05	4.477D 01
1.039D 04	-3.471D 05	3.822D 01	-1.155D 04	-9.017D 00	1.558D 04	-1.961D 00	-3.615D 05	4.629D 01
1.070D 04	-3.691D 05	4.027D 01	-1.294D 04	-9.396D 00	1.718D 04	-2.202D 00	-3.834D 05	4.792D 01
1.101D 04	-3.923D 05	4.244D 01	-1.448D 04	-9.774D 00	1.894D 04	-2.473D 00	-4.067D 05	4.965D 01
1.133D 04	-4.168D 05	4.474D 01	-1.618D 04	-1.015D 01	2.086D 04	-2.775D 00	-4.313D 05	5.150D 01
1.166D 04	-4.427D 05	4.718D 01	-1.807D 04	-1.052D 01	2.295D 04	-3.111D 00	-4.573D 05	5.347D 01
1.200D 04	-4.702D 05	4.976D 01	-2.015D 04	-1.087D 01	2.523D 04	-3.487D 00	-4.848D 05	5.556D 01

***************SYNCH BRG CHARACTERISTICS***************

RPM	MIN STIFF	MIN DAMP	[illegible] STIFF	[illegible] DAMP	STABILITY PARAMETERS
9.0000D 03	-2.6816D 05	7.7926D-02	-2.5463D 05	4.5999D-02	UNCONDITIONALLY STABLE
9.2627D 03	-2.8464D 05	7.8817D-02	-2.7122D 05	4.5829D-02	UNCONDITIONALLY STABLE
9.5330D 03	-3.0209D 05	7.9867D-02	-2.8876D 05	4.5656D-02	UNCONDITIONALLY STABLE
9.8112D 03	-3.2057D 05	8.1067D-02	-3.0733D 05	4.5488D-02	UNCONDITIONALLY STABLE
1.0098D 04	-3.4014D 05	8.2409D-02	-3.2696D 05	4.5330D-02	UNCONDITIONALLY STABLE
1.0392D 04	-3.6086D 05	8.3885D-02	-3.4773D 05	4.5189D-02	UNCONDITIONALLY STABLE
1.0696D 04	-3.8280D 05	8.5485D-02	-3.6969D 05	4.5070D-02	UNCONDITIONALLY STABLE
1.1008D 04	-4.0601D 05	8.7204D-02	-3.9292D 05	4.4978D-02	UNCONDITIONALLY STABLE
1.1329D 04	-4.3056D 05	8.9036D-02	-4.1750D 05	4.4917D-02	UNCONDITIONALLY STABLE
1.1660D 04	-4.5653D 05	9.0985D-02	-4.4350D 05	4.4891D-02	UNCONDITIONALLY STABLE
1.2000D 04	-4.8399D 05	9.3031D-02	-4.7100D 05	4.4900D-02	UNCONDITIONALLY STABLE

SAMPLE 1

DATA LINES IN RSVP FORMAT

```
-9.863D 04 1.593D 01-1.036D 03-3.021D 00 1.982D 03-3 488D-01-1 134D 05 2 970D 01
-1.092D 05 1.678D 01-1.259D 03-3 342D 00 2 341D 03-3 758D-01-1.239D 05 3 029D 01
-1.206D 05 1.773D 01-1.526D 03-3.683D 00 2 757D 03-4 081D-01-1.352D 05 3 094D 01
-1.330D 05 1.877D 01-1.844D 03-4.044D 00 3 239D 03-4 473D-01-1.476D 05 3 167D 01
-1.464D 05 1.992D 01-2.222D 03-4 427D 00 3 795D 03-4.956D-01-1.609D 05 3 249D 01
-1.609D 05 2.118D 01-2 670D 03-4.832D 00 4.437D 03-5 542D-01-1.754D 05 3 339D 01
-1.767D 05 2.257D 01-3.200D 03-5.258D 00 5.177D 03-6 259D-01-1.912D 05 3 439D 01
-1.938D 05 2.410D 01-3.824D 03-5.704D 00 6.028D 03-7 137D-01-2 082D 05 3 551D 01
-2.124D 05 2.577D 01-4.559D 03-6.170D 00 7.005D 03-8.208D-01-2.268D 05 3 674D 01
-2.325D 05 2.759D 01-5.421D 03-6 653D 00 8.124D 03-9 509D-01-2 468D 05 3 810D 01
-2.542D 05 2.959D 01-6.430D 03-7.154D 00 9.405D 03-1.108D 00-2.686D 05 3 961D 01
-2.542D 05 2.959D 01-6.430D 03-7 154D 00 9.405D 03-1 108D 00-2.686D 05 3 961D 01
-2.708D 05 3.111D 01-7.247D 03-7.517D 00 1.042D 04-1 239D 00-2 851D 05 4 077D 01
-2.883D 05 3.273D 01-8.158D 03-7.886D 00 1 154D 04-1 388D 00-3.026D 05 4.202D 01
-3.068D 05 3.445D 01-9.172D 03-8.260D 00 1.277D 04-1.556D 00-3.211D 05 4 335D 01
-3.264D 05 3.628D 01-1 030D 04-8.638D 00 1 411D 04-1 746D 00-3 407D 05 4.477D 01
-3.471D 05 3.822D 01-1.155D 04-9 017D 00 1.558D 04-1 961D 00-3 615D 05 4 629D 01
-3.691D 05 4.027D 01-1.294D 04-9.396D 00 1.718D 04-2 202D 00-3.834D 05 4.792D 01
-3.923D 05 4.244D 01-1.448D 04-9.774D 00 1.894D 04-2.473D 00-4.067D 05 4.965D 01
-4.168D 05 4.474D 01-1.618D 04-1.015D 01 2.086D 04-2 775D 00-4.313D 05 5 150D 01
-4.427D 05 4.718D 01-1.807D 04-1 052D 01 2.295D 04-3 111D 00-4.573D 05 5 347D 01
-4.702D 05 4.976D 01-2.015D 04-1.087D 01 2 523D 04-3.487D 00-4 848D 05 5 556D 01
```

SAMPLE 2

RECORD OF INTERACTIVE SESSION

```
ENTER DATA TABLE NAME: PJ-05-1
ENTER OUTPUT FILE NAME: OUTPUT

SELECT:   (1) PREPARE DATA FOR RSVP INPUT
          (2) DIMENSIONAL TABLE
          (3) DIMENSIONLESS TABLE
          (4) QUIT
1

SELECT:   (1) SYNCH FREQ, OR
          (2) ASYNCH FREQ?
1
ENTER BEARING LENGTH (IN)
1.0
ENTER BEARING DIAMETER (IN)
1.5
ENTER BEARING CLEARANCE (IN)
0.001
ENTER VISCOSITY (CENTI-POISE)
40.0
ENTER BEARING LOAD (LBS)
750.0
ENTER BEARING COEFS FILE NAME: RSVP
SELECT:   (1) USE DEFAULT L/D =        0.5000
          (2) ADJUST DATA FOR L/D =       0.6667
1

SELECT:   (1) LOAD VECTOR IN VERTICAL PLANE, OR
          (2) INCLINED LOAD VECTOR?
1

SELECT:  (1) RIGID FOUNDATION
         (2) ISOTROPIC FOUNDATION COMPLIANCE, OR
         (3) ANISOTROPIC FOUNDATION COMPLIANCE?
1
ENTER LOWEST SPEED (RPM)
6000.0
ENTER HIGHEST SPEED (RPM)
9000.0
ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)
11
```

(Page 1 of 2)

Sample 2 - Record of Interactive Session (continued)

```
SELECT - (1) ANOTHER SPEED GROUP
         (2) QUIT
1
ENTER LOWEST SPEED (RPM)
9000.0
ENTER HIGHEST SPEED (RPM)
12000.0
ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)
11

SELECT - (1) ANOTHER SPEED GROUP
         (2) QUIT
2
```

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RETRIEVAL FILE NO PJ-05-1
FILE SIZE = 17
L/D = 0.5000
ALFA = 1.1250

SAMPLE 2

TABULATION OF BEARING DATA

L (IN)	DIA (IN)	C (IN)	VISC (CP)	W (LBS)	SPEED RANGE (RPM)	
1.0000	1.5000	0.001000	4.0000D 01	750.00	6000.00 TO 9000.00	11 PTS

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)	Q-LOST(GPM)
6.0000D 03	4.5916D-04	6.1276D 01	8.8661D-04	8.6399D-02	5.1403D-02
6.2483D 03	4.4947D-04	6.1907D 01	9.5796D-04	8.9433D-02	5.2391D-02
6.5068D 03	4.3975D-04	6.2539D 01	1.0353D-03	9.2567D-02	5.3372D-02
6.7761D 03	4.3003D-04	6.3172D 01	1.1191D-03	9.5807D-02	5.4343D-02
7.0565D 03	4.2030D-04	6.3804D 01	1.2099D-03	9.9155D-02	5.5304D-02
7.3485D 03	4.1056D-04	6.4434D 01	1.3084D-03	1.0261D-01	5.6250D-02
7.6525D 03	4.0082D-04	6.5060D 01	1.4152D-03	1.0619D-01	5.7181D-02
7.9692D 03	3.9108D-04	6.5682D 01	1.5312D-03	1.0988D-01	5.8093D-02
8.2990D 03	3.8135D-04	6.6299D 01	1.6571D-03	1.1370D-01	5.8987D-02
8.6424D 03	3.7167D-04	6.6912D 01	1.7938D-03	1.1765D-01	5.9862D-02
9.0000D 03	3.6203D-04	6.7520D 01	1.9422D-03	1.2173D-01	6.0717D-02

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
6.000D 03	1.504D 06	7.746D 03	2.748D 06	2.916D 03	-1.026D 06	2.916D 03	1.528D 06	4.565D 03
6.248D 03	1.469D 06	7.479D 03	2.757D 06	2.794D 03	-1.075D 06	2.794D 03	1.531D 06	4.487D 03
6.507D 03	1.436D 06	7.226D 03	2.767D 06	2.678D 03	-1.125D 06	2.678D 03	1.535D 06	4.412D 03
6.776D 03	1.404D 06	6.987D 03	2.779D 06	2.566D 03	-1.177D 06	2.566D 03	1.538D 06	4.340D 03
7.056D 03	1.373D 06	6.762D 03	2.793D 06	2.459D 03	-1.231D 06	2.459D 03	1.541D 06	4.271D 03
7.348D 03	1.344D 06	6.550D 03	2.809D 06	2.357D 03	-1.286D 06	2.357D 03	1.545D 06	4.204D 03
7.653D 03	1.315D 06	6.350D 03	2.828D 06	2.259D 03	-1.344D 06	2.259D 03	1.548D 06	4.141D 03
7.969D 03	1.288D 06	6.162D 03	2.849D 06	2.166D 03	-1.404D 06	2.166D 03	1.551D 06	4.080D 03
8.299D 03	1.262D 06	5.984D 03	2.873D 06	2.076D 03	-1.466D 06	2.076D 03	1.554D 06	4.021D 03
8.642D 03	1.236D 06	5.817D 03	2.899D 06	1.991D 03	-1.530D 06	1.991D 03	1.557D 06	3.965D 03
9.000D 03	1.212D 06	5.660D 03	2.929D 06	1.909D 03	-1.596D 06	1.909D 03	1.560D 06	3.911D 03

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Sample 2 - Tabulation of Bearing Data

L (IN)	DIA (IN)	C (IN)	VISC (CP)	W (LBS)	SPEED RANGE (RPM)	
1.0000	1.5000	0.001000	4.0000 01	750 00	9000 00 TO 12000.00	11 PTS

**************SYNCH BRG CHARACTERISTICS**************					STABILITY PARAMETERS	
RPM	MIN STIFF	MIN DAMP	MAJ STIFF	MAJ DAMP	CP MASS	F RATIO
6.0000D 03	9.4421D 05	5.9765D-01	2.0876D 06	1.5824D 00	1.0218D 04	5.3047D-01
6.2483D 03	9.5235D 05	6.1143D-01	2 0484D 06	1.6268D 00	1 0232D 04	5.3115D-01
6.5068D 03	9.6058D 05	6.2569D-01	2.0104D 06	1.6733D 00	1 0248D 04	5.3176D-01
6.7761D 03	9.6888D 05	6.4046D-01	1.9734D 06	1.7220D 00	1 0266D 04	5.3229D-01
7.0565D 03	9.7724D 05	6.5577D-01	1.9376D 06	1.7731D 00	1 0287D 04	5.3276D-01
7.3485D 03	9.8566D 05	6.7162D-01	1.9028D 06	1.8267D 00	1 0309D 04	5.3318D-01
7.6525D 03	9.9413D 05	6.8805D-01	1 8691D 06	1.8830D 00	1 0332D 04	5.3356D-01
7.9692D 03	1.0027D 06	7.0505D-01	1 8364D 06	1 9421D 00	1.0355D 04	5.3392D-01
8.2990D 03	1.0112D 06	7.2267D-01	1.8046D 06	2.0042D 00	1 0378D 04	5.3425D-01
8.6424D 03	1 0198D 06	7.4092D-01	1.7739D 06	2.0695D 00	1 0402D 04	5.3456D-01
9.0000D 03	1.0284D 06	7.5986D-01	1.7441D 06	2 1781D 00	1 0425D 04	5 3486D-01

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)	Q-LOST(GPM)
9.0000D 03	3.6203D-04	6.7520D 01	1.9422D-03	1 2173D-01	6 0717D-02
9 2627D 03	3 5523D-04	6.7950D 01	2.0551D-03	1.2471D-01	6.1312D-02
9 5330D 03	3.4847D-04	6.8377D 01	2.1748D-03	1.2777D-01	6 1897D-02
9.8112D 03	3.4175D-04	6.8803D 01	2.3017D-03	1 3090D-01	6.2471D-02
1 0098D 04	3 3507D-04	6.9227D 01	2 4362D-03	1 3411D-01	6.3035D-02
1 0392D 04	3.2844D-04	6.9648D 01	2.5789D-03	1 3739D-01	6 3589D-02
1.0696D 04	3.2186D-04	7.0068D 01	2 7301D-03	1.4077D-01	6 4132D-02
1 1008D 04	3.1534D-04	7.0485D 01	2 8904D-03	1.4422D-01	6 4664D-02
1 1329D 04	3.0888D-04	7.0900D 01	3.0603D-03	1.4777D-01	6.5185D-02
1.1660D 04	3.0248D-04	7.1311D 01	3 2406D-03	1 5140D-01	6 5694D-02
1.2000D 04	2.9614D-04	7.1720D 01	3 4317D-03	1 5513D-01	6 6192D-02

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Sample 2 - Tabulation of Bearing Data (continued)

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
9.000D 03	1.212D 06	5.660D 03	2.929D 06	1.909D 03	-1.596D 06	1.909D 03	1.560D 06	3.911D 03
9.263D 03	1.196D 06	5.555D 03	2.951D 06	1.853D 03	-1.645D 06	1.853D 03	1.562D 06	3.874D 03
9.533D 03	1.179D 06	5.454D 03	2.975D 06	1.798D 03	-1.695D 06	1.798D 03	1.564D 06	3.838D 03
9.811D 03	1.164D 06	5.357D 03	3.001D 06	1.745D 03	-1.747D 06	1.745D 03	1.566D 06	3.803D 03
1.010D 04	1.149D 06	5.264D 03	3.028D 06	1.694D 03	-1.799D 06	1.694D 03	1.568D 06	3.769D 03
1.039D 04	1.134D 06	5.176D 03	3.057D 06	1.645D 03	-1.854D 06	1.645D 03	1.570D 06	3.736D 03
1.070D 04	1.120D 06	5.091D 03	3.088D 06	1.597D 03	-1.909D 06	1.597D 03	1.572D 06	3.703D 03
1.101D 04	1.106D 06	5.010D 03	3.120D 06	1.550D 03	-1.966D 06	1.550D 03	1.574D 06	3.672D 03
1.133D 04	1.092D 06	4.932D 03	3.154D 06	1.505D 03	-2.025D 06	1.505D 03	1.575D 06	3.641D 03
1.166D 04	1.079D 06	4.859D 03	3.190D 06	1.461D 03	-2.085D 06	1.461D 03	1.577D 06	3.611D 03
1.200D 04	1.066D 06	4.788D 03	3.228D 06	1.418D 03	-2.147D 06	1.418D 03	1.579D 06	3.582D 03

***************SYNCH BRG	CHARACTERISTICS	***************			STABILITY	PARAMETERS
RPM	MIN STIFF	MIN DAMP	MAJ STIFF	MAJ DAMP	CP MASS	F RATIO
9.0000D 03	1.0284D 06	7.5986D-01	1.7441D 06	2.1381D 00	1.0425D 04	5.3486D-01
9.2627D 03	1.0344D 06	7.7372D-01	1.7235D 06	2.1889D 00	1.0441D 04	5.3505D-01
9.5330D 03	1.0404D 06	7.8796D-01	1.7033D 06	2.2415D 00	1.0458D 04	5.3524D-01
9.8112D 03	1.0464D 06	8.0257D-01	1.6837D 06	2.2960D 00	1.0473D 04	5.3542D-01
1.0098D 04	1.0524D 06	8.1757D-01	1.6644D 06	2.3525D 00	1.0489D 04	5.3560D-01
1.0392D 04	1.0583D 06	8.3298D-01	1.6456D 06	2.4109D 00	1.0504D 04	5.3578D-01
1.0696D 04	1.0642D 06	8.4879D-01	1.6272D 06	2.4715D 00	1.0518D 04	5.3596D-01
1.1008D 04	1.0700D 06	8.6504D-01	1.6093D 06	2.5342D 00	1.0532D 04	5.3613D-01
1.1329D 04	1.0758D 06	8.8171D-01	1.5917D 06	2.5992D 00	1.0545D 04	5.3632D-01
1.1660D 04	1.0813D 06	8.9890D-01	1.5745D 06	2.6667D 00	1.0559D 04	5.3648D-01
1.2000D 04	1.0872D 06	9.1649D-01	1.5578D 06	2.7364D 00	1.0570D 04	5.3667D-01

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SAMPLE 2

DATA LINES IN RSVP FORMAT

```
1.504D 06 7.746D 03 2.748D 06 2.916D 03-1.026D 06 2.916D 03 1.528D 06 4.565D 03
1.469D 06 7.479D 03 2.757D 06 2.794D 03-1.075D 06 2.794D 03 1.531D 06 4.487D 03
1.436D 06 7.226D 03 2.767D 06 2.678D 03-1.125D 06 2.678D 03 1.535D 06 4.412D 03
1.404D 06 6.987D 03 2.779D 06 2.566D 03-1.177D 06 2.566D 03 1.538D 06 4.340D 03
1.373D 06 6.762D 03 2.793D 06 2.459D 03-1.231D 06 2.459D 03 1.541D 06 4.271D 03
1.344D 06 6.550D 03 2.809D 06 2.357D 03-1.286D 06 2.357D 03 1.545D 06 4.204D 03
1.315D 06 6.350D 03 2.828D 06 2.259D 03-1.344D 06 2.259D 03 1.548D 06 4.141D 03
1.288D 06 6.162D 03 2.849D 06 2.166D 03-1.404D 06 2.166D 03 1.551D 06 4.080D 03
1.262D 06 5.984D 03 2.873D 06 2.076D 03-1.466D 06 2.076D 03 1.554D 06 4.021D 03
1.236D 06 5.817D 03 2.899D 06 1.991D 03-1.530D 06 1.991D 03 1.557D 06 3.965D 03
1.212D 06 5.660D 03 2.929D 06 1.909D 03-1.596D 06 1.909D 03 1.560D 06 3.911D 03
1.212D 06 5.660D 03 2.929D 06 1.909D 03-1.596D 06 1.909D 03 1.560D 06 3.911D 03
1.196D 06 5.555D 03 2.951D 06 1.853D 03-1.645D 06 1.853D 03 1.562D 06 3.874D 03
1.179D 06 5.454D 03 2.975D 06 1.798D 03-1.695D 06 1.798D 03 1.564D 06 3.838D 03
1.164D 06 5.357D 03 3.001D 06 1.745D 03-1.747D 06 1.745D 03 1.566D 06 3.803D 03
1.149D 06 5.264D 03 3.028D 06 1.694D 03-1.799D 06 1.694D 03 1.568D 06 3.769D 03
1.134D 06 5.176D 03 3.057D 06 1.645D 03-1.854D 06 1.645D 03 1.570D 06 3.736D 03
1.120D 06 5.091D 03 3.088D 06 1.597D 03-1.909D 06 1.597D 03 1.572D 06 3.703D 03
1.106D 06 5.010D 03 3.120D 06 1.550D 03-1.966D 06 1.550D 03 1.574D 06 3.672D 03
1.092D 06 4.932D 03 3.154D 06 1.505D 03-2.025D 06 1.505D 03 1.575D 06 3.641D 03
1.079D 06 4.859D 03 3.190D 06 1.461D 03-2.085D 06 1.461D 03 1.577D 06 3.611D 03
1.066D 06 4.788D 03 3.228D 06 1.418D 03-2.147D 06 1.418D 03 1.579D 06 3.582D 03
```

SAMPLE 3

RECORD OF INTERACTIVE SESSION

```
ENTER DATA TABLE NAME: PJ-05-1
ENTER OUTPUT FILE NAME: OUTPUT

SELECT:    (1) PREPARE DATA FOR RSVP INPUT
           (2) DIMENSIONAL TABLE
           (3) DIMENSIONLESS TABLE
           (4) QUIT
1

SELECT:    (1) SYNCH FREQ, OR
           (2) ASYNCH FREQ?
1
ENTER BEARING LENGTH (IN)
1.0
ENTER BEARING DIAMETER (IN)
1.5
ENTER BEARING CLEARANCE (IN)
0.001
ENTER VISCOSITY (CENTI-POISE)
40.0
ENTER BEARING LOAD (LBS)
750.0
ENTER BEARING COEFS FILE NAME: RSVP
SELECT:    (1) USE DEFAULT L/D =      0.5000
           (2) ADJUST DATA FOR L/D =    0.6667
2

SELECT:    (1) LOAD VECTOR IN VERTICAL PLANE, OR
           (2) INCLINED LOAD VECTOR?
1


SELECT:  (1) RIGID FOUNDATION
         (2) ISOTROPIC FOUNDATION COMPLIANCE, OR
         (3) ANISOTROPIC FOUNDATION COMPLIANCE?
1
ENTER LOWEST SPEED (RPM)
6000.0
ENTER HIGHEST SPEED (RPM)
9000.0
ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)
11
```

Sample 3 - Record of Interactive Session (continued)

```
SELECT - (1) ANOTHER SPEED GROUP
         (2) QUIT
1
ENTER LOWEST SPEED (RPM)
9000.0
E[illegible]HEST SPEED (RPM)
1[illegible]
[illegible]ER OF SPEED POINTS (NOT MORE THAN 11)
[illegible]

SELECT - (1) ANOTHER SPEED GROUP
         (2) QUIT
2
```

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SAMPLE 3

TABULATION OF BEARING DATA

RETRIEVAL FILE NO PJ-05-1
FILE SIZE = 17
L/D = 0.5000
ALFA = 1.1250

L (IN)	DIA (IN)	C (IN)	VISC (CP)	W (LBS)	SPEED RANGE (RPM)	
1 0000	1.5000	0.001000	4.0000 01	750.00	6000.00 TO 9000 00	11 PTS

LOAD PARAMETER IS ADJUSTED FOR L/D = 0.6667

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)	Q-LOST(GPM)
6.0000D 03	3.4171D-04	6.8805D 01	8.6080D-04	8 0048D-02	3.8200D-02
6.2483D 03	3.3232D-04	6.9402D 01	9.3257D-04	8.2827D-02	3.8685D-02
6 5068D 03	3.2302D-04	6.9994D 01	1.0105D-03	8.5705D-02	3 9156D-02
6.7761D 03	3 1383D-04	7.0582D 01	1.0951D-03	8 8686D-02	3.9614D-02
7.0565D 03	3.0476D-04	7.1164D 01	1 1871D-03	9 1775D-02	4 0059D-02
7 3485D 03	2.9581D-04	7.1741D 01	1 2869D-03	9 4976D-02	4.0489D-02
7.6525D 03	2.8698D-04	7.2312D 01	1.3953D-03	9 8294D-02	4.0905D-02
7 9692D 03	2.7829D-04	7.2873D 01	1.5130D-03	1 0173D-01	4.1305D-02
8 2990D 03	2 6972D-04	7.3425D 01	1.6410D-03	1.0530D-01	4.1688D-02
8 6424D 03	2.6128D-04	7.3966D 01	1.7799D-03	1.0899D-01	4.2054D-02
9 0000D 03	2 5298D-04	7.4494D 01	1.9309D-03	1 1283D-0	4 2402D-02

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0 6667

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
6.000D 03	1.164D 06	8.760D 03	3.001D 06	2.854D 03	-1 747D 06	2.854D 03	1.566D 06	6.219D 03
6 248D 03	1.142D 06	8.548D 03	3 040D 06	2.737D 03	-1 822D 06	2 737D 03	1 569D 06	6.141D 03
6 507D 03	1.122D 06	8.350D 03	3.082D 06	2 625D 03	-1.899D 06	2 625D 03	1.572D 06	6.066D 03
6.776D 03	1 102D 06	8.163D 03	3.128D 06	2.517D 03	-1 980D 06	2 517D 03	1 574D 06	5 993D 03
7.056D 03	1.084D 06	7.989D 03	3.177D 06	2.414D 03	-2 064D 06	2 414D 03	1 576D 06	5.923D 03
7.348D 03	1.066D 06	7.824D 03	3.230D 06	2.315D 03	-2 150D 06	2 315D 03	1 579D 06	5.856D 03
7.653D 03	1 049D 06	7.671D 03	3 287D 06	2 221D 03	-2 241D 06	2 221D 03	1 581D 06	5 792D 03
7.969D 03	1 032D 06	7 526D 03	3 348D 06	2 131D 03	-2 335D 06	2 131D 03	1 583D 06	5 730D 03
8 299D 03	1 017D 06	7 392D 03	3.413D 06	2 044D 03	-2 432D 06	2 044D 03	1.585D 06	5.671D 03
8.642D 03	1 002D 06	7 265D 03	3 483D 06	1 962D 03	-2 534D 06	1 962D 03	1 587D 06	5.616D 03
9 000D 03	9 887D 05	7.148D 03	3 558D 06	1.884D 03	-2 639D 06	1 884D 03	1 588D 06	5 563D 03

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Sample 3 - Tabulation of Bearing Data (continued)

***************SYNCH BRG CHARACTERISTICS*************** STABILITY PARAMETERS

RPM	MIN STIFF	MIN DAMP	MAJ STIFF	MAJ DAMP	CR MASS	F RATIO
6.0000D 03	1 0465D 06	8.0264D-01	1.6836D 06	2.2963D 00	1.0474D 04	5.3542D-01
6.2483D 03	1.0549D 06	8.2390D-01	1.6566D 06	2.3764D 00	1.0495D 04	5.3568D-01
6.5068D 03	1.0632D 06	8.4597D-01	1.6304D 06	2.4606D 00	1.0516D 04	5.3592D-01
6.7761D 03	1.0714D 06	8.6888D-01	1.6052D 06	2.5492D 00	1.0535D 04	5.3618D-01
7.0565D 03	1.0795D 06	8.9272D-01	1.5806D 06	2.6423D 00	1.0554D 04	5.3641D-01
7.3465D 03	1.0875D 06	9.1742D-01	1.5570D 06	2.7401D 00	1.0571D 04	5.3668D-01
7.6525D 03	1.0953D 06	9.4311D-01	1.5342D 06	2.8427D 00	1 0586D 04	5.3695D-01
7.9692D 03	1.1029D 06	9.6989D-01	1.5123D 06	2.9503D 00	1.0600D 04	5.3722D-01
8.2990D 03	1.1104D 06	9.9786D-01	1.4913D 06	3.0631D 00	1.0614D 04	5.3748D-01
8.6424D 03	1.1177D 06	1.0271D 00	1.4714D 06	3.1813D 00	1.0627D 04	5.3772D-01
9.0000D 03	1.1247D 06	1.0577D 00	1.4524D 06	3.3051D 00	1.0641D 04	5.3794D-01

LOAD PARAMETER IS ADJUSTED FOR L/D = 0.6667

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)	Q-LOST(GPM)
9.0000D 03	2.5298D-04	7.4494D 01	1.9309D-03	1.1283D-01	4.2402D-02
9.2627D 03	2.4718D-04	7.4860D 01	2.0459D-03	1 1563D-01	4.2638D-02
9.5330D 03	2 4145D-04	7.5219D 01	2.1679D-03	1.1851D-01	4.2864D-02
9 8112D 03	2.3580D-04	7.5570D 01	2.2973D-03	1.2146D-01	4.3081D-02
1.0098D 04	2.3022D-04	7.5914D 01	2.4345D-03	1.2449D-01	4.3288D-02
1 0392D 04	2.2472D-04	7.6249D 01	2.5801D-03	1.2760D-01	4.3486D-02
1.0696D 04	2 1930D-04	7.6575D 01	2.7346D-03	1.3079D-01	4.3674D-02
1.1008D 04	2.1396D-04	7.6893D 01	2.8985D-03	1.3407D-01	4.3853D-02
1 1329D 04	2.0870D-04	7.7202D 01	3.0723D-03	1.3743D-01	4.4022D-02
1 1660D 04	2 0352D-04	7.7502D 01	3.2567D-03	1.4088D-01	4.4183D-02
1 2000D 04	1 9843D-04	7.7793D 01	3.4524D-03	1.4442D-01	4.4334D-02

Sample 3 - Tabulation of Bearing Data (continued)

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0.6667

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
9.000D 03	9.887D 05	7.148D 03	3.558D 06	1.884D 03	-2.639D 06	1.884D 03	1.588D 06	5.563D 03
9.263D 03	9.796D 05	7.069D 03	3.614D 06	1.831D 03	-2.717D 06	1.831D 03	1.590D 06	5.528D 03
9.533D 03	9.709D 05	6.994D 03	3.672D 06	1.779D 03	-2.796D 06	1.779D 03	1.591D 06	5.494D 03
9.811D 03	9.626D 05	6.923D 03	3.733D 06	1.729D 03	-2.878D 06	1.729D 03	1.592D 06	5.462D 03
1.010D 04	9.548D 05	6.855D 03	3.797D 06	1.681D 03	-2.962D 06	1.681D 03	1.592D 06	5.431D 03
1.039D 04	9.474D 05	6.790D 03	3.864D 06	1.635D 03	-3.049D 06	1.635D 03	1.593D 06	5.402D 03
1.070D 04	9.404D 05	6.729D 03	3.934D 06	1.590D 03	-3.138D 06	1.590D 03	1.594D 06	5.375D 03
1.101D 04	9.338D 05	6.671D 03	4.006D 06	1.547D 03	-3.230D 06	1.547D 03	1.595D 06	5.349D 03
1.133D 04	9.276D 05	6.616D 03	4.082D 06	1.505D 03	-3.324D 06	1.505D 03	1.596D 06	5.325D 03
1.166D 04	9.218D 05	6.563D 03	4.161D 06	1.465D 03	-3.421D 06	1.465D 03	1.596D 06	5.302D 03
1.200D 04	9.164D 05	6.513D 03	4.243D 06	1.426D 03	-3.521D 06	1.426D 03	1.597D 06	5.280D 03

***************SYNCH BRG CHARACTERISTICS**************					STABILITY	PARAMETERS
RPM	MIN STIFF	MIN DAMP	MAJ STIFF	MAJ DAMP	CR MASS	F RATIO
9.0000D 03	1.1247D 06	1.0577D 00	1.4524D 06	3.3051D 00	1.0641D 04	5.3794D-01
9.2627D 03	1.1296D 06	1.0803D 00	1.4395D 06	3.3963D 00	1.0650D 04	5.3809D-01
9.5330D 03	1.1343D 06	1.1038D 00	1.4271D 06	3.4905D 00	1.0660D 04	5.3822D-01
9.8112D 03	1.1390D 06	1.1280D 00	1.4152D 06	3.5877D 00	1.0669D 04	5.3833D-01
1.0098D 04	1.1435D 06	1.1531D 00	1.4038D 06	3.6880D 00	1.0679D 04	5.3843D-01
1.0392D 04	1.1478D 06	1.1791D 00	1.3929D 06	3.7915D 00	1.0690D 04	5.3851D-01
1.0696D 04	1.1521D 06	1.2061D 00	1.3825D 06	3.8981D 00	1.0700D 04	5.3857D-01
1.1008D 04	1.1562D 06	1.2340D 00	1.3725D 06	4.0082D 00	1.0711D 04	5.3862D-01
1.1329D 04	1.1602D 06	1.2630D 00	1.3630D 06	4.1216D 00	1.0723D 04	5.3864D-01
1.1660D 04	1.1640D 06	1.2929D 00	1.3540D 06	4.2382D 00	1.0733D 04	5.3869D-01
1.2000D 04	1.1677D 06	1.3240D 00	1.3453D 06	4.3587D 00	1.0745D 04	5.3868D-01

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SAMPLE 3

DATA LINES IN RSVP FORMAT

```
1.164D 06 8.760D 03 3.001D 06 2.854D 03-1.747D 06 2.854D 03 1.566D 06 6.219D 03
1.142D 06 8.548D 03 3.040D 06 2.737D 03-1.822D 06 2.737D 03 1.569D 06 6.141D 03
1.122D 06 8.350D 03 3.082D 06 2.625D 03-1.899D 06 2.625D 03 1.572D 06 6.066D 03
1.102D 06 8.163D 03 3.128D 06 2.517D 03-1.980D 06 2.517D 03 1.574D 06 5.993D 03
1.084D 06 7.989D 03 3.177D 06 2.414D 03-2.064D 06 2.414D 03 1.576D 06 5.923D 03
1.066D 06 7.824D 03 3.230D 06 2.315D 03-2.150D 06 2.315D 03 1.579D 06 5.856D 03
1.049D 06 7.671D 03 3.287D 06 2.221D 03-2.241D 06 2.221D 03 1.581D 06 5.792D 03
1.032D 06 7.526D 03 3.348D 06 2.131D 03-2.335D 06 2.131D 03 1.583D 06 5.730D 03
1.017D 06 7.392D 03 3.413D 06 2.044D 03-2.432D 06 2.044D 03 1.585D 06 5.671D 03
1.002D 06 7.265D 03 3.483D 06 1.962D 03-2.534D 06 1.962D 03 1.587D 06 5.616D 03
9.887D 05 7.148D 03 3.558D 06 1.884D 03-2.639D 06 1.884D 03 1.588D 06 5.563D 03
9.887D 05 7.148D 03 3.558D 06 1.884D 03-2.639D 06 1.884D 03 1.588D 06 5.563D 03
9.796D 05 7.069D 03 3.614D 06 1.831D 03-2.717D 06 1.831D 03 1.590D 06 5.528D 03
9.709D 05 6.994D 03 3.672D 06 1.779D 03-2.796D 06 1.779D 03 1.591D 06 5.494D 03
9.626D 05 6.923D 03 3.733D 06 1.729D 03-2.878D 06 1.729D 03 1.592D 06 5.462D 03
9.548D 05 6.855D 03 3.797D 06 1.681D 03-2.962D 06 1.681D 03 1.592D 06 5.431D 03
9.474D 05 6.790D 03 3.864D 06 1.635D 03-3.049D 06 1.635D 03 1.593D 06 5.402D 03
9.404D 05 6.729D 03 3.934D 06 1.590D 03-3.138D 06 1.590D 03 1.594D 06 5.375D 03
9.338D 05 6.671D 03 4.006D 06 1.547D 03-3.230D 06 1.547D 03 1.595D 06 5.349D 03
9.276D 05 6.616D 03 4.082D 06 1.505D 03-3.324D 06 1.505D 03 1.596D 06 5.325D 03
9.218D 05 6.563D 03 4.161D 06 1.465D 03-3.421D 06 1.465D 03 1.596D 06 5.302D 03
9.164D 05 6.513D 03 4.243D 06 1.426D 03-3.521D 06 1.426D 03 1.597D 06 5.280D 03
```

SAMPLE 4

RECORD OF INTERACTIVE SESSION

```
ENTER DATA TABLE NAME: PJ-05-1
ENTER OUTPUT FILE NAME: OUTPUT

SELECT:   (1) PREPARE DATA FOR RSVP INPUT
          (2) DIMENSIONAL TABLE
          (3) DIMENSIONLESS TABLE
          (4) QUIT
1

SELECT:   (1) SYNCH FREQ, OR
          (2) ASYNCH FREQ?
1
ENTER BEARING LENGTH (IN)
1.0
ENTER BEARING DIAMETER (IN)
1.5
ENTER BEARING CLEARANCE (IN)
0.001
ENTER VISCOSITY (CENTI-POISE)
40.0
ENTER BEARING LOAD (LBS)
750.0
ENTER BEARING COEFS FILE NAME: RSVP
SELECT:   (1) USE DEFAULT L/D =     0.5000
          (2) ADJUST DATA FOR L/D =     0.6667
2

SELECT:   (1) LOAD VECTOR IN VERTICAL PLANE, OR
          (2) INCLINED LOAD VECTOR?
2
      ENTER LOAD INCLINATION ANGLE (DEG)?
30.0

SELECT:  (1) RIGID FOUNDATION
         (2) ISOTROPIC FOUNDATION COMPLIANCE, OR
         (3) ANISOTROPIC FOUNDATION COMPLIANCE?
1
ENTER LOWEST SPEED (RPM)
6000.0
ENTER HIGHEST SPEED (RPM)
9000.0
ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)
11

 SELECT - (1) ANOTHER SPEED GROUP
          (2) QUIT
1
ENTER LOWEST SPEED (RPM)
9000.0
ENTER HIGHEST SPEED (RPM)
12000 0
ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)
```

(Page 1 of 2)

Sample 4 - Record of Interactive Session (continued)

```
11
SELECT - (1) ANOTHER SPEED GROUP
         (2) QUIT
1
ENTER LOWEST SPEED (RPM)
12000.0
ENTER HIGHEST SPEED (RPM)
15000.0
ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)
5
SELECT - (1) ANOTHER SPEED GROUP
         (2) QUIT
2
```

(Page 2 of 2)

RETRIEVAL FILE NO PJ-05-1
FILE SIZE = 17
L/D = 0 5000
ALFA = 1 1250

SAMPLE 4

TABULATION OF BEARING DATA

L (IN)	DIA (IN)	C (IN)	VISC (CP)	W (LBS)	SPEED RANGE (RPM)	
1 0000	1.5000	0 001000	4 0000 01	750 00	6000 00 TO 9000 00	11 PTS

LOAD PARAMETER IS ADJUSTED FOR L/D = 0 6667

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)	Q-LOST(GPM)
6 0000D 03	3 4171D-04	6 8805D 01	8.6080D-04	8 0048D-02	3 8200D-02
6 2483D 03	3 3232D-04	6.9402D 01	9 3257D-04	8 2827D-02	3 8685D-02
6 5068D 03	3 2302D-04	6.9994D 01	1 0105D-03	8 5705D-02	3 9156D-02
6 7761D 03	3 1383D-04	7.0582D 01	1 0951D-03	8 8686D-02	3 9614D-02
7 0565D 03	3 0476D-04	7 1164D 01	1 1871D-03	9 1775D-02	4 0059D-02
7 3485D 03	2 9581D-04	7 1741D 01	1 2869D-03	9 4976D-02	4 0489D-02
7 6525D 03	2 8698D-04	7 2312D 01	1.3953D-03	9 8294D-02	4.0905D-02
7 9692D 03	2 7829D-04	7.2873D 01	1 5130D-03	1 0173D-01	4 1305D-02
8 2990D 03	2 6972D-04	7 3425D 01	1.6410D-03	1 0530D-01	4 1688D-02
8 6424D 03	2 6128D-04	7 3966D 01	1 7799D-03	1 0899D-01	4 2054D-02
9.0000D 03	2 5298D-04	7 4494D 01	1 9309D-03	1 1283D-01	4 2402D-02

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0 6667

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
6 000D 03	7 213D 05	5.653D 03	2.513D 06	2 5[illegible]7D 03	-2 235D 06	2 527D 03	2 009D 06	9 326D 03
6 248D 03	7.216D 05	5.576D 03	2.551D 06	2.411D 03	-2.311D 06	2 411D 03	1.990D 06	9 113D 03
6.507D 03	7 222D 05	5 506D 03	2.592D 06	2 301D 03	-2 390D 06	2 301D 03	1 971D 06	8 910D 03
6 776D 03	7.233D 05	5.441D 03	2 636D 06	2 198D 03	-2 471D 06	2 198D 03	1 953D 06	8.716D 03
7.056D 03	7 248D 05	5 382D 03	2 685D 06	2 101D 03	-2 555D 06	2 101D 03	1 935D 06	8 531D 03
7 348D 03	7 266D 05	5.327D 03	2.738D 06	2 010D 03	-2 642D 06	2 010D 03	1 918D 06	8.353D 03
7 653D 03	7 288D 05	5.277D 03	2.795D 06	1 924D 03	-2 773D 06	1 924D 03	1 901D 06	8.185D 03
7 969D 03	7 313D 05	5 232D 03	2.856D 06	1 843D 03	-2 826D 06	1 843D 03	1 884D 06	8 024D 03
8 299D 03	7 341D 05	5.191D 03	2 922D 06	1 767D 03	-2 923D 06	1 767D 03	1 868D 06	7 872D 03
8 642D 03	7 374D 05	5 154D 03	2 993D 06	1 695D 03	-3 024D 06	1 695D 03	1 852D 06	7.727D 03
9 000D 03	7.409D 05	5 120D 03	3 068D 06	1 628D 03	-3 128D 06	1 628D 03	1 836D 06	7 591D 03

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Sample 4 - Tabulation of Bearing Data (continued)

	***************SYNCH BRG CHARACTERISTICS***************				STABILITY	PARAMETERS
RPM	MIN STIFF	MIN DAMP	MAJ STIFF	MAJ DAMP	CR MASS	F RATIO
6.0000D 03	1.0465D 06	8.0264D-01	1.6836D 06	2.2963D 00	1.0474D 04	5 3542D-01
6.2483D 03	1.0549D 06	8.2390D-01	1 6566D 06	2.3764D 00	1.0495D 04	5.3568D-01
6.5068D 03	1.0632D 06	8.4597D-01	1.6304D 06	2.4606D 00	1.0516D 04	5.3592D-01
6.7761D 03	1.0714D 06	8.6888D-01	1.6052D 06	2.5492D 00	1 0535D 04	5.3618D-01
7.0565D 03	1.0795D 06	8.9272D-01	1' 5806D 06	2.6423D 00	1 0554D 04	5.3641D-01
7.3485D 03	1.0875D 06	9.1742D-01	1 5570D 06	2.7401D 00	1.0571D 04	5.3668D-01
7.6525D 03	1.0953D 06	9.4311D-01	1 5342D 06	2.8427D 00	1.0586D 04	5.3695D-01
7.9692D 03	1.1029D 06	9.6989D-01	1.5123D 06	2.9503D 00	1.0600D 04	5.3722D-01
8.2990D 03	1.1104D 06	9.9786D-01	1.4913D 06	3.0631D 00	1.0614D 04	5.3748D-01
8.6424D 03	1.1177D 06	1.0271D 00	1.4714D 06	3.1813D 00	1.0627D 04	5.3772D-01
9.0000D 03	1.1247D 06	1.0577D 00	1.4524D 06	3.3051D 00	1 0641D 04	5 3794D-01

LOAD PARAMETER IS ADJUSTED FOR L/D = 0.6667

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)	Q-LOST(GPM)
9.0000D 03	2.5298D-04	7 4494D 01	1.9309D-03	1 1283D-01	4 2402D-02
9.2627D 03	2.4718D-04	7.4860D 01	2.0459D-03	1 1563D-01	4 2638D-02
9.5330D 03	2.4145D-04	7.5219D 01	2.1679D-03	1 1851D-01	4 2864D-02
9.8112D 03	2.3580D-04	7.5570D 01	2.2973D-03	1 2146D-01	4.3081D-02
1.0098D 04	2.3022D-04	7.5914D 01	2.4345D-03	1.2449D-01	4.3288D-02
1.0392D 04	2.2472D-04	7.6249D 01	2.5801D-03	1 2760D-01	4.3486D-02
1.0696D 04	2.1930D-04	7.6575D 01	2.7346D-03	1 3079D-01	4 3674D-02
1.1008D 04	2 1396D-04	7.6893D 01	2.8985D-03	1 3407D-01	4 3853D-02
1 1329D 04	2 0870D-04	7.7202D 01	3.0723D-03	1 3743D-01	4.4022D-02
1 1660D 04	2.0352D-04	7.7502D 01	3 2567D-03	1 4088D-01	4 4183D-02
1.2000D 04	1.9843D-04	7.7793D 01	3.4524D-03	1 4442D-01	4.4334D-02

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Sample 4 - Tabulation of Bearing Data (continued)

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0 6667

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
9.000D 03	7.409D 05	5.120D 03	3.068D 06	1.628D 03	-3.128D 06	1.628D 03	1.836D 06	7.591D 03
9.263D 03	7.436D 05	5.098D 03	3.125D 06	1.583D 03	-3.205D 06	1.583D 03	1.825D 06	7.498D 03
9.533D 03	7.465D 05	5.070D 03	3.185D 06	1.539D 03	-3.283D 06	1.539D 03	1.815D 06	7.410D 03
9.811D 03	7.495D 05	5.060D 03	3.247D 06	1.497D 03	-3.364D 06	1.497D 03	1.805D 06	7.325D 03
1.010D 04	7.526D 05	5.043D 03	3.312D 06	1.457D 03	-3.447D 06	1.457D 03	1.795D 06	7.243D 03
1.039D 04	7.559D 05	5.027D 03	3.380D 06	1.418D 03	-3.532D 06	1.418D 03	1.785D 06	7.165D 03
1.070D 04	7.593D 05	5.013D 03	3.452D 06	1.381D 03	-3.620D 06	1.381D 03	1.775D 06	7.091D 03
1.101D 04	7.628D 05	5.001D 03	3.526D 06	1.346D 03	-3.710D 06	1.346D 03	1.766D 06	7.019D 03
1.133D 04	7.664D 05	4.989D 03	3.603D 06	1.312D 03	-3.803D 06	1.312D 03	1.757D 06	6.951D 03
1.166D 04	7.700D 05	4.979D 03	3.684D 06	1.279D 03	-3.898D 06	1.279D 03	1.748D 06	6.885D 03
1.200D 04	7.738D 05	4.970D 03	3.768D 06	1.247D 03	-3.996D 06	1.247D 03	1.739D 06	6.823D 03

***************SYNCH BRG CHARACTERISTICS**************					STABILITY	PARAMETERS
RPM	MIN STIFF	MIN DAMP	MAJ STIFF	MAJ DAMP	CR MASS	F RATIO
9.0000D 03	1.1247D 06	1.0577D 00	1.4524D 06	3.3051D 00	1.0641D 04	5.3794D-01
9.2627D 03	1.1296D 06	1.0803D 00	1.4395D 06	3.3963D 00	1.0650D 04	5.3809D-01
9.5330D 03	1.1343D 06	1.1038D 00	1.4271D 06	3.4905D 00	1.0660D 04	5.3822D-01
9.8112D 03	1.1390D 06	1.1280D 00	1.4152D 06	3.5877D 00	1.0669D 04	5.3833D-01
1.0098D 04	1.1435D 06	1.1531D 00	1.4038D 06	3.6880D 00	1.0679D 04	5.3843D-01
1.0392D 04	1.1478D 06	1.1791D 00	1.3929D 06	3.7915D 00	1.0690D 04	5.3851D-01
1.0696D 04	1.1521D 06	1.2061D 00	1.3825D 06	3.8981D 00	1.0700D 04	5.3857D-01
1.1008D 04	1.1562D 06	1.2340D 00	1.3725D 06	4.0082D 00	1.0711D 04	5.3862D-01
1.1329D 04	1.1602D 06	1.2630D 00	1.3630D 06	4.1216D 00	1.0723D 04	5.3864D-01
1.1660D 04	1.1640D 06	1.2929D 00	1.3540D 06	4.2382D 00	1.0733D 04	5.3869D-01
1.2000D 04	1.1677D 06	1.3240D 00	1.3453D 06	4.3587D 00	1.0745D 04	5.3868D-01

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Sample 4 - Tabulation of Bearing Data (continued)

L (IN)	DIA (IN)	C (IN)	VISC (CP)	W (LBS)	SPEED RANGE (RPM)	
1.0000	1 5000	0.001000	4.0000D 01	750 00	12000 00 TO 15000.00	5 PTS

LOAD PARAMETER IS ADJUSTED FOR L/D = 0.6667

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)	Q-LOST(GPM)
1 20000 04	1.98430-04	7.7793D 01	3.4524D-03	1 4442D-01	4.4334D-02
1.2688D 04	1.8882D-04	7.8336D 01	3.8664D-03	1.5156D-01	4.4605D-02
1 3416D 04	1 7957D-04	7 8857D 01	4.3304D-03	1 5909D-01	4.4852D-02
1.4186D 04	1 7070D-04	7.9361D 01	4.8505D-03	1.6703D-01	4.5079D-02
1 5000D 04	1.6220D-04	7 9853D 01	5 4332D-03	1 7542D-01	4 5291D-02

LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR L/D = 0.6667

RPM	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
1 200D 04	7.738D 05	4.970D 03	3.768D 06	1.247D 03	-3.996D 06	1.247D 03	1.739D 06	6.823D 03
1 269D 04	7 811D 05	4.956D 03	3 940D 06	1.189D 03	-4 194D 06	1.189D 03	1.723D 06	6.709D 03
1.342D 04	7.884D 05	4 945D 03	4.126D 06	1.136D 03	-4 404D 06	1 136D 03	1.707D 06	6.604D 03
1 419D 04	7 956D 05	4.937D 03	4.325D 06	1.087D 03	-4 626D 06	1.087D 03	1.693D 06	6.505D 03
1.500D 04	8.024D 05	4.931D 03	4.538D 06	1 043D 03	-4 861D 06	1.043D 03	1.678D 06	6.412D 03

***************SYNCH BRG CHARACTERISTICS*************** STABILITY PARAMETERS

RPM	MIN STIFF	MIN DAMP	MAJ STIFF	MAJ DAMP	CP MASS	F RATIO
1 20000 04	1.1677D 06	1.3240D 00	1.3453D 06	4 3587D 00	1.0745D 04	5.3868D-01
1 2668D 04	1.1746D 06	1.3875D 00	1.3296D 06	4.6032D 00	1 0768D 04	5.3864D-01
1.3416D 04	1.1809D 06	1.4549D 00	1.3150D 06	4.8629D 00	1 0788D 04	5 3862D-01
1.4186D 04	1 1868D 06	1.5264D 00	1.3013D 06	5.1392D 00	1.0804D 04	5.3865D-01
1.5000D 04	1.1922D 06	1.6018D 00	1.2883D 06	5 4330D 00	1 0814D 04	5.3876D-01

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SAMPLE 4

DATA LINES IN RSVP FORMAT

```
7.213D 05 5.653D 03 2.513D 06 2.527D 03-2.235D 06 2.527D 03 2.009D 06 9.326D 03
7.216D 05 5.576D 03 2.551D 06 2.411D 03-2.311D 06 2.411D 03 1.990D 06 9.113D 03
7.222D 05 5.506D 03 2.592D 06 2.301D 03-2.390D 06 2.301D 03 1.971D 06 8.910D 03
7.233D 05 5.441D 03 2.636D 06 2.198D 03-2.471D 06 2.198D 03 1.953D 06 8.716D 03
7.248D 05 5.382D 03 2.685D 06 2.101D 03-2.555D 06 2.101D 03 1.935D 06 8.531D 03
7.266D 05 5.327D 03 2.738D 06 2.010D 03-2.642D 06 2.010D 03 1.918D 06 8.353D 03
7.288D 05 5.277D 03 2.795D 06 1.924D 03-2.733D 06 1.924D 03 1.901D 06 8.185D 03
7.313D 05 5.232D 03 2.856D 06 1.843D 03-2.826D 06 1.843D 03 1.884D 06 8.024D 03
7.341D 05 5.191D 03 2.922D 06 1.767D 03-2.923D 06 1.767D 03 1.868D 06 7.872D 03
7.374D 05 5.154D 03 2.993D 06 1.695D 03-3.024D 06 1.695D 03 1.852D 06 7.727D 03
7.409D 05 5.120D 03 3.068D 06 1.628D 03-3.128D 06 1.628D 03 1.836D 06 7.591D 03
7.409D 05 5.120D 03 3.068D 06 1.628D 03-3.128D 06 1.628D 03 1.836D 06 7.591D 03
7.436D 05 5.098D 03 3.125D 06 1.583D 03-3.205D 06 1.583D 03 1.825D 06 7.498D 03
7.465D 05 5.078D 03 3.185D 06 1.539D 03-3.283D 06 1.539D 03 1.815D 06 7.410D 03
7.495D 05 5.060D 03 3.247D 06 1.497D 03-3.364D 06 1.497D 03 1.805D 06 7.325D 03
7.526D 05 5.043D 03 3.312D 06 1.457D 03-3.447D 06 1.457D 03 1.795D 06 7.243D 03
7.559D 05 5.027D 03 3.380D 06 1.418D 03-3.532D 06 1.418D 03 1.785D 06 7.165D 03
7.593D 05 5.013D 03 3.452D 06 1.381D 03-3.620D 06 1.381D 03 1.775D 06 7.091D 03
7.628D 05 5.001D 03 3.526D 06 1.346D 03-3.710D 06 1.346D 03 1.766D 06 7.019D 03
7.664D 05 4.989D 03 3.603D 06 1.312D 03-3.803D 06 1.312D 03 1.757D 06 6.951D 03
7.700D 05 4.979D 03 3.684D 06 1.279D 03-3.898D 06 1.279D 03 1.748D 06 6.885D 03
7.738D 05 4.970D 03 3.768D 06 1.247D 03-3.996D 06 1.247D 03 1.739D 06 6.823D 03
7.738D 05 4.970D 03 3.768D 06 1.247D 03-3.996D 06 1.247D 03 1.739D 06 6.823D 03
7.811D 05 4.956D 03 3.940D 06 1.189D 03-4.194D 06 1.189D 03 1.723D 06 6.709D 03
7.884D 05 4.945D 03 4.126D 06 1.136D 03-4.404D 06 1.136D 03 1.707D 06 6.604D 03
7.956D 05 4.937D 03 4.325D 06 1.087D 03-4.626D 06 1.087D 03 1.693D 06 6.505D 03
8.024D 05 4.931D 03 4.538D 06 1.043D 03-4.861D 06 1.043D 03 1.678D 06 6.412D 03
```

SAMPLE 5

RECORD OF INTERACTIVE SESSION

```
ENTER DATA TABLE NAME: PJ-05-1
ENTER OUTPUT FILE NAME: OUTPUT

SELECT:   (1) PREPARE DATA FOR RSVP INPUT
          (2) DIMENSIONAL TABLE
          (3) DIMENSIONLESS TABLE
          (4) QUIT
1

SELECT:   (1) SYNCH FREQ, OR
          (2) ASYNCH FREQ?
2
      ENTER NUMBER OF FREQ GROUPS?
2
ENTER BEARING LENGTH (IN)
1 0
ENTER BEARING DIAMETER (IN)
2.0
ENTER BEARING CLEARANCE (IN)
0.001
ENTER VISCOSITY (CENTI-POISE)
40.0
ENTER BEARING LOAD (LBS)
800.0
ENTER BEARING COEFS FILE NAME: RSVP

SELECT:   (1) LOAD VECTOR IN VERTICAL PLANE, OR
          (2) INCLINED LOAD VECTOR?
1

SELECT:  (1) RIGID FOUNDATION
         (2) ISOTROPIC FOUNDATION COMPLIANCE, OR
         (3) ANISOTROPIC FOUNDATION COMPLIANCE?
1
ENTER LOWEST SPEED (RPM)
7500.0
ENTER HIGHEST SPEED (RPM)
7500.0
ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)
1
      ENTER FREQ DATA (HZ) FOR FREQ GROUP    1 AT   7.5000D 03 RPM
            LOWEST FREQ?
25 0
            HIGHEST FREQ?
50.0
            NUMBER OF FREQ POINTS?
11
      ENTER FREQ DATA (HZ) FOR FREQ GROUP    2 AT   7.5000D 03 RPM
            LOWEST FREQ?
50.0
            HIGHEST FREQ?
100.0

            LOWEST FREQ?
5. 0
            HIGHEST FREQ?
100 0
            NUMBER OF FREQ POINTS?
11

  SELECT - (1) ANOTHER SPEED GROUP
           (2) QUIT
2
```

RETRIEVAL FILE NO PJ-05-1
FILE SIZE = 17
L/D = 0.5000
ALFA = 1.1250

SAMPLE 5

TABULATION OF BEARING DATA

L (IN)	DIA (IN)	C (IN)	VISC (CP)	W (LBS)	SPEED RANGE (RPM)	
1.0000	2.0000	0.001000	4.0000D 01	800.00	7500.00 TO 7500.00	1 PTS

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)	Q-LOST(GPM)
7.50000D 03	2.2845D-04	7.6022D 01	3.1841D-03	1.2313D-01	4.2540D-02

RPM = 7.500D 03

FREQ	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
5.000D 01	1.016D 06	9.905D 03	4.073D 06	2.415D 03	-3.189D 06	2.415D 03	1.699D 06	7.859D 03

ASYNCHRONOUS BEARING CHARACTERISTICS

	**************MINOR	MODE**************			**************MAJOR	MODE**************		
FREQUENCY	STIFFNESS	CR DAMP	ELLIPTIC	ORIENT	STIFFNESS	CR DAMP	ELLIPTIC	ORIENT
5.000D 01	1.296D 06	-3.438D-01	8.879D-01	1.428D 02	1.419D 06	2.281D 00	-6.904D-01	2.786D 01
5.359D 01	1.292D 06	-2.728D-01	8.766D-01	1.406D 02	1.423D 06	2.349D 00	-6.797D-01	2.813D 01
5.743D 01	1.288D 06	-1.965D-01	8.642D-01	1.386D 02	1.427D 06	2.423D 00	-6.684D-01	2.839D 01
6.156D 01	1.283D 06	-1.145D-01	8.506D-01	1.369D 02	1.432D 06	2.502D 00	-6.565D-01	2.864D 01
6.598D 01	1.278D 06	-2.655D-02	8.359D-01	1.355D 02	1.437D 06	2.586D 00	-6.441D-01	2.890D 01
7.071D 01	1.273D 06	6.792D-02	8.202D-01	1.342D 02	1.442D 06	2.677D 00	-6.311D-01	2.914D 01
7.579D 01	1.267D 06	1.694D-01	8.035D-01	1.331D 02	1.447D 06	2.774D 00	-6.175D-01	2.939D 01
8.123D 01	1.262D 06	2.783D-01	7.859D-01	1.321D 02	1.453D 06	2.878D 00	-6.034D-01	2.962D 01
8.706D 01	1.256D 06	3.953D-01	7.674D-01	1.312D 02	1.459D 06	2.989D 00	-5.887D-01	2.986D 01
9.330D 01	1.250D 06	5.210D-01	7.481D-01	1.304D 02	1.465D 06	3.109D 00	-5.735D-01	3.008D 01
1.000D 02	1.243D 06	6.559D-01	7.281D-01	1.297D 02	1.472D 06	3.238D 00	-5.578D-01	3.030D 01

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Sample 5 - Tabulation of Bearing Data (continued)

RPM = 7.500D 03

FREQ	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
2.500D 01	1.016D 06	9.905D 03	4.073D 06	2 415D 03	-3.189D 06	2.415D 03	1.699D 06	7 859D 03

ASYNCHRONOUS BEARING CHARACTERISTICS

	*************MINOR MODE*************				*************MAJOR MODE*************			
FREQUENCY	STIFFNESS	CR DAMP	ELLIPTIC	ORIENT	STIFFNESS	CR DAMP	ELLIPTIC	ORIENT
2.500D 01	1.326D 06	-8.356D-01	9.246D-01	1.760D 02	1.389D 06	1.803D 00	-7.703D-01	2.518D 01
2.679D 01	1.324D 06	-8.005D-01	9.262D-01	1.731D 02	1.391D 06	1.837D 00	-7.643D-01	2.544D 01
2.872D 01	1.322D 06	-7.628D-01	9.272D-01	1.698D 02	1.393D 06	1.874D 00	-7.579D-01	2.571D 01
3.078D 01	1.319D 06	-7.224D-01	9.271D-01	1.662D 02	1.396D 06	1.913D 00	-7.511D-01	2.598D 01
3.299D 01	1.316D 06	-6.791D-01	9.258D-01	1 625D 02	1.398D 06	1.956D 00	-7.439D-01	2.625D 01
3.536D 01	1.314D 06	-6.326D-01	9.232D-01	1.587D 02	1.401D 06	2.001D 00	-7.362D-01	2 652D 01
3.789D 01	1.310D 06	-5.827D-01	9.192D-01	1.550D 02	1.404D 06	2.050D 00	-7.281D-01	2 679D 01
4.061D 01	1.307D 06	-5.292D-01	9.136D-01	1.515D 02	1.408D 06	2.102D 00	-7.194D-01	2.706D 01
4.353D 01	1.304D 06	-4.717D-01	9.064D-01	1.483D 02	1.411D 06	2.157D 00	-7.103D-01	2.733D 01
4.665D 01	1.300D 06	-4.100D-01	8.979D-01	1.454D 02	1.415D 06	2.217D 00	-7 006D-01	2.760D 01
5.000D 01	1.296D 06	-3.438D-01	8.879D-01	1 428D 02	1 419D 06	2.281D 00	-6.904D-01	2.786D 01

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SAMPLE 5

DATA LINES IN RSVP FORMAT

```
1.016D 06 9.905D 03 4.073D 06 2.415D 03-3.189D 06 2.415D 03 1.699D 06 7.859D 03
1.016D 06 9.905D 03 4.073D 06 2.415D 03-3 189D 06 2.415D 03 1.699D 06 7.859D 03
```

SAMPLE 6

RECORD OF INTERACTIVE SESSION

```
ENTER DATA TABLE NAME   P.-05-10
ENTER OUTPUT FILE NAME? OUTPUT

SELECT:    (1) PREPARE DATA FOR RSVP INPUT
           (2) DIMENSIONAL TABLE
           (3) DIMENSIONLESS TABLE
           (4) QUIT
1

SELECT:    (1) SYNCH FREQ, OR
           (2) ASYNCH FREQ?
2
     ENTER NUMBER OF FREQ GROUPS?
2
ENTER BEARING LENGTH (IN)
1.0
ENTER BEARING DIAMETER (IN)
2.0
ENTER BEARING CLEARANCE (IN)
0.001
ENTER VISCOSITY (CENTI-POISE)
40.0
ENTER BEARING LOAD (LBS)
800.0
ENTER BEARING COEFS FILE NAME. RSVP

SELECT:    (1) LOAD VECTOR IN VERTICAL PLANE, OR
           (2) INCLINED LOAD VECTOR?
1

SELECT:  (1) RIGID FOUNDATION
         (2) ISOTROPIC FOUNDATION COMPLIANCE  OR
         (3) ANISOTROPIC FOUNDATION COMPLIANCE?
2

SELECT:  (1) RADIAL BEARING, OR
         (2) ANGULAR BEARING?
1
     ENTER PEDESTAL WEIGHT (LB)?
0.0
     ENTER PEDESTAL STIFFNESS IN VERTICAL PLANE?
     (LB/IN) FOR RADIAL BRG, OR (IN-LB/RAD) FOR ANG BR
1.0D+05
     ENTER PEDESTAL DAMPING IN VERTICAL PLANE?
     (LB-SEC/IN) FOR RAD BRG, OR (IN-LB-SEC/RAD) FOR ANG BRG
0.0
```

Sample 6 - Record of Interactive Session (continued)

```
ENTER LOWEST SPEED (RPM)
7500 0
ENTER HIGHEST SPEED (RPM)
7500 0
ENTER NUMBER OF SPEED POINTS (NOT MORE THAN 11)

        ENTER FREQ DATA (HZ) FOR FREQ GROUP     1 AT  7 5000 03 RPM
              LOWEST FREQ?
10 0
              HIGHEST FREQ?
50 0
              NUMBER OF FREQ POINTS?
11
        ENTER FREQ DATA (HZ) FOR FREQ GROUP     2 AT  7 5000 03 RPM
              LOWEST FREQ?
50 0
              HIGHEST FREQ?
100 0
              NUMBER OF FREQ POINTS?
11

 SELECT - (1) ANOTHER SPEED GROUP
          (2) QUIT
2
```

SAMPLE 6

TABULATION OF BEARING DATA

RETRIEVAL FILE NO PJ-05-1
FILE SIZE = 17
L/D = 0.5000
ALFA = 1.1250

L (IN)	DIA (IN)	C (IN)	VISC (CP)	W (LBS)	SPEED RANGE (RPM)	
1.0000	2.0000	0.001600	4.9000 01	300.00	7500.00 TO 7500.00	1 PTS

RPM	ECC(IN)	ATT ANGLE	FRICT(HP)	Q-REQ(GPM)	Q-LOST(GPM)
7.5000 03	2.2845D-04	7.6022D 01	3.1841D-03	1.2313D-01	4.2540D-02

RPM = 7.5000 03

FREQ	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
1.0000 01	9.9760 04	-3.274D 00	2.749D 03	-2.928D 00	-2.134D 03	5.188D 00	9.921D 04	-5.413D 00
1.1750 01	9.974D 04	-3.269D 00	2.762D 03	-2.971D 00	-2.136D 03	5.231D 00	9.919D 04	-5.420D 00
1.3800 01	9.971D 04	-3.261D 00	2.779D 03	-3.031D 00	-2.139D 03	5.289D 00	9.916D 04	-5.430D 00
1.6210 01	9.968D 04	-3.249D 00	2.803D 03	-3.115D 00	-2.142D 03	5.372D 00	9.912D 04	-5.441D 00
1.984D 01	9.963D 04	-3.230D 00	2.835D 03	-3.235D 00	-2.146D 03	5.487D 00	9.906D 04	-5.454D 00
2.236D 01	9.956D 04	-3.197D 00	2.879D 03	-3.408D 00	-2.148D 03	5.649D 00	9.898D 04	-5.466D 00
2.627D 01	9.946D 04	-3.139D 00	2.938D 03	-3.659D 00	-2.146D 03	5.879D 00	9.886D 04	-5.469D 00
3.085D 01	9.931D 04	-3.031D 00	3.013D 03	-4.029D 00	-2.131D 03	6.205D 00	9.869D 04	-5.443D 00
3.624D 01	9.909D 04	-2.820D 00	3.100D 03	-4.586D 00	-2.081D 03	6.664D 00	9.841D 04	-5.339D 00
4.257D 01	9.775D 04	-2.389D 00	3.173D 03	-5.427D 00	-1.945D 03	7.284D 00	9.797D 04	-5.027D 00
5.000D 01	9.727D 04	-1.485D 00	3.131D 03	-6.643D 00	-1.594D 03	8.003D 00	9.730D 04	-4.194D 00

-SYNCHRONOUS BEARING CHARACTERISTICS

FREQUENCY	**************MINOR MODE*************** STIFFNESS	CR DAMP	ELLIPTIC	ORIENT	**************MAJOR MODE************** STIFFNESS	CR DAMP	ELLIPTIC	ORIENT
1.000D 01	9.972D 04	1.361D-02	8.894D-01	1.933D 02	9.924D 04	1.079D-02	8.217D-01	2.022D 02
1.175D 01	9.965D 04	1.390D-02	8.949D-01	1.926D 02	9.927D 04	1.058D-02	8.157D-01	2.262D 01
1.380D 01	9.857D 04	1.425D-02	9.008D-01	1.902D 02	9.931D 04	1.035D-02	8.086D-01	2.311D 01
[illegible]	[illegible]	[illegible]	9.074D-01	1.878D 02	[illegible] 04	1.009D-02	8.002D-01	2.362D 01
[illegible] 01	9.951D 04	1.519D-02	9.145D-01	1.846D 02	[illegible] 04	9.799D-03	7.905D-01	2.418D 01
2.236D 01	9.912D 04	1.580D-02	9.209D-01	1.801D 02	9.942D 04	9.472D-03	7.792D-01	2.476D 01
2.627D 01	9.786D 04	1.652D-02	9.258D-01	1.748D 02	9.947D 04	9.112D-03	7.661D-01	2.536D 01
3.085D 01	9.748D 04	1.732D-02	9.271D-01	1.661D 02	9.951D 04	[illegible]-03	7.505D-01	2.598D 01
3.624D 01	9.692D 04	[illegible]-02	9.220D-01	1.574D 02	[illegible]	[illegible]-03	7.334D-01	2.661D 01
4.257D 01	[illegible]	[illegible]-02	[illegible]-01	1.497D 02	[illegible]	[illegible]-03	7.173D-01	2.724D 01
[illegible] 01	[illegible] 04	[illegible]-02	[illegible]-01	1.427D 02	[illegible]	[illegible]-03	[illegible]-01	2.786D 01

(Page 1 of 2)

Sample 6 - Tabulation of Bearing Data (continued)

RPM = [illegible] 5000 HZ

FREQ	K-XX	B-XX	K-XY	B-XY	K-YX	B-YX	K-YY	B-YY
5.0000D 01	9.7270D 04	-1.4850D 00	3.[illegible]310D 03	-6.8470D 00	-1.5940D 03	[illegible].0030D 00	9.7300D 04	-4.1940D 00
5.7590D 01	9.7020D 04	-8.4740D-01	3.3160D 03	-7.2590D 00	-1.3190D 03	8.2540D 00	9.6940D 04	-3.5280D 00
5.7430D 01	9.6790D 04	-1.4730D-02	2.7940D 03	-7.8610D 00	-9.3440D 02	9.3660D 00	9.6540D 04	-2.5920D 00
6.1560D 01	9.6610D 04	1.0060D 00	2.4270D 03	-8.3320D 00	-4.7200D 02	9.2190D 00	9.6180D 04	-1.3560D 00
6.5980D 01	9.6560D 04	2.1330D 00	1.9000D 03	-8.5070D 00	1.6300D 02	7.6910D 00	9.5940D 04	1.1990D-01
7.0710D 01	9.6680D 04	3.1900D 00	1.2510D 03	-8.2350D 00	7.7230D 02	6.7220D 00	9.5900D 04	1.6470D 00
7.3790D 01	9.7000D 04	3.9640D 00	5.8020D 02	-7.4250D 00	1.2840D 03	5.4430D 00	9.6110D 04	2.9470D 00
8.1230D 01	9.7450D 04	4.3290D 00	4.2450D 00	-6.3970D 00	1.6110D 03	4.0560D 00	9.6530D 04	3.7980D 00
8.7060D 01	9.7940D 04	4.3040D 00	-4.0580D 02	-5.2040D 00	1.7780D 03	2.8030D 00	9.7060D 04	4.1550D 00
9.3300D 01	9.8390D 04	4.0130D 00	-6.4600D 02	-4.0970D 00	1.7100D 03	1.8110D 00	9.7590D 04	4.1210D 00
1.0000D 02	9.8760D 04	3.5910D 00	-7.5370D 02	-3.1700D 00	1.5880D 03	1.0940D 00	9.8060D 04	3.8500D 00

ASYNCHRONOUS BEARING CHARACTERISTICS

	************MINOR MODE************				************MAJOR MODE************			
FREQUENCY	STIFFNESS	CR DAMP	ELLIPTIC	ORIENT	STIFFNESS	CR DAMP	ELLIPTIC	ORIENT
5.0000D 01	9.4910D 04	-1.7110D-02	8.8790D-01	1.4280D 02	9.9660D 04	7.3480D-03	-6.9040D-01	2.7860D 01
5.3590D 01	9.4280D 04	-1.5350D-02	8.7660D-01	1.4060D 02	9.9680D 04	7.1330D-03	-6.7970D-01	2.0810D 02
5.7430D 01	9.3640D 04	-1.2380D-02	8.6420D-01	1.3860D 02	9.9700D 04	6.9140D-03	-6.6840D-01	2.0840D 02
6.1560D 01	9.3080D 04	-7.8970D-03	8.5060D-01	1.3690D 02	9.9710D 04	6.6930D-03	-6.5650D-01	2.0860D 02
6.5980D 01	9.2760D 04	-1.9220D-03	8.3590D-01	1.3550D 02	9.9730D 04	6.4700D-03	-6.4410D-01	2.0890D 02
7.0710D 01	9.2830D 04	4.8640D-03	8.2020D-01	1.3420D 02	9.9750D 04	6.2440D-03	-6.3110D-01	2.0910D 02
7.5790D 01	9.3340D 04	1.1200D-02	8.0350D-01	1.3310D 02	9.9770D 04	6.0180D-03	-6.1750D-01	2.0940D 02
8.1230D 01	9.4200D 04	1.5880D-02	7.8590D-01	1.3210D 02	9.9790D 04	5.7920D-03	-6.0340D-01	2.0960D 02
8.7060D 01	9.5200D 04	1.8470D-02	7.6740D-01	1.3120D 02	9.9800D 04	5.5650D-03	-5.8870D-01	2.0990D 02
9.3300D 01	9.6160D 04	1.9250D-02	7.4810D-01	1.3040D 02	9.9820D 04	5.3400D-03	-5.7350D-01	2.1010D 02
1.0000D 02	9.6990D 04	1.8830D-02	7.2810D-01	1.2970D 02	9.9830D 04	5.1160D-03	-5.5780D-01	2.1030D 02

(Page 2 of 2)

<u>SAMPLE 6</u>

<u>DATA LINES IN RSVP FORMAT</u>

```
9 876D 04-3 274D 00 2 749D 03-2 928D 00-2.134D 03 5 188D 00 9.921D 04-5.413D 00
9 874D 04-3.269D 00 2 762D 03-2 971D 00-2 136D 03 5 231D 00 9.919D 04-5.420D 00
9 871D 04-3 261D 00 2.779D 03-3 031D 00-2 139D 03 5 289D 00 9 916D 04-5.430D 00
9 868D 04-3.249D 00 2.803D 03-3.115D 00-2 142D 03 5 372D 00 9 912D 04-5.441D 00
9 863D 04-3.230D 00 2 835D 03-3.235D 00-2 146D 03 5 487D 00 9 906D 04-5.454D 00
9.856D 04-3.197D 00 2 879D 03-3.408D 00-2 148D 03 5 649D 00 9 898D 04-5.466D 00
9.846D 04-3.139D 00 2 938D 03-3 658D 00-2 146D 03 5 879D 00 9.886D 04-5.469D 00
9 831D 04-3 031D 00 3 013D 03-4 029D 00-2 131D 03 6 205D 00 9 869D 04-5 443D 00
9 809D 04-2 820D 00 3.100D 03-4 586D 00-2 081D 03 6.664D 00 9 841D 04-5.339D 00
9 775D 04-2 389D 00 3 173D 03-5 427D 00-1 945D 03 7 284D 00 9 797D 04-5.027D 00
9 727D 04-1 485D 00 3 131D 03-6.643D 00-1 594D 03 8 003D 00 9.730D 04-4.194D 00
9 727D 04-1 485D 00 3 131D 03-6 643D 00-1 594D 03 8 003D 00 9 730D 04-4 194D 00
9 702D 04-8 474D-01 3 016D 03-7 259D 00-1 318D 03 8 254D 00 9.694D 04-3.526D 00
9 6.9?D 04-1 4?3D-02 2 794D 03-7 861D 00-9 344D 02 8 366D 00 9.654D 04-2.592D 00
? [illegible] 04 ? [illegible] 00 2 427D 03-8 332D 00-4 320D 02 8 219D 00 9.618D 04-1.356D 00
9 656D 04 ? 137D 00 1 900D 03-8 507D 00 1 630D 02 7 691D 00 9 594D 04 1 199D-01
9 658D 04 ? 190D 00 1 251D 03-8 235D 00 7 723D 02 6 732D 00 9.590D 04 1 647D 00
9 710D 04 3 964D 00 5.802D 02-7 485D 00 1 284D 03 5 443D 00 9 611D 04 2 947D 00
9 745D 04 4 329D 00 4 245D 00-6 397D 00 1 611D 03 4 056D 00 9.653D 04 3.798D 00
9 784D 04 4 304D 00-4 058D 02-5 204D 00 1 738D 03 2 803D 00 9 706D 04 4.155D 00
9 839D 04 4 013D 00-6 460D 02-4 097D 00 1 710D 03 1 811D 00 9.759D 04 4.121D 00
9 876D 04 3 591D 00-7 537D 02-3 170D 00 1 588D 03 1 094D 00 9 806D 04 3 850D 00
```

APPENDIX B

SHORT JOURNAL BEARING

The short bearing analysis of Dubois and Ccvirk [10] makes available explicit analytical expressions for the dynamic perturbation coefficients of circular and journal bearings valid for $L/D \leq 0.25$. Although these results are not precise enough for direct use at larger values of L/D, they still yield valid qualitative trends between the dynamic perturbation coefficients and static operating condition. The essential elements of this important work are summarized here.

Under the assumptions of an isoviscous lubricant and negligible misalignment, the governing equation for the film pressure of a short circular arc bearing is reduced to

$$\frac{\partial p}{\partial z^2} = \frac{6\mu}{h^3} \left(\omega\frac{\partial}{\partial\theta} + 2\frac{\partial}{\partial t}\right)h \qquad \text{(B-1)}$$

The film thickness as illustrated in Fig. B-1, is given by the equation

$$h = C\{1-\varepsilon \cos(\theta-\psi)\} \qquad \text{(B-2)}$$

Separating static equilibrium and dynamic perturbation parts, one can write

$$\varepsilon = \varepsilon_o + \delta\varepsilon; \quad \psi = \psi_o + \delta\psi; \quad h = h_o + \delta h$$

$$h_o = C\{1 - \varepsilon_o \cos(\theta-\psi_o)\} \qquad \text{(B-3)}$$

$$\delta h = -\delta\varepsilon \cos(\theta-\psi_o) - \varepsilon_o\delta\psi \sin(\theta-\psi_o)$$

Integration of Eq. (B-1) with respect to z twice, one finds

$$p = \frac{3\mu}{h^3}\left(z^2 - \frac{L^2}{4}\right)\left(\omega\frac{\partial}{\partial\theta} + 2\frac{\partial}{\partial t}\right)h \qquad \text{(B-4)}$$

Integrating over the full bearing length, one obtains

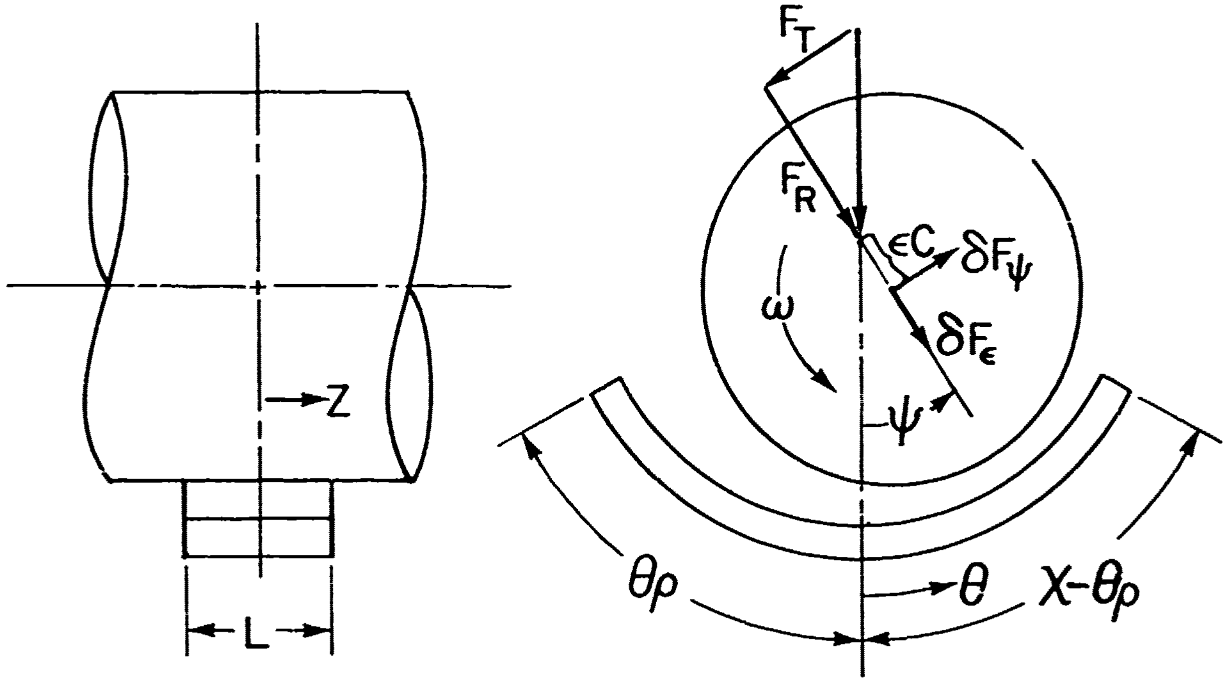

Figure B-1 Description of a Short Circular Arc Bearing

$$q = \int_{-\frac{L}{2}}^{\frac{L}{2}} p dz = -\frac{\mu L^3}{2h^3} (\omega \frac{\partial}{\partial \theta} + 2\frac{\partial}{\partial t})h \quad \text{(B-5)}$$

Substituting Eq. (B-3) into Eq. (B-5) and separate static equilibrium and dynamic perturbation parts, one obtains

$$q = q_o + \delta q \quad \text{(B-6)}$$

$$q_o = -(\frac{\mu \omega L^3}{2C^2}) \frac{\varepsilon_o \sin(\theta-\psi_o)}{\{1 - \varepsilon_o \cos(\theta-\psi_o)\}^3} \quad \text{(B-7)}$$

$$\delta q = -(\frac{\mu \omega L^3}{2C^2}) \{(f_1 + \varepsilon_o f_3)\delta\varepsilon - (f_2 - \varepsilon_o f_4)\varepsilon_o \delta\psi\} + (\frac{\mu L^3}{C^2}) (f_2 \delta\dot{\varepsilon} + f_1 \varepsilon_o \delta\dot{\psi}) \quad \text{(B-8)}$$

$$f_1 = \frac{\sin(\theta-\psi_o)}{\{1 - \varepsilon_o \cos(\theta-\psi_o)\}^3} \; ; \quad f_2 = \frac{\cos(\theta-\psi_o)}{\{1 - \varepsilon_o \cos(\theta-\psi_o)\}^3}$$

$$f_3 = \frac{3\sin(\theta-\psi_o)\cos(\theta-\psi_o)}{\{1-\varepsilon_o \cos(\theta-\psi_o)\}^4} \; ; \quad f_4 = \frac{3\sin^2(\theta-\psi_o)}{\{1 - \varepsilon_o \cos(\theta-\psi_o)\}^4} \quad \text{(B-9)}$$

Global effects are obtained by integrating over projected areas through appropriate limits θ_1 and θ_2. That is

$$(F_R, F_T) = \int_{\theta_1}^{\theta_2} q_o \{\cos(\theta-\psi_o), -\sin(\theta-\psi_o)\} R d\theta \quad \text{(B-10)}$$

$$\frac{\partial(F_\varepsilon, F_\psi)}{\partial e}$$

$$= \left(\frac{\mu\,\omega\,L^3 R}{2C^3}\right) \int_{\theta_1}^{\theta_2} (f_1 + \varepsilon_o\, f_3)\ \{\cos\,(\theta-\psi_o)\ ,\ \ \sin\,(\theta-\psi_o)\}d\theta$$

(B-11)

$$\frac{\partial(F_\varepsilon, F_\psi)}{e_o\,\partial\psi}$$

$$= -\left(\frac{\mu\,\omega\,L^3 R}{2C^3}\right) \int_{\theta_1}^{\theta_2} (f_2 - \varepsilon_o f_4)\ \{\cos\,(\theta-\psi_o),\ \ \sin\,(\theta-\psi_o)\}d\theta \qquad \text{(B-12)}$$

$$\frac{\partial(F_\varepsilon, F_\psi)}{\partial \dot{e}}$$

$$= -\left(\frac{\mu L^3 R}{C^3}\right) \int_{\theta_1}^{\theta_2} f_2\ \{\cos\,(\theta-\psi_o),\ \ \sin\,(\theta-\psi_o)\}d\theta \qquad \text{(B-13)}$$

$$\frac{\partial(F_\varepsilon,\ F_\psi)}{e_o\,\partial\psi}$$

$$= -\ \left(\frac{\mu L^3 R}{C^3}\right) \int_{\theta_1}^{\theta_2} f_1\ \{\cos\,(\theta-\psi_o),\ \ \sin\,(\theta-\psi_o)\}d\theta \qquad \text{(B-14)}$$

Closed form integrals are available:

$$\int \frac{\sin(\theta-\psi_o)\ \cos\,(\theta-\psi_o)\ d\theta}{\{1 - \varepsilon_o\ \cos\,(\theta-\psi_o)\}^3}$$

$$= \frac{1-2\ \varepsilon_o\ \cos\,(\theta-\psi_o)}{2\varepsilon_o^{\,2}\ \{1-\varepsilon_o\ \cos\,(\theta-\psi_o)\}^2} \qquad \text{(B-15)}$$

$$\int \frac{\sin^2(\theta-\psi_o)\, d\theta}{\{1-\varepsilon_o \cos(\theta-\psi_o)\}^3}$$

$$= \frac{\chi - \sin\chi \cos\chi}{2(1-\varepsilon_o^2)^{3/2}} \quad \text{(B-16)}$$

where

$$\chi = 2 \tan^{-1}\left[\sqrt{\frac{1+\varepsilon_o}{1-\varepsilon_o}} \tan\left(\frac{\theta-\psi_o}{2}\right)\right] \quad \text{(B-17)}$$

$$\int f_1 \cos(\theta-\psi_o)\, d\theta = \int f_2 \sin(\theta-\psi_o)\, d\theta$$
$$= -\frac{1}{2}\left[\frac{\cos(\theta-\psi_o)}{1-\varepsilon_o \cos(\theta-\psi_o)}\right]^2 \quad \text{(B-18)}$$

$$\int f_2 \cos(\theta-\psi_o)\, d\theta$$
$$= (1-\varepsilon_o^2)^{-5/2} \{(\frac{1}{2}+\varepsilon_o^2)\chi + \sin\chi(2\varepsilon_o + \frac{1}{2}\cos\chi)\} \quad \text{(B-19)}$$

$$\int f_1 \sin(\theta-\psi_o)\, d\theta$$
$$= \frac{1}{2}(1-\varepsilon_o^2)^{-3/2} \{\chi - \sin\chi \cos\chi\} \quad \text{(B-20)}$$

$$\int f_3 \cos(\theta-\psi_o)\, d\theta = -\left[\frac{\cos(\theta-\psi_o)}{1-\varepsilon_o \cos(\theta-\psi_o)}\right]^3 \quad \text{(B-21)}$$

$$\int f_4 \cos(\theta-\psi_o)\, d\theta = \int f_3 \sin(\theta-\psi_o)\, d\theta$$

$$= (1-\varepsilon_o^2)^{-5/2} \{\frac{3}{2} \varepsilon_o (\chi-\sin\chi \cos\chi) + \sin^3\chi\} \quad \text{(B-22)}$$

$$\int f_4 \sin(\theta-\psi_o)\, d\theta = \frac{\cos^3(\theta-\psi_o) - \frac{1}{\varepsilon_o}}{\{1-\varepsilon_o \cos(\theta-\psi_o)\}^3} \quad \text{(B-23)}$$

Consider now the full cylindrical journal bearing. Accepting the Gümbel cavitation condition and the assumption of film initiation at the maximum gap, then for the static equilibrium problem,

$$\theta_1 = -\pi + \psi_o; \qquad \theta_2 = \psi_o \quad \text{(B-24)}$$

Consequently,

$$F_R = (\frac{\mu\omega L^3 R}{C^2}) \frac{\varepsilon_o^2}{(1-\varepsilon_o^2)^2} \quad ; \quad F_T = (\frac{\mu\omega L^3 R}{C^2}) \frac{\pi\varepsilon_o}{4(1-\varepsilon_o^2)^{3/2}}$$

or

$$\overline{W} = (\pi\frac{L}{D})^2 \frac{\varepsilon_o\sqrt{1-\varepsilon_o^2 + (4\frac{\varepsilon_o}{\pi})^2}}{(1-\varepsilon_o^2)^2} \qquad \psi_o = \tan^{-1}(\frac{\pi\sqrt{1-\varepsilon_o^2}}{4\varepsilon_o})$$

(B-25)

represent the dimensionless static equilibrium operating parameters previously defined in Section 2.

Note that

$$\lim_{\varepsilon_o \to 0} \overline{W} = (\pi \frac{L}{D})^2 \varepsilon_o$$

$$\lim_{\varepsilon_o \to 1} \overline{W} = (\frac{L}{D})^2 \frac{4\pi}{(1-\varepsilon_o^2)^2}$$

Thus

$$\lim_{\overline{W} \to 0} \varepsilon_o = (\pi \frac{L}{D})^{-2} \overline{W}$$

$$\lim_{\overline{W} \to \infty} 1-\varepsilon_o = 2(\frac{L}{D})\sqrt{\frac{\pi}{\overline{W}}}$$

respectively depict near-field and far-field asymptotic behaviors.

For the perturbation problems, θ_1 would remain unchanged but θ_2 would be shifted so the sum $q_o + \delta q$ vanishes. Therefore,

$$\theta_2 = \theta_{20} + \delta\theta_2$$

$$(\frac{\partial q_o}{\partial \theta})_{\theta_{20}} \delta\theta_2 + (\delta q)_{\theta_{20}} = 0$$

$$\delta\theta_2 = - (\frac{\delta q}{\partial q_o / \partial \theta})_{\theta_{20}} \qquad \text{(B-26)}$$

From Eqs. (B-8 and B-9), since at $\theta = \theta_{20} = \psi_o$

$$(f_1, f_3, f_4)_{\theta_{20}} = 0$$

$$f_2 = (1-\varepsilon_o)^{-3} \qquad \text{(B-27)}$$

$\delta\theta_2$ is zero for perturbations with respect to $\delta\varepsilon$ and $\delta\psi$ and needs to be evaluated only for perturbations with respect to $\delta\psi$ and $\delta\varepsilon$. Differentiating Eq. (B-7) with respect to θ, one finds

$$\frac{\partial q_o}{\partial \theta} = -\left(\frac{\mu\omega L^3}{2C^2}\right) \frac{\varepsilon_o}{\{1-\varepsilon_o \cos(\theta-\psi_o)\}^3} \left[\cos(\theta-\psi_o) - \frac{3\varepsilon_o \sin(\theta-\psi_o)}{\{1-\varepsilon_o \cos(\theta-\psi_o)\}}\right]$$

Therefore,

$$\delta\theta_2 = \delta\psi + \frac{2}{\varepsilon_o}\delta\varepsilon \tag{B-28}$$

Accordingly, allowing for the perturbed shift of $_2$, from Eq. (B-10, one finds

$$(F_R, F_T) = -\left(\frac{\mu\omega L^3 R}{2C^2}\right) \left[\left(\frac{\delta\theta_2{}^2}{2}\right), -\left(\frac{\delta\theta_2{}^3}{3}\right)\right] \frac{\varepsilon_o}{(1-\varepsilon_o)^3} \tag{B-29}$$

Clearly, in comparison with terms given by Eqs. (B-11) through (B-14), these are higher order effects and can be omitted from a dynamic perturbation analysis.

Upon substituting Eq. (B-24) for the limits of integration of Eqs. (B-18) through (B-23), Eqs. B-11) through (B-14) become

$$\frac{C^2}{\mu\omega L^3 R}\begin{bmatrix}\delta F_\varepsilon\\ \delta F_\psi\end{bmatrix} = -\left[\bar{Z}_{\varepsilon\psi}\right]\begin{Bmatrix}\delta\varepsilon\\ \varepsilon_o\delta\psi\end{Bmatrix}$$

$$= -\begin{Bmatrix} \left[\dfrac{2\varepsilon_o(1+\varepsilon_o^2)}{(1-\varepsilon_o^2)^3} + \dfrac{\pi(1+2\varepsilon_o^2)}{2(1-\varepsilon_o^2)^{5/2}}\dfrac{d}{\omega dt}\right] & \left[\dfrac{\pi}{4(1-\varepsilon_o^2)^{3/2}} - \dfrac{2\varepsilon_o}{(1-\varepsilon_o^2)^2}\dfrac{d}{\omega dt}\right] \\ \left[\dfrac{-\pi(1+2\varepsilon_o^2)}{4(1-\varepsilon_o^2)^{5/2}} - \dfrac{2\varepsilon_o}{(1-\varepsilon_o^2)^2}\dfrac{d}{\omega dt}\right] & \left[\dfrac{\varepsilon_o}{(1-\varepsilon_o^2)^2} + \dfrac{\pi}{2(1-\varepsilon_o^2)^{3/2}}\dfrac{d}{\omega dt}\right]\end{Bmatrix}\begin{Bmatrix}\delta\varepsilon\\ \varepsilon_o\delta\psi\end{Bmatrix}$$

(B-30)

Using the nomenclature and coordinate system defined in Section 2, one obtains

$$\left\{4\pi\left(\frac{L}{D}\right)^2\right\}^{-1}\left[\bar{K}\right]_{\text{short bearing}}$$

$$= \begin{Bmatrix}\cos\psi_o & \sin\psi_o\\ \sin\psi_o & \cos\psi_o\end{Bmatrix}\begin{Bmatrix}\dfrac{2\varepsilon_o(1+\varepsilon_o)^2}{(1-\varepsilon_o^2)^3} & \dfrac{\pi}{4(1-\varepsilon_o^2)^{3/2}}\\ -\dfrac{\pi(1+2\varepsilon_o^2)}{4(1-\varepsilon_o^2)^{5/2}} & \dfrac{\varepsilon_o}{(1-\varepsilon_o^2)^2}\end{Bmatrix}\begin{Bmatrix}\cos\psi_o & \sin\psi_o\\ -\sin\psi_o & \cos\psi_o\end{Bmatrix}$$

(B-31)

$$\{4\pi \left(\frac{L}{D}\right)^2\}^{-1} \omega \left[\bar{B}\right]$$

$$= \begin{Bmatrix} \cos\psi_o & -\sin\psi_o \\ \sin\psi_o & \cos\psi_o \end{Bmatrix} \begin{Bmatrix} \dfrac{\pi(1+2\varepsilon_o^2)}{2\,(1-\varepsilon_o^2)^{5/2}} & \dfrac{-2\varepsilon_o}{(1-\varepsilon_o^2)^2} \\ \dfrac{-2\varepsilon_o}{(1-\varepsilon_o^2)^2} & \dfrac{\pi}{2\,(1-\varepsilon_o^2)^{3/2}} \end{Bmatrix} \begin{Bmatrix} \cos\psi_o & \sin\psi_o \\ -\sin\psi_o & \cos\psi_o \end{Bmatrix}$$

(B-32)

Numerical results for Eqs. (B-25), (B-) and (B-32) are given in Table B-1. These results can be used to illustrate the natural motion analysis discussed in Section 2.4. At each static equilibrium condition as may be fixed by ε_o of $\bar{W}$, the set of eight (dimensionless) dynamic perturbation coefficients can be used to calculate the stiffness and damping constants ($\bar{k}_o$, $(\nu/\omega)\ \bar{b}_o$) as functions of the frequency ratio (ν/ω). At each (ν/ω) there are two sets of ($\bar{k}_o$, $(\nu/\omega)\ \bar{b}_o$) corresponding to the alternate signs in Eq. (20). One can define

$$\bar{m}_o - \bar{k}_o(\nu/\omega)^{-2}$$

which may be called the consistent (dimensionless) mass of the natural motion. Accordingly, one can further define the consistent dimensionless gravitational acceleration as

$$\bar{g}_o = \bar{W}/\bar{m}_o = (\nu/\omega)^2\ \bar{W}/\bar{k}_o$$

TABLE B-1

STATIC AND DYNAMIC CHARACTERISTICS OF SHORT JOURNAL BEARING

ecc	load	att angle	K-xx	B-xx	K-xy	B-xy	K-yx	B-yx	K-yy	B-yy
0.0000	0.0000E+00	90.0000	0.0000E+00	1.5707E+00	7.8539E-01	0.0000E+00	-7.8539E-01	0.0000E+00	0.0000E+00	1.5707E+00
0.0250	1.9663E-02	88.1762	2.5103E-02	1.5754E+00	7.8840E-01	5.0054E-02	-7.8533E-01	5.0054E-02	5.0052E-02	1.5720E+00
0.0500	3.9497E-02	86.3528	5.0832E-02	1.5895E+00	7.9747E-01	1.0044E-01	-7.8515E-01	1.0044E-01	1.0042E-01	1.5757E+00
0.0750	5.9677E-02	84.5298	7.7831E-02	1.6131E+00	8.1275E-01	1.5149E-01	-7.8483E-01	1.5149E-01	1.5143E-01	1.5819E+00
0.1000	8.0382E-02	82.7077	1.0678E-01	1.6468E+00	8.3446E-01	2.0356E-01	-7.8435E-01	2.0356E-01	2.0343E-01	1.5908E+00
0.1250	1.0180E-01	80.8866	1.3843E-01	1.6909E+00	8.6296E-01	2.5703E-01	-7.8367E-01	2.5703E-01	2.5675E-01	1.6023E+00
0.1500	1.2415E-01	79.0667	1.7360E-01	1.7463E+00	8.9869E-01	3.1228E-01	-7.8276E-01	3.1228E-01	3.1180E-01	1.6166E+00
0.1750	1.4765E-01	77.2482	2.1324E-01	1.8137E+00	9.4226E-01	3.6975E-01	-7.8155E-01	3.6975E-01	3.6898E-01	1.6338E+00
0.2000	1.7254E-01	75.4312	2.5844E-01	1.8945E+00	9.9440E-01	4.2992E-01	-7.7995E-01	4.2992E-01	4.2876E-01	1.6541E+00
0.2250	1.9912E-01	73.6157	3.1049E-01	1.9899E+00	1.0560E+00	4.9333E-01	-7.7789E-01	4.9333E-01	4.9166E-01	1.6779E+00
0.2500	2.2769E-01	71.8017	3.7092E-01	2.1017E+00	1.1282E+00	5.6059E-01	-7.7521E-01	5.6059E-01	5.5825E-01	1.7052E+00
0.2750	2.5863E-01	69.9292	4.4159E-01	2.2321E+00	1.2125E+00	6.3241E-01	-7.7177E-01	6.3241E-01	6.2923E-01	1.7365E+00
0.3000	2.9237E-01	68.1780	5.2477E-01	2.3837E+00	1.3105E+00	7.0958E-01	-7.6736E-01	7.0958E-01	7.0537E-01	1.7721E+00
0.3250	3.2940E-01	66.3679	6.2324E-01	2.5596E+00	1.4243E+00	7.9308E-01	-7.6172E-01	7.9308E-01	7.8757E-01	1.8125E+00
0.3500	3.7032E-01	64.5584	7.4050E-01	2.7639E+00	1.5565E+00	8.8401E-01	-7.5452E-01	8.8401E-01	8.7694E-01	1.8582E+00
0.3750	4.1585E-01	62.7492	8.8091E-01	3.0014E+00	1.7103E+00	9.8371E-01	-7.4534E-01	9.8371E-01	9.7474E-01	1.9099E+00
0.4000	4.6623E-01	60.9396	1.0500E+00	3.2781E+00	1.8896E+00	1.0938E+00	-7.3362E-01	1.0938E+00	1.0825E+00	1.9683E+00
0.4250	5.2432E-01	59.1269	1.2550E+00	3.6017E+00	2.0994E+00	1.2162E+00	-7.1867E-01	1.2162E+00	1.2022E+00	2.0345E+00
0.4500	5.8961E-01	57.3161	1.5052E+00	3.9818E+00	2.3460E+00	1.3534E+00	-6.9956E-01	1.3534E+00	1.3360E+00	2.1094E+00
0.4750	6.6429E-01	55.5003	1.8126E+00	4.4305E+00	2.6374E+00	1.5082E+00	-6.7507E-01	1.5082E+00	1.4868E+00	2.1945E+00
0.5000	7.5038E-01	53.6802	2.1935E+00	4.9635E+00	2.9839E+00	1.6845E+00	-6.4360E-01	1.6845E+00	1.6582E+00	2.2916E+00
0.5250	8.5042E-01	51.8541	2.6696E+00	5.6015E+00	3.3990E+00	1.8869E+00	-6.0298E-01	1.8869E+00	1.8548E+00	2.4025E+00
0.5500	9.6772E-01	50.0203	3.2704E+00	6.3712E+00	3.9004E+00	2.1215E+00	-5.5027E-01	2.1215E+00	2.0822E+00	2.5301E+00
0.5750	1.1065E+00	48.1766	4.0373E+00	7.3089E+00	4.5118E+00	2.3960E+00	-4.8142E-01	2.3960E+00	2.3479E+00	2.6776E+00
0.6000	1.2723E+00	46.3207	5.0284E+00	8.4638E+00	5.2657E+00	2.7208E+00	-3.9078E-01	2.7208E+00	2.6619E+00	2.8492E+00
0.6250	1.4735E+00	44.4493	6.3273E+00	9.9038E+00	6.2069E+00	3.1098E+00	-2.7030E-01	3.1098E+00	3.0375E+00	3.0506E+00
0.6500	1.7192E+00	42.5591	8.0576E+00	1.1725E+01	7.3988E+00	3.5819E+00	-1.0830E-01	3.5819E+00	3.4928E+00	3.2290E+00
0.6750	2.0263E+00	40.6457	1.0405E+01	1.4067E+01	8.9333E+00	4.1635E+00	1.1253E-01	4.1635E+00	4.0530E+00	3.5743E+00
0.7000	2.4140E+00	38.7040	1.3662E+01	1.7136E+01	1.0947E+01	4.8926E+00	4.1861E-01	4.8926E+00	4.7545E+00	3.9203E+00
0.7250	2.9143E+00	36.7276	1.8294E+01	2.1250E+01	1.3649E+01	5.8249E+00	8.5136E-01	5.8249E+00	5.6505E+00	4.3461E+00
0.7500	3.5748E+00	34.7086	2.5084E+01	2.6913E+01	1.7374E+01	7.0452E+00	1.4781E+00	7.0452E+00	6.8221E+00	4.8792E+00
0.7750	4.4717E+00	32.6371	3.5408E+01	3.4962E+01	2.2677E+01	8.6879E+00	2.4136E+00	8.6879E+00	8.3976E+00	5.5641E+00
0.8000	5.7313E+00	30.5001	5.1824E+01	4.6864E+01	3.0527E+01	1.0975E+01	3.8623E+00	1.0975E+01	1.0589E+01	6.4653E+00
0.8250	7.5771E+00	28.2804	7.9439E+01	6.5352E+01	4.2738E+01	1.4301E+01	6.2150E+00	1.4301E+01	1.3773E+01	7.6943E+00
0.8500	1.0434E+01	25.9543	1.2941E+02	9.5074E+01	6.2990E+01	1.9408E+01	1.0279E+01	1.9408E+01	1.8656E+01	9.4471E+00
0.8750	1.5196E+01	23.4872	2.2920E+02	1.5125E+02	9.9598E+01	2.7852E+01	1.7920E+01	2.7852E+01	2.6724E+01	1.2103E+01
0.9000	2.4006E+01	20.8260	4.5841E+02	2.6401E+02	1.7437E+02	4.3351E+01	3.4119E+01	4.3351E+01	4.1516E+01	1.6430E+01
0.9250	4.3132E+01	17.8808	1.1117E+03	5.4159E+02	3.5867E+02	7.6740E+01	7.5479E+01	7.6740E+01	7.3353E+01	2.4758E+01
0.9500	9.8049E+01	14.4747	3.8359E+03	1.4915E+03	9.9024E+02	1.7186E+02	2.2226E+02	1.7186E+02	1.6397E+02	4.4366E+01
0.9750	3.9613E+02	10.1481	3.1348E+04	8.4334E+03	5.6112E+03	6.8404E+02	1.3332E+03	6.840[illegible]E+02	6.5139E+02	1.2243E+02

Gecmetrical characterization of the natural orbit can be described in terms of the ratio of the minor radius to the major radius and the orientation angle of the major axis measured from the static equilibrium load vector. Tables B-2 (a) and B-2 (b) list results of natural orbit analysis performed for the short journal bearing at two static equilibrium conditions. Mode 1 and Mode 2, respectively, correspond to the lower and upper signs of Eq. (20). Symbols used in the headings of these tables are defined as follows:

ecc	static equilibrium eccentricity, ratio, ε_o
freq.	ν/ω
G	dimensionless consistent gravitational acceleration, $g_o/(C\omega^2)$
K	dimensionless stiffness constant, $k_o C^3/(\mu\omega L^3 R)$
N*C	dimensionless damping constant, $\nu b_o C^3/(\mu\omega L^3 R)$
b/a	minor/major radius ratio
orient	orientation angle in degrees of major axis measured from load vector

Table B-2 (a) is for $\varepsilon_o = 0.5$. Negative damping is indicated in the range

$$0 < \frac{\nu}{\omega} < 0.5$$

for Mode 1 which has a positive value of minor/major radius ratio at all frequencies, indicating a forward whirling mode. A lower bound of consistent gravitational acceleration for stable operation is

$$\left(\frac{g_o}{C\omega^2}\right)_{\text{lower bound}} \simeq 0.15$$

The corresponding consistent mass is often called the critical mass for instability. Mode 2 has a positive damping at all frequencies and has a negative minor/major radius ratio, indicating a backward whirl orbit. Table B-2 (b) is for $\varepsilon_o = 0.8$. The damping constant is positive at all frequencies. Thus, by static loading, it is possible to suppress instability.

TABLE B-2

NATURAL ORBIT PARAMETERS OF SHORT JOURNAL BEARING

(a)

ecc	freq	mode 1 G	mode 1 K	mode 1 N*C	mode 1 b/a	mode 1 orient	mode 2 G	mode 2 K	mode 2 N*C	mode 2 b/a	mode 2 orient
0.5000	0.0000	0.0000E+00	1.9259E+00	-1.3597E+00	0.4511	-6.4410	0.0000E+00	1.9259E+00	1.3597E+00	-0.4511	-6.4410
	0.1000	4.2683E-03	1.7580E+00	-1.0240E+00	0.4805	-12.9095	3.5837E-03	2.0938E+00	1.7495E+00	-0.4204	-0.6731
	0.2000	1.8675E-02	1.6071E+00	-7.3577E-01	0.5034	-19.6800	1.3371E-02	2.2446E+00	2.1868E+00	-0.3914	4.1591
	0.3000	4.5607E-02	1.4807E+00	-4.8114E-01	0.5155	-26.3147	2.8482E-02	2.3710E+00	2.6577E+00	-0.3646	8.0507
	0.4000	8.7135E-02	1.3778E+00	-2.4863E-01	0.5157	-32.4167	4.8529E-02	2.4739E+00	3.1507E+00	-0.3397	11.1348
	0.5000	1.4489E-01	1.2947E+00	-3.0917E-02	0.5058	-37.7218	7.3361E-02	2.5571E+00	3.6585E+00	-0.3168	13.5747
	0.6000	2.2009E-01	1.2273E+00	1.7630E-01	0.4890	-42.1473	1.0292E-01	2.6244E+00	4.1768E+00	-0.2958	15.5145
	0.7000	3.1359E-01	1.1725E+00	3.7561E-01	0.4683	-45.7500	1.3723E-01	2.6793E+00	4.7030E+00	-0.2765	17.0685
	0.8000	4.2593E-01	1.1275E+00	5.6865E-01	0.4459	-48.6525	1.7627E-01	2.7243E+00	5.2355E+00	-0.2589	18.3243
	0.9000	5.5746E-01	1.0903E+00	7.5655E-01	0.4232	-50.9881	2.2009E-01	2.7615E+00	5.7731E+00	-0.2429	19.3481
	1.0000	7.0832E-01	1.0593E+00	9.4013E-01	0.4011	-52.8755	2.6871E-01	2.7924E+00	6.3150E+00	-0.2284	20.1898
	1.2000	1.0681E+00	1.0115E+00	1.2967E+00	0.3604	-55.6721	3.8043E-01	2.8402E+00	7.4095E+00	-0.2032	21.4709
	1.4000	1.5050E+00	9.7717E-01	1.6421E+00	0.3250	-57.5863	5.1162E-01	2.8746E+00	8.5151E+00	-0.1822	22.3781
	1.6000	2.0182E+00	9.5181E-01	1.9790E+00	0.2947	-58.9413	6.6239E-01	2.9000E+00	9.6293E+00	-0.1648	23.0385
	1.8000	2.6066E+00	9.3270E-01	2.3091E+00	0.2689	-59.9296	8.3285E-01	2.9191E+00	1.0750E+01	-0.1500	23.5311
	2.0000	3.2695E+00	9.1803E-01	2.6340E+00	0.2468	-60.6698	1.0230E+00	2.9338E+00	1.1876E+01	-0.1375	23.9065
	2.2000	4.0061E+00	9.0656E-01	2.9546E+00	0.2277	-61.2369	1.2331E+00	2.9452E+00	1.3006E+01	-0.1268	24.1983
	2.4000	4.8160E+00	8.9745E-01	3.2717E+00	0.2112	-61.6802	1.4629E+00	2.9544E+00	1.4140E+01	-0.1176	24.4289
	2.6000	5.6988E+00	8.9011E-01	3.5861E+00	0.1968	-62.0326	1.7127E+00	2.9617E+00	1.5277E+01	-0.1095	24.6139
	2.8000	6.6540E+00	8.8412E-01	3.8982E+00	0.1841	-62.3172	1.9823E+00	2.9677E+00	1.6416E+01	-0.1024	24.7644
	3.0000	7.6815E+00	8.7917E-01	4.2083E+00	0.1729	-62.5501	2.2718E+00	2.9726E+00	1.7557E+01	-0.0962	24.8883
	3.2000	8.7810E+00	8.7505E-01	4.5168E+00	0.1629	-62.7429	2.5812E+00	2.9767E+00	1.8699E+01	-0.0906	24.9914
	3.4000	9.9525E+00	8.7158E-01	4.8239E+00	0.1540	-62.9043	2.9106E+00	2.9802E+00	[illegible]	-0.0856	25.0781
	3.6000	1.1195E+01	8.6863E-01	5.1298E+00	0.1459	-63.0407	3.2598E+00	2.9832E+00	[illegible]	-0.0812	25.1516
	3.8000	1.2510E+01	8.6610E-01	5.4344E+00	0.1387	-63.1569	3.6290E+00	2.9857E+00	2.2134E+01	-0.0771	25.2144
	4.0000	1.3897E+01	8.6392E-01	5.7388E+00	0.1321	-63.2567	4.0182E+00	2.9879E+00	2.3281E+01	-0.0734	25.2686

(b)

ecc	freq	mode 1 G	mode 1 K	mode 1 N*C	mode 1 b/a	mode 1 orient	mode 2 G	mode 2 K	mode 2 N*C	mode 2 b/a	mode 2 orient
0.8000	0.0000	0.0000E+00	7.9051E+00	0.0000E+00	0.0000	-55.1978	0.0000E+00	5.4509E+01	0.0000E+00	0.0000	5.0258
	0.1000	7.2785E-03	7.8742E+00	7.2772E-02	0.0321	-55.3687	1.0508E-03	5.4540E+01	5.2601E+00	-0.0154	5.1164
	0.2000	2.9444E-02	7.7860E+00	1.6508E-01	0.0625	-55.8624	4.1966E-03	5.4628E+01	1.0500E+01	-0.0299	5.3758
	0.3000	6.7406E-02	7.6523E+00	2.9161E-01	0.0898	-56.6279	9.4193E-03	5.4761E+01	1.5707E+01	-0.0426	5.7707
	0.4000	1.2246E-01	7.4882E+00	4.5992E-01	0.1132	-57.5963	1.6695E-02	5.4926E+01	2.0871E+01	-0.0532	6.2586
	0.5000	1.9606E-01	7.3080E+00	6.7111E-01	0.1324	-58.6955	2.6001E-02	5.5106E+01	2.5993E+01	-0.0616	6.7981
	0.6000	2.8965E-01	7.1231E+00	9.2196E-01	0.1474	-59.8608	3.7316E-02	5.5291E+01	3.1075E+01	-0.0680	7.3554
	0.7000	4.0456E-01	6.9417E+00	1.2071E+00	0.1586	-61.0397	5.0625E-02	5.5472E+01	3.6123E+01	-0.0725	7.9055
	0.8000	5.4190E-01	6.7688E+00	1.5207E+00	0.1666	-62.1931	6.5918E-02	5.5645E+01	4.1142E+01	-0.0755	8.4323
	0.9000	7.0259E-01	6.6074E+00	1.8570E+00	0.1717	-63.2946	8.3186E-02	5.5806E+01	4.6139E+01	-0.0773	8.9262
	1.0000	8.8735E-01	6.4588E+00	2.2110E+00	0.1746	-64.3279	1.0242E-01	5.5955E+01	5.1118E+01	-0.0782	9.3826
	1.2000	1.3310E+00	6.2003E+00	2.9566E+00	0.1754	-66.1620	1.4681E-01	5.6213E+01	6.1038E+01	-0.0778	10.1795
	1.4000	1.8756E+00	5.9892E+00	3.7330E+00	0.1718	-67.6862	1.9908E-01	5.6425E+01	7.0928E+01	-0.0757	10.8322
	1.6000	2.5217E+00	5.8181E+00	4.5251E+00	0.1658	-68.9331	2.5924E-01	5.6596E+01	8.0802E+01	-0.0727	11.3620
	1.8000	3.2695E+00	5.6795E+00	5.3236E+00	0.1586	-69.9479	3.2730E-01	5.6734E+01	9.0669E+01	-0.0693	11.7915
	2.0000	4.1181E+00	5.5668E+00	6.1236E+00	0.1511	-70.7744	4.0327E-01	5.6847E+01	1.0055E+02	-0.0659	12.1409
	2.2000	5.0669E+00	5.4745E+00	6.9221E+00	0.1435	-71.4505	4.8717E-01	5.6939E+01	1.1040E+02	-0.0625	12.4268
	2.4000	6.1150E+00	5.3985E+00	7.7176E+00	0.1363	-72.0068	5.7900E-01	5.7015E+01	1.2027E+02	-0.0593	12.6623
	2.6000	7.2615E+00	5.3354E+00	8.5095E+00	0.1294	-72.4679	6.7877E-01	5.7078E+01	1.3014E+02	-0.0563	12.8577
	2.8000	8.5058E+00	5.2827E+00	9.2974E+00	0.1230	-72.8530	7.8649E-01	5.7131E+01	1.4002E+02	-0.0534	13.0212
	3.0000	9.8472E+00	5.2382E+00	1.0081E+01	0.1170	-73.1769	9.0215E-01	5.7176E+01	1.4990E+02	-0.0508	13.1589
	3.2000	1.1285E+01	5.2004E+00	1.0861E+01	0.1114	-73.4513	1.0257E+00	5.7213E+01	1.5979E+02	-0.0484	13.2758
	3.4000	1.2819E+01	5.1681E+00	1.1638E+01	0.1063	-73.6855	1.1573E+00	5.7246E+01	1.6968E+02	-0.0461	13.3756
	3.6000	1.4449E+01	5.1403E+00	1.2412E+01	0.1016	-73.8866	1.2968E+00	5.7273E+01	1.7957E+02	-0.0441	13.4615
	3.8000	1.6175E+01	5.1163E+00	1.3183E+01	0.0972	-74.0604	1.4443E+00	5.7297E+01	1.8946E+02	-0.0421	13.5358
	4.0000	1.7996E+01	5.0954E+00	1.3951E+01	0.0931	-74.2115	1.5998E+00	5.7318E+01	1.9936E+02	-0.0404	13.6005

APPENDIX C

THE HALF SOMMERFELD SOLUTION

The classical solution for an infinitely long journal bearing is remembered by the name of the noted mathematician Sommerfeld [11]. The differential equation to be solved is

$$\frac{d}{d\theta}\left[\frac{h^3}{12\mu}\frac{dp}{Rd\theta} - \left(\frac{\omega R}{2}\right)h\right] = 0 \tag{C-1}$$

where $h = C\,(1-\varepsilon\cos\theta) = CH$. Upon integrating once,

$$\frac{dp}{d\theta} = \frac{6\mu\omega R^2}{C^2}\left(\frac{1}{H^2} - \frac{H^*}{H^3}\right) \tag{C-2}$$

H^* is the value of the dimensionless gap at the pressure peak. Integrating again

$$p = \frac{6\mu\omega R^2}{C^2}\left\{\left(\int\frac{d\theta}{H^2} + H^*\int\frac{d\theta}{H^3}\right) + A\right\}$$

$$= \frac{6\mu\omega R^2}{C^2}\left\{(1-\varepsilon^2)^{-3/2}(\chi + \varepsilon\sin\chi)\right.$$

$$\left. + H^*(1-\varepsilon^2)^{-5/2}\left[\left(1 + \frac{\varepsilon^2}{2}\right)\chi + 2\varepsilon\sin\chi + \frac{\varepsilon^2}{4}\sin 2\chi\right] + A\right\}$$

where $\chi = 2\tan^{-1}\left[\sqrt{\frac{1+\varepsilon}{1-\varepsilon}}\left(\tan\frac{\theta}{2}\right)\right]$. A is a second integration constant. Requiring p to be periodic, one finds

$$H^* = \frac{2(1-\varepsilon^2)}{2 + \varepsilon^2} \tag{C-3}$$

A is set to zero since it only represents a pressure level. Thus

$$\frac{2\pi p C^2}{\mu\omega R^2}$$

$$= \frac{-12\pi \sin\chi \; (2-\varepsilon^2 + \varepsilon \cos\chi)}{(1 - \varepsilon^2)^{3/2} \; (2 + \varepsilon^2)}$$

$$= - \frac{12\pi\varepsilon \; (1 + H) \sin\theta}{(2 + \varepsilon^2) \; H^2} \qquad \text{(C-4)}$$

This is seen to be an odd function of θ, being positive in the converging gap but negative in the divergent gap. Gümbel [8] suggested that the lubricant film would not sustain the negative pressure so that Eq. (C-4) is valid only in the convergent half of the circumference. This is known as the half Sommerfeld solution.

Dimensionless force components based on half Sommerfeld solution are

$$\overline{W}_R = \frac{\pi C^2}{\mu\omega R^2} \int_{-\pi}^{0} p \cos\theta \; d\theta$$

$$= \frac{\pi C^2}{\mu\omega R^2} \left\{ p \sin\theta \Big|_{-\pi}^{0} - \int_{-\pi}^{0} \sin\theta \frac{dp}{d\theta} d\theta \right\}$$

$$= -6\pi \int_{-\pi}^{0} \left(\frac{1}{H^2} - \frac{H^*}{H^3}\right) \sin\theta \; d\theta$$

$$= \frac{12\pi\varepsilon^2}{(1-\varepsilon^2)(2+\varepsilon^2)} \qquad \text{(C-5)}$$

$$\overline{W}_T = \frac{\pi C^2}{\mu\omega R^2} \int_{-\pi}^{0} - p \sin\theta \, d\theta$$

$$= - 6\pi \int_{-\pi}^{0} \left(\frac{1}{H^2} - \frac{H^*}{H^3}\right) \cos\theta \, d\theta$$

$$= \frac{6\pi^2 \varepsilon}{\sqrt{1-\varepsilon^2}\,(2+\varepsilon^2)} \tag{C-6}$$

Or, the dimensionless load and the attitude angle are

$$\overline{W} = \frac{2\pi W C^2}{\mu\omega R^2 LD}$$

$$= \sqrt{\overline{W}_R^2 + \overline{W}_T^2}$$

$$= \frac{6\pi^2 \varepsilon}{(1-\varepsilon^2)(2+\varepsilon^2)} \sqrt{1 - \left(1 - \frac{4}{\pi^2}\right) \varepsilon^2} \tag{C-7}$$

$$= \tan^{-1} \left(\frac{\pi\sqrt{1-\varepsilon^2}}{2\varepsilon}\right)$$

APPENDIX D

LISTING OF RETRIEVAL FILES

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6 [illegible]D-01	3 7524D 00	9 [illegible]	2 1625D 03	7 3621D-01	4 3[illegible] 00	1 .[illegible]80D 02
2 2254D 04	7 5961D-01	5 1894D 00	2 4027D 02	-2 4409D 03	7 [illegible]-01	6 1312D 00
2 3050D 02	2 9414D 04	8 0626D-01	7 1526D 00	2 3351D 02	5 7[illegible] 0[illegible]	8 2154D-01
8 5179D 00	5 0737D 02	6 4926D 04	8 5906D-01	1 0237D 01	6 9[illegible]D 02	-6 2594D 04

```
1.0000D 00
0 0000D-01 0 0000D-01 1 6913D 01 7 0147D 01 [illegible]
8 3550D 00 3 0675D-01-5 0610D-0[illegible] 2 2[illegible]2D 00-[illegible]
8.4776D-02 4.5213D 00 7.0235D-01-2 [illegible]D-01 [illegible] 7 [illegible] 00 6 86[illegible]D-01
-1 3910D-01 1 0303D 00 1 2306D 01 [illegible]
6 8024D-01 7.7959D-02 3 6031D 00 3 [illegible] 01 6 [illegible]D-01 [illegible]D-01 5 0402D 00
8 8254D 01 6.9497D-01 4 1731D-01 7 [illegible] 00 [illegible] 6 [illegible]D-01
1 2615D 01 1.5072D 02 7.2355D-01 9 [illegible]D-01 [illegible] 7 42[illegible]D-01
1 3145D 00 2 8359D 01 4.4595D 02 [illegible]
7.8900D-01 2 3743D 00 6 5580D 01 [illegible] 02 [illegible]D-01 [illegible] 00 [illegible]
2 1089D 04 8 3202D-01 3 6695D 00 [illegible] 02-5 [illegible] 4 3[illegible] 00
1.5014D 02 2.3284D 04 8 6488D-01 5 [illegible] 00 [illegible] 04 8 82[illegible]D-01
5 9746D 00 3 4257D 02 4 6872D 04 9 [illegible] 02-4 30[illegible] 04
1 0000D 00
```

APPENDIX E

LISTING OF SOURCE PROGRAM

```
C      NEP PPS DATA
C SYSGON [illegible]        [illegible] FOR [illegible]         1 AUGUST, 1977
       NOLIST
       IMPLICIT REAL*8 (A-H,O-Z)
       INTEGER*2 FN3(16),FN2(16),FN1(16)
       LOGICAL ANS
       DIMENSION X(40 [illegible] ZEP(6,5)
       DIMENSION ZZ(40),[illegible],FRE(51)
       DIMENSION [illegible](51)
       KW1=1
       KW2=2
       KW3=3
       KW=KW1+4
       KR=KW2+4
       KT=KW3+4
       ANS=.FALSE.
       LN=72
       ANS=OPNPSA('ENTER DATA TABLE NAME',21,A$READ+A$SAMF,FN2,LN,KW3)
       IF(ANS) GO TO 1000
       WRITE(1,1001)
1001   FORMAT(29H ERROR IN OPENING DATA TABLE)
       CALL EXIT
C
C       READ IN DATA TABLE INDEX AND [illegible]
C
1000   ANS=RWND$A(KW3)
       READ(KT,1002)(FN2(I),I=1,16),NN,AL9,ALF
1002   FORMAT(20X,16A2/10X,I5/10X,F10.4/10X,F10.4)
       READ(KT,1003)([illegible](I),I=1,NN)
1003   FORMAT(7D11.4)
       NM=NN-1
       P4=DATAN(1.0D-00)
       F2=2.0*P4
       ANS=OPNP$A('ENTER OUTPUT FILE NAME',22,A$WRIT+A$SAMF,FN1,LN,KW1)
       IF(ANS) GO TO 1005
       WRITE(1,1004)
1004   FORMAT(19H ERROR IN OPENING OUTPUT FILE)
       CALL EXIT
1005   WRITE(KW,1006) (FN2(I),I=1,16),NN,ALS,ALF
1006   FORMAT(19H RETRIEVAL FILE NO.,1X,16A2/18H        FILE SIZE =,I5/
      +        18H        L/D        =,F10.4/7X,4HALFA,6X,1H=,F10.4/1H )
       KPAGE=5
C
C      SELECT DATA EXTRACTION MODE
C
101    WRITE(1,1010)
1010   FORMAT(/41HSELECT:    (1) PREPARE DATA FOR RSVP INPUT/10X,
      +21H(2) DIMENSIONAL TABLE/10X,23H(3) DIMENSIONLESS TABLE/10X,
      +8H(4) QUIT)
       READ(1,*)NSEL
       IF (NSEL.EQ.4) CALL EXIT
       WRITE(1,1011)
1011   FORMAT(/28HSELECT:    (1) SYNCH FREQ, OR/10X,
      +16H(2) ASYNCH FREQ?)
```

```
      READ (1,*) NSYN
      IF (NSYN.EQ.2) GO TO 1020
      LFREQ = 1
      FRRAT = 1.0
      GO TO 1030
1020  WRITE(1,1021)
1021  FORMAT(5X,28HENTER NUMBER OF FREQ GROUPS?)
      READ (1,*) LFREQ
1030  GO TO (2100,2100,2200,102),NSEL
      GO TO 101
102   CALL EXIT
C
C     INPUT BEARING DESIGN DATA
C
2100  WRITE(1,2101)
2101  FORMAT(25HENTER BEARING LENGTH (IN))
      READ(1,*) ALEN
      WRITE(1,2102)
2102  FORMAT(27HENTER BEARING DIAMETER (IN))
      READ(1,*)ADIA
      WRITE(1,2103)
2103  FORMAT(28HENTER BEARING CLEARANCE (IN))
      READ(1,*) ACLE
      WRITE(1,2104)
2104  FORMAT(29HENTER VISCOSITY (CENTI-POISE))
      READ(1,*) ACPO
      WRITE(1,2105)
2105  FORMAT(24HENTER BEARING LOAD (LBS))
      READ(1,*) ALOA
      IF(NSEL.EQ.2) GO TO 2106
      ANS=OPNP$A('ENTER BEARING COEFS FILE NAME',29,A$WRIT+A$SAMF,
     +FN3,LN,KW2)
      IF(ANS) GO TO 2106
      WRITE(1,2131)
2131  FORMAT(36H ERROR IN OPENING BEARING COEFS FILE)
      CALL EXIT
C
C    SPEED INDEPENDENT SCALING CONSTANTS
C
2106  COR = 2.0*ACLE/ADIA
      AL8=ALEN/ADIA
      AREA=ALEN*ADIA
      REYN=1.450377?4D-07*ACPO
      ALOAD=REYN*AREA
      BHP=P4/1.182D+07*ALOAD*ADIA*ADIA/ACLE
      ALOAD=ALOAD/COR/COR
      BGPM=AREA*ACLE/2.31D+02
      IF(AL8.EQ.AL9) GO TO 2107
      WRITE(1,1040) AL9,AL8
1040  FORMAT(/31HSELECT:    (1) USE DEFAULT L/D = F10.4/
     +10X,25H(2) ADJUST DATA FOR L/D =,F10.4,1H )
      READ(1,*)NAL
      IF(NAL.EQ.1) GO TO 2107
      WFAC=SHORT(AL9,AL8,ALF)
```

```
      GO TO 2108
2107  WFAC=1.0
      AL8=AL9
2108  ALOAD=ALOAD/WFAC
      BLOAD=ALOAD/60.0
      BSTIF=BLOAD/ACLE
      BDAMP=ALOAD/ACLE/P4/8.0
      BLOA=ALOA/BLOAD
      WRITE(1,2109)
2109  FORMAT(/47HSELECT:    (1) LOAD VECTOR IN VERTICAL PLANE, OR/10X,
     +25H(2) INCLINED LOAD VECTOR?)
      READ (1,*) NVEC
      IF (NVEC.EQ.1) GO TO 2135
      WRITE(1,2132)
2132  FORMAT(5X,35HENTER LOAD INCLINATION ANGLE (DEG)?)
      READ (1,*) WANG
      WRAD = WANG*P2/9.0D+01
      CC = DCOS(WRAD)
      SS = DSIN(WRAD)
      ROT(1) = CC*CC
      ROT(2) = CC*SS
      ROT(3) = SS*SS
2135  CALL BASE(NBA,BMA,BST,BDA)
C
C     SPEED LOOP FOR ARCTAN PARAMETER
C
      NMAX=11
      IF(NSEL.EQ.2) NMAX=51
2110  WRITE(1,2111)
2111  FORMAT(24HENTER LOWEST SPEED (RPM))
      READ(1,*) RPM1
      WRITE(1,2112)
2112  FORMAT(25HENTER HIGHEST SPEED (RPM))
      READ(1,*) RPM2
      WRITE(1,2113) NMAX
2113  FORMAT(43HENTER NUMBER OF SPEED POINTS (NOT MORE THAN,I3,1H))
      READ(1,*) NRPM
      IF(NRPM GT.1) GO TO 2120
      SPRAT=1 0
      GO TO 2130
2120  XP=1 0/(NRPM-1)
      SPRAT=(RPM2/RPM1)**XP
2130  RPM=RPM1
      NTAB=NRPM
      WRITE(KW,2141) ALEN,ADIA,ACLE,ACPO,ALOA,RPM1,RPM2,NRPM
2141  FORMAT(2X,6HL (IN),3X,8HDIA (IN),3X,6HC (IN),3X,9HVISC (CP),2X,
     +7HW (LBS),7X,17HSPEED RANGE (RPM)/2(1X,F8.4,1X),F9 6,1PD11 3,
     +0PF9 2,2X,F9 2,4H TO ,F9.2,I5,4H PTS/1H )
      KPAGE = KPAGE+3
      GO TO 2300
2200  WRITE(1,2201) AL9
2201  FORMAT(/14H DEFAULT L/D =,F10 4/27H ENTER DESIRED L/D OR 0 TO ,
     +14HACCEPT DEFAULT)
      READ(1,*) AL8
```

```
      IF(AL8.EQ.0) GO TO 2202
      WFAC=SHORT(AL9,AL8,ALF)
      GO TO 2203
2202  WFAC=1.0
      AL8 = AL9
2203  WRITE(1,2204)
2204  FORMAT(27HENTER LOWEST LOAD PARAMETER)
      READ(1,*) W1
      WW1=W1*WFAC
      WRITE(1,2205)
2205  FORMAT(28HENTER HIGHEST LOAD PARAMETER)
      READ(1,*) W2
      WW2=W2*WFAC
      WRITE(1,2206)
2206  FORMAT(46HENTER NUMBER OF DATA POINTS (NOT MORE THAN 51))
      READ(, *) NTAB
      IF(NTAB.GT.1) GO TO 2207
      SPRAT = 1.0
      GO TO 2208
2207  XP = 1 0/(NTAB-1)
      SPRAT=(WW2/WW1)**XP
2208  WW=WW1
      NBA = 1
      NVEC = 1
2300  DO 2330 ITAB=1,NTAB
      IF(NSEL.EQ.3) GO TO 2310
      WW=BLOA/RPM
2310  XX(ITAB)=DATAN(WW)/P2
      WO(ITAB)=WW
      IF(NSEL.EQ 3) GO TO 2320
      XO(ITAB)=RPM
      IF (ITAB EQ.NTAB) GO TO 2330
      RPM=RPM*SPRAT
      GO TO 2330
2320  XO(ITAB)=WW/WFAC
      IF (ITAB.EQ.NTAB) GO TO 2330
      WW=WW*SPRAT
2330  CONTINUE
C
C     RETRIEVAL LOOP
C
      WRITE(KW,2331)
2331  FORMAT(////)
      KPAGE=KPAGE+4
      IF(AL8.EQ.AL9) GO TO 2340
      WRITE(KW,2333) AL8
2333  FORMAT(37H LOAD PARAMETER IS ADJUSTED FOR L/D =,F10.4/1H )
      KPAGE=KPAGE+2
2340  IF(NSEL.EQ.3) GO TO 2350
      WRITE(KW,2341)
2341  FORMAT(5X,3HRPM,10X,7HECC(IN),5X,9HATT ANGLE,3X,9HFRICT HP,
     +4X,10HQ-REQ(GPM),3X,11HQ-LOST(GPM))
      GO TO 2360
2350  WRITE(KW,2351)
```

```
2351  FORMAT(5X,4HLOAD,8X,42HECC RATIO    ATT ANGLE    FRICTION     REQ.
     +19H FLOW      LOST FLOW)
2360  KPAGE=KPAGE+1
C
C     STATIC PARAMETERS
C
      DO 2390 L1=1,5
      READ(KR,2371) S1,S2,AA,BB,((ZZ(I),(Y1(K,I),K=1,2)),I=1,NM),ZZ(NM)
2371  FORMAT(7D11.4)
C
C      ARCTAN LOOP
C
      DO 2376 ITAB=1,NTAB
      XXX=XX(ITAB)
      N1=NWHERE(XXX,X,NM)
      NPLACE(ITAB)=N1
      DX=XXX-X(N1)
      Z=SPL(ZZ,Y1,DX,N1)
      WW=W0(ITAB)
      Z1=PEFER(AA,BB,S1,S2,WW)
      YY=Z+Z1
      IF(NSEL.EQ.3) GO TO 2375
      RPM=X0(ITAB)
      GO TO (2372,2375,2373,2374,2374),L1
2372  YY=YY*ACLE
      GO TO 2375
2373  YY=YY*BHP*RPM*RPM
      GO TO 2375
2374  YY=YY*BGPM*RPM
2375  Y0(L1,ITAB)=YY
2376  CONTINUE
2380  CONTINUE
      DO 2400 ITAB=1,NTAB
      WRITE(KW,2381) X0(ITAB),(Y0(L1,ITAB),L1=1,5)
2381  FORMAT(6(1X,1PD12.4))
      KPAGE=KPAGE+1
      IF(KPAGE.LT.61.OR.ITAB.EQ.NTAB) GO TO 2400
      KPAGE=1
      WRITE(KW,2382)
2382  FORMAT(1H1)
      IF(NSEL.EQ.3) GO TO 2390
      WRITE(KW,2341)
      GO TO 2400
2390  WRITE(KW,2351)
2400  CONTINUE
C
C     DYNAMIC PARAMETERS
C
      IF(AL8.EQ.AL9) GO TO 2420
      WRITE(KW,2412) AL8
2412  FORMAT(////48H LOAD AND DYNAMIC COEFFICIENTS ARE ADJUSTED FOR ,
     +5HL/D =,F8.4/1H )
      KPAGE = KPAGE+6
      IF (KPAGE.GT.60) KPAGE = KPAGE-60
```

```
      GO TO 2415
 2420 WRITE(KW,2331)
      KPAGE = KPAGE+4
      IF (KPAGE.GT.60) KPAGE = KPAGE-60
 2415 IF (NSYN.EQ.2) GO TO 2445
      IF (NSEL.EQ.3) GO TO 2430
      WRITE(KW,2421)
 2421 FORMAT(3X,3HRPM,7X,4HK-XX,6X,4HB-XX,6X,4HK-XY,6X,4HB-XY,6X,4HK-YX,
     +6X,4HB-YX,6X,4HK-YY,6X,4HB-YY)
      GO TO 2440
 2430 WRITE(KW,2431)
 2431 FORMAT(2X,4HLOAD,7X,4HK-XX,6X,4HB-XX,6X,4HK-XY,6X,4HB-XY,6X,
     +4HK-YX,6X,4HB-YX,6X,4HK-YY,6X,4HB-YY)
 2440 KPAGE = KPAGE+1
 2445 DO 2480 L1=6,13
      L=L1-5
      L2=L/2
      LL=2*L2
      READ(KT,2371) S1,S2,AA,BB,((ZZ(I),(Y1(I,K),K=1,7),I=1,NM),ZZ(NN)
C
C     ARCTAN LOOP
C
      DO 2480 ITAB=1,NTAB
      XXX=XX(ITAB)
      N1=NPLACE(ITAB)
      DX=XXX-X(N1)
      Z=SPL(ZZ,Y1,DX,N1)
      WW=WO(ITAB)
      Z1=REFER(AA,BB,S1,S2,WW)
      YY=Z*Z1
      IF(NSEL.EQ.3) GO TO 2460
      IF(LL.EQ.L) GO TO 2450
      YY=YY*BSTIF*XO(ITAB)
      GO TO 2470
 2450 YY=YY*BDAMP
      GO TO 2470
 2460 YY=YY/WFAC
 2470 YO(L,ITAB)=YY
      IF(L.NE.6) GO TO 2480
      YY=(YY+YO(4,ITAB))/2.0
      YO(L,ITAB)=YY
      YO(4,ITAB)=YY
 2480 CONTINUE
      DO 2490 ITAB=1,NTAB
      IF (NSYN.EQ.1) INDX = ITAB
      DO 3000 L=1,8
      Y(L,ITAB) = YO(L,ITAB)
 3000 CONTINUE
      IF (NVEC.EQ.2) CALL TILT(Y,ROT,ITAB)
      DO 6030 KFF=1,LFFEQ
      IF (NSYN.EQ.2) GO TO 5010
      NFRE = 1
      IF (NSEL.EQ.3) GO TO 5000
      FF = XO(ITAB)
```

```
      GO TO 5060
 5000 FF = 1.0
      GO TO 5060
 5010 IF(NSEL.EQ.3) GO TO 4010
      WRITE(KW,4001) XO(ITAB)
 4001 FORMAT(1H1,6H RPM = ,1PD10.3)
      GO TO 4020
 4010 WRITE(KW,4002) XO(ITAB)
 4002 FORMAT(1H1,7H LOAD =,1PD10.3)
 4020 WRITE(KW,5011)
 5011 FORMAT(2X,4HFREQ,7X,4HK-XX,6X,4HB-XX,6X,4HK-XY,6X,4HB-XY,6X,
     +4HK-YX,6X,4HB-YX,6X,4HK-YY,6X,4HB-YY)
      KPAGE=1
      IF (NSEL.EQ.3) GO TO 5015
      WRITE(1,5012) KFF,XO(ITAB)
 5012 FORMAT(5X,35HENTER FREQ DATA (HZ) FOR FREQ GROUP,I5,3H AT,1PD12.4,
     +4H RPM/10X,12HLOWEST FREQ?)
      GO TO 5020
 5015 WRITE(1,5016) KFF,XO(ITAB)
 5016 FORMAT(5X,30HENTER FREQ DATA FOR FREQ GROUP,I5,9H AT LOAD
     +11HPARAMETER =,1PD12.4/10X,18HLOWEST FREQ RATIO?)
 5020 READ (1,*) FREQ1
      IF (NSEL.EQ.3) GO TO 5021
      FF = 6.0D+01*FREQ1
      GO TO 5022
 5021 FF = FREQ1
 5022 IF (NSEL.NE.3) WRITE(1,5023)
 5023 FORMAT(10X,13HHIGHEST FREQ?)
      IF (NSEL.EQ.3) WRITE(1,50230)
50230 FORMAT(10X,19HHIGHEST FREQ RATIO?)
      READ (1,*) FREQ2
      WRITE(1,5024)
 5024 FORMAT(10X,22HNUMBER OF FREQ POINTS?)
      READ (1,*) NFRE
      IF (NSEL.EQ.3) GO TO 5040
      IF (NFRE.LE.1) GO TO 5030
      XP = 1.0/(NFRE-1)
      FFRAT = (FREQ2/FREQ1)**XP
      GO TO 5060
 5030 FFRAT = 1.0
      GO TO 5060
 5040 IF (NFRE.LE.1) GO TO 5050
      DFRE = (FREQ2-FREQ1)/(NFRE-1)
      GO TO 5060
 5050 DFRE = 0.0
 5060 DO 5200 IFRE=1,NFRE
      IF (NSYN.EQ.2) INDX = IFRE
      FRQ(INDX) = FF
      DO 5070 L=1,8
      ZEP(L,INDX) = Y(L,ITAB)
 5070 CONTINUE
      IF (NBA.EQ.1.AND.NSYN.EQ.2.AND.IFRE.GT.1) GO TO 5103
      IF (NBA.EQ.1) GO TO 5080
      CALL GOAT(FF,ZEP,INDX,BHA,BST,BDA)
```

```
5080  IF (NSEL EQ 3) GO TO 5085
      IF (NSYN EQ.1) GO TO 5090
      GG = FF/6.0D+01
      GO TO 5100
5085  IF (NSYN EQ 2) GO TO 5090
      GG = XO(ITAB)
      GO TO 5100
5090  GG = FF
5100  WRITE(KW 5101) GG,(ZEP(I),IND ...
      KPAGE=KPAGE+1
5101  FORMAT(1PD12 3)
      IF (NSEL EQ 1) WRITE(KW 5102) (ZEP( , IND
5102  FORMAT(1PD10.7)
5103  IF (NBR.NE 1 OR NSYN NE 2) GO TO 5104
      IF (IFRE EQ.NFRE) GO TO 5107
      GO TO 5105
5104  IF (IFRE.EQ NFRE) GO TO 5150
5105  IF (NSEL.EQ 3) GO TO 5110
      FF = FF*FFRAT
      GO TO 5150
5110  FF = FF+DFRE
5150  IF (NSYN EQ 2 AND IFRE EQ NFRE) GO TO 5200
      IF (KPAGE LT.61) GO TO 5200
      WRITE(KW,2382)
      IF(NSYN EQ 1) GO TO 5152
5151  WRITE(KW 5011)
      GO TO 5190
5152  IF(NSEL EQ.3) GO TO 5153
      WRITE(KW.2421)
      GO TO 5190
5153  WRITE(KW.2431)
5190  KPAGE = 1
5200  CONTINUE
      IF (NSYN EQ.1) GO TO 6030
      IF (KPAGE.LT.57) GO TO 2491
      WRITE(KW,2382)
      KPAGE = 0
      GO TO 2492
2491  WRITE(KW,2331)
      KPAGE = KPAGE+4
2492  IF (NSEL EQ.3) GO TO 2493
      FF = 6 0D+01*FREQ1
      GO TO 2494
2493  FF = FREQ1
2494  WRITE(KW,6001)
6001  FORMAT(37H ASYNCHRONOUS BEARING CHARACTERISTICS/12X 14(1H
     +10HMINOR MODE,14(1H*),2X.14(1H*).10HMAJOR MODE.14(1H*)/
     +61H  FREQUENCY STIFFNESS  CR DAMP  ELLIPTIC   ORIENT   STIFFNESS
     +20H  CR DAMP  ELLIPTIC   ORIENT)
      KPAGE = KPAGE+3
6010  DO 6020 IFRE=1,NFRE
      FF = FRQ(IFRE)
      CALL STAB(ZEP,FF,NSEL,NSYN IFRE,KW.KPAGE)
6020  CONTINUE
```

```
      IF (KPAGE.GE.57) GO TO 6025
      WRITE(KW,2331)
      KPAGE = KPAGE+4
      GO TO 6030
6025  WRITE(KW,2382)
      KPAGE = 0
6030  CONTINUE
      IF (NSYN.EQ.1) GO TO 2490
      IF (KPAGE.LT.61.OR.ITAB.EQ.NTAB) GO TO 2490
      WRITE (KW,2382)
      IF (NSEL.EQ.3) GO TO 6031
      WRITE (KW,2421)
      GO TO 6032
6031  WRITE(KW,2431)
6032  KPAGE = KPAGE+1
2490  CONTINUE
      IF (NSYN.EQ.2) GO TO 7000
      IF (KPAGE.LT.57) GO TO 6035
      WRITE (KW,2382)
      KPAGE = 0
      GO TO 6040
6035  WRITE (KW,2331)
      KPAGE = KPAGE+4
6040  WRITE(KW,2495)
2495  FORMAT(1X,15(1H*),25HSYNCH BRG CHARACTERISTICS,15(1H*),2X,
     +21HSTABILITY  PARAMETERS)
      IF (NSEL.EQ.3) GO TO 2497
      WRITE(KW,2496)
2496  FORMAT(55H   RPM        MIN  STIFF  MIN DAMP   MAJ  STIFF  MAJ DAMP,
     +22H   CR MASS      F RATIO)
      GO TO 2499
2497  WRITE(KW,2498)
2498  FORMAT(55H   LOAD       MIN  STIFF  MIN DAMP   MAJ  STIFF  MAJ DAMP
     +22H   CR MASS      F RATIO)
2499  KPAGE = KPAGE+2
      DO 2500 ITAB=1,NTAB
      FF = XO(ITAB)
      CALL STAB(ZEP,FF,NSEL,NSYN,ITAB,KW,KPAGE)
2500  CONTINUE
7000  IF(NSEL.NE.1) GO TO 2510
      WRITE(1,2501)
2501  FORMAT(/33H SELECT - (1) ANOTHER SPEED GROUP/10X,8H(2) QUIT)
      READ(1,*) NCASE
      IF(NCASE.EQ.2) GO TO 2510
      ANS=RWND$A(KW3)
      READ(KT,1002)(FN2(I),I=1,16),NN,AL9,ALF
      READ(KT,1003) (X(I),I=1,NN)
      WRITE(KW,2382)
      KPAGE = 0
      GO TO 2110
2510  ANS=CLOS$A(KW1)
      IF(ANS) GO TO 2520
      WRITE(1,2511) KW1
2511  FORMAT('ERROR IN CLOSING FILE ON UNIT',I5)
```

```
2520  ANS=CLOS$A(KW2)
      IF(ANS) GO TO 2530
      WRITE(1,2511) KW2
2530  ANS=CLOS$A(KW3)
      IF(ANS) GO TO 2540
      WRITE(1,2511) KW3
2540  CALL EXIT
      END
```

```
C
C
C
      SUBROUTINE STAB(YO,RP,NS,NY,IT,KW,KPAGE)
C
C     CALCULATION OF
C     SYNS1,SYNS2            MINOR AND MAJOR STIFFNESS COEFFICIENTS
C     SYNB1,SYNB2            MINOR AND MAJOR CRITICAL DAMPING FACTORS
C
C         CRMA                     CRITICAL MASS FOR INSTABILITY
C         FRAT                     FREQUENCY RATIO OF INSTABILITY
C         FOR SYNCHRONOUS DATA (NY.EQ.1)
C
C         EE(K)                    MINOR/MAJOR RADIUS RATIO
C         OO(K)                    ORIENTATION ANGLE OF MAJOR AXIS
C         FOR ASYNCHRONOUS DATA (NY.EQ.2)
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION YO(8,1),Y(8),EE(2),OO(2)
      PI = DATAN(1.0D-00)*4.0
      IF (NS.EQ.3) GO TO 1000
      FF = PI/3.0D+01*RP
      GO TO 1
1000  IF (NY.EQ.1) GO TO 1010
      FF = RP
      GO TO 1
1010  FF = 1.0
1     DO 10 I=2,8,2
      J=I-1
      Y(J) = YO(J,IT)
10    Y(I) = FF*YO(I,IT)
      Y34 = Y(3)**2+Y(4)**2
      IF (Y34) 20,40,20
20    Y56 = Y(5)**2+Y(6)**2
      IF (Y56) 30,40,30
C
C     COEFFICIENTS FOR PRINCIPAL MODE ANALYSIS
C
30    SKPA = Y(1)+Y(7)
      SBPA = Y(2)+Y(8)
      DKPA = Y(1)-Y(7)
      DBPA = Y(2)-Y(8)
      XKB = Y(3)*Y(6)+Y(4)*Y(5)
      XKK = Y(3)*Y(5)
      XBB = Y(4)*Y(6)
      DKK=DKPA*DKPA+4.0*XKK
      DKB=2.0*DKPA*DBPA+4.0*XKB
      DBB=DBPA*DBPA+4.0*XBB
      CALL PRINCE(DKK,DKB,DBB,ZK,ZB)
      SYNS1=(SKPA-ZK)/2.0
      SYNS2=SYNS1+ZK.
      SYNB1=(SBPA-ZB)/2.0
      SYNB2=SYNB1+ZB
      SYNB1=SYNB1/DABS(SYNS1)/2.0
```

```
      SYNB2=SYNB2/DABS(SYNS2)/2.0
      IF (NY.EQ.2) GO TO 100
      CRMA = (Y(1)*Y(8)+Y(7)*Y(2)-XKB)/SBPA
      IF (CRMA.LE.0.0) GO TO 60
      F2 = ((Y(1)-CRMA)*(Y(7)-CRMA)-XKK)/(Y(2)*Y(8)-XBB)
      IF (F2.LT.0.0) GO TO 60
      CRMA = CRMA/F2/386.4
      FRAT = DSQRT(F2)
      GO TO 50
40    SYNS1 = Y(7)
      SYNB1 = Y(8)
      SYNS2 = Y(1)
      SYNB2 = Y(2)
      IF (NY.EQ.2) GO TO 200
60    WRITE(KW,6001) RP,SYNS1,SYNB1,SYNS2,SYNB2
      GO TO 55
50    WRITE(KW,5002) RP,SYNS1,SYNB1,SYNS2,SYNB2,CRMA,FRAT
5002  FORMAT(1PD11.4,2(2D11.4,1X),2D11.4)
5010  KPAGE=KPAGE+1
      IF(KPAGE.LT.61) GO TO 70
      WRITE(KW,5050)
55    KPAGE=1
5050  FORMAT(1H1)
6001  FORMAT(1PD11.4,2(2D11.4,1X),23H UNCONDITIONALLY STABLE)
70    RETURN
C     ASNYCHRONOUS MODAL DATA PRINTOUT OF THE ANISOTROPIC CASE
100   K = 1
      KK = 1
      GX1 = (DKPA+ZK)/2.0
      GX2 = (DBPA+ZB)/2.0
      GY1 = Y(3)
      GY2 = Y(4)
105   U0 = DSQRT(GY1*GY1+GY2*GY2)
110   V0 = DSQRT(GX1*GX1+GX2*GX2)
      YY = GX1*U0+GY1*V0
      XX = GX2*U0-GY2*V0
      AA = DATAN2(YY,XX)
      CC = DCOS(AA)
      SS = DSIN(AA)
      X1 = U0*CC
      X2 = U0*SS
      Y1 = V0*CC
      Y2 =-V0*SS
      CALL WHIRL(U1,U2,V1,V2,X1,X2,Y1,Y2)
      CALL SHAPE(E,O,U1,U2,V1,V2)
      IF (E.GT.1.0) GO TO 150
      EE(K) = E
      OO(K) = 1.8E+02*(1.0+O/PI)
      IF (KK.EQ.2) GO TO 266
      IF (K.EQ.2) GO TO 130
      K = 2
      GX1 = GX1-ZK
      GX2 = GX2-ZB
      GO TO 110
```

```
130     IF (NS.NE.3) FF = RP/6.0D+01
        WRITE(KW,5100) FF,SYNS1,SYNB1,EE(1),OO(1),SYNS2,SYNB2,EE(2),OO(2)
5100    FORMAT(1X,1P9D10.3)
        GO TO 5010
150     WRITE(KW,5110)
5110    FORMAT(19H FAULTY MODAL SHAPE)
        CALL EXIT
C       ASYNCHRONOUS MODAL DATA PRINTOUT OF THE ISOTROPIC CASE
200     IF (Y34.NE.0.0.OR.Y56.NE.0.0) GO TO 250
        EE(1) = 0.0
        OO(1) = 9.0D+01
        EE(2) = 0.0
        OO(2) = 0.0
        GO TO 130
250     IF (Y(1).NE.Y(7).OR.Y(2).NE.Y(8)) GO TO 260
        EE(1) = 0.0
        OO(1) = 0.0
        IF (NS.NE.3) FF = RP/6.0D+01
        WRITE(KW,5200) FF,SYNS1,SYNB1,EE(1),OO(1)
5200    FORMAT(1X,1P4D10.3,16H DEGENERATE MODE)
        GO TO 5010
260     KK = 2
        IF (Y34.EQ.0.0) GO TO 270
        K = 1
        GX1 = Y(3)
        GX2 = Y(4)
        GY1 = Y(1)-Y(7)
        GY2 = Y(2)-Y(8)
        GO TO 105
266     IF (K.EQ.2) GO TO 130
        EE(2) = 0.0
        OO(2) = 0.0
        GO TO 130
270     EE(1) = 0.0
        OO(1) = 9.0D+01
        K = 2
        GX1 = Y(7)-Y(1)
        GX2 = Y(8)-Y(2)
        GY1 = Y(5)
        GY2 = Y(6)
        GO TO 105
        END
```

```
C
C
C
      SUBROUTINE PRINCE(DKK,DKB,DBB,ZK,ZB)
      IMPLICIT REAL*8 (A-H,O-Z)
      DRE = DKK-DBB
      DIM = DKB
      DAMP = DSQRT(DRE*DRE+DIM*DIM)
      GO TO 40
30    DAMP = DABS(DKK)
      DRE = DKK
      DIM = 0.0
40    DARG = DATAN2(DIM,DRE)
      AMP = DSQRT(DAMP)
      ARG = DARG/2.0
      ZK = AMP*DCOS(ARG)
      ZB = AMP*DSIN(ARG)
      RETURN
      END
```

```
C
C
C
      SUBROUTINE WHIRL(U1,U2,V1,V2,X1,X2,Y1,Y2)
      IMPLICIT REAL*8 (A-H,O-Z)
C     TRANSFORMS COMPLEX CARTESION REPRESENTATION (X1,X2),(Y1,Y2)
C           INTO COMPLEX ROTATING  REPRESENTATION (U1,U2),(V1,V2)
      U1 = (X1-Y2)/2.0
      U2 = (X2+Y1)/2.0
      V1 = U1+Y2
      V2 = U2-Y1
      RETURN
      END
```

```
C
C
C
      SUBROUTINE SHAPE(E,O,U1,U2,V1,V2)
      IMPLICIT REAL*8 (A-H,O-Z)
C     CALCULATES MINOR/MAJOR RADIUS RATIO AND ORIENTATION FROM COMPLEX
C           WHIRL COMPONENTS
      UU = U1*U1+U2*U2
      VV = V1*V1+V2*V2
      WW = UU+VV
      UW = UU/WW
      VW = VV/WW
      IF (UW.LT.1.0D-20) GO TO 10
      IF (VW.LT.1.0D-20) GO TO 20
      U = DSQRT(UU)
      V = DSQRT(VV)
      A1 = DATAN2(U2,U1)
      A2 = DATAN2(V2,V1)
      O = (A1-A2)/2.0
      UV = U+V
      E = (U-V)/UV
      GO TO 40
10    IF (VW.LT.1.0D-20) GO TO 30
      E =-1.0
15    O =-4.0*DATAN2(1.0D-00)
      GO TO 40
20    IF (UW.LT.1.0D-20) GO TO 30
      E = 1.0
      GO TO 15
30    E = 2.0
40    RETURN
      END
```

```
      FUNCTION SHORT(ALT,ALD,ALF)
      IMPLICIT REAL*8 (A-H,O-Z)
      A2=ALF*ALF/3.0
      KTIME=1
      X=ALF*ALT
10    XX=2.0*X
      YY=DEXP(-XX)
      T=(1.0-YY)/(1.0+YY)
      A=(1.0-T/X)/A2
      IF(KTIME EQ.2) GO TO 20
      A1=A
      KTIME=2
      X=ALF*ALD
      GO TO 10
20    SHORT=A1/A
      RETURN
      END
```

```
C
C
C
      FUNCTION NWHERE(XX,X,NM)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X(1)
      N1=0
      MM = NM
      DO 10 I=2,MM
      Y=XX-X(I)
      IF(Y.GT.0.0) GO TO 10
      N1=I-1
      MM=I
10    CONTINUE
      IF(N1.EQ.0) N1=MM
      NWHERE=N1
      RETURN
      END
```

```
C
C
C
      FUNCTION SPL(ZZ,Y1,DX,N)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION ZZ(1),Y1(3,1)
      SPL=ZZ(N)+DX*(Y1(1,N)+DX*(Y1(2,N)+DX*Y1(3,N)/3.0)/2.0)
      RETURN
      END
```

```
C
C
C
      FUNCTION REFER (AA,BB,S1,S2,W)
C     CALCULATES REFERENCE FUNCTION
C
      IMPLICIT REAL*8 (A-H,O-Z)
      IF (S1.LT.0.0) GO TO 100
      W1=DABS(AA)
      W2=DABS(BB)
      IF(W.EQ.0.0) GO TO 30
      W1=W1*(W**S1)
      W2=W2*(W**S2)
      S3=S1-S2
      IF(S3.GT.0.0) GO TO 10
      IF(S3.GT.-1.0D-00) W2=W2*W
      REFER=W1+W2
      IF(S3.LE.-1.0D-00) GO TO 20
      REFER=REFER/(1.0D-00+W)
      GO TO 20
10    REFER = W1*W2*(1.0D-00+W)/(W*W1+W2)
20    RETURN
30    IF(S1.GT.0.0) GO TO 40
      REFER = W1
      GO TO 20
40    REFER = 0.0
      GO TO 20
100   WRITE(1,1001)
1001  FORMAT(/35H FAULTY DATA. NEAR FIELD EXPONENT =,1PD12.4)
      CALL EXIT
      END
```

```
C
C
C
      SUBROUTINE TILT(Y,ROT,IT)
C     ROTATIONAL TRANSFROMATION OF IMPEDANCE MATRIX
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION ROT(1),Y(8,1)
      YK11 = Y(1,IT)
      YB11 = Y(2,IT)
      YK22 = Y(7,IT)
      YB22 = Y(8,IT)
      YK12 = Y(3,IT)
      YB12 = Y(4,IT)
      YK21 = Y(5,IT)
      YB21 = Y(6,IT)
      DKPA = YK11-YK22
      DBPA = YB11-YB22
      SKXX = YK12+YK21
      SBXX = YB12+YB21
      Y(1,IT) = YK11*ROT(1)-SKXX*ROT(2)+YK22*ROT(3)
      Y(2,IT) = YB11*ROT(1)-SBXX*ROT(2)+YB22*ROT(3)
      Y(3,IT) = DKPA*ROT(2)+YK12*ROT(1)-YK21*ROT(3)
      Y(4,IT) = DBPA*ROT(2)+YB12*ROT(1)-YB21*ROT(3)
      Y(5,IT) = Y(3,IT)-YK12+YK21
      Y(6,IT) = Y(4,IT)-YB12+YB21
      Y(7,IT) =-Y(1,IT)+YK11+YK22
      Y(8,IT) =-Y(2,IT)+YB11+YB22
      RETURN
      END
```

```
C
C
C
      SUBROUTINE BASE(NBA,BMA,BST,BDA)
C     PEDESTAL PROPERTIES
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION BMA(1),BST(1),BDA(1),BIN(2),R2(2)
      WRITE(1,1001)
1001  FORMAT(/29HSELECT:  (1) RIGID FOUNDATION/9X,13H(2) ISOTROPIC,
     +26H FOUNDATION COMPLIANCE, OR/9X,27H(3) ANISOTROPIC FOUNDATION ,
     +11HCOMPLIANCE?)
      READ (1,*) NBA
      IF (NBA.EQ.1) GO TO 1220
      WRITE(1,1002)
1002  FORMAT(/31HSELECT:  (1) RADIAL BEARING, OR/9X,12H(2) ANGULAR ,
     +8HBEARING?)
      READ (1,*) NTY
      WRITE(1,1003)
1003  FORMAT(5X,27HENTER PEDESTAL WEIGHT (LB)?)
      READ (1,*) BWT
      IF (NTY.EQ.2) GO TO 105
      BMA(1) = BWT/386.4
      BMA(2) = BMA(1)
      GO TO 120
105   WRITE(1,1004)
1004  FORMAT(5X,32HENTER CG OFFSET OF PEDESTAL (IN)/5X,6HAXIAL?,4X,
     +21HVERTICAL? HORIZONTAL?)
      READ (1,*) OZ,OX,OY
      RRX = OZ*OZ
      RRY = OZ*OZ
      IF (NBA.EQ.2) GO TO 106
      RRX = RRX+OX*OX
      RRY = RRY+OY*OY
106   R2(1) = RRX*BWT
      R2(2) = RRY*BWT
      WRITE(1,1005)
1005  FORMAT(5X,49HENTER MOMENT OF INERTIA IN VERT PLANE (LB-SQ IN)?)
      READ (1,*) BIN(1)
      IF (NBA.EQ.3) GO TO 1006
      BIN(2) = BIN(1)
      GO TO 1010
1006  WRITE(1,1007)
1007  FORMAT(5X,50HENTER MOMENT OF INERTIA IN HORIZ PLANE (LB-SQ IN)?)
      READ (1,*) BIN(2)
1010  DO 110 I=1,2
      BMA(I) = (BIN(I)+R2(I))/386.4
110   CONTINUE
120   WRITE(1,1201)
1201  FORMAT(5X,43HENTER PEDESTAL STIFFNESS IN VERTICAL PLANE?)
      WRITE(1,1202)
1202  FORMAT(5X,50H(LB/IN) FOR RADIAL BRG, OR (IN-LB/RAD) FOR ANG BRG)
      READ (1,*) BST(1)
      IF (NBA.EQ.3) GO TO 1203
      BST(2) = BST(1)
```

```
      GO TO 1210
1203  WRITE(1,1204)
1204  FORMAT(5X,45HENTER PEDESTAL STIFFNESS IN HORIZONTAL PLANE?)
      WRITE(1,1202)
      READ (1,*) BST(2)
1210  WRITE(1,1211)
1211  FORMAT(5X,41HENTER PEDESTAL DAMPING IN VERTICAL PLANE?)
      WRITE(1,1212)
1212  FORMAT(5X,52H(LB-SEC/IN) FOR RAD BRG, OR (IN-LB-SEC/RAD) FOR ANG ,
     +3HBRG)
      READ (1,*) BDA(1)
      IF (NBA.EQ.3) GO TO 1213
      BDA(2) = BDA(1)
      GO TO 1220
1213  WRITE(1,1214)
1214  FORMAT(5X,43HENTER PEDESTAL DAMPING IN HORIZONTAL PLANE?)
      WRITE(1,1212)
      READ (1,*) BDA(2)
1220  RETURN
      END
```

```
C
C
C
      SUBROUTINE GOAT(FF,Y,IFRE,BM,BS,BD)
C     SUMMATION OF BEARING AND PEDETAL COMPLIANCES
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION Y(8,1),BM(1),BS(1),BD(1)
      DIMENSION AB(2,2),BB(2,2),BZ1(2),BZ2(2),DZ1(2),DZ2(2)
      DIMENSION CB(2,2),DB(2,2),EB(2,2),FB(2,2)
C     ASSEMBLE BEARING IMPEDANCE
C
      RP = FF*DATAN(1.0D-00)/7.5D-00
      K = 0
      DO 10 I=1,2
      DO 10 J=1,2
      K = K+1
      KK = 2*K
      K1 = KK-1
      CB(I,J) = Y(K1,IFRE)
      DB(I,J) = Y(KK,IFRE)*RP
10    CONTINUE
C     CALCULATE PEDESTAL IMPEDANCE ELEMENTS
C
      RP2 = RP*RP
      DO 20 I=1,2
      BZ1(I) = BS(I)-BM(I)*RP2
      BZ2(I) = BD(I)*RP
20    CONTINUE
C     COMBINE PEDESTAL AND BRG IMPEDANCES
C
      DO 30 I=1,2
      DO 30 J=1,2
      IF (I.EQ.J) GO TO 25
      AB(I,J) = CB(I,J)
      BB(I,J) = DB(I,J)
      GO TO 30
25    AB(I,J) = CB(I,J)+BZ1(I)
      BB(I,J) = DB(I,J)+BZ2(I)
30    CONTINUE
C     INVERT
C
      DD1 = AB(1,1)*AB(2,2)-BB(1,1)*BB(2,2)
     +      -AB(1,2)*AB(2,1)+BB(1,2)*BB(2,1)
      DD2 = AB(1,1)*BB(2,2)+BB(1,1)*AB(2,2)
     +      -AB(1,2)*BB(2,1)-BB(1,2)*AB(2,1)
      DD = DD1*DD1+DD2*DD2
      DD1 = DD1/DD
      DD2 =-DD2/DD
      DO 40 I=1,2
      K = 3-I
      EB(I,I) = DD1*AB(K,K)-DD2*BB(K,K)
      FB(I,I) = DD1*BB(K,K)+DD2*AB(K,K)
      EB(I,K) =-DD1*AB(I,K)+DD2*BB(I,K)
      FB(I,K) =-DD1*BB(I,K)-DD2*AB(I,K)
```

```
40    CONTINUE
C     POST MULTIPLY BY BRG IMPEDANCE
C
      DO 50 I=1,2
      DO 50 J=1,2
      AB(I,J) = 0.0
      BB(I,J) = 0.0
      DO 50 K=1,2
      AB(I,J) = AB(I,J)+EB(I,K)*CB(K,J)-FB(I,K)*DB(K,J)
      BB(I,J) = BB(I,J)+EB(I,K)*DB(K,J)+FB(I,K)*CB(K,J)
50    CONTINUE
C     PRE MULTIPLY BY PEDESTAL IMPEDANCE AND RESTORE Y
      K = 0
      DO 60 I=1,2
      DO 60 J=1,2
      K = K+1
      KK = 2*K
      K1 = KK-1
      Y(K1,IFRE) = BZ1(I)*AB(I,J)-BZ2(I)*BB(I,J)
      Y(KK,IFRE) = (BZ1(I)*BB(I,J)+BZ2(I)*AB(I,J))/RP
60    CONTINUE
      RETURN
      END
```

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