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ASD TECHNICAL NOTE 61-117

PART III

10 260

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CATALOG STIA  
AS FILE NO.

MECHANICAL PROPERTIES  
INFORMATION PROCESSING SYSTEM

*Fatigue of Metals*

**LOW ALLOY STEEL**

SECTION I

62-2-6

*Effect of Ultimate Tensile Strength  
on the Fatigue Behavior of 4340 Steel*

Contract AF 33(616)-7238

February 1962

113 250

BELFOUR ENGINEERING CO.

SUTTONS BAY, MICHIGAN

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MECHANICAL PROPERTIES  
INFORMATION PROCESSING SYSTEM

*Fatigue of Metals*

**LOW ALLOY STEEL**

SECTION I

*Effect of Ultimate Tensile Strength  
on the Fatigue Behavior of 4340 Steel*

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February 1962

BELFOUR ENGINEERING CO.

SUTTONS BAY, MICHIGAN

## FOREWORD

The graphic displays of metals fatigue data presented in this report have been prepared by the BELFOUR ENGINEERING COMPANY under U.S.A.F. Contract No. AF33(616)-7238, S.A.1 (61-1094), and S.A.2 (62-479). This contract was initiated under Project No. 7381, "Development of a Materials Property Data Processing System", Task No. 73812. Administration of the project is under the direction of the Applications Laboratory, Directorate of Materials and Processes, Aeronautical Systems Division, Wright-Patterson Air Force Base, with Don M. Ingels, Lt/USAF acting as project engineer.

This report is one of a series being prepared for periodic dissemination.

**ABSTRACT**

The graphs presented herein display metals fatigue information from various sources of published and unpublished test reports which have been processed and regenerated through a semi-automatic data processing system. Each series or set of graphs contain descriptive information (legends) which identifies the material, test procedure, test conditions and the most significant test and/or material variables associated with the plotted data. The data displayed in each set of graphs is intended to answer very general "questions" and to serve as a guide to further investigation of specific areas within the subject presented.

**PUBLICATION REVIEW**

This report has been reviewed and is approved.

**FOR THE COMMANDER:**



**D. A. Shim  
Chief, Materials Information Branch  
Application Laboratory  
Materials Central**

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<p>Graphic displays of the effect of ultimate tensile strength on the fatigue behavior of AMS 6415 (AISI 4340) steel tested at room temperature with zero mean stress and rotary beam loading. (Results of tests conducted with stresses of other than zero will be displayed in a subsequent Section of this series of Technical Notes).</p>				
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## INTRODUCTION

This is one of a series of reports presenting compilations of test results pertaining to fatigue of metals.

The information contained in each set of graphs is the result of a relatively general "question" asked of a semi-automatic data processing system which stores, processes and regenerates the information in the requested form. More specific and detailed presentations and analyses are usually possible. These are available upon request. The graphic form in which this information is presented is only one of various types of output of which this mechanized system is capable. Tabulations and listings may also be generated by the system.

These data are intended to assist in the determination of reliable and efficient materials properties. The information contained herein should be used with due consideration to applicable specifications and established organizational procedures.

All graphs are labeled with a "search number". These serve to identify a broad block of information associated with a particular (internal) data processing pattern. Graph numbers are assigned in sequence within any search for the purpose of separating and identifying sub-groups of useful information. There is no requirement for graphs in any number sequence to have any relationship other than being the product of the same search. Alphabetic characters following a common graph number are used to identify a series or set of graphs which are related. Subsequent graphs within a series (bearing a common graph number) are used to indicate effects and interactions associated with some obvious variables. The unlimited number of combinations available for display and analysis dictates that these presentations be limited to relatively general subject matter. Detailed studies can be performed on request.

A legend on each graph describes the material, test type and other variables necessary to identify the plotted data. Additional description of material, processing, and testing is provided by a Summary Data Sheet for each display of data. All references, identified by code numbers on the Summary Data Sheets, are completely identified on the Reference List which is the last page of the Technical Note.

# AUTOMATIC DATA ANALYSIS

Search No. 521

Graph 1A

S/N diagram of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material:

AMS 6415 (AISI 4340) Steel

U.T.S., KSI:

143 & 144

Plotted Points:

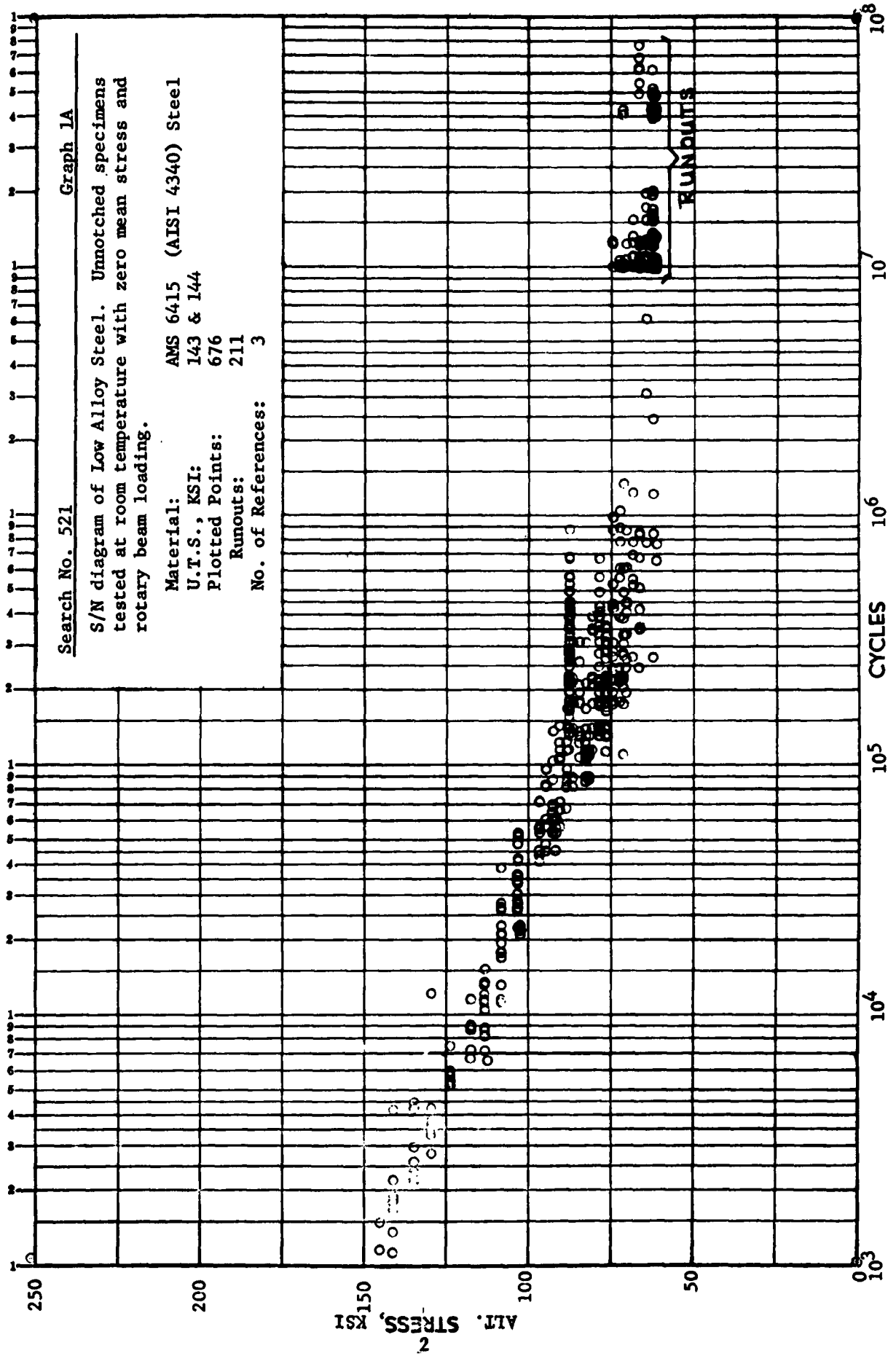
676

Runouts:

211

No. of References:

3



SUMMARY DATA SHEET  
METALS FATIGUE TESTS

Search No. 521

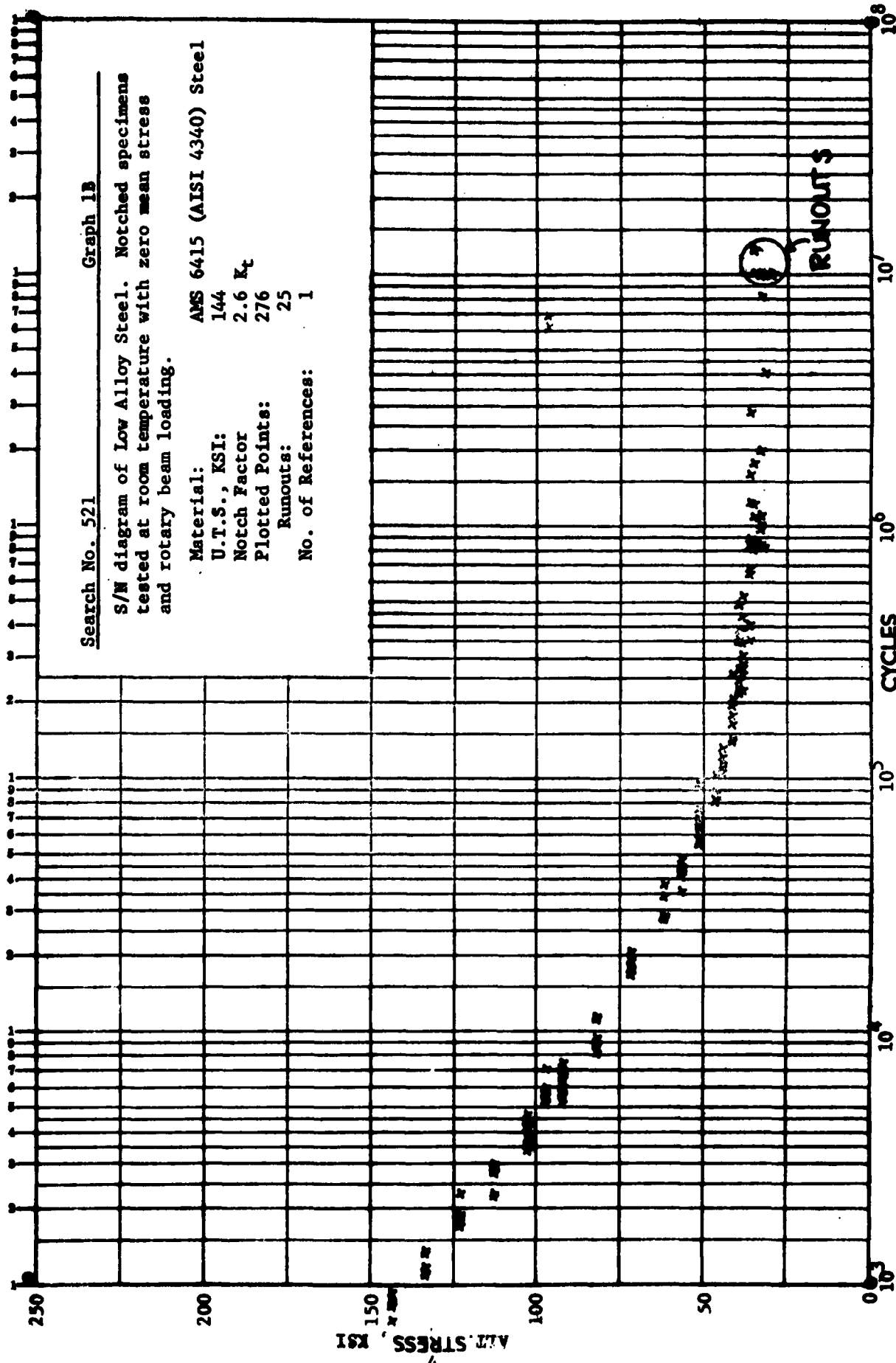
Graph 1A

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Reference Code Nos.:	* 001, 067 & 117
Material:	AMS 6415 (AISI 4340) Steel
Melting Practice:	Electric Furnace & Not Recorded
Heat Treatment:	Normalized 1600 <sup>o</sup> F, 1.5 Hr, AC Austenitized 1525 <sup>o</sup> F, 1.5 Hr, OQ Tempered 1150 <sup>o</sup> F, 4 Hrs, AC
	Normalized 1600 <sup>o</sup> F, 2 Hrs, AC Austenitized 1500 <sup>o</sup> F, 2 Hrs, OQ Tempered 1150 <sup>o</sup> F, 4 Hrs, AC
	Normalized 1600 <sup>o</sup> F, 4 Hrs, AC Austenitized 1525 <sup>o</sup> F, 2 Hrs, OQ Tempered 875 <sup>o</sup> F, 4 Hrs, AC Stress Relieved 700 <sup>o</sup> F, 2 Hrs, F.C. to 300 <sup>o</sup> F, AC
Yield Strength, KSI:	128 or 132
Elongation:	20%, Gage not specified; 21%, 1" Gage; 21%, Gage not specified.
Hardness :	R <sub>c</sub> 30, 31, 32 or Not Recorded
Surface Condition:	Mechanical Polishing
Surface Finish:	5 Microinch
Primary Fabrication:	Forged or Hot Rolled
Secondary Operation:	Lathe Turned or Ground
Specimen Type:	Unnotched bars over 0.125" thick

\*See Reference list for complete identification of reference documents.

# AUTOMATIC DATA ANALYSIS



Search No. 521

Graph 1B

S/N diagram of Low Alloy Steel. Notched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material:

AMS 6415 (AISI 4340) Steel

U.T.S., KSI:

144

Notch Factor

2.6 K<sub>t</sub>

Plotted Points:

276

Runouts:

25

No. of References:

1

SUMMARY DATA SHEET  
METALS FATIGUE TESTS

Search No. 521

Graph 1B

---

Reference Code Nos.:	001
Material:	AMS 6415 (AISI 4340) Steel
Melting Practice:	Electric Furnace
Heat Treatment:	Normalized            1600 <sup>o</sup> F, 1.5 Hr. AC Austenitized        1525 <sup>o</sup> F, 1.5 Hr. OQ Tempered            1150 <sup>o</sup> F, 4 Hrs. AC
Yield Strength, KSI:	132
Elongation:	21%, Gage length not specified
Hardness:	R <sub>c</sub> 32
Surface Condition:	Longitudinal Polishing
Surface Finish:	5 Microinch
Primary Fabrication:	Hot Rolled
Secondary Operation:	Lathe Turned
Specimen Type:	Notched bars over 0.125" thick. V-notch, 60 <sup>o</sup> flank angle
Cyclic Speed:	167 CPS

\*See Reference list for complete identification of reference documents.

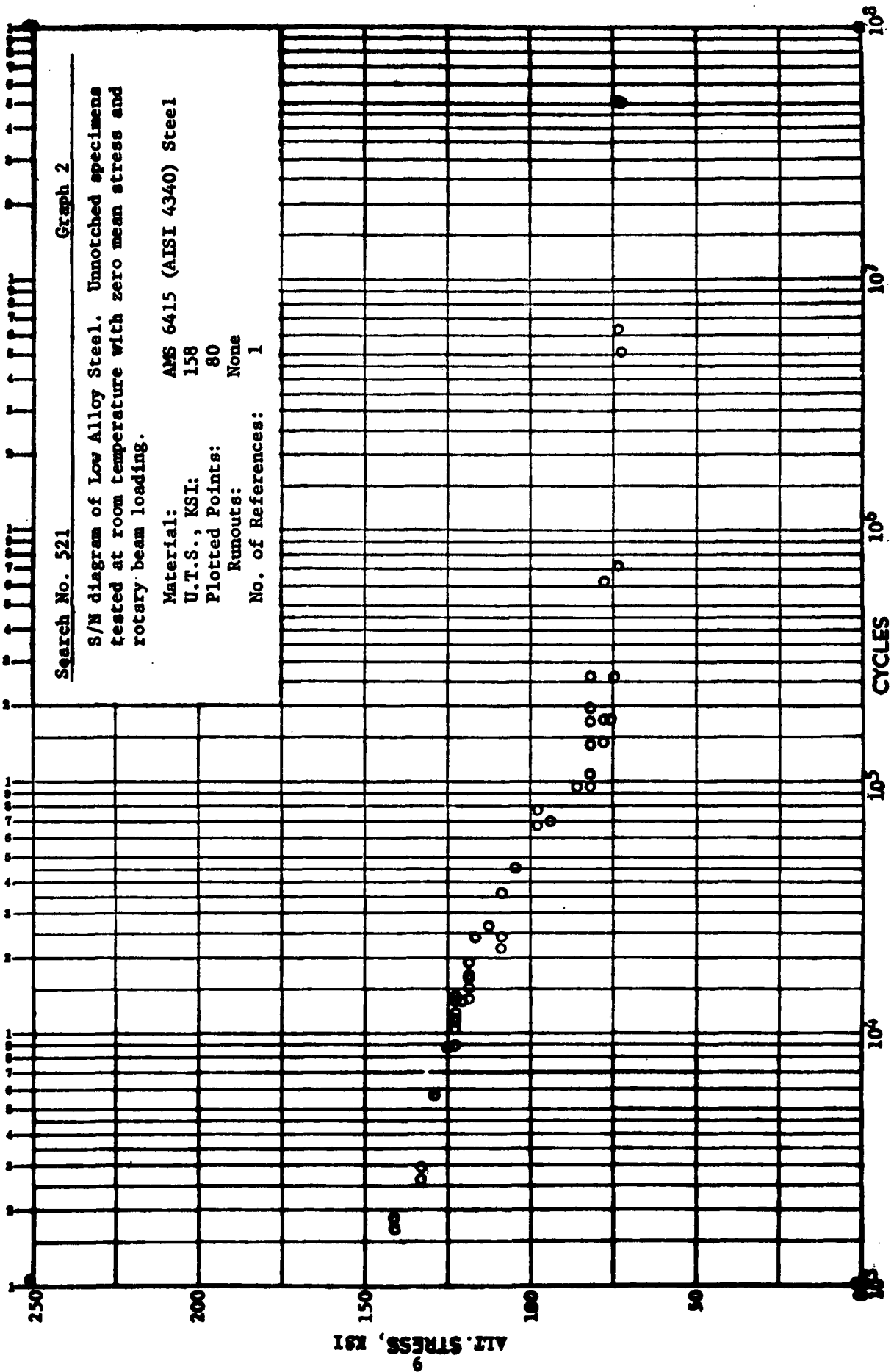
# AUTOMATIC DATA ANALYSIS

Search No. 521

Graph 2

S/N diagram of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material: AMS 6415 (AISI 4340) Steel  
 U.T.S., KSI: 158  
 Plotted Points: 80  
 Runouts: None  
 No. of References: 1



SUMMARY DATA SHEET  
METALS FATIGUE TESTS

Search 521

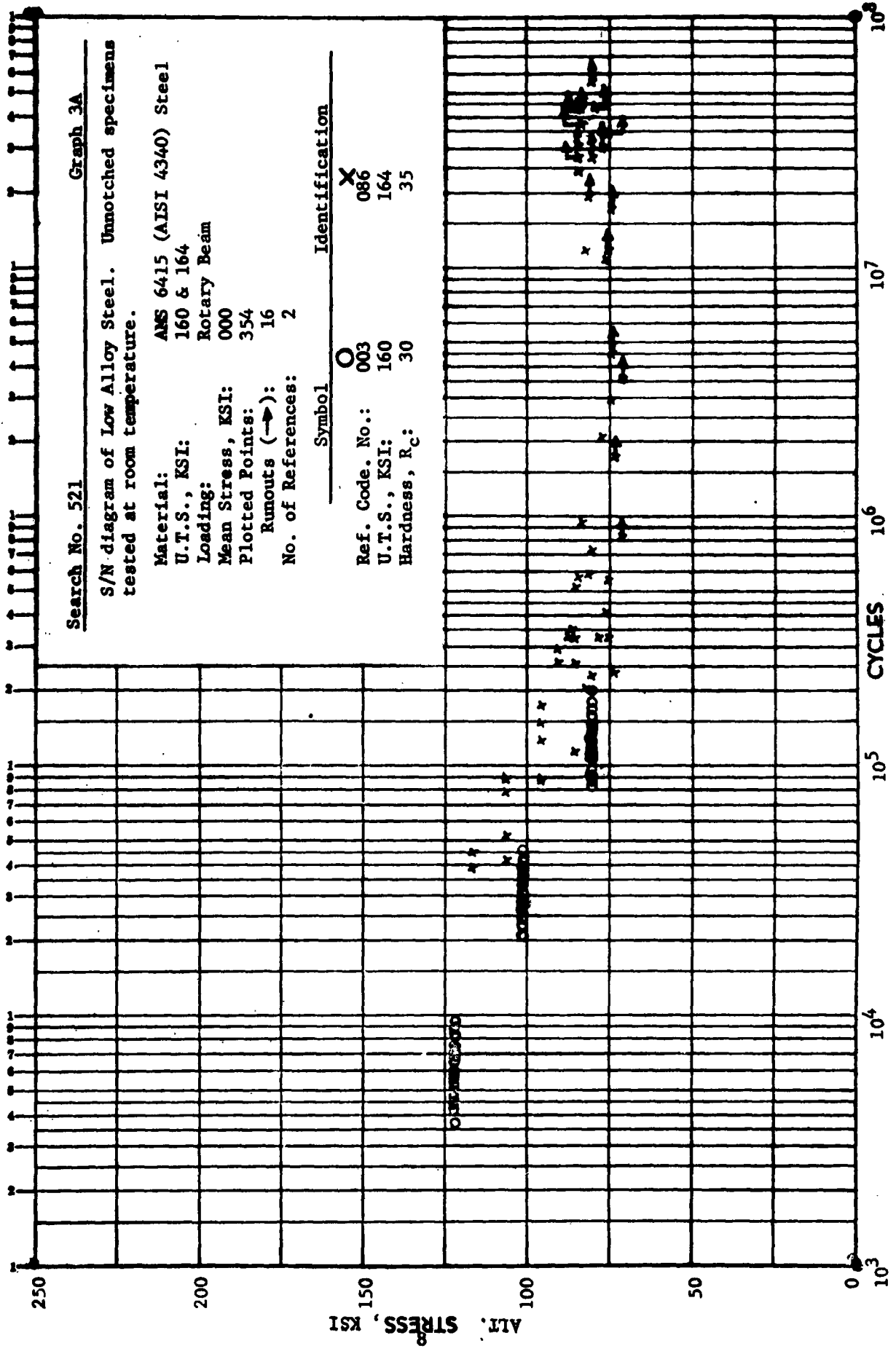
Graph 2

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Reference Code Nos.:	* 030
Material:	AMS 6415 (AISI 4340) Steel
Melting Practice:	Not Recorded
Heat Treatment:	Normalized 1600 <sup>o</sup> F, 2 Hrs. Austenitized 1500 <sup>o</sup> F, 2 Hrs. Tempered 1150 <sup>o</sup> F, 4 Hrs. and Not Recorded
Yield Strength, KSI:	138
Elongation:	Not Recorded
Hardness:	R <sub>c</sub> 30
Surface Condition:	Longitudinal Polishing
Surface Finish:	4 Microinch
Primary Fabrication:	Hot Rolled
Secondary Operation:	Lathe Turned
Specimen Type:	Unnotched bars over 0.125" thick
Cyclic Speed, CPS:	57.5

\*See Reference list for complete identification of reference documents.

# AUTOMATIC DATA ANALYSIS



Search No. 521

Graph 3A

S/N diagram of Low Alloy Steel. Unnotched specimens tested at room temperature.

Material: **AMS 6415 (AISI 4340) Steel**  
 U.T.S., KSI: **160 & 164**  
 Loading: **Rotary Beam**  
 Mean Stress, KSI: **000**  
 Plotted Points: **354**  
 Runouts (→): **16**  
 No. of References: **2**

Symbol Identification

Ref. Code No.:	<b>003</b>	<b>O</b>	<b>X</b>
U.T.S., KSI:	<b>160</b>		<b>164</b>
Hardness, R <sub>C</sub> :	<b>30</b>		<b>35</b>

SUMMARY DATA SHEET  
METALS FATIGUE TESTS

Search No. 521

Graph 3A

Reference Code Nos.:	* 003 & 086
Material:	AMS 6415 (AISI 4340) Steel
Surface Condition:	Longitudinal Polishing
Surface Finish:	Not Recorded
Primary Fabrication:	Hot Rolled
Secondary Operation:	Lathe Turned
Specimen Type:	Unnotched Bars over 0.125" thick

Additional Symbol Identification

	○	×
Melting Practice:	Electric Furnace	Not Recorded
Heat Treatment:	Austenitized 1525 <sup>o</sup> F, O.Q. Tempered 1010 <sup>o</sup> F, 1 Hr.	Not Recorded
Elongation:	Not Recorded	16%, 2" Gage
Yield Strength, KSI:	138	156
Cyclic Speed, CPS:	33 & 167	63.3

\*See Reference list for complete identification of reference documents.

# AUTOMATIC DATA ANALYSIS

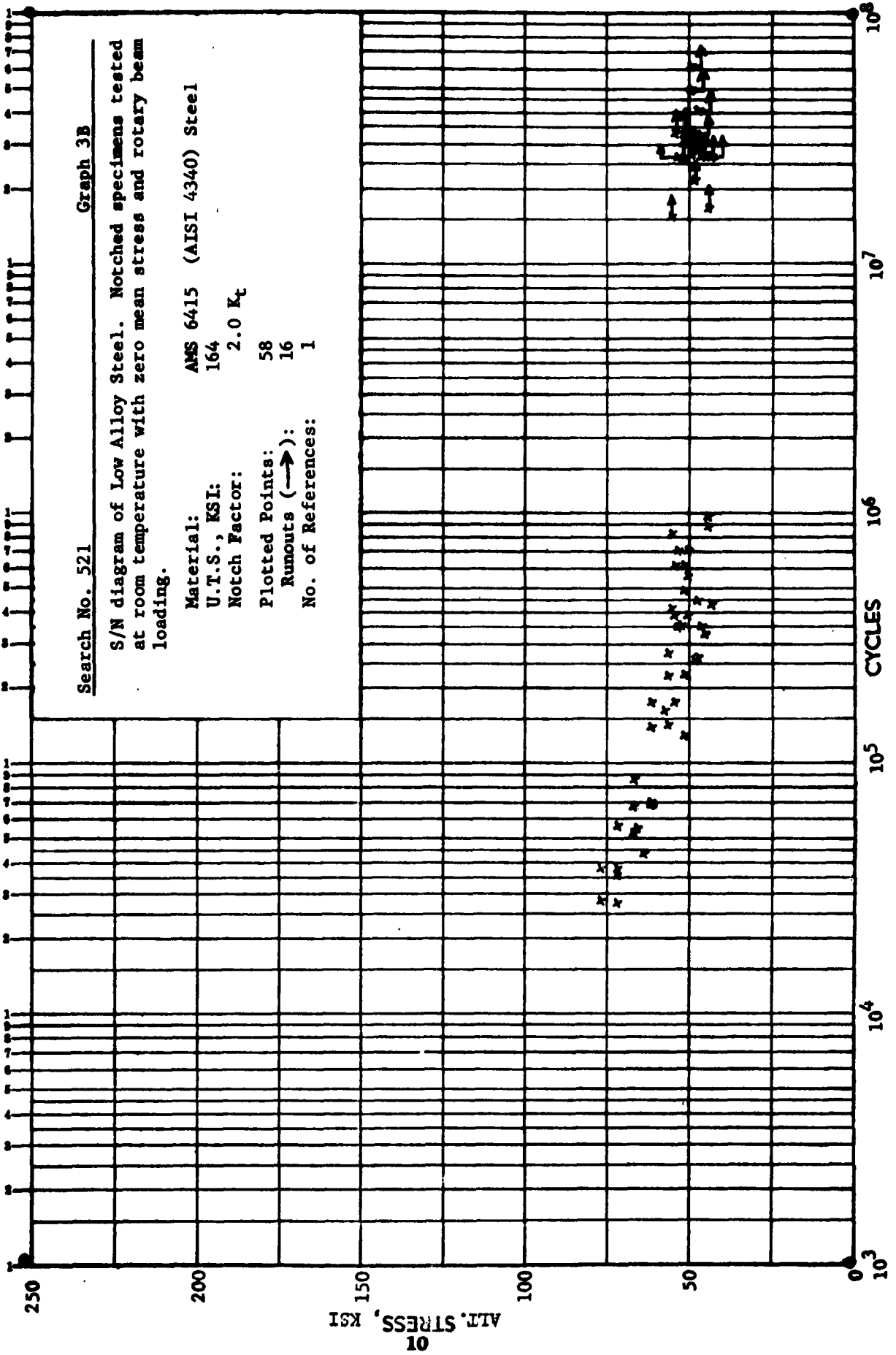
Search No. 521

Graph 3B

S/N diagram of Low Alloy Steel. Notched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material: AMS 6415 (AISI 4340) Steel  
U.T.S., KSI: 164  
Notch Factor: 2.0  $K_t$

Plotted Points: 58  
Runouts (→): 16  
No. of References: 1



SUMMARY DATA SHEET  
METALS FATIGUE TESTS

Search No. 521

Graph 3B

---

Reference Code Nos.:	* 086
Material:	AMS 6415 (AISI 4340) Steel
Melting Practice:	Electric Furnace
Heat Treatment:	Austenitized 1525 <sup>o</sup> F, OQ Tempered 1010 <sup>o</sup> F, 1 Hr.
Yield Strength, KSI:	156
Elongation:	16%, 2" Gage
Hardness:	R <sub>c</sub> 35
Surface Condition:	Longitudinal Polishing
Surface Finish:	Not Recorded
Primary Fabrication:	Hot Rolled
Secondary Operation:	Lathe Turned
Specimen Type:	Notched bars over 0.125" thick. Circular notch, flank angle 0 <sup>o</sup>
Cyclic Speed, CPS:	135 & 163

\*See Reference list for complete identification of reference documents.

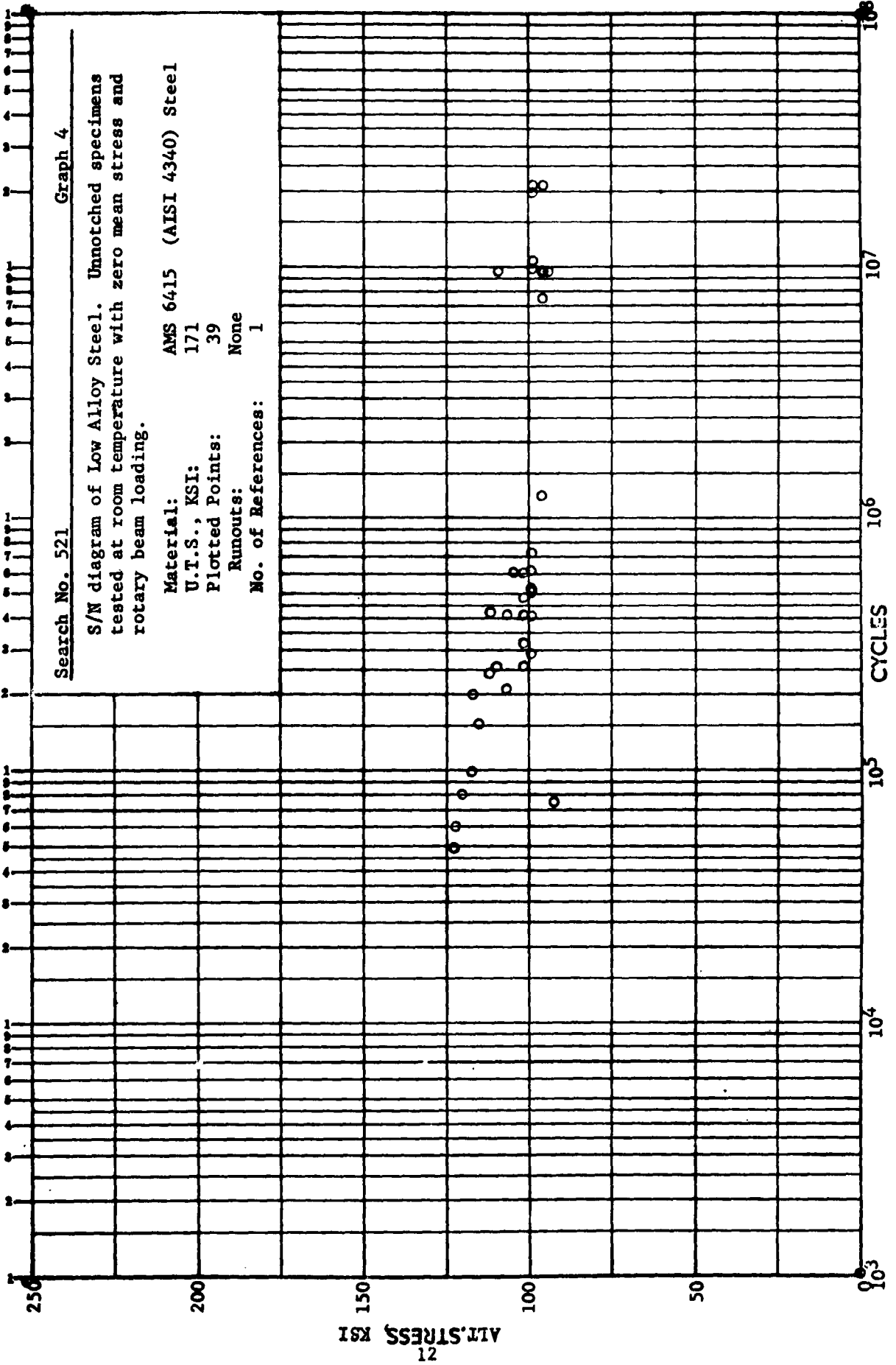
# AUTOMATIC DATA ANALYSIS

Search No. 521

Graph 4

S/N diagram of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material: AMS 6415 (AISI 4340) Steel  
U.T.S., KSI: 171  
Plotted Points: 39  
Runouts: None  
No. of References: 1



SUMMARY DATA SHEET  
METALS FATIGUE TESTS

Search No. 521

Graph 4

---

Reference Code Nos.:	* 095
Material:	AMS 6415 (AISI 4340) Steel
Melting Practice:	Electric Furnace
Heat Treatment:	Normalized - 1600 <sup>o</sup> F, 1 Hr.
Elongation:	15%, Gage Length not specified
Hardness:	Not Recorded
Surface Condition:	Longitudinal Polishing
Surface Finish:	Not Recorded
Primary Fabrication:	Hot Rolled
Secondary Operation:	Machined (no details)
Specimen Type:	Unnotched Bars over 0.125" thick
Cyclic Speed, CPS:	125

\*See Reference list for complete identification of reference documents.

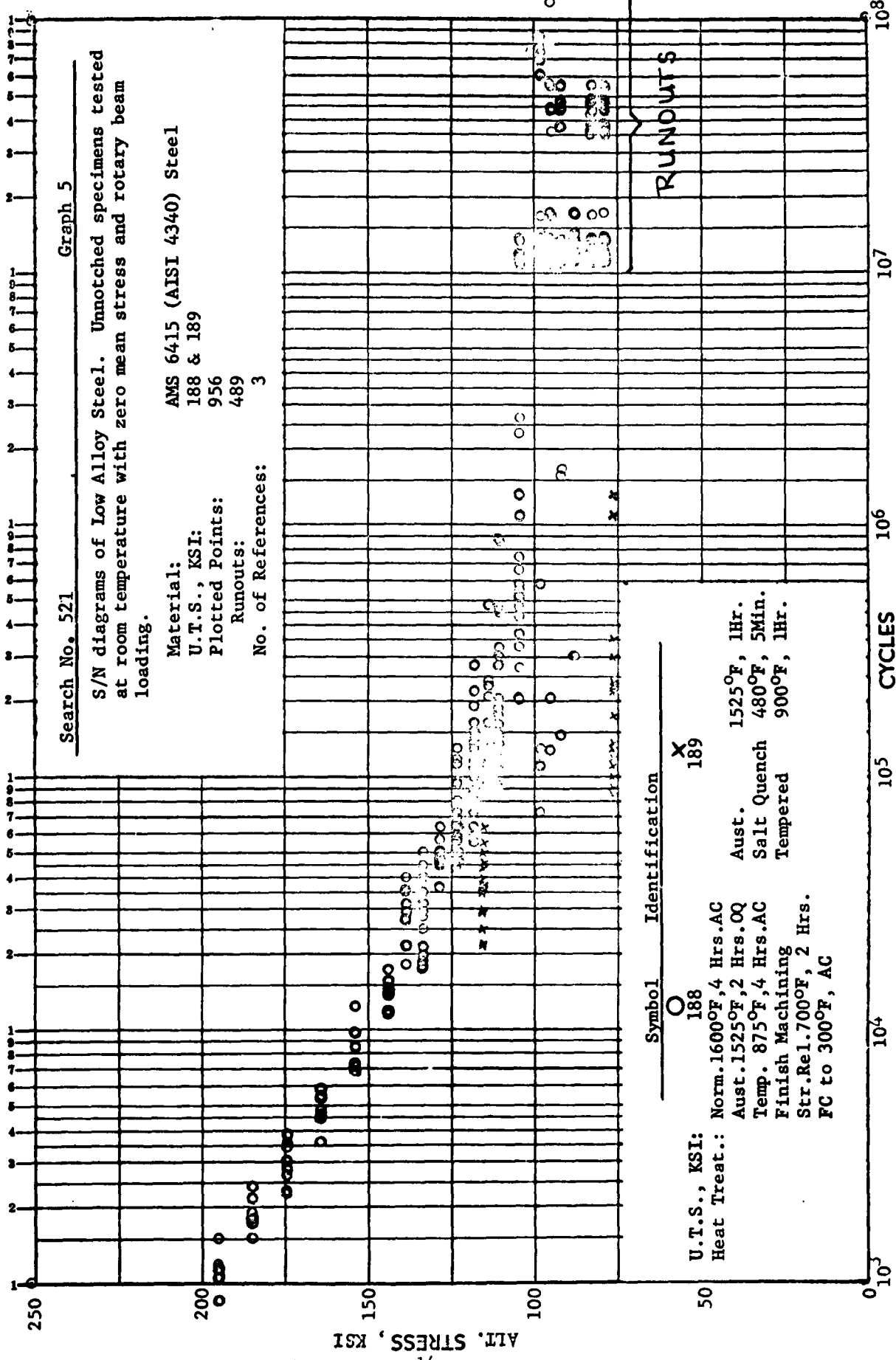
# AUTOMATIC DATA ANALYSIS

Search No. 521

Graph 5

S/N diagrams of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material: AMS 6415 (AISI 4340) Steel  
 U.T.S., KSI: 188 & 189  
 Plotted Points: 956  
 Runouts: 489  
 No. of References: 3



Symbol Identification

O	188	U.T.S., KSI:	188
X	189	Heat Treat.:	Norm. 1600°F, 4 Hrs. AC
			Aust. 1525°F, 2 Hrs. OQ
			Temp. 875°F, 4 Hrs. AC
			Finish Machining
			Str. Rel. 700°F, 2 Hrs.
			FC to 300°F, AC
			Aust. 1525°F, 1Hr.
			Salt Quench 480°F, 5Min.
			Tempered 900°F, 1Hr.

SUMMARY DATA SHEET

METALS FATIGUE TESTS

Search No. 521

Graph 5

Material: AMS 6415 (AISI 4340) Steel  
 Specimen Type: Unnotched bars over 0.125" thick

Additional Symbol Identification

	○	×
Reference Code Nos.:	087 & 098	060
Melting Practice:	Vacuum Furnace	Not Recorded
Yield Strength, KSI:	170 & 172	Not Recorded
Elongation:	14%, 2" Gage	Not Recorded
Hardness:	R <sub>c</sub> 37	Not Recorded
Surface Condition:	Mechanical Polish	Mech. Polish-Electroplated
Surface Finish:	1 & 5 Microinch	10 Microinch or Not Recorded
Primary Fabrication:	Hot Rolled or Not Recorded	Not Recorded
Secondary Operation:	Lathe Turned or Not Recorded	Mech. Polish-Ni Cd Plated
Cyclic Speed, CPS:	2 & 183	167

\*See Reference list for complete identification of reference documents.

# AUTOMATIC DATA ANALYSIS

Search No. 521

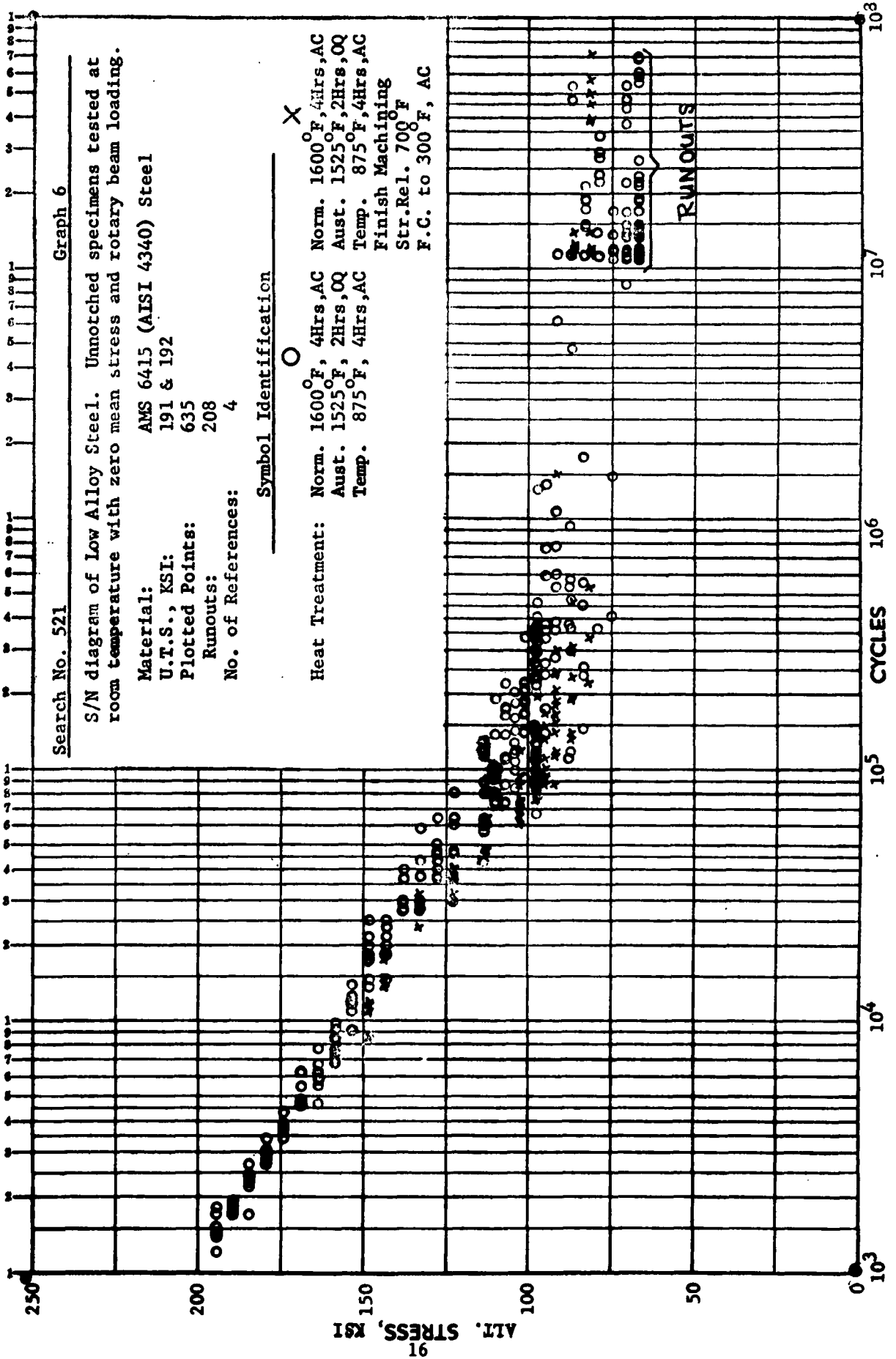
Graph 6

S/N diagram of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material: AMS 6415 (AISI 4340) Steel  
 U.T.S., KSI: 191 & 192  
 Plotted Points: 635  
 Runouts: 208  
 No. of References: 4

Symbol Identification

○	Heat Treatment: Norm. 1600° F, 4Hrs, AC
×	Aust. 1525° F, 2Hrs, OQ
×	Temp. 875° F, 4Hrs, AC
○	Norm. 1600° F, 4Hrs, AC
×	Aust. 1525° F, 2Hrs, OQ
×	Temp. 875° F, 4Hrs, AC
○	Finish Machining
×	Str.Rel. 700° F
×	F.C. to 300 F, AC



SUMMARY DATA SHEET  
METALS FATIGUE TESTS

Search No. 521

Graph 6

Material: AMS 6415 (AISI 4340) Steel  
Specimen Type: Unnotched bars 0.125" thick

Additional Symbol Identification

	○	×
Reference Code Nos.:	001 & 117	67 & 98
Melting Practice:	Electric Furnace	Electric Furnace or Not Recorded
Yield Strength, KSI:	184	180 & 184
Elongation:	15%, 2" Gage	15%, 2" Gage
Hardness:	R <sub>c</sub> 40, 41	R <sub>c</sub> 40 or Not Recorded
Surface Condition:	Mechanical Polish	Mech.Pol. or Not Recorded
Surface Finish:	5 Microinch	5 Microinch
Primary Fabrication:	Hot Rolled	Extruded or Hot Rolled
Secondary Operation:	Ground or Mech.Pol.	Lathe Turned or Not Rec.
Cyclic Speed, CPS:	167 & 184	183 & 200

\*See Reference list for complete identification of reference documents.

# AUTOMATIC DATA ANALYSIS

Search No. 521

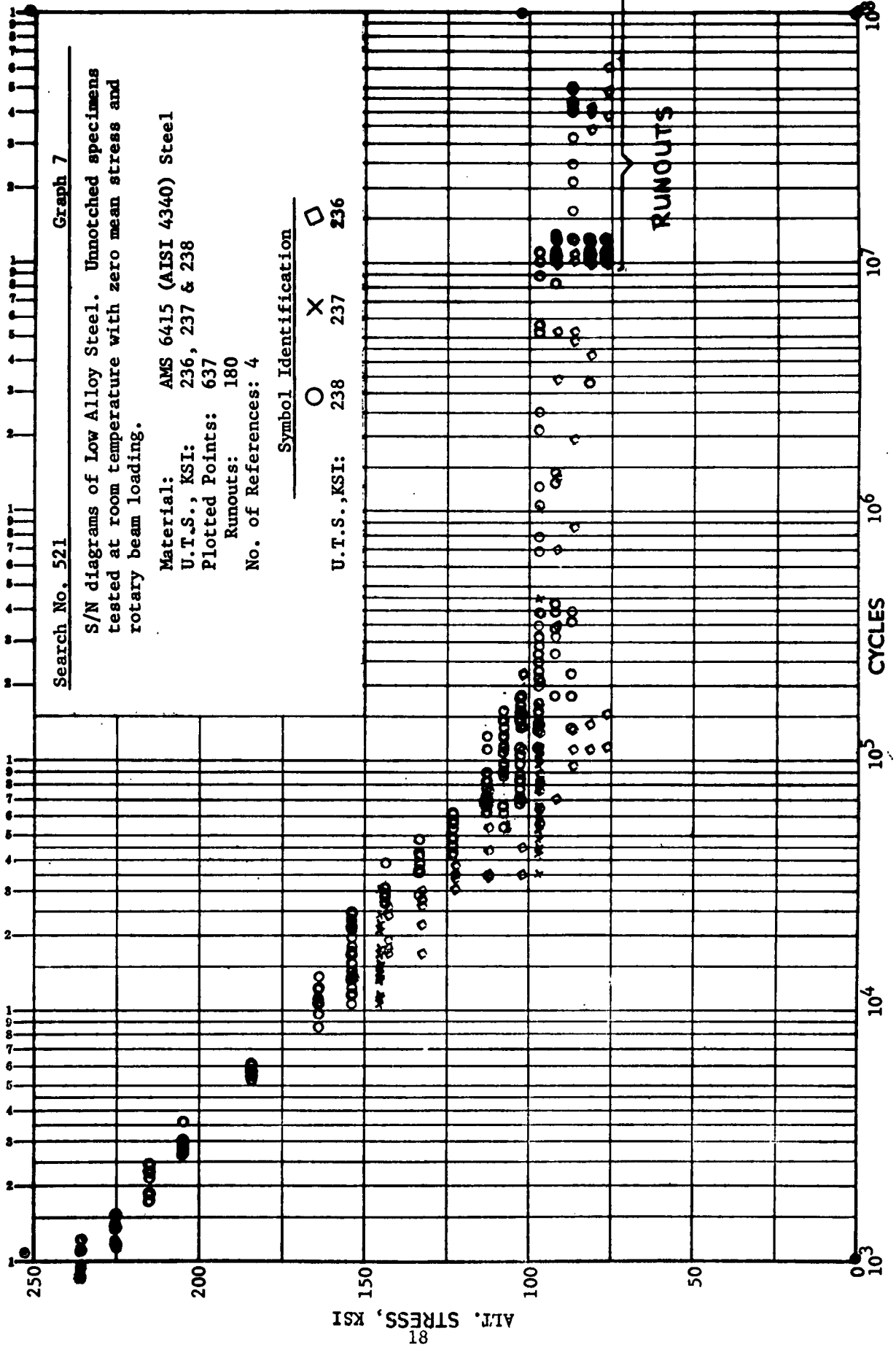
Graph 7

S/N diagrams of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material: AMS 6415 (AISI 4340) Steel  
 U.T.S., KSI: 236, 237 & 238  
 Plotted Points: 637  
 Runouts: 180  
 No. of References: 4

Symbol Identification

○	X	□
U.T.S., KSI: 238	237	236



SUMMARY DATA SHEET  
METALS FATIGUE TESTS

Search No. 521

Graph 7

Material: AMS 6415 (AISI 4340) Steel  
Specimen Type: Unnotched bars over 0.125" thick

Symbol Identification

	○	×	◇
Reference Code Nos.:	* 087 & 098	060	067
Melting Practice:	Elec. Furnace or Not Recorded	Not Recorded	Not Recorded
Heat Treatment:	Norm. 1600°F, 2Hrs. AC Aust. 1525°F, 1.5Hr. OQ Temp. 650°F, 4Hrs. AC Finish Machining Str. Rel. 500°F, 4Hrs.	Aust. 1525°F, 1Hr. Salt Q. 480°F, 5Min. Temp. 700°F, 1Hr.	Norm. 1600°F, 4Hrs. Aust. 1525°F, 2Hrs. OQ Temp. 650°F, 4Hrs. Str. Rel. 550°F FC to 400°F, AC
Yield Strength, KSI:	230 or 233	Not Recorded	212
Elongation:	11% or 12%, 2" Gage	Not Recorded	9%, 2" Gage
Hardness:	R <sub>c</sub> 42 or 49	Not Recorded	Not Recorded
Surface Condition:	Mechanical Polish	Mech. Polish- Electroplated	Mech. Polish
Surface Finish:	1 & 5 Microinch	10 Microinch	5 Microinch
Primary Fabrication:	Hot Rolled or Not Recorded	Not Recorded	Forged
Secondary Operation:	Lathe Turned or Not Recorded	Mech. Pol. & Plated	Not Recorded

\*See Reference list for complete identification of reference documents.

# AUTOMATIC DATA ANALYSIS

Search No. 521

Graph 8

S/N diagram of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

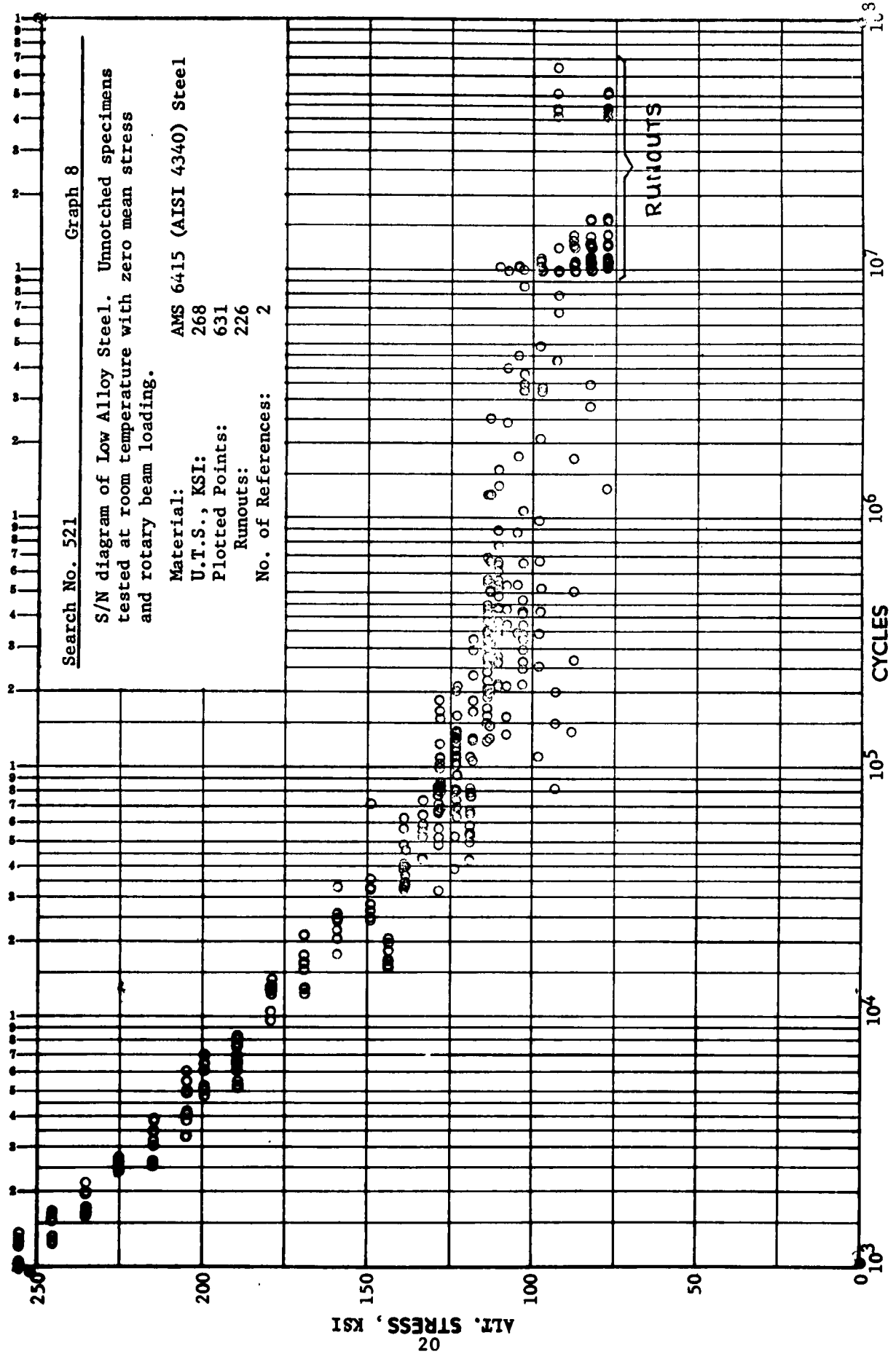
Material: AMS 6415 (AISI 4340) Steel

U.T.S., KSI: 268

Plotted Points: 631

Runouts: 226

No. of References: 2



SUMMARY DATA SHEET  
METALS FATIGUE TESTS

Search 521

Graph 8

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Reference Code Nos.:	* 001 & 117
Material:	AMS 6415 (AISI 4340) Steel
Melting Practice:	Electric Furnace
Heat Treatment:	Norm. 1600 <sup>o</sup> F, 4 Hrs. AC Aust. 1475 <sup>o</sup> F, 4 Hrs. OQ Stab. 450 <sup>o</sup> F, 8 Hrs. AC Temp. 250 <sup>o</sup> F, 24 Hrs. AC
Yield Strength:	250 KSI
Elongation:	11%, gage length not specified
Hardness:	R <sub>C</sub> 53 & 56
Surface Condition:	Longitudinal Polishing
Surface Finish:	5 Microinch
Primary Fabrication:	Hot Rolled
Secondary Operation:	Ground Surface
Specimen Type:	Unnotched bars over 0.125" thick
Cyclic Speed, CPS:	2.1, 167, 184

\*See Reference list for complete identification of reference documents.

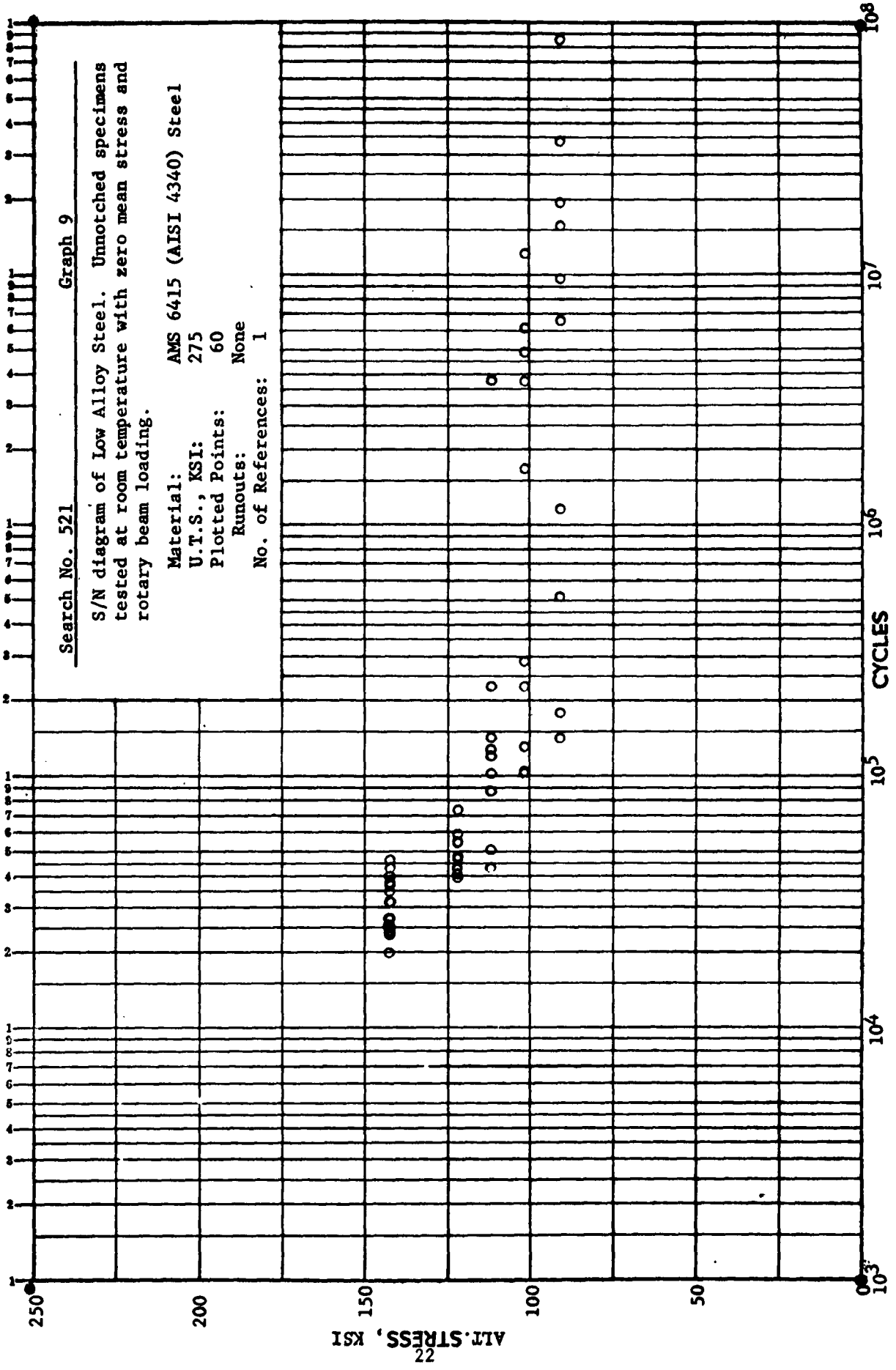
# AUTOMATIC DATA ANALYSIS

Search No. 521

Graph 9

S/N diagram of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material: AMS 6415 (AISI 4340) Steel  
 U.T.S., KSI: 275  
 Plotted Points: 60  
 Runouts: None  
 No. of References: 1



SUMMARY DATA SHEET  
METALS FATIGUE TESTS

Search No. 521

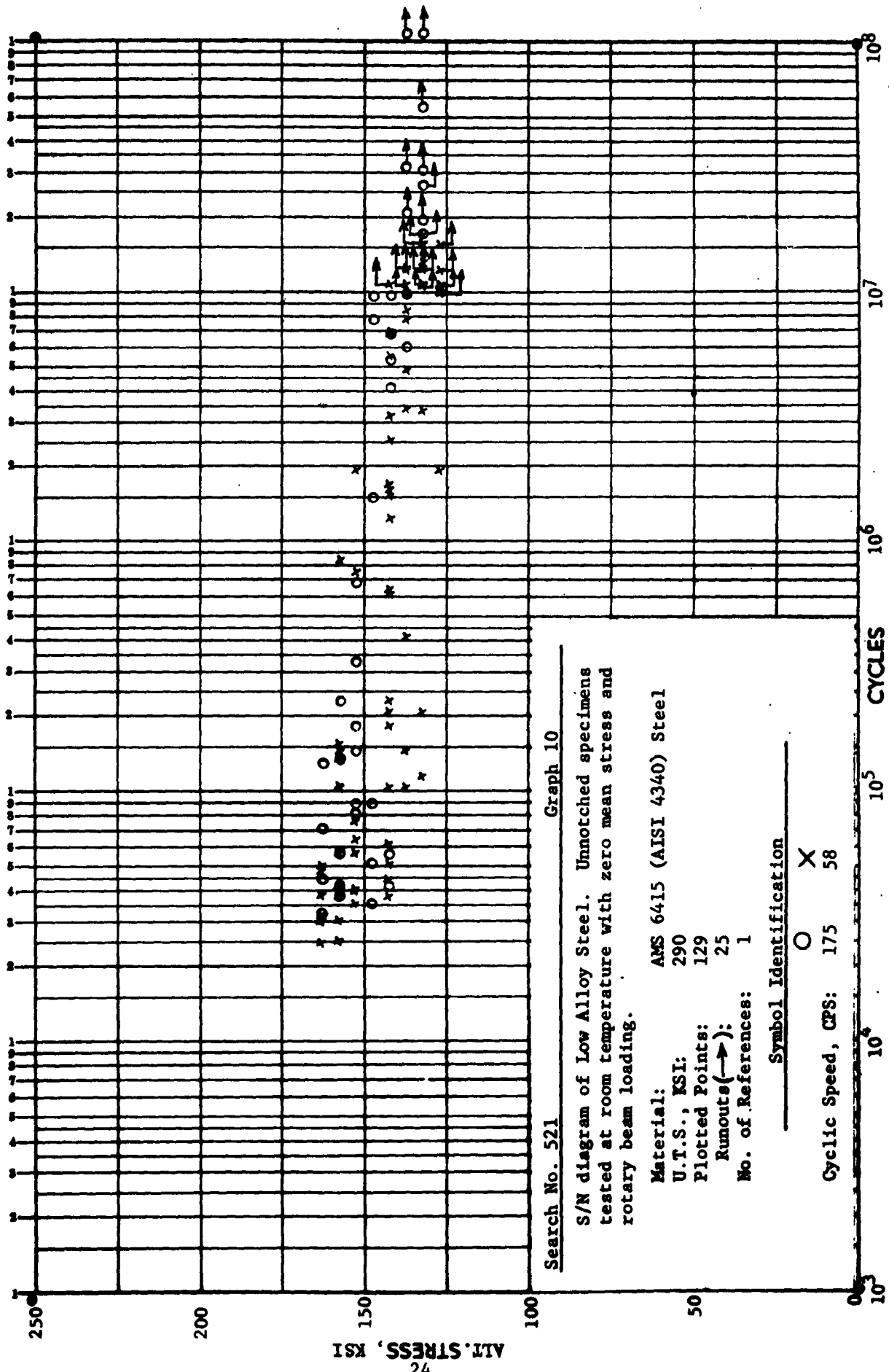
Graph 9

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Reference Code Nos.:	* 041
Material:	AMS 6415 (AISI 4340) Steel
Melting Practice:	Electric Furnace
Heat Treatment:	Austenitized 1550 <sup>o</sup> F, Salt Bath 20 Min. OQ at 120 <sup>o</sup> F to 150 <sup>o</sup> F Tempered 400 F, 4 Hrs.
Yield Strength; KSI:	Not Recorded
Elongation:	14%, 2" Gage
Hardness:	R <sub>c</sub> 50
Surface Condition:	Mechanical Polishing
Surface Finish:	3 Microinch
Primary Fabrication:	Forged
Secondary Operation:	All Surface Ground
Specimen Type:	Unnotched Bars over 0.125" thick
Cyclic Speed, CPS:	58

\*See Reference list for complete identification of reference documents.

# AUTOMATIC DATA ANALYSIS



Search No. 521

Graph 10

S/N diagram of Low Alloy Steel. Unnotched specimens tested at room temperature with zero mean stress and rotary beam loading.

Material: AMS 6415 (AISI 4340) Steel  
 U.T.S., KSI: 290  
 Plotted Points: 129  
 Runouts(→): 25  
 No. of References: 1

Symbol Identification

O X

Cyclic Speed, CPS: 175 58

SUMMARY DATA SHEET  
METALS FATIGUE TESTS

Search No. 521

Graph 10

---

Reference Code Nos.:	* 041
Material:	AMS 6415 (AISI 4340) Steel
Melting Practice:	Vacuum Furnace
Heat Treatment:	Austenitized 1550 <sup>o</sup> F, Salt Bath 20 Min. OQ at 120 <sup>o</sup> F to 150 <sup>o</sup> F Tempered 400 <sup>o</sup> F, 4 Hrs.
Yield Strength, KSI:	Not Recorded
Elongation:	Not Recorded
Hardness:	R <sub>c</sub> 51
Surface Condition:	Mechanical Polishing
Surface Finish:	3 Microinch
Primary Fabrication:	Forged
Secondary Operation:	All Surfaces Ground, Mechanical Polish
Specimen Type:	Unnotched bars over 0.125" thick

\*See Reference list for complete identification of reference documents.

REFERENCES ----- SEARCH NO. 521

<u>Reference Code Number</u>	<u>Reference</u>
001	Cummings, H.N., Stulen, F.B., and Schulte, W.C., "Investigation of Materials, Fatigue Problems Applicable to Propeller Design", WADC Technical Report 54-531 (May 1955)
003	Starkey, W.L., "Vibration Fatigue Studies", Annual Report Part I, Rept #3 on Cont.# AF 33(616)-259, The Ohio State Univ. Research Foundation.E.O. #R-591-80 SR-1e(Sept. 1953)
030	Marco, S.M., Starkey, W.L., Foster, T.G., "Fatigue Characteristics of SAE 4340 Steel; The Effects of Sequential Loading on SAE 4340 Steel", The Ohio State University, AMC Contract No. AF 33(039)-12393, Report No. 2 (Oct. 9, 1951)
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