WADC TECHNICAL REPORT 54-531
SUPPLEMENT 1

INVESTIGATION OF MATERIALS FATIGUE PROBLEMS APPLICABLE TO PROPELLER DESIGN

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FOREWORD

This report was prepared by the Technical Section, H.N. Cummings, Consulting Engineer, and F.B. Stulen, Chief Technical Engineer, and the Metallurgy Department, W.C. Schulte, Chief Metallurgist, of the Curtiss-Wright Corporation, Propeller Division, under Contract 33(616)-493, and covers work performed during the period of 1 April to 30 September 1955. The work was supported jointly by the Materials Laboratory and the Propeller Laboratory of Wright Air Development Center and the contract was initiated under Project No. 3346, "Propeller Blades", Task No. 73497, "Investigation of the Statistical Nature of Fatigue", formerly RDO No. 591-80. The contract was monitored by Lt. D.M. Forney, Jr., Materials Laboratory and J.S. Keeler, Propeller Laboratory, Project Engineers.

The interest and suggestions of Mr. G.W. Brady, Director of Engineering of Curtiss-Wright Corporation Propeller Division, are gratefully acknowledged. Other personnel of the Propeller Division who have assisted in the work are R.B. Christofferson, W.D. Lamson, F.G. Lehman, J.H. Redfern, C.A. Madden, and J.J. Scannelli.

ABSTRACT

WADC Technical Report 54-531 reported the fatigue characteristics of SAE 4340 steel as a guide for propeller and rotor designers. Stress levels for probabilities of 10, 50 and 90% survival under repeated loading were determined for a constant life. The knowledge, however, that 90% of a material will survive a given stress for, say, ten million cycles is not adequate for the design engineer. What he would like to know is at what stress 100% of the material will survive. Therefore, the tests reported in WADC Technical Report 54-531 have been supplemented by additional fatigue tests in the long-life region in order to determine higher survival probabilities, in the order of 99%. Inclusion studies have revealed variability within the steel ingot that caused greater scatter in strength than was predicted by the tests reported in WADC TR 54-531.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. R. WHITMORE
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SECTION I. INTRODUCTION

The general purpose of these investigations is set forth in the contract as follows: ". . . . to conduct a test program planned and analysed using statistical methods for the purpose of furnishing designers with the fatigue characteristics of SAE 4340 steel and which will serve as a guide for obtaining the fatigue characteristics of other propeller and rotor blade materials" (1)[1/]. In reference (1) probabilities of 10, 50 and 90% survival of fatigue stress at constant life were determined. The probability that 90% of the specimens of a structural material will survive a given stress for, say, ten million cycles is not adequate information for the design engineer. What he would like to know is the stress that 100% of the specimens will probably survive. Even the powerful methods of modern statistical analysis will not give probabilities much beyond the ranges covered by a set of test data, unless the law of distribution of probabilities is known, and the only way to establish this law of distribution is to test very large numbers of specimens.

In the case of the SAE 4340 steel being investigated it has been established that in the long-life region, for the range from 10 to 90%, strength at constant life can be assumed to be either normally or log-normally distributed whichever is more convenient. This means that it is not known certainly whether either distribution is exact. And when probabilities of survival higher than 90% are sought small deviations from perfect normal distribution can change the survival stress very appreciably. In the terminology of the statistician, seeking for high-survival probabilities means looking for the fatigue strength of the weaker specimens in the uncertain thin width of the lower tail of the distribution of fatigue strengths.

The tests reported in this supplemental report were made for the purpose of obtaining probabilities of survival of stress at constant life, as much higher than 90% as time and the number of specimens available would permit. For the lowest stress at which tests were made a hundred specimens were used. This gave information regarding the probabilities of survival of the order of about 99%, based on the data reported herein combined with those reported in reference (1).

The specimens tested were from the same heat of steel as those used for reference (1), and the fabrication, testing, and analysing techniques were the same. However, wherever comparisons can be made, consistent and persistent small but significant differences appear between the results of the tests reported herein (which will be referred to as the "1955 tests"), and those reported in reference (1) (which will be referred to as the "1954 tests"). Possible explanations of these differences were investigated (see Appendix I) and it was finally concluded that differences in inclusion size and distribution in different parts of an ingot were responsible. In order to get more representative values of the mean and the high probability strength of the heat of steel, the 1954 tests were combined with the 1955 tests in the probit analyses from which the values shown in Tables 1 and 2 were obtained. For comparison, these tables show also the values as computed from the 1955 tests alone and from the 1954 tests alone. Test data for the 1955 tests are given in Tables 3, 4 and 5. Final results are given in Tables 1 and 2, and on Figs. 1 and 2.

SECTION II. TEST MATERIALS AND SPECIMENS

The SAE 4340 steel used for the tests reported herein was from the same heat (Republic Steel Heat No. H15701A) from which specimens were cut for the 1954 tests. The specimens were numbered as described in reference (1), and so distributed that each bar contributed speci-

1/ Numbers in parenthesis refer to references in the Bibliography.

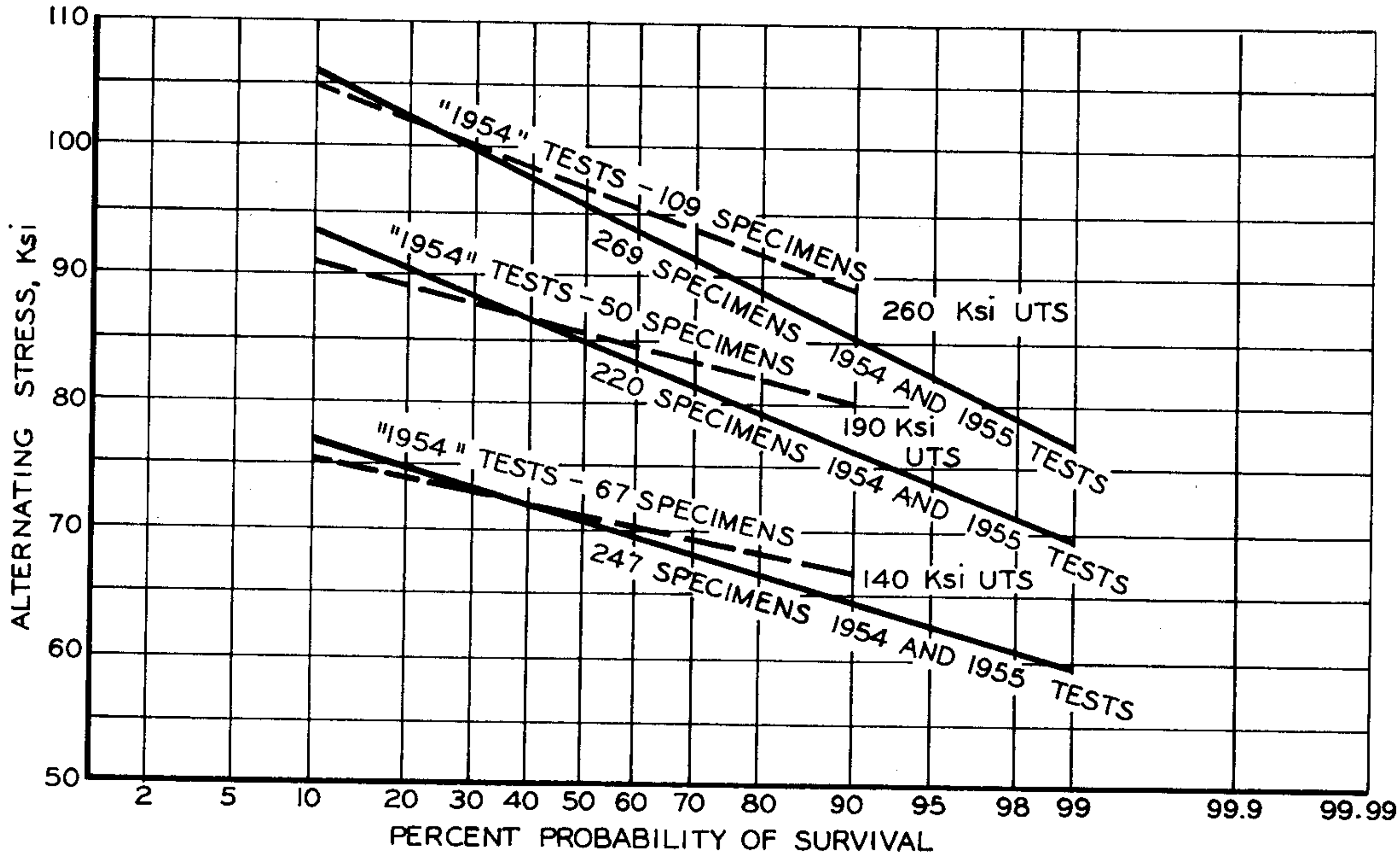

FIG. I

PROBABILITIES OF SURVIVING 10^7 CYCLES OF ALTERNATING STRESS SMOOTH R.R. MOORE ROTATING BEAM SPECIMENS OF SAE 4340 STEEL TESTED AT 10,000 - 11,000 RPM

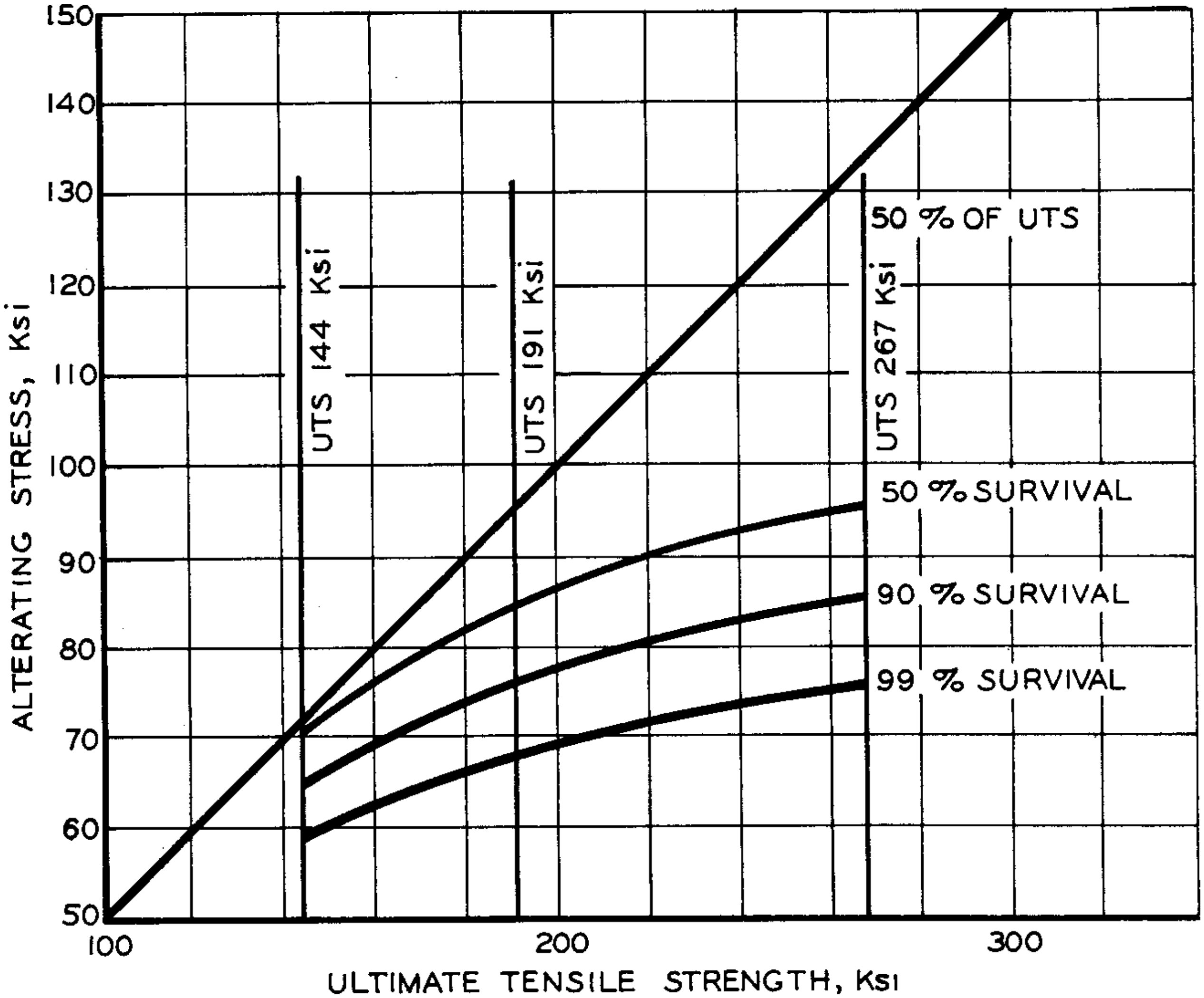

FIG. 2

(REVISION OF PART OF FIG. 30 REFERENCE 1)

SAE 4340 STEEL, LINES OF 50, 90 AND 99 %

SURVIVAL OF STRESS AT 10^7 CYCLES

R.R. MOORE ROTATING BEAM TESTS OF SMOOTH SPECIMENS

AT 10,000 – 11,000 RPM VS. ULTIMATE TENSILE STRENGTH mens to each of the three hardness levels, 140, 190, and 260 ksi, UTS, nominal. The fabrication, heat treatment, and stress relief procedures were also as described in reference (1).

SECTION III. TESTING PROCEDURES

The testing-laboratory routine was the same as was followed during the 1954 tests. The laboratory personnel was not the same, although supervision was by the same personnel as before. A possibility existed, of course, that this might account for the persistent differences between 1954 and 1955 results, but this was eliminated later (see Appendix I).

For each of the three hardness levels, the first tests were made at a stress level corresponding to a set of 1954 tests in the finite life region, to check on the validity of the assumption that the 1955 tests could be used for simply extending the 1954 test results to lower stress levels. Since all specimens were to be from the same heat of steel used previously, it had been supposed that this would be a mere matter of routine. However, after tests of 140 ksi UTS steel at 81 ksi stress level showed a singificantly lower life at constant stress than the "adjusted" life of 1954 specimens, tests were run at 77 ksi, and at 75 ksi, with the same result - lower life at constant stress (see Table 6). This caused a change from the original plan of testing only at stress levels below those reported in reference (1). Test levels were set to over-lap the lower stress levels of the 1954 tests, and a set of ten specimens was tested at each step downward until a level was reached at which the ten all survived ten million cycles. At that same level testing continued in sets of ten until one or more failures occurred. Then testing was started at the next lower step, at which time about a hundred specimens were left. No breaks occurred in testing the 140 ksi steel until after 70 specimens had been tested. Then it was decided to continue testing on that level until the supply of specimens was exhausted. The same procedure was followed in testing the 190 and the 260 ksi UTS specimens.

It will be noted in Tables 3, 4, and 5, for test sets in which one or more specimens survived 10^7 cycles, the number of "kilocycles at end of test" is given. Failures to survive 10^7 cycles are indicated by asterisks. For the other specimens the tests were stopped after running for anywhere from just over 10 million to as many as 40 or 50 million cycles. Since no time could be gained by stopping tests as soon as 10 million cycles had been run, it was decided to let the tests run as long as convenient, and to let tests started Fridays run over the weekend, to see if breaks might occur after the traditional "endurance limit" test period of 10^7 cycles. A few such breaks did occur.

SECTION IV. ANALYSIS PROCEDURE

It was stated in Appendix XII of reference (1) that the "high survival probability" data that were to be the subject of this supplemental report would be analysed by a modification, recommended by Bartlett, of the usual methods of probit analysis. The data for the tests of 140 ksi UTS were analysed by the Bartlett procedure (see ref. 2), and also by the ordinary method that was used in reference (1). It was found, as suggested by Finney (2) that since there were so many specimens tested at the low stress levels, the results of the two methods were close to each other. Furthermore, for the 190 ksi UTS tests, since there were no failures in the 100 specimens available for testing at the lowest stress the Bartlett procedure could not be used. Therefore, this report is based on analyses by the same methods used in reference (1).

SECTION V. RESULTS AND DISCUSSION

The final results of the analysis of combined 1954 and 1955 test data are shown in Fig. 1. Mean fatigue strengths and standard deviations, for 10 million cycles of fatigue stressing are given in Table 1, and 99% probabilities of strength for 10 million cycles of fatigue strength are given in Table 2. Fig. 2 is a revision of part of Fig. 30, reference (1). It shows slightly lower mean (50%) strengths at 10 million cycles than the 1954 tests showed, a somewhat greater lowering of 90% survival strengths, and an additional line for 99% survival strengths. The gradual flattening of the survival curves, on Fig. 2, as very high survival probabilities are approached suggests that although mean fatigue strengths of this SAE 4340 steel do not increase linearly with "static" ultimate tensile strengths, possibly very high probability strengths may be taken as increasing at a constant rate with tensile strength within the range of the tests and for a short distance outside the range, that is, from say 140 to 280 ksi UTS.

On Fig. 1, the relative reliability of the graphs is indicated thus:

a. More reliable results plotted as heavy solid lines.

b. Less reliable results shown by light dash lines. Reliability depends upon both the number of specimens tested and their distribution among the stress levels. The total number of specimens for each of the lines is shown on the chart. Obviously more reliable probabilities can be obtained from large numbers of tests than from a quarter to a half as many. This gives more presumptive reliability to the solid than to the dash lines. Furthermore, whereas the specimens used in the 1954 tests were distributed about evenly along the lines, relatively large numbers of specimens were used for the lowest stress levels to determine the low ends of the heavy solid lines. The method of probit analysis takes this into account and justifies stating that not only the mean (50%) points on the heavy lines but also the low ends are pretty close to correct. Attention is called to the fact that the heavy lines, representing results obtained from combinations of the stronger 1954 steel and the less strong 1955 steel, are lower than the 1954 lines, and that they have steeper slopes. The steeper slopes indicate larger standard deviations, that is, a widening of the scatter bands so as to include the lower strengths of the 1955 specimens that resulted from many of them having larger inclusions.

Table 2 brings out strongly the danger of extrapolating from inadequate data. Tentative extrapolation from the 1954 data alone gave results that were too optimistic. However, except for the accidental order in which bars were taken from the bundle for testing, the reverse could just as well have occurred, that is, the early results could have been too pessimistic.

SECTION VI. SUMMARY AND CONCLUSIONS

Data are presented for determining high probabilities of survival of stress at constant life, for SAE 4340 steel heat treated to 140, 190, and 260 ksi UTS. These data were combined with those reported in reference (1) in order to compute fatigue stresses that there are 50, 90 and 99% probabilities the specimens can survive for 10^7 cycles. The survival stresses are shown in Fig. 2.

The average size of inclusions in single nucleus fractures was found to be significantly larger in the 1955 specimens than in the 1954 specimens. This was taken to indicate variation within an ingot of steel, and to account for the lower values of life of the 1955 specimens as compared with the 1954 specimens. The 1955 tests were planned to overlap the 1954 tests so that when the two sets were combined the computed survival stresses would be more representative of the ingot than those computed from either set alone.

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2. Finney, D.J., Probit Analysis, Cambridge University Press, 1952.

3. Frankel, H.E., and Bennett, J.A., Understressing as a Means of Eliminating the Damaging Effect of Fatigue Stressing, Paper presented to ASTM, June 1955.

APPENDIX I

STUDIES OF DIFFERENCES BETWEEN 1954 TESTS AND 1955 TESTS

I.1 Comparison Tests at Finite Life.

The first indication that the 1955 tests might not check with the 1954 tests appeared when tests of 140 ksi UTS specimens at 81 ksi stress-level were compared. The fatigue life values of the 1954 tests were reported (1) as observed (i.e., before adjustment), and also as adjusted because of stress-relief damage to the surfaces of stress relief groups 1 and 3. Statistical significance tests indicated (Table 6) no significant difference between the 1955 tests and the unadjusted 1954 tests. Similar results were found in the tests at 77 and at 75 ksi stress levels, and, later, in the tests of 190 and 260 ksi steel. This suggested the possibility that the 1955 test specimens were in general not as strong in fatigue as the 1954 specimens.

I.2 Comparison Tests at Long Life.

The fact that the values of mean strength at 10^7 cycles that are recorded in Table 1 are, in every case, a small amount lower for 1955 tests than for 1954 tests, and that this was predicted by the tests at finite life, indicates the existence of one or more "assignable causes". The differences are small, but statistically significant, and some supplementary testing and considerable supplementary analysis was required to track down what seems to be the main assignable cause. The next paragraphs describe in chronological order these investigations.

I.3 Possible "Assignable Causes" for Differences Between 1955 and 1954 Tests.

I.3.1 Oiled VS. Dry Surfaces of Specimens.

Early in the testing period a paper by Frankel and Bennett (3) became available. The authors found that "oil . . . . raised the fatigue limit and increased the fatigue life . . . ." of SAE 4340 steel. At about the time reference (3) became available, oiling of the 190 ksi UTS and the 260 ksi UTS specimens were being considered since hot humid weather had arrived and rusting of the surfaces was a possibility. It was immediately decided to test four sets of ten specimens each, of 190 ksi UTS steel, at 96 ksi stress level, for comparison with the corresponding set of ten in the 1954 tests. Surface treatment was as follows:

a. Not oiled. Tested as received after stress relief.
b. Oiled with Cosmoline 265 (Houghton Oil Co.) and tested without cleaning.
c. Oiled with Cosmoline 265, then degreased with trichlorethylene vapor degreaser before testing.
d. Oiled with Cosmoline 265, then wiped dry, with soft tissue paper, before testing.

Results of the tests are given in Table 4. Statistical studies of the data, as shown in Table 7, fully confirmed the findings reported in reference (3), and also indicated that there was no significant difference among treatments a, c, and d. Based on these findings, it was decided to immediately oil specimens when received after stress relief, and to wipe them dry with soft tissue paper just before testing. (The tests just described do not give any indication as to how thin the oil coating can be and still appreciably increase the fatigue life of a specimen of this steel. This subject requires further investigation.)

Upon questioning the laboratory technician who did the 1954 testing it was learned that although the specimens were not oiled, they were wiped with soft tissue paper before testing, to remove any grease that might have gotten onto their surfaces. This put the 1954 specimens in the same category as the 1955 specimens that had treatments a, c, or d as listed above, and appeared to eliminate oiled or greasy surfaces as the reason for higher values in the 1954 tests.

I.3.2 Variations in Heat Treatments.

It was thought that possibly the temperature controls on the heat treatment furnaces might have varied so that small differences in hardness and in corresponding tensile strength might have occurred. Tensile strength and fatigue strength depend upon hardness, therefore tests of hardness were made on samples chosen at random from specimens tested in 1954 and in 1955. The following values of Rockwell C-scale hardness were found - each number being the average of three tests on a specimen. Hardness readings were taken to one decimal place and averages computed to two places.

Rockwell C Hardness Tests on Specimens of 260 ksi UTS

	1954 Specimens	1955 Specimens
	52.10	52.03
	52.07	52.00
	51.93	51.97
	51.93	51.83
	51.87	51.77
	51.63	51.77
	51.63	51.70
	51.57	51.70
	51.50	51.60
	51.43	51.03
Mean,	51.77	51.74

There is no indication in this brief study that heat treatments were out of control.

I.3.3 Eccentricity of Specimens in R. R. Moore Machines.

The laboratory reports on the 1955 tests indicated that there was upwards of twice as much eccentricity in the mounting of the specimens as there was in the 1954 tests. This might be caused by (a) less perfect machining of the specimens, (b) more wear in the collets and bearings of the machines, or (c) less care by the laboratory technician in placing specimens in the machines.

a. Since the general testing of both 1954 and 1955 specimens had been completed there were no specimens in "as received" condition for comparison as to machining imperfections. There was no reason to believe the machining vendor had lowered his standards, but the possibility remained until an opinion could be reached from other tests.

b. Although it had been concluded, as stated in reference (1), that eccentricities of the magnitude measured in the early tests did not correlate with fatigue life, records have been kept of the static eccentricity of practically all specimens tested. An analysis of these records gave the following results, which have a definite significance as to the cause of increased 1955 eccentricity, since the data below are listed in chronological order of testing.

Hardness Level ksi	Mid Date of Testing	No. of Specimens	Mean Eccentricity 10^{-3} inch	Increase in Eccentricity 10^{-3} inch	Stand. Dev. 10^{-3} in.	Increase in St. Dev. 10^{-3} inch
140	3-31-54	324	0.775		0.233	
				0.140		0.002
190	4- 8-54	315	0.915		0.235	
				0.350		0.057
260	9- 7-54	312	1.265		0.292	
				0.320		0.086
140	5-24-55	196	1.585		0.378	
				0.270		0.052
190	6-16-55	209	1.855		0.430	
				0.300		0.030
260	7-18-55	169	2.155		0.460	

From these data it is concluded that the consistency of the increase in eccentricity, as testing continued, indicates a continuous wear in equipment, which made low eccentricity more and more impossible to obtain. This seemed to indicate that the change in laboratory personnel was not responsible for the increased eccentricity. It further indicated that if the 1955 technician were given new spindle assemblies for the R. R. Moore machines he could match the close settings of the earliest tests, or perhaps better them, and produce a set of tests that could be used to compare with the 1954 tests and/or with his 1955 tests to study the effect of eccentricity on fatigue strength.

c. Although lack of careful work by the laboratory technician seemed to have been eliminated as in any way responsible for the lower values obtained in the 1955 tests, there was no longer any reason to doubt his workmanship when tests were made using new spindle assemblies. At no time did his first assembling of specimen and housings give an eccentricity of over 0.00075 inches, and two or three or even four re-assembling operations failed to noticeably improve the reading of the dial (see Fig. 54, p. 80, ref. 1). Two sets of tests were run, with the following results, shown in comparison with earlier 1955 tests.

UTS ksi	Stress ksi	No. of Specimens	Surface Treatment	Mean Eccentricity	Mean Life1/
190	96	10	Oiled & Degreased	0.00205 in.	105 Kc
		5	" "	0.00035	100
260	116	10	Oiled & Wiped	0.00205 in.	66
		6	" & Degreased	0.00040	57

Statistical studies based on F-ratio and on t-tests indicate no significant difference between the results shown above obtained with large and with low eccentricities. It was concluded that wear in the testing equipment had not progressed far enough to account for the lower results obtained in the 1955 tests, and that there had been no lowering of machining standards.

I.3.4 Variation Within An Ingot.

Along with the lower fatigue strength values reported in the 1955 tests, larger inclusions were frequently reported. When the 1955 testing was finished, a general study of inclusion sizes was made. It was felt that a comparison of the sizes of all the single-nucleus inclusions found in all the fractured specimens tested in 1955 with those tested in 1954 might indicate a difference in inclusion size and/or distribution. The results of this study were as follows:

	No. of Specimens	Mean of Inclusion Sizes	Standard Deviation
1954 tests	208	0.00132 in.	0.00046 in.
1955 tests	125	0.00173 in.	0.00054 in.

1/ Life corresponding to mean log-life.

Statistical analysis, using F-ratio and t-tests indicate that the scatter is somewhat significant and that the difference in mean sizes is very significant. This leads to the conclusion that the specimens tested in 1955 were more vulnerable to fatigue stressing, at least in the long-life (generally single nucleus) region than were the specimens tested in 1954. The steel bars were received from the steel company in bundles and the bundles were stored in racks. So far only one bundle has been opened. Bars for 1954 tests were taken from the top of that bundle and bars for 1955 tests were taken from about the middle of the same bundle. On the assumption that each bundle came from an ingot, the difference between the inclusion contents of the two sets of bars brings out a variation of fatigue strength within an ingot.

TABLE 1

Comparison of Combined Tests with 1954 and with 1955 Tests in the Long Life Region, Based on Probit Analysis of Strength at $N = 10^7$ Cycles

R. R. Moore Rotating Beam Tests of Smooth Specimens of SAE 4340 Steel, all from the Same Heat

	140 ksi UTS		190 ksi UTS		260 ksi UTS	
	Mean (50%) Strength	Standard Deviation	Mean (50%) Strength	Standard Deviation	Mean (50%) Strength	Standard Deviation
Combined Tests	69.0 ksi	4.4 ksi	84.5 ksi	6.7 ksi	95.8 ksi	8.5 ksi
1954 Tests	71.0 ksi	3.5 ksi	85.5 ksi	4.4 ksi	97.0 ksi	6.3 ksi
1955 Tests	67.4	4.0	84.0	7.0	93.8	7.8

TABLE 2

Ninety-nine Percent Probabilities of Survival of Stress (Strength) for 10^7 Cycles, as Determined from Combined 1954 and 1955 Tests, and from 1954 Tests Alone, of SAE 4340 Steel. Smooth Specimens. R. R. Moore Rotating Beam Tests. Speed of Testing, 10,000 - 11,000 RPM.

	140 ksi UTS	190 ksi UTS	260 ksi UTS
Combined Tests	59 ksi	69 ksi	76 ksi
1954 Tests, ksi	63 *	75 *	82 *

* These 1954 values were extrapolated from inadequate data. This matter is discussed in TR 54-531.

TABLE 3

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 140 ksi UTS

NOTE: Specimens not oiled previous to testing.

81 ksi Stress Level, Nominal

Specimen No.	FHBI03	FLBK18	FPBL05	DUBD13	DYBF34	FCBH18	FDBH20			
Diam., Inches	0.2310	0.2305	0.2305	0.2308	0.2308	0.2303	0.2298			
Machine No.	10	13	10	13	10	13	10			
Kilocycles to Fracture	113	150	111	102	84	120	116			
Dist., Ctr. to Fracture **	-0.02	-0.09	-0.12	0	+0.02	-0.03 1/2	-0.07 1/2			

(Reproduced from WADC TR 54-531) 81 ksi Stress Level, Nominal

Specimen No.	ABAA04	AFAB06	AKAC11	ANAD01	BMAN31	BPA028	BUAP05	BXAR35	CBAS06	CFAT02
Diam., Inches	0.2298	0.2300	0.2301	0.2306	0.2310	0.2305	0.2310	0.2310	0.2300	0.2305
Machine No.	19	20	21	22	23	24	19	20	21	22
Kilocycles to Fracture *	163	120	124	125	228	293	112	123	118	98
Dist., Ctr. to Fracture **	+0.02 1/2	+0.02 1/2	-0.05	-0.14 1/2	+0.01 1/2	+0.02 1/2	+0.02	-0.02 1/2	-0.01 1/2	+0.05 1/2
Stress Relief Group	1	1	1	1	2	2	2	3	3	3
Adjusted Kilocycles	260	188	195	198	228	293	112	195	186	153

77 ksi Stress Level, Nominal

Specimen No.	FBBH01	FFBI22	FLBK06	FOBL30	DUBD04	FCBH09	FHBI30	FMBK14	FNBL01	FDBH05
Diam., Inches	0.2300	0.2310	0.2305	0.2305	0.2310	0.2305	0.2310	0.2310	0.2305	0.2311
Machine No.	10	13	19	20	21	22	23	24	25	13
Kilocycles to Fracture	152	281	301	191	216	132	180	186	140	127
Dist., Ctr. to Fracture **	+0.04	-0.14	+0.08 1/2	+0.09 1/2	+0.02	+0.07 1/2	-0.03	+0.03 1/2	+0.04	+0.01

* Before adjustment.
** Minus sign indicates distance toward motor end of specimen. Distance in inches.

TABLE 3

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 140 ksi UTS

NOTE: Specimens not oiled previous to testing.

(Reproduced from WADC TR 54-531) 77 ksi Stress Level, Nominal

Specimen No.	ACAA34	AHAB36	AMAD01	AIAC05	APAF09	AWAH33	AXAI11	BAAK10	BDAL20	BIAM16
Diam., Inches	0.2295	0.2300	0.2300	0.2296	0.2295	0.2300	0.2298	0.2300	0.2305	0.2300
Machine No.	23	24	25	26	19	20	21	22	23	19
Kilocycles to Fracture*	198	136	168	732	404	234	315	449	549	419
Dist., Ctr. to Fracture **	-0.14	-0.03½	-0.06	-0.23½	+0.08½	-0.11½	-0.02	-0.14½	+0.13½	-0.07½
Stress Relief Group	1	1	1	1	2	2	2	2	2	2
Adjusted Kilocycles	373	251	314	1480	404	234	315	449	549	419

(Reproduced from WADC TR 54-531) 77 ksi Stress Level, Nominal (Continued)

Specimen No.	BMAN25	BPAO22	AXAI17	CHAT36	ATAH03	BTAP33	BXAR29	CAAS37	CDAT34
Diam., Inches	0.2295	0.2302	0.2290	0.2295	0.2296	0.2310	0.2302	0.2305	0.2305
Machine No.	20	21	22	23	19	20	21	22	23
Kilocycles to Fracture*	317	330	313	172	390	155	229	134	136
Dist., Ctr. to Fracture **	+0.03½	+0.03½	+0.03	-0.04½	+0.13	+0.04	-0.07	+0.02	+0.02
Stress Relief Group	2	2	2	3	2	3	3	3	3
Adjusted Kilocycles	317	330	313	321	390	288	425	248	251

75 ksi Stress Level, Nominal

Specimen No.	DUBD22	DYBF07	FBBH19	FFBI13	FKBK28	FNBL25	DWBD30	FABF05	FCBH03	FHBI18
Diam., Inches	0.2308	0.2307	0.2297	0.2305	0.2302	0.2298	0.2302	0.2302	0.2307	0.2306
Machine No.	19	23	19	23	19	23	19	23	19	23
Kilocycles to Fracture	292	255	203	171	298	151	221	176	185	158
Dist., Ctr. to Fracture **	-0.06	+0.11	+0.05	+0.04	+0.01½	+0.00½	+0.01½	+0.09	-0.03½	+0.02

* Before adjustment.
** Minus sign indicates distance toward motor end of specimen. Distances in inches.

TABLE 3

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 140 ksi UTS

NOTE: Specimens not oiled previous to testing.

(Reproduced from WADC TR 54-531) 75 ksi Stress Level, Nominal

Specimen No.	ABAA34	AFAB36	ALAC02	ANAD31	BRA021	ASAF02	BUAP35	BYAR25	CBAS36	CFAT32
Diam., Inches	0.2295	0.2295	0.2305	0.2275	0.2298	0.2300	0.2300	0.2300	0.2300	0.2305
Machine No.	23	24	25	26	19	20	19	20	21	22
Kilocycles to Fracture *	275	299	228	392	383	208	225	319	190	188
Dist., Ctr. to Fracture **	$+0.08\frac{1}{2}$	$-0.06\frac{1}{2}$	$+0.00\frac{1}{2}$	+0.12	$+0.00\frac{1}{2}$	$+0.06\frac{1}{2}$	-0.11	$-0.08\frac{1}{2}$	0.00	-0.01
Stress Relief Group	1	1	1	1	2	2	3	3	3	3
Adjusted Kilocycles	302	330	251	432	383	208	247	352	208	206

* Before Adjustment
** Minus sign indicates distance toward motor end of specimen. Distances in inches.

73 ksi Stress Level, Nominal

Specimen No.	FABF35	FDBH23	FHBI06	FKBK10	FNBL34	DWBD36	DZBF03	FCBH24	FIBI08	FKBK19
Diam., Inches	0.2299	0.2305	0.2304	0.2306	0.2307	0.2308	0.2307	0.2307	0.2307	0.2305
Machine No.	10	16	18	19	20	21	22	23	25	26
Kilocycles to End of Test	195*	241*	571*	14,232	184*	261*	474*	251*	270*	275*
Dist., Ctr. to Fracture **	-0.09	$+0.07\frac{1}{2}$	-0.13		-0.07	-0.16	+0.08	-0.04	-0.11	$+0.03\frac{1}{2}$

71 ksi Stress Level, Nominal

Specimen No.	FPBL32	DXDB02	DYBF19	FBBH28	FFBI07	FLBK21	FOBL03	DUBD16	DZBF06	FDBH35
Diam., Inches	0.2305	0.2306	0.2302	0.2305	0.2299	0.2305	0.2306	0.2304	0.2309	0.2310
Machine No.	24	16	18	19	20	21	22	23	25	26
Kilocycles to End of Test	243*	359*	744*	197*	11,426	11,989	511*	232*	232*	238*
Dist., Ctr. to Fracture **	$+0.04\frac{1}{2}$	$+0.10\frac{1}{2}$	-0.03	$-0.03\frac{1}{2}$			-0.06	+0.06	-0.05	+0.06

* FAILED
** Minus sign indicates distance toward motor end of specimen. Distancesin inches.

TABLE 3

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 140 ksi UTS

NOTE: Specimens not oiled previous to testing.

69 ksi Stress Level, Nominal

Specimen No.	FFBI10	FKBK22	FNBL31	DXBD05	FABF20	FDBH32	FHBI24	FKBK34	FOBL06	FABF23
Diam., Inches	0.2306	0.2307	0.2305	0.2305	0.2308	0.2305	0.2303	0.2298	0.2302	0.2298
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	12,035	441*	230*	326*	397*	182*	429*	513*	11,710	286*
Dist., Ctr. to Fracture **		-0.07	-0.13	+0.06½	0	+0.05	-0.08	-0.06		-0.04

67 ksi Stress Level, Nominal

Specimen No.	DUBD19	DYBF04	FCBH27	FIBI11	FLBK36	FOBL15	FDBL26	FIBI23	FABF32	DXBD29
Diam., Inches	0.2310	0.2305	0.2311	0.2303	0.2308	0.2302	0.2306	0.2308	0.2308	0.2308
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	12,436	12,243	12,753	13,429	757*	1,179*	12,250	12,889	513*	265*
Dist., Ctr. to Fracture **					-0.09	+0.24			+0.09	+0.07

65 ksi Stress Level, Nominal

Specimen No.	DWBD33	FABF02	FIBI26	FLBK03	FOBL18	FPBL29	FABF26	DXBD08	FHBI21	FBBH31
Diam., Inches	0.2302	0.2301	0.2298	0.2298	0.2305	0.2297	0.2300	0.2302	0.2300	0.2308
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	62,220	62,480	68,440	810*	62,673	56,301	63,434	404*	57,324	63,495
Dist., Ctr. to Fracture **				+0.11				+0.02		

63 ksi Stress Level, Nominal

Specimen No.	DUBD01	DYBF22	FCBH06	FHBI27	FMBK11	FPBL35	DWBD03	DZBF24	FDBH08	FIBI29
Diam., Inches	0.2305	0.2305	0.2310	0.2310	0.2305	0.2305	0.2310	0.2300	0.2305	0.2305
Machine No.	10	13	19	20	21	22	23	24	25	26
Kilocycles to End of Test	12,856	12,822	12,514	12,681	11,604	11,959	11,818	12,035	700*	12,325
Dist., Ctr. to Fracture **									+0.00½	

* FAILED

** Minus sign indicates distance toward motor end of specimen. Distances in inches.

TABLE 3

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 140 ksi UTS

NOTE: Specimens not oiled previous to testing.

63 ksi Stress Level, Nominal (Continued)

Specimen No.	DZBF27	FDBH11	FIBI32	FMBK29	FPBL08	DXBD20	DYBF01	FBBH16	FFBI04	DUBD34
Diam., Inches	0.2310	0.2305	0.2310	0.2305	0.2306	0.2305	0.2301	0.2301	0.2307	0.2302
Machine No.	10	13	19	16	18	19	20	21	22	23
Kilocycles to End of Test	17,216	2,612*	16,527	11,554	11,246	12,875	12,630	5,953*	11,688	11,644
Dist., Ctr. to Fracture **		-0.02						+0.09		

61 ksi Stress Level, Nominal

Specimen No.	DYBF28	FCBH12	FHBI33	FMBK17	FNBL04	DWBD09	DZBF30	FDBH14	FIBI35	FKBK04
Diam., Inches	0.2305	0.2310	0.2300	0.2300	0.2305	0.2300	0.2305	0.2307	0.2308	0.2308
Machine No.	20	21	22	23	24	25	26	10	13	19
Kilocycles to End of Test	20,181	20,311	15,493	15,349	16,017	14,463	15,877	17,392	17,567	17,405
Dist., Ctr. to Fracture										

61 ksi Stress Level, Nominal (Continued)

Specimen No.	FKBK01	FBBH04	FFBI25	FLBK09	FOBL33	DUBD07	DYBF25	FMBK20	FNBL07	FBBH07
Diam., Inches	0.2300	0.2300	0.2315	0.2308	0.2310	0.2310	0.2311	0.2302	0.2307	0.2309
Machine No.	22	23	24	25	26	16	18	10	13	16
Kilocycles to End of Test	15,496	15,760	15,969	14,807	16,236	17,564	16,743	52,297	50,291	52,977
Dist., Ctr. to Fracture										

61 ksi Stress Level, Nominal (Continued)

Specimen No.	FFBI28	FLBK15	FOBL36	DUBD10	DYBF31	FCBH15	DXBD35	FHBI36	FDBH17	FLBK12
Diam., Inches	0.2310	0.2307	0.2305	0.2305	0.2310	0.2300	0.2307	0.2306	0.2306	0.2302
Machine No.	18	19	20	21	22	23	24	25	26	10
Kilocycles to End of Test	49,449	49,947	51,493	47,730	46,645	48,903	48,782	46,044	49,469	16,562
Dist., Ctr. to Fracture										

* FAILED

** Minus sign indicates distance toward motor end of specimen. Distances in inches.

TABLE 3

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 140 ksi UTS

NOTE: Specimens not oiled previous to testing.

61 ksi Stress Level, Nominal (Continued)

Specimen No.	FMBK23	FNBL10	DWBD12	DZBF33	FFBI31	FBBH10	FPBL02	FFBI34	DXBD23	FABF14
Diam., Inches	0.2302	0.2307	0.2310	0.2302	0.2303	0.2300	0.2302	0.2302	0.2310	0.2300
Machine No.	13	16	18	19	20	21	22	23	24	25
Kilocycles to End of Test	16,001	16,643	16,379	16,084	16,334	14,521	15,128	15,374	15,533	14,563
Dist., Ctr. to Fracture **										

61 ksi Stress Level, Nominal (Continued)

Specimen No.	FBBH13	FIBI02	FMBK26	FNBL13	DWBD15	DZBF36	FFBI01	FKBK07	FNBL07	DXBD32
Diam., Inches	0.2307	0.2303	0.2305	0.2308	0.2309	0.2310	0.2305	0.2297	0.2300	0.2299
Machine No.	26	10	13	16	18	19	20	21	22	23
Kilocycles to End of Test	15,472	46,699	47,024	47,482	44,753	46,585	45,153	45,854	42,883	43,310
Dist., Ctr. to Fracture **										

61 ksi Stress Level, Nominal (Continued)

Specimen No.	FABF17	FCBH21	FIBI05	FKBK13	FNBL28	DWBD27	DZBF09	FBBH34	FHBI15	FLBK24
Diam., Inches	0.2300	0.2298	0.2305	0.2306	0.2295	0.2305	0.2307	0.2302	0.2299	0.2295
Machine No.	24	Not Recorded		16	18	19	20	21	22	23
Kilocycles to End of Test	46,242	45,002	46,729	10,620	10,130	12,236	12,010	10,887	10,722	11,154
Dist., Ctr. to Fracture **										

61 ksi Stress Level, Nominal (Continued)

Specimen No.	FCBL27	DXBD26	DZBF12	FDBH02	FIBI14	FMBK08	FOBL09	DUBD31	DYBF16	FCBH36
Diam., Inches	0.2309	0.2308	0.2305	0.2302	0.2310	0.2305	0.2307	0.2303	0.2305	0.2310
Machine No.	24	25	26	16	18	19	20	21	22	23
Kilocycles to End of Test	11,278	11,057	11,256	12,175	11,448	13,160	12,895	12,113	11,709	11,887
Dist., Ctr. to Fracture **										

** Minus sign indicates distance toward motor end of specimen. Distances in inches.

TABLE 3

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 140 ksi UTS

NOTE: Specimens not oiled previous to testing.

61 ksi Stress Level, Nominal (Continued)

Specimen No.	FFBI16	FKBK31	FOBL12	FMBK35	FPBL11	DUBD25	DZBF18	FCBH30	FMBK05	FPBL17
Diam., Inches	0.2297	0.2302	0.2305	0.2300	0.2308	0.2303	0.2293	0.2308	0.2304	0.2299
Machine No.	24	25	26	16	18	19	20	21	22	23
Kilocycles to End of Test	12,643	11,280	296*	12,225	10,945	13,354	1,120*	11,376	11,840	12,085
Dist., Ctr. to Fracture **			-0.10				-0.13			

61 ksi Stress Level, Nominal (Continued)

Specimen No.	DWBD21	FDBH26	FLBK30	DXBD11	FABF29	FHBI09	FLBK33	FPBL23	DWBD18	DZBF15
Diam., Inches	0.2303	0.2295	0.2305	0.2309	0.2307	0.2302	0.2301	0.2299	0.2304	0.2304
Machine No.	24	25	26	16	18	19	29	21	22	23
Kilocycles to End of Test	13,191	928*	12,845	14,998	13,758	15,527	15,573	14,065	14,562	14,447
Dist., Ctr. to Fracture **		0.00								

61 ksi Stress Level, Nominal (Concluded)

Specimen No.	FBBH22	FIBI17	DWBD06	FNBL19	DXBD14	DYBF10	FBBH25	FFBI19	FMBK02	FOBL21
Diam., Inches	0.2302	0.2310	0.2307	0.2302	0.2307	0.2302	0.2309	0.2309	0.2308	0.2308
Machine No.	24	25	26	24	25	26	16	18	19	20
Kilocycles to End of Test	15,463	13,443	15,243	12,454	2,334*	12,025	11,796	11,538	12,855	12,343
Dist., Ctr. to Fracture **					-0.03					

* FAILED
** Minus sign indicates diatance toward motor end of specimen. Distances in inches.

TABLE 4

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 190 ksi UTS

NOTE: All specimens oiled, and dried with Kleenex before testing, unless otherwise noted.

96 ksi Stress Level, Nominal (Not Oiled)

Specimen No.	DULC02	DYLD23	FCLF07	FHLH28	FMLI12	FPLK36	DWL004	DZLD25	FDLF09	FILH30
Diam., Inches	0.2309	0.2305	0.2299	0.2304	0.2306	0.2301	0.2300	0.2305	0.2299	0.2303
Machine No.	19	23	19	23	19	23	19	23	19	23
Kilocycles to Fracture	96	90	93	103	97	102	100	146	70	114
Dist., Ctr. to Fracture **	-0.05 1/2	-0.04	0	+0.12	-0.06	+0.12	-0.15	-0.05	+0.02	-0.12

96 ksi Stress Level, Nominal

Specimen No.	DXLC12	FALD30	FDLF06	FHLH10	FLLI34	FPLK24	DWLC19	DZLD16	FBLF23	FILH18
Diam., Inches	0.2305	0.2300	0.2302	0.2307	0.2303	0.2302	0.2308	0.2302	0.2307	0.2307
Machine No.	19	23	19	23	19	23	19	23	19	23
Kilocycles to Fracture	114	110	91	117	135	101	240	116	98	122
Dist., Ctr. to Fracture **	-0.05	-0.02	+0.04	+0.14	0	-0.13	-0.01 1/2	-0.03 1/2	0	+0.07 1/2

96 ksi Stress Level, Nominal - Oiled, then degreased.

Specimen No.	FNLK20	DXLC15	DYLD11	FBLF26	FFLH20	FMLI03	FOLK22	DULC29	DZLD22	FDLF30
Diam., Inches	0.2308	0.2307	0.2303	0.2300	0.2302	0.2309	0.2305	0.2309	0.2305	0.2305
Machine No.	19	23	19	23	19	23	19	23	19	23
Kilocycles to Fracture	114	86	101	94	134	103	129	115	101	86
Dist., Ctr. to Fracture **	+0.04 1/2	-0.06	+0.01	+0.04 1/2	-0.12	-0.01 1/2	-0.04	-0.17	-0.04	+0.06

96 ksi Stress Level, Nominal - Oiled, then tested while oiled.

Specimen No.	FMLI36	FPLK12	DULC26	DZLD19	FCLF31	FMLI06	FPLK18	DWLC22	FDLF27	FLLI31
Diam., Inches	0.2306	0.2306	0.2305	0.2307	0.2305	0.2301	0.2303	0.2308	0.2303	0.2295
Machine No.	19	23	19	23	19	23	19	23	19	23
Kilocycles to Fracture	231	220	475	1031	346	166	231	388	299	300
Dist., Ctr. to Fracture **	-0.13 1/2	+0.01	-0.06	+0.05	+0.01	+0.12	+0.07	-0.06	+0.02	+0.05

** Minus sign indicates distance toward motor end of specimen. Distance in inches.

TABLE 4

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 190 ksi UTS

NOTE: All specimens oiled, and dried with Kleenex before testing, unless otherwise noted.

(Reproduced from WADC TN 54-531) 96 ksi Stress Level, Nominal

Specimen No.	ASKF27	AWKH25	AZKI36	CCKS15	CHKT22	ACKA11	AHKB10	ALKC21	AOKD20	BIKM05
Diam., Inches	0.2310	0.2310	0.2305	0.2295	0.2301	0.2306	0.2298	0.2305	0.2300	0.2301
Machine No.	22	23	24	20	24	10	13	10	20	24
Kilocycles to Fracture	322	304	226	136	92	209	286	316	207	135
Dist., Ctr. to Fracture **	-0.17	+0.14 1/2	-0.12	-0.14	-0.02	-0.07	-0.24	+0.10	-0.03	-0.02

86 ksi Stress Level, Nominal

Specimen No.	FPLK33	DXLC03	DYLD20	FBLF29	FFLH08	FFLI22	FOLK04	DULC17	DZLD07	FDLF36
Diam., Inches	0.2309	0.2305	0.2300	0.2309	0.2300	0.2308	0.2312	0.2304	0.2305	0.2307
Machine No.	14	18	17	20	21	22	23	24	25	26
Kilocycles to End of Test	437*	307*	4944*	337*	43,439	342*	43,832	45,935	43,132	123*
Dist., Ctr. to Fracture **	+0.08	+0.02	-0.05 1/2	-0.22		+0.05				-0.08 1/2

82 ksi Stress Level, Nominal

Specimen No.	FALD36	FDLF24	FHLH07	FKLI11	FNLK35	DWLC01	DZLD04	FCLF25	FILH09	FKLI20
Diam., Inches	0.2305	0.2303	0.2306	0.2302	0.2307	0.2302	0.2307	0.2303	0.2315	0.2306
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	15,317	223*	17,315	16,843	135*	218	16,021	231	15,528	16,684
Dist., Ctr. to Fracture **		+0.03			-0.07	-0.05		-0.08 1/2		

78 ksi Stress Level, Nominal - Not Oiled

Specimen No.	FBLF02	FFLH23	FLLI07	FOLK31	DULC05	FCLF10	FHLH31	FMLI15	FNLK02	DWLC07
Diam., Inches	0.2297	0.2302	0.2301	0.2297	0.2300	0.2301	0.2301	0.2300	0.2301	0.2297
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	25,608	24,710	27,009	24,283	25,546	24,334	26,894	340*	22,968	25,545
Dist., Ctr. to Fracture **								+0.05 1/2		

* FAILED

** Minus sign indicates distance toward motor end of specimen. Distance in inches.

TABLE 4

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 190 ksi UTS

NOTE: All specimens oiled, and dried with Kleenex before testing, unless otherwise noted.

74 ksi Stress Level, Nominal - Not Oiled.

Specimen No.	DZLD28	FDLF12	FILH33	FKLI02	FBLF05	FFLH26	FLLI10	FOLK34	DULC08	DYLD26
Diam., Inches	0.2303	0.2303	0.2306	0.2303	0.2303	0.2305	0.2308	0.2300	0.2308	0.2305
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	12,343	371*	12,643	12,500	1,544*	11,867	12,123	12,588	12,285	11,302
Dist., Ctr. to Fracture **		-0.06			+0.12					

70 ksi Stress Level, Nominal - Not Oiled

Specimen No.	DYLD29	FCLF13	FHLH34	FMLI18	FNLK05	DWLC10	DZLD31	FDLF15	FILH36	FKLI05
Diam., Inches	0.2305	0.2304	0.2302	0.2306	0.2307	0.2302	0.2300	0.2310	0.2305	0.2305
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	11,100	10,650	10,087	8,963*	10,493	10,806	10,137	11,559	11,149	10,530
Dist., Ctr. to Fracture **				-0.06						

70 ksi Stress Level, Nominal (Continued)

Specimen No.	FFLH35	DXLC24	FALD15	FBLF14	FHLH04	FLLI19	FPLK06	DULC14	DYLD35	FCLF19
Diam., Inches	0.2304	0.2308	0.2302	0.2300	0.2308	0.2309	0.2310	0.2302	0.2308	0.2305
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	43,489	44,328	45,577	45,416	43,458	39,092	43,440	44,902	22,721*	43,131
Dist., Ctr. to Fracture **									-0.07	

70 ksi Stress Level, Nominal (Concluded)

Specimen No.	FFLH11	FKLI23	FNLK32	DXLC06	FALD21	FDLF33	FHLH25	FKLI35	FOLK07	FALD24
Diam., Inches	0.2307	0.2302	0.2304	0.2307	0.2305	0.2308	0.2310	0.2308	0.2308	0.2305
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	12,196	12,006	13,749	12,885	12,185	11,437	12,352	12,902	11,968	12,103
Dist., Ctr. to Fracture **										

* FAILED

** Minus sign indicates distance toward motor end of specimen. Distance in inches.

TABLE 4

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 190 ksi UTS

NOTE: All specimens oiled, and dried with Kleenex before testing, unless otherwise noted.

66 ksi Stress Level, Nominal

Specimen No.	FILH03	FMLI27	FNLK14	DWLC16	DZLD01	FDLF21	FFLH02	FKLI08	FNLK17	DXLC33
Diam., Inches	0.2303	0.2302	0.2303	0.2307	0.2303	0.2310	0.2303	0.2304	0.2309	0.2302
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	10,708	10,944	11,505	11,291	10,692	10,652	10,504	10,032	10,561	10,989
Dist., Ctr. to Fracture										

66 ksi Stress Level, Nominal (Continued)

Specimen No.	FHLH01	FMLI24	FNLK11	DWLC13	DZLD34	FDLF18	FFLH32	FBLF11	FLLI16	FPLK03
Diam., Inches	0.2303	0.2306	0.2307	0.2302	0.2308	0.2306	0.2309	0.2310	0.2308	0.2308
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	11,057	11,686	11,812	11,264	11,604	11,629	11,487	11,947	11,148	11,389
Dist., Ctr. to Fracture										

66 ksi Stress Level, Nominal (Continued)

Specimen No.	FMLI21	FNLK08	FBLF08	FFLH29	FLLI13	FOLK01	DULC11	DYLD32	FCLF16	DXLC36
Diam., Inches	0.2298	0.2300	0.2305	0.2295	0.2303	0.2298	0.2310	0.2300	0.2298	0.2302
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	12,506	11,230	10,854	12,191	11,203	11,977	10,056	12,414	11,979	10,990
Dist., Ctr. to Fracture										

66 ksi Stress Level, Nominal (Continued)

Specimen No.	FALD18	FCLF22	FILH06	FMLI30	FPLK09	DXLC21	DYLD02	FBLF17	FFLH05	DULC35
Diam., Inches	0.2312	0.2300	0.2308	0.2305	0.2299	0.2312	0.2298	0.2305	0.2303	0.2309
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test 1/	18,972	19,403	21,513	20,931	19,317	17,459	19,681	19,277	18,856	20,561
Dist., Ctr. to Fracture										

1/ Because of power failure these 10 specimens were under static load for several hours, after about 3,000 kilocycles of stressing.

TABLE 4

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 190 ksi UTS

NOTE: All specimens oiled, and dried with Kleenex before testing, unless otherwise noted.

66 ksi Stress Level, Nominal (Continued)

Specimen No.	DWLC34	FALD03	FILH27	FLLI04	FOLK19	FPLK30	FALD27	DXLC09	FHLH22	FBLF32
Diam., Inches	0.2302	0.2304	0.2304	0.2295	0.2306	0.2305	0.2312	0.2302	0.2303	0.2306
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	12,004	12,307	13,459	12,854	12,661	12,138	12,413	12,577	11,946	12,392
Dist., Ctr. to Fracture										

66 ksi Stress Level, Nominal (Continued)

Specimen No.	DULC20	DYLD05	FCLF28	FILH12	FLLI01	FOLK16	FPLK27	FILH24	FALD33	DXLC30
Diam., Inches	0.2304	0.2310	0.2307	0.2292	0.2305	0.2305	0.2303	0.2308	0.2295	0.2299
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	14,370	14,105	15,657	15,175	14,126	14,156	14,002	14,789	13,987	15,117
Dist., Ctr. to Fracture										

66 ksi Stress Level, Nominal (Continued)

Specimen No.	DULC23	DYLD08	FBLF20	FFLH14	FKLI29	FNLK26	DWLC31	FALD06	FCLF04	FHLH19
Diam., Inches	0.2315	0.2310	0.2306	0.2300	0.2300	0.2315	0.2302	0.2308	0.2305	0.2307
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	14,150	13,984	15,014	14,936	13,359	13,635	13,625	14,369	13,518	14,436
Dist., Ctr. to Fracture										

66 ksi Stress Level, Nominal (Continued)

Specimen No.	FKLI14	FNLK29	DWLC28	DZLD10	FBLF35	FHLH16	FLLI25	FOLK28	DXLC27	DZLD13
Diam., Inches	0.2306	0.2305	0.2307	0.2295	0.2308	0.2301	0.2304	0.2305	0.2304	0.2304
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	58,642	61,651	63,662	64,196	60,982	56,276	60,514	60,496	58,582	64,672
Dist., Ctr. to Fracture										

TABLE 4

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 190 ksi UTS

NOTE: All specimens oiled, and dried with Kleenex before testing, unless otherwise noted.

66 ksi Stress Level, Nominal (Continued)

Specimen No.	FDLF03	EILH15	FMLI09	FOLK10	DULC32	DYLD17	FCLF01	FFLH17	FKLI32	FOLK13
Diam., Inches	0.2307	0.2312	0.2295	0.2306	0.2310	0.2308	0.2309	0.2306	0.2305	0.2309
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	10,880	11,229	11,933	12,203	11,394	10,803	11,227	11,359	10,957	11,907
Dist., Ctr. to Fracture										

66 ksi Stress Level, Nominal (Concluded)

Specimen No.	FHLH13	FKLI17	FPLK21	DWLC25	DYLD14	FKLI26	FPLK15	DXLC18	FALD12	FLLI28
Diam., Inches	0.2308	0.2310	0.2310	0.2303	0.2305	0.2306	0.2306	0.2302	0.2303	0.2305
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	10,718	11,216	11,828	11,795	11,290	10,374	11,085	11,536	10,919	11,662
Dist., Ctr. to Fracture										

TABLE 5

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 260 ksi UTS

NOTE: All specimens, oiled, then dried with Kleenex, before testing.

116 ksi Stress Level, Nominal

Specimen No.	FBTC03	FFTD24	FLTF08	FOTH32	DUTA06	FCTC11	FHTD32	FMTF16	FNTH03	DWTA08
Diam., Inches	0.2305	0.2306	0.2305	0.2306	0.2303	0.2300	0.2308	0.2307	0.2305	0.2301
Machine No.	19	23	19	23	19	23	19	23	19	23
Kilocycles to Fracture	54	66	83	76	55	110	57	50	43	90
Dist., Ctr. to Fracture **	-0.07	0	+0.04 1/2	+0.14	-0.03	+0.06	-0.18	+0.02	+0.02	+0.09 1/2

Reproduced from WADC TR 54-531 - 116 ksi Stress Level, Nominal

Specimen No.	AASA12	ADSB11	AISC16	AMSD15	APSF20	ASTH14	AXSI28	BASK30	AISC04	APSF08
Diam., Inches	0.2310	0.2315	0.2317	0.2315	0.2320	0.2315	0.2310	0.2310	0.2311	0.2311
Machine No.	19	21	20	19	21	19	20	19	20	21
Kilocycles to Fracture	128	168	205	108	331	89	132	258	107	180
Dist., Ctr. to Fracture **	-0.04	+0.04	+0.04	+0.14	+0.11	+0.07	0	+0.15	-0.03	+0.11

96 ksi Stress Level, Nominal

Specimen No.	DZTB29	FDTC13	FITD34	FKTF03	FBTC06	FFTD27	FLTF11	FOTH35	DUTA09	DYTB27
Diam., Inches	0.2302	0.2308	0.2310	0.2310	0.2297	0.2304	0.2303	0.2309	0.2305	0.2302
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	122*	341*	4008*	664*	249*	10,013	10,859	10,972	10,541	2300*
Dist., Ctr. to Fracture **	-0.04	-0.06	-0.23	+0.01	-0.11 1/2					+0.15 1/2

91 ksi Stress Level, Nominal

Specimen No.	DYTB30	FCTC14	FHTD35	FMTF19	FNTH06	DWTA11	DZTB32	FMTF22	FITD01	FKTF06
Diam., Inches	0.2308	0.2312	0.2302	0.2308	0.2308	0.2303	0.2305	0.2309	0.2306	0.2308
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	145*	4280*	51,422	40,000+	200*	40,627	47,376	47,265	94*	48,526
Dist., Ctr. to Fracture **	0	+0.06			+0.06				+0.01	

* FAILED
** Minus sign indicates distance toward motor end of specimens. Distance in inches.

TABLE 5

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 260 ksi UTS

NOTE: All specimens oiled, then dried with Kleenex, before testing.

86 ksi Stress Level, Nominal

Specimen No.	FDTC16	FNTH09	FBTC09	FFTD30	FLTF14	FOTH02	DUTA12	DYTB33	FCTC17	DXTA01
Diam., Inches	0.2305	0.2301	0.2302	0.2306	0.2303	0.2307	0.2307	0.2307	0.2307	0.2306
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	11,530	11,559	13,474	12,445	11,453	10,509	12,001	11,771	11,602	138*
Dist., Ctr. to Fracture **										-0.07

81 ksi Stress Level, Nominal

Specimen No.	FITD04	FMTF28	FNTH15	DWTA17	DZTB02	FDTC22	FFTD03	FKTF09	FNTH18	DXTA34
Diam., Inches	0.2303	0.2306	0.2307	0.2308	0.2304	0.2305	0.2304	0.2308	0.2305	0.2305
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	11,512	11,301	12,801	12,126	11,374	10,270	12,113	11,778	11,210	12,514
Dist., Ctr. to Fracture										

81 ksi Stress Level, Nominal (Continued)

Specimen No.	FHTD02	FMTF25	FNTH12	DWTA14	DZTB35	FDTC19	FFTD33	FBTC12	FLTF17	FPTH04
Diam., Inches	0.2304	0.2305	0.2307	0.2306	0.2302	0.2305	0.2308	0.2302	0.2303	0.2300
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	11,226	11,661	13,621	12,479	11,512	10,969	11,868	11,983	11,587	12,880
Dist., Ctr. to Fracture										

81 ksi Stress Level, Nominal (Concluded)

Specimen No.	FATB19	FCTC23	FITD07	FMTF31	FPTH10	DXTA22	DYTB03	FBTC18	FFTD06	DUTA36
Diam., Inches	0.2305	0.2310	0.2305	0.2305	0.2303	0.2304	0.2309	0.2309	0.2310	0.2307
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	11,564	11,018	12,615	3,118*	11,560	10,606	12,463	3,424*	11,502	12,720
Dist., Ctr. to Fracture **				0				-0.09		

* FAILED
** Minus sign indicates distance toward motor end of specimens. Distance in inches.

TABLE 5

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 260 ksi UTS

NOTE: All specimens oiled, then dried with Kleenex, before testing.

76 ksi Stress Level, Nominal

Specimen No.	FATB01	FDTC25	FHTD08	FKTF12	FNTH36	DWTA02	DZTB05	FCTC26	FITD10	FKTF21
Diam., Inches	0.2307	0.2309	0.2305	0.2300	0.2308	0.2308	0.2298	0.2306	0.2303	0.2310
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	45,056	43,487	48,661	46,672	43,231	41,310	44,635	44,376	42,596	49,494
Dist., Ctr. to Fracture										

76 ksi Stress Level, Nominal (Continued)

Specimen No.	FPTH34	DXTA04	DYTB21	FBTC30	FFTD09	FLTF23	FOTH05	DUTA18	DZTB08	FDTC01
Diam., Inches	0.2306	0.2305	0.2298	0.2306	0.2305	0.2305	0.2307	0.2309	0.2309	0.2305
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	11,603	11,389	13,015	12,461	11,567	10,776	12,084	11,694	11,433	10,005
Dist., Ctr. to Fracture										

76 ksi Stress Level, Nominal (Continued)

Specimen No.	FFTD12	FKTF24	FNTH33	DXTA07	FATB22	FDTC34	FHTD26	FKTF36	FOTH08	FATB25
Diam., Inches	0.2305	0.2303	0.2303	0.2305	0.2306	0.2301	0.2305	0.2301	0.2295	0.2306
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	10,924	11,312	12,426	12,173	11,329	10,390	11,006	11,570	10,913	11,056
Dist., Ctr. to Fracture										

76 ksi Stress Level, Nominal (Continued)

Specimen No.	DUTA21	DYTB06	FCTC29	FITD13	FLTF02	FOTH17	FPTH28	FITD25	FATB34	DXTA31
Diam., Inches	0.2310	0.2310	0.2308	0.2300	0.2304	0.2309	0.2300	0.2297	0.2305	0.2306
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	11,683	11,652	12,442	11,997	11,302	10,647	11,809	11,813	11,270	11,504
Dist., Ctr. to Fracture										

TABLE 5

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 260 ksi UTS

NOTE: All specimens oiled, then dried with Kleenex, before testing.

76 ksi Stress Level, Nominal (Continued)

Specimen No.	DUTA24	DYTB09	FBTC21	FFTD15	FKTF30	FNTH27	DWTA32	FATB07	FCTC05	FHTD20
Diam., Inches	0.2310	0.2310	0.2308	0.2303	0.2308	0.2305	0.2297	0.2310	0.2309	0.2305
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	10,246	10,414	11,118	11,076	10,368	10,085	10,240	10,025	10,254	10,662
Dist., Ctr. to Fracture										

76 ksi Stress Level, Nominal (Continued)

Specimen No.	FHTD14	FRTF18	FPTH22	DWTA26	DYTB15	FRTF27	FOTH26	DXTA19	FATB13	FLTF29
Diam., Inches	0.2311	0.2309	0.2305	0.2310	0.2305	0.2298	0.2308	0.2305	0.2307	0.2308
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	45,203	42,456	50,147	47,758	46,118	42,241	43,478	48,495	45,489	50,132
Dist., Ctr. to Fracture										

76 ksi Stress Level, Nominal (Continued)

Specimen No.	FNTH21	DXTA16	DYTB12	FBTC27	FFTD21	FMTF04	FOTH23	DUTA30	DZTB23	FOTC31
Diam., Inches	0.2308	0.2305	0.2309	0.2305	0.2303	0.2301	0.2310	0.2302	0.2296	0.2307
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	11,070	1,444*	11,985	12,281	11,628	12,002	10,427	11,557	10,779	11,936
Dist., Ctr. to Fracture **		-0.22								

76 ksi Stress Level, Nominal (Continued)

Specimen No.	DXTA13	FATB31	FDTC07	FHTD11	FLTF35	FPTH25	DWTA20	DZTB17	FBTC24	FITD19
Diam., Inches	0.2310	0.2310	0.2306	0.2306	0.2303	0.2306	0.2309	0.2308	0.2310	0.2298
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	14,575	14,043	12,042	15,755	15,377	14,582	13,385	15,890	14,574	16,056
Dist., Ctr. to Fracture										

* FAILED
** Minus sign indicates distance toward motor end of specimens. Distance in inches.

TABLE 5

R. R. Moore Rotating Beam Fatigue Tests, at 11,000 RPM, of Smooth Specimens of SAE 4340 Steel, of Nominal 260 ksi UTS

NOTE: All specimens oiled, then dried with Kleenex, before testing.

76 ksi Stress Level, Nominal (Continued)

Specimen No.	FDTC04	FITD16	FMTF10	FOTH11	DUTA33	DYTB18	FCTC02	FFTD18	FKTF33	FOTH14
Diam., Inches	0.2302	0.2306	0.2310	0.2306	0.2312	0.2308	0.2308	0.2308	0.2311	0.2306
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	10,936	11,034	12,285	11,866	11,844	10,439	10,711	11,737	10,808	11,956
Dist., Ctr. to Fracture										

76 ksi Stress Level, Nominal (Concluded)

Specimen No.	FKTF15	FNTH30	DWTA29	DZTB11	FBTC36	FHTD17	FLTF26	FOTH29	DXTA28	DZTB14
Diam., Inches	0.2310	0.2306	0.2300	0.2310	0.2308	0.2308	0.2306	0.2309	0.2310	0.2307
Machine No.	16	18	19	20	21	22	23	24	25	26
Kilocycles to End of Test	42,131	42,313	45,732	45,862	43,763	42,629	44,351	44,616	41,419	44,553
Dist., Ctr. to Fracture										

TABLE 6

Comparison of "1955" Tests with "1954" Tests in the Finite Life Region. R. R. Moore Rotating Beam Tests of Smooth Specimens of SAE 4340 Steel.

(Values of Fatigue Life at the Specified Stress Level are Anti-logs of Mean Log-Life.)

Ult. Strength Nominal	140 ksi					
Alternating Stress Level	81 ksi		77 ksi		75 ksi	
Life, 1955 Tests	112 kc	112 kc	183 kc	183 kc	205 kc	205 kc
Life, 1954 Tests	123 kc, <u>not</u> adjusted	193 kc, adjusted	193 kc, <u>not</u> adjusted	362 kc, adjusted	257 kc, <u>not</u> adjusted	282 kc, adjusted
Indications of F- and t- Tests on difference in log-life	not significant	significant	not significant	significant	may be significant	significant

Ult. Strength, Nominal	190 ksi	260 ksi
Alternating Stress Level	96 ksi	116 ksi
Life, 1955 Tests, Specimens oiled, then cleaned	119 kc	66 kc
Life, 1954 Tests	207 kc	157 kc
Indications of F- and t- Tests on Difference in log-life	significant	significant

TABLE 7

Effect of Oiling and Cleaning Surface of Specimens
R. R. Moore Rotating Beam Tests of Smooth Specimens of SAE 4340 Steel
(Values of Fatigue Life at the Specified Stress Level are Anti-logs of Mean Log-Life)

190 ksi UTS	96 ksi Stress Level	"1955" Tests
Oiled, then wiped dry, 119 kc Oiled 321 kc F- and t- tests: Significant	Oiled, then wiped dry, 119 kc Not Oiled 100 kc F- and t- Tests: Not significant	Oiled, then wiped dry, 119 kc Oiled, then degreased 105 kc F- and t- Tests: Not significant

190 ksi UTS 96 ksi Stress Level	
1954 Tests	207 kc
1955 Tests: Oiled then wiped dry	321 kc
F- and t- tests:	Significant