ENGINEERING REPORT ON:

Evaluation of Charging-Safety Injection Pump Motor Bearing Temperatures at

Progress Energy Harris Nuclear Plant

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Progress Energy

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Summary

Pioneer Motor Bearing has analyzed the performance of the radial bearings of the Charging-Safety Injection Pump Motors from Progress Energy's Harris Nuclear Plant under both normal operating conditions and a potential high ambient temperature condition. Results of the analysis show excellent correlation with the normal running conditions and indicate that the bearing will operate satisfactorily under the high ambient conditions.

Background

The bearings in question are ring oiled babbitted sleeve bearings installed in a horizontal 900 HP, 1800 RPM Westinghouse squirrel cage induction motor. This motor drives a Charging-Safety Injection Pump for the Harris plant. There was a period of time when one of the A/C Chillers responsible for the heat load in the area where these pumps operate was unavailable. Should these pumps have been operated during this time, it is conservatively estimated that the ambient temperature in this room could have risen to 160 degrees F. The bearings are self contained with all of the heat that is generated in the bearing housings being dissipated through convection to the surrounding air. The normal operating characteristics of this motor bearing yield bearing metal temperatures that are around 50 degrees F higher than the ambient temperature. There is concern that if this delta T remains constant then the bearing metal temperatures will exceed the temperature limits specified by the OEM for this equipment. This temperature limit is currently specified as 203 degrees F.

Analysis

A numerical analysis was performed on the bearing design using the computer program THBRG. This program was developed by The University of Virginia and is available through their ROMAC Industrial Program. This suite of analytical programs is in active use by bearing manufactures, OEMs and consultants around the world. The following is a brief description of the program itself:

THBRG [UNIX & PC]
THBRG calculates the pressure profiles, temperature distribution in film and bearing housing, lubricant flow rates, power loss, and dynamic coefficients for a multilobe journal bearing with an incompressible lubricant. A combination of finite element and finite difference methods are used to solve the governing equations. THBRG uses an assumed axial pressure profile and an assumed cross-film viscosity variation to decrease the dimensionality of the problem to the circumferential direction only. This significantly increases the speed of the program while retaining high accuracy. The analysis includes fluid film conduction, cross-film viscosity variation, two-phase cavitation models for the energy equation, conduction in the housing, convection heat transfer from housing and turbulence. ROMAC Report No. 273.

Input Data

Data for modeling the bearing for analysis was obtained through inspection of an existing bearing from a spare motor. This data is as follows:

Bearing Diameter	4.507 inch
Bearing Length	4.600 inch
Effective pad angle	120 degrees
Design Clearance	.006 to .008 inch diametral
Oil Supply	Mobil DTE Medium supplied by a single oil ring
Load	1000 lbs (conservative estimate)

Results

As we are primarily concerned with the maximum operating temperature, the bearing was modeled with minimum diametral clearance. The first analytical run was to estimate the normal operating conditions and check the accuracy of predicted performance. With an ambient temperature of 77 degrees F, the predicted maximum bearing operating temperature is 142.85 degrees F. This prediction agrees quite well with the operating data that was provided to Pioneer (127 and 148 degrees F with an ambient temperature of 77 degrees F). The difference in operating temperatures can readily be explained in that one of the bearings is electrically insulated which will provide a certain degree of thermal insulation as well. In this case, the computer program is predicting a temperature very close to the highest temperature observed while the motor is in operation. During the normal operation of this bearing, the predicted minimum oil film thickness is .00247 inch. The next step was to take this same model and increase the ambient temperature to 160 degrees F. Results of this analysis predict the maximum bearing temperature will reach 185.93 degrees F while operating under these conditions. The predicted oil film thickness while operating at this elevated temperature is .00202 inch. In considering a yet more conservative assumption, it is conceivable that while running at this elevated ambient condition the oil sump temperature could reach a maximum stabilized temperature on the order of 180 degrees F. This is based on adding the normal steady state sump surface-to-air delta temperature (20 Degrees F) to the predicted 160 degrees F ambient condition. Analysis under these conditions predicts the babbitt temperature will reach 196.92 degrees F and the minimum film thickness will be .00188 inch.

Discussion

The original concerns for operation of this motor under the adverse ambient conditions were based on the assumption that the difference in bearing metal temperature and the ambient temperature would remain constant. This is in fact not the case. In the closed system of the bearing housing, the internal temperatures are a result of the heat generated within the housing and the ability of the housing to dissipate this heat to the surrounding atmosphere. While the higher ambient conditions will impact the heat transfer from the housing to the atmosphere, the reduction in effective viscosity of the oil will, at the same time, reduce the heat load that is being generated within the bearing housing. In this specific case, the power loss of the bearing assembly is effectively cut in half. This fact accounts for the significant reduction in the differential between the predicted bearing metal temperatures and the ambient temperature as the ambient temperature is increased. A review of the minimum oil film thickness shows that even when operating in an elevated ambient temperature environment, the predicted operating oil film thickness of .00188 is still nearly double the generally industrially accepted minimum prediction of .001 inch.

The maximum predicted babbitt temperature of 196.92 degrees F is also still below the OEM limit that is set at 203 degrees F. As the operational prediction is close to the current alarm point a discussion on temperature alarms also seems appropriate. The current alarm point of 203 degrees F was certainly not established simply based on protecting the babbitt material. Typical industrial machinery operating on babbitted journal bearings run reliably with alarm and shut down limits between 240 and 260 degrees F. In fact, the main propulsion steam turbine thrust bearing, constructed with tin based babbitt on a steel backing, on a specific class of US Navy warship runs up to 300 degrees F every time the ship is run at flank speed. There has never been a bearing failure attributed to operating at this elevated temperature. Moreover, as the current alarm point for the bearing temperature for this machine is set so much lower than that required to simply protect the babbitt material, it is more likely that the alarm point for this bearing was based on bounding reasonable temperature excursion or deviations beyond the predicted babbitt temperature during normal operating conditions. The intention being to alert the operator of a significant temperature excursion or deviation rather than simply protecting the babbitt material.

Conclusions

Based on the information provided to Pioneer Motor Bearing, the bearing temperatures of the Charging-Safety Injection Pump Motors will remain below the OEM specified bearing temperature limits while operating with an ambient temperature of 160 degrees F.

Appendix A

Computer Program Output File Run at 77 Degrees F Ambient

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1***MULITLOBE BEARING PROGRAM -- THBRG               VERSION 2.46   (17
Mar 1)

 Harris Safety Injection Motor Bearings Hot Operation Analysis [THBRG
10/04/06]

 1800 rpm, 1000 #, DTE medium @ 77 F

 OVERALL GEOMETRY:
   RADIUS          =  2.253 IN            DIAMETER          =  4.507 IN
   RADIAL PAD CLEAR= .00300 IN            DIAMETRAL         = .00600 IN
   AXIAL LENGTH    =  4.600 IN            PAD OUTER DIAMETER=  6.500 IN
   LENGTH/DIAMETER =  1.021

     PAD GEOMETRY:
                    LEAD    PIVOT     ARC      END   PRELOAD  DELTH   GRANG
        NUMBER     ANGLE    ANGLE    ANGLE    ANGLE    DIM    ANGLE   ANGLE
           1       29.00    90.00   122.00   151.00    .000    4.07   58.00
           2      209.00   270.00   122.00   331.00    .000    4.07   58.00




 OIL PROPERTIES:
   MU( 104.0 F)       = .5359E-05 LB-SEC/IN2
   MU( 212.0 F)       = .8600E-06 LB-SEC/IN2
   THERMAL SLOPE      = -.1694E-01 1/F
   INLET VISCOSITY    =  .847E-05 LB-SEC/IN2
   OIL DENSITY        =  .800E-04 LB-S2/IN4
   SPECIFIC HEAT      =  .180E+03 BTU-IN/(LB-S2-F)
   OIL SUPPLY PRESSURE=     .00 PSI
   SUPPLY TEMPERATURE =   77.00 F

 GENERAL SETUP:
    30 ELEMENTS PER PAD
   ERROR CRITERIA (DIM)          =  .001000
   AXIAL PRESSURE EXPONENT (DIM) = 2.000
   INITIAL  ( X , Y )            = (   .200 ,  -.200 )

 OPTIONS SELECTED:
   ITERATED ECCENTRICITY - TO MATCH SPECIFIED LOAD
   GROOVE TEMPERATURE:  FOUND BY ITERATION
   BOUNDARY CONDITION:  REYNOLDS WITH FLOW CORRECTION
   LAMINAR/TURBULENT FLOW
   ENERGY EQUATION:  INCLUDES PRESSURE GRADIENT TERMS
   CAVITATION:  NEGLECT HEAT GENERATION IN THIS REGION
   VISCOSITY IN REYNOLDS EQN.:  CONSTANT ACROSS FILM
   VISCOSITY IN ENERGY EQN.:  CONSTANT ACROSS THE FILM
   THERMAL SOLUTION:  CONDUCTION TO THE SHAFT AND SHELL
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     FILM THERMAL CONDUCTIVITY = .2000E-05 BTU/IN/S/F
     SHELL THERMAL CONDUCTIVIY = .2000E-03 BTU/IN/S/F
     SHELL CONDUCTION SOLUTION:  2-DIMENSIONAL
     GROOVE MIDLINE TEMPERATURE:  AVERAGE ACROSS GROOVE
     ITERATIVE SHAFT TEMPERATURE:  AVERAGE FILM
        INITIAL JOURNAL TEMP =  120.00 F
     CONVECTION HEAT TRANSFER TO BACK OF SHELL
        AMBIENT TEMP=   77.00 F
        H COEFF     =   .2000E-04 BTU/S/IN^2/F
        CONSTANT CONVECTION COEFFICIENT
     CAVITATION:  INSULATION EFFECT  (RATIO=  5.0000)
     CAVITATION:  LATENT HEAT EFFECT (RATIO=   .0000)


 Harris Safety Injection Motor Bearings Hot Operation Analysis [THBRG
10/04/06]



 1800 rpm, 1000 #, DTE medium @ 77 F

 SPEED/LOAD CASE #  1

 SPEED=     1800.0 RPM          WEIGHT=    1000.00 LBS
 EXTERNAL LOADS:  X=        .00 LBS      Y=        .00 LBS     SPECIFIC
LOAD=      48.23 PSI
 DIMENSIONLESS LOAD:  X=    .00000       Y=  10.71225

 SOMMERFELD # =  .2971E+01          FACTOR=  100.00000
POS.RELAX= 1.000

 CONVERGENCE IN  53 ITERATIONS TO POSITION (X/CP , Y/CP) = (  .1613 , -
.0714 )          (X , Y) = (  .00048 , -.00021 ) IN
      OPERATING POSITION (E/CP) =  .1764 AT   66.1 DEG

 ERROR SUMMARY:  FORCE ( -.5E-05 ,   .1E-02);  FILM TEMPERATURE (  .1E-
03);  GROOVE TEMPERATURE (  .6E-03)

 PAD   PIVOT      PRELOAD      X FORCE       Y FORCE   % CAPACITY
PRESS LEAD     PRESS TR
  1     90.0       .0000           .0            .0       100.00
.00          .00
  2    270.0       .0000           .0         998.1       100.00
.00          .00

 KBXX=    .8849  KBYX=  -6.3509        KXX=         294963. LB/IN
KYX=       -2116976. LB/IN
 KBXY=    .8043  KBYY=   2.0990        KXY=         268104. LB/IN
KYY=         699681. LB/IN

 CBXX=   1.7300  CBYX=   -.7659        CXX=        3059. LB-S/IN  CYX=
-1354. LB-S/IN
 CBXY=   -.7659  CBYY=  12.7088        CXY=       -1354. LB-S/IN  CYY=
22474. LB-S/IN
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RIGID ROTOR STABILITY THRESHOLD =    5899.4 RPM

 FLOW:                /SLOPE/ =    .381 CIPS    /DIFFERENTIAL/ =
.451 CIPS
                      /SLOPE/ =    .099 GPM     /DIFFERENTIAL/ =
.117 GPM
 FRICTION LOSS: /UNCAVITATED/ =    .674 HP              /FULL/ =
1.255 HP
 TEMP RISE:     /UNCAVITATED/ = 8.6     DEGF-GPM        /FULL/ = 16.
DEGF-GPM

 GROOVE TEMPERATURES AND FLOWS:
    PAD   INLET TEMP (F)   INLET (CIPS)     OUTLET TEMP (F)   OUTLET
(CIPS)
     1         138.95         2.634              136.69         2.634
     2         129.63         2.985              141.45         2.534

  JOURNAL TEMPERATURE IS 137.55 F
  MAXIMUM BABBITT TEMPERATURE IS 142.85 F
  MAXIMUM FILM PRESSURE IS  115.55 PSI
  MINIMUM FILM THICKNESS IS  .002473 IN
  NO TURBULENCE PREDICTED IN THE OIL FILM
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Appendix B

Computer Program Output File Run at 160 Degrees F Ambient

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1***MULITLOBE BEARING PROGRAM -- THBRG               VERSION 2.46   (17
Mar 1)

 Harris Safety Injection Motor Bearings Hot Operation Analysis [THBRG
10/04/06]

 1800 rpm, 1000 #, DTE medium @ 160 F

 OVERALL GEOMETRY:
   RADIUS          =  2.253 IN            DIAMETER          =  4.507 IN
   RADIAL PAD CLEAR= .00300 IN            DIAMETRAL         = .00600 IN
   AXIAL LENGTH    =  4.600 IN            PAD OUTER DIAMETER=  6.500 IN
   LENGTH/DIAMETER =  1.021

     PAD GEOMETRY:
                LEAD   PIVOT    ARC     END   PRELOAD  DELTH   GRANG
        NUMBER  ANGLE   ANGLE   ANGLE   ANGLE    DIM    ANGLE   ANGLE
           1    29.00   90.00  122.00  151.00    .000    4.07   58.00
           2   209.00  270.00  122.00  331.00    .000    4.07   58.00



 OIL PROPERTIES:
   MU( 104.0 F)       = .5546E-05 LB-SEC/IN2
   MU( 212.0 F)       = .8600E-06 LB-SEC/IN2
   THERMAL SLOPE      = -.1726E-01 1/F
   INLET VISCOSITY    =  .211E-05 LB-SEC/IN2
   OIL DENSITY        =  .800E-04 LB-S2/IN4
   SPECIFIC HEAT      =  .180E+03 BTU-IN/(LB-S2-F)
   OIL SUPPLY PRESSURE=     .00 PSI
   SUPPLY TEMPERATURE =  160.00 F

 GENERAL SETUP:
    30 ELEMENTS PER PAD
   ERROR CRITERIA (DIM)          =  .001000
   AXIAL PRESSURE EXPONENT (DIM) = 2.000
   INITIAL  ( X , Y )            = (   .200 ,  -.200 )

 OPTIONS SELECTED:
   ITERATED ECCENTRICITY - TO MATCH SPECIFIED LOAD
   GROOVE TEMPERATURE:  FOUND BY ITERATION
   BOUNDARY CONDITION:  REYNOLDS WITH FLOW CORRECTION
   LAMINAR/TURBULENT FLOW
   ENERGY EQUATION:  INCLUDES PRESSURE GRADIENT TERMS
   CAVITATION:  NEGLECT HEAT GENERATION IN THIS REGION
   VISCOSITY IN REYNOLDS EQN.:  CONSTANT ACROSS FILM
   VISCOSITY IN ENERGY EQN.:  CONSTANT ACROSS THE FILM
   THERMAL SOLUTION:  CONDUCTION TO THE SHAFT AND SHELL
     FILM THERMAL CONDUCTIVITY = .2000E-05 BTU/IN/S/F
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     SHELL THERMAL CONDUCTIVIY = .2000E-03 BTU/IN/S/F
     SHELL CONDUCTION SOLUTION:  2-DIMENSIONAL
     GROOVE MIDLINE TEMPERATURE:  AVERAGE ACROSS GROOVE
     ITERATIVE SHAFT TEMPERATURE:  AVERAGE FILM
        INITIAL JOURNAL TEMP =  120.00 F
     CONVECTION HEAT TRANSFER TO BACK OF SHELL
        AMBIENT TEMP=  160.00 F
        H COEFF     =   .2000E-04 BTU/S/IN^2/F
        CONSTANT CONVECTION COEFFICIENT
     CAVITATION:  INSULATION EFFECT  (RATIO=  5.0000)
     CAVITATION:  LATENT HEAT EFFECT (RATIO=   .0000)



 Harris Safety Injection Motor Bearings Hot Operation Analysis [THBRG
10/04/06]

 1800 rpm, 1000 #, DTE medium @ 160 F

 SPEED/LOAD CASE #  1

 SPEED=     1800.0 RPM          WEIGHT=    1000.00 LBS
 EXTERNAL LOADS:  X=        .00 LBS      Y=        .00 LBS     SPECIFIC
LOAD=      48.23 PSI
 DIMENSIONLESS LOAD:  X=    .00000       Y=  42.98947

 SOMMERFELD # =  .7404E+00          FACTOR=  100.00000
POS.RELAX= 1.000

 CONVERGENCE IN  60 ITERATIONS TO POSITION (X/CP , Y/CP) = (  .2483 , -
.2130 )          (X , Y) = (  .00074 , -.00064 ) IN
      OPERATING POSITION (E/CP) =  .3272 AT   49.4 DEG

 ERROR SUMMARY:  FORCE ( -.5E-05 ,   .1E-02);  FILM TEMPERATURE (  .1E-
03);  GROOVE TEMPERATURE (  .5E-03)

 PAD   PIVOT      PRELOAD      X FORCE       Y FORCE   % CAPACITY
PRESS LEAD     PRESS TR
  1     90.0       .0000           .0            .0       100.00
.00          .00
  2    270.0       .0000           .0         998.2       100.00
.00          .00

 KBXX=   1.0697  KBYX=  -4.4034        KXX=         356566. LB/IN
KYX=       -1467787. LB/IN
 KBXY=    .5308  KBYY=   2.2753        KXY=         176948. LB/IN
KYY=         758445. LB/IN

 CBXX=   1.2932  CBYX=  -1.1093        CXX=        2287. LB-S/IN  CYX=
-1962. LB-S/IN
 CBXY=  -1.1093  CBYY=   8.9849        CXY=       -1962. LB-S/IN  CYY=
15889. LB-S/IN
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RIGID ROTOR STABILITY THRESHOLD =    5989.8 RPM

 FLOW:                /SLOPE/ =    .545 CIPS    /DIFFERENTIAL/ =
.660 CIPS
                      /SLOPE/ =    .142 GPM     /DIFFERENTIAL/ =
.172 GPM
 FRICTION LOSS: /UNCAVITATED/ =    .369 HP             /FULL/ =
.629 HP
 TEMP RISE:     /UNCAVITATED/ = 4.7     DEGF-GPM        /FULL/ = 8.0
DEGF-GPM

 GROOVE TEMPERATURES AND FLOWS:
    PAD   INLET TEMP (F)   INLET (CIPS)     OUTLET TEMP (F)   OUTLET
(CIPS)
     1         179.45         2.629              180.28         2.629
     2         179.40         2.743              184.61         2.083

  JOURNAL TEMPERATURE IS 181.52 F
  MAXIMUM BABBITT TEMPERATURE IS 185.93 F
  MAXIMUM FILM PRESSURE IS  121.11 PSI
  MINIMUM FILM THICKNESS IS  .002019 IN
  NO TURBULENCE PREDICTED IN THE OIL FILM
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Appendix C

Computer Program Output File Run at 160 Degrees F Ambient and 180 Degrees F Oil Inlet Temperature

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1***MULITLOBE BEARING PROGRAM -- THBRG               VERSION 2.46   (17
Mar 1)

 Harris Safety Injection Motor Bearings Hot Operation Analysis [THBRG
10/13/06]

 1800 rpm, 1000 #, DTE medium @ 180F, 160 F ambient

 OVERALL GEOMETRY:
   RADIUS          =  2.253 IN            DIAMETER          =  4.507 IN
   RADIAL PAD CLEAR= .00300 IN            DIAMETRAL         = .00600 IN
   AXIAL LENGTH    =  4.600 IN            PAD OUTER DIAMETER=  6.500 IN
   LENGTH/DIAMETER =  1.021

     PAD GEOMETRY:
                    LEAD   PIVOT    ARC     END   PRELOAD  DELTH   GRANG
        NUMBER     ANGLE   ANGLE   ANGLE   ANGLE    DIM    ANGLE   ANGLE
           1       29.00   90.00  122.00  151.00    .000    4.07   58.00
           2      209.00  270.00  122.00  331.00    .000    4.07   58.00




 OIL PROPERTIES:
   MU( 104.0 F)       = .5546E-05 LB-SEC/IN2
   MU( 212.0 F)       = .8600E-06 LB-SEC/IN2
   THERMAL SLOPE      = -.1726E-01 1/F
   INLET VISCOSITY    =  .149E-05 LB-SEC/IN2
   OIL DENSITY        =  .800E-04 LB-S2/IN4
   SPECIFIC HEAT      =  .180E+03 BTU-IN/(LB-S2-F)
   OIL SUPPLY PRESSURE=     .00 PSI
   SUPPLY TEMPERATURE =  180.00 F

 GENERAL SETUP:
    30 ELEMENTS PER PAD
   ERROR CRITERIA (DIM)          =  .001000
   AXIAL PRESSURE EXPONENT (DIM) = 2.000
   INITIAL  ( X , Y )            = (   .200 ,  -.200 )

 OPTIONS SELECTED:
   ITERATED ECCENTRICITY - TO MATCH SPECIFIED LOAD
   GROOVE TEMPERATURE:  FOUND BY ITERATION
   BOUNDARY CONDITION:  REYNOLDS WITH FLOW CORRECTION
   LAMINAR/TURBULENT FLOW
   ENERGY EQUATION:  INCLUDES PRESSURE GRADIENT TERMS
   CAVITATION:  NEGLECT HEAT GENERATION IN THIS REGION
   VISCOSITY IN REYNOLDS EQN.:  CONSTANT ACROSS FILM
   VISCOSITY IN ENERGY EQN.:  CONSTANT ACROSS THE FILM
   THERMAL SOLUTION:  CONDUCTION TO THE SHAFT AND SHELL
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     FILM THERMAL CONDUCTIVITY = .2000E-05 BTU/IN/S/F
     SHELL THERMAL CONDUCTIVIY = .2000E-03 BTU/IN/S/F
     SHELL CONDUCTION SOLUTION:  2-DIMENSIONAL
     GROOVE MIDLINE TEMPERATURE:  AVERAGE ACROSS GROOVE
     ITERATIVE SHAFT TEMPERATURE:  AVERAGE FILM
        INITIAL JOURNAL TEMP =  120.00 F
     CONVECTION HEAT TRANSFER TO BACK OF SHELL
        AMBIENT TEMP=  160.00 F
        H COEFF     =   .2000E-04 BTU/S/IN^2/F
        CONSTANT CONVECTION COEFFICIENT
     CAVITATION:  INSULATION EFFECT  (RATIO=  5.0000)
     CAVITATION:  LATENT HEAT EFFECT (RATIO=   .0000)



 Harris Safety Injection Motor Bearings Hot Operation Analysis [THBRG
10/13/06]

 1800 rpm, 1000 #, DTE medium @ 180F, 160 F ambient

 SPEED/LOAD CASE #  1

 SPEED=     1800.0 RPM          WEIGHT=    1000.00 LBS
 EXTERNAL LOADS:  X=        .00 LBS      Y=        .00 LBS     SPECIFIC
LOAD=      48.23 PSI
 DIMENSIONLESS LOAD:  X=    .00000       Y=  60.71082

 SOMMERFELD # =  .5243E+00          FACTOR=  100.00000
POS.RELAX= 1.000

 CONVERGENCE IN  62 ITERATIONS TO POSITION (X/CP , Y/CP) = (  .2697 , -
.2597 )          (X , Y) = (  .00081 , -.00078 ) IN
      OPERATING POSITION (E/CP) =  .3744 AT   46.1 DEG

 ERROR SUMMARY:  FORCE ( -.4E-05 ,   .9E-03);  FILM TEMPERATURE (  .1E-
03);  GROOVE TEMPERATURE (  .5E-03)

 PAD   PIVOT      PRELOAD      X FORCE       Y FORCE   % CAPACITY
PRESS LEAD     PRESS TR
  1     90.0       .0000            .0            .0       100.00
.00          .00
  2    270.0       .0000            .0         998.2       100.00
.00          .00

 KBXX=   1.1228  KBYX=  -4.1667        KXX=        374282. LB/IN
KYX=       -1388886. LB/IN
 KBXY=    .4968  KBYY=   2.3628        KXY=        165591. LB/IN
KYY=          787611. LB/IN

 CBXX=   1.2621  CBYX=  -1.2154        CXX=        2232. LB-S/IN  CYX=
-2149. LB-S/IN
 CBXY=  -1.2154  CBYY=   8.5677        CXY=       -2149. LB-S/IN  CYY=
15151. LB-S/IN
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      RIGID ROTOR STABILITY THRESHOLD =    5998.0 RPM

 FLOW:                /SLOPE/ =    .576 CIPS    /DIFFERENTIAL/ =
.705 CIPS
                      /SLOPE/ =    .150 GPM     /DIFFERENTIAL/ =
.183 GPM
 FRICTION LOSS: /UNCAVITATED/ =    .321 HP              /FULL/ =
.527 HP
 TEMP RISE:     /UNCAVITATED/ = 4.1     DEGF-GPM        /FULL/ = 6.7
DEGF-GPM

 GROOVE TEMPERATURES AND FLOWS:
    PAD   INLET TEMP (F)   INLET (CIPS)     OUTLET TEMP (F)   OUTLET
(CIPS)
     1         191.61         2.646              191.93         2.646
     2         191.88         2.649              195.86         1.944

  JOURNAL TEMPERATURE IS 193.23 F
  MAXIMUM BABBITT TEMPERATURE IS 196.92 F
  MAXIMUM FILM PRESSURE IS  123.54 PSI
  MINIMUM FILM THICKNESS IS  .001877 IN
  NO TURBULENCE PREDICTED IN THE OIL FILM
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