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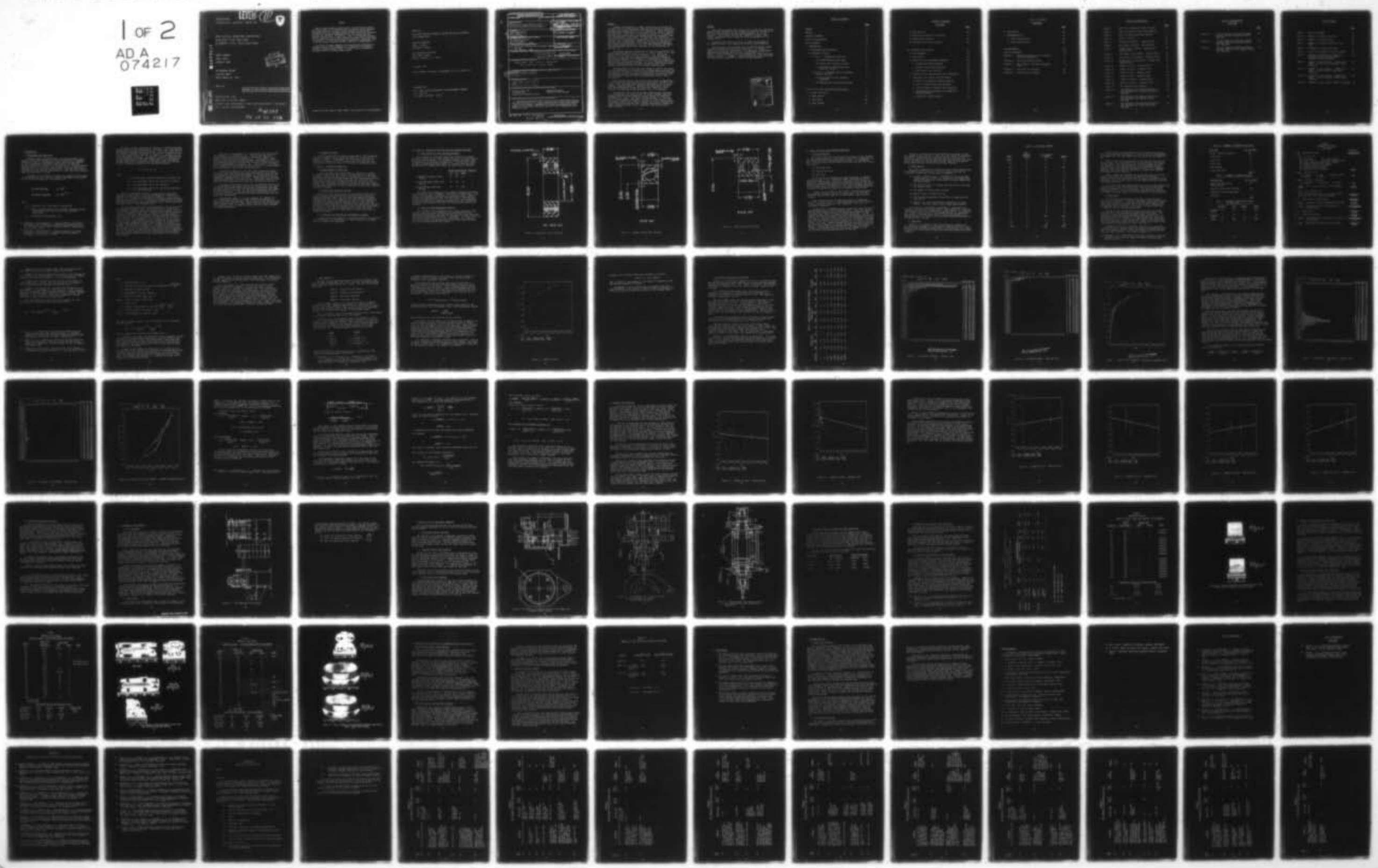

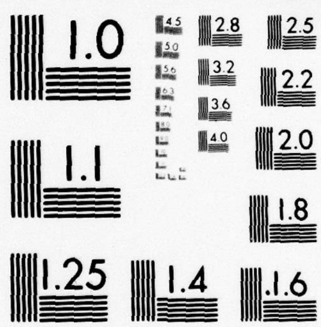

MICROCOPY RESOLUTION TEST CHART

AVRADCOM

TECHNICAL REPORT TR79-35

M50 STEEL BEARING MATERIAL FACTORS FOR ROLLING ELEMENT LIFE CALCULATIONS

FRANK R. MORRISON

JOHN I. McCOOL

NICHOLAS J. NINOS

SKF TECHNOLOGY SERVICES

1100 FIRST AVENUE

KING OF PRUSSIA, PA. 19406

APRIL 1979

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PREPARED FOR

UNITED STATES ARMY

AVIATION RESEARCH AND DEVELOPMENT COMMAND

ST. LOUIS, MO 63166

NOTICE

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Material and lubrication factors for M-50 steel rolling contact bearings have been determined basis a survey accumulating life results from previously conducted test programs. Experimental life results are presented on three groups of rolling contact bearings (2 ball and 1 roller) manufactured from VIMVAR M-50 steel.

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Summary

Lundberg and Palmgren of ABSKF Sweden have predicted the fatigue life of rolling element bearings according to theoretical and empirical factors based on 1950 technology. Newer materials and processing techniques are now providing the means to improve bearing life. Since 1950 a considerable amount of information has been generated on bearings manufactured from materials other than conventional 52100 steel. In addition, the effects of certain bearing operational parameters on bearing life have been studied. As a consequence, modifying factors, accounting for the influence of materials, processing techniques and machine operational characteristics, i.e. oil film thickness and speed, have been defined and are now employed in the estimation of bearing life.

The newest industry formulation of the rolling bearing life calculation equation is $L_{10} = a_1 a_2 a_3 (C/P)^w$, where w is 3 for point contact and 10/3 for line contact. Life adjustment factors, a_1, a_2, and a_3, allow the user to take advantage of increases in bearing life produced by technological advances. One of these factors, a_2, is related to the material composition and material processing variables. It is an important consideration in rating bearings for Army helicopter applications where vacuum processed M-50 tool steel is most commonly used.

The Department of the Army has a need to verify the material and lubrication life factors of rolling element bearing life calculations in order to more accurately rate the life potential of bearings from all manufacturing regardless of material used over the entire range of service applications seen in Army helicopters.

This report presents the results of a survey accumulating life results achieved from bearings manufactured from M-50 tool steel. Life data have been analyzed according to an existing computer program, "TABACY". Material and lubrication factors have been determined using this data base, enabling a more accurate calculation of the potential life of a bearing.

In addition, this report includes experimental endurance life data obtained on three groups of rolling element bearings manufactured of Vacuum Induction Melted Vacuum Arc Remelted (VIMVAR) M-50 steel. The three bearing designs, all of which have a 45 mm internal diameter, consist of a deep groove ball, an angular contact ball, and a cylindrical roller configuration. These types have been run under several operational conditions using circulating Mobil Jet II synthetic lubricating fluid (MIL-L-23699).

PREFACE

This report presents the results of an analytical and experimental study conducted by SKF Technology Services for the U. S. Army Aviation Research and Development Command, St. Louis, Missouri 63166 under Contract No. DAAK50-77-C-0009. This report encompasses effort conducted from 18 December 1977 to 1 April 1979.

Technical direction for the U. S. Army was provided by Mr. Harold Schuetz, the Contracting Officers Representative.

The principal investigators from the SKF Mechanical Laboratories who worked on this project were Mr. N. J. Ninos - Scientist and Project Leader; Mr. F. R. Morrison - Supervisor, under whose direction the work was accomplished; Mr. J. I. McCool - Senior Mathematician who performed the statistical data analysis; and Mr. G. Hughes - Senior Metallurgist who performed the metallurgical analysis of certain failed hardware.

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I. INTRODUCTION

A. Background and Objectives

Rolling element bearing fatigue life was originally quantified through life prediction theories developed by Lundberg-Palmgren [1 and 2]. Subsequently, these theories were adopted by the International Standards Organization, the American National Standards Institute and the majority of rolling bearing manufacturers in the world as the primary means of predicting bearing lives for potential applications. The empirical factors included in these theories were based on 52100 type steel bearing data collected prior to 1950.

According to the formulas developed by Lundberg and Palmgren, the estimated life that 90% of a group of bearings will achieve or 10% of the bearings will fail before are:

for Ball Bearings $$L_{10} = \left(\frac{C}{P}\right)^3$$

for Roller Bearings $$L_{10} = \left(\frac{C}{P}\right)^{10/3}$$

where:

L_{10} = Bearing life in millions of revolutions

C = Basic bearing load rating in pounds (Bearing Catalog Value) which will give a life of one million revolutions

P = Equivalent bearing load, lbs.

---

[1] Lundberg, G. and Palmgren A., "Dynamic Capacity of Rolling Bearings", Acta Polytechnica, Mechanical Engineering Series 1, Proceedings of the Royal Swedish Academy of Engineering, Vol. 7, No. 3, 1947.

[2] Lundberg, G. and Palmgren A., "Dynamic Capacity of Roller Bearings", Proceedings of the Royal Swedish Academy of Engineering. Vol. 2, No. 4, 1952.

However, current technological advances in improved bearing design, materials and manufacturing techniques have significantly increased the fatigue life of bearings. Thus life predictions by the Lundberg-Palmgren method may be excessively conservative and a new life calculation technique is required to account for the life improvements achieved. In addition, a better understanding of the influence of certain operational factors on bearing performance and longevity has been established. These parameters are now taken into consideration when determining the expected life of a bearing according to the following formula:

$$L_A = a_1 \, a_2 \, a_3 \, L_{10}$$

where:

L_A = the adjusted, expected theoretical bearing life

a_1 = life adjustment factor for reliability (90%=1)

a_2 = life adjustment factor for material

a_3 = life adjustment factor for operating conditions, i.e. film thickness

The life adjustment factors, a_1, a_2, and a_3, have been included to allow the user to take advantage of increases in bearing life produced by technological advances. One of these factors, a_2, is related to the material composition and material processing variables. It is an important consideration in rating bearings for Army helicopter applications where vacuum processed M-50 tool steel is most commonly used.

At the present time the values assigned to the a_2 a_3 factors for these calculations vary and depend upon the combination of airframe or engine manufacturer and bearing supplier involved in each individual design case. Reasons given for the existence of these variations range from differences in experimentally collected life data, to differences in environmental conditions which do not take into account the influence of the a_3 lubrication factor. The ambiguity in the calculation of the theoretical life of a given bearing design causedby the inconsistency in the values assigned to these factors makes it difficult to evaluate the potential adequacy of a proposed helicopter system design. The need exists, therefore, to establish a consistent base value of a_2 for vacuum melt M-50 material, and to examine the quantification of the material-lubrication factor combination a_2 a_3 in order to provide a life modification function valid over the entire range of conditions encountered in helicopter applications.

The direct establishment of a factor modifying the bearing life formula is an extensive task. Rolling bearing life is a statistical function that contains a significant degree of scatter within any one experimental lot. Furthermore, significant life variations are noted between experimental lots by as yet undefined variations of material melt lot, manufacturing processes, environmental conditions, etc. Therefore, it is necessary to consider a large volume of data prior to the establishment of a statistically valid life modifying factor.

A significant amount of life test data accumulated under a variety of test conditions now exist from bearing and element test specimens which were manufactured of vacuum processed, CVM (consumably vacuum melted) and VIMVAR (vacuum induction melted, vacuum arc remelted) M-50 tool steel. These data have now been compiled along with the respective test conditions, and form the basis for the derivation of a value for the material factor a_2.

Accordingly, the objectives of this program have been first to collect and statistically analyze existing bearing life data on vacuum melted M-50 steel and secondly to generate life data on three specific test lots of bearings manufactured from VIMVAR M-50 steel material. From this data base, preliminary calculations of material and lubricant factors affecting bearing life have been established.

Concurrently, under U. S. Army Contract No. DAAK50-78-C-0027, additional bearing life data are being accumulated on angular contact ball bearings. These data will be combined with that reported herein at a later date to provide better estimates of the value at the a_2 material factor for M-50 steel prepared by VIMVAR processing.

B. Statement of Work

The following work has been accomplished by SKF Technology Services according to the agreement outlined in Contract No. DAAK50-77-C-0009. Accordingly, the first part deals with a statistical analysis of all available test data and part two involves the testing of full size bearings as explained below.

(1) Part I - Statistical Analysis

(a) Establishment of Data Base

A data base has been established by conducting a survey to collect those M-50 tool steel life data which are currently available, along with the specific information as to the test configuration, test specimen design and test conditions utilized. These data consist of bearing life data and life data from element test specimens, accumulated through literature search, contact with government testing facilities and life data collection agencies, and from the data accumulated through SKF conducted life test programs.

(b) Statistical Analysis of Data

These data have been reduced to an equivalent base by (1) recalculation of the theoretically predicted life using the computer program "TABACY" for bearings and Lundberg Palmgren techniques for the test elements, (2) identifying the value of the lubricant factor for each specific set of test conditions following currently accepted practice and (3) using the SKF computer program "MAXLIKE" to establish the experimental Weibull parameters. Experimental material factors have been calculated for each test lot, and the population as a whole has been characterized by geometric mean material value along with its standard deviation.

(c) Influence of Operational and Material Factors

Scatter plots were prepared to determine whether the material factor exhibited any dependency on stress, bearing or element test size and oil film parameter.

(2) Part II - Endurance Tests on Rolling Element Bearings

(a) Description of Test Bearing Specimens

Three specific life tests have been conducted to obtain specific results on the three primary variables of importance to helicopter applications, i.e. material melting practice, speed of operation, and bearing configuration. This has been accomplished by endurance testing three 20 specimen bearing groups manufactured of VIMVAR M-50 steel and identified as follows:

	Boundry Dimensions-mm			Figure No.
	I.D.	O.D.	Width	
(1) NU309 VCG Cylindrical Roller Bearing	45	100	25	1
(2) 7209 VAP Angular Contact Ball Bearing	45	85	19	2
(3) 6009 VAT Deep Groove Ball Bearing	45	75	15.8	3

The above test bearings are not those originally specified in the contract work statement. Difficulties encountered at the start of the program, prevented the testing of 7309 B Angular Contact Ball Bearings and 6309 Deep Groove Ball Bearings manufactured of VIMVAR M-50 steel. In July 1978, it was suggested to the government and subsequently approved by the Contracting Officers representative that the 7209 VAP and 6009 VAT be substituted.

(b) Material and Lubrication Factors

The results of the endurance tests run on the above three bearing types have been statistically integrated into the compilation previously obtained and the life variation functions previously established have been re-evaluated. A general value for the M-50 material factor has been established and specific values of lubrication and material factors have been provided for various bearing operating ranges.

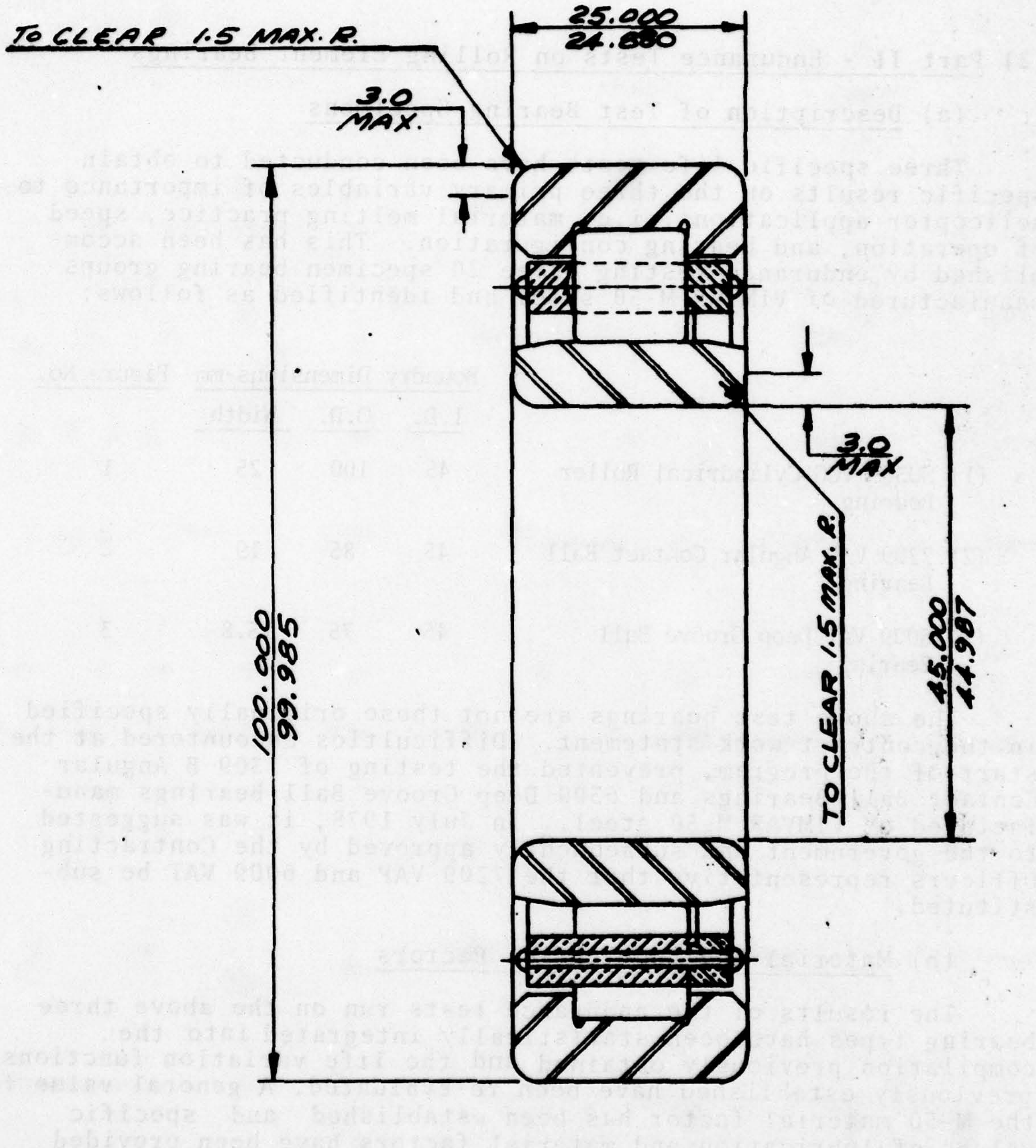

Figure 1. Cylindrical Roller Bearing

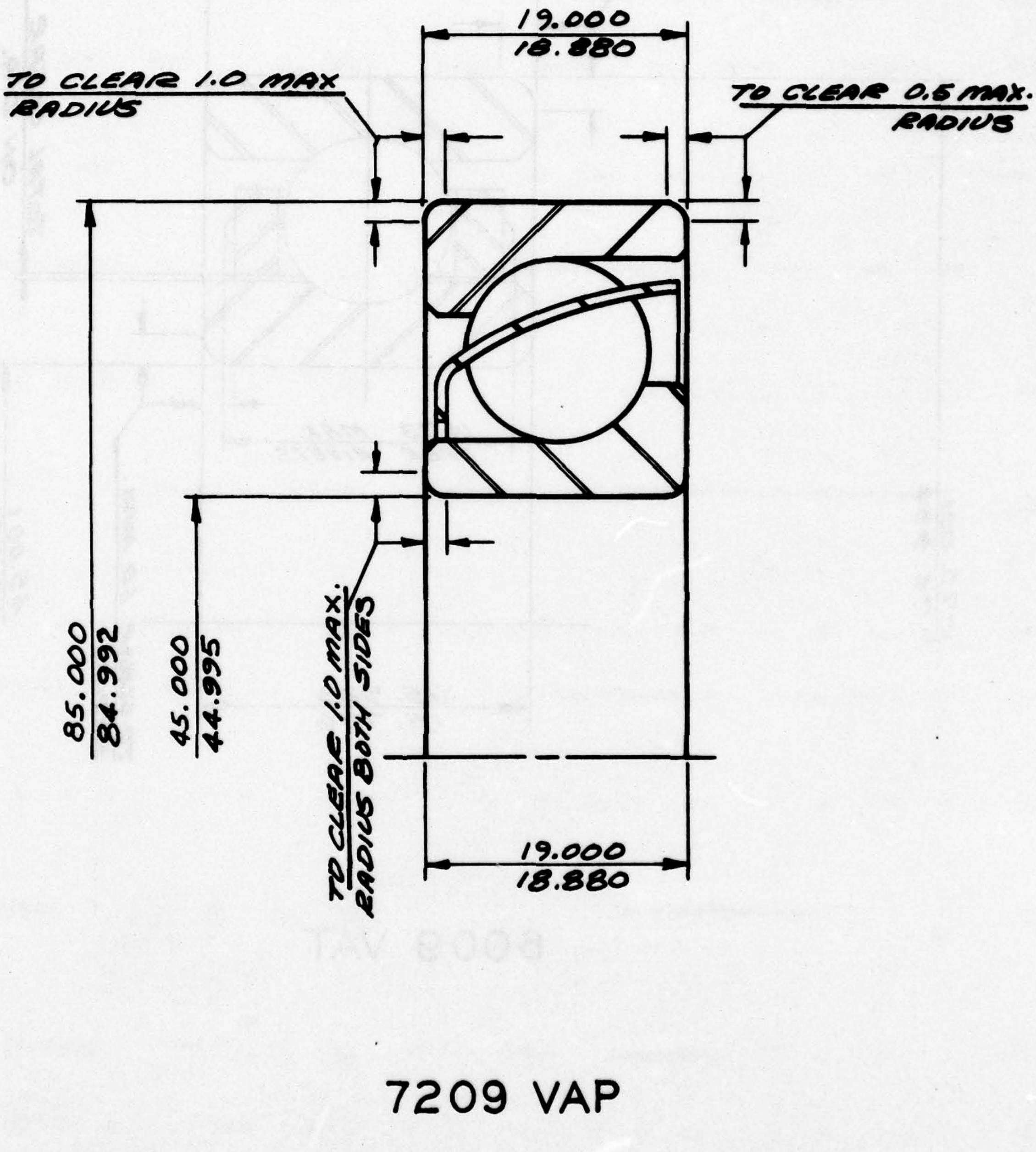

Figure 2. Angular Contact Ball Bearing

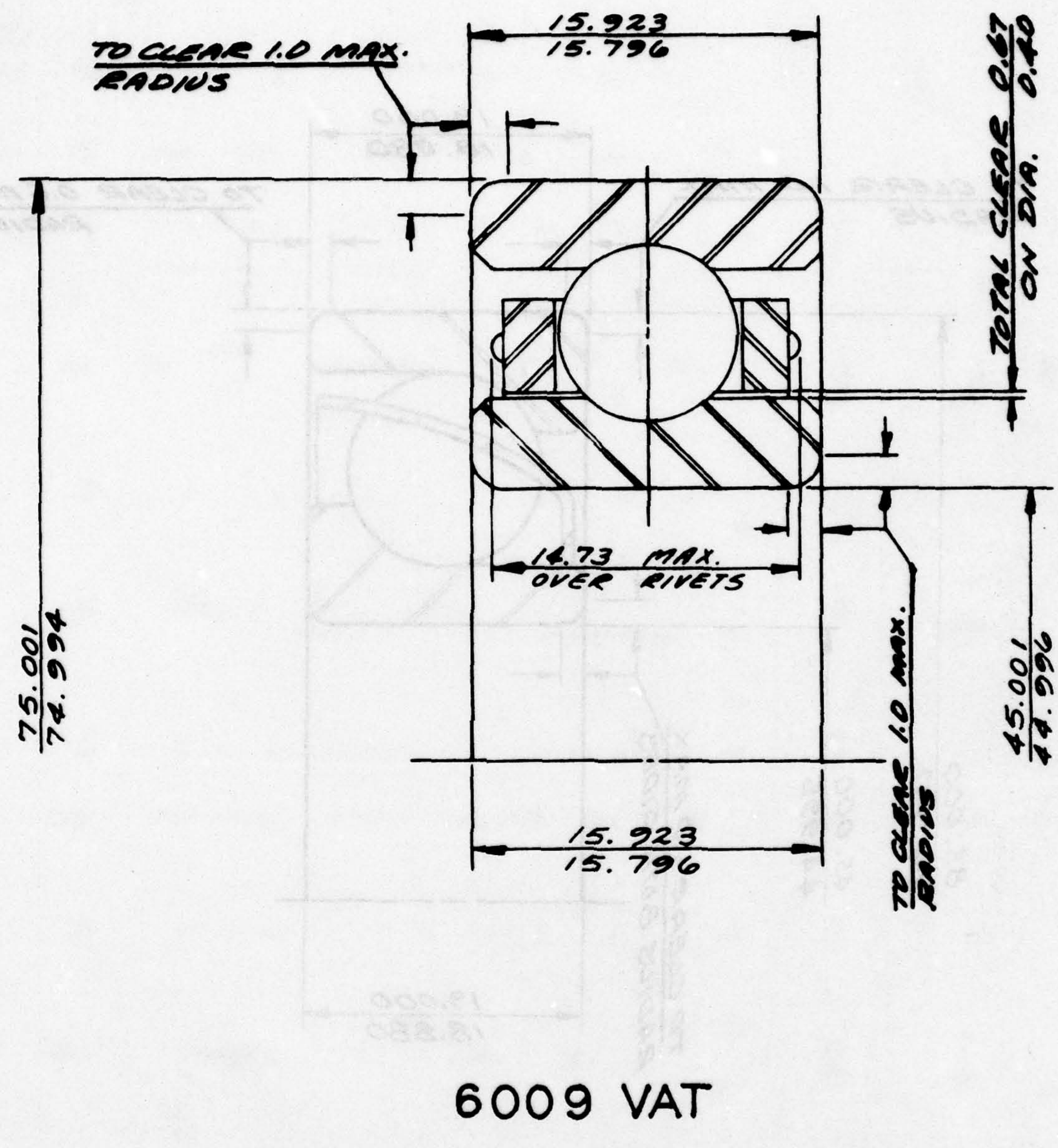

Figure 3. Deep Groove Ball Bearing

II. M-50 LIFE DATA COLLECTION AND ANALYSIS

A. Data Collection

The initial activity of the analytical phase of the program was the establishment of a data base to serve as a foundation for the determination of an M-50 material factor. To accomplish this, life test data on M-50 steel were assembled from the following sources:

(1) Published data

(2) Contributed files

(3) SKF files

In the course of searching for published data, a computer search was made of the "ISMEC-MECH-ENGR" (Information Service Mechanical Engineering, Louisville, Kentucky) file listing of mechanical engineering references and abstracts and of the "NTIS" (National Technical Information Service) file containing abstracts of Government sponsored research. The search yielded respective totals of 62 and 80 citations in the general subject area.

A query was also made of the "GIDEP" (Government/Industry Data Exchange Program) failure rate data base, but the only citations located were found to be applicable to wear and not fatigue.

After acquiring and reviewing the papers of potential interest, a final list of 22 published sources of M-50 rolling contact endurance experience was assembled. This list is included as Appendix A.

In addition, a telephone survey was made in order to locate unpublished sources of M-50 endurance data. Major jet engine and helicopter manufacturers were among those called as well as cognizant Army, Navy, Air Force and NASA personnel. If the contact indicated that applicable data existed and could be made available, a followup letter requesting the forwarding of these data and the specific test particulars was submitted. A typical letter of this type is given in Appendix B. A total of 19 such letters were sent. These included solicitation letters sent to SKF affiliate companies in Canada, England, Germany, France and Sweden. Letters were also distributed courtesy of the Anti-friction Bearing Manufacturers Association (AFBMA) to all participating bearing manufacturers in the USA.

Every set of data that was collected was assigned a reference number of the form YY-X. The first two digits YY represents the year of publication for published sources, the year of receipt for private sources, and the year of testing for SKF test data. The digit X is an arbitrary serial index to distinguish between data sources having the same year reference.

B. Data Sources

The survey conducted established 48 data sources which could be included in the data base. The data sources listing the following information are presented in Appendix C.

(1) A source reference,e.g. a literature citation for published sources, a letter of transmittal for unpublished contributed data and a test series or report number for SKF data sources.

(2) The type of test i.e. bearing type and size or rig type for element tests.

(3) The number of test groups included.

(4) Sample size(s) of each test lot.

(5) The operating parameters controlled in conducting the test series.

(6) Remarks i.e. any extenuating circumstances or limitations. Material type is also listed under Remarks.

Of the 48 data references in Appendix C, seven were subsequently omitted from the data base. Some reasons for omitting a data source were (1) insufficient rig/test details to establish the validity of the data, (2) the unavailability of individiual data points or Weibull plots and (3) rig design judged to be unrepresentative of typical rolling contact fatigue phenomena as for sources 59-1 and 60-1.

C. Data Base

Table 1 is a summary of the distribution of elements of the data base assembled, including the 3 bearing tests also conducted in this program and described in Section III of this report. A total of 53 full scale bearing tests and 306 element tests were compiled.

Table 1 - DATA BASE SUMMARY

YEAR	NO. BEARING TESTS	NO. ELEMENT TESTS	TOTAL
1958	2	0	2
59	1	0	1
60	0	10	10
61	3	0	3
62	1	0	1
64	5	0	5
66	5	9	14
67	1	6	7
68	9	3	12
69	4	0	4
70	1	0	1
71	1	3	4
72	3	7	10
74	3	0	3
75	0	1	1
76	4	2	6
77	0	258	258
78	7	7	14
79	3	0	3
TOTAL	53	306	359

Table 2 shows the distribution of the element tests among the six common basic rig types. By far, the largest accumulation of element test data was obtained on the GE RC rig described in [3].

Table 3 shows the distribution of the bearing test data by design types. It is noted that 50% of the bearings were single row deep groove ball bearings while 34% were angular contact ball bearings. The bearing data are thus dominated by point contact tests and might not adequately reflect the parameters available from line contacts existing in cylindrical, tapered and spherical roller bearings.

Table 4 shows the distribution of melting practice for the element and bearing test groups included in the data base. Melting practice was classified into air melt, consumable vacuum melt and a third category that includes VIMVAR and other multiple remelting processes.

It is seen that the predominant factor in both the element and bearing tests is the CVM process which was until recently the industry standard for M-50 tool steel. The advent of VIMVAR processing which is now the standard process has been too recent to produce a sizable impact of the distribution of the data base.

D. Data Format

To facilitate the ultimate processing of the collected data, it was reduced to a computer acceptable format and entered into punch card records. The data form for keypunching of the cards was prepared to include all of the factors considered to be important in the analysis of the data. A copy of the form is shown as Table 5 and described below:

The first four columns contain the test reference number entitled REF in the subsequent computer printout forms. This consists of the data source reference number followed by a sequential digit to distinguish between the several tests that may comprise the data source, e.g. 7613 denotes the third test within source 76-1. (The form design failed to anticipate the 254 tests contained within source 77-1. These tests were accordingly numbered sequentially as 1001, 1002 etc.).

Columns 5 and 6 are a two digit code for test type which is entitled TYPE. Element tests are readily distinguished from full scale bearing tests in data processing by testing whether this two digit integer is less than or equal to 4.

[3] Baughman, R.A., "Experimental Laboratory Studies of Bearing Fatigue", ASME Technical Digest, Mechanical Engineering, March 1959 p. 94.

Table 2 - SUMMARY OF ELEMENT TEST TYPES

Rig Type	No. of Tests
RC RIG (General Electric)	279
1 BALL RIG	11
4 BALL RIG	3
5 BALL RIG	7
FLAT WASHER	2
3 BALL AND CONE	4
	306

Table 3 - SUMMARY OF BEARING DESIGN

Bearing Type	No. of Tests
Single Row Deep Groove Ball Bearings	26
Angular Contact Ball Bearings	18
Cylindrical Roller Bearings	7
Spherical	2
	53

Table 4 - SUMMARY OF MELTING PRACTICE BY TEST TYPE

	AIR MELT	CVM	OTHER	TOTAL
ELEMENT TESTS	13	281	12	306
BEARING TESTS	5	41	7	53
TOTAL	18	322	19	359

Table 5

AVRADCOM M-50 STUDY

DATA FORM

Card Col.

1. REF - Reference Number — 1-4

2. TYPE - Tester Type — 5-6

   01) GE RC Rig   02) 4 ball tester
   03) 5 ball tester   04) other element tester
   10) single row deep groove ball bearing
   11) angular contact ball bearing
   12) cylindrical roller bearing
   13) tapered roller bearing
   14) spherical roller bearing

3. MAT - Material Type — 7

   1) Air Melt   2) CVM   3) Multiple CVM
   4) VIMVAR   5) Other

4. PROC - Material Processing — 8

   1) Standard   2) Ausformed   3) Powder

5. STRESS (ksi) - Max. Contact Stress on Test Element — 9-11

6. SIZE - Test Element Size — 12-16

   Test specimen radius (in.) for element tests
   Bore size (in.) for rolling bearings

7. H - Film Thickness (microinch) — 17-20

8. SIGMA - Composite Surface Roughness (microinch) — 21-23

9. LIOTH - Theoretical L_{10} Life (millions of revolutions) — 24-30

10. N - Sample Size — 31-33

11. R - Number of Failures — 34-36

12. LIOEX - Experimental L_{10} Estimate (million of revolutions) — 37-43

13. BETA - Experimental Weibull Slope Estimate — 44-47

Columns 7 and 8 are single digit codes denoting material type (MAT) and processing method (PROC) respectively.

Columns 9-11 contain the integer portion of the maximum contact stress in ksi units (STRESS). (The decimal point is understood at the location indicated. It is not keypunched).

Columns 12-16 contain a measure of the test element size (SIZE) expressed in inches, the specimen radius for element tests, the bearing bore diameter for bearing tests.

Columns 17-20 contain the lubricant film thickness (H) in microinches. For bearings the film thickness at the ring contacts was calculated within a bearing analysis computer program developed by SKF and named "TABACY" [4] using a formula due to Cheng [5]. The viscosity at operating temperature and the pressure viscosity index are program input.

For the element test rigs with point contact, the film thickness was calculated from Archard and Kirk [6].

$$\frac{h}{R'} = 0.84 \left[\frac{\mu_o \alpha V}{R'}\right]^{0.741} \left[\frac{Q}{E'R'^2}\right]^{-0.074}$$

[4] Liu, J. Y., "Final Report on Analytical Method of Life Calculation for Ball and Roller Bearings - A Computer Program", SKF Report No. AL75P033, submitted to USAAVSCOM, and Contract No. DAAJ01-75-C-0349, October, 1975.

[5] Cheng, H. S., "A Numerical Solution of the EHD Film Thickness in an Elliptical Contact", Journal of Lubrication Technology, ASME Trans., Series F, Vol. 92, No. 1, January, 1970, pp. 155-162.

[6] Archard, G. and M. Kirk, "Lubrication at Point Contacts", Proceedings of the Royal Society, A. 261, pp. 532-550 (1961).

where

h = film thickness (in.)

μ_o = absolute viscosity at operating temperature $\frac{\text{lbs-sec}^2}{\text{in}^2}$

α = pressure viscosity index

V = entrainment velocity (in/sec.)

R' = effective radius $= (\frac{1}{R_1} + \frac{1}{R_2})^{-1}$

R_1, R_2 = radii of bodies 1 and 2 in.

Q = load (lbs.)

E' = reduced Youngs Modulus (lbs/in^2) $= [\frac{1-\nu_1^{\ 2}}{\pi E_1} + \frac{1-\nu_2^{\ 2}}{\pi E_2}]^{-1}$

ν_1, ν_2 = Poisson's ratio for bodies 1 and 2

E_1, E_2 = Young modulus for bodies 1 and 2

For rigs with line contacts, the film thickness was calculated from the formula.

$$\frac{h}{R'} = 1.13 \left[\frac{\mu_o \alpha V}{R'}\right]^{0.727} \left[\frac{P'}{E'R'}\right]^{-0.091}$$

where P' denotes the load per unit length (lb/in.)

Columns 21-23 contain the composite surface roughness (SIGMA) defined as the square root of the sum of the mean square roughness values for each of the contacting bodies. When inner and outer ring roughness differed, the value was used for which h/σ was smallest. For many particularly older tests surface roughness had to be estimated.

Columns 24-30 contain the theoretical or catalog L_{10} life for the test group, (LIOTH). For bearings (or bearing inner rings in some cases) the value of the theoretical L_{10} is calculated using the computer program TABACY to insure consistency in the data. For element test groups, it is computed by direct application of life estimation theory.

Columns 31-33 and 34-36 contain respectively the sample size (N) and the number of failures (R) for each test. It is necessary for the sample size to be at least 2 and the number of failures to be at least 1.

The experimental L_{10} life achieved from the test group (LIOEX) is entered in columns 37-43 and the Weibull slope estimate (BETA) is entered in columns 44-46. For tests where the raw data were available, the experimental L_{10} life and the Weibull slope were determined using the method of maximum likelihood, again to insure consistency of the data base. However, bias correction was not applied since the appropriate factors were not available for all the combinations of sample sizes and censoring methods used in the various tests. On the basis of past experience, the error produced by the lack of bias correction is considered to be negligible compared to other random and systematic error sources encountered in the life testing process.

E. Data Analysis

The data were processed using the statistical analysis computer program package BMDP (Aug. 1977 revision) developed at the Health Sciences Computing Facility, UCLA*. The specific programs used were:

BMDP1D - Single Data Description

BMDP2D - Frequency Count Routine

BMDP5D - Univariate Plotting

BMDP6D - Bivariate Plotting

With the BMDP system, it is possible to supply a Fortran subroutine to add, transform and combine the input variables. One may also assign mnemonic names of up to six digits in length to the input variables and to the variables added by transformations, to facilitate the reading of the program output.

The 13 variables coded on the data sheet of Table 5 were named as previously indicated for use in the programs.

In addition a film parameter, H/SIG, was added as a 14th variable by dividing the film thickness variable (H) by the composite surface roughness (SIGMA). The film factor variable a_3 from the life formulation was added as a 15th variable entitled FILFAC using a piecewise linear approximation to the curve presented in [7]. The approximation is defined as follows:

H/SIG	FILFAC
<0.6	0.2
0.6 to 1.0	0.75 (H/SIG)-0.25
1 to 2.0	1.7 (H/SIG)-1.2
2 to 9.0	0.114 (H/SIG) + 1.97
≥9	3

*The Health Sciences Computing Facility is sponsored by NIH Special Research Resources Grant RR-3.

[7] Bamberger, E. N., Harris, T. A., Kacmarsky, W. M. Moyer, C. A., Parker, R. J., Sherlock, J. J., and Zaretsky, E. V., Life Adjustment Factors for Ball and Roller Bearings, The American Society of Mechanical Engineers, 1971.

A computer representation of the values of FILFAC plotted as a function of H/SIG is shown in Figure 4 for the data points employed in the subsequent analysis.

Once the preceding variables have been established, it becomes possible to calculate the experimental value of the a_2 material factor for each group. This is accomplished by considering the definition of the life factors and assuming that the total difference between the experimentally determined L_{10} life and the theoretical L_{10} life is defined by the value of the a_2 a_3 factors. This can be expressed as

$$a_2 \, a_3 \, L_{10_{Theoretical}} = L_{10_{experimental}}$$

Converting this expression to the variable names used for the computer analysis and rearranging terms, this formulation becomes

$$MATFAC = \frac{LIOEX}{LIOTH \cdot FILFAC}$$

where MATFAC is the name used for the a_2 variable.

Calculated in this manner the estimated value of MATFAC will exhibit random variation in repeat testing because of random error in the experimental value of the L_{10} life. Some systematic error may also be expected due to the approximate nature of the formulas relating FILFAC to h/σ and in the Lundberg-Palmgren rating theory used to compute the theoretical L_{10} life. To the extent that the Lundberg-Palmgren theory is systematically in error in different amounts depending on factors such as size, geometry etc., this will appear as additional random error in a large heterogeneous collection of data.

Two additional reference variables were calculated. The use of these variables is discussed later in this report. The first of these, called LOGMAT, was calculated as the natural logarithm of the material factor, i.e. LOGMAT = l_n (MATFAC).

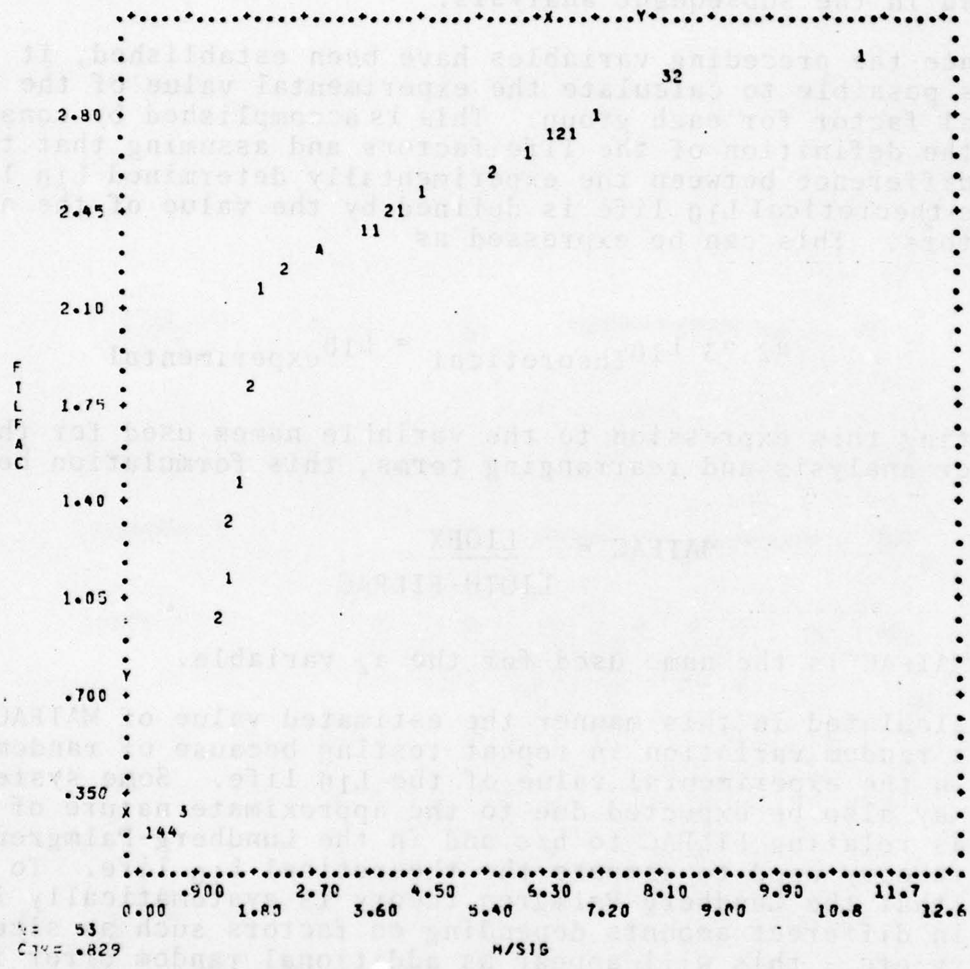

Figure 4. FILFAC VS H/SIG

Secondly, the variable WTFAC was calculated as follows:

$$WTFAC = R \times LN\ (MATFAC)$$

That is, WTFAC is the product of the number of failures, R, and the natural logarithm of MATFAC.

Appendices D and E respectively are output lists from program BMDPD1 of the values of each of these 18 variables for each of the bearing tests and for each of the element tests.

F. Statistical Analysis of the Data

Table 6 is a statistical summary of 8 of the variables broken down by bearing tests alone, element tests alone and the combined bearing and element tests. This table contains for each variable: the mean, the standard deviation, and the extreme values of the variables.

It is noted that the sample size of the bearing tests averaged 22.2 specimens and each group had an average of 11.0 failures. The sample size ranged from 4 to 100. The number of failures ranged from 1 to 30.

For the element tests, an average sample comprised 9.3 test specimens of which 8.6 failed. The sample size and number of failures range from 2 to 72. The mean Weibull slope for the bearing tests was 2.15 while for the element tests, it was significantly higher at 4.86. This difference between the bearing a_2 and element tests may be due to the generally higher stress levels used in the conduct of the element tests. The mean stress was 356 ksi for the bearing tests and 687 ksi for the element tests.

The average film parameter H/SIG was higher for the bearing tests (3.43 vs 1.29) and therefore the average film factor was also greater for the bearing tests i.e. 1.83 vs 0.70.

The mean material factor is 9.12 for the bearing tests, 10.64 for the element tests and 10.43 overall. These values are misleadingly high, however, because the distribution of the values of MATFAC does not follow a normal distribution, but is severely skewed to the right. This is illustrated in the histograms of Figures 5 and 6 which were generated by program BMDP5D.

Figure 7 is a probability plot of the same data. In a graph of this type, normally distributed data would generate a straight line. It is clear by the nonlinear nature of both lines that both element and bearing tests give markedly non-normal distributions for MATFAC.

Table 6 - STATISTICAL SUMMARY FOR KEY VARIABLES

VARIABLE	Bearing Tests MEAN	STD. DEV.	MIN.	MAX.	Element Tests MEAN	STD. DEV.	MIN.	MAX.	All Tests MEAN	STD. DEV.	MIN.	MAX.
N	22.2	15.1	4	100	9.33	7.81	2.0	72.0	11.22	10.29	2	100
R	11.0	8.95	1	30	8.57	5.77	2.0	72.0	8.88	6.38	1	72
BETA	2.15	3.49	0.49	20.4	4.86	3.00	0.51	20.9	4.49	3.23	0.49	20.4
H/SIG	3.43	2.79	0.15	11.4	1.29	3.72	0.025	25.1	1.60	3.67	0.025	25.1
FILFAC	1.83	0.999	0.2	3.0	0.700	0.652	0.20	3.00	0.87	0.82	0.20	3.00
MATFAC	9.12	15.23	0.11	73.6	10.64	14.19	0.006	130.8	10.43	14.33	0.006	130.8
WTFAC	12.4	26.7	-59.9	129.0	14.57	13.13	-40.8	139.0	14.25	15.81	-59.9	139.0
LOGMAT	1.14	1.57	-2.20	4.30	1.83	1.18	-5.04	4.87	1.73	1.26	-5.04	4.87

```
HISTOGRAM OF VARIABLE    16 MATFAC
                                  SYMBOL   COUNT        MEAN         ST.DEV.
                        ELEMENTS    A       306        10.643        14.189
INTERVAL                                                                                     FREQUENCY PERCENTAGE
NAME            5    10    15    20    25    30    35    40    45    50    55    60    65    70    75    80   INT. CUM. INT.  CUM.
               +----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
 • 3.0000 +AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA                    54   54  17.6  17.6
 • 6.0000 +AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA 75  129  24.5  42.2
 • 9.0000 +AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA   73  202  23.9  66.0
 • 12.000 +AAAAAAAAAAAAAAAAAAAAAAAAAAAAA                                             29  231   9.5  75.5
 • 15.000 +AAAAAAAAAAAAAAAAAAAAA                                                     21  252   6.9  82.4
 • 18.000 +AAAAAAAAA                                                                  9  261   2.9  85.3
 • 21.000 +AAAAAAAAAAAAAAA                                                           15  276   4.9  90.2
 • 24.000 +AAAAAA                                                                     6  282   2.0  92.2
 • 27.000 +AAA                                                                        3  285   1.0  93.1
 • 30.000 +AAAA                                                                       4  289   1.3  94.4
 • 33.000 +                                                                           0  289   0.0  94.4
 • 36.000 +AAAA                                                                       4  293   1.3  95.8
 • 39.000 +A                                                                          1  294   0.3  96.1
 • 42.000 +A                                                                          1  295   0.3  96.4
 • 45.000 +AA                                                                         2  297   0.7  97.1
 • 48.000 +AA                                                                         2  299   0.7  97.7
 • 51.000 +A                                                                          1  300   0.3  98.0
 • 54.000 +A                                                                          1  301   0.3  98.4
 • 57.000 +                                                                           0  301   0.0  98.4
 • 60.000 +                                                                           0  301   0.0  98.4
 • 63.000 +A                                                                          1  302   0.3  98.7
 • 66.000 +                                                                           0  302   0.0  98.7
 • 69.000 +A                                                                          1  303   0.3  99.0
 • 72.000 +                                                                           0  303   0.0  99.0
 • 75.000 +                                                                           0  303   0.0  99.0
 • 78.000 +                                                                           0  303   0.0  99.0
 • 81.000 +A                                                                          1  304   0.3  99.3
 • 84.000 +                                                                           0  304   0.0  99.3
 • 87.000 +                                                                           0  304   0.0  99.3
 • 90.000 +                                                                           0  304   0.0  99.3
 • 93.000 +                                                                           0  304   0.0  99.3
 • 96.000 +                                                                           0  304   0.0  99.3
 • 99.000 +                                                                           0  304   0.0  99.3
 • 102.00 +                                                                           0  304   0.0  99.3
 • 105.00 +                                                                           0  304   0.0  99.3
 • 108.00 +                                                                           0  304   0.0  99.3
 • 111.00 +                                                                           0  304   0.0  99.3
 • 114.00 +                                                                           0  304   0.0  99.3
 • 117.00 +                                                                           0  304   0.0  99.3
 • 120.00 +                                                                           0  304   0.0  99.3
 • 123.00 +A                                                                          1  305   0.3  99.7
 • 126.00 +                                                                           0  305   0.0  99.7
 • 129.00 +                                                                           0  305   0.0  99.7
 • 132.00 +A                                                                          1  306   0.3 100.0
 • 135.00 +                                                                           0  306   0.0 100.0
 • 138.00 +                                                                           0  306   0.0 100.0
 • 141.00 +                                                                           0  306   0.0 100.0
 • 144.00 +                                                                           0  306   0.0 100.0
 • 147.00 +                                                                           0  306   0.0 100.0
 • 150.00 +                                                                           0  306   0.0 100.0
               +----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
                5    10    15    20    25    30    35    40    45    50    55    60    65    70    75    80
```


Figure 5. Histogram of MATFAC - Element Tests

HISTOGRAM OF VARIABLE 16 MATFAC

	SYMBOL	COUNT	MEAN	ST.DEV.
BEARINGS	B	53	9.120	15.230

INTERVAL NAME	5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80	FREQUENCY INT.	FREQUENCY CUM.	PERCENTAGE INT.	PERCENTAGE CUM.
3.0000	+BBBBBBBBBBBBBBBBBBBBB	21	21	39.6	39.6
6.0000	+BBBBBBBBBBBBBBB	15	36	28.3	67.9
9.0000	+BBBBBBB	7	43	13.2	81.1
12.000	+B	1	44	1.9	83.0
15.000	+	0	44	0.0	83.0
18.000	+B	1	45	1.9	84.9
21.000	+B	1	46	1.9	86.8
24.000	+	0	46	0.0	86.8
27.000	+B	1	47	1.9	88.7
30.000	+	0	47	0.0	88.7
33.000	+B	1	48	1.9	90.6
36.000	+B	1	49	1.9	92.5
39.000	+	0	49	0.0	92.5
42.000	+B	1	50	1.9	94.3
45.000	+B	1	51	1.9	96.2
48.000	+	0	51	0.0	96.2
51.000	+	0	51	0.0	96.2
54.000	+	0	51	0.0	96.2
57.000	+B	1	52	1.9	98.1
60.000	+	0	52	0.0	98.1
63.000	+	0	52	0.0	98.1
66.000	+	0	52	0.0	98.1
69.000	+	0	52	0.0	98.1
72.000	+	0	52	0.0	98.1
75.000	+B	1	53	1.9	100.0
78.000	+	0	53	0.0	100.0
81.000	+	0	53	0.0	100.0
84.000	+	0	53	0.0	100.0
87.000	+	0	53	0.0	100.0
90.000	+	0	53	0.0	100.0
93.000	+	0	53	0.0	100.0
96.000	+	0	53	0.0	100.0
99.000	+	0	53	0.0	100.0
102.00	+	0	53	0.0	100.0
105.00	+	0	53	0.0	100.0
108.00	+	0	53	0.0	100.0
111.00	+	0	53	0.0	100.0
114.00	+	0	53	0.0	100.0
117.00	+	0	53	0.0	100.0
120.00	+	0	53	0.0	100.0
123.00	+	0	53	0.0	100.0
126.00	+	0	53	0.0	100.0
129.00	+	0	53	0.0	100.0
132.00	+	0	53	0.0	100.0
135.00	+	0	53	0.0	100.0
138.00	+	0	53	0.0	100.0
141.00	+	0	53	0.0	100.0
144.00	+	0	53	0.0	100.0
147.00	+	0	53	0.0	100.0
150.00	+	0	53	0.0	100.0
	5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80				

Figure 6. Histogram MATFAC - Bearing Tests

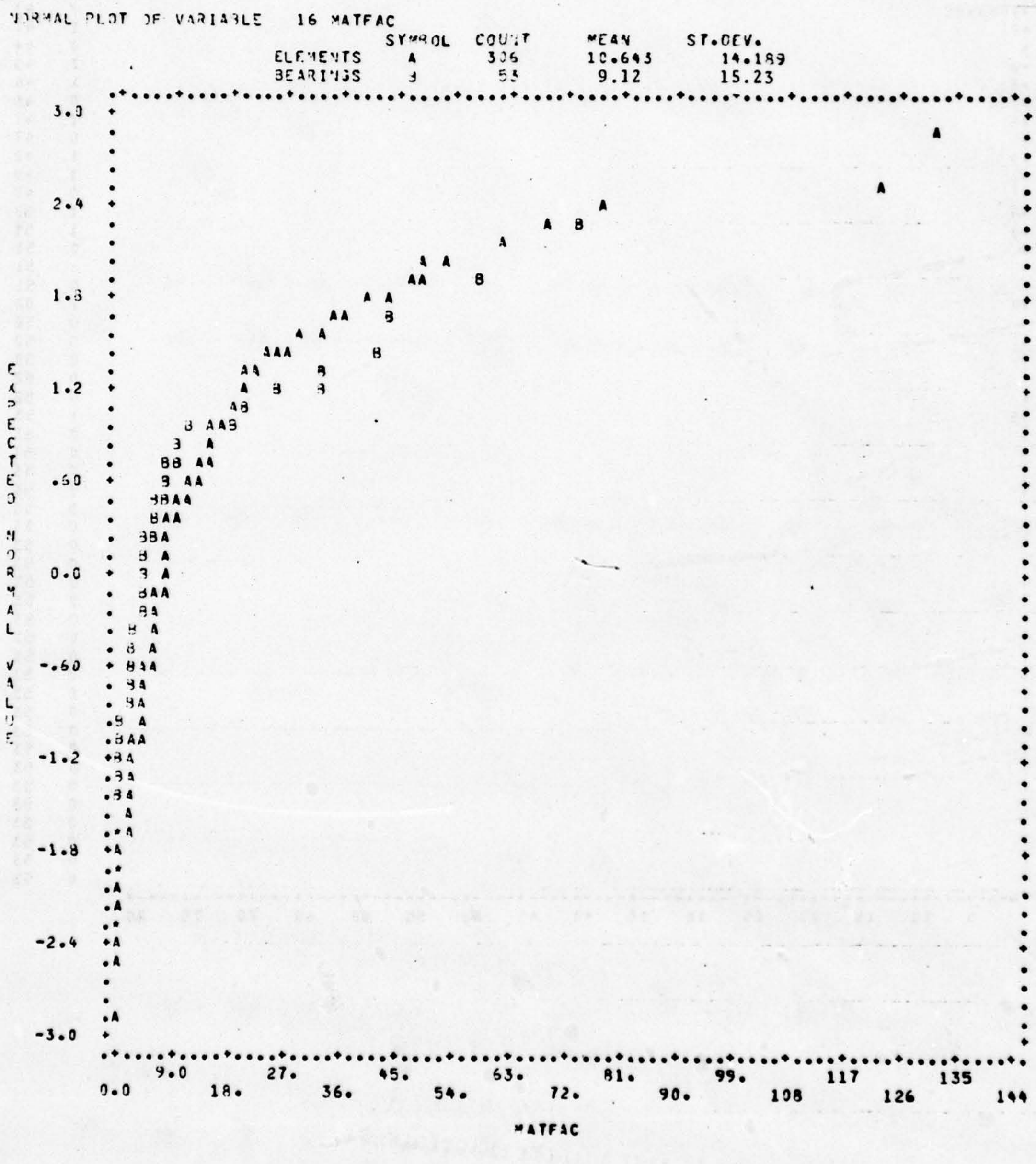

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Figure 7. Normal Plot of MATFAC - Bearing and Element Tests

Figures 8, 9 and 10 are the corresponding histograms and probability plots for the logarithm of MATFAC (LOGMAT). The histograms now appear to be substantially symmetrical. The probability plot of Figure 10 shows that the bearing data now are well approximated by a straight line indicating that the distribution of the data approaches a normal distribution. The distribution for element test data still demonstrates some skewness in the lower tail.

This skewness notwithstanding, the graphs establish that the use of logarithmic values is a more representative method of combining the results from a sequence of life test data than the use of standard arithmetic techniques which tend to overestimate the value of the combined parameters. This single factor, plus the normal scatter inherent in endurance test sequences, is mostly responsible for the lack of agreement over the values to be used for experimentally determined life related variables such as the material factor.

The data also show that the bearing tests exhibit more scatter than did the element tests; the standard deviations of LOGMAT are 1.57 for the bearing tests and 1.18 for the element tests. A statistical test for the equality of these standard deviation values conducted assuming that the data are normally distributed, shows that the difference is significant. The reason lies in (a) the higher Weibull slope exhibited by the element test data and (b) the greater heterogeneity among the bearing types which results in a contribution to scatter due to differences in systematic errors among bearing types and sizes.

Values of the material factors represented by the data can then be calculated by taking the average value of LOGMAT and then taking the antilog of that value. Thus considering the total data base the material factor for bearings is calculated as 3.13, and that for element tests is 6.23. If these are recalculated for vacuum melted steels only, i.e. eliminating the air-melt groups, the values become 3.55 for bearings and 6.49 for element tests.

90% confidence limits on the average logarithm of MATFAC may be calculated as:

$$\overline{\text{LOGMAT}} - \frac{1.645 \times \text{S.D.}}{N^{1/2}} < \text{LOGMAT} < \overline{\text{LOGMAT}} + \frac{1.645 \times \text{S.D.}}{N^{1/2}}$$

```
HISTOGRAM OF VARIABLE    18 LOGMAT
                                   SYMBOL  COUNT     MEAN     ST.DEV.
                         ELEMENTS    A      306      1.831     1.180
INTERVAL                                                                              FREQUENCY PERCENTAGE
NAME        5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   INT. CUM. INT.  CUM.
          +----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
*-6.0000  +                                                                                 0    0   0.0    0.0
*-5.7500  +                                                                                 0    0   0.0    0.0
*-5.5000  +                                                                                 0    0   0.0    0.0
*-5.2500  +                                                                                 0    0   0.0    0.0
*-5.0000  +A                                                                                1    1   0.3    0.3
*-4.7500  +                                                                                 0    1   0.0    0.3
*-4.5000  +                                                                                 0    1   0.0    0.3
*-4.2500  +                                                                                 0    1   0.0    0.3
*-4.0000  +A                                                                                1    2   0.3    0.7
*-3.7500  +                                                                                 0    2   0.0    0.7
*-3.5000  +                                                                                 0    2   0.0    0.7
*-3.2500  +                                                                                 0    2   0.0    0.7
*-3.0000  +                                                                                 0    2   0.0    0.7
*-2.7500  +A                                                                                1    3   0.3    1.0
*-2.5000  +                                                                                 0    3   0.0    1.0
*-2.2500  +                                                                                 0    3   0.0    1.0
*-2.0000  +AA                                                                               2    5   0.7    1.6
*-1.7500  +                                                                                 0    5   0.0    1.6
*-1.5000  +AA                                                                               2    7   0.7    2.3
*-1.2500  +A                                                                                1    8   0.3    2.6
*-1.0000  +A                                                                                1    9   0.3    2.9
*-.75000  +                                                                                 0    9   0.0    2.9
*-.50000  +AAA                                                                              3   12   1.0    3.9
*-.25000  +A                                                                                1   13   0.3    4.2
* 0.0000  +AA                                                                               2   15   0.7    4.9
* .25000  +AAAA                                                                             4   19   1.3    6.2
* .50000  +AAAAAAAA                                                                         8   27   2.6    8.8
* .75000  +AAAAAA                                                                           6   33   2.0   10.8
* 1.0000  +AAAAAAAAAA                                                                      10   43   3.3   14.1
* 1.2500  +AAAAAAAAAAAAAAAAAAAA                                                            20   63   6.5   20.6
* 1.5000  +AAAAAAAAAAAAAAAAAAAAAAAAAA                                                      26   89   8.5   29.1
* 1.7500  +AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA                                                 31  120  10.1   39.2
* 2.0000  +AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA                                   45  165  14.7   53.9
* 2.2500  +AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA                                    44  209  14.4   68.3
* 2.5000  +AAAAAAAAAAAAAAAAAAAAAA                                                          22  231   7.2   75.5
* 2.7500  +AAAAAAAAAAAAAAAAAAAAAAA                                                         23  254   7.5   83.0
* 3.0000  +AAAAAAAAAAAAAAAAAAA                                                             19  273   6.2   89.2
* 3.2500  +AAAAAAAAAAAA                                                                    12  285   3.9   93.1
* 3.5000  +AAAAA                                                                            5  290   1.6   94.8
* 3.7500  +AAAAA                                                                            5  295   1.6   96.4
* 4.0000  +AAAAAA                                                                           6  301   2.0   98.4
* 4.2500  +AA                                                                               2  303   0.7   99.0
* 4.5000  +A                                                                                1  304   0.3   99.3
* 4.7500  +                                                                                 0  304   0.0   99.3
* 5.0000  +AA                                                                               2  306   0.7  100.0
* 5.2500  +                                                                                 0  306   0.0  100.0
* 5.5000  +                                                                                 0  306   0.0  100.0
* 5.7500  +                                                                                 0  306   0.0  100.0
* 6.0000  +                                                                                 0  306   0.0  100.0
* 6.2500  +                                                                                 0  306   0.0  100.0
          +----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
            5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80
```

Figure 8. Histogram of Log MATFAC - Element Tests

HISTOGRAM OF VARIABLE 13 LOGMAT

	SYMBOL	COUNT	MEAN	ST.DEV.
BEARINGS	B	53	1.140	1.570

INTERVAL NAME	5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80	FREQUENCY INT.	FREQUENCY CUM.	PERCENTAGE INT.	PERCENTAGE CUM.
-6.0000		0	0	0.0	0.0
-5.7500		0	0	0.0	0.0
-5.5000		0	0	0.0	0.0
-5.2500		0	0	0.0	0.0
-5.0000		0	0	0.0	0.0
-4.7500		0	0	0.0	0.0
-4.5000		0	0	0.0	0.0
-4.2500		0	0	0.0	0.0
-4.0000		0	0	0.0	0.0
-3.7500		0	0	0.0	0.0
-3.5000		0	0	0.0	0.0
-3.2500		0	0	0.0	0.0
-3.0000		0	0	0.0	0.0
-2.7500		0	0	0.0	0.0
-2.5000		0	0	0.0	0.0
-2.2500		0	0	0.0	0.0
-2.0000	B	1	1	1.9	1.9
-1.7500	BB	2	3	3.8	5.7
-1.5000		0	3	0.0	5.7
-1.2500	B	1	4	1.9	7.5
-1.0000	B	1	5	1.9	9.4
-.75000	BB	2	7	3.8	13.2
-.50000		0	7	0.0	13.2
-.25000	BBB	3	10	5.7	18.9
0.0000	BB	2	12	3.8	22.6
.25000	BBB	3	15	5.7	28.3
.50000	BB	2	17	3.8	32.1
.75000	BB	2	19	3.8	35.8
1.0000	B	1	20	1.9	37.7
1.2500	BBBB	4	24	7.5	45.3
1.5000	BBBBBBB	7	31	13.2	58.5
1.7500	BBBB	4	35	7.5	66.0
2.0000	BBBB	4	39	7.5	73.6
2.2500	BBBB	4	43	7.5	81.1
2.5000	B	1	44	1.9	83.0
2.7500		0	44	0.0	83.0
3.0000	BB	2	46	3.8	86.8
3.2500	B	1	47	1.9	88.7
3.5000	BB	2	49	3.8	92.5
3.7500	B	1	50	1.9	94.3
4.0000	B	1	51	1.9	96.2
4.2500	B	1	52	1.9	98.1
4.5000	B	1	53	1.9	100.0
4.7500		0	53	0.0	100.0
5.0000		0	53	0.0	100.0
5.2500		0	53	0.0	100.0
5.5000		0	53	0.0	100.0
5.7500		0	53	0.0	100.0
6.0000		0	53	0.0	100.0
6.2500		0	53	0.0	100.0

Figure 9. Histogram of Log MATFAC - Bearing Tests

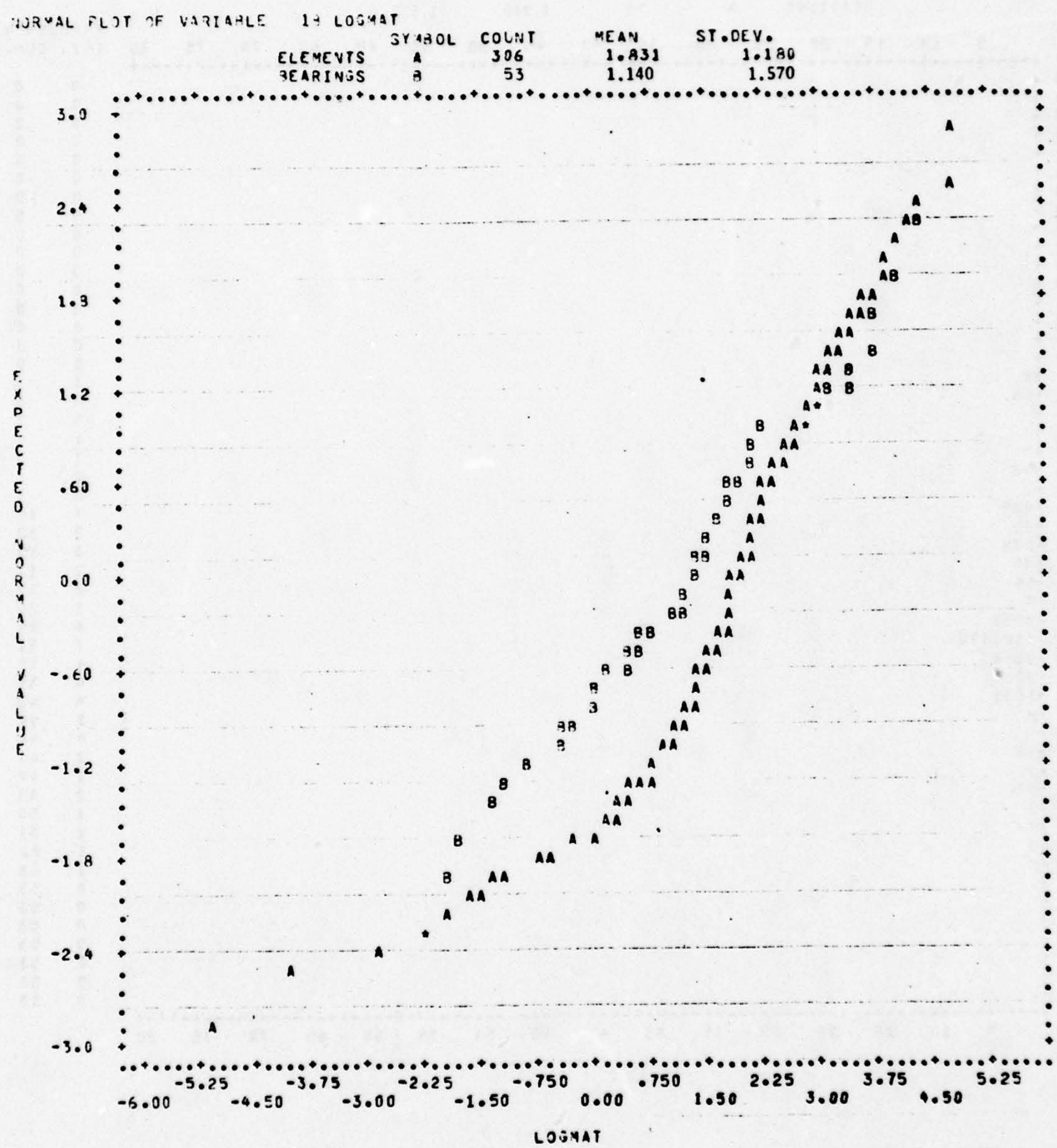


Figure 10. Normal Plot of Log MATFAC - Element and Bearing Tests

where S.D. denotes the standard deviation of LOGMAT and N is the sample size. This interval does not depend strongly on an assumption that LOGMAT is normally distributed because, by the central limit theorem $\overline{\text{LOGMAT}}$ will tend to be normally distributed for large N irrespective of the distribution of LOGMAT.

Using the values from Table 6 gives:

for bearings:

$$1.14 - \frac{1.645 \times 1.57}{(53)^{1/2}} < \overline{\text{LOGMAT}} < 1.14 + \frac{1.645 \times 1.57}{(53)^{1/2}}$$

$$0.7852 < \overline{\text{LOGMAT}} < 1.495$$

$$\exp(0.7852) < \overline{\text{MATFAC}} < \exp(1.495)$$

$$2.19 < \overline{\text{MATFAC}} < 4.46$$

and for elements:

$$1.83 - \frac{1.645 \times 1.18}{(306)^{1/2}} < \overline{\text{LOGMAT}} < 1.83 + \frac{1.645 \times 1.18}{(306)^{1/2}}$$

$$5.58 < \overline{\text{MATFAC}} < 6.96$$

The fact that the confidence interval on the material factor calculated for bearings does not overlap that calculated for element tests indicates that the material factor differs for bearings and element tests as a class. This may be confirmed directly by calculating the standardized difference in the average value of LOGMAT [8].

[8] Dixon, W. J., and Massey, F. J., "Introduction to Statistical Analysis", McGraw-Hill Book Company, Inc., 2nd Edition 1957.

$$Z = \frac{\overline{(LOGMAT)}\ Elements - \overline{(LOGMAT)}\ Brgs.}{\left[\left(\frac{(S.D.)^2}{N}\right)_{Bearings} + \left(\frac{(S.D.)^2}{N}\right)_{Elements}\right]^{1/2}}$$

Using the values in Table 6

$$Z = \frac{1.83 - 1.14}{\left[\frac{(1.57)^2}{53} + \frac{(1.18)^2}{306}\right]^{1/2}} = 3.05$$

From tables of the standard normal distribution this value is significantly different from zero at a level 0.3%, establishing the statistical significance of the difference seen between the two values of the material factor.

In the foregoing analysis, each test series was considered equally in calculating the estimated value of MATFAC. This is a valid procedure, but optimally, for minimum variance estimation of the mean, each individual value of LOGMAT should be weighed inversely to the variance with which it is determined [9]. This variance will depend upon sample size and the number of failures in a way that would have to be determined by Monte Carlo sampling. To date, the appropriate weighting factors have not been established.

It was felt, however, that it might be an improvement over the equal weighting case to weigh the contribution of each test by the number of failed elements.

For notational convenience denote the i-th value of the logarithm of MATFAC within the element or bearing test series by X_i and the associated number of failures as r_i. The weighted estimate of ln [MATFAC] is then:

$$\ln\,[MATFAC] = \sum_1^N r_i X_i \Big/ \sum_1^N r_i$$

[9] Bain, L. J., "Statistical Analysis of Reliability and Life-Testing Models", Marcel Dekker, Inc. 1978

where N is the number of tests. The quantity $r_i X_i$ was defined previously as WTFAC. Dividing numerator and denominator of this expression by N gives the equivalent form

$$\ln\ \overline{[\text{MATFAC}]} = \frac{\sum_1^N r_i X_i / N}{\sum_1^N r_i / N} = \frac{\overline{\text{WTFAC}}}{\bar{r}}$$

where the bar denotes averaging over the number tests. From the values in Table 6 one has:

$$\ln\ \overline{[\text{MATFAC}]} = 12.4/11.0 = 1.13$$

or

$$\overline{\text{MATFAC}} = 3.09$$

in agreement with the value calculated with equal weighting.

For elements:

$$\ln\ \overline{[\text{MATFAC}]} = [14.57/8.57] = 1.700$$

or

$$\overline{\text{MATFAC}} = 5.47$$

this value is somewhat lower than the unweighted value of 6.23.

The variance of the weighted average is:

$$\text{var}\ [\Sigma r_i X_i / \Sigma r_i] = \frac{N \text{var}[\text{WTFAC}]}{(\Sigma r_i)^2}$$

The standard deviation is:

$$\text{S.D.} = \text{var}^{1/2}[\Sigma r_i X_i / \Sigma r_i] = \frac{N^{1/2} \text{S.D.}[\text{WTFAC}]}{\Sigma r_i}$$

$$= \frac{\text{S.D.}\ [\text{WTFAC}]}{N^{1/2}\ \bar{r}}$$

90% confidence limits are then

$$\ln\,[\overline{\text{MATFAC}}] - \frac{1.645\ \text{S.D.}\ (\text{WTFAC})}{N^{1/2}\,\bar{r}} < \ln\,[\text{MATFAC}] < \ln\,[\overline{\text{MATFAC}}] + \frac{1.645\ \text{S.D.}\ (\text{WTFAC})}{N^{1/2}\,\bar{r}}$$

For bearings:

Using the values in Table 6 gives:

$$0.582 = 1.13 - \frac{1.645 \times 26.7}{(53)^{1/2} \cdot 11.0} < \ln\,[\text{MATFAC}] < 1.13 + \frac{1.645 \times 26.7}{(53)^{1/2} \cdot 11.0} = 1.678$$

or

$$1.79 = \exp\,(0.582) < \text{MATFAC} < \exp\,(1.678) = 5.36$$

For elements the confidence interval is,

$$1.486 = 1.70 - \frac{1.645 \times 13.13}{(306)^{1/2} \times 5.77} < \ln\,[\text{MATFAC}] < 1.70 + \frac{1.645 \times 13.13}{(306)^{1/2} \times 5.77} = 1.913$$

or

$$4.42 = \exp\,[1.48] < \text{MATFAC} < \exp\,[1.913] = 6.78$$

The confidence intervals on the calculated values of the material factor are now seen to be wider (i.e. the ratio of upper to lower limit is greater) with weighting by failure number then with equal weighting. Weighting by failure number is evidently too severe i.e. a test with 72 failures is not 72 times more informative than a test with a single failure.

Thus there is no reason to substitute the values obtained from this weighting technique for the ones calculated by the equal weighting method applied first. It is assumed that other approximate weighting schemes could be evaluated to improve the estimates, but this type of evaluation was considered to be outside the general scope of this program.

G. Scatter Plot Analysis

As discussed earlier, if the theoretical life and FILFAC are adequately calculated, the value of the material factor should, not vary with respect to the variables that enter those calculations. For example, since element size is included in the L_{10} capacity (life) calculation, there should be no systematic variation of the experimental values of the material factor achieved from test bearings of varying sizes. Any trend in the material factor with variables that should thus be accounted for, is indicative of a systematic error in the formulation.

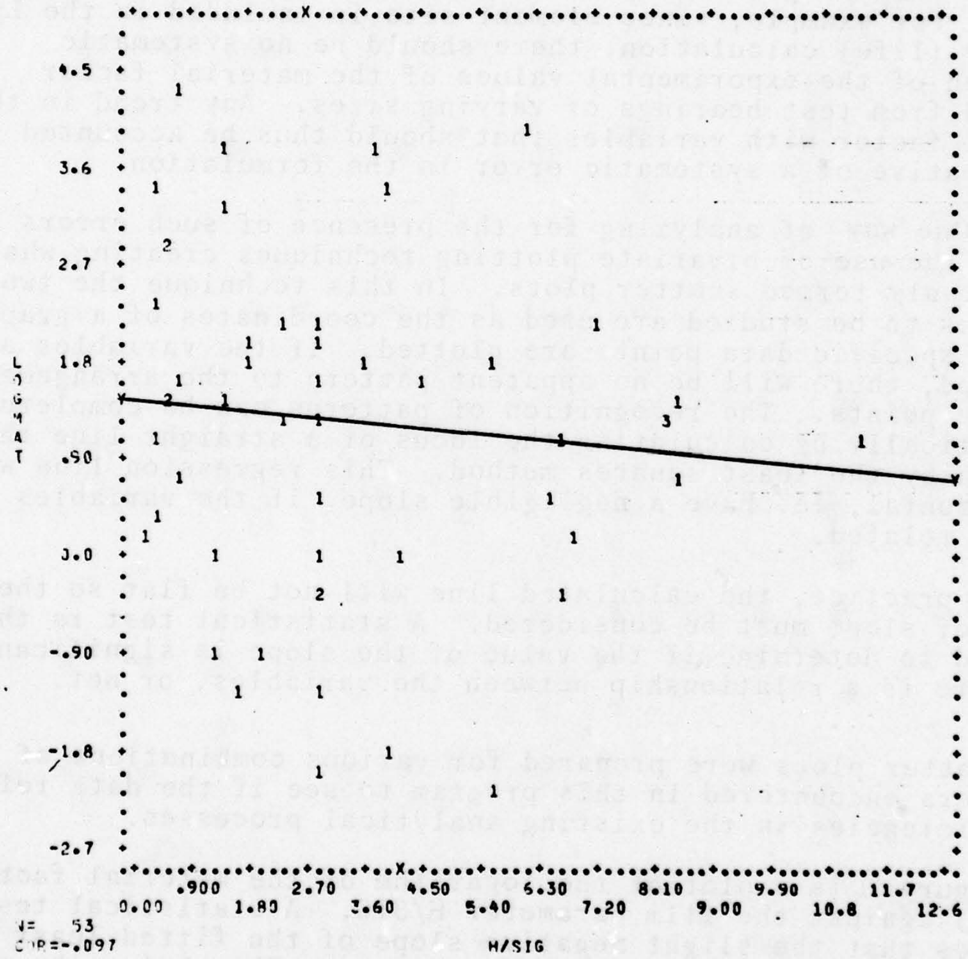
One way of analyzing for the presence of such errors is through the use of bivariate plotting techniques creating what are commonly termed scatter plots. In this technique the two variables to be studied are used as the coordinates of a graph and the specific data points are plotted. If the variables are unrelated, there will be no apparent pattern to the arrangement of these points. The recognition of patterns can be completed mathematically by calculating the locus of a straight line through the data by the least squares method. This *regression line* will be horizontal, ie. have a negligible slope, if the variables are not related.

In practice, the calculated line will not be flat so the degree of slope must be considered. A statistical test is then employed to determine if the value of the slope is significant, ie. there is a relationship between the variables, or not.

Scatter plots were prepared for various combinations of parameters encountered in this program to see if the data reflect any deficiencies in the existing analytical processes.

Figure 11 is a plot of the logarithm of the material factor (LOGMAT) against the film parameter H/SIG. A statistical test indicates that the slight negative slope of the fitted least squares regression line is not significant. This being the case, there is no systematic error in the method of calculating the film factor which biases the values obtained for the material factor for full scale bearing data.

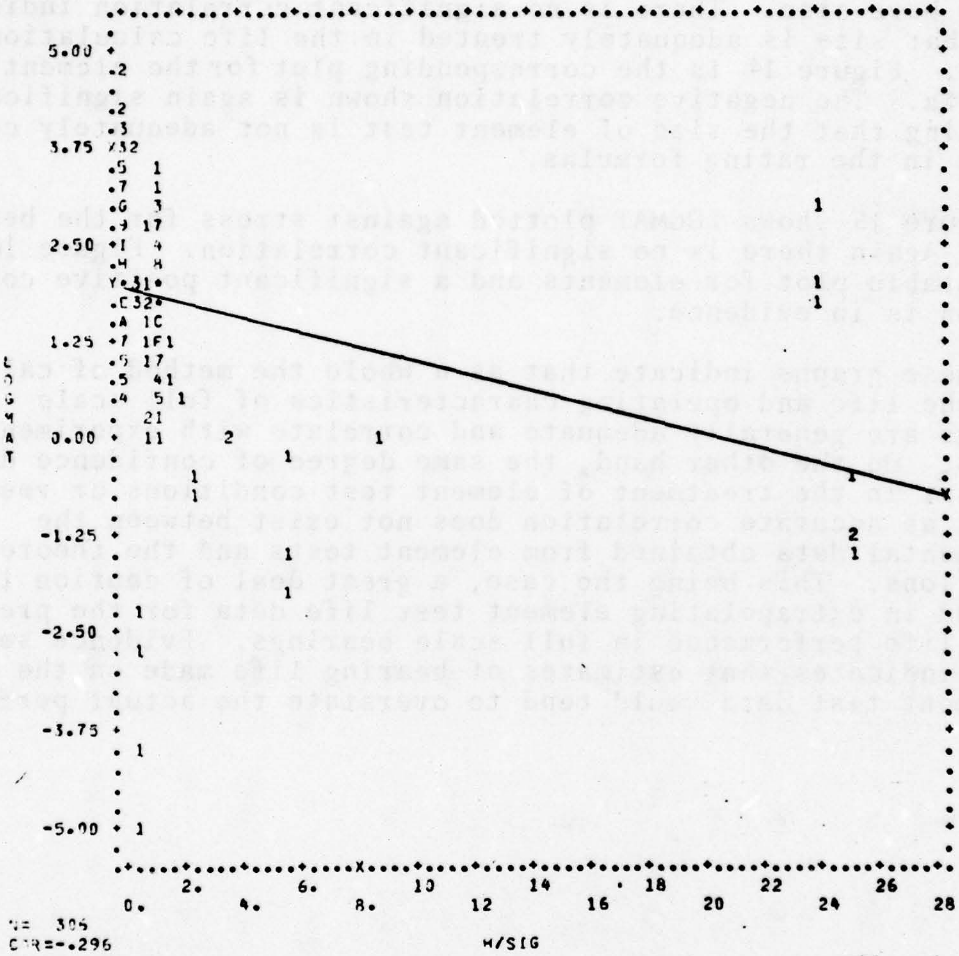
On the other hand, Figure 12 shows the same variables plotted for the element test data. The plot shows a significant negative correlation in these data suggesting that for element tests the values assigned to the film factor are too small in the low film thickness regions i.e. element tests conducted at low film conditions live longer than the ASME curve suggests.



N= 53
CORR=-.097

	MEAN	ST.DEV.	REGRESSION LINE	RES.MS.
X	3.4253	2.7928	X=-.17358*Y+ 3.6279	7.4780
Y	1.1671	1.5567	Y=-.05393*X+ 1.3519	2.4477

Figure 11. LOGMAT VS H/SIG - Bearing Tests



N= 305
COR=-.296

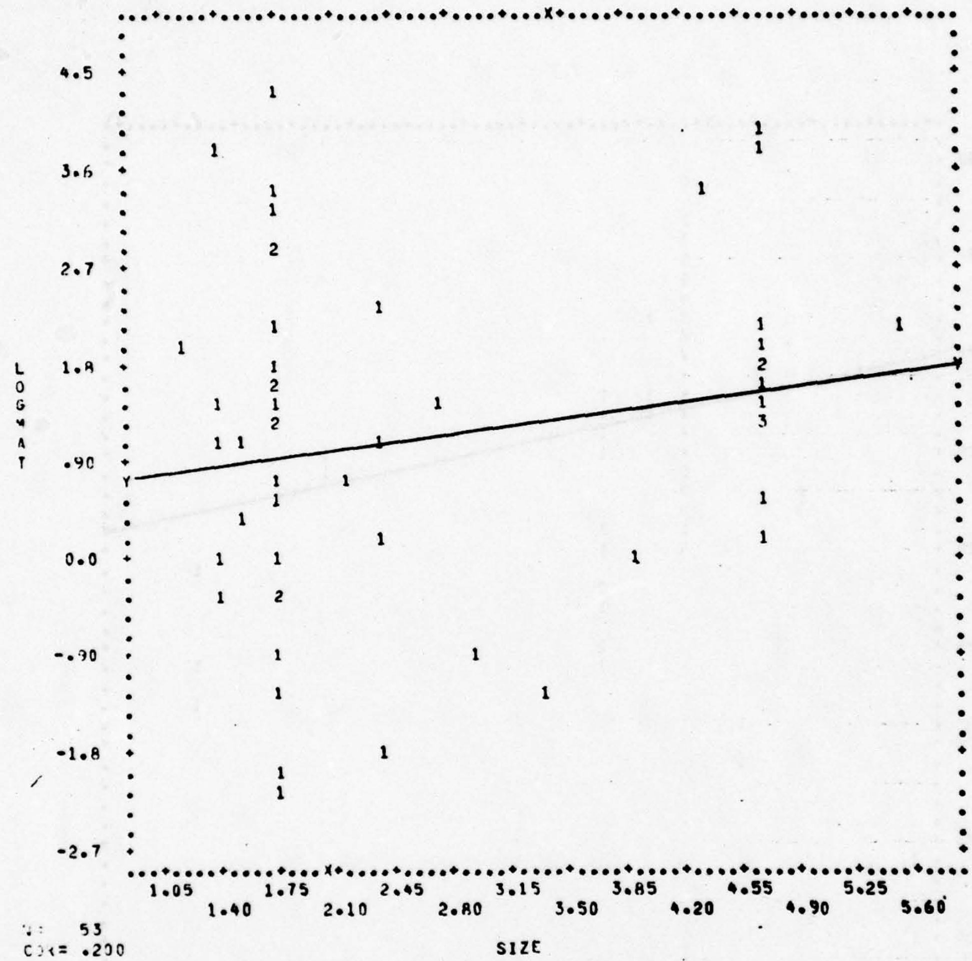
	MEAN	ST.DEV.	REGRESSION LINE	RES.MS.
X	1.2881	3.7158	X=-.93160*Y+ 2.9939	12.639
Y	1.8310	1.1804	Y=-.09402*X+ 1.9522	1.2755

Figure 12. LOGMAT VS H/SIG - Element Tests

Figure 13 is a plot of LOGMAT for the bearing data versus bearing bore size. There is no significant correlation indicating that size is adequately treated in the life calculation process. Figure 14 is the corresponding plot for the element test data. The negative correlation shown is again significant suggesting that the size of element test is not adequately considered in the rating formulas.

Figure 15 shows LOGMAT plotted against stress for the bearing tests. Again there is no significant correlation. Figure 16 is a comparable plot for elements and a significant positive correlation is in evidence.

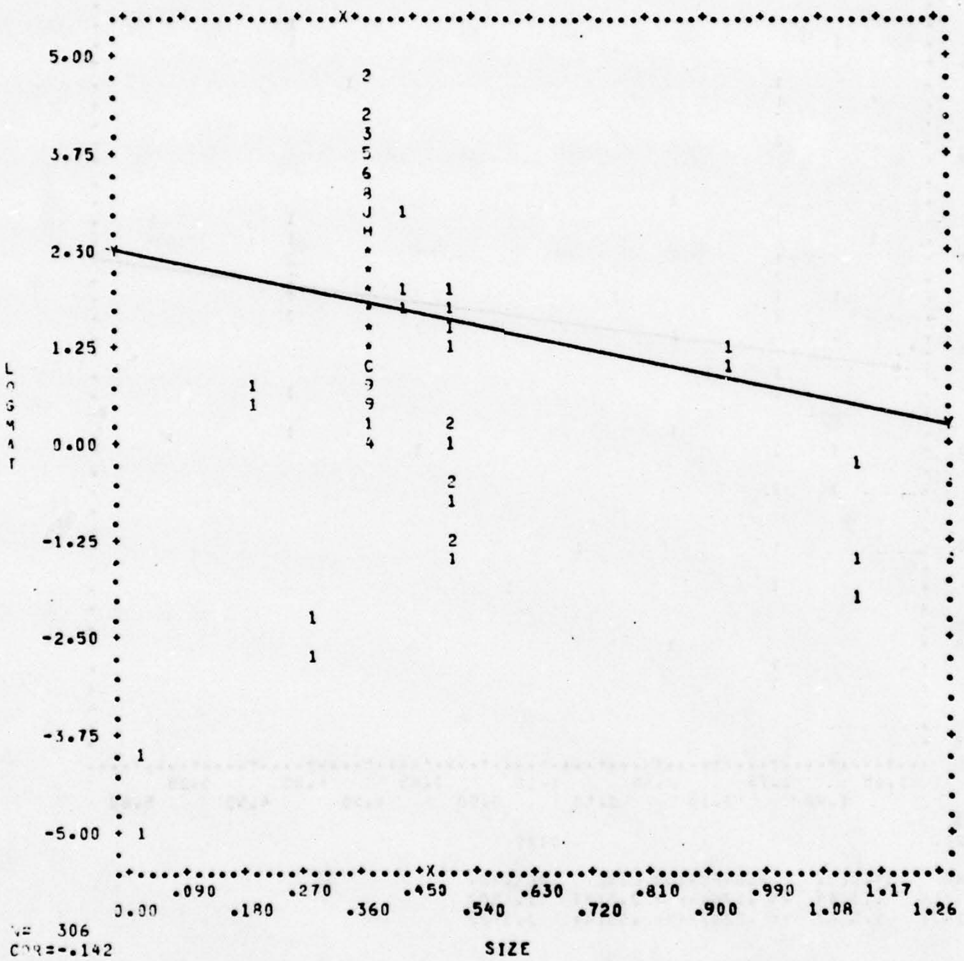
These graphs indicate that as a whole the method of calculating the life and operating characteristics of full scale bearings are generally adequate and correlate with experimental results. On the other hand, the same degree of confidence does not exist in the treatment of element test conditions or results so that an accurate correlation does not exist between the experimental data obtained from element tests and the theoretical predictions. This being the case, a great deal of caution is required in extrapolating element test life data for the prediction of life performance in full scale bearings. Evidence seen herein indicates that estimates of bearing life made on the basis of element test data would tend to overstate the actual performance.



N= 53
CORR= .200

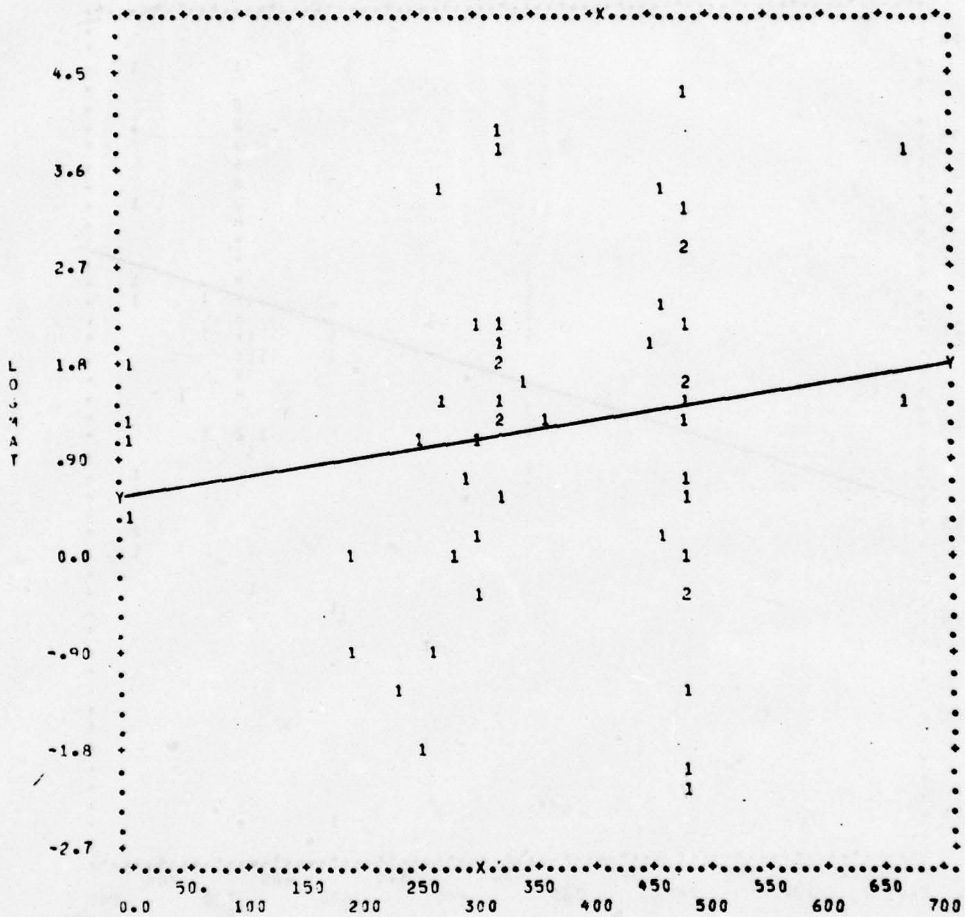
	MEAN	ST.DEV.	REGRESSION LINE	RES.MS.
X	2.7216	1.3749	X= .17644*Y+ 2.5157	1.8502
Y	1.1671	1.5567	Y= .22622*X+ .55144	2.3722

Figure 13. LOGMAT VS Size - Bearing Tests



	MEAN	ST.DEV.	REGRESSION LINE	RES.MS.
X	.38786	.09622	X=-.01154*Y+ .40898	.00910
Y	1.8310	1.1804	Y=-1.7361*X+ 2.5044	1.3700

Figure 14. LOGMAT VS Size - Element Tests

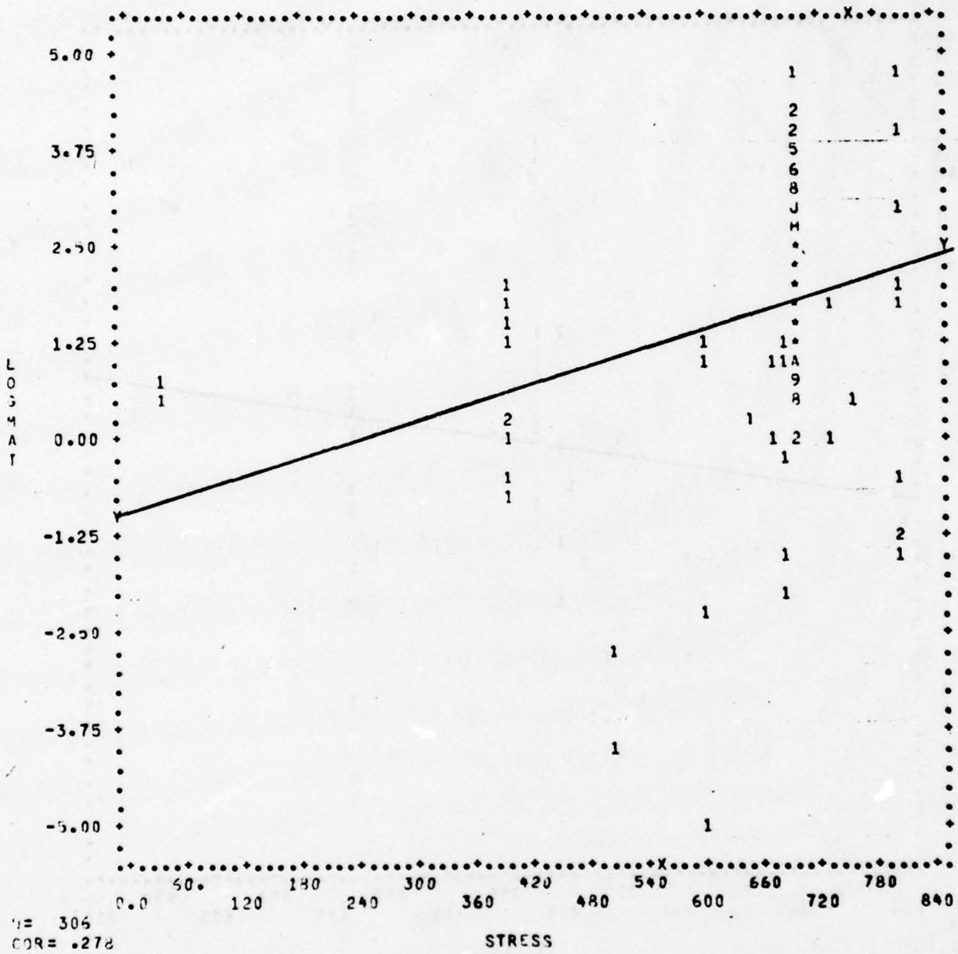


N= 53
COR= .151

STRESS

	MEAN	ST.DEV.	REGRESSION LINE	RES.MS.
X	356.79	149.37	X= 14.518*Y+ 339.85	22227.
Y	1.1671	1.5567	Y= .00158*X+ .60450	2.4143

Figure 15. LOGMAT VS Stress - Bearing Tests



N= 306
COR= .278

	MEAN	ST.DEV.	REGRESSION LINE	RES.MS.
X	686.78	78.405	X= 13.490*Y+ 652.94	5690.1
Y	1.8310	1.1804	Y= .00419*X-1.0457	1.2898

Figure 16. LOGMAT VS Stress - Element Tests

H. Principal Statistical Results

1. The distribution of the calculated material factor for both bearing and element tests made of M-50 steel was found to be severely skewed to the right. Consequently more than 70% of the observed material factor values are lower than their arithmetic average. Arithmetic averages are therefore quite misleadingly high. This explains why honest claims based on average material factor could be received with skepticism since it is likely that lower than average values would result if testing were done to corroborate a claimed value.

2. The geometric mean or logarithmic average value, was found to be close to the data median, i.e., roughly 50% of the tests give values above and 50% give values below the geometric mean. In a data base of 53 tests of M-50 rolling contact bearings, dominated by point contacts, the geometric mean material factor was found to be 3.13. Considering vacuum melted data only, 48 test lots, the geometric mean material factor increases to 3.55.

A total of 306 element tests, performed principally on an RC rig yielded a geometric mean material factor of 6.23 which was established to be statistically different from the factor calculated for bearings.

Material factors derived from element test results are thus likely to be overstated when applied to full scale bearings.

3. No systematic errors in the ASME film factor or the rating life formula could be discerned for the bearing tests. This does not mean there are no such errors, just that their magnitude is too small, relative to the substantial scatter in the data to emerge in as few as 53 tests.

4. The material factor for the element tests shows significant dependence on the film parameter, stress and element size indicative of small but real errors in the factor used to compensate for the effect of the lubricant film parameter, and in the rating formulas used to calculate the base life for the tests.

III. ENDURANCE TEST DETAILS

A. Test Equipment

All tests were conducted on SKF R-2 Endurance Test Machines which have been developed over a period of years for the evaluation of full size rolling element bearings. Basically, these test machines consist of a horizontal arbor of symmetrical configuration, as shown in Figure 17, supported on either side of its center by two cylindrical roller bearings located in pillow blocks fastened to a machine base. The test bearings are located on each end of this arbor in independent housings to minimize interactions between the test specimens.

Three variations of the basic test machine were employed in this program in order to accommodate the three different types of bearings tested. Each machine configuration was designed to accept the test bearings and to control those parameters critical to the specific bearing configuration. Each was equipped with a means to load the bearings as required, i.e. radial load for the deep groove ball and cylindrical roller bearings; and thrust load for the angular contact ball bearings.

Each test machine variation had a number of features in common which are discussed in the following paragraphs, while the specific alterations to accommodate the bearing designs are described in Sections C1 to C3. The operating temperature of the test bearing was measured by a spring loaded thermocouple contacting the outer ring. The output from this transducer was monitored by a Test Floor Control System containing a Data General Nova 800 Computer System as a central processing unit. The same computer system measures and controls the applied thrust load in the case of the 7209 VAP angular contact ball bearings.

All bearings were run to failure or 300 million revolutions, unless the test was suspended for mechanical reasons, i.e. failure of test machine hardware. Bearing failure was detected by a Robertshaw Vibraswitch which was set at the beginning of each run. The Vibraswitch stopped the test machine when the general vibration level increased significantly over the original magnitude, indicative of a spall on a bearing component.

B. Lubrication

Each bearing was lubricated from a common oil supply system containing Mobil Jet II synthetic lubricating fluid conforming

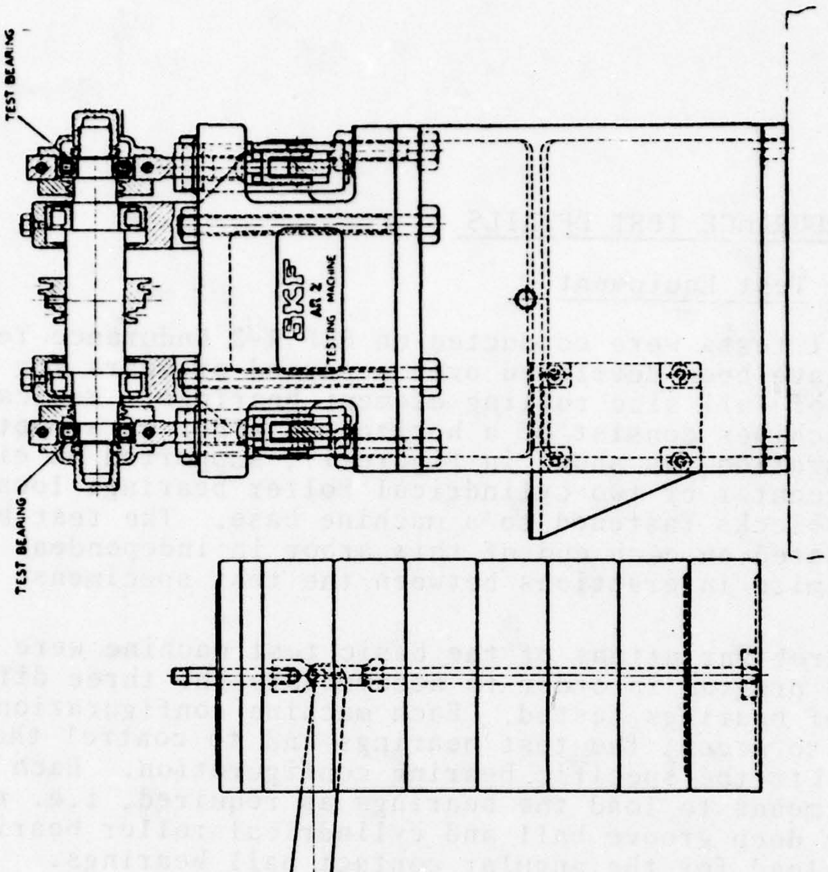


Figure 17. SKF Endurance Test Machine

to government specification MIL-L-23699. The oil was jetted into the test bearing housing and aimed to impinge directly in the rolling contact region. A sufficient quantity of oil was supplied in each instance to assure adequate lubrication and to control the bearing operating temperature at the following levels:

	^{o}C
(a) NU309 VCG Cylindrical Roller Bearing	75-85
(b) 7209 VAP Angular Contact Ball Bearing	60-75
(c) 6009 VAT Deep Groove Ball Bearing	70-75

C. Details of Test Equipment Employed

The following sections discuss the details of the test machine hardware employed for each of the test bearing configurations tested.

1. Cylindrical Roller Bearing

The endurance test machine arrangement employed to determine the life of the NU309 VCG cylindrical roller bearing specimens is shown in Figure 18. The test bearings located on the ends of the machine arbor are radially loaded by means of a lever and dead weight system. The centrally positioned drive pulley on the machine arbor rotates the inner rings at a speed of 9700 rpm.

2. Angular Contact Ball Bearing

Details of the test arrangement used to determine the life of 7209 VAP Angular Contact Ball Bearings are shown in Figure 19. The test bearings located near the ends of the machine arbor are axially loaded by means of a tie rod passing through a clearance hole in the center of the arbor. A Strain Cert (strain gaged) bolt (not shown) on one end of the tie rod measures the amount of thrust load applied as the loading nut (shown) on the other end of the rod is turned. A centrally located pulley on the machine arbor rotates the inner rings at 5500 rpm.

Alignment of the test bearing outer ring with respect to the inner ring and arbor is maintained by means of a small cylindrical roller bearing located at the end of the machine arbor.

3. Deep Groove Ball Bearing

Figure 20 shows the details of the test machine employed to test the 6009 VAT Deep Groove Ball Bearings. The test bearings are located near the ends of the machine arbor. Radial load is applied to the test bearings by means of a lever and dead weight arrangement as shown in Figure 17. Test bearing housing alignment with respect to the machine arbor is maintained by a small cylindrical roller bearing located at the ends of the machine arbor. A quill drive, shown on the left side of the test machine, Figure 20 rotates the machine arbor at 21,200 rpm.

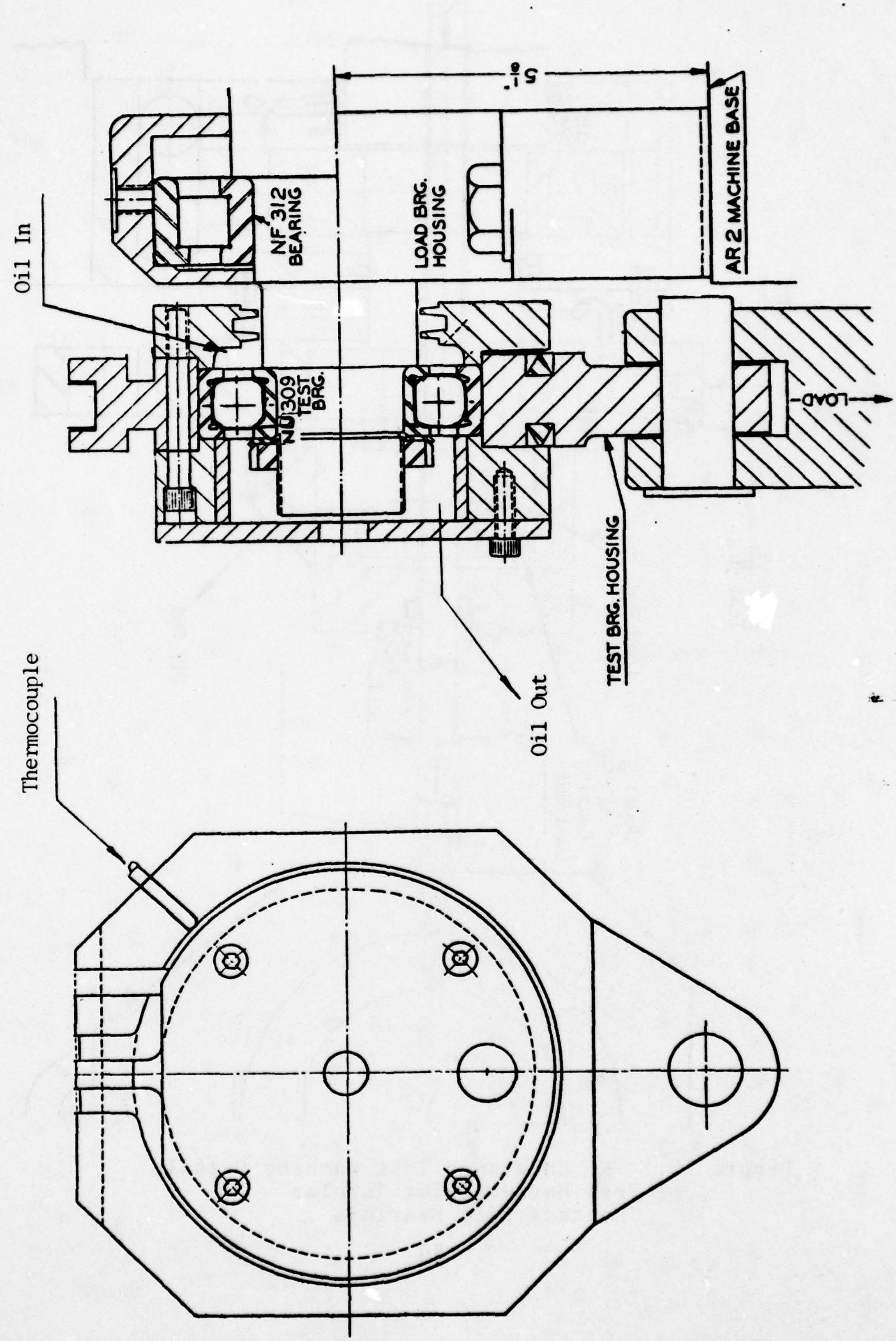


Figure 18. SKF Endurance Test Machine Details of Test Hardware for Cylindrical Roller Bearings

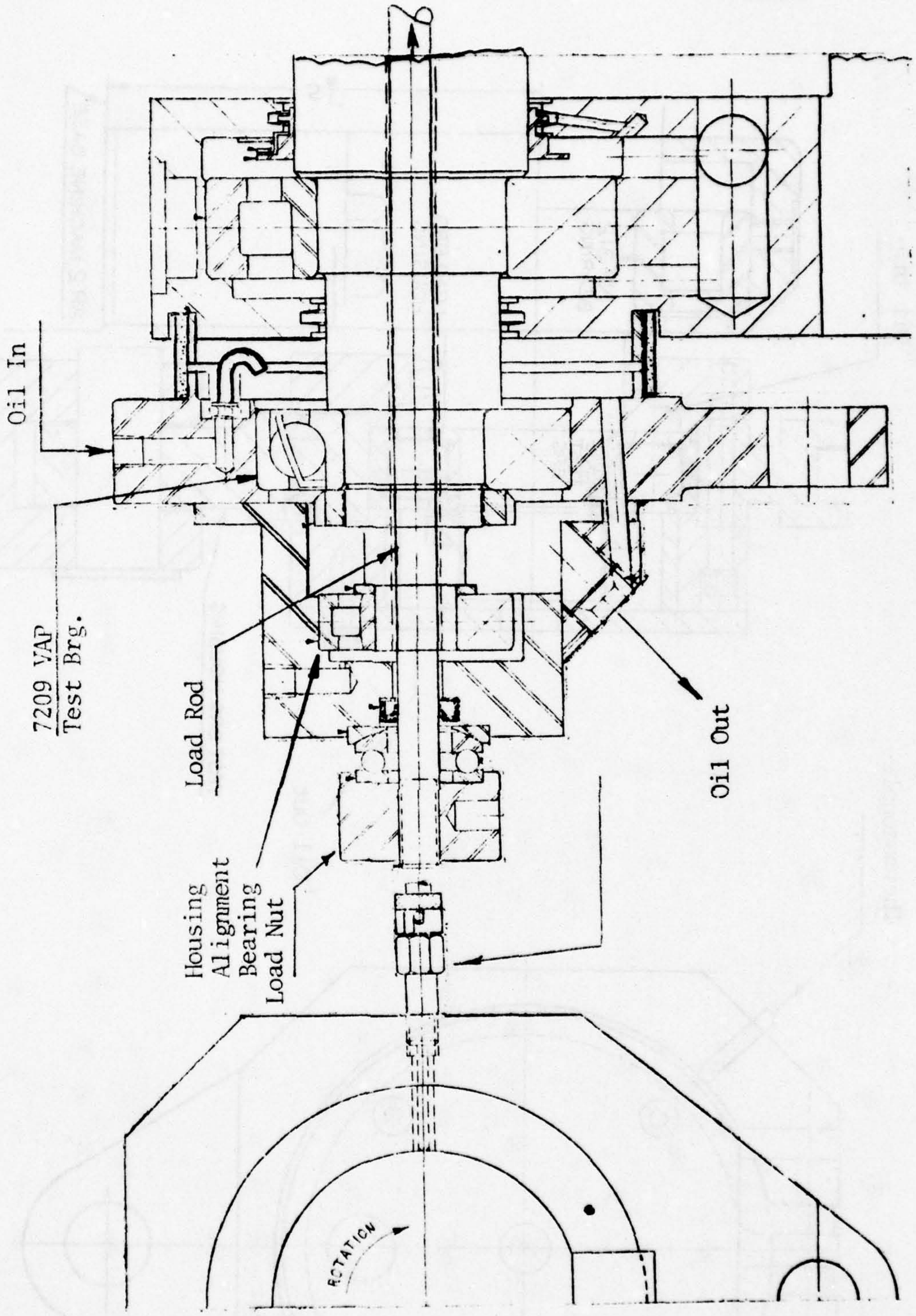


Figure 19. SKF Endurance Test Machine Details
of Test Hardware for Angular
Contact Ball Bearings

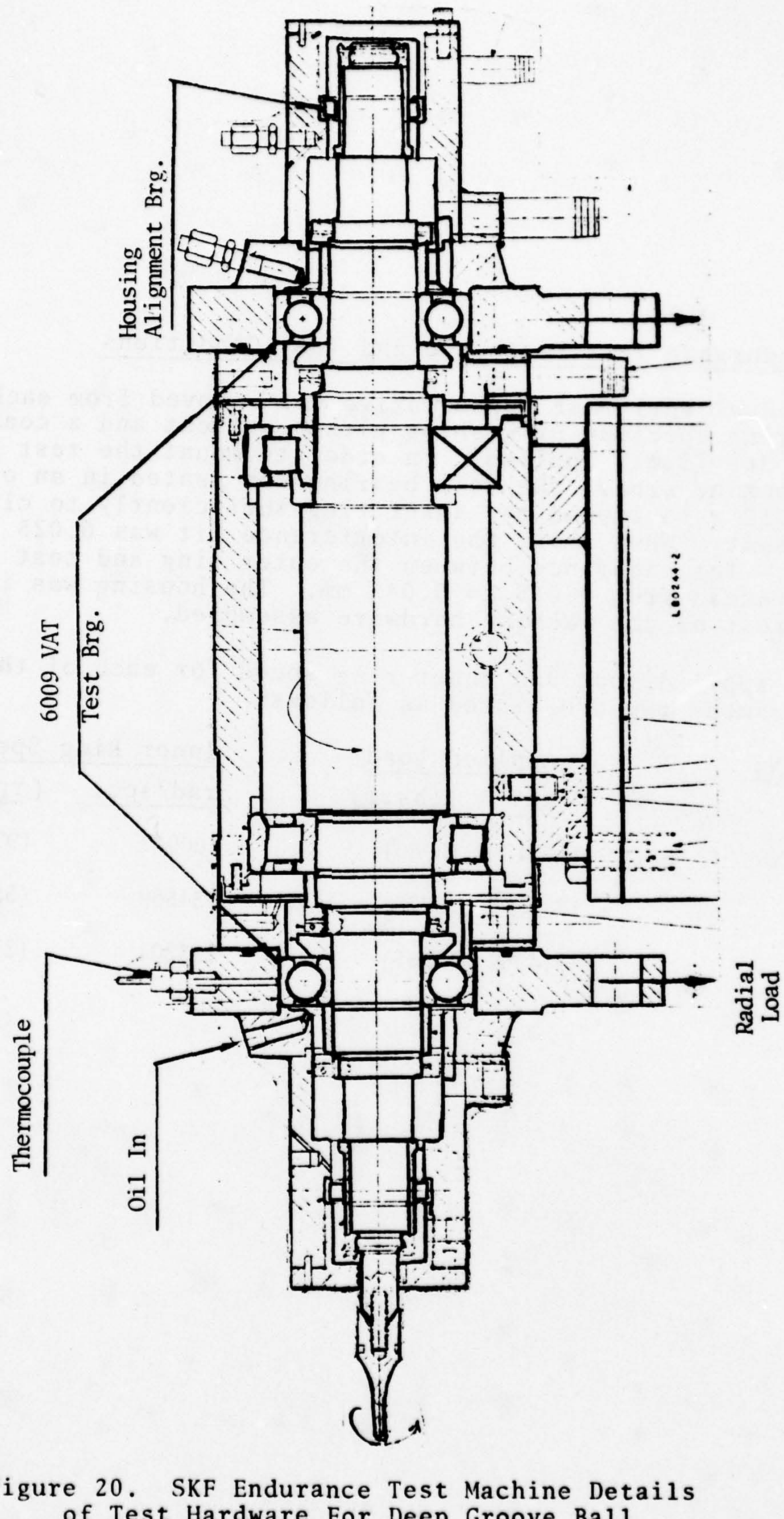


Figure 20. SKF Endurance Test Machine Details of Test Hardware For Deep Groove Ball Bearings

D. Endurance Test Procedure and Test Conditions

Residual anti-rust preservative was removed from each test bearing specimen by washing with a solvent and a coating of Mobil Jet II oil applied. In order to mount the test bearing on the machine arbor, the test bearing was heated in an oven to $408^{o}K$ ($135^{o}C$) to expand the inner ring sufficiently to clear the bearing seat. When cool, the interference fit was 0.025 to 0.035 mm. The clearance between the outer ring and test machine housing ranged from 0.025 to 0.045 mm. The housing was installed and the rest of the machine hardware assembled.

The applied load and inner ring speed for each of the bearing test specimens run are listed as follows:

Bearing No.	Applied Load		Inner Ring Speed	
	Kn	(lbs.f)	rad/sec.	(rpm)
NU309 VCG	31.047	(6980)	60947	(9700)
7209 VAP	12.321	(2770)	34560	(5500)
6009 VAT	7.495	(1685)	133204	(21,200)

E. Endurance Test Results and Discussion

The endurance data collected on the three types of bearings are presented in the following sections of this report. Each section documents the life of a bearing specimen in millions of revolutions and the mode of failure.

The life data of each bearing specimen group have been statistically treated according to an SKF developed maximum likelihood computer program MAXLIKE [10 , and 11]. The program establishes the L_{10} and L_{50} lives and 90% confidence interval estimates for each bearing specimen group, as well as the slope of the experimental Weibull distribution.

A summary of the test results is presented in Table 7. Detailed observations are presented in Tables 8, 9, and 10 for the three bearing types tested.

1. NU309 VCG Cylindrical Roller Bearings

The results shown in Table 8 indicate that most of the NU309 VCG bearings completed the test, and had run 300 million revolutions without failure. The two failures reported are attributed to spalling of one roller in each case as shown in Figure 21. The statistically estimated experimental L_{10} life of 314 million revolutions is 80 times the theoretical L_{10} life of 3.9 million revolutions shown in Table 7. This great difference not only is indicative of the beneficial properties of VIMVAR M-50 steel, but reflects the conservative estimate of theoretical life of thecylindrical roller bearings based upon current engineering approximation practice.

Endurance tests are run on pairs of bearings. When one of the pair fails, the failed bearing is replaced with another test bearing. In the case of bearing No. 419, the companion bearing had reached a time up life of 300 million revolutions at which time bearing No. 419 had accumulated 104 million revolutions. Since there were no additional bearings to test, and considering that further running of bearing No. 419 would not have significantly altered the final outcome of the results, the test was suspended as noted.

[10] McCool, J. I., "Evaluating Weibull Endurance Data by the Method of Maximum Likelihood", ASLE Trans., No. 13, 189-202 (1970).

[11] McCool, J. I., "Interference on Weibull Percentiles and Shape Parameter from Maximum Likelihood Estimates", IEEE Trans. on Reliability, No. R-19, 177-59 (1970).

TABLE 7

SUMMARY OF ENDURANCE LIFE RESULTS - BALL AND ROLLER BEARING TESTS

MATERIAL: VIMVAR M-50 STEEL MATERIAL

LUBRICATION: MOBIL JET II SYNTHETIC FLUID (MIL-L-23699)

BEARING NO.	FAILURE BASIS	SAMPLE NO.	NO. FAILURES	L_{10} LIFE X 10^6 REVS THEORETICAL (a)	EXPERIMENTAL	LCL (b)	UCL (c)	SLOPE BETA	H/SIG
NU309VCG	All Parts	19	2	3.9	314	0.1	40,700	0.543	4.0
6009 VAT	All Parts	20	18	10.9	62	38	84	2.601	2.89
	Excluding Balls	18	4	-	174	132	189	-	-
7209 VAP	All Parts	17	10	122	50	8.3	111	1.002	1.99
	Excluding Balls	17	5	-	115	90	252	-	-

(a) Theoretical calculated life from TABACY

(b) LCL - Lower Confidence Limit

(c) UCL - Upper Confidence Limit

TABLE 8

SUMMARY TEST RESULTS

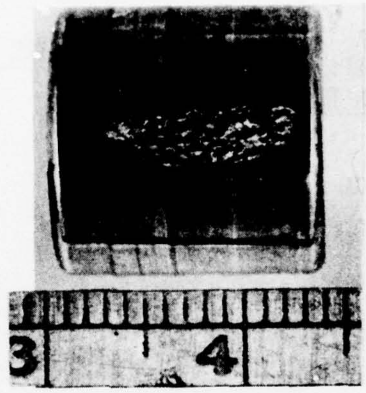
VIMVAR M-50 STEEL - NU309 VCG CYLINDRICAL ROLLER BEARING

BEARING NO.	BEARING LIFE MILLION REVS.	FAILURE MODE RING	ROLLERS	OTHER
401	300	-	-	Suspended
402	300	-	-	Suspended
403	39	-	1	
404	320	-	-	Suspended
405	298	-	-	Suspended
406	298	-	-	Suspended
408	334	-	-	Suspended
409	306	-	-	Suspended
410	300	-	-	Suspended
411	300	-	-	Suspended
412	59.4	-	1	-
413	402	-	-	Suspended
414	355	-	-	Suspended
415	355	-	-	Suspended
416	457	-	-	Suspended
417	457	-	-	Suspended
418	343	-	-	Suspended
419	104	-	-	Suspended
420	313	-	-	Suspended

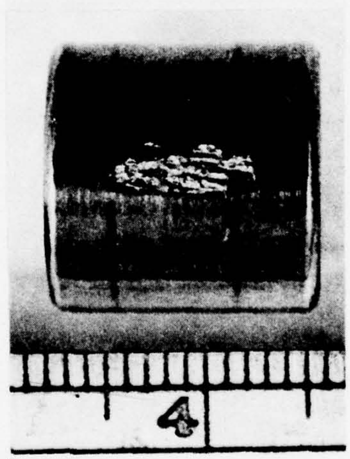
Experimental Bearing Life - Millions of Revs.

L_{10}	L_{10} LCL	L_{10} UCL
314	0.1	40,700
L_{50}	L_{50} LCL	L_{50} UCL
1.6×10^6	1.4×10^3	0.7×10^{76}

Weibull Slope - 0.543



Roller
Bearing No. 403
39 X 10^6 Revs.
(a)



Roller
Bearing No. 412
59 X 10^6 Revs.
(b)

Figure 21. Typical Examples of Roller Failures From NU 309 VCG Cylindrical Roller Bearings

2. 6009 VAT Deep Groove Ball Bearings

Table 9 presents the results obtained on the 6009 VAT deep groove ball bearing specimens. As noted under the mode of failure, all of the failed bearings contained spalled balls; and only eleven bearings had outer or inner ring failures. Examples of these failures are shown in Figure 22. This number of ball failures is abnormally high in comparision to past test and field experience.

In view of this, the fatigue characteristics of this lot of balls were considered to be questionable, and a detailed failure analysis was made on the failed balls (see Section 4). In addition, the experimental life of this group of bearings was determined in two ways: (a) considering all of the element failures, and (b) considering only those failures attributed to ring fatigue and suspending those failures presumed to have been caused by failure of the ball material. The statistical analysis results of the experimental L_{10} lives obtained are given in Table 9.

As shown in the summary, Table 7, the L_{10} median life is 62 million revolutions when the experimental life is based upon all parts failed, and 174 million revolutions if ball failures are excluded and the life is based upon only ring failures. These lives are approximately 6 to 17 times greater than the theoretical L_{10} life of 10.9 million revolutions, once again pointing to the beneficial influence of VIMVAR M-50 steel.

3. 7209 VAP Angular Contact Ball Bearings

The details of the test results obtained on the 7209 VAP angular contact ball bearings run are listed in Table 10. All ten of the 7209 VAP bearings which had failed had suffered ball failures. Of the 10 failures only five bearings had ring failures. Examples of these failures are shown in Figure 23. As with the 6009 VAT bearings, the ball failures are considered to be abnormal not only in quantity, but in the sizes of the spall, as shown in Figure 23(a). The ring failures in some instances were rather small, Figures 23(b) and (c) and it is considered that these could have been initiated by spalled balls.

The experimental median L_{10} life of this group of bearings, considering all element failures, is 50 million revolutions, and 115 million if the ball failures are excluded. These lives are less than the theoretical L_{10} of 122 million which reflects the presence of a degrading influence in this particular test series.

TABLE 9

SUMMARY OF TEST RESULTS

VIMVAR M-50 STEEL - 6009 VAT DEEP GROOVE BALL BEARING

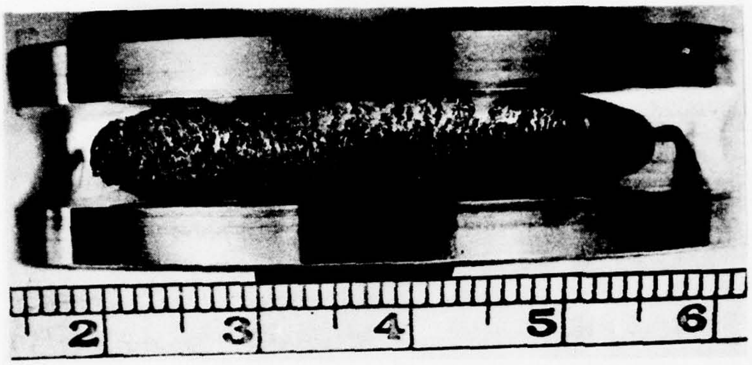
BEARING NO.	BEARING LIFE MILLIONS REVOLUTIONS	FAILURE MODE RING	BALLS	OTHER
301	146.0	IR & OR	3	
302	108.0	-	2	
303	146.0	IR	7	
304	63.6	IR	5	
305	47.0	-	1	
306	33.0	-	-	VOID-Shaft Failure
307	7.6	-	-	VOID-Shaft Failure
308	185.3	-	2	
309	198.4	OR	6	
310	176.5	IR & OR	8	
311	222.0	IR	8	
312	65.9	OR	7	
313	77.5	OR	7	
314	49.5	OR	13	
315	182.8	-	1	
316	160.0	OR	6	
317	119.4	-	1	
318	170.2	-	1	
319	92.8	-	2	
320	222	IR	3	

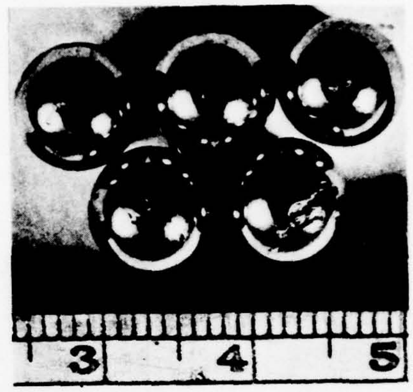
IR = Inner Ring
OR = Outer Ring

Experimental Bearing Life-Millions of Revs.

Failure Basis	L_{10}	L_{10} LCL	L_{10} UCL	Weibull Slope
All Parts	62	38	84	2.601
Rings Only	174	132	189	11.37

Failure Basis	L_{50}	L_{50} LCL	L_{50} UCL
All Parts	132	108	157
Rings Only	219	196	340

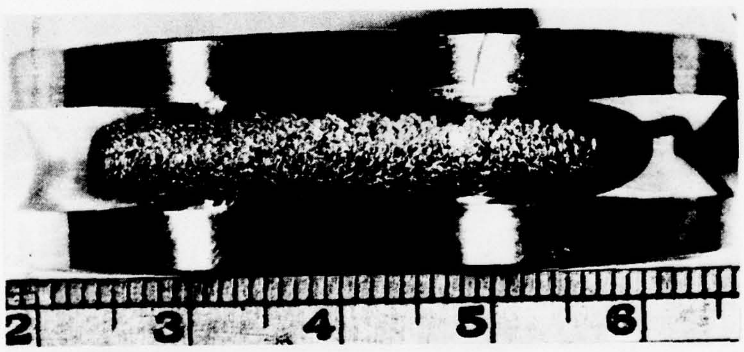




Inner Ring

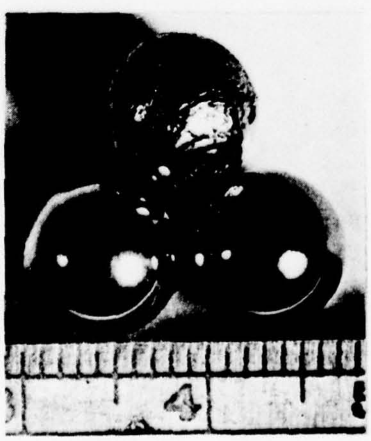
Balls

Bearing No. 304
63.6 X 10^6 Revs.
(a)



Inner Ring

Bearing No. 303
146 X 10^6 Revs.
(b)



Balls

Bearing No. 305
47 X 10^6 Revs.
(c)

Figure 22. Typical Examples of Bearing Element Failures from 6009 VAT Deep Groove Ball Bearings

TABLE 10

SUMMARY OF TEST RESULTS

VIMVAR M-50 STEEL 7209 VAP ANGULAR CONTACT BALL BEARING

BEARING NO.	BEARING LIFE MILLIONS REVOLUTIONS	FAILURE MODE RING	BALLS	OTHER
501	964	-	-	None
502	334	-	7	
503	921	IR	5	
504	212	IR	14	
505	243	-	5	
506	141	IR	6	
507	118	IR	5	
508	47	-	9	
509	307	-	-	None
510	115	-	4	
511	590	-	-	None
512	71	IR & OR	12	
513	399	-	-	None
514	113	-	2	
515	42	IR & OR	11	VOID-Tight Housing
516	300	-	-	None
517	-	-	-	Not Run
518	-	-	-	VOID-Bearing Damaged
519	402	-	-	None
520	300	-	-	None

IR - Inner Ring
OR - Outer Ring

Experimental Bearing Life - Millions of Revs.

FAILURE BASIS	L_{10}	L_{10} LCL	L_{10} UCL	WEIBULL SLOPE
All Parts	50	8.3	111	1.002
Rings Only	115	90	252	1.113

FAILURE BASIS	L_{50}	L_{50} LCL	L_{50} UCL
All Parts	404	220	905
Rings Only	1024	428	10,910

Balls
Bearing No. 510
115 X 10^6 Revs.
(a)

Inner Ring
Bearing No. 508
47 X 10^6 Revs.
(b)

Inner Ring
Bearing No. 514
113 X 10^6 Revs.
(c)

Figure 23. Typical Examples of Bearing Element Failures From 7209 VAP Angular Contact Ball Bearings

4. Metallugrical Examination of VIMVAR M-50 Bearing Failures

6009 VAT Deep Groove Ball Bearing

Two failed 6009 VAT bearings were examined metallurgically. Both bearings had failed prematurely, and were basically "typical" of the remaining failures. The outer rings and a multiple number of balls from each bearing had spalled.

Examination of several of the balls revealed an unusual surface condition, possibly decarburization or at least a carbon gradient. This condition has been found to be "spotty" on several balls while almost continuous on others. Hardness measurements in the aforementioned areas revealed a hardness of R_c61 while the interior hardnesses measured R_c64. Additional inspection of one of the balls indicated that the decarb/carbon gradient occurred after forming, i.e., it is not totally a result of decarburization from raw material.

Further examination of the failures revealed a seemingly "rough" surface on the spalled outer ring. A new bearing was obtained (from the same lot) and measured for surface roughness. Measurements ranged from 0.320 to 0.340 micrometers AA CLA which is slightly above the specified limit of 0.305 micrometers. Visual examination of the generated surface trace disclosed that the surface also contained some localized discontinuities.

From this examination, it appears there are two contributory factors to the failures. Neither one of these conditions is serious enough to cause rejection of the respective parts. However, the combination of the two discrepancies and the fact that the bearings were run under a heavy load contributed to the premature failures.

7209 VAN Angular Contact Ball Bearing

Examination of a number of spalled balls from a failed 7209 VAN ball bearing revealed a heat treat problem, i.e., the balls contained a high amount of soft constituent (troostite/bainite) throughout the microstructure. The remainder of usually rated microstructure and the hardness measurements taken on the balls was acceptable. Several other balls, from the same bearing and other failed bearings, were found to be acceptable to SKF specified limits. While this condition may have affected the life results, the deviation would normally not be considered serious enough to precipitate the large number of very early failures that were experienced in this test.

Visual examination of the premature failures (excluding the ball failure) versus those bearings which had completed the test without failure revealed several small differences in appearance. However, nothing prominent was found between the "failures" and the bearings that had not failed which would in itself explain the premature failures.

In summary, it can be said that the metallurgical analysis disclosed the presence of a ball condition which most likely affected the endurance test results. However, the condition is very mild and therefore it is doubtful that the balls are totally responsible for the foreshortened endurance performance.

5. VIMVAR M-50 Steel Results

A summary of the values of the life multiplication factors a_2 and a_3 that were achieved in the test runs is shown in Table 11. These data show that the log average value of the a_2 material factor ranged from 2.6 to 4.6 depending on whether all failures or only ring failures are considered. These values are essentially the same as the log average material factor of 3.55 which was calculated for CVM M-50 material from the survey. Thus a further life improvement based on the use of VIMVAR processing in lieu of CVM processing has not been established. Therefore, on the basis of the test and survey data, total life multiplication factors, a_2 a_3 ranging from 6-10 are justifiable for both CVM and VIMVAR M-50 material with good lubrication.

Another item of interest which can be observed from Table 11 is the scatter in the calculated a_2 values ranging from 0.2 to 33. While endurance test programs are noted for their wide range of variability and a difference can not be statistically established due to the relatively small amount of data collected, these results do imply that the current methods of calculating the lives of cylindrical roller bearings are conservative. This being the case, an additional multiplication factor for design variation might well be warranted when considering bearings containing line contacts.

This situation has not been sufficiently investigated to date. In Phase II of the program, U.S. Army Contract Number DAAK50-78-C-0027, available life data from current tests and that included in the data base of past work will be statistically analyzed to determine if a significant difference can be established between life modifying factors of cylindrical and ball bearings. If possible, a separate identifiable factor will then be defined for line contact bearings.

TABLE 11

SUMMARY OF TEST RESULTS ON VIMVAR M-50 STEEL

BEARING		a_2 MATERIAL FACTOR	a_3 LUBRICATION FACTOR
NU309 VCG		32.9	2.43
6009 VAT	- All Parts	2.56	2.30
	- Excluding Balls	6.9	2.30
7209 VAP	- All Parts	0.22	2.18
	- Excluding Balls	0.43	2.18

Log AVE a_2 - All Parts 2.6

Log AVE a_2 - Excluding Balls 4.6

IV. CONCLUSIONS

1. The best estimate of the a_2 material factor for both CVM and VIMVAR processed M-50 tool steel has been established as 3.55. This means that for most aerospace applications where good lubrication exists, a film factor of 2 to 3, and the use of a total life multiplication value a_2 a_3 ranging from 6 to 10 is justified.

2. The test data infer that the identified value of the a_2 material factor will be conservative when used to rate cylindrical roller bearings. Further effort is required to determine if a separate factor should be used with line contacts.

3. The use of element test data to establish values of material factors is apt to produce estimates which overstate the actual life advantage available.

4. The proper interpretation of large amounts of endurance test data requires the data to be combined logrithmically and not arithmetically. Life data based on the arithmetic mean produce excessive estimates of the parent population life.

5. Statistical analysis of the experimental data collected do not define any systematic errors in the life calculation formula related to variations in bearing size, stress levels or generated EHD lubricant film. Thus, it is concluded that these parameters are adequately modeled by the analytical techniques.

V. RECOMMENDATIONS

A. Future Data Analysis

The variables included in the current study were basic parameters considered to be inherent in the life estimation process. Now that these have been examined and a degree of confidence has been established in the way these specific parameters are handled in bearing analysis, a number of additional variables that are currently not directly included in the calculation process are open for consideration. The examination of the data base for the inclusions of variations created by alterations in operating parameters such as speed, operating temperature, bearing design type, lubricant chemistry could be extremely revealing. The identification of a parametric relationship which needs to be included in the life estimation process would be of significant interest to bearing users and suppliers; and would provide a means of adding further confidence to the calculation of predicted bearing lives for future applications.

In Phase II of this extended program, U.S. Army Contract No. DAAK50-78-C-0027, a search will be made of the available data base to determine if the documented operational parameters are of sufficient quantity and variety to enable an examination of the influence of these variables on bearing life.

The results of the current tests on cylindrical roller bearings strongly suggest that the life modifying factor for cylindrical roller bearings is underestimated. Results in the data base on cylindrical roller and other line contact bearings will be examined further under Phase II to assess the validity of the trend noted and to define a separate factor for cylindrical bearings if the data warrant.

One major shortcoming defined by the data base is the current inadequacy of life estimates obtained from element test series. While major analytical work is required to correct the predictive deficiencies, the data could be treated to yield correlation factors which could be applied to specific types of element test generated data to provide more adequate extrapolations for bearing applications. Judging from the amount of element test data included in the data base, this would be an extremely important value to have available for future use. However, this analysis is beyond the scope of the work currently contemplated in Phase II.

B. Future Bearing Tests

The amount of data collected to date on VIMVAR processed M-50 tool steel is insufficient to allow a satisfactory statistical estimate of the material factor for this steel variety by itself.

Since this is now the primary aerospace bearing material, the accumulation of additional bearing life test data is warranted in order to improve the statistical validity of the material factor estimate.

Concurrently, the potential influence of variations in operating conditions on bearing life will be explored in Phase II by conducting tests under several additional sets of operational parameters.

Phase II will include the testing of a sample of ball bearings of VIMVAR M-50 steel under several speed and load conditions using two different jet engine synthetic fluids conforming to MIL-L-23699 and MIL-L-7808 government specifications. It is expected that these additional data will augment the information now available, and provide the necessary means to conduct a more comprehensive statistical analysis of the effect of these operational parameters on ball bearing life. However, a similar type of study on line contact bearings, which is also required, is outside the scope of that follow on effort.

ACKNOWLEDGEMENT

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21. Erwin V. Zaretsky, NASA Lewis Research Center, Cleveland, Ohio

LIST OF REFERENCES

[1] Lundberg, G. and Palmgren A., "Dynamic Capacity of Rolling Bearings", Acta Polytechnica, Mechanical Engineering Series 1, Proceedings of the Royal Swedish Academy of Engineering, Vol. 7, No. 3, 1947.

[2] Lundberg, G. and Palmgren A., "Dynamic Capacity of Roller Bearings", Proceedings of the Royal Swedish Academy of Engineering, Vol.2, No. 4, 1952.

[3] Baughman, R. A., "Experimental Laboratory Studies of Bearing Fatigue", ASME Technical Digest, Mechanical Engineering, March 1959 p. 94.

[4] Liu, J. Y., "Final Report on Analytical Method of Life Calculation for Ball and Roller Bearings - A Computer Program", SKF Report No. AL75P033, submitted to USAAVSCOM, and Contract No. DAAJ01-75-C-0349, October, 1975.

[5] Cheng, H. S., "A Numerical Solution of the EHD Film Thickness in an Elliptical Contact", Journal of Lubrication Technology, ASME Trans., Series F, Vol. 92, No. 1, January, 1970, pp. 155-162.

[6] Archard, G. and M. Kirk, "Lubrication at Point Contacts", Proceedings of the Royal Society, A. 261, pp. 532-550 (1961).

[7] Bamberger, E. N., Harris, T. A., Kacmarsky, W. M. Moyer, C. A., Parker, R. J., Sherlock, J. J., and Zaretsky, E. V., Life Adjustment Factors for Ball and Roller Bearings, The American Society of Mechanical Engineers, 1971.

[8] Dixon, W. J., and Massey, F. J., "Introduction to Statistical Analysis", McGraw-Hill Book Company, Inc., 2nd Edition 1957.

[9] Bain, L. J., "Statistical Analysis of Reliability and Life-Testing Models", Marcel Dekker, Inc. 1978.

LIST OF REFERENCES

CONTINUED

[10] McCool, J. I., "Evaluation Weibull Endurance Data by the Method of Maximum Likelihood", ASLE Trans., No. 13, 189-202 (1970).

[11] McCool, J. I., "Inference on Weibull Per-Centiles and Shape Parameter from Maximum Likelihood Estimates", IEEE Trans. on Reliability, No. R-19, 177-59 (1970).

APPENDIX A

Published Sources of M-50 Rolling Contact Fatigue Data

1) Carter, Thomas L., "A Study of Some Factors Affecting Rolling-Contact Fatigue Life," National Aeronautics and Space Administration Technical Report No. NASA TR-R-60, December 1960.

2) Jackson, E. G., "Rolling Contact Fatigue Evaluation of Bearing Materials and Lubricants," ASLE Transactions, Vol. 2, No.1, pp.121-128 (1959).

3) Carter, T. L., Zaretsky, E. V., and Anderson, W. J., "Effect of Hardness and Other Mechanical Properties on Rolling-Contact Fatigue Life of Four High-Temperature Bearing Steels," National Aeronautics and Space Administration Technical Note D-270, March 1960.

4) Baughman, R. A., "Effect of Hardness, Surface Finish, and Grain Size on Rolling-Contact Fatigue Life of M-50 Bearing Steel," ASME Trans., Journal of Basic Engineering, June 1960, pp. 287-294.

5) Bamberger, E. N., Zaretsky, E. V. and Anderson, W. J., "Fatigue Life of 120-mm Bore Ball Bearings at 600°F with Fluorocarbon, Polyphenyl Ether, and Synthetic Paraffinic Base Lubricants," NASA TN D-4850, National Aeronautics and Space Administration, Washington, DC, October 1968.

6) Parker, R. J. and Zaretsky, E. V., "Rolling-Element Fatigue Life of Ausformed M-50 Steel Balls," NASA TN D-4954, National Aeronautics and Space Administration, Washington, DC, December 1968.

7) Zaretsky, E. V., Anderson, W. J. and Bamberger, E. N., "Rolling-Element Bearing Life From 400° to 600°F," NASA TN D-5002, National Aeronautics and Space Administration, Washington, DC, January 1969.

8) Parker, R. J., Zaretsky, E. V. and Dietrich, M. W., "Rolling-Element Fatigue Lives of Four M-Series Steels and AISI 52100 at 150°F," NASA TN D-7033, National Aeronautics and Space Administration, Washington,DC, February 1971.

9) Bamberger, E. N. and Zaretsky, E. V., "Fatigue Lives at 600°F of 120-Millimeter-Bore Ball Bearings of AISI M-50, AISI M-1, and WB-49 Steels," NASA TN D-6156, National Aeronautics and Space Administration, Washington, DC, March 1971.

10) Schlatter, R. and Stroup, J. P., "Improved M50 Aircraft Bearing Steel Through Advanced Vacuum Melting Processes," J. Vac. Sci. Technol., Vol. 9, No. 6, December 1962, pp. 1326-1333.

11) Zaretsky, E. V. and Bamberger, E. N., "Advanced Airbreathing Engine Lubricants Study with a Tetraester Fluid and a Synthetic Paraffinic Oil at 492 K (425°F)," NASA TN D-6771, National Aeronautics and Space Administration, Washington, DC, April 1972.

12) Parker, R. J., Zaretsky, E. V. and Bamberger, E. N., "Evaluation of Load-Life Relation with Ball Bearings at 500°F," ASME Trans., Journal of Lubrication Tech., pp. 391-397, July 1974.

13) Schlatter, R., Double Vacuum Melting of High Performance Bearings Steels, Industrial Heating, September, 1974.

14) Bamberger, E. N., Zaretsky, E. V. and Signer, H., "Endurance and Failure Characteristics of Main-Shaft Jet Engine Bearing at 3 x 10^6 DN," ASME Trans., Journal of Lubrication Tech., Vol. 98, No.4, October 1976.

15) Parker, R. J., and Hodder, R. S., "Rolling-Element Fatigue Life of AMS 5749 Corrosion Resistant, High Temperature Bearing Steel," ASME Trans., Journal of Lubrication Tech., June 1977, Paper No. 77-Lub-30.

16) Bamberger, E. N., "The Effect of Ausforming on the Rolling Contact Fatigue Life of a Typical Bearing Steel," ASME Trans., J. Lub. Tech., Vol. 89, No. 1, January 1967, pp. 63-75.

17) Scott, D. and Blackwell, J., "Study of Materials for Unlubricated and Elevated Temperature Rolling Elements," National Engineering Laboratory Report No. 278, February 1967.

18) Scott, D. and Blackwell, J., "A Study of the Effects of Elevated Temperature Lubricants on Materials for Rolling Elements," National Engineering Laboratory Report No. 317, August 1967.

19) Bamberger, E. N., "The Production, Testing and Evaluation of Ausformed Ball Bearings," Final Engineering Report prepared under Navy, Bureau of Naval Weapons Contract NOw-65-0070-f, June 1966.

20) Simon, K., "Life Improvement of Helicopter Transmission Bearings Airmelt vs. Vacuum Melt Steel Bearings," Boeing Co., Vertol Div., Morton, Pa., No. 107M-T-172, U. S. Navy Bureau of Weapons Contract No. NOw65-0130-f, February 1969.

21) Bamberger, E. N., Clark, J. C., Russell, T. E. and Smeaton, D. A., "Axial-Centrifugal Compressor Program, Evaluation of Ausformed Bearings," GE Final Report, USAAMRDL Contract No. DAAJ02-71-C-0050, USAAMRDL-TR-75-55, February, 1976.

22) Santé, Michel, "Amélioration de l'endurance des roulements par l'emploi d'aciers rapides," Ingenieurs et Techniciens, 292, Janvier-Fevrier 1975.

APPENDIX B

DATA SOLICITATION LETTER

Address

Dear Sir:

We are compiling, under a contract to AVRADCOM, St. Louis, rolling contact endurance data on M50 tool steel. The objective of the effort is to determine the material factor with which to correct the catalog life predictions for this steel.

We are herewith soliciting any data and/or reference you can contribute on M50 steel obtained either in element (ball, disc, washer) or full scale bearing tests.

Ideally a full set of test particulars would be most desirable, but we can make use of the data even if some details of the test are unspecified. The following information is desired:

(1) Bearing size and (operating clearance) or test element geometry

(2) Material melting practice (CVM, VIMVAR, etc.)

(3) Type and Magnitude(s) of Loading

(4) Speed

(5) Operating Temperature

(6) Lubricant Type

(7) Lubricant viscosity, at operating temperature

(8) Method of Lubricant Supply (circulating oil, drip feed, etc.)

(9) Life at failure or test suspension of each specimen

(10) Surface finish of each ring and the rolling elements

Our approach will be to:

(1) Recalculate L_{10} life if necessary using the method of maximum likelihood.

(2) Calculate "catalog type" life, but accounting for combined load and centrifugal effects via a load distribution computer program we have developed.

(3) Calculate a lubricant film based upon a calculated ratio of film thickness to surface roughness ration.

The material factor will then be calculated for each test group by dividing the estimated L10 life by the product of the catalog life and the lubricant film correction factor.

We intend to observe whether estimated material factor varies systematically with other factors.

We feel that this study will be quite illuminating and useful if sufficient data can be assembled.

APPENDIX C

DATA SOURCES M-50 STEEL ENDURANCE TESTS

REF. NO.	REFERENCE	TYPE OF TEST	NO. OF TESTS	SAMPLE SIZE	TEST VARIABLES	REMARKS
58-1	SKF Test Series No. F849(1958)	45mm bore single row deep groove ball bearings	2	31, 32	Temp: ambient and 230^{o}C	Air melt
59-1	Carter, T.L., "A Study of Some Factors Affecting Rolling-Contact Fatigue," NASA Technical Report NASA-TR-R-60 (1960)	Spin rig	2	23, 11	Stress: 600,000 and 750,000 psi	Cylinders are test element. Air melt M-50. Raw data not given.
59-2	Jackson, E.G., "Rolling Contact Fatigue Evaluation of Bearing Materials and Lubricants," ASLE Trans. Vol. 2, No. 1, pp 121-128 (1959).	Thompson single ball tester	8	8, 13	Melting practice - air and vacuum hardness and oil condition (fresh or old)	Raw data given on Weibull Plots only. Rig details not given. Omitted.
59-3	SKF Test Series No. F1041	45mm bore single row deep groove ball bearings	1	30		CVM M50
60-1	Carter, T.L., Zaretsky, E.V. and Anderson, W. J., "Effect of Hardness and Other Mechanical Properties on Rolling-Contact Life of Four High-Temperature Bearing Steels," NASA TN D-270 (1960)	Spin rig	4	26-44	Hardness	CVM Data on Weibull plots - only failures are shown
60-2	Baughman, R.A., "Effect of Hardness, Surface Finish and Grain Size on Rolling-Contact Fatigue Life of M-50 Bearing Steel".	RC rig	10	4,12	Stress and surface finish	Samples were combined from tests run with different grain size and hardness. Data for hardness levels bel[illegible] RC58 were excluded. Air melt.

APPENDIX C

DATA SOURCES M-50 STEEL ENDURANCE TESTS

REF. NO.	REFERENCE	TYPE OF TEST	NO. OF TESTS	SAMPLE SIZE	TEST VARIABLES	REMARKS
61-1	SKF Test Series No. F1254	45mm bore single row deep groove ball bearings	3	30	replicate tests	Air melt M-50
62-1	SKF Test Series No. F1456 (1962)	45mm bore single row deep groove ball bearing inners	1	30		CVM
64-1	SKF Test Series F4491 (1964)	45mm bore single row deep groove ball bearing inners	1	10		CVM
64-2	SKF Test Series F4806	45mm bore single row deep groove ball bearing inners	4	10-14	heat and number of remelts	CVM
66-1	Pratt & Whitney Aircraft Co., "PWA Bearing Research and Development," Nov. 1965	PWA, one ball rig	9	10 - 34	lubricant	CVM, data must be read from Weibull plots
66-2	Bamberger, E.N., "The Production, Testing and Evaluation of Ausformed Ball Bearings", submitted to Bureau of Weapons under Contract NOW-65-0070, AD637576 (1966)	radially loaded 35mm bore single row deep groove inner rings and balls	2	20, 27	heat treatment: ausformed vs std. heat treated CVM M-50	
66-3	SKF Test Series F6083 (1966)	radially loaded 45mm single row deep groove inner rings	2	27, 31	processing: ausformed and conventional	CVM

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DATA SOURCES M-50 STEEL ENDURANCE TESTS

REF. NO.	REFERENCE	TYPE OF TEST	NO. OF TESTS	SAMPLE SIZE	TEST VARIABLES	REMARKS
66-4	SKF Test Series No. F6900	45mm bore single row deep groove ball bearings	1	30		Hopkins Process
67-1	Bamberger, E.N., "The Effect of Ausforming on the Rolling Contact Fatigue Life of a Typical Bearing Steel," J. Lub. Tech., Vol. 89, No. 1 pp. 63-75 (1967)	RC rig	4	10 - 18	Heat treatment: standard, 40, 70 and 80% ausformed	CVM
67-2	Scott, D. and Blackwell, J., "Study of Materials for Unlubricated and Elevated Temperature Rolling Elements," National Engineering Laboratory Report No. 278, Feb. 1967	4 ball	3		Lubricant: Diester, Polyphenyl ether silicon	Only mean life given. No details available. Data Omitted.

APPENDIX C

DATA SOURCES M-50 STEEL ENDURANCE TESTS

REF. NO.	REFERENCE	TYPE OF TEST	NO. OF TESTS	SAMPLE SIZE	TEST VARIABLES	REMARKS
67-3	Scott, D. and Blackwell, J., "A Study of the Effects of Elevated Temperature Lubricants on Materials for Rolling Elements," National Eng. Laboratory Report No. 317, Aug. (1967)	4 ball	22		Temperature: ambient and 200°C Lubricant: 11 types	Only mean life given. No details available. Data omitted
67-4	Morrison, F., "Experimental Lives Obtained from CVM M-50 Rollers Used in Flat Thrust Washer Tests," SKF Report No. AL67T053 (1967)	Flat Washer	2	45, 62	Washer Load: 1200 lbs. and 1000 lbs.	CVM
67-5	SKF Test Series F6308 (1967)	45mm bore single row deep groove ball bearing inners	1	11		Dulited inner rings, CVM
68-1	Bamberger, E.N., Zaretsky, E.V., and Anderson, W. J., "Fatigue Life of 120 mm Bore Ball Bearings at 600°F With Fluorocarbon, Polyphenyl Ether and Synthetic Paraffinic Base Lubricants," NASA Technical Note No. TN-D-4850 (1968)	Thrust loaded 120mm bore angular contact ball bearings	2	26, 17	Lube type: synthetic paraffinic oil and fluorocarbon	CVM

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DATA SOURCES M-50 STEEL ENDURANCE TESTS

REF. NO.	REFERENCE	TYPE OF TEST	NO. OF TESTS	SAMPLE SIZE	TEST VARIABLES	REMARKS
68-2	Parker, R.J. and Zaretsky, E.V., "Rolling-Element Fatigue Life of Ausformed M-50 Steel Balls," NASA TN D-4954 (1968)	5-ball tester	3	22 - 28	Heat treat: one ausformed and two standard heat treat	CVM
68-3	Simon, K., "Life Improvement of Helicopter Transmission Bearings: Airmelt vs. Vacuum Melt Steel Bearings," Vertol Div., Boeing Co., submitted to the U.S. Navy Dept. under Contract No. NOW65-0130-f (1969)	6 Groups: radially loaded cylindrical bearings bore sizes from 35 to 100mm	6	6	bearing size	one group has only 1 failure, CVM
68-4	SKF Test Series F7155 (1968)	140mm bore angular contact ball bearings	1	20		CVM
69-1	Zaretsky, E.V., Anderson, W.J. and Bamberger, E.N., "Rolling-Element Bearing Life from 400^{o} to $600^{o}F$," NASA TN D-5002 (1969)	Thrust loaded 120 mm bore angular contact ball bearings	3	23 - 26	Temperature: 400, 500, and $600^{o}F$	CVM
69-2	SKF Test Series No. F9774 (1969)	45mm bore single row deep groove ball bearings	1	16		Hopkins Process
70-1	SKF Test Series No. F9879	45mm bore single row deep groove ball bearings	1	30		Hopkins Process

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DATA SOURCES M-50 STEEL ENDURANCE TESTS

REF. NO.	REFERENCE	TYPE OF TEST	NO. OF TESTS	SAMPLE SIZE	TEST VARIABLES	REMARKS
71-1	Parker, R.J., Zaretsky, E.V. and Dietrich, M.W., "Rolling-Element Fatigue Lives and Four M-Series Steels and AISI-52100 at 150°F," NASA TN D-7033 (1971)	Five ball rig	3	29 - 30	Heat treat lots	Testing was done at SKF under code names LA, LB and LC. CVM
71-2	Bamberger, E.N., and Zaretsky, E.V. "Fatigue Lives at 600°F of 120mm Bore Ball Bearings of AISI M-50, AISI M-1 and WB-49 Steels," NASA Technical Note NASA TN D-6156 (1971)	120mm bore angular contact ball bearings	1	26		CVM
72-1	Schlatter, R. and Stroup, J.P., "Improved M50 Aircraft Bearing Steel Through Advanced Vacuum Melting Processes," J. Vac. Sci, Tech., Vol. 9, No. 6, pp. 1326-1333 (1972)	RC rig	7	9-15 for 72-1-4 to 72-1-7	Melting Practice: 3 heats of air melted vacuum arc remelted and 4 heats of therm-I-vac and vacuum arc remelted.	Sample size not available for 72-1-1 to 72-1-3. Used Weibull plots for L_{10} and shape parameter estimates and assumed complete samples of size 10.
72-2	Zaretsky, E.V. and Bamberger, E.N., "Advanced Air-breathing Engine Lubricants Study With a Tetraester Fluid and a Synthetic Paraffinic Oil", NASA TN D-6771 (1972).	120mm bore thrust loaded, angular contact ball bearings	2	27 - 29	Lubricant-Tetra ester and a synthetic paraffinic oil	CVM

APPENDIX C

DATA SOURCES M-50 STEEL ENDURANCE TESTS

REF. NO.	REFERENCE	TYPE OF TEST	NO. OF TESTS	SAMPLE SIZE	TEST VARIABLES	REMARKS
72-3	SKF Test Series F961 (1972)	45mm bore single row deep groove ball bearing inners	1	20		Duplex structure, CVM
74-1	Parker, R.J., Zaretsky, E.V. and Bamberger, E.N., "Evaluation of Load-Life Relation with Ball Bearings at 500 Deg. F, ASME, Jnl. Lub. Tech. pp. 391-397 (1974)	thrust loaded 120mm bore angular contact bearings at 500°F	3	20 - 40	Load 4600, 5800 and 7310 lbs.	CVM
74-2	Schlatter, R., "Double Vacuum Melting of High Performance Bearing Steels", Industrial Heating, pp. 40-55 (1974)	RC rig	2	not given	Melting Practice: (1) Air-melt with vacuum arc remelt (2) double vacuum melt	Sample size not available for 72-1-1 to 72-1-3. Used Weibull plots for L_{10} and shape parameter estimates and assumed complete samples of size 10.
75-1	Morrison, F., "Endurance Testing of SKF Production 1-1/8 Balls, SKF Report AL75Q225L	4 ball tester	1	12		VIMVAR
76-1	Bamberger, E.N., Zaretsky, E.V., and Signer, H., "Endurance and Failure Characteristic of Main-Shaft Jet Engine Bearing at 3 x 10 DN, Jnl, Lub. Tech., ASME Trans., pp. 580-585 (1976)	Thrust loaded 120mm bore angular contact ball bearings	2	30	Speed-12000 and 25000 RPM	VIMVAR

APPENDIX C

DATA SOURCES M-50 STEEL ENDURANCE TESTS

REF. NO.	REFERENCE	TYPE OF TEST	NO. OF TESTS	SAMPLE SIZE	TEST VARIABLES	REMARKS
76-2	Morrison, F., "Endurance Testing of SKF Experimental 1-1/8" Diameter Balls", SKF Report AL76Q017L, (1976)	4 ball	1	12		VIMVAR
76-3	Morrison, F., "Endurance of 1-1/8" D M50 Balls" SKF Report AL76T010L	4 ball ring	1	12		CVM
76-4	Bamberger, E.N., etal, "Axial-Centrifugal Compressor Program, Evaluation of Ausformed Bearings", U.S. Army Air Mobility Research and Development Lab.	Thrust loaded 35mm ball bearings	2	4, 10	Forming Method: Standard and Ausformed	CVM
77-1	Naval Air Propulsion Center - Letter of Nov. 22, 1977	RC	254	5 - 10	Temperature	CVM
77-2	Air Force Aero-Propulsion Laboratory Letter of November 2, 1977	RC	1	72		CVM
77-3	Brown, P.F. and Potts, J.R., "Evaluation of Powder Processed Turbine Engine Ball Bearings", Air Force Aero-Propulsion Lab. Report No. AFAPL-TR-77-26 (1977)	Single Ball	2	15, 30 - single ball rig	Processing: Standard and Powder	CVM

APPENDIX C

DATA SOURCES M-50 STEEL ENDURANCE TESTS

REF. NO.	REFERENCE	TYPE OF TEST	NO. OF TESTS	SAMPLE SIZE	TEST VARIABLES	REMARKS
77-4	Parker, R. J., and Hodder, R.S., "Rolling-Element Fatigue Life of AMS 5749 Corrosion Resistant, High Temperature Bearing Steel", ASME Paper No. 77-Lub-30 (1977)	5 ball rig	1	40		VIMVAR, Failures given on Weibull plots
78-1	Bell Helicopter-Textron, private correspondance from C. Baskin, Jan. 1978	Full scale 60 and 110mm bore angular contact ball bearings	3	6 - 9	Bearing type, manufacturer	Bearings are known only to be either VIMVAR or CVM
78-2	SKF Gothenburg, Sweden, Private correspondance from G. Rosengren	Full scale 6408 deep groove ball bearings	2	25 - 30	Material form: Forgings, Tube	CVM
78-3	Detroit Diesel Allison, Private correspondance from W. L. McIntire, Jan. 1978	3 ball and cone	4	4 - 9	Stress 400, 500, 600 ksi	CVM
78-4	Boeing Vertol Co., Private correspondance from J. Lenski, Jan. 1978	Spherical Bearings in Transmissions	2	95, 100	Bearing size	CVM

APPENDIX C

DATA SOURCES M-50 STEEL ENDURANCE TESTS

REF. NO.	REFERENCE	TYPE OF TEST	NO. OF TESTS	SAMPLE SIZE	TEST VARIABLES	REMARKS
78-5	Sante, M., "Amelioration de l'endurance des Roulements par l'emploi d'aciers Rapides" ingenieurs et Techniciens, pp. 33-37, Jan. 1975	Flat washers	1	16		Missing Geometry Details - Omitted
78-6	Latrobe Steel Company, private correspondence with R. Schlatter, Jan. 1978	RC	3	11- 15	Hardness levels: 61.5, 61.7 and 62.0 RC	VIMVAR

AD-A074 217 SKF INDUSTRIES INC KING OF PRUSSIA PA TECHNOLOGY SERV--ETC F/G 13/9
M-50 STEEL BEARING MATERIAL FACTORS FOR ROLLING ELEMENT LIFE CA--ETC(U)
APR 79 F R MORRISON, J I MCCOOL, N J NINOS DAAK50-77-C-0009

UNCLASSIFIED SKFAL79T013 USAAVRADCOM-TR-79-35 NL

2 OF 2
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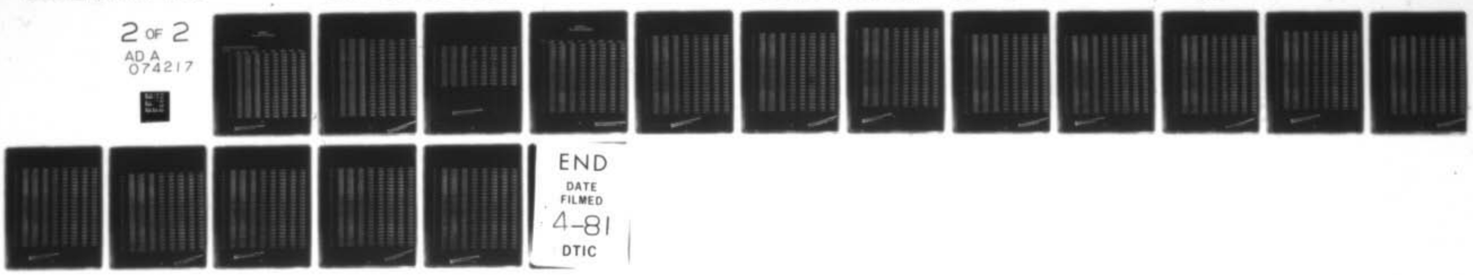

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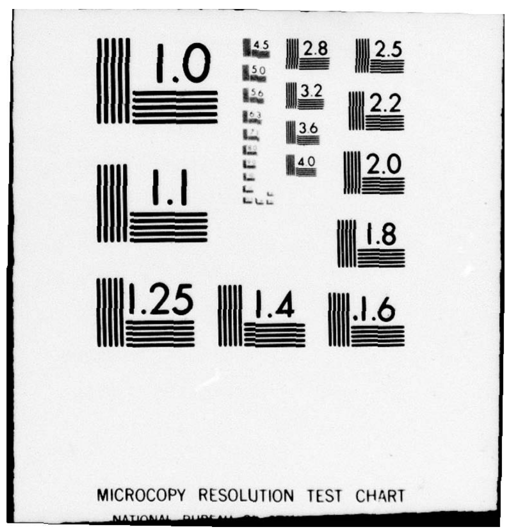
1.0
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5.6
MICROCOPY RESOLUTION TEST CHART

APPENDIX D

DATA BASE FOR BEARINGS

DATA AFTER TRANSFORMATIONS FOR FIRST 359 CASES
CASES WITH ZERO WEIGHTS AND MISSING DATA NOT INCLUDED.

CASE LABEL	NUMBER	WEIGHT / 8 SIGMA / 16 MATFAC	1 REF / 9 LIDTH / 17 WTFAC	2 TYPE / 10 N / 18 LOGMAT	3 MAT / 11 R	4 PROC / 12 LIDEX	5 STRESS / 13 BETA	6 SIZE / 14 H/SIG	7 H / 15 FILFAC
	255	1.00000	5511.00000	10.00000	2.00000	1.00000	480.00000	1.77000	3.90000
		8.00000	10.00000	32.00000	15.00000	38.31999	0.91000	0.48750	0.20000
		19.16000	44.29236	2.35252					
	256	1.00000	5812.00000	10.00000	2.00000	1.00000	480.00000	1.77000	4.30000
		8.00000	10.00000	31.00000	22.00000	8.06000	1.11000	0.53750	0.20000
		4.03270	30.66296	1.39377					
	257	1.00000	5931.00000	10.00000	2.00000	1.00000	480.00000	1.77000	3.90000
		8.00000	10.00000	30.00000	28.00000	35.09999	1.40000	0.48750	0.20000
		17.55000	80.22151	2.86505					
	258	1.00000	6111.00000	10.00000	1.00000	1.00000	480.00000	1.77000	22.59999
		8.00000	10.00000	30.00000	30.00000	3.11000	1.11000	2.82500	2.29205
		0.13569	-57.92223	-1.99741					
	259	1.00000	6112.00000	10.00000	1.00000	1.00000	480.00000	1.77000	22.59999
		8.00000	10.00000	30.00000	28.00000	6.36000	1.66000	2.82500	2.29205
		0.27748	-35.59604	-1.28200					
	260	1.00000	6113.00000	10.00000	1.00000	1.00000	480.00000	1.77000	22.59999
		8.00000	10.00000	30.00000	15.00000	16.53000	1.11000	2.82500	2.29205
		0.72119	-4.90281	-0.32685					
	261	1.00000	6211.00000	10.00000	2.00000	1.00000	480.00000	1.77000	22.59999
		8.00000	10.00000	30.00000	16.00000	120.56999	1.07000	2.82500	2.29205
		5.26056	26.56320	1.66020					
	262	1.00000	6411.00000	10.00000	3.00000	1.00000	480.00000	1.77000	22.59999
		8.00000	10.00000	10.00000	6.00000	22.39999	1.93000	2.82500	2.29205
		0.97729	-0.13782	-0.02297					
	263	1.00000	6421.00000	10.00000	3.00000	1.00000	480.00000	1.77000	22.59999
		8.00000	10.00000	10.00000	4.00000	35.98999	1.11000	2.82500	2.29205
		1.57221	1.80494	0.45121					
	264	1.00000	6422.00000	10.00000	3.00000	1.00000	480.00000	1.77000	22.59999
		8.00000	10.00000	10.00000	7.00000	14.74000	1.24000	2.82500	2.29205
		0.64309	-3.09026	-0.44147					
	265	1.00000	6423.00000	10.00000	3.00000	1.00000	480.00000	1.77000	6.00000
		8.00000	10.00000	14.00000	4.00000	15.22000	0.66000	0.75000	0.31250
		4.87040	6.33270	1.58318					
	266	1.00000	6424.00000	10.00000	3.00000	1.00000	480.00000	1.77000	22.59999
		8.00000	10.00000	10.00000	2.00000	76.70999	0.76000	2.82500	2.29205
		3.34679	2.41600	1.20800					
	267	1.00000	6631.00000	10.00000	2.00000	2.00000	480.00000	1.77000	5.50000
		8.00000	10.00000	31.00000	25.00000	5.07000	0.90000	0.68750	0.26563
		1.93371	16.15063	0.64643					
	268	1.00000	6632.00000	10.00000	2.00000	1.00000	480.00000	1.77000	5.50000
		8.00000	10.00000	30.00000	30.00000	195.59000	1.25000	0.68750	0.26563
		73.63388	128.97313	4.29910					
	269	1.00000	6641.00000	10.00000	5.00000	1.00000	480.00000	1.77000	22.59999
		8.00000	10.00000	30.00000	12.00000	199.68999	2.29000	2.82500	2.29205
		8.71230	25.97692	2.16474					
	274	1.00000	6751.00000	10.00000	2.00000	1.00000	480.00000	1.77000	5.50000
		4.00000	10.00000	11.00000	2.00000	280.90991	1.87000	1.37500	1.13750
		24.69537	6.41323	3.20662					
	275	1.00000	6911.00000	11.00000	2.00000	1.00000	320.00000	4.72400	10.00000
		2.80000	15.30000	25.00000	10.00000	213.00000	1.70000	3.57143	2.37714
		5.35643	17.67540	1.76754					
	276	1.00000	6912.00000	11.00000	2.00000	1.00000	320.00000	4.72400	6.80000
		2.90000	15.30000	26.00000	11.00000	286.00000	3.20000	2.42857	2.24686
		8.31955	23.30467	2.11861					
	277	1.00000	6913.00000	11.00000	2.00000	1.00000	320.00000	4.72400	5.00000
		2.80000	15.30000	26.00000	6.00000	182.00000	1.80000	1.78571	1.83571
		6.48000	11.21232	1.36872					
	278	1.00000	6921.00000	10.00000	5.00000	1.00000	0.0	1.77000	22.59999
		4.00000	10.00000	10.00000	3.00000	169.20999	1.17000	5.65000	2.614[illegible]

	6.47298	5.60291	1.86764					
279	1.00000	7011.00000	10.00000	5.00000	1.00000	0.0	1.77000	9.10000
	4.00000	10.00000	30.00000	8.00000	81.90999	2.55000	2.27500	2.22935
	3.67417	10.41361	1.30133					
240	1.00000	7121.00000	11.00000	2.00000	1.00000	320.00000	4.72000	5.00000
	2.80000	13.40000	26.00000	6.00000	182.00000	1.40000	1.78571	1.83571
	7.33881	12.00791	2.00132					
284	1.00000	7221.00000	11.00000	2.00000	1.00000	320.00000	4.72400	18.79999
	2.90000	13.40000	29.00000	17.00000	64.00000	1.40000	6.48275	2.70903
	1.76333	1.63962	0.56734					
289	1.00000	7222.00000	11.00000	2.00000	1.00000	320.00000	4.72400	23.79999
	2.90000	13.40000	27.00000	14.00000	140.00000	1.90000	8.20689	2.90558
	3.59575	17.91653	1.27975					
290	1.00000	7231.00000	10.00000	2.00000	1.00000	480.00000	1.77000	22.59999
	4.00000	10.90000	20.00000	2.00000	3.13000	29.37000	5.65000	2.61410
	0.11387	-4.39886	-2.19943					
304	1.00000	6621.00000	10.00000	2.00000	2.00000	670.00000	1.37800	12.00000
	8.00000	1.68000	20.00000	18.00000	94.39000	2.36000	1.50000	1.35000
	41.61819	67.11366	3.72854					
305	1.00000	6622.00000	10.00000	2.00000	1.00000	670.00000	1.37800	12.00000
	8.00000	1.68000	27.00000	27.00000	9.53000	1.07000	1.50000	1.35000
	4.20174	38.75977	1.43555					
306	1.00000	6811.00000	11.00000	2.00000	1.00000	340.00000	4.72400	12.80000
	2.80000	15.21000	26.00000	6.00000	182.00000	1.80000	4.57143	2.49114
	4.80335	9.41588	1.56931					
307	1.00000	6812.00000	11.00000	2.00000	1.00000	300.00000	4.72400	19.29999
	2.80000	30.34000	17.00000	4.00000	92.00000	1.40000	6.89285	2.75578
	1.10034	0.38248	0.09562					
311	1.00000	6831.00000	12.00000	2.00000	1.00000	190.00000	2.95300	14.80000
	11.70000	16.12000	6.00000	4.00000	5.76000	1.33000	1.26496	0.95043
	0.37726	-3.89924	-0.97481					
312	1.00000	6832.00000	12.00000	2.00000	1.00000	250.00000	2.36200	45.89999
	11.70000	13.41000	6.00000	4.00000	5.40000	1.36000	3.92308	2.41723
	0.16653	-7.16889	-1.79222					
313	1.00000	6833.00000	12.00000	2.00000	1.00000	280.00000	3.93700	10.80000
	8.50000	5.10000	6.00000	5.00000	5.56000	2.49000	1.27059	0.96000
	0.94945	-0.25934	-0.05187					
314	1.00000	6834.00000	12.00000	2.00000	1.00000	290.00000	2.16500	90.59999
	10.60000	4.47000	6.00000	2.00000	28.59000	1.19000	8.54717	2.94438
	2.17227	1.55154	0.77577					
315	1.00000	6835.00000	12.00000	2.00000	1.00000	190.00000	1.37800	36.79999
	8.90000	21.53000	6.00000	4.00000	53.28000	0.94000	4.13483	2.44137
	1.01365	0.05422	0.01355					
316	1.00000	6836.00000	12.00000	2.00000	1.00000	250.00000	2.36200	101.59999
	8.90000	11.99000	6.00000	1.00000	115.29999	0.49000	11.41573	3.00080
	3.20813	1.16569	1.16569					
317	1.00000	6841.00000	11.00000	2.00000	1.00000	300.00000	5.51200	13.00000
	1.80000	12.48000	20.00000	4.00000	276.98999	1.64000	7.22223	2.79333
	7.94551	8.29247	2.07262					
321	1.00000	7411.00000	11.00000	2.00000	1.00000	320.00000	4.72400	18.59999
	2.20000	23.50000	20.00000	13.00000	302.00000	1.70000	8.45454	2.93382
	4.38032	19.20258	1.47712					
322	1.00000	7412.00000	11.00000	2.00000	1.00000	320.00000	4.72400	18.39999
	2.20000	15.21000	30.00000	20.00000	159.00000	1.67000	8.36363	2.92345
	3.57579	25.48370	1.27419					
323	1.00000	7413.00000	11.00000	2.00000	1.00000	360.00000	4.72400	18.20000
	2.20000	7.50000	40.00000	24.00000	83.00000	3.32000	8.27273	2.91309
	3.79895	32.03336	1.33472					
324	1.00000	7611.00000	11.00000	4.00000	1.00000	320.00000	4.72400	8.20000
	2.20000	25.92000	30.00000	1.00000	2700.00000	2.10000	3.72727	2.39491
	43.49506	3.77265	3.77265					
325	1.00000	7612.00000	11.00000	4.00000	1.00000	320.00000	4.72400	13.60000
	2.20000	15.80000	30.00000	6.00000	2400.00000	2.10000	6.18182	2.67473
	56.79041	24.23621	4.03937					
326	1.00000	7641.00000	10.00000	2.00000	1.00000	300.00000	1.38000	42.29999
	6.30000	23.10999	4.00000	3.00000	43.42000	1.05000	6.71428	2.73543

	0.68685	-1.12690	-0.37563					
327	1.00000	7642.00000	10.00000	2.00000	2.00000	300.00000	1.38000	42.29999
	6.50000	23.12999	10.00000	3.00000	194.20999	18.09999	6.71428	2.73543
	3.07218	3.36716	1.12239					
330	1.00000	7311.00000	11.00000	4.00000	1.00000	460.00000	4.33100	1.30000
	3.60000	1.33000	6.00000	2.00000	8.78000	1.59000	0.36111	0.20000
	33.00752	6.99347	3.49674					
331	1.00000	7312.00000	11.00000	-0.0	1.00000	460.00000	2.36200	1.00000
	6.60000	3.08000	8.00000	4.00000	0.72000	0.56000	0.15152	0.20000
	1.16845	0.62402	0.15600					
332	1.00000	7313.00000	11.00000	-0.0	1.00000	460.00000	2.36200	1.00000
	3.60000	3.08000	9.00000	2.00000	6.24000	0.70000	0.27778	0.20000
	10.12987	4.63096	2.31549					
333	1.00000	7821.00000	10.00000	2.00000	1.00000	0.0	1.57400	2.00000
	5.90000	11.20000	30.00000	22.00000	6.10000	0.54000	0.33898	0.20000
	2.72321	22.03987	1.00181					
334	1.00000	7822.00000	10.00000	2.00000	1.00000	0.0	1.57400	2.00000
	5.20000	11.20000	25.00000	23.00000	3.30000	0.59000	0.38462	0.20000
	1.47321	8.91125	0.38745					
335	1.00000	7841.00000	14.00000	2.00000	1.00000	230.00000	3.34600	7.90000
	5.00000	84.59000	47.00000	11.00000	37.45999	1.72000	1.58000	1.48600
	0.29801	-13.31692	-1.21063					
336	1.00000	7842.00000	14.00000	2.00000	1.00000	270.00000	2.75600	3.10000
	5.00000	10.45999	100.00000	17.00000	19.76999	2.88000	0.62000	0.21500
	4.46625	25.51726	1.50102					
337	1.00000	7311.00000	11.00000	4.00000	1.00000	260.00000	1.77100	14.30000
	7.20000	122.00000	17.00000	10.00000	59.00000	1.00000	1.98611	2.17639
	0.22221	-15.04149	-1.50415					
338	1.00000	7313.00000	10.00000	4.00000	1.00000	450.00000	1.17700	27.50000
	4.50000	10.90000	20.00000	14.00000	64.20000	2.60000	2.89474	2.30000
	2.56083	16.92596	0.94033					
339	1.00000	7312.00000	12.00000	1.00000	1.00000	270.00000	1.77100	21.59959
	3.40000	3.94000	13.00000	2.00000	314.00000	0.54000	4.00000	2.42600
	32.66057	6.98394	3.49197					

APPENDIX E

DATA BASE FOR ELEMENTS

E NUMBER	WEIGHT	1 REF	2 TYPE	3 MAT	4 PROC	5 STRESS	6 SIZE	7 M
	8 SIGMA	9 L10TH	10 N	11 R	12 L10EX	13 BETA	14 H/SIG	15 FILFAC
	16 MATFAC	17 WTFAC	18 LOGMAT					
1	1.00000	1002.00000	1.00000	2.00000	1.00000	800.00000	0.37500	0.70000
	12.10000	0.21455	4.00000	4.00000	5.25000	4.28000	0.05785	0.20000
	122.34627	19.22742	4.30686					
2	1.00000	1004.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.93000	4.20000	0.02479	0.20000
	6.55765	18.95766	1.89577					
3	1.00000	1003.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.29000	5.11000	0.02479	0.20000
	9.23481	22.22978	2.22274					
4	1.00000	1006.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	5.00000	5.00000	2.84000	5.65000	0.04959	0.20000
	20.33087	15.06070	3.01214					
5	1.00000	1007.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	6.00000	6.00000	2.87000	5.89000	0.04959	0.20000
	20.54564	18.13588	3.02265					
6	1.00000	1008.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	10.00000	10.00000	3.81000	7.05000	0.05785	0.20000
	27.27439	33.05966	3.30597					
7	1.00000	1009.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	10.00000	10.00000	2.74000	3.83000	0.05785	0.20000
	13.61531	29.76294	2.97624					
8	1.00000	1010.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.85000	5.84000	0.02479	0.20000
	6.08495	18.05918	1.80582					
9	1.00000	1011.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.92000	5.40000	0.02479	0.20000
	6.53606	18.34955	1.88496					
10	1.00000	1012.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	10.00000	10.00000	1.83000	5.40000	0.04959	0.20000
	13.13054	25.72652	2.57265					
11	1.00000	1013.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	10.00000	10.00000	1.28000	5.98000	0.04959	0.20000
	9.16522	22.15196	2.21520					
12	1.00000	1014.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	10.00000	10.00000	1.30000	5.25000	0.04959	0.20000
	9.30639	22.30699	2.23070					
13	1.00000	1015.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	10.00000	10.00000	1.07000	2.14000	0.04959	0.20000
	7.65987	20.35875	2.03600					
14	1.00000	1016.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	8.00000	8.00000	1.31000	3.71000	0.04959	0.20000
	9.37793	17.90691	2.23336					
15	1.00000	1017.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	10.00000	10.00000	1.91000	4.73000	0.04959	0.20000
	13.67324	26.15440	2.61544					
16	1.00000	1018.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	10.00000	10.00000	1.54000	5.54000	0.04959	0.20000
	11.02450	24.00119	2.40012					
17	1.00000	1019.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	3.00000	3.00000	2.64000	3.92000	0.04959	0.20000
	18.89912	8.81735	2.93912					
18	1.00000	1020.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	3.00000	0.44000	1.35000	0.02479	0.20000
	3.14986	3.44207	1.14736					
19	1.00000	1021.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.79000	9.62000	0.02479	0.20000
	5.65542	17.32614	1.73261					
20	1.00000	1022.00000	1.00000	2.00000	1.00000	680.00000	0.37500	0.30000

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	12.10000	0.91300	10.00000	10.00000	0.70000	9.36000	0.02479	0.20000
	3.83352	13.43782	1.34378					
21	1.00000	1023.00000	1.00000	2.00000	1.00000	680.00000	0.37500	0.30000
	12.10000	0.91300	10.00000	10.00000	0.51000	5.72000	0.02479	0.20000
	2.73299	10.27112	1.02711					
22	1.00000	1024.00000	1.00000	2.00000	1.00000	700.00000	0.37500	2.50000
	12.10000	0.69844	5.00000	5.00000	5.51000	3.52000	0.20661	0.20000
	39.44478	18.37450	3.67490					
23	1.00000	1025.00000	1.00000	2.00000	1.00000	700.00000	0.37500	2.50000
	12.10000	0.69844	5.00000	5.00000	6.16000	5.71000	0.20661	0.20000
	44.09793	18.93207	3.78641					
24	1.00000	1026.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	2.83000	3.29000	0.02479	0.20000
	20.25929	30.08614	3.00861					
25	1.00000	1027.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	2.52000	4.76000	0.02479	0.20000
	18.34007	28.92595	2.89260					
26	1.00000	1028.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.41000	3.99000	0.02479	0.20000
	10.09386	23.11926	2.31193					
27	1.00000	1029.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.49000	1.59000	0.02479	0.20000
	3.50779	12.54947	1.25493					
28	1.00000	1030.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	9.00000	0.89000	1.39000	0.02479	0.20000
	6.37130	16.66621	1.85180					
29	1.00000	1031.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	11.00000	10.00000	2.58000	4.45000	0.02479	0.20000
	13.46360	29.16125	2.91613					
30	1.00000	1032.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	6.00000	6.00000	1.64000	1.69000	0.02479	0.20000
	11.74337	14.77820	2.46303					
31	1.00000	1033.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	2.67000	8.84000	0.02479	0.20000
	19.11389	29.50415	2.95042					
32	1.00000	1034.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	2.28000	8.16000	0.02479	0.20000
	16.32134	27.92511	2.79251					
33	1.00000	1035.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	2.70000	6.39000	0.02479	0.20000
	19.32806	29.61588	2.96159					
34	1.00000	1036.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	5.00000	5.00000	5.06000	2.92000	0.05785	0.20000
	36.22354	17.94852	3.58970					
35	1.00000	1037.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	5.00000	5.00000	18.26999	4.99000	0.05785	0.20000
	130.73054	24.36798	4.87360					
36	1.00000	1038.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	2.14000	7.00000	0.02479	0.20000
	15.31975	27.29141	2.72914					
37	1.00000	1039.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.91000	6.44000	0.02479	0.20000
	13.67324	26.15440	2.61544					
38	1.00000	1040.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	2.52000	5.01000	0.02479	0.20000
	18.04007	28.92595	2.89260					
39	1.00000	1041.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	6.68000	6.76000	0.02479	0.20000
	47.82054	19.33727	3.86746					
40	1.00000	1042.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	3.09000	4.66000	0.02479	0.20000
	22.12057	30.96507	3.09651					
41	1.00000	1043.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.47000	7.26000	0.02479	0.20000
	10.52533	23.53598	2.35360					
42	1.00000	1044.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000

	12.10000	0.69844	9.00000	9.00000	1.27000	5.61000	0.02479	0.20000
	9.09163	19.86613	2.20735					
43	1.00000	1045.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	8.00000	8.00000	9.57000	3.70000	0.02479	0.20000
	69.50937	33.81577	4.22697					
44	1.00000	1046.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.21000	4.13000	0.02479	0.20000
	8.66210	21.58955	2.15896					
45	1.00000	1047.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.03000	7.46000	0.02479	0.20000
	7.37352	19.97894	1.99799					
46	1.00000	1048.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	5.00000	5.00000	1.89000	3.07000	0.04959	0.20000
	13.53006	13.02457	2.60491					
47	1.00000	1049.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	5.00000	5.00000	2.28000	5.98000	0.04959	0.20000
	16.32194	13.96256	2.79251					
48	1.00000	1050.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	5.00000	5.00000	1.82000	6.14000	0.04959	0.20000
	13.02895	12.83587	2.56717					
49	1.00000	1051.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	5.00000	5.00000	1.50000	3.77000	0.04959	0.20000
	10.73815	11.86901	2.37380					
50	1.00000	1052.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.59000	4.60000	0.02479	0.20000
	4.22367	7.20352	1.44070					
51	1.00000	1053.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	4.00000	4.00000	0.96000	2.91000	0.02479	0.20000
	5.87241	7.71036	1.92752					
52	1.00000	1054.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.59000	4.60000	0.02479	0.20000
	4.22367	7.20352	1.44070					
53	1.00000	1055.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.24000	1.19000	0.02479	0.20000
	1.71810	2.70610	0.54122					
54	1.00000	1056.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.40000
	12.10000	0.69844	5.00000	5.00000	0.85000	4.84000	0.03306	0.20000
	6.04495	9.02909	1.80582					
55	1.00000	1057.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.40000
	12.10000	0.69844	5.00000	5.00000	1.19000	3.62000	0.03306	0.20000
	8.51493	10.71145	2.14229					
56	1.00000	1058.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	5.00000	5.00000	1.02000	5.71000	0.04959	0.20000
	7.30194	9.34070	1.93814					
57	1.00000	1059.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	5.00000	5.00000	2.58000	8.56000	0.04959	0.20000
	13.46963	14.58063	2.91613					
58	1.00000	1060.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	5.00000	5.00000	1.65000	12.58000	0.05785	0.20000
	11.91195	12.34556	2.46911					
59	1.00000	1061.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	5.00000	5.00000	2.10000	3.38000	0.05785	0.20000
	15.03340	13.55137	2.71027					
60	1.00000	1062.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	9.00000	6.03000	2.35000	0.02479	0.20000
	43.16734	33.85576	3.76508					
61	1.00000	1063.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.72000	3.69000	0.02479	0.20000
	12.31307	25.10660	2.51066					
62	1.00000	1064.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	4.00000	4.00000	2.52000	9.36000	0.02479	0.20000
	13.94307	11.57338	2.93260					
63	1.00000	1065.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.40000
	12.10000	0.69844	4.00000	4.00000	4.02000	9.94000	0.03306	0.20000
	24.77823	13.43948	3.35962					
64	1.00000	1066.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000

	12.10000	0.69844	4.00000	4.00000	8.43000	4.85000	0.05785	0.28?00
	60.34837	16.40053	4.10013					
65	1.00000	1067.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	4.00000	4.00000	11.89000	3.81000	1.38017	1.14628
	14.85111	10.79230	2.69807					
66	1.00000	1068.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	2.20000	5.35000	0.02479	0.20000
	15.74924	13.78397	2.75679					
67	1.00000	1069.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	11.12000	4.55000	1.38017	1.14628
	13.88935	13.15561	2.63112					
68	1.00000	1070.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.93000	7.97000	0.02479	0.20000
	13.81641	26.25856	2.62586					
69	1.00000	1071.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.11000	5.95000	0.02479	0.20000
	7.94623	20.72696	2.07270					
70	1.00000	1072.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.04000	4.30000	0.02479	0.20000
	7.44511	20.07558	2.00756					
71	1.00000	1073.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.53000	9.33000	0.02479	0.20000
	10.95271	23.93604	2.39360					
72	1.00000	1074.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.76000	4.09000	0.02479	0.20000
	12.59942	25.33650	2.53365					
73	1.00000	1075.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.34000	3.57000	0.02479	0.20000
	9.59274	22.61006	2.26101					
74	1.00000	1076.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.04000	4.65000	0.02479	0.20000
	7.44511	20.07558	2.00756					
75	1.00000	1077.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.06000	6.74000	0.02479	0.20000
	7.58829	20.26605	2.02651					
76	1.00000	1078.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.83000	5.31000	0.02479	0.20000
	5.94177	17.82007	1.78201					
77	1.00000	1079.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.91000	7.46000	0.02479	0.20000
	6.51447	19.74025	1.87493					
78	1.00000	1080.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.63000	3.57000	0.02479	0.20000
	4.51002	15.06302	1.59633					
79	1.00000	1081.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	9.00000	9.00000	0.74000	5.33000	0.02479	0.20000
	5.23743	15.00598	1.66723					
80	1.00000	1082.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.87000	4.61000	0.02479	0.20000
	6.22812	18.29074	1.82917					
81	1.00000	1083.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.11000	7.26000	0.02479	0.20000
	7.94623	20.72696	2.07270					
82	1.00000	1084.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.64000	7.35000	0.02479	0.20000
	4.58161	15.22050	1.52205					
83	1.00000	1085.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.50000	6.79000	0.02479	0.20000
	3.57938	12.75189	1.27519					
84	1.00000	1086.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.29000	2.51000	0.02479	0.20000
	9.23481	22.22978	2.22298					
85	1.00000	1087.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	2.72000	7.25000	0.02479	0.20000
	19.47143	29.68968	2.96897					
86	1.00000	1088.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000

	12.10000	0.69844	10.00000	10.00000	1.73000	4.57000	0.02479	0.20000
	12.38466	25.16458	2.51646					
87	1.00000	1089.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.63000	3.07000	0.02479	0.20000
	11.66878	24.56917	2.45692					
88	1.00000	1090.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	9.00000	9.00000	2.00000	10.78000	0.02479	0.20000
	14.51753	23.95335	2.66148					
89	1.00000	1091.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	9.00000	9.00000	1.91000	6.70000	0.02479	0.20000
	13.67324	23.53896	2.61544					
90	1.00000	1092.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	5.00000	5.00000	4.84000	4.62000	0.05785	0.20000
	34.64841	17.72626	3.54525					
91	1.00000	1093.00000	1.00000	2.00000	1.00000	800.00000	0.37500	0.70000
	12.10000	0.20999	5.00000	5.00000	2.22000	2.38000	0.05785	0.20000
	52.85965	19.83820	3.96764					
92	1.00000	1094.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	1.37000	1.47000	1.38017	1.14628
	1.71119	2.68594	0.53719					
93	1.00000	1095.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	6.11000	5.33000	1.38017	1.14628
	7.63165	10.16151	2.03230					
94	1.00000	1096.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	15.42000	12.40000	1.38017	1.14628
	19.26022	14.79021	2.95804					
95	1.00000	1097.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	15.63000	3.01000	1.38017	1.14628
	19.52252	14.85765	2.97157					
96	1.00000	1098.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	19.76999	2.85000	1.38017	1.14628
	24.69354	16.03270	3.20654					
97	1.00000	1099.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	7.82000	9.82000	1.38017	1.14628
	9.76751	11.39531	2.27906					
98	1.00000	1100.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	3.12000	5.59000	1.38017	1.14628
	3.89731	6.80105	1.36021					
99	1.00000	1101.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	7.93000	8.53000	1.38017	1.14628
	9.90490	11.46515	2.29303					
100	1.00000	1102.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	4.57000	7.65000	1.38017	1.14628
	5.70812	8.70945	1.74189					
101	1.00000	1103.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	5.02000	6.08000	1.38017	1.14628
	6.27019	9.17903	1.83581					
102	1.00000	1104.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	3.05000	3.19000	1.38017	1.14628
	3.80958	6.68759	1.33752					
103	1.00000	1105.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	3.00000	3.73000	0.02479	0.20000
	21.47629	30.66948	3.06695					
104	1.00000	1106.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	8.00000	8.00000	2.94000	2.66000	0.02479	0.20000
	21.04675	24.37396	3.04675					
105	1.00000	1107.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.90000	6.00000	0.02479	0.20000
	6.44289	9.31488	1.86298					
106	1.00000	1108.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	4.00000	6.57000	4.00000	0.02479	0.20000
	47.03307	15.42540	3.08085					
107	1.00000	1109.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	1.11000	8.16000	0.02479	0.20000
	7.94623	10.36348	2.07270					
108	1.00000	1110.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000

	12.10000	0.69844	7.00000	7.00000	2.40000	3.04000	0.02479	0.20000
	17.18103	19.90663	2.24381					
109	1.00000	1111.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	5.00000	5.00000	0.54000	1.36000	0.05785	0.20000
	3.86373	6.76075	1.35215					
110	1.00000	1112.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	5.00000	5.00000	0.82000	3.32000	0.05785	0.20000
	5.87019	8.84343	1.76789					
111	1.00000	1113.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.30000	2.73000	0.02479	0.20000
	2.14763	3.82182	0.76436					
112	1.00000	1114.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.22000	2.73000	0.02479	0.20000
	1.57493	2.27105	0.45421					
113	1.00000	1115.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.73000	4.57000	0.02479	0.20000
	5.22590	16.53625	1.65363					
114	1.00000	1116.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.94000	4.66000	0.02479	0.20000
	13.88800	26.31024	2.63105					
115	1.00000	1117.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.56000	3.59000	0.02479	0.20000
	4.00891	13.88518	1.38852					
116	1.00000	1118.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.47000	4.68000	0.02479	0.20000
	10.52338	23.55578	2.35562					
117	1.00000	1119.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.90000	3.81000	0.02479	0.20000
	13.60165	26.10173	2.61019					
118	1.00000	1120.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.11000	3.09000	0.02479	0.20000
	7.94623	20.72696	2.07270					
119	1.00000	1121.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	6.00000	6.00000	3.30000	3.42000	0.05785	0.20000
	23.62392	18.97354	3.16226					
120	1.00000	1122.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	6.00000	6.00000	4.62000	3.71000	0.05785	0.20000
	33.07349	20.88239	3.48673					
121	1.00000	1123.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	10.00000	10.00000	1.54000	2.57000	0.04959	0.20000
	11.02450	24.00119	2.40012					
122	1.00000	1124.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.60000
	12.10000	0.69844	10.00000	10.00000	1.00000	2.10000	0.04959	0.20000
	7.15876	19.68336	1.96834					
123	1.00000	1125.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.41000	7.45000	0.02479	0.20000
	10.09386	23.11326	2.31133					
124	1.00000	1126.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.70000	3.67000	0.02479	0.20000
	5.01113	16.11661	1.61166					
125	1.00000	1127.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.01000	5.81000	0.02479	0.20000
	7.23035	19.78287	1.97829					
126	1.00000	1128.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.30000	3.75000	0.02479	0.20000
	6.44289	18.62976	1.86298					
127	1.00000	1129.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	3.45000	5.74000	0.02479	0.20000
	24.69772	32.06711	3.20671					
128	1.00000	1130.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	3.33000	7.05000	0.02479	0.20000
	24.19661	31.26212	3.18621					
129	1.00000	1131.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	1.79000	5.00000	0.02479	0.20000
	12.81419	25.50552	2.55055					
130	1.00000	1132.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000

	12.10000	0.69844	10.00000	10.00000	1.03000	2.63000	0.02479	0.20000
	7.37352	10.97894	1.99790					
131	1.00000	1133.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	8.00000	8.00000	1.82000	5.50000	0.02479	0.20000
	13.02375	20.53738	2.56717					
132	1.00000	1134.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	10.91000	4.77000	0.02479	0.20000
	78.10211	21.79008	4.35802					
133	1.00000	1135.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	9.00000	9.00000	1.42000	2.43000	0.02479	0.20000
	10.16544	20.87094	2.31899					
134	1.00000	1136.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.58000	3.87000	0.02479	0.20000
	4.15208	14.23610	1.42361					
135	1.00000	1137.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	9.00000	9.00000	0.64000	3.67000	0.02479	0.20000
	4.58161	13.69845	1.52205					
136	1.00000	1138.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	9.00000	9.00000	1.05000	7.78000	0.02479	0.20000
	7.51670	18.15413	2.01713					
137	1.00000	1139.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.93000	6.95000	0.02479	0.20000
	6.65765	18.95766	1.89577					
138	1.00000	1140.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	4.70000	4.40000	0.02479	0.20000
	33.64618	17.57950	3.51590					
139	1.00000	1144.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	4.00000	6.90000	15.73000	0.02479	0.20000
	46.67958	15.54114	3.44526					
140	1.00000	1145.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.66000	3.62000	0.02479	0.20000
	4.72473	15.52821	1.55282					
141	1.00000	1146.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	3.96000	4.37000	0.02479	0.20000
	28.34369	33.44580	3.34458					
142	1.00000	1147.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	4.71000	6.21000	0.02479	0.20000
	33.71777	17.59012	3.51803					
143	1.00000	1148.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	3.33000	3.43000	0.02479	0.20000
	23.83365	15.86655	3.17131					
144	1.00000	1149.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	10.00000	10.00000	0.69000	7.89000	0.02479	0.20000
	4.93955	15.97273	1.59727					
145	1.00000	1151.00000	1.00000	2.00000	1.00000	700.00000	0.37500	3.40000
	12.10000	0.69844	5.00000	5.00000	1.07000	11.92000	0.28099	0.20000
	7.65987	10.17998	2.03600					
146	1.00000	1152.00000	1.00000	2.00000	1.00000	700.00000	0.37500	3.40000
	12.10000	0.69844	5.00000	5.00000	0.88000	7.52000	0.28099	0.20000
	6.23971	9.20252	1.84050					
147	1.00000	1153.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	5.00000	5.00000	1.33000	9.04000	0.05785	0.20000
	9.52116	11.26758	2.25352					
148	1.00000	1154.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	5.00000	5.00000	1.10000	7.08000	0.05785	0.20000
	7.87464	10.31823	2.06365					
149	1.00000	1155.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.49000	12.89000	0.02479	0.20000
	3.50779	6.27493	1.25499					
150	1.00000	1156.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.38000	15.07000	0.02479	0.20000
	2.72053	5.00376	1.00075					
151	1.00000	1157.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.41000	7.48000	0.02479	0.20000
	2.93509	5.38369	1.07674					
152	1.00000	1158.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000

	12.10000	0.69843	5.00000	5.00000	0.21000	3.75000	0.02479	0.20000
	1.50334	2.03845	0.40769					
153	1.00000	1159.00000	1.00000	2.00000	1.00000	700.00000	0.37500	3.40000
	12.10000	0.69844	5.00000	5.00000	1.07000	11.92000	0.28099	0.20000
	7.65987	10.17998	2.03600					
154	1.00000	1160.00000	1.00000	2.00000	1.00000	700.00000	0.37500	3.40000
	12.10000	0.69844	5.00000	5.00000	0.88000	7.52000	0.28099	0.20000
	6.29371	9.20252	1.84050					
155	1.00000	1161.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	5.00000	5.00000	1.33000	9.04000	0.05785	0.20000
	9.52116	11.26758	2.25352					
156	1.00000	1162.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	5.00000	5.00000	1.10000	7.08000	0.05785	0.20000
	7.87464	10.31923	2.06365					
157	1.00000	1163.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.48000	12.89000	0.02479	0.20000
	3.45621	6.17184	1.23437					
158	1.00000	1164.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.38000	15.07000	0.02479	0.20000
	2.72033	5.00376	1.00075					
159	1.00000	1165.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.41000	7.98000	0.02479	0.20000
	2.93509	5.38369	1.07674					
160	1.00000	1166.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.21000	3.75000	0.02479	0.20000
	1.50334	2.03845	0.40769					
161	1.00000	1167.00000	1.00000	2.00000	1.00000	700.00000	0.37500	3.40000
	12.10000	0.69844	5.00000	5.00000	1.15000	13.04000	0.28099	0.20000
	8.08940	10.45277	2.09055					
162	1.00000	1168.00000	1.00000	2.00000	1.00000	700.00000	0.37500	3.40000
	12.10000	0.69844	5.00000	5.00000	0.86000	16.21999	0.28099	0.20000
	6.15654	9.08757	1.81751					
163	1.00000	1169.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	5.00000	5.00000	0.88000	3.24000	0.05785	0.20000
	6.29371	9.20252	1.84050					
164	1.00000	1170.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.70000
	12.10000	0.69844	5.00000	5.00000	0.78000	4.57000	0.05785	0.20000
	5.58584	8.59938	1.71988					
165	1.00000	1171.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.32000	8.62000	0.02479	0.20000
	2.29080	4.14451	0.82890					
166	1.00000	1172.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.31000	10.46000	0.02479	0.20000
	2.21922	3.98577	0.79715					
167	1.00000	1173.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.33000	8.41000	0.02479	0.20000
	2.36239	4.29837	0.85967					
168	1.00000	1174.00000	1.00000	2.00000	1.00000	700.00000	0.37500	0.30000
	12.10000	0.69844	5.00000	5.00000	0.29000	11.61000	0.02479	0.20000
	2.07604	3.65231	0.73046					
169	1.00000	1175.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	6.22000	6.38000	1.38017	1.14628
	7.76904	18.45131	2.05015					
170	1.00000	1176.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	3.23000	4.22000	1.38017	1.14628
	4.03440	12.55373	1.39486					
171	1.00000	1177.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	6.33000	3.53000	1.38017	1.14628
	7.90644	10.33838	2.06768					
172	1.00000	1178.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	5.42000	7.33000	1.38017	1.14628
	6.76981	17.21225	1.91247					
173	1.00000	1179.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	3.92000	4.99000	1.38017	1.14628
	4.89624	14.29621	1.58847					
174	1.00000	1180.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000

	12.10000	0.69844	9.00000	9.00000	3.39000	3.93000	1.38017	1.14628
	4.23425	12.38865	1.44321					
175	1.00000	1181.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	2.19000	6.99000	1.38017	1.14628
	2.73540	9.05650	1.00628					
176	1.00000	1182.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	3.12000	6.86000	1.38017	1.14628
	3.89701	12.24189	1.36021					
177	1.00000	1183.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	5.28000	6.61000	1.38017	1.14628
	6.59494	9.43151	1.88630					
178	1.00000	1184.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	3.23000	4.68000	1.38017	1.14628
	4.03440	12.55373	1.39486					
179	1.00000	1185.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	2.35000	6.24000	1.38017	1.14628
	2.93525	9.69113	1.07679					
180	1.00000	1186.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	1.77000	8.02000	1.38017	1.14628
	2.21030	7.14020	0.79335					
181	1.00000	1187.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	8.00000	8.00000	8.91000	3.10000	1.38017	1.14628
	11.12896	19.27640	2.40955					
182	1.00000	1188.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	8.31000	4.43000	1.38017	1.14628
	10.37354	21.05852	2.33984					
183	1.00000	1189.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	6.29000	6.00000	1.38017	1.14628
	7.85647	18.55203	2.06134					
184	1.00000	1190.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	8.00000	8.00000	2.49000	3.67000	1.38017	1.14628
	3.11011	9.07727	1.13466					
185	1.00000	1191.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	2.64000	3.24000	1.38017	1.14628
	3.29747	10.73840	1.19316					
186	1.00000	1192.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	2.62000	3.86000	1.38017	1.14628
	3.27249	10.66996	1.18555					
187	1.00000	1193.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	3.13000	6.29000	1.38017	1.14628
	3.90950	12.27068	1.36341					
188	1.00000	1194.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	11.35000	2.52000	1.38017	1.14628
	14.17663	13.25797	2.65159					
189	1.00000	1195.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	4.61000	6.56000	1.38017	1.14628
	5.75808	15.75544	1.75060					
190	1.00000	1196.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	7.00000	7.00000	2.62000	5.57000	1.38017	1.14628
	3.27249	8.29885	1.18555					
191	1.00000	1197.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	7.00000	7.00000	3.11000	7.46000	1.38017	1.14628
	3.88452	9.49900	1.35700					
192	1.00000	1198.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	4.00000	4.00000	6.47000	3.41000	1.38017	1.14628
	8.08130	8.35821	2.08955					
193	1.00000	1199.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	3.42000	3.81000	1.38017	1.14628
	4.27172	13.06815	1.45202					
194	1.00000	1200.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	12.00000	12.00000	2.10000	2.74000	1.38017	1.14628
	2.62299	11.57176	0.96431					
195	1.00000	1201.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	1.41000	2.61000	1.38017	1.14628
	1.76115	5.65966	0.56597					
196	1.00000	1202.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000

	12.10000	0.69844	5.00000	5.00000	1.60000	7.08000	1.38017	1.14628
	1.99347	3.46190	0.69238					
197	1.00000	1203.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	6.00000	6.00000	4.10000	4.02000	1.38017	1.14628
	5.12107	9.80019	1.63336					
198	1.00000	1204.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	0.76000	4.33000	1.38017	1.14628
	0.94927	-0.26030	-0.05206					
199	1.00000	1205.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	5.04000	3.17000	1.38017	1.14628
	6.29517	18.39783	1.83978					
200	1.00000	1206.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	3.11000	6.91000	1.38017	1.14628
	3.88452	13.56399	1.35700					
201	1.00000	1207.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	2.30000	6.39000	1.38017	1.14628
	2.87280	5.27643	1.05529					
202	1.00000	1208.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	11.44000	3.87000	1.38017	1.14628
	14.28904	26.59492	2.65949					
203	1.00000	1209.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	11.00000	11.00000	3.11000	1.85000	1.38017	1.14628
	3.88452	14.92699	1.35700					
204	1.00000	1210.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	6.42000	3.77000	1.38017	1.14628
	[illegible].01885	20.81795	2.08179					
205	1.00000	1211.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	4.69000	4.32000	1.38017	1.14628
	5.85801	17.67409	1.76751					
206	1.00000	1212.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	4.00000	4.00000	2.95000	3.82000	1.38017	1.14628
	3.68467	5.21672	1.30418					
207	1.00000	1213.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	11.00000	11.00000	2.55000	6.44000	1.38017	1.14628
	3.18506	12.74316	1.15847					
208	1.00000	1214.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	40.00000	40.00000	3.95000	2.72000	1.38017	1.14628
	4.93372	63.84369	1.59609					
209	1.00000	1215.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	4.00000	4.00000	6.85000	6.14000	1.38017	1.14628
	8.55594	8.54650	2.14663					
210	1.00000	1216.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	4.00000	4.00000	6.22000	2.99000	1.38017	1.14628
	7.76904	8.20058	2.05015					
211	1.00000	1217.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	9.47000	5.01000	1.38017	1.14628
	11.82843	12.35253	2.47051					
212	1.00000	1218.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	4.74000	3.52000	1.38017	1.14628
	5.92046	8.89207	1.77841					
213	1.00000	1219.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	8.93000	5.59000	1.38017	1.14628
	11.15394	12.05896	2.41179					
214	1.00000	1220.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	4.57000	7.43000	1.38017	1.14628
	5.70812	8.70945	1.74189					
215	1.00000	1221.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	4.31000	4.47000	1.38017	1.14628
	5.38337	16.83313	1.68331					
216	1.00000	1222.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	4.44000	2.52000	1.38017	1.14628
	5.54575	17.13023	1.71303					
217	1.00000	1223.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	11.00000	11.00000	4.86000	3.37000	1.38017	1.14628
	6.07034	19.83735	1.80340					
218	1.00000	1224.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000

	12.10000	0.69844	10.00000	10.00000	4.73000	4.16000	1.38017	1.14628
	5.90797	17.76300	1.77630					
219	1.00000	1225.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	4.00000	4.00000	3.66000	4.99000	1.38017	1.14628
	4.57149	6.07936	1.51984					
220	1.00000	1226.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	4.00000	4.00000	4.08000	1.76000	1.38017	1.14628
	5.09609	6.51389	1.62847					
221	1.00000	1227.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	4.78000	1.66000	1.38017	1.14628
	5.97042	17.86816	1.78682					
222	1.00000	1228.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	14.40000	6.61000	1.38017	1.14628
	17.98619	28.89603	2.88960					
223	1.00000	1229.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	9.00000	9.00000	6.23000	1.80000	1.38017	1.14628
	7.79153	18.46577	2.05175					
224	1.00000	1230.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	5.94000	3.47000	1.38017	1.14628
	7.41931	20.04085	2.00409					
225	1.00000	1231.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	5.07000	2.92000	1.38017	1.14628
	6.33264	18.45717	1.84572					
226	1.00000	1232.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	4.00000	4.00000	5.57000	12.52000	1.38017	1.14628
	8.20621	8.41956	2.10489					
227	1.00000	1233.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	4.00000	4.00000	2.86000	10.64000	1.38017	1.14628
	3.57226	[illegible]	1.27320					
228	1.00000	1234.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	5.00000	5.00000	2.19000	4.17000	1.38017	1.14628
	2.73540	5.03139	1.00628					
229	1.00000	1235.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	4.00000	4.00000	5.99000	2.04000	1.38017	1.14628
	8.73080	8.66743	2.16686					
230	1.00000	1236.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	12.98000	4.95000	1.38017	1.14628
	16.21255	27.85785	2.78579					
231	1.00000	1237.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	6.83000	3.74000	1.38017	1.14628
	8.53036	21.43701	2.14370					
232	1.00000	1238.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	4.00000	4.00000	3.69000	5.50000	1.38017	1.14628
	4.60896	6.11201	1.52800					
233	1.00000	1239.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	6.00000	6.00000	1.70000	3.79000	1.38017	1.14628
	2.12337	4.51803	0.75301					
234	1.00000	1240.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	7.00000	7.00000	7.38000	4.77000	1.38017	1.14628
	9.21795	15.54805	2.22115					
235	1.00000	1241.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	4.00000	4.00000	5.18000	3.23000	1.38017	1.14628
	6.47004	7.46873	1.86718					
236	1.00000	1242.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	3.98000	3.28000	1.38017	1.14628
	4.97119	16.03658	1.60366					
237	1.00000	1243.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	6.00000	6.00000	5.40000	3.53000	1.38017	1.14628
	4.74574	8.67631	1.44615					
238	1.00000	1244.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	6.00000	6.00000	5.04000	3.90000	1.38017	1.14628
	6.29517	11.03470	1.83974					
239	1.00000	1245.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	6.00000	6.00000	6.44000	3.50000	1.38017	1.14628
	[illegible]	12.50943	2.08490					
240	1.00000	1246.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000

	12.10000	0.69844	2.00000	2.00000	4.34000	20.89999	1.38017	1.14628
	5.42084	3.38050	1.69025					
241	1.00000	1247.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	6.00000	6.00000	5.12000	7.34000	1.38017	1.14628
	6.39309	11.13318	1.85553					
242	1.00000	1248.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	6.00000	6.00000	3.48000	3.30000	1.38017	1.14628
	4.34667	8.81645	1.46941					
243	1.00000	1249.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	6.00000	6.00000	6.73000	7.77000	1.38017	1.14628
	8.40605	12.77371	2.12895					
244	1.00000	1250.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	6.00000	6.00000	6.55000	3.09000	1.38017	1.14628
	8.18122	12.61105	2.10184					
245	1.00000	1251.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	6.00000	6.00000	4.68000	3.74000	1.38017	1.14628
	5.84552	10.59405	1.76567					
246	1.00000	1252.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	6.00000	6.00000	4.46000	4.62000	1.38017	1.14628
	5.57073	10.30515	1.71753					
247	1.00000	1253.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	6.00000	6.00000	5.99000	5.49000	1.38017	1.14628
	7.48176	12.07481	2.01247					
248	1.00000	1254.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	3.00000	3.00000	11.15000	6.15000	1.38017	1.14628
	13.92682	7.90145	2.63382					
249	1.00000	1255.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	2.00000	2.00000	9.46000	8.24000	1.38017	1.14628
	11.81594	4.93490	2.46945					
250	1.00000	1256.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	15.00000	15.00000	6.55000	3.45000	1.38017	1.14628
	8.18122	31.52762	2.10184					
251	1.00000	1257.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	15.00000	15.00000	4.10000	4.49000	1.38017	1.14628
	5.12107	26.13392	1.63336					
252	1.00000	1258.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	15.00000	15.00000	5.20000	2.46000	1.38017	1.14628
	6.49502	28.06552	1.47104					
253	1.00000	1259.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	15.00000	15.00000	4.60000	4.00000	1.38017	1.14628
	5.74559	26.22547	1.74843					
254	1.00000	1260.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.69844	10.00000	10.00000	5.54000	2.80000	1.38017	1.14628
	6.91969	19.34370	1.93437					
270	1.00000	6711.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.10000	0.72583	15.00000	15.00000	4.44000	1.97000	1.38017	1.14628
	5.33647	30.14217	1.67457					
271	1.00000	6712.00000	1.00000	2.00000	2.00000	700.00000	0.37500	16.70000
	12.10000	0.72583	10.00000	10.00000	6.39000	2.70000	1.38017	1.14628
	7.68020	20.38644	2.03464					
272	1.00000	6713.00000	1.00000	2.00000	2.00000	700.00000	0.37500	16.70000
	12.10000	0.72583	10.00000	10.00000	13.99000	1.78000	1.38017	1.14628
	16.81470	28.22252	2.82225					
273	1.00000	6714.00000	1.00000	2.00000	2.00000	700.00000	0.37500	16.70000
	12.30000	0.72583	10.00000	10.00000	23.60999	2.84000	1.35772	1.10613
	23.35403	33.79430	3.37943					
281	1.00000	7211.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.70000	0.69844	10.00000	10.00000	1.56000	2.58000	1.31496	1.03543
	2.15710	7.65767	0.76577					
282	1.00000	7212.00000	1.00000	2.00000	1.00000	700.00000	0.37500	16.70000
	12.70000	0.69844	10.00000	10.00000	2.04000	2.15000	1.31496	1.03543
	2.82683	10.37030	1.03703					
283	1.00000	7213.00000	1.00000	1.00000	1.00000	700.00000	0.37500	16.70000
	12.70000	0.69844	10.00000	10.00000	2.45000	2.74000	1.31496	1.03543
	3.38776	12.20169	1.22017					
284	1.00000	7214.00000	1.00000	5.00000	1.00000	700.00000	0.37500	16.70000

	12.70000	0.69844	12.00000	12.00000	2.94000	2.51000	1.31496	1.03543
	4.06531	16.82988	1.40249					
285	1.00000	7215.00000	1.00000	5.00000	1.00000	700.00000	0.37500	16.70000
	12.70000	0.69844	15.00000	15.00000	4.08000	3.09000	1.31496	1.03543
	5.64166	25.95267	1.73018					
286	1.00000	7216.00000	1.00000	5.00000	1.00000	700.00000	0.37500	16.70000
	12.70000	0.69844	11.00000	11.00000	4.19000	3.14000	1.31496	1.03543
	5.79376	19.32456	1.75678					
287	1.00000	7217.00000	1.00000	5.00000	1.00000	700.00000	0.37500	16.70000
	12.70000	0.69844	9.00000	9.00000	5.66000	6.52000	1.31496	1.03543
	7.82642	18.51753	2.05750					
291	1.00000	7621.00000	2.00000	4.00000	1.00000	680.00000	1.12500	4.00000
	0.70000	5.93450	12.00000	12.00000	10.86000	3.01000	5.71428	2.62143
	0.69808	-4.31299	-0.35942					
292	1.00000	7631.00000	2.00000	2.00000	1.00000	680.00000	1.12500	4.00000
	0.70000	5.93450	12.00000	12.00000	2.10000	1.31000	5.71428	2.62143
	0.13499	-24.03076	-2.00256					
293	1.00000	7511.00000	2.00000	4.00000	1.00000	680.00000	1.12500	4.00000
	0.70000	5.93450	11.00000	10.00000	3.17000	1.76000	5.71428	2.62143
	0.20377	-15.90770	-1.59077					
294	1.00000	6021.00000	1.00000	1.00000	1.00000	670.00000	0.37500	13.00000
	3.80000	1.12299	8.00000	8.00000	2.87000	2.64000	3.42105	2.36000
	1.08232	0.63725	0.07966					
295	1.00000	6022.00000	1.00000	1.00000	1.00000	730.00000	0.37500	13.00000
	3.30000	0.47476	8.00000	8.00000	1.26000	1.68000	3.42105	2.36000
	1.12457	0.93917	0.11740					
296	1.00000	6023.00000	1.00000	1.00000	1.00000	670.00000	0.37500	13.00000
	14.80000	1.12299	4.00000	4.00000	1.33000	1.45000	0.87838	0.40878
	[illegible]	[illegible]	1.06375					
297	1.00000	6024.00000	1.00000	1.00000	1.00000	730.00000	0.37500	13.00000
	14.80000	0.47476	8.00000	8.00000	1.39000	1.40000	0.87838	0.40878
	5.61641	13.80553	1.72569					
298	1.00000	6025.00000	1.00000	1.00000	1.00000	700.00000	0.37500	13.00000
	3.80000	0.69844	12.00000	12.00000	1.14000	1.54000	1.32653	1.05510
	1.54696	5.23548	0.43629					
299	1.00000	6026.00000	1.00000	1.00000	1.00000	700.00000	0.37500	13.00000
	3.40000	0.69844	4.00000	4.00000	1.23000	1.48000	1.38298	1.15106
	1.52974	1.70091	0.42523					
300	1.00000	6027.00000	1.00000	1.00000	1.00000	700.00000	0.37500	13.00000
	1.50000	0.69844	4.00000	4.00000	2.15000	3.53000	8.66667	2.95800
	1.04066	0.15942	0.03985					
301	1.00000	6028.00000	1.00000	1.00000	1.00000	700.00000	0.37500	13.00000
	17.00000	0.69844	4.00000	4.00000	3.12000	3.43000	0.76471	0.32353
	13.80730	10.50079	2.62520					
302	1.00000	6029.00000	1.00000	1.00000	1.00000	650.00000	0.37500	13.00000
	9.80000	1.47449	4.00000	4.00000	2.06000	2.35000	1.32653	1.05510
	1.32413	1.12301	0.28075					
303	1.00000	6020.00000	1.00000	1.00000	1.00000	750.00000	0.37500	13.00000
	9.80000	0.40172	4.00000	4.00000	0.70000	2.40000	1.32653	1.05510
	1.65151	2.00675	0.50169					
308	1.00000	6321.00000	3.00000	2.00000	2.00000	800.00000	0.43800	19.29999
	0.80000	4.93020	22.00000	7.00000	315.00000	1.60000	24.12498	3.00000
	21.23730	21.41005	3.05853					
309	1.00000	6322.00000	3.00000	2.00000	1.00000	800.00000	0.43800	19.29999
	0.80000	4.93020	29.00000	11.00000	84.00000	1.30000	24.12498	3.00000
	5.67928	19.10507	1.73682					
310	1.00000	6323.00000	3.00000	2.00000	1.00000	800.00000	0.43800	19.29999
	0.80000	4.93020	56.00000	14.00000	101.00000	1.70000	24.12498	3.00000
	6.82866	24.89578	1.72113					
318	1.00000	7111.00000	3.00000	2.00000	1.00000	800.00000	0.50000	20.09999
	0.80000	5.23410	33.00000	20.00000	4.09000	1.56000	25.12498	3.00000
	0.26187	-26.79027	-1.33351					
319	1.00000	7112.00000	3.00000	2.00000	1.00000	800.00000	0.50000	20.09999
	0.80000	5.23410	23.00000	23.00000	4.57000	1.87000	25.12498	3.00000
	0.24272	-23.25653	-1.02365					
320	1.00000	7113.00000	3.00000	2.00000	1.00000	800.00000	0.50000	20.09999

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.80000	5.34105	29.00000	26.00000	3.33000	1.16000	25.12498	3.00000
	0.20762	-40.84761	-1.57105					
328	1.00000	7721.00000	1.00000	2.00000	1.00000	700.00000	0.37500	13.00000
	12.20000	0.71670	72.00000	72.00000	3.02000	3.08000	1.06557	0.61147
	6.89109	133.97650	1.93023					
329	1.00000	7741.00000	3.00000	4.00000	1.00000	800.00000	0.50000	20.09999
	0.80000	5.20410	40.00000	34.00000	8.90000	1.33000	25.12498	3.00000
	0.57006	-13.10826	-2.56201					
337	1.00000	7861.00000	1.00000	4.00000	1.00000	700.00000	0.37500	13.00000
	12.10000	0.69844	13.00000	13.00000	2.73000	3.09000	1.07438	0.62645
	6.23946	23.80161	1.83039					
338	1.00000	7862.00000	1.00000	2.00000	1.00000	700.00000	0.37500	13.00000
	12.10000	0.69844	11.00000	11.00000	3.00000	2.65000	1.07438	0.62645
	6.85655	21.17725	1.92520					
339	1.00000	7863.00000	1.00000	1.00000	1.00000	700.00000	0.37500	13.00000
	12.10000	0.69844	15.00000	15.00000	2.87000	2.64000	1.07438	0.62645
	6.55943	28.21356	1.88090					
340	1.00000	6611.00000	4.00000	2.00000	1.00000	400.00000	0.50000	7.70000
	10.00000	5.90000	34.00000	21.00000	8.64000	0.90000	0.77000	0.32750
	4.57498	31.93262	1.52060					
341	1.00000	6612.00000	4.00000	2.00000	1.00000	400.00000	0.50000	7.70000
	10.00000	5.90000	14.00000	10.00000	15.70000	0.66000	0.77000	0.32750
	8.12525	20.94975	2.09498					
342	1.00000	6613.00000	4.00000	2.00000	1.00000	400.00000	0.50000	8.70000
	10.00000	5.90000	14.00000	6.00000	13.60000	0.66000	0.87000	0.40250
	5.72692	10.47106	1.74518					
343	1.00000	6614.00000	4.00000	2.00000	1.00000	400.00000	0.50000	8.70000
	10.00000	5.90000	10.00000	6.00000	9.30000	0.83000	0.87000	0.40250
	3.91620	8.19073	1.56512					
344	1.00000	6615.00000	4.00000	2.00000	1.00000	400.00000	0.50000	25.59999
	10.00000	5.90000	13.00000	13.00000	7.30000	0.88000	2.56000	2.26184
	0.54703	-7.44233	-0.60326					
345	1.00000	6616.00000	4.00000	2.00000	1.00000	400.00000	0.50000	25.59999
	10.00000	5.90000	18.00000	11.00000	6.40000	0.90000	2.56000	2.26184
	0.47359	-8.08316	-0.73463					
346	1.00000	6617.00000	4.00000	2.00000	1.00000	400.00000	0.50000	8.70000
	10.00000	5.90000	14.00000	14.00000	2.95000	1.80000	0.87000	0.40250
	1.24224	3.83578	0.21691					
347	1.00000	6618.00000	4.00000	2.00000	1.00000	400.00000	0.50000	7.70000
	10.00000	5.90000	18.00000	11.00000	2.70000	0.51000	0.77000	0.32750
	1.39734	3.68023	0.33457					
348	1.00000	6619.00000	4.00000	2.00000	1.00000	400.00000	0.50000	7.70000
	10.00000	5.90000	31.00000	23.00000	1.82000	0.55000	0.77000	0.32750
	0.33365	-0.14628	-0.00636					
349	1.00000	7731.00000	4.00000	4.00000	1.00000	600.00000	0.93700	7.50000
	5.10000	5.90000	15.00000	15.00000	23.71999	1.99000	1.47059	1.30000
	3.07257	13.93503	1.12[illegible]					
350	1.00000	7732.00000	4.00000	4.00000	3.00000	600.00000	0.93700	7.50000
	5.80000	5.90000	30.00000	30.00000	15.39000	1.80000	1.29310	0.99827
	2.61298	28.81476	0.96049					
351	1.00000	6742.00000	4.00000	2.00000	1.00000	30.00000	0.19700	10.50000
	5.80000	4.76000	63.00000	29.00000	13.69000	1.60000	1.81034	1.87759
	1.53178	11.94007	0.42643					
352	1.00000	6741.00000	4.00000	2.00000	1.00000	30.00000	0.19700	10.40000
	5.80000	2.50000	45.00000	9.00000	9.22000	1.23000	1.79310	1.84828
	2.16449	6.96792	0.77421					
353	1.00000	7331.00000	4.00000	2.00000	1.00000	600.00000	0.28900	1.10000
	4.10000	1443.00000	9.00000	7.00000	32.14999	0.64000	0.26829	0.20000
	0.11140	-15.34240	-2.19463					
354	1.00000	7332.00000	4.00000	2.00000	1.00000	500.00000	0.28900	1.10000
	4.10000	8046.00000	4.00000	7.00000	92.31000	0.92000	0.26829	0.20000
	0.03726	-20.[illegible]	-2.85634					
355	1.00000	7333.00000	4.00000	2.00000	1.00000	600.00000	0.01300	1.10000
	4.10000	1443.00000	4.00000	4.00000	1.87000	0.54000	0.26829	0.20000
	0.00645	-20.15640	-5.03910					
356	1.00000	7334.00000	4.00000	2.00000	1.00000	500.00000	0.01300	1.10000
	4.10000	8046.00000	0.00000	4.00000	27.55000	0.68000	0.26829	0.20000
	0.01711	-16.27236	-4.06822					