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DESIGN PROPERTIES OF HIGH-STRENGTH STEELS IN THE PRESENCE OF STRESS CONCENTRATIONS

Part II. Axial-Load Fatigue Properties of High-Strength Steels

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FOREWORD

This report was prepared by Syracuse University under USAF Contract No. AF 33(616)-2362, S/A 4(56-445). The contract was initiated under Project No. 7360 "Materials Analysis and Evaluation Techniques, "Task No. 73605 "Design and Evaluation Data for Structural Metals." This project was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Mr. A. W. Brisbane as project engineer. This work was performed in the period between September 1, 1955 and August 1956.

ABSTRACT

In this report are presented the results of axial-load (completely reversed) fatigue tests on Tricent (Inco), Cru. SHS-260 and Super TM-2 steels heat treated to strength levels between approximately 250,000 and 300,000 psi. The fundamental effects of several variables on the fatigue properties of these steels are discussed and evaluated. These variables included the notch sharpness or the stress concentration, the strength level and the specimen orientation.

The results indicated that the fatigue strength was lowered as the stress-concentration factor was increased, a maximum lowering effect occurring for stress concentration factors between one and three. This effect was observed to depend upon the strength level. The endurance limit for both smooth and notched specimens developed minimum values at a strength level between 240,000 and 260,000 psi, and maximum values at a strength level between 270,000 and 300,000 psi approximately. In general, the endurance limit was found to be lower for transverse than for longitudinal specimens. Furthermore, this effect was much more pronounced for smooth than for notched specimens and was observed to be severe at high strength levels and to decrease with decrease in this quantity.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. R. Whitmore

M. R. WHITMORE
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INTRODUCTION*

The repeated occurrence of fatigue failures in steel parts heat treated to strength levels above 200,000 psi has resulted in the belief that steels heat treated to such high-strength values possess fatigue properties inferior to those of steels in the range below 200,000 psi (1)**. However, a number of recent investigations (1), (2), (3) have demonstrated, contrary to common concepts, that high-strength steels may exhibit endurance-strength values considerably superior to those of steels heat treated to a strength of 200,000 psi or lower. The metallurgical considerations alone are, therefore, insufficient for the prediction of performance and other factors, particularly those resulting from certain design requirements, cannot be ignored.

In a previous investigation performed at Syracuse University (3), rotating beam fatigue tests were performed on a number of high-strength aircraft steels. The results indicated that while the endurance ratio*** of both smooth and notched specimens decreased, the endurance limit, in general, slightly increased with increase in the tensile strength above 200,000 psi.

In this investigation the fundamental effects of a number of variables on the fatigue properties of high-strength steels were examined. Tension-compression ($R = -1$)**** fatigue tests were performed on specimens machined from 3 to 4-1/2 inches (round or square) hot rolled sections from commercial, electric-furnace heats. The strength range investigated varied between 250,000 and 300,000 psi approximately. One to three strength levels were investigated in each of Tricent (Inco), Cru. SHS-260 and Super TM-2 steels. In all instances both longitudinal (parallel to the rolling

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* Manuscript released by authors September 1, 1956 for publication as a WADC Technical Report.

** Numbers in parentheses refer to the bibliography.

***Endurance ratio is the ratio of endurance limit to the tensile strength.

****R is the ratio between the minimum and maximum stress applied to the specimen.

direction, symbol L) and transverse (perpendicular to the rolling direction, symbol T) were tested. Unnotched specimens (K = 1)* and specimens provided with notches leading to stress concentration factors, K = 3, 5 and 8 were examined.

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* K is the theoretical stress-concentration factor as computed by Neuber's theory.

EXPERIMENTAL PROCEDURE

1. Materials:

The steels examined in this investigation were hot rolled sections from commercial electric-furnace heats of Tricent (Inco), Cru. SHS-260 and Super TM-2. The chemical analyses and the as-processed section sizes of these steels are presented in Table I.

2. Test Specimen:

The fatigue and notch-fatigue specimens used in this investigation are presented in Figure 1. They were rough machined to approximately 0.015 inch oversize on each surface and finished to proper dimensions after heat treatment. Smooth specimens were mechanically polished in a direction parallel to their axes. This was accomplished by turning the specimen against a fine polishing belt moving parallel to the specimen and tightly pressed along its contour. Notches, on the other hand, were finish machined by means of a properly ground carbide tool.

The specimens were heated to the recommended austenitizing temperature for each steel, and maintained at this temperature for a period of one hour. They were then oil quenched, tempered for a period of four hours and air cooled.

3. Fatigue and Notch Fatigue Tests:

All fatigue and notch fatigue tests performed in this investigation were of the tension-compression type with the stress ratio maintained constant at R = -1.

The smooth specimen used in this study is illustrated in Figure 1(a) and the notched specimen in Figure 1(b)*. The notch on the latter specimen

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* The 3 in. dia. Super TM-2 steel section was forged, by upsetting in the rolling direction, into 4 in. square slabs. This was done in order to allow the preparation of 4 in.-long transverse specimens.

TABLE I

COMPOSITION AND SIZE OF THE VARIOUS STEELS EXAMINED

Alloy	Size and Shape	Percent of Alloying Elements									
		C	Mn	P	S	Si	Ni	Cr	Mo	V	Cu
Tricent (Inco)	4-1/4 in. sq.	0.39	0.74	0.014	0.014	1.54	1.83	0.83	0.38	0.07	--
Cru. SHS-260	4 in. sq.	0.35	1.20	0.023	0.017	1.62	--	1.26	0.32	0.20	--
Super TM-2	3 in. rd.	0.41	0.72	0.012	0.014	0.61	2.08	1.15	0.44	--	0.14

was of the 60-degree, 50-percent type where the 50 percent represents the area removed by notching. Three different stress concentration factors were employed, namely K = 3, 5 and 10. The radii at the notch root, corresponding to these stress-concentration factors, were computed by Neuber's theory according to Peterson (4) and are given in Table II.

A 1000 pound Sontag Fatigue Testing machine was used in this program. By means of a special amplification device, Figure 2, this machine was converted into an axial-load fatigue machine, capable of exerting a maximum load of ± 8,000 pounds. To insure concentricity of loading, the fixture shown in Figure 3 was used. The assembly consisting of the specimen and the aligning fixture was aligned by bringing the two outer plates (marked A) into parallelism. This was done by adjusting one or more of the six adjusting screws indicated in Figure 3. The whole assembly was then placed between the two parallel platforms of the amplification fixture, as indicated in Figure 2, and screwed to them, pains being taken not to disturb the alignment of the specimens.

TABLE II

STRESS-CONCENTRATION FACTORS AND CORRESPONDING NOTCH RADII FOR NOTCH-FATIGUE SPECIMENS

D - in.	d - in.	K	r - in.
0.250	0.177	3	0.009
		5	0.003
		8	0.001

D = Unnotched Diameter

d = Notch Diameter

r = Notch Root Radius

EXPERIMENTAL RESULTS

1. Experimental S-N Curves for Smooth and Notched Specimens:

The results of axial-load fatigue tests performed on longitudinal and transverse, both smooth and notched, specimens are presented in Figures 4 to 9 for Inco steel; in Figures 10 to 13 for Cru. SHS-260 steel; and in Figures 14 and 15 for Super TM-2 steel. The curves were accurately established for the range of 10^2 to 10^6 cycles. No experimental values could be obtained for less than 100 cycles as the equipment reached full speed and load only after about 50 cycles, and the counter recorded in multiples of 100 cycles.

However, previous investigations on both smooth and notched specimens, (5), (6) and (7) indicate that the direct-stress fatigue strength of various metals, including high-strength steels, differs only slightly from the tensile-strength of the material, if the number of cycles to failure is less than about 100. This fatigue data also agrees well with the concept that the tensile strength represents the origin of the S-N curve, in spite of the quite different rate of loading in the static and dynamic tests, respectively.

The curves in Figures 4 to 15 are, therefore, extended by dotted lines to lower cycles, indicating their expected position in this range which could not be experimentally covered.

It may be noted from Figures 4 to 15 that the S-N curves smoothly extrapolate at the left to the tensile strength and notch strength values. The only exceptions in this respect are a few transverse specimens of Cru. SHS-260. This discrepancy is explained by the fact that a different heat was used for the fatigue test than for the tension and notch-tension test and that the latter heat obviously possessed inferior transverse properties.

It is further observed that the direct-stress S-N curves for smooth and notched specimens respectively usually intersect or come very close to doing so. This also applies to the highest strength levels investigated, see Figure 4, and even to transverse specimens, see Figure 5. In contrast, the previously obtained bending-fatigue S-N curves of the highest strength levels extrapolated to static (bending) strength values which were considerably higher for smooth than for notched specimens, see Figure 44, Ref. (3). This was ascribed to the fact that the nominal bending strength of a smooth specimen having a high ductility should be much in excess of its tensile strength, while such "bend-strengthening" may be expected to be rather small in the case of notched specimens having low ductility. This problem is being further investigated at Syracuse University.

The axial-load fatigue strength of notched specimens is observed to fall below that of smooth specimens in the range above 200 cycles approximately. In general the difference between notch- and smooth-fatigue strengths increases to a maximum value at about 10^4 cycles and decreases with further increase in the number of cycles.

Below about 200 cycles, however, the notch-fatigue strength can be above or below the smooth-fatigue strength, approaching the static notch-tension strength at 1 (or 1/4) cycle. This static notch-tension strength can be greater or less than the tensile strength depending upon the ductility and notch sensitivity of the steel (3).

2. Effect of Stress Concentration on Endurance Limit of High-Strength Steels:

As previously mentioned, the fatigue program included tests on smooth specimens and on specimens provided with notches leading to stress concentration factors of 3, 5 and 8. The results of these tests are presented in Figure 16 as the endurance limit versus the stress concentration for both longitudinal and transverse specimens. These results clearly reveal that the effect of stress concentration on the endurance limit is most severe when the stress concentration is between 1 and 3 and is more pronounced at high than at low strength levels. Beyond a value of 3 the effect of stress concentration is minimized and the curves appear to approach a certain value of endurance limit assymptotically. This behavior is equally true of the three strength ranges indicated and of both longitudinal and transverse specimens. However, it appears that the effect of the critical range of stress concentration (K = 1 - 3) on the endurance limit is much more pronounced in the longitudinal than in the transverse direction.

In the previous work on similar steels, heat treated to very high strength levels (3), rotating-beam bending-fatigue tests were performed for the same stress concentrations as used here. These regularly yielded minimum values of endurance limit for a stress concentration of K = 3, as shown for one example in Figure 17. However, it was already pointed out at that time that these specimens (K = 3) were finished by grinding while all other notched specimens (K = 5 and 8) were finish machined with a carbide tool. In contrast, maximum notch sensitivity at an intermediate stress concentration (K = 3) was absent in the direct-stress fatigue tests reported here. These specimens were all finish machined. While the difference in test procedure--bending vs. direct stress-renders a definite statement impossible, it now still becomes very probable that grinding, in contrast to finish machining, of a notch decreases the endurance limit of super-high-strength steels by nearly 20,000 psi or 30 percent.

The effect of stress concentration is further illustrated in Figure 18 where the ratio of endurance limit of smooth to that of notched specimens is plotted against the stress concentration factor using the tempering temperature as parameter. Only longitudinal properties are considered in this graph since transverse properties are, in general, subject to a greater degree of scattering. Previous tests on high-strength steels related generally to milder notches (1), (2), which revealed that the ratio of the endurance limits of smooth to notched specimens was generally equal to the stress concentration for mild notches, but became appreciably less than this as the stress concentration was increased. The results obtained in this program were, in general, observed to agree well with previous evidence.

Figure 18 indicates that the ratio of the endurance limits of smooth to notched specimens increases rapidly as the stress concentration factor is increased from 1 to 3. As the stress concentration is increased above K = 3, this ratio continues to increase at slower rates which vary with the steel composition and the tempering temperature.

The results presented in Figure 18 indicate that, of the three steels examined, Tricent (Inco) steel is the most sensitive to notching, particularly when tempered at 400°F. On tempering at 550 and 700°F Tricent steel exhibits a notch sensitivity comparable to that of Super TM-2 steel tempered at 500°F. Cru. SHS-260 possesses the least sensitivity to notching, particularly when tempered at 550°F.

3. Dependence of Endurance Limit on Tempering Temperature or Strength Level:

It was generally accepted that the endurance limit of heat-treated steels increased with increase in strength level to a maximum value at a strength level of approximately 200,000 psi, and then gradually decreased with further increase in strength (1). However, the results of tests on a number of high-strength steels (1), (2), (3) have demonstrated that the endurance limit may continue to increase with increase in the strength level above 200,000 psi. In the present investigation the strength level examined extended between 240,000 and 300,000 psi approximately, and the results obtained were, generally, in good agreement with the trends previously established.

Figure 19 summarizes the results of fatigue tests performed on three steels which ranged in carbon content from 0.35 to 0.41%. This graph illustrates the dependence of the endurance limit and the endurance ratio on the tensile strength. For all testing conditions examined, the endurance limit appears to attain a minimum value at a strength level between 240,000 and approximately 260,000 psi. Above 260,000 psi the endurance limit increases to a maximum value which occurs between 280,000 and 300,000 psi for smooth specimens, and between 270,000 and 290,000 psi for notched specimens.

The endurance ratio depends upon the tensile strength in a manner similar to that of the endurance limit.

4. Effects of Directionality on the Endurance Limit of High-Strength Steels:

Figure 19 illustrates the reduction in endurance limit produced by changing the specimen orientation from parallel to perpendicular to the rolling direction. The effect of directionality on the endurance limit is observed to be most severe with unnotched (smooth) specimens. The endurance limit of transverse smooth specimens may be as much as 40% lower than longitudinal smooth specimens depending upon the strength level. This effect is pronounced at high strength levels and decreases with decrease in strength level.

The effect of directionality on the endurance limit of notched specimens is much less severe than that discussed for smooth specimens. However, the effect does exist and is responsible for a maximum drop of about 15% in the endurance limit when the specimen orientation is changed from longitudinal to transverse. The fact that the difference between longitudinal and transverse strength is greater for smooth than for notched specimens is probably explained by a difference in stress state. The regular tensile test comprises uniaxial load application, while high lateral stresses develop on loading a notched section. Therefore, in a tensile test on a smooth section, only the metal properties in the testing direction are of significance. In contrast, the strength of notched sections may well depend on the properties in the directions perpendicular to that of testing, as well as in that of testing. Confirming this concept, it has been repeatedly observed that a low transverse notch strength is also correlated with a comparatively low longitudinal notch strength. However, as this effect is rather small, it has not yet been definitely established.

CONCLUSIONS

The results presented in this report can be summarized as follows:

1. The fatigue strength of notched specimens in the low cycle range may be greater or less than the fatigue strength of smooth specimens depending upon the number of cycles, and notch sensitivity of the steel. In general, the notch-fatigue strength is above the smooth-fatigue strength below about 10^2 cycles, and the reverse is true beyond about 10^2 cycles.

2. The endurance limit decreases with increase in the stress concentration. This effect is pronounced for stress concentrations between 1 and 3 and decreases with further increase in the stress concentration.

3. In general the endurance limit and the endurance ratio of both smooth and notched specimens develop minimum values between 240,000 and 260,000 psi, and maximum values between 270,000 and 300,000 psi.

4. The effects of directionality on the endurance limit are more pronounced with smooth than with notched specimens and at high than at low strength levels.

BIBLIOGRAPHY

1. Sachs, G., Survey of Low-Alloy Aircraft Steels Heat-Treated to High-Strength Levels, Pt. 2 - Fatigue, WADC TR 53-254 (1954).

2. Melcon, M. A., Ultra High-Strength Steel for Aircraft Structures, Product Eng., Vol. 24, Oct. (1953) p. 129.

3. Sachs, G., Muvdi, B. B. and Klier, E. P., Effect of a Number of Variables on the Fatigue Properties of High-Strength Steels (Accepted for publication in the Am. Soc. Test. Mat., 1956).

4. Peterson, R. E., "Stress Concentration Design Factors, John Wiley and Sons, Inc., New York.

5. Hartmann, E. C. and Stickley, G. W., The Direct-Stress Fatigue Strength of 17 ST Aluminum Alloy Through the Range from 1/2 to 500,000,000 Cycles of Stress, National Advisory Committee for Aeronautics, Tech. Note No. 865 (1942).

6. Weisman, M. H. and Kaplan, M. H., The Fatigue Strength of Steel Through the Range From 1/2 to 30,000 Cycles of Stress, Proc. Am. Soc. Test. Mat., Vol. 50 (1950) p. 649.

7. Pomp, A. and Hempel, M., Notch-Impact Energy, Fatigue Strength and Endurance Limit of Smooth and Notched Specimens of Various Steels Under Axial-Tension Loading, Archiv Eisenhuettenwesen, Vol. 21 (1950-1951) p. 67.

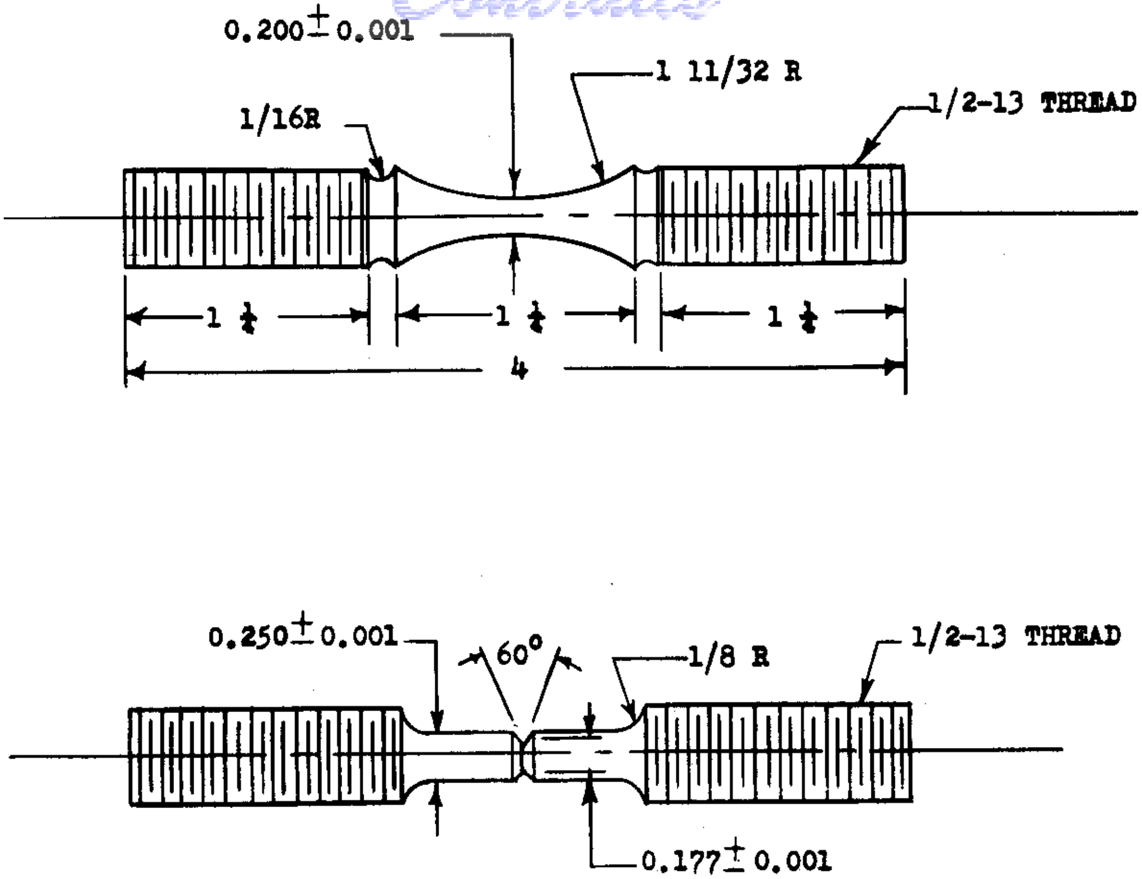

FIG. 1 FATIGUE AND NOTCH-FATIGUE SPECIMENS USED IN THIS PROGRAM.

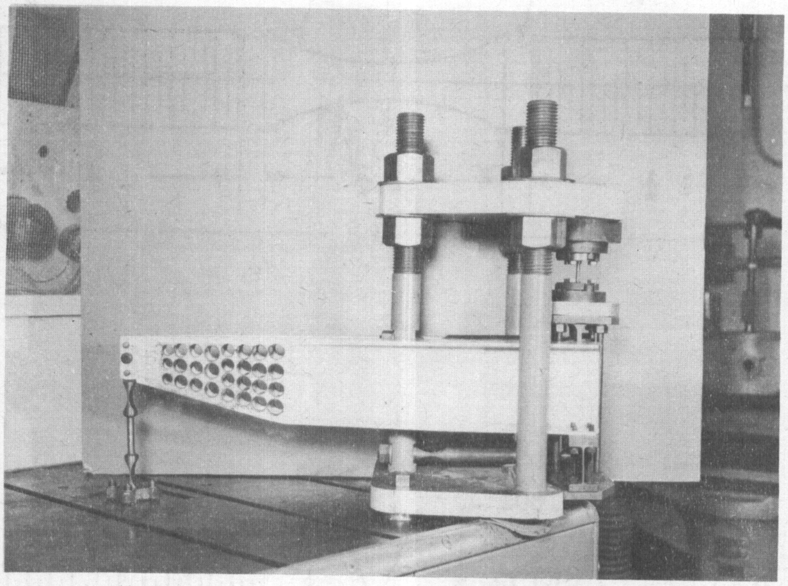

FIG. 2 PHOTOGRAPH OF AMPLIFICATION FIXTURE.

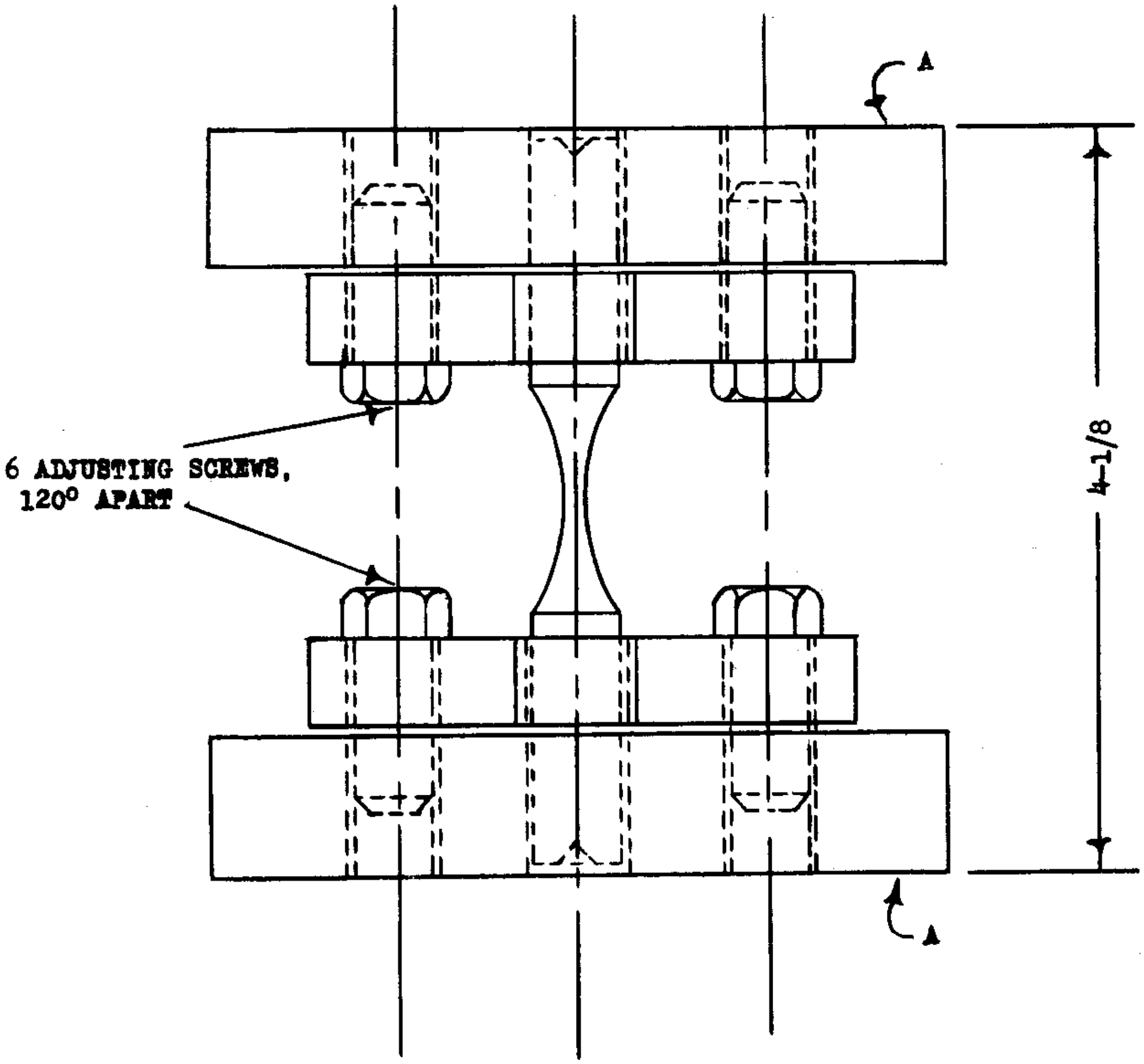

FIG. 3 ASSEMBLY OF ALIGNING FIXTURE AND FATIGUE SPECIMEN.

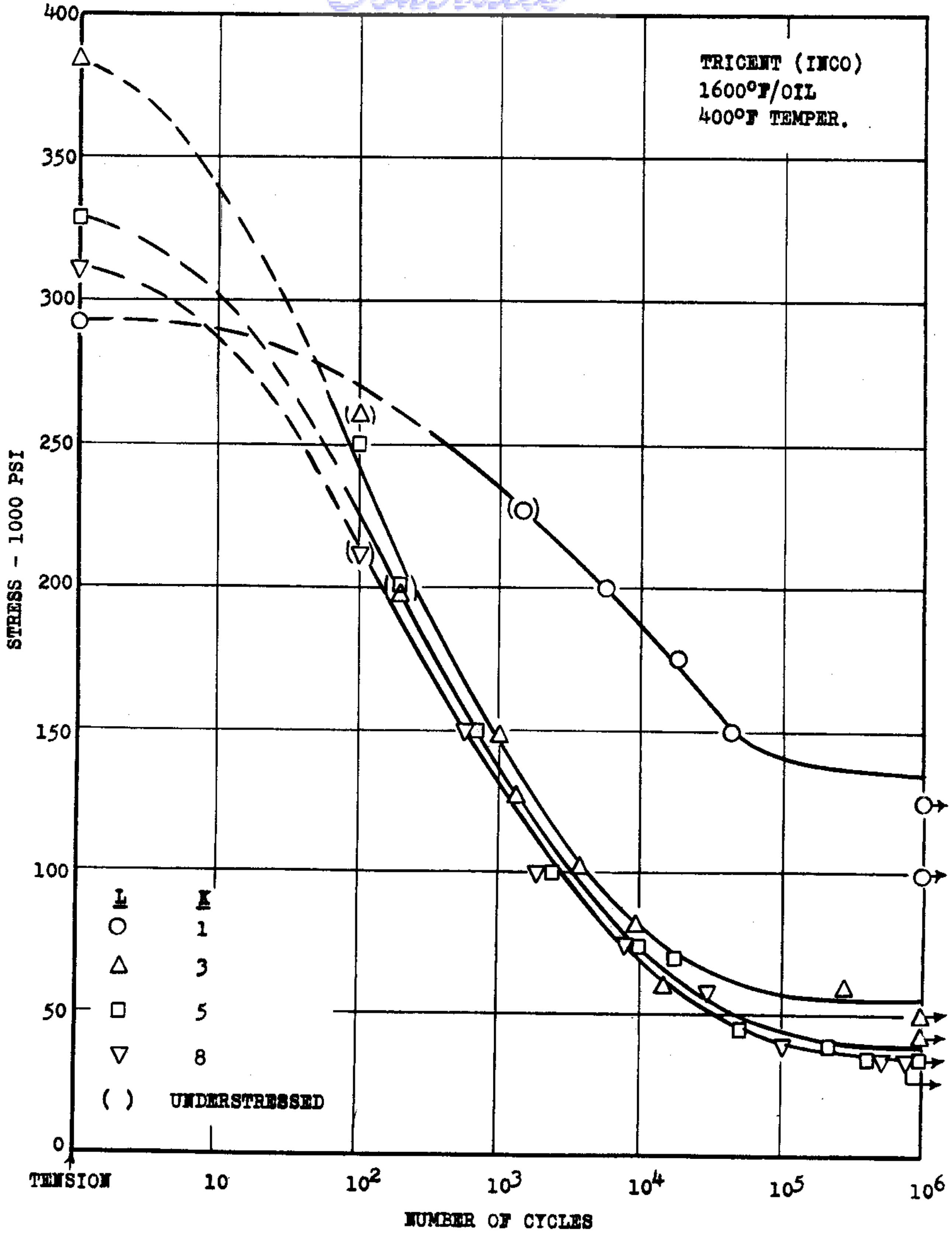

FIG. 4 S-N CURVES FOR SMOOTH AND NOTCHED LONGITUDINAL SPECIMENS OF TRICENT (INCO) STEEL TEMPERED AT 400°F.

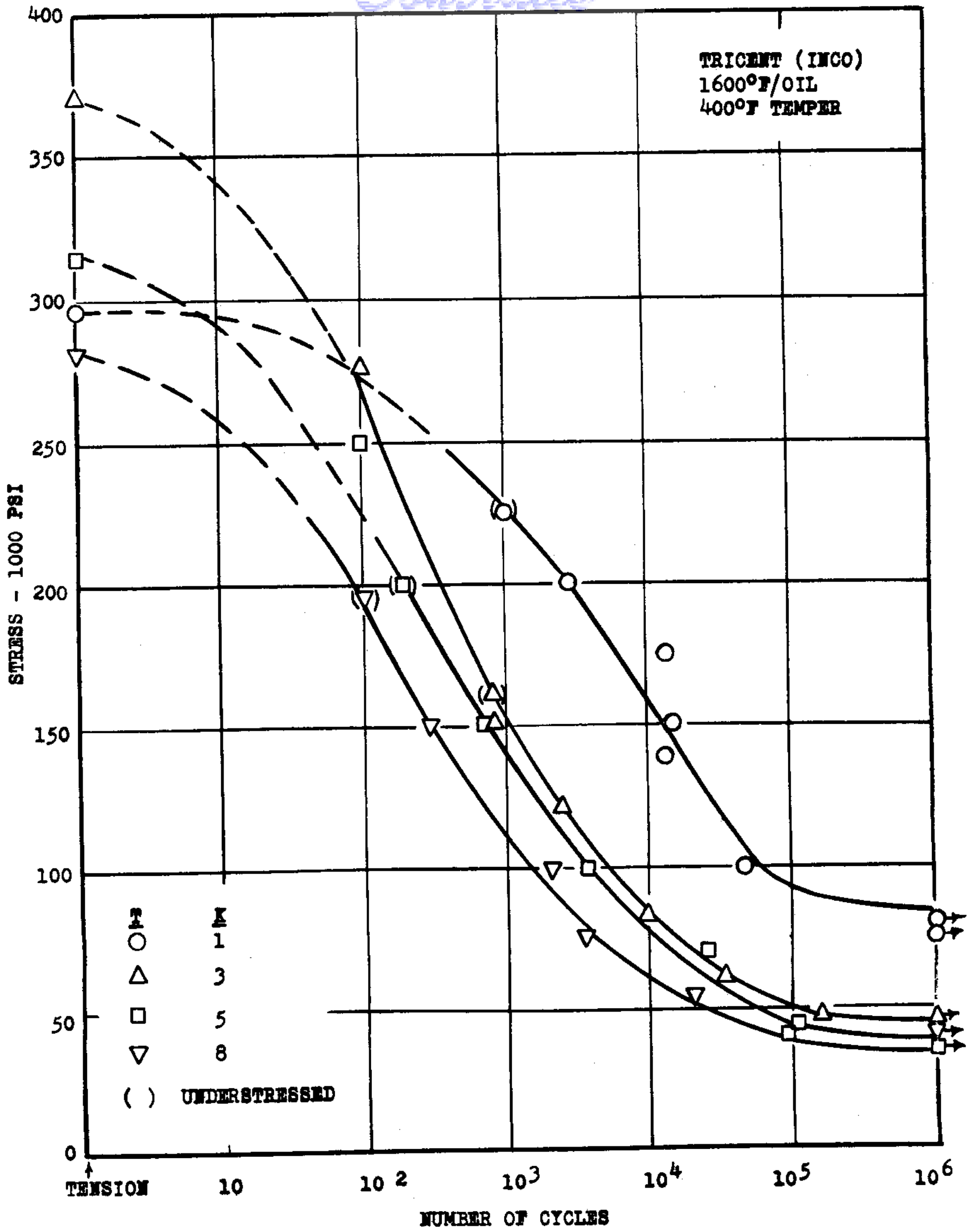

FIG. 5 S-N CURVES FOR SMOOTH AND NOTCHED TRANSVERSE SPECIMENS OF TRICENT (INCO) STEEL TEMPERED AT 400°F.

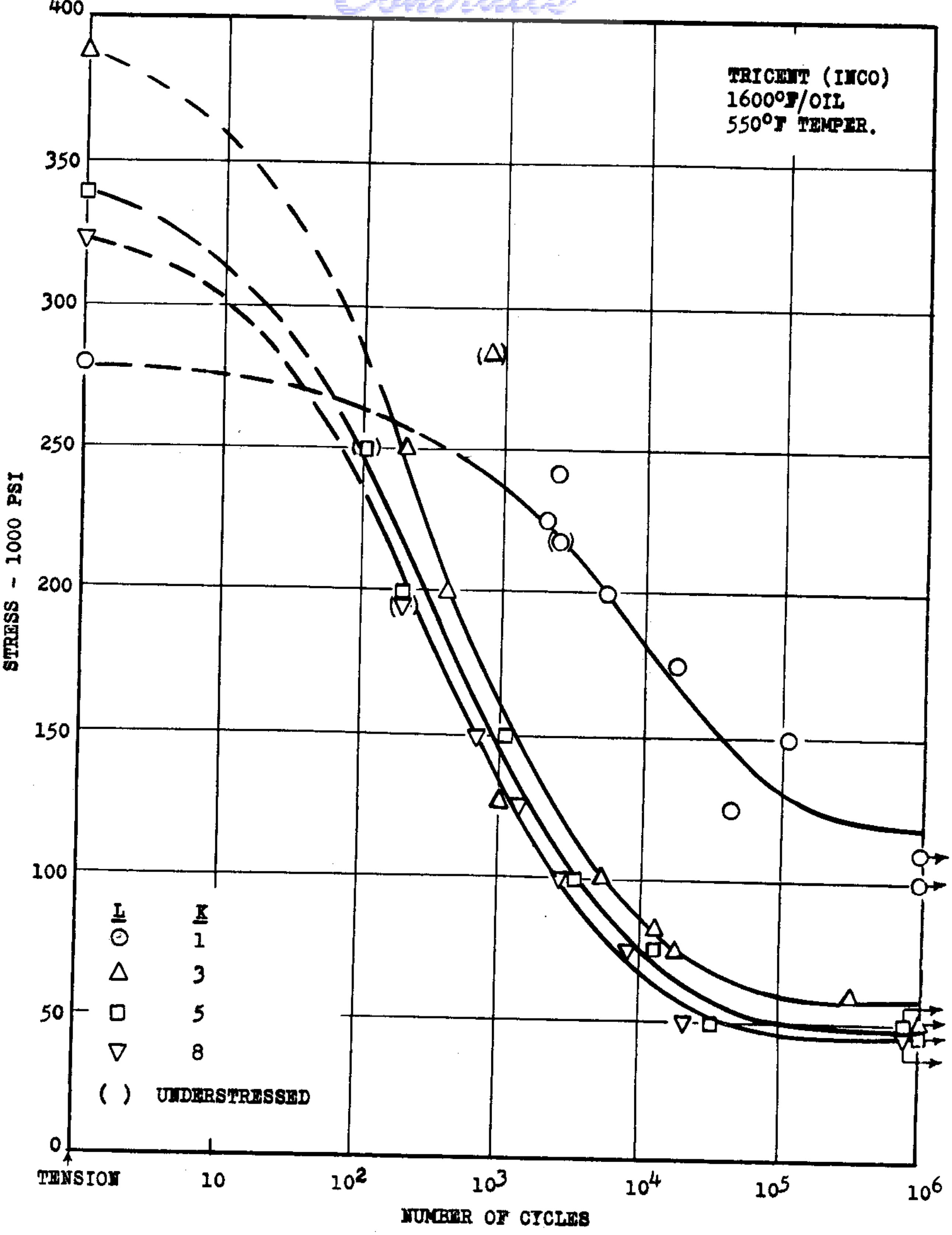

FIG. 6 S-N CURVES FOR SMOOTH AND NOTCHED LONGITUDINAL SPECIMENS OF TRICENT (INCO) STEEL TEMPERED AT 550°F.

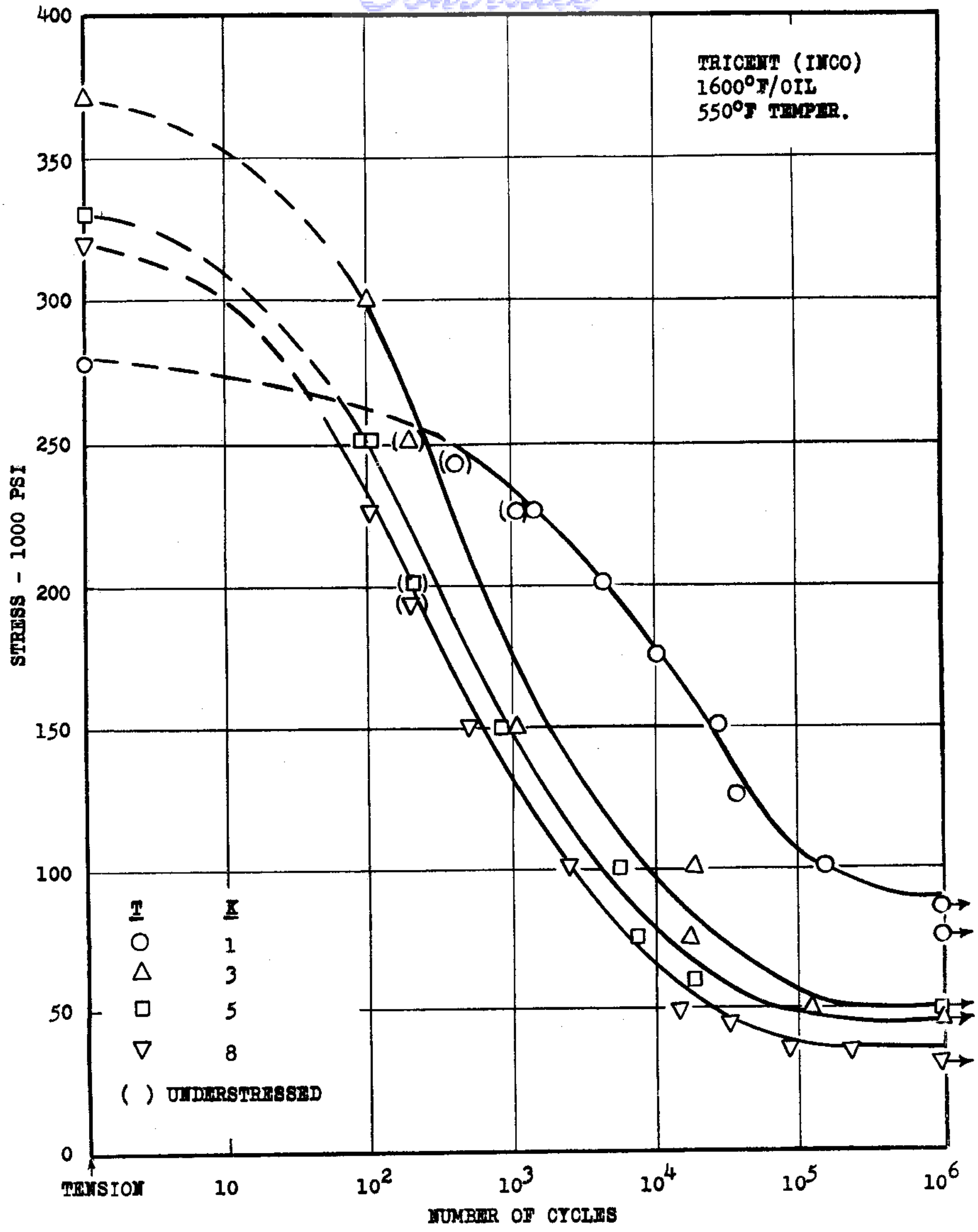

FIG. 7 S-N CURVES FOR SMOOTH AND NOTCHED TRANSVERSE SPECIMENS OF TRICENT (INCO) STEEL TEMPERED AT 550°F.

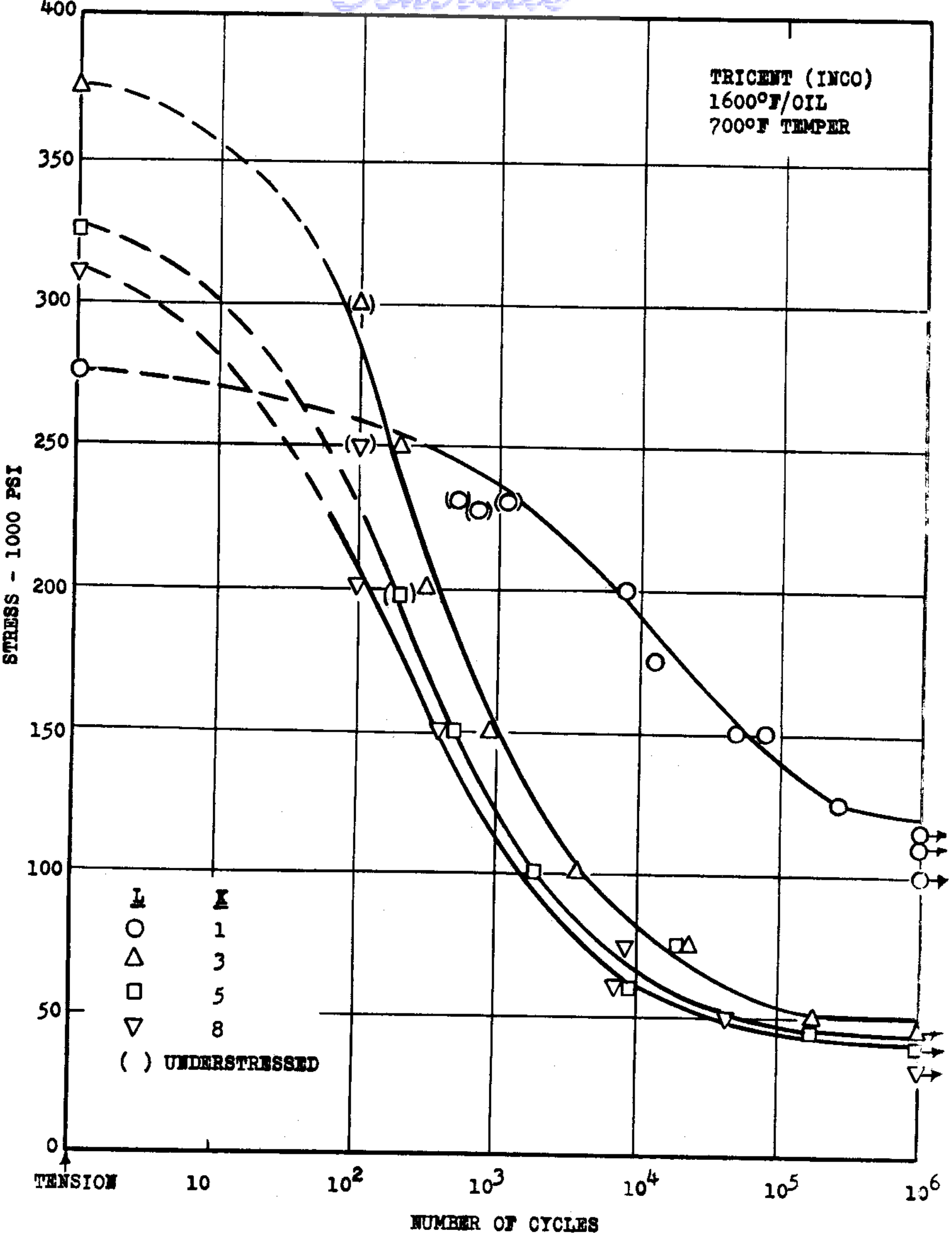

FIG. 8 S-N CURVES FOR SMOOTH AND NOTCHED LONGITUDINAL SPECIMENS OF TRICENT (INCO) STEEL TEMPERED AT 700°F.

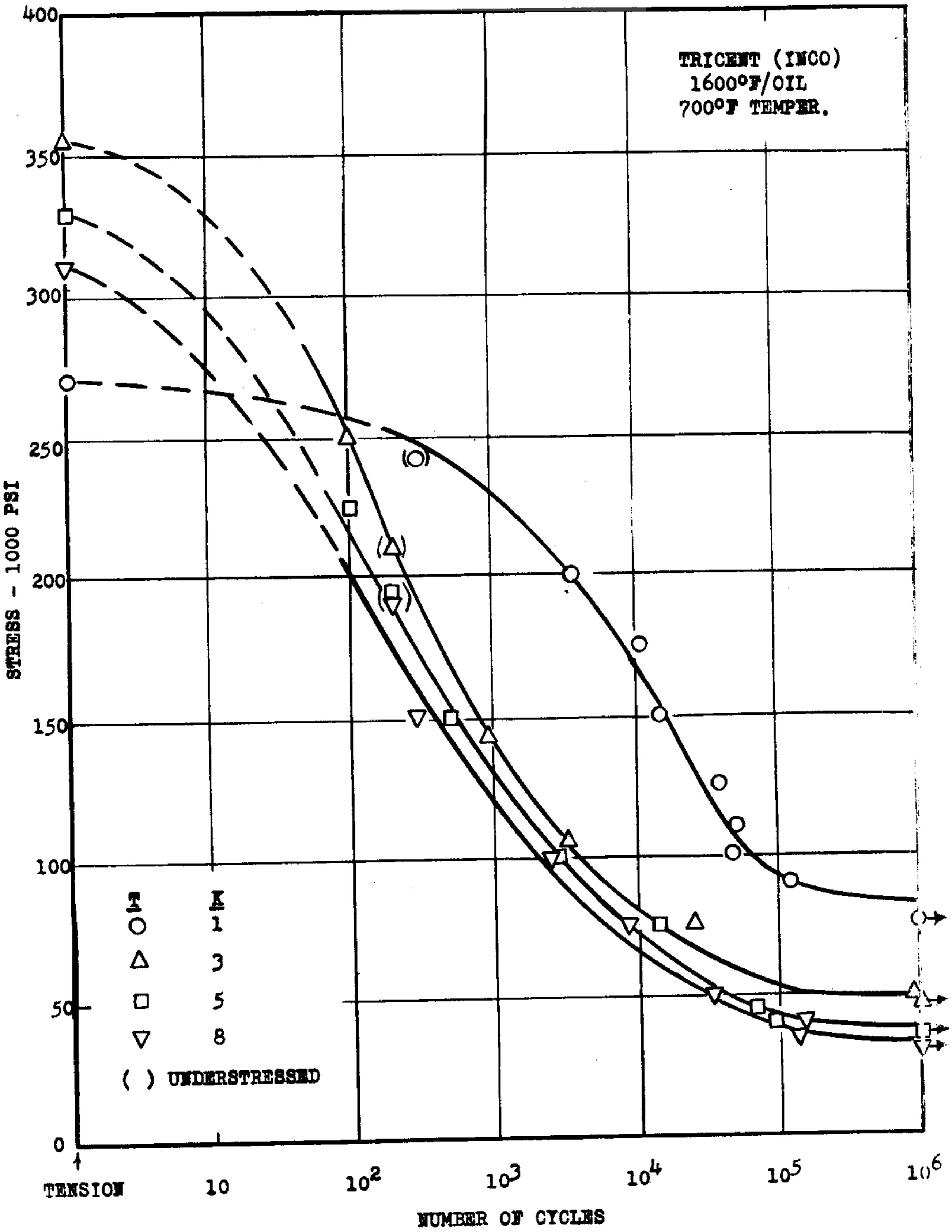

FIG. 9 S-N CURVES FOR SMOOTH AND NOTCHED TRANSVERSE SPECIMENS OF TRICENT (INCO) STEEL TEMPERED AT 700°F.

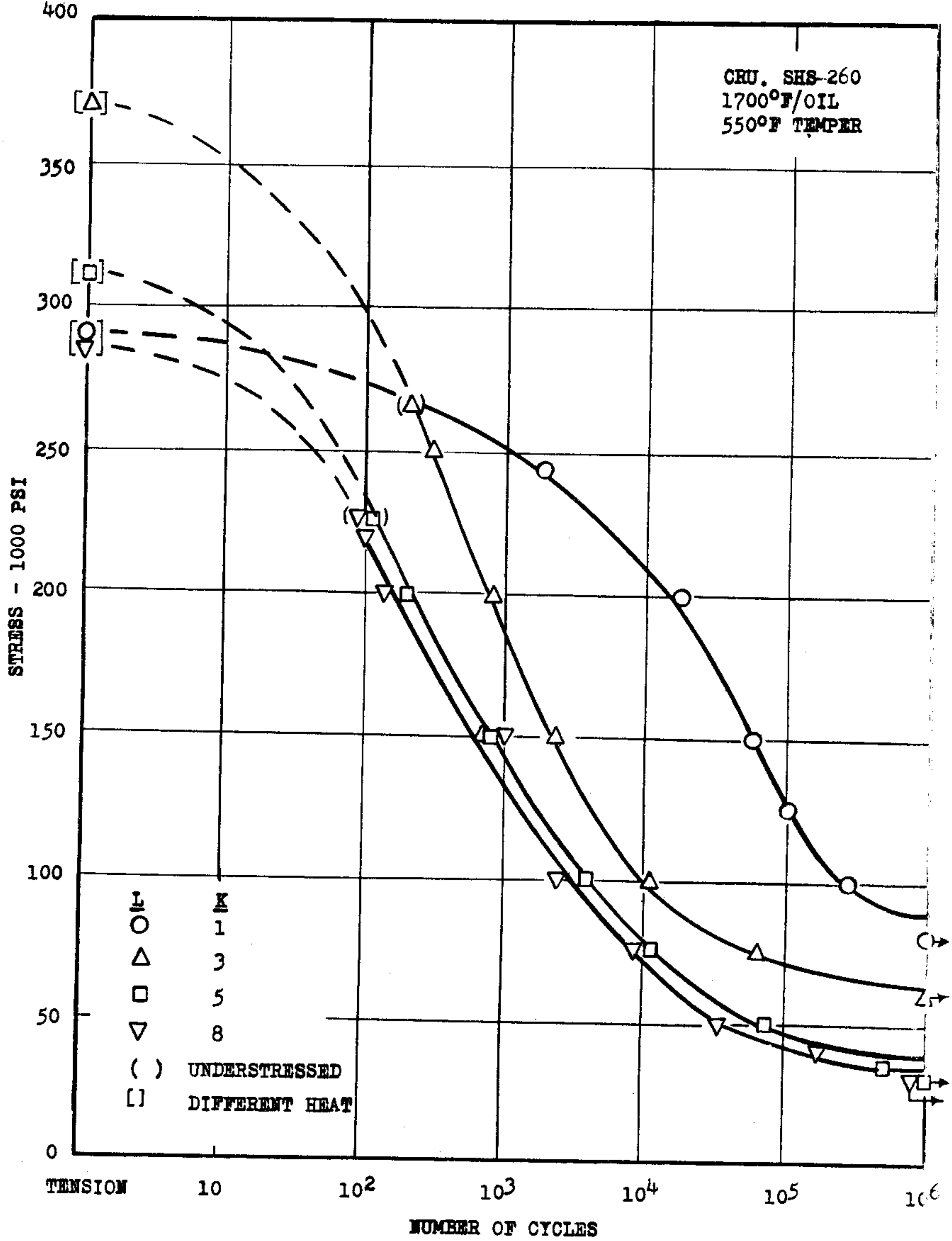

FIG. 10 S-N CURVES FOR SMOOTH AND NOTCHED LONGITUDINAL SPECIMENS OF CRU. SHS260 STEEL TEMPERED AT 550°F.

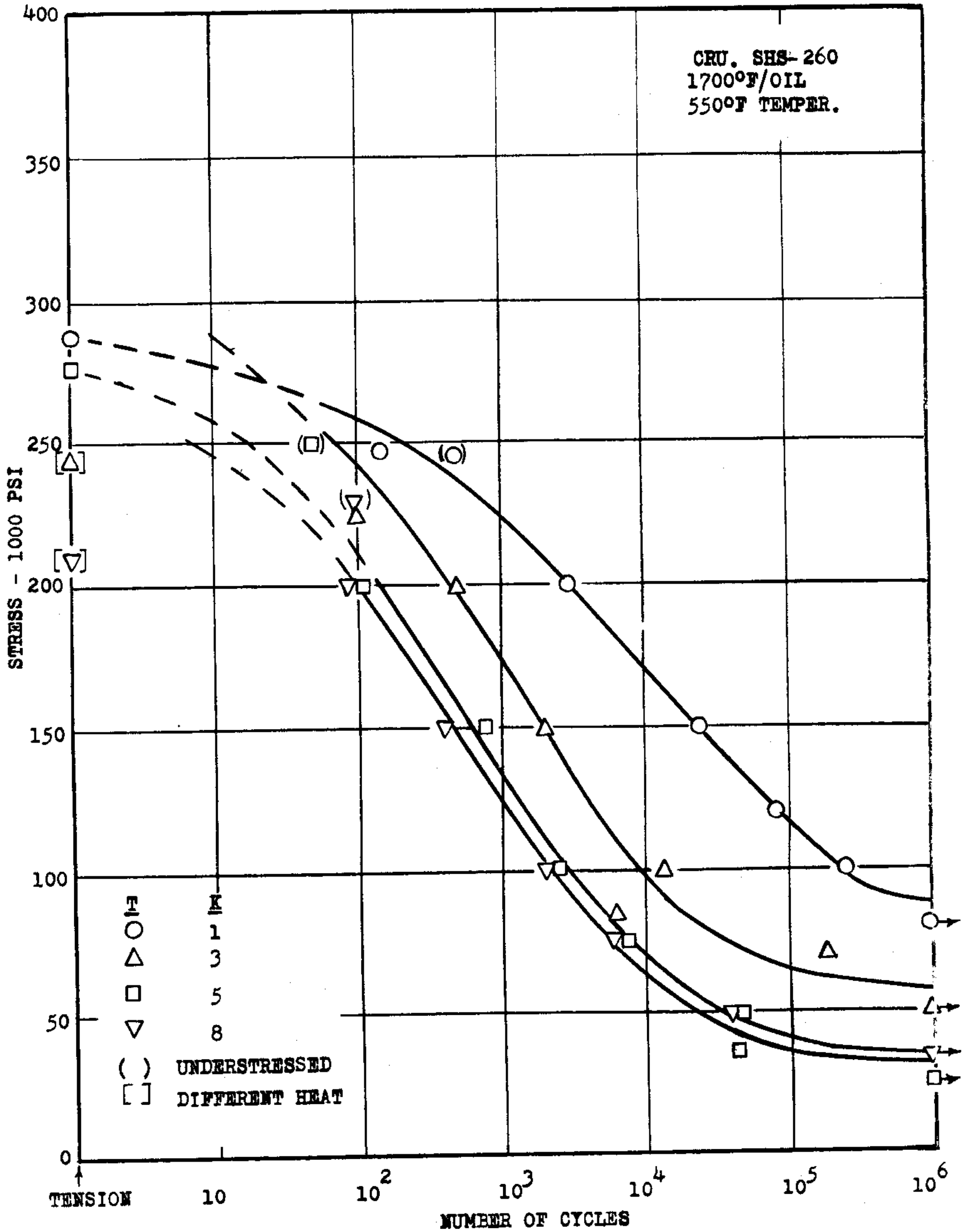

FIG. 11 S-N CURVES FOR SMOOTH AND NOTCHED TRANSVERSE SPECIMENS OF CRU. SHS260 STEEL TEMPERED AT 550°F.

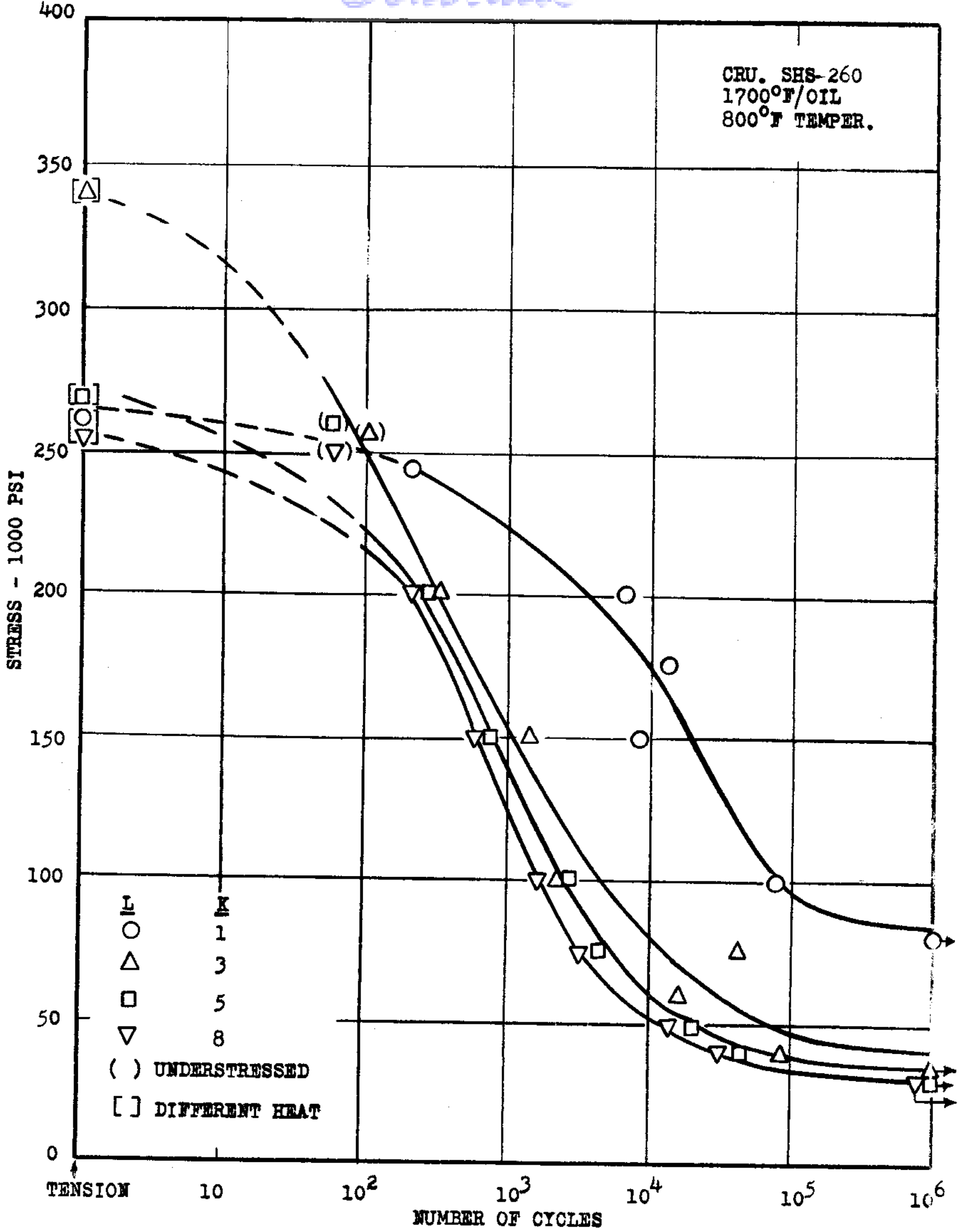

FIG. 12 S-N CURVES FOR SMOOTH AND NOTCHED LONGITUDINAL SPECIMENS OF CRU. SHS260 STEELS TEMPERED AT 800°F.

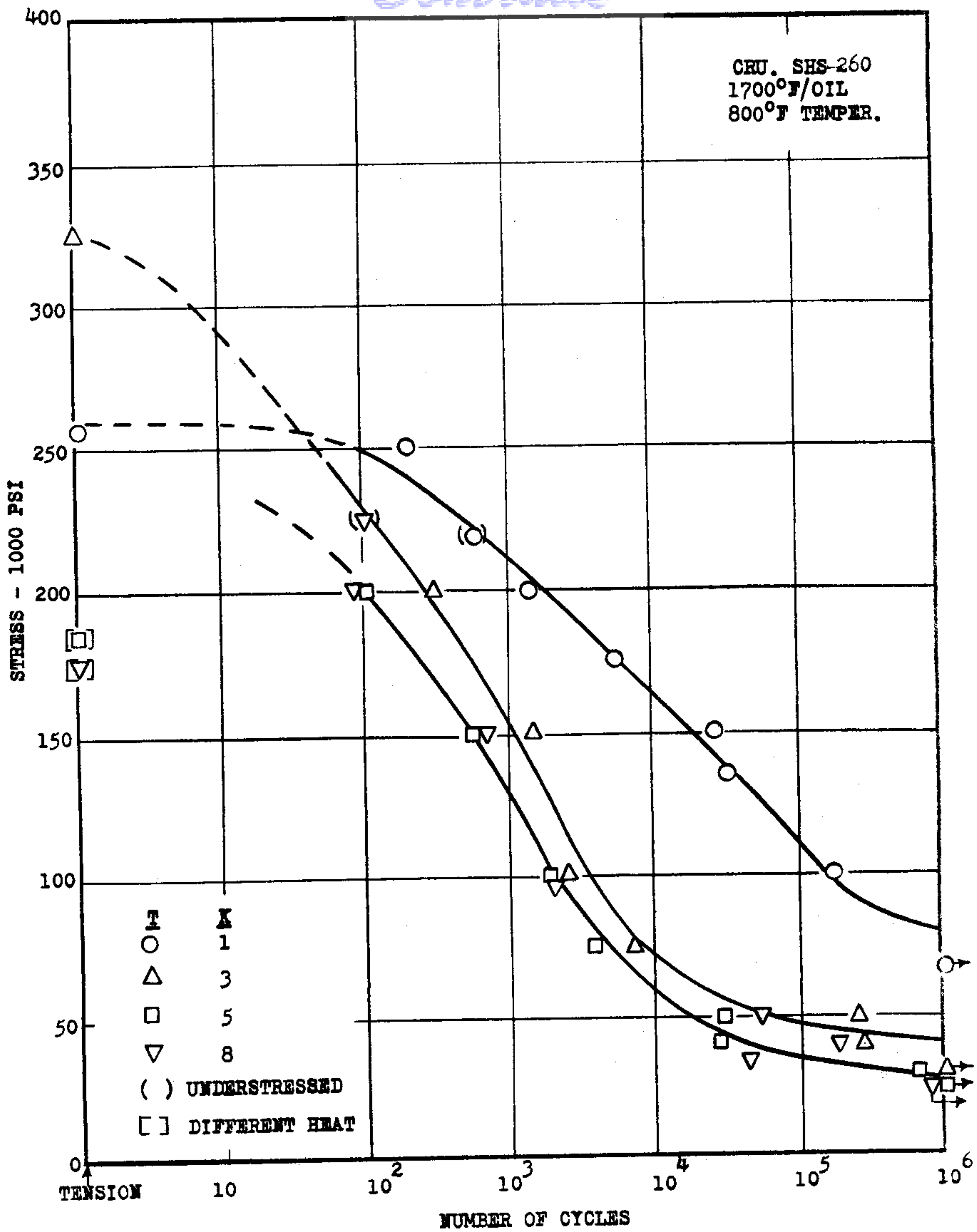

FIG. 13 S-N CURVES FOR SMOOTH AND NOTCHED TRANSVERSE SPECIMENS OF CRU. SHS260 STEEL TEMPERED AT 800°F.

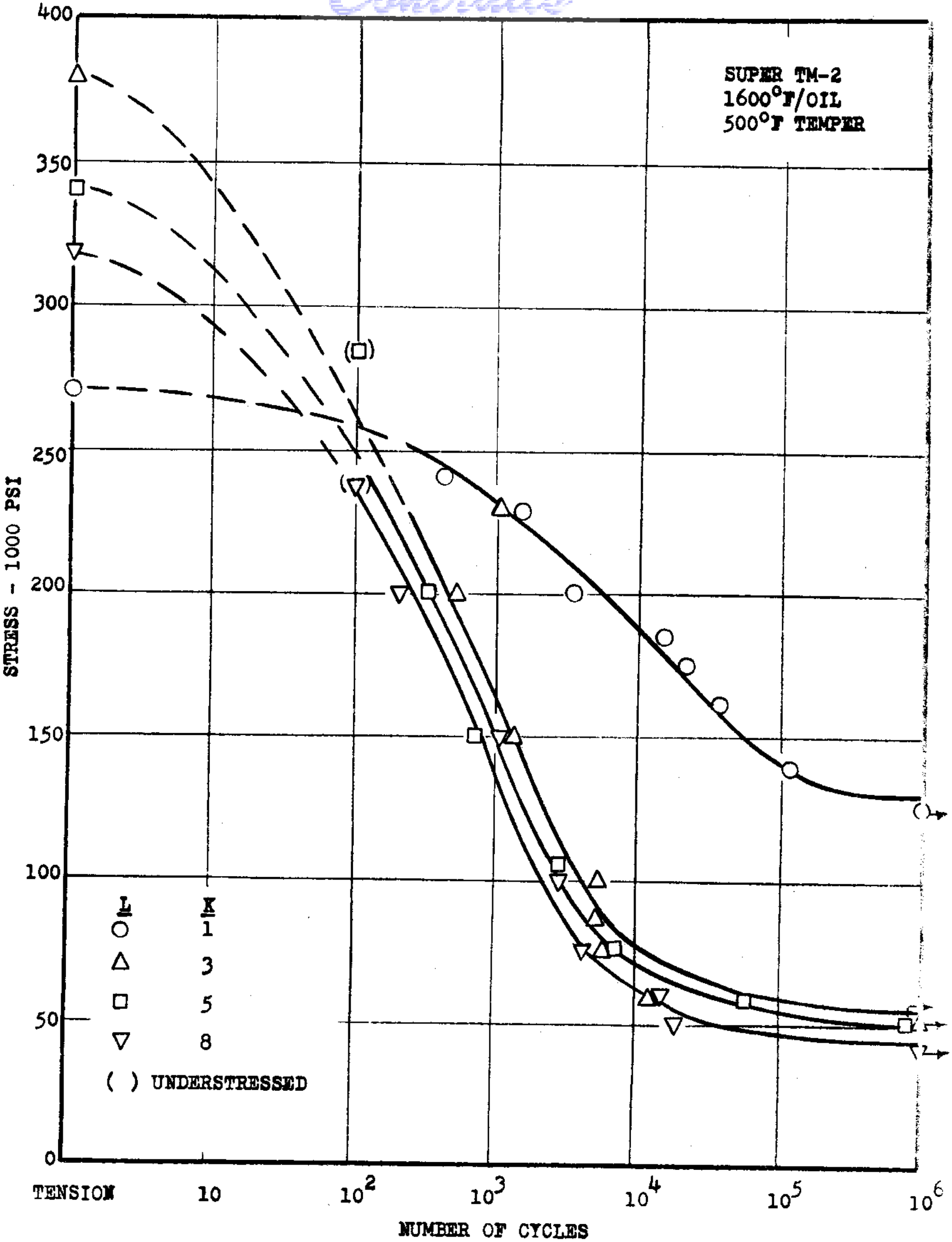

FIG. 14 S-N CURVES FOR SMOOTH AND NOTCHED LONGITUDINAL SPECIMENS OF SUPER TM-2 STEEL TEMPERED AT 500°F.

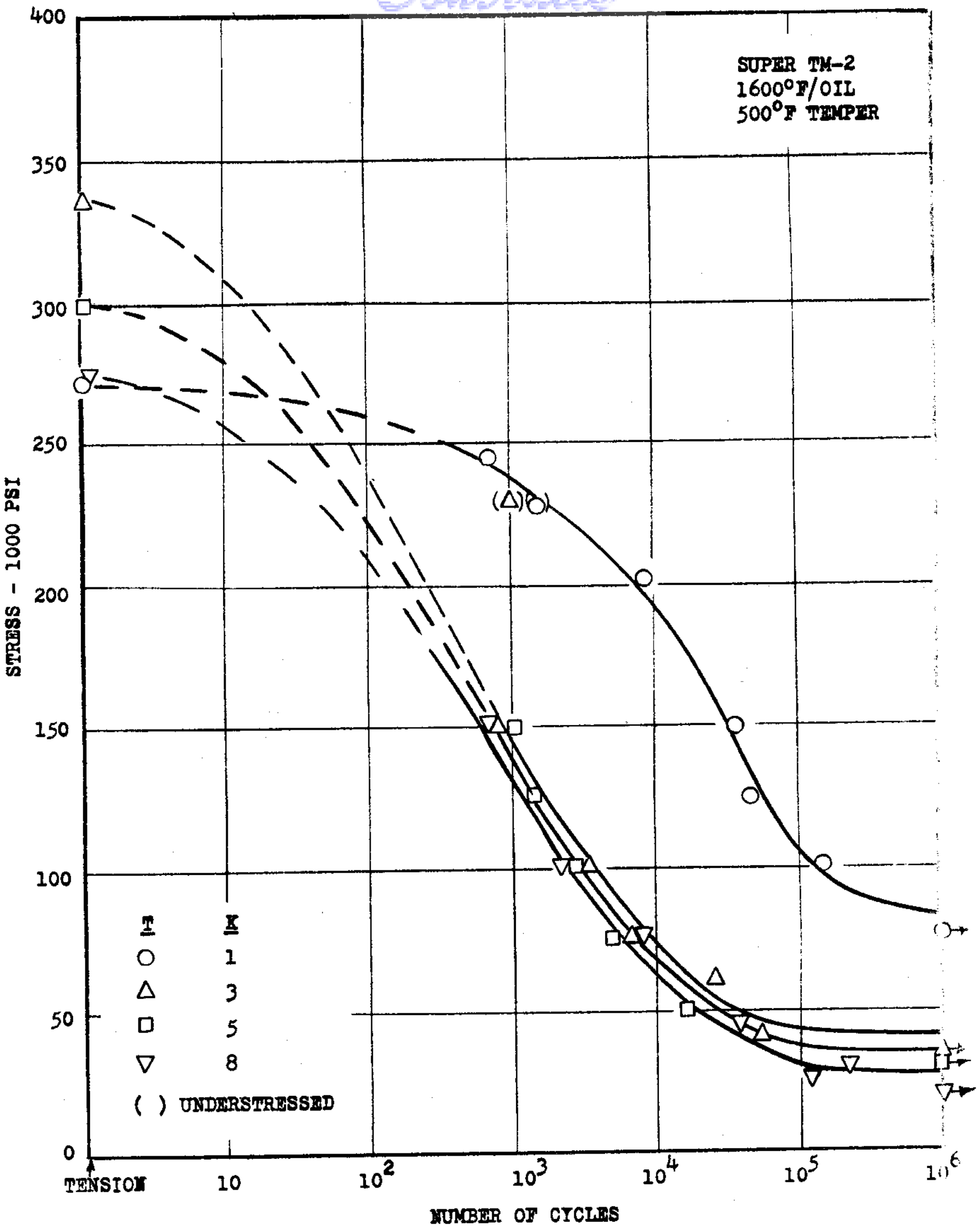

FIG. 15 S-N CURVES FOR SMOOTH AND NOTCHED TRANSVERSE SPECIMENS OF SUPER TM-2 STEEL TEMPERED AT 500°F.

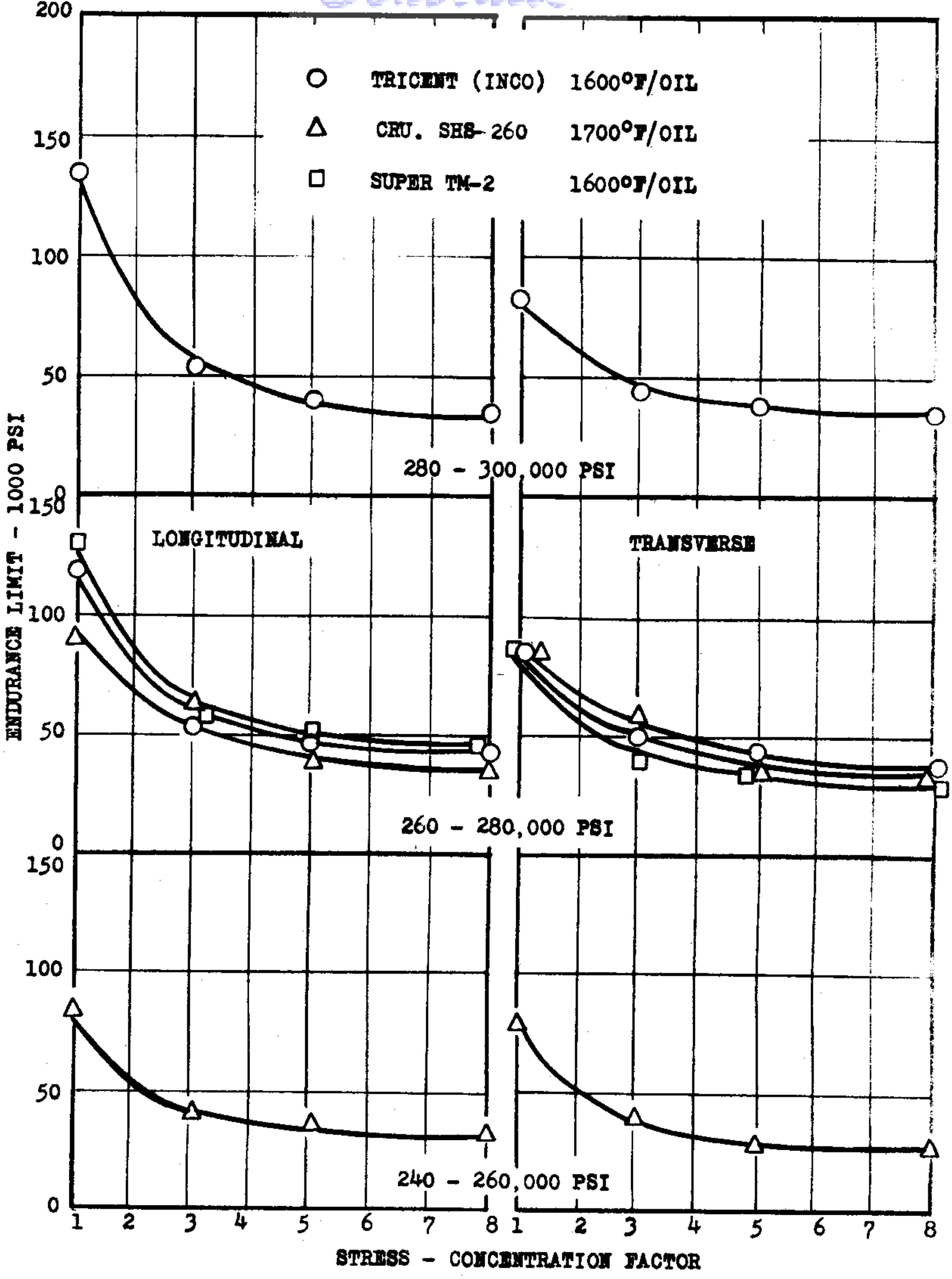

FIG. 16 DEPENDENCE OF ENDURANCE LIMIT OF HIGH-STRENGTH STEELS ON THE STRESS CONCENTRATION.

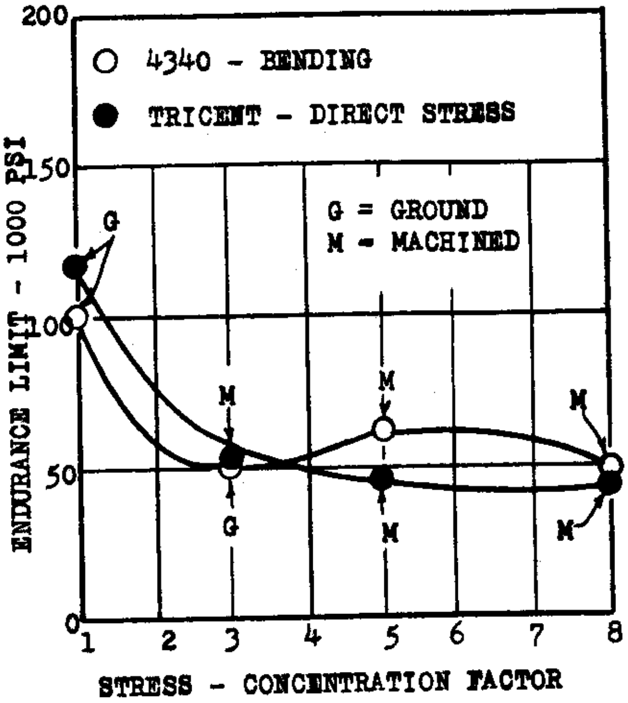

FIG. 17 EFFECTS OF GRINDING AND MACHINING OF NOTCHES ON THE ENDURANCE LIMIT OF HIGH-STRENGTH STEELS. HEAT TREATED TO 260-280,000 PSI.

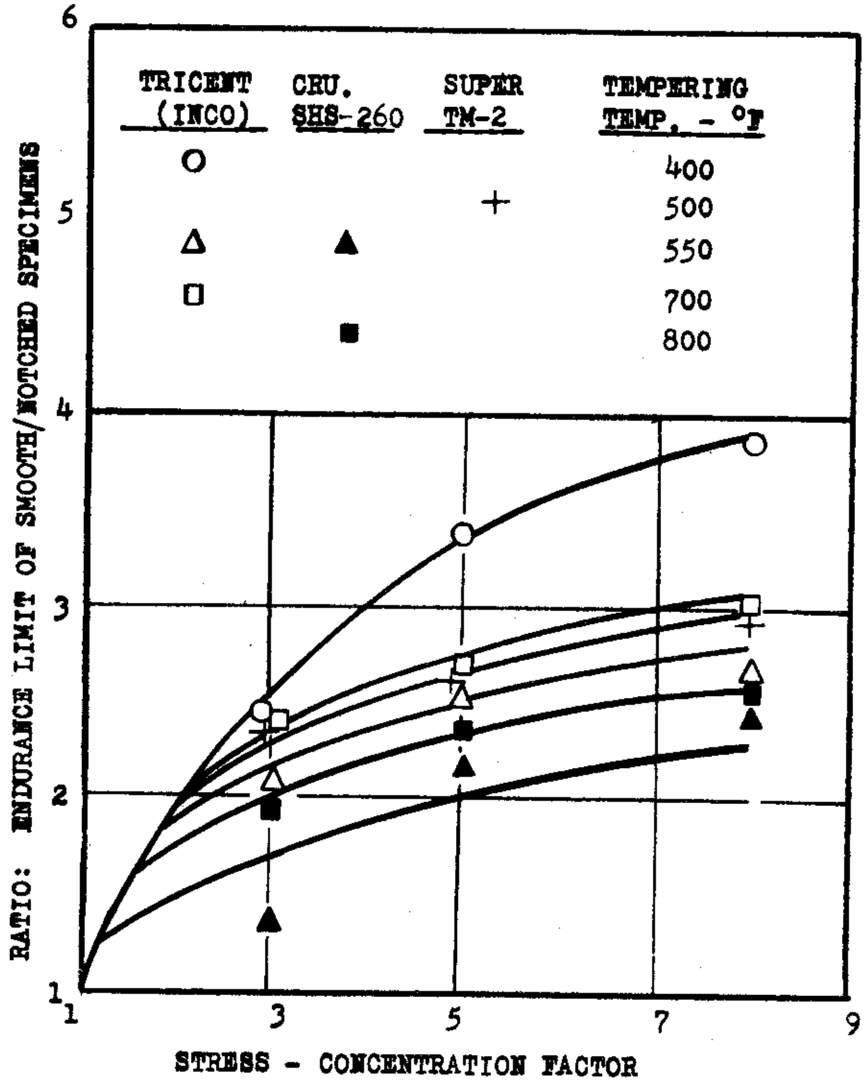

FIG. 18 EFFECT OF STRESS CONCENTRATION ON THE NOTCH SENSITIVITY OF HIGH-STRENGTH STEELS.

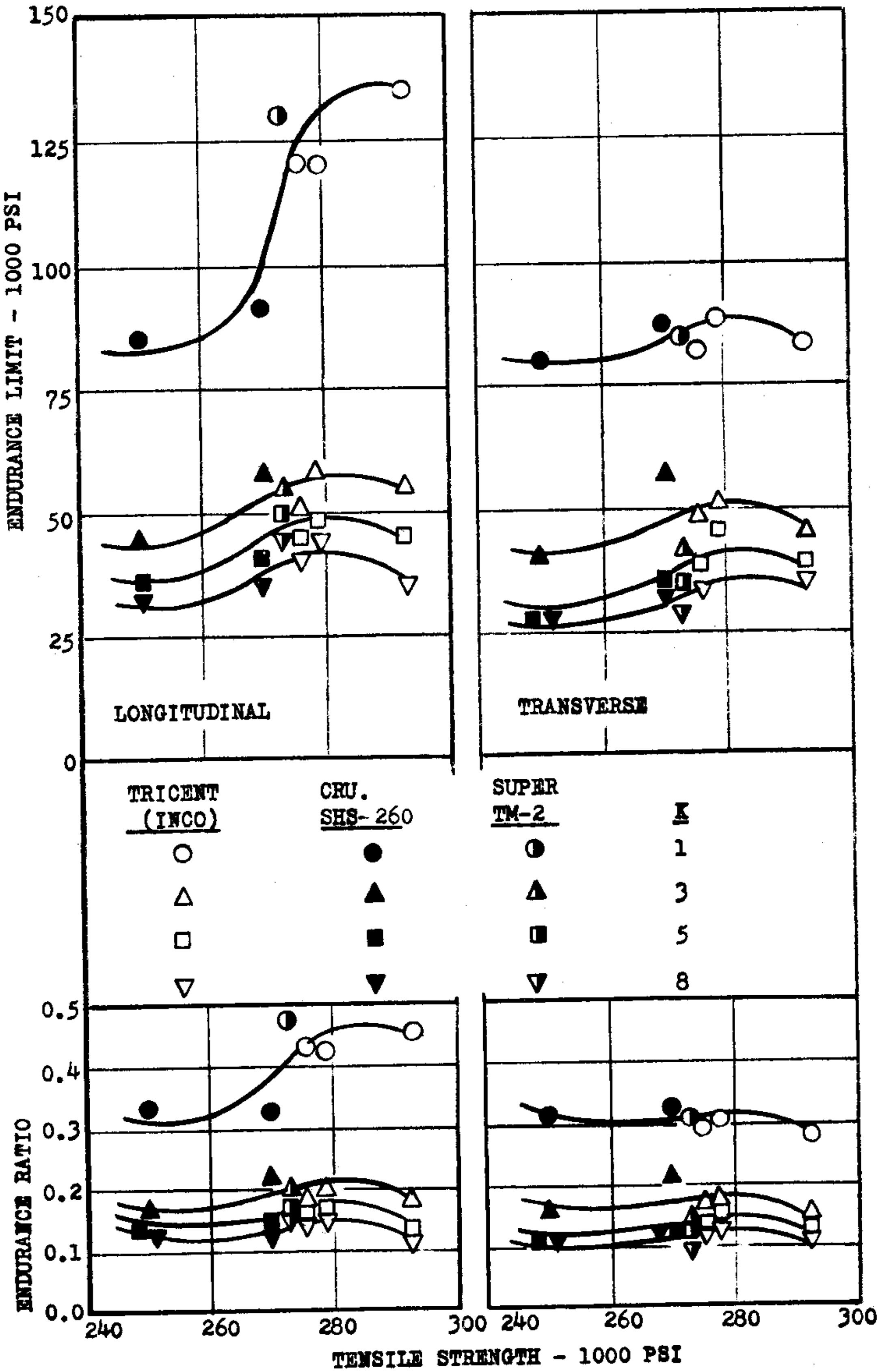

FIG. 19 VARIATION OF ENDURANCE LIMIT AND ENDURANCE RATIO OF HIGH-STRENGTH STEELS WITH THE TENSILE STRENGTH.

APPENDIX

NUMERICAL DATA IN TABULAR FORM

TABLE III

AXIAL-LOAD FATIGUE DATA FOR SMOOTH AND NOTCHED TRICENT (INCO) STEEL SPECIMENS TEMPERED AT 400°F

Type of Specimen	Fatigue Strength - 1000 psi				Fatigue Life - 1000 Cycles			
	K = 1	K = 3	K = 5	K = 8	K = 1	K = 3	K = 5	K = 8
Longitudinal	100	34	35	35	1445.9	1635.5	1796.0 433.9	1927.5
	125	43	40	35	1167.4	1020.3	225.0	589.
	150	50	45	40	44.8	2013.9	52.3	105.9
	175	61	70	60	18.4	14.7	18.4	30.5
	200	61	75	75	5.9	270.0	9.7	8.3
	*227	82	100	100	*1.5	9.6	2.4	2.0
		102	150	150		3.8	0.7	0.6
		127	*200	*211		1.3	*0.2	*0.1
		148				1.0		
		*197				*0.2		
		*260				*0.1		
Transverse	75	45	35	40	1387.0	2453.6	17720.	1766.6
	100	48	40	55	48.4	168.6	93.6	20.0
	139	61	45	75	12.3	31.9	102.5	3.5
	150	83	70	100	16.7	9.1	24.5	2.1
	175	122	100	150	13.3	2.3	3.6	0.3
	200	151	150	*195	2.7	0.8	0.7	*0.1
		*161	*200			*0.8	*0.2	
		277	250			0.1	0.1	

*Understressed

TABLE IV

AXIAL-LOAD FATIGUE DATA FOR SMOOTH AND NOTCHED TRICENT (INCO) STEEL SPECIMENS TEMPERED AT 550°F

Type of Specimen	Fatigue Strength - 1000 psi				Fatigue Life - 1000 Cycles			
	K = 1	K = 3	K = 5	K = 8	K = 1	K = 3	K = 5	K = 8
Longitudinal	100	49	45	45	1200.4	1692.0	1637.3	1996.5
	110	60	50	50	1100.4	321.2	32.9	22.1
	125	75	50	75	44.7	19.5	1598.8	8.5
	150	83	75	100	104.0	13.4	14.0	3.3
	175	100	100	125	18.5	5.4	3.4	1.5
	200	126	150	150	5.4	1.0	1.1	0.7
	*218	200	200	*196	*2.4	0.4	0.2	*0.2
	225	250	*250		2.0	0.2	*0.1	
		*283				*0.8		
Transverse	75	45	50	30	2183.6	17925.	1587.7	2356.6
	100	50	60	35	156.1	117.5	19.3	239.7
	125	75	75	35	37.7	17.6	7.0	86.6
	150	100	100	45	29.0	18.4	6.8	31.1
	175	150	150	50	10.4	11.0	0.8	15.1
	200	*250	*200	100	4.4	*0.2	*0.2	2.4
	225	300	250	150	1.5	0.1	0.1	0.5
	*225		250	*193	*1.1		0.1	*0.2
				225				0.1

*Understressed

TABLE V

AXIAL-LOAD FATIGUE DATA FOR SMOOTH AND NOTCHED TRICENT (INCO) STEEL SPECIMENS TEMPERED AT 700°F

Type of Specimen	Fatigue Strength - 1000 psi				Fatigue Life - 1000 Cycles			
	K = 1	K = 3	K = 5	K = 8	K = 1	K = 3	K = 5	K = 8
Longitudinal	100	45	40	31	2384.0	16640.	1974.2	2611.0
	110	50	45	50	1622.4	185.5	176.0	43.2
	125	75	60	65	552.0	22.3	8.6	8.1
	150	100	75	75	49.3	3.8	21.8	8.4
	150	150	100	100	77.2	0.9	1.9	3.1
	175	200	150	150	11.6	0.3	0.5	0.4
	200	250	*198	200	7.8	0.2	*0.2	0.1
	*227	*300		*250	*0.7	*0.1		*0.1
	*230				*1.1			
Transverse	75	46	35	30	2100.0	10000.	1027.7	2611.
	100	50	40	35	49.7	980.	90.9	130.4
	110	75	45	40	51.9	25.4	68.8	149.7
	125	105	75	50	38.5	3.1	14.2	34.8
	150	143	100	75	14.7	0.9	2.9	8.4
	175	*210	150	100	10.2	*0.2	0.5	2.7
	200	250	*194	150	3.5	0.1	*0.2	0.3
	*242		225	*194	*0.3		0.1	*0.2

*Understressed

TABLE VI

AXIAL-LOAD FATIGUE DATA FOR SMOOTH AND NOTCHED CRU. SHS 260 STEEL SPECIMENS TEMPERED AT 550°F

Type of Specimen	Fatigue Strength - 1000 psi				Fatigue Life - 1000 Cycles			
	K = 1	K = 3	K = 5	K = 8	K = 1	K = 3	K = 5	K = 8
Longitudinal	80	60	30	30	1815.3	1200.0	1000.0	1900.0
	100	75	35	40	264.5	63.6	507.4	180.1
	150	100	50	50	60.0	10.7	77.6	35.0
	200	150	75	75	18.3	2.2	11.3	8.3
	244	150	100	100	1.8	0.7	3.8	2.3
		200	150	150		0.8	0.8	1.0
		250	200	200		0.3	0.2	0.15
		*266	*226	220		*0.2	*0.1	0.1
				*225				*0.08
Transverse	80	50	25	35	1000.0	1000.0	2147.0	1343.0
	100	70	35	40	267.2	191.4	44.2	1000.0
	120	85	50	50	83.1	6.2	47.0	41.5
	150	100	75	75	21.9	12.1	7.5	7.5
	200	150	100	100	2.9	2.0	2.6	2.2
	*246	200	150	150	*0.5	6.2	0.8	0.4
	247	225	200	200	0.15	0.1	< 0.1	0.1
		*233	*260	*228		*0.4	*0.05	*0.1
		*290		*240		*0.1		*0.1

*Understressed

TABLE VII

AXIAL-LOAD FATIGUE DATA FOR SMOOTH AND NOTCHED CRU-SHS 260 STEEL SPECIMENS TEMPERED AT 800°F

Type of Specimen	Fatigue Strength - 1000 psi				Fatigue Life -1000 Cycles			
	K = 1	K = 3	K = 5	K = 8	K = 1	K = 3	K = 5	K = 8
Longitudinal	80	35	30	30	1811.7	1000.0	1000.0	1621.8
	100	40	40	40	79.3	84.4	44.3	31.0
	150	60	50	50	8.5	16.9	20.0	12.1
	175	75	75	75	14.1	40.2	4.3	3.2
	200	100	100	100	7.0	2.5	2.6	1.7
	244	150	150	150	0.2	1.2	0.7	0.7
		200	200	200		0.3	0.3	0.2
		*256	*260	*250		*0.1	*0.05	*0.05
Transverse	67	30	25	25	2194.6	1900.0	1214.0	7000.0
	100	40	30	35	187.9	289.1	683.3	41.2
	135	50	40	40	31.0	260.2	24.4	195.3
	150	75	50	40	25.2	7.0	29.8	52.0
	175	100	75	100	5.1	2.3	3.7	2.0
	200	150	100	150	1.2	1.5	1.9	0.7
	*229	200	150	200	*0.6	0.3	0.6	0.1
	250		200	*225	0.2		0.1	*0.1

*Understressed

TABLE VIII

AXIAL-LOAD FATIGUE DATA FOR SMOOTH AND NOTCHED SUPER TM-2 STEEL SPECIMENS TEMPERED AT 500°F

Type of Specimen	Fatigue Strength - 1000 psi				Fatigue Life - 1000 Cycles			
	K = 1	K = 3	K = 5	K = 8	K = 1	K = 3	K = 5	K = 8
Longitudinal	125	50	50	41	1971.6	1742.0	1104.0	1421.0
	140	60	59	50	104.7	11.3	59.8	19.4
	162	75	75	60	36.0	5.9	6.5	14.0
	175	87	105	75	20.1	5.0	2.8	4.0
	185	100	150	100	14.5	4.7	0.7	2.9
	200	150	200	150	3.1	1.1	0.3	1.0
	*228	200	*284	200	1.5	0.5	0.1	0.2
	240	*280		*263	4.0	1.0		0.1
Transverse	75	33	30	20	1484.5	1000.0	1000.0	1132.0
	100	40	50	25	137.2	52.2	18.4	112.1
	125	60	75	30	48.7	23.8	5.0	217.9
	150	75	100	45	37.4	6.6	2.8	37.9
	200	100	125	75	8.3	3.3	1.4	8.0
	*228	150	150	100	1.6	0.8	1.0	2.6
	245	*230		150	0.7	1.0		0.7

*Understressed