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Review of Cryogenic Mechanical and Thermal Properties of Al-Li Alloys and Alloy 2219

September 1990

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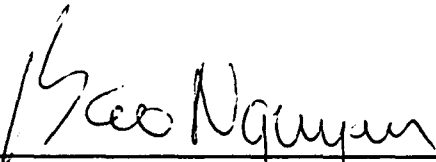
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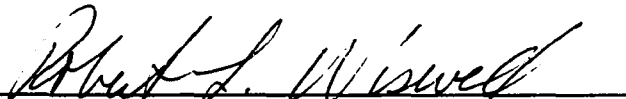
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FOREWORD

This final report was submitted by National Institute of Standards and Technology, Boulder CO on completion of contract AL 99011 with the Astronautics Laboratory (AFSC), Edwards AFB CA. AL Project Managers were Bao Nguyen and Lt Bruce Pham.

This report has been reviewed and is approved for release and distribution in accordance with the distribution statement on the cover and on the DD Form 1473.



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The review of cryogenic mechanical and thermal properties presented here is part of a broader NIST program to assess new high-strength Al-Li alloys for use in the cryogenic tankage of the Advanced Launch System. This program is sponsored by the Air Force Systems Command, Astronautics Laboratory, Edwards Air Force Base, with Bao Nguyen, Task Manager. It is part of the Materials and Process Validation (3101) of the Structures, Materials, and Manufacturing (3000) portion of the ALS Advanced Development Program. Since the purpose of the NIST program has been to assess the relative suitability of high-strength Al-Li alloys and alloy 2219 for use in ALS cryogenic tanks, data on Al-Li alloys 8090, 2090, WeldaliteTM 049, and Al alloy 2219 have been included in the survey. Properties covered in this survey are tensile strength, yield strength, elongation, fracture toughness, elastic constants, specific heat, thermal conductivity, and thermal expansion.					
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EXECUTIVE SUMMARY

The review of cryogenic mechanical and thermal properties presented here is part of a broader National Institute of Standards and Technology (NIST) program to assess new high-strength Al-Li alloys for use in the cryogenic tankage of the Advanced Launch System (ALS). This program is sponsored by the Air Force Systems Command, Astronautics Laboratory, Edwards Air Force Base, with Bao Nguyen, Task Manager. It is part of the Materials and Process Validation (3101) of the Structures, Materials, and Manufacturing (3000) portion of the ALS Advanced Development Program.

Since the purpose of the NIST program has been to assess the relative suitability of high-strength Al-Li alloys and alloy 2219 for use in ALS cryogenic tanks, data on Al-Li alloys 8090, 2090, WL049,* and Al alloy 2219 have been included in the survey. A table of alloy composition limits follows this introduction. Properties covered in this survey are tensile strength, yield strength, elongation, fracture toughness, elastic constants, specific heat, thermal conductivity, and thermal expansion.

* The WL049 alloy does not have a generic specification at this time, and is commonly termed WELDALITE 049. Trade names are furnished to identify the material adequately. Such identification does not imply recommendation or endorsements by NIST, nor does it imply that the materials identified are necessarily the best available for the purpose.

Composition Limits for Al-Li Alloys and Alloy 2219 in wt%.

Elements	ALLOY			
	8090	2090	WL049	2219
Cu	1.0-1.6	2.4-3.0	4.0-6.3	5.8-6.8
Li	2.2-2.7	1.9-2.6	1.3	--
Mg	0.6-1.3	0.25	0.4	0.02
Zr	0.04-0.16	0.08-0.15	0.14	0.10-0.25
Si	0.20	0.10	--	0.20
Fe	0.30	0.12	--	0.30
Ti	0.10	0.15	0.03	0.02-0.10
Cr	0.10	0.05	--	--
Zn	0.25	0.10	--	0.10
Ag	--	--	0.4	--
Mn	0.10	0.05	--	0.20-0.40
Others, each	0.05	0.05	--	--
Others, total	0.15	0.15	--	--
Al	Remainder	Remainder	Remainder	Remainder

1. TENSILE PROPERTIES

1.1. Introduction to Graphs

In general, only measurement sets that included cryogenic data were included in the graphs and tables. However, some ambient temperature values, such as the producers' typical values, are presented. The horizontal scale of the graphs was extended to 600 K because some cryogenic data sets also included measurements at temperatures above ambient and it was considered useful to present the additional information. When available, data are provided in the following orientations: longitudinal (L), transverse (T), 45° from the rolling direction, and through-thickness (S). The graphs show data for the T8 temper for all the alloys. Additional graphs are provided for the T3 temper for alloys 8090, WL049, and 2219, and the T6 temper for alloy WL049. The graphs are organized in descending order by temper for each alloy.

All tensile property data points shown graphically are listed and referenced in the tables following the graphs. A reference number is provided in the legend of each graph. Two formats are used in the tensile property tables: 1) data, and 2) test parameters, including further documentation. The data tables present temperature and tensile properties, including reduction of area (not presented in the graphs). This is followed by information on orientation, temper, product form and thickness, thermomechanical processing, grain size, hardness, number of tests per data point, and a reference and note number. The reference and note number (which corresponds to the reference number on the graphs) is a guide to the accompanying test parameter table. The test parameter table gives information on the strain rate during testing; specimen type, dimensions, and location; exposure time at test temperature (available chiefly for data above ambient temperature); supplier; year produced; lot number; product dimensions; and chemistry. Note that the tables are ordered by temper, starting with T8 tempers and ending with T3 or annealed (O) tempers for each orientation. Some cryogenic data is presented in the tables but not in the graphs; for example, data on the T4 temper of alloy 2090. A list of comments follows the tensile data table and the test parameter table for each alloy where necessary.

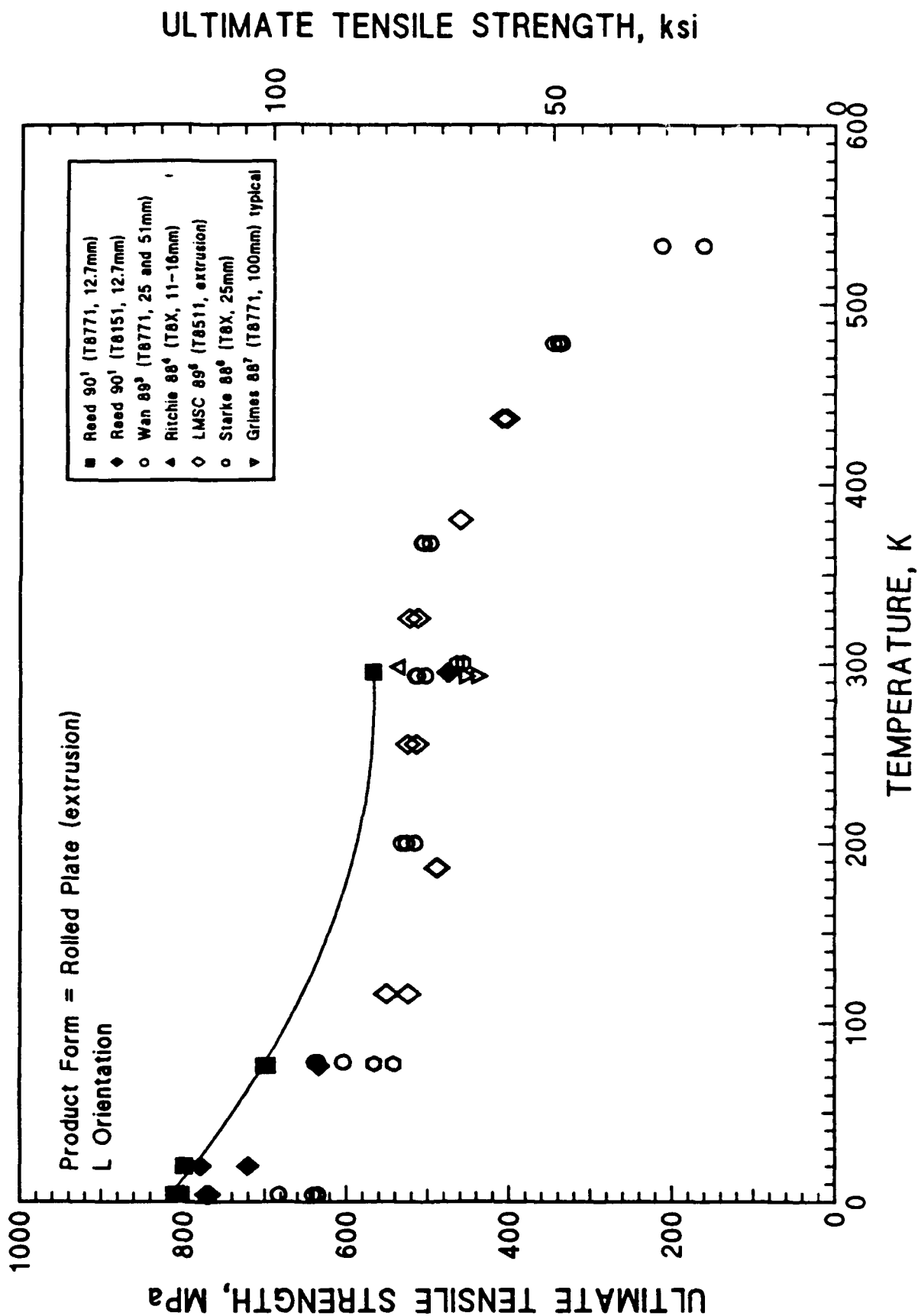
Much of the cryogenic data, especially on current production vintages and tempers, are from recent measurements at the National Institute of Standards and Technology (NIST), under sponsorship of the Advanced Launch System (ALS) program. A forthcoming report¹ includes more detailed information on measurement techniques, stress-strain curves, and microstructure. The NIST data are denoted by solid square and solid diamond symbols on the graphs. A smoothed line connects the NIST data points corresponding to tempers under consideration for use in the ALS program. The position of the line and the indicated temperature dependence generally are based on measurements made on two specimens at 4, 20, 76, and 295 K. The material in the NIST program was usually 12.7-mm (0.5-in) plate; and only ultimate tensile strength measurements were obtained from tests in the S orientation.

The four graphs of alloy 2219-T8 data in the L and T orientations for tensile yield strength and ultimate tensile strength include dashed lines. These lines, labeled MIL-HNBK-5E, were derived from curves presented in Figures 3.2.6.41(a) and (b) of that handbook² which give cryogenic values as a percentage of the room temperature value for ultimate and yield strengths.

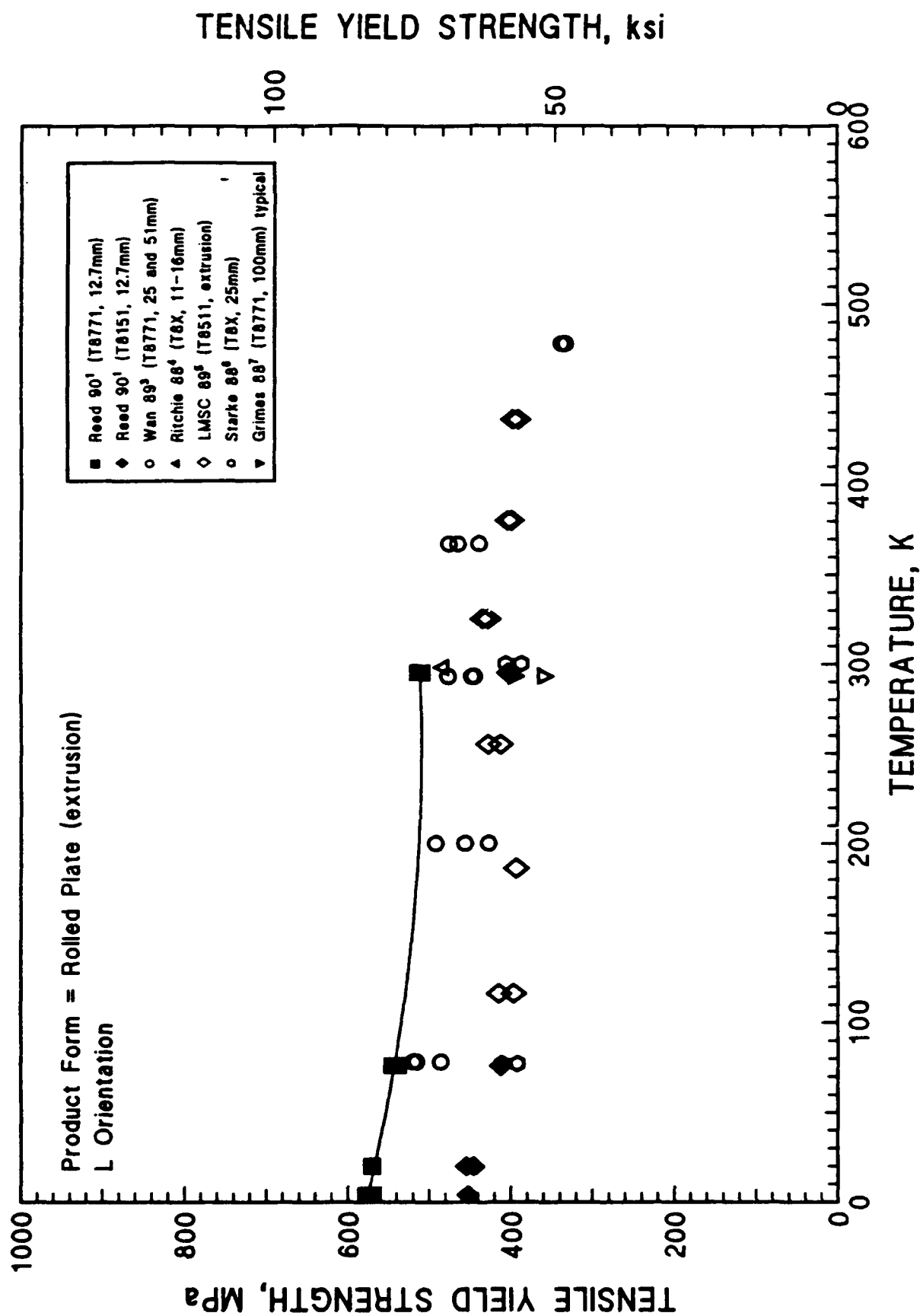
respectively. The room temperature values used to obtain the curves on our graphs for ultimate and yield strengths came from Table 3.2.6.0(b) in the MIL-HNBK-5E handbook. These values are "A basis" minimums and indicate that 99% of the data should fall on or above the curve, with a confidence level of 95%. (Please note that this information is also provided on the graphs by the asterisked footnote.)

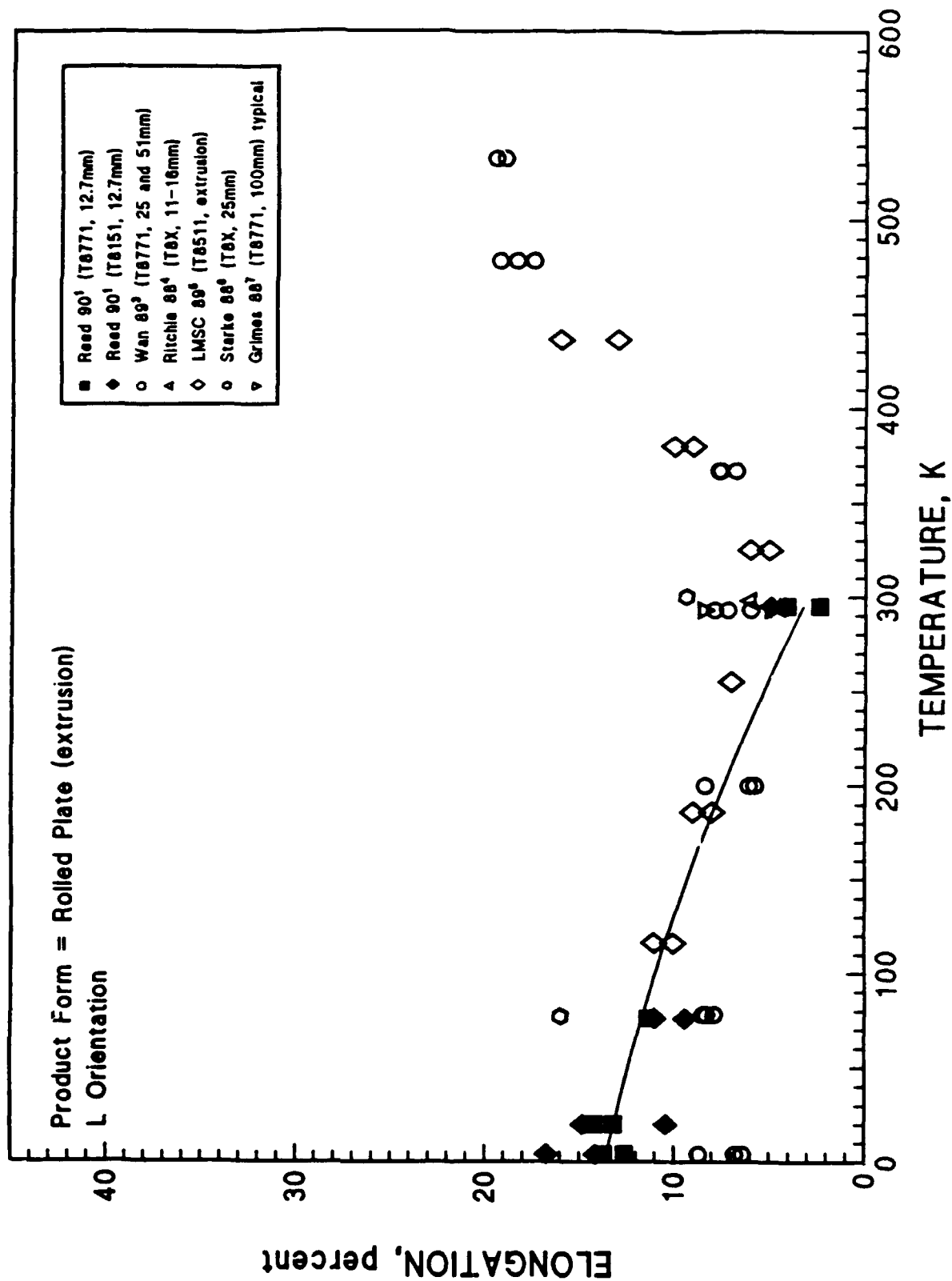
It is apparent that 99% of the cryogenic data do not fall on or above the handbook-derived minimum line for temper T87. We do not have a complete explanation for why this occurred. It is to be expected that the solid squares, temper T851, consistently would fall below the line. Very thick plate results frequently fall below the line. The "A basis" value does not pertain to plates of these thicknesses. At thicknesses of 100-125 mm the "A basis" line would fall 21 and 14 MPa lower for ultimate and yield strengths, respectively, in the T orientation. No value is provided for thicker plate in the L orientation.

8090-T8

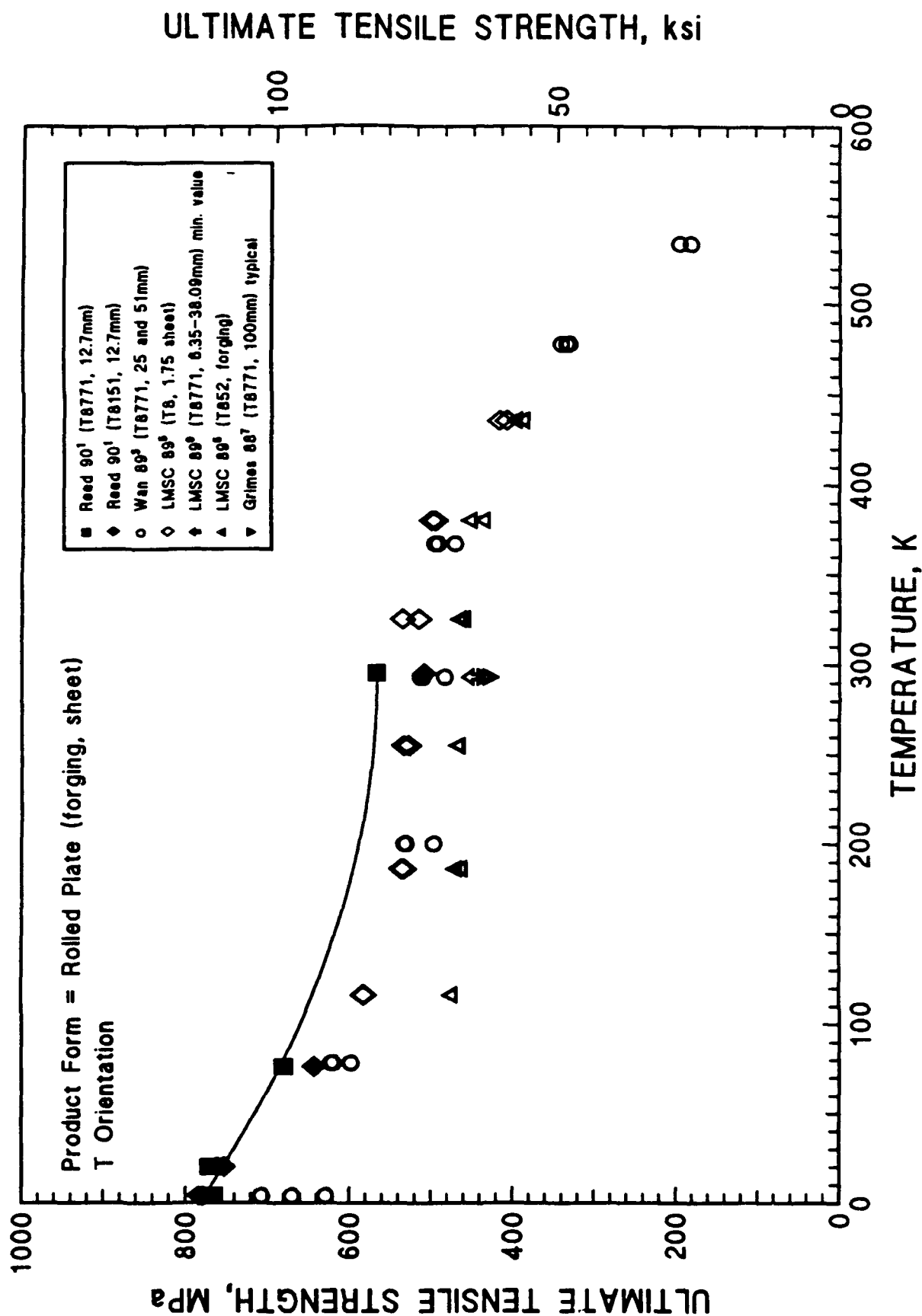


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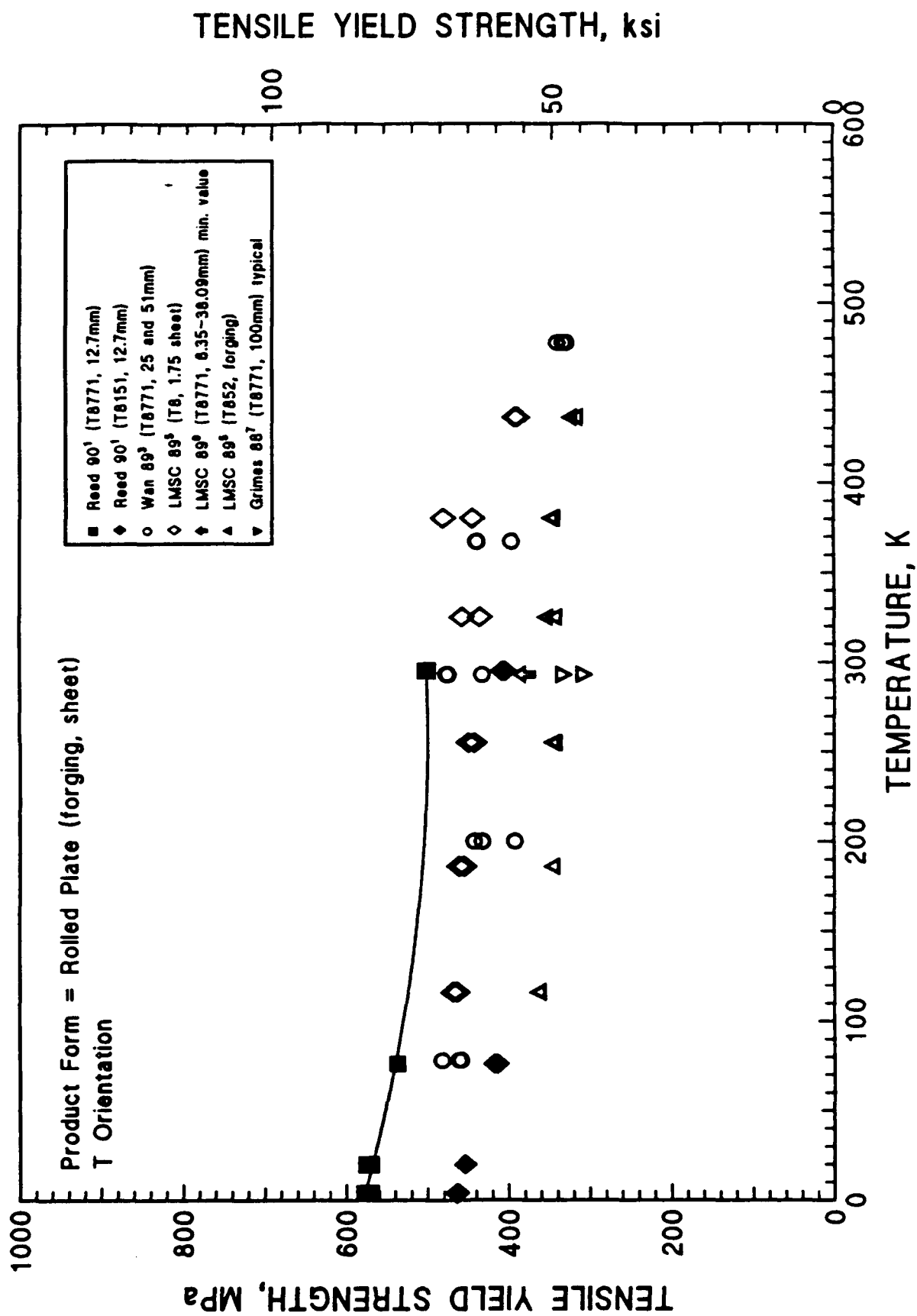


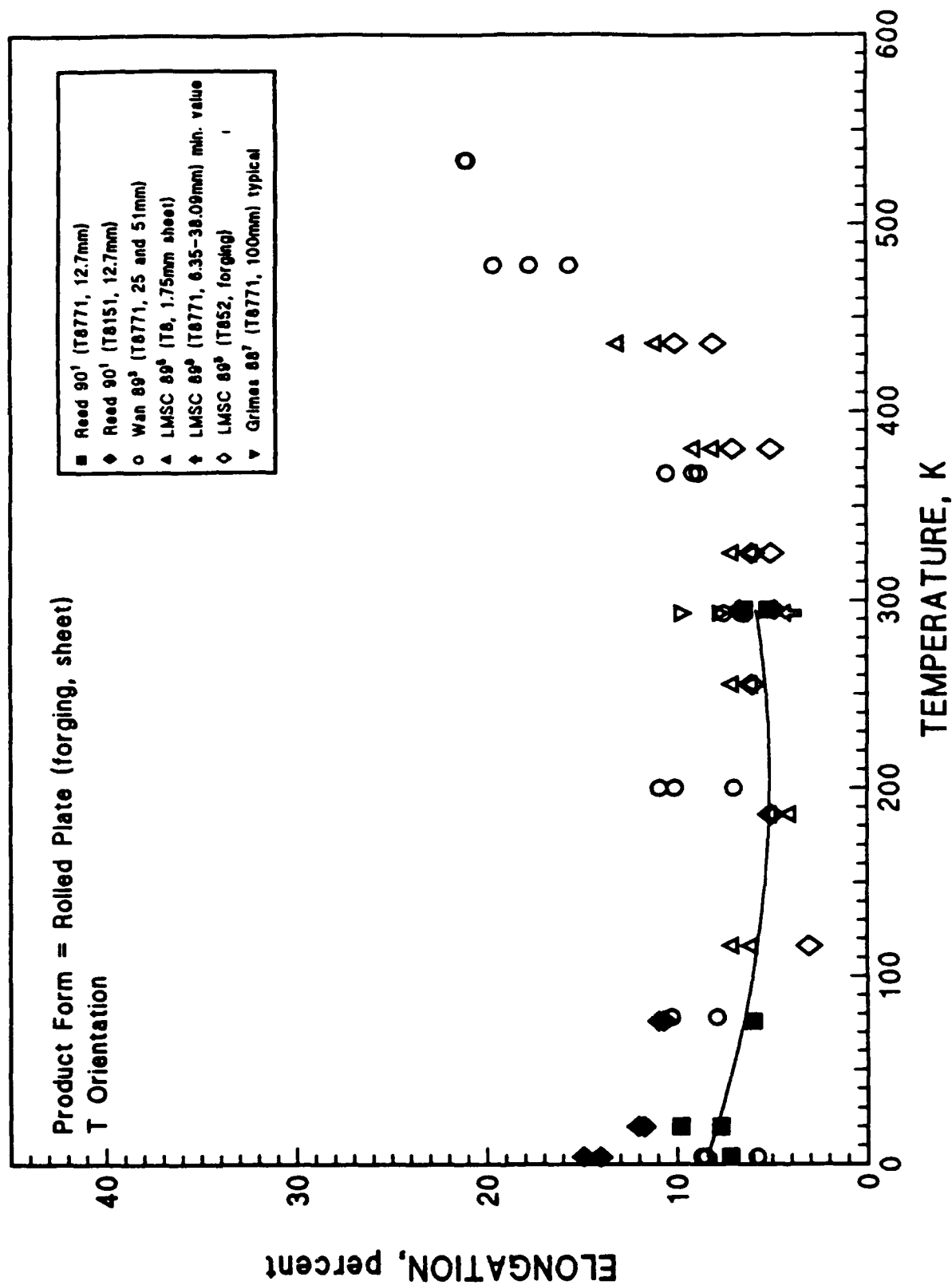


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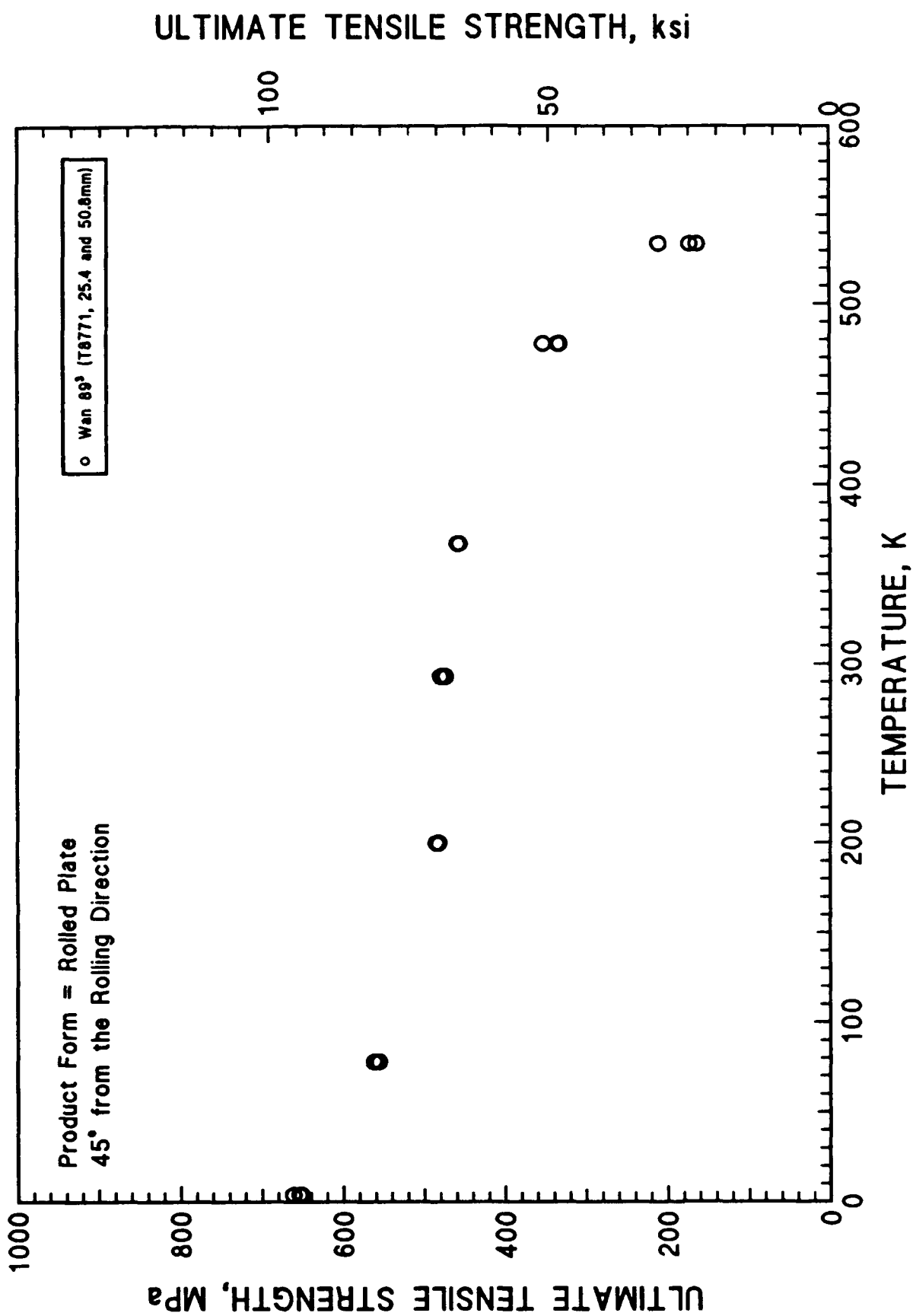


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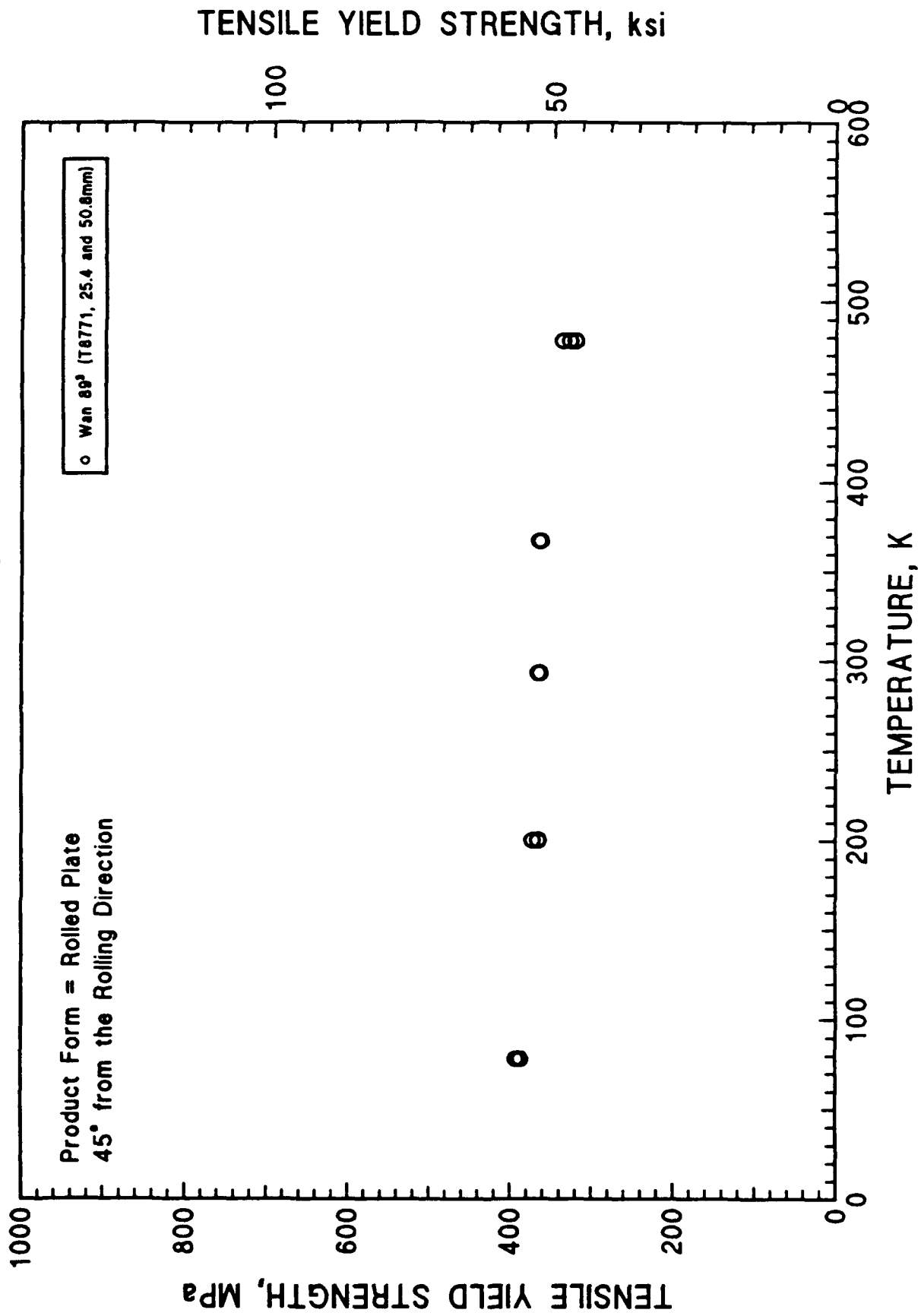




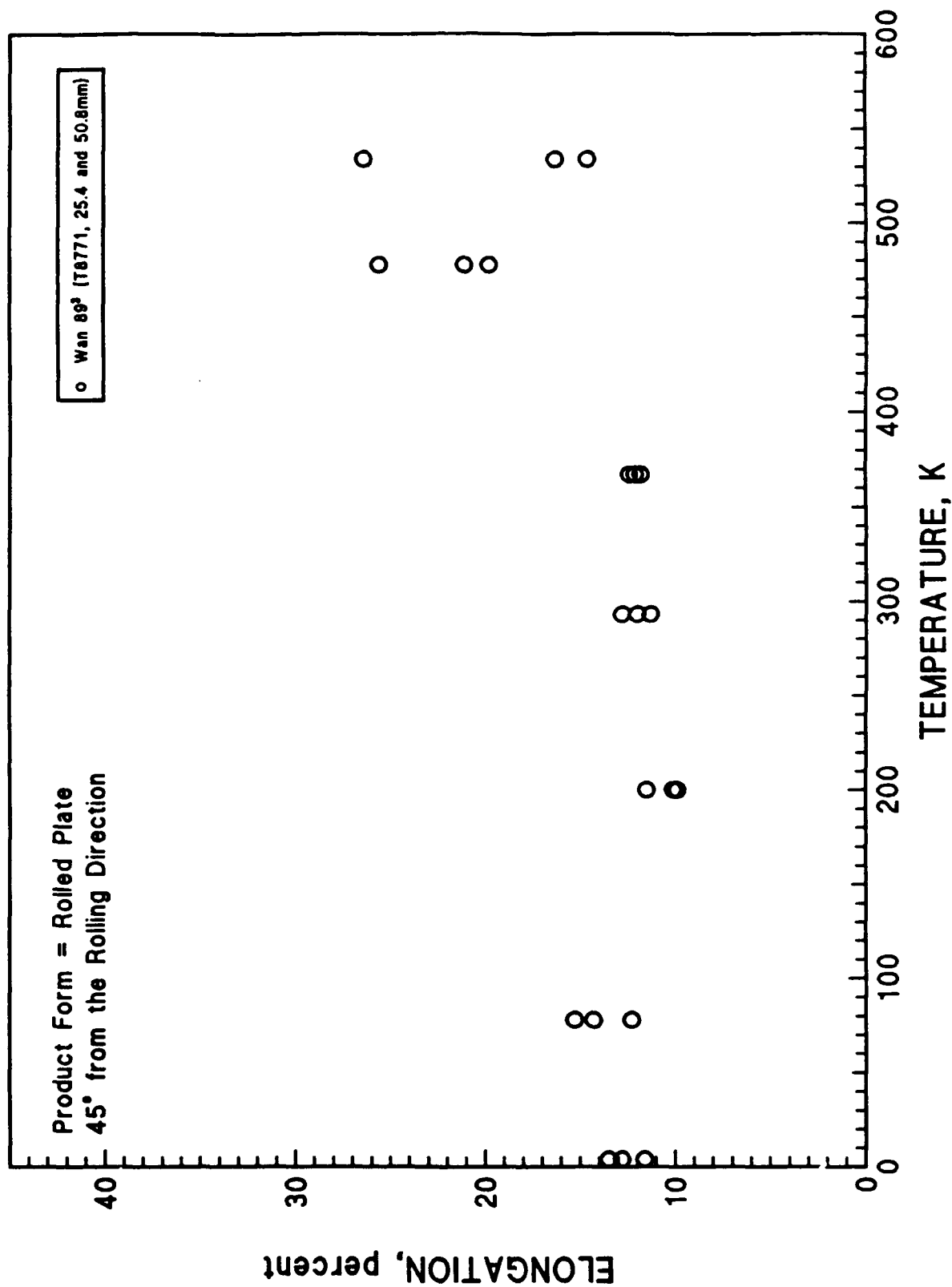
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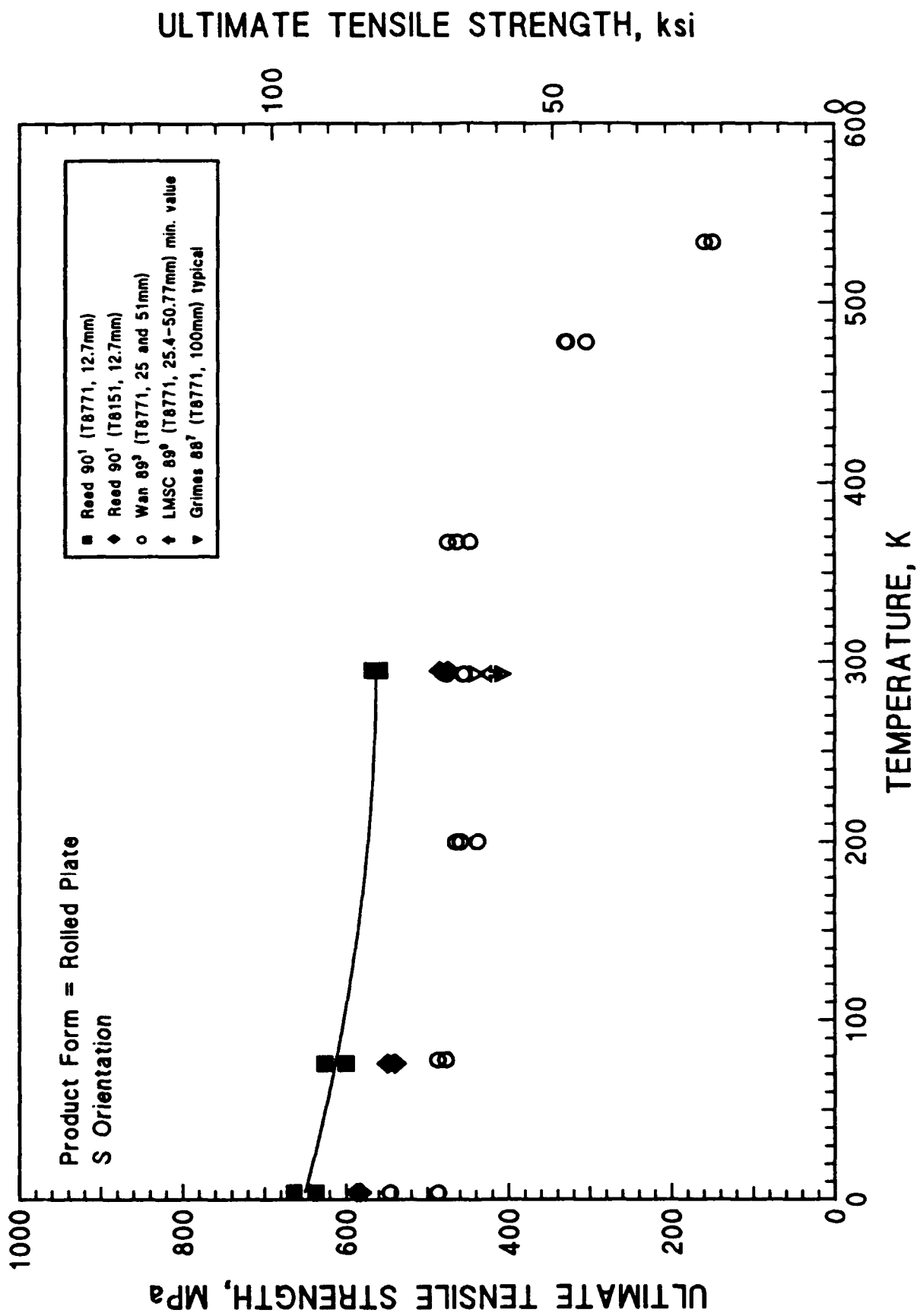
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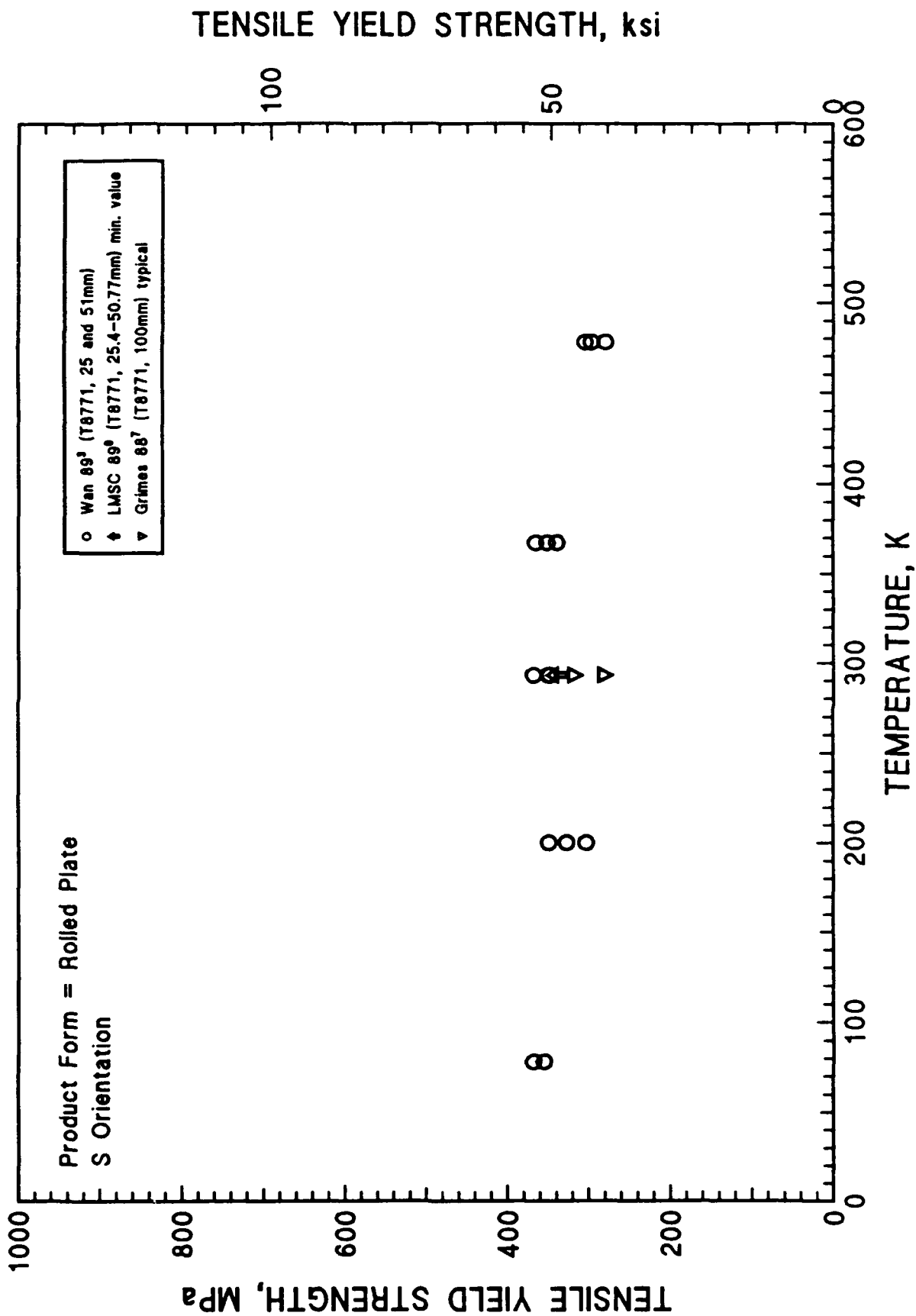
8090-T8



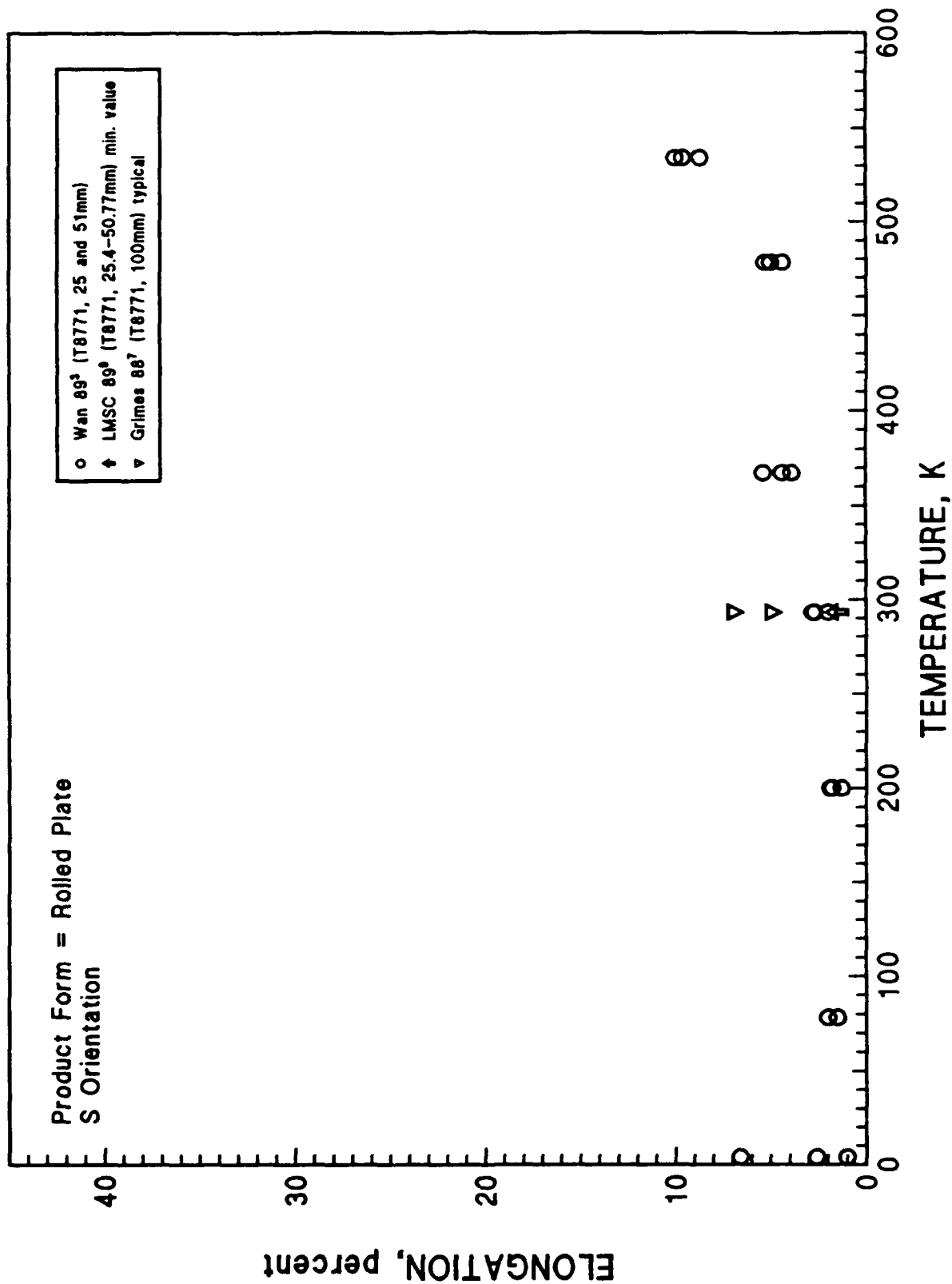
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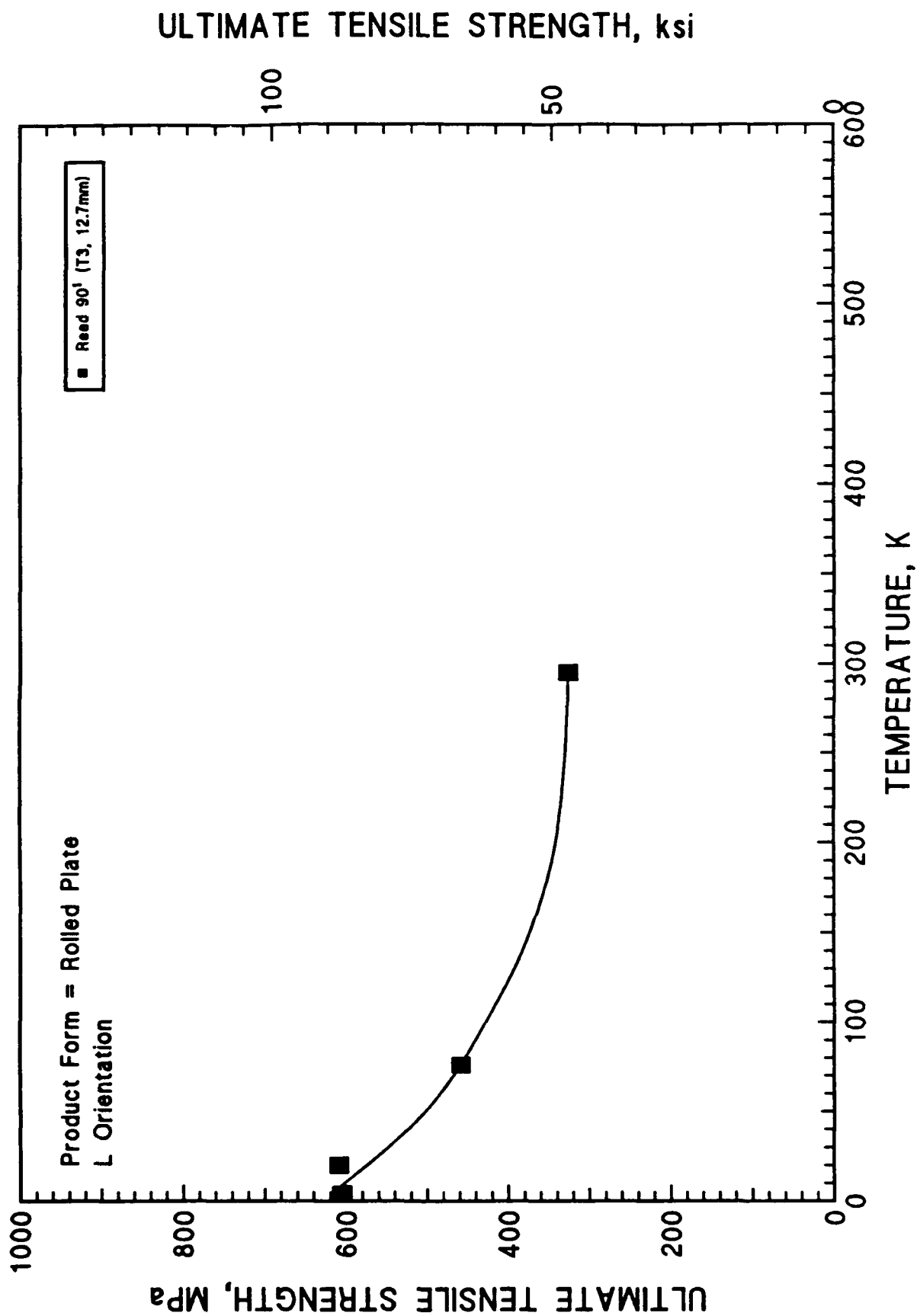
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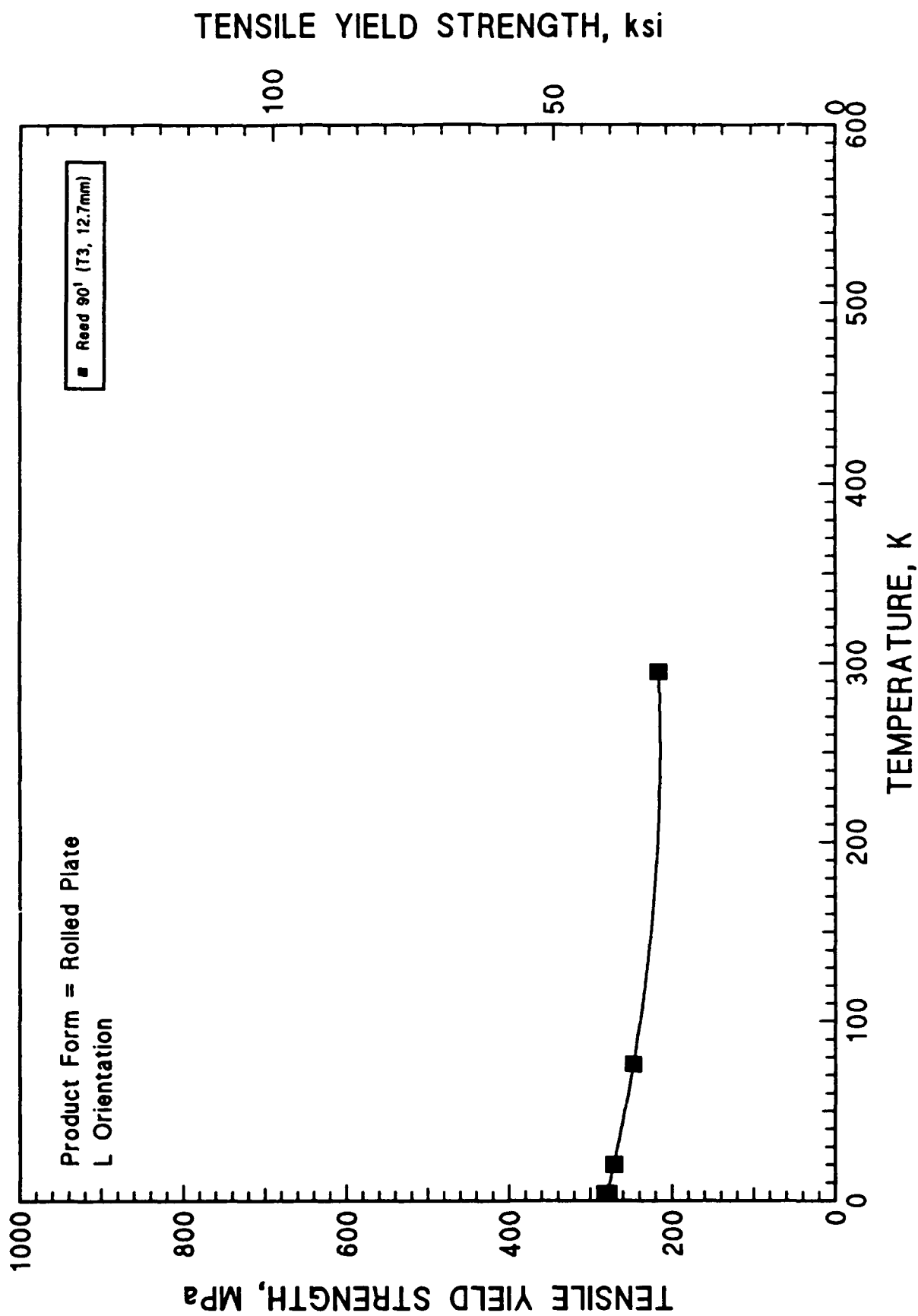
8090-T8



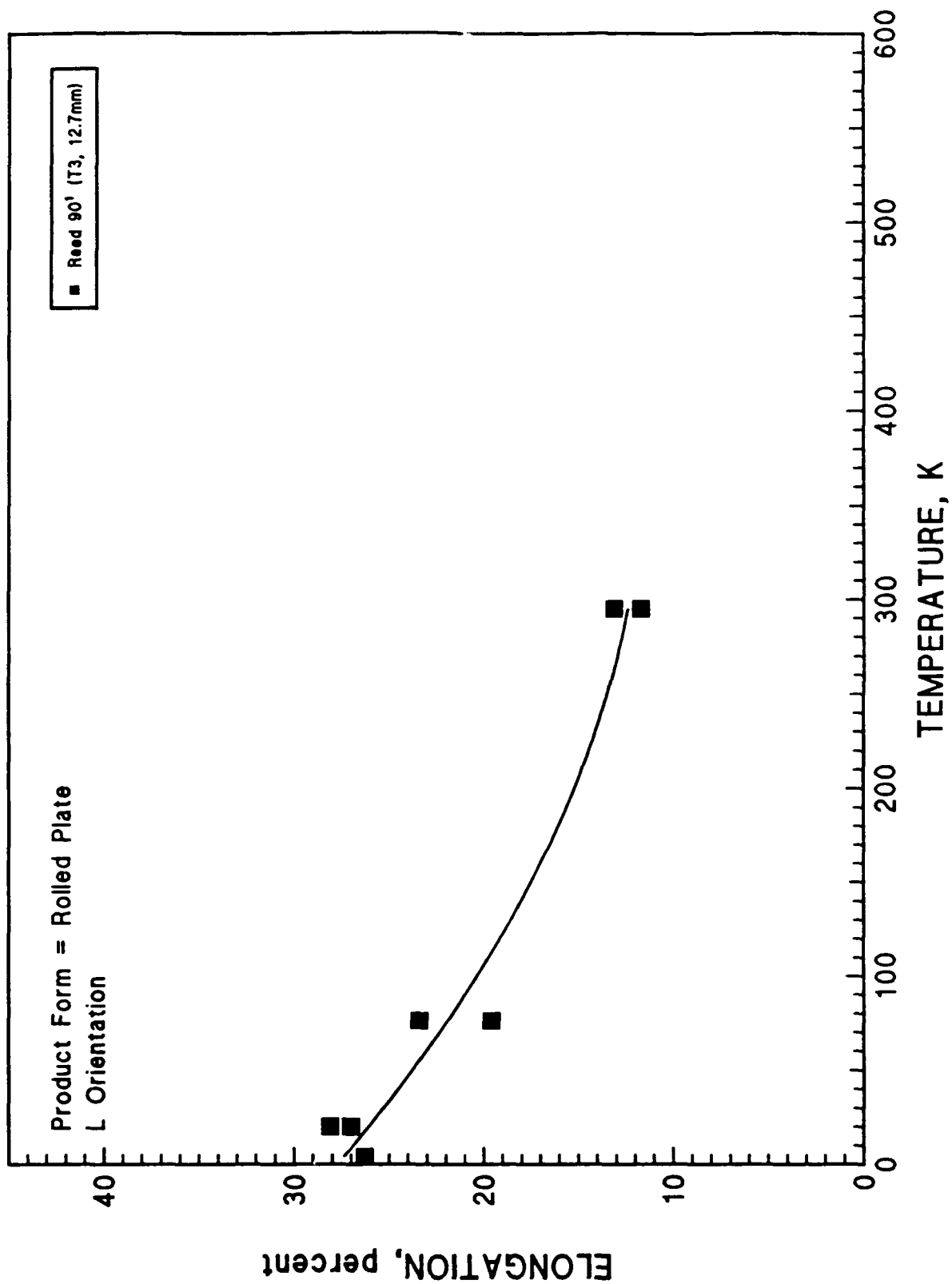
8090-T3



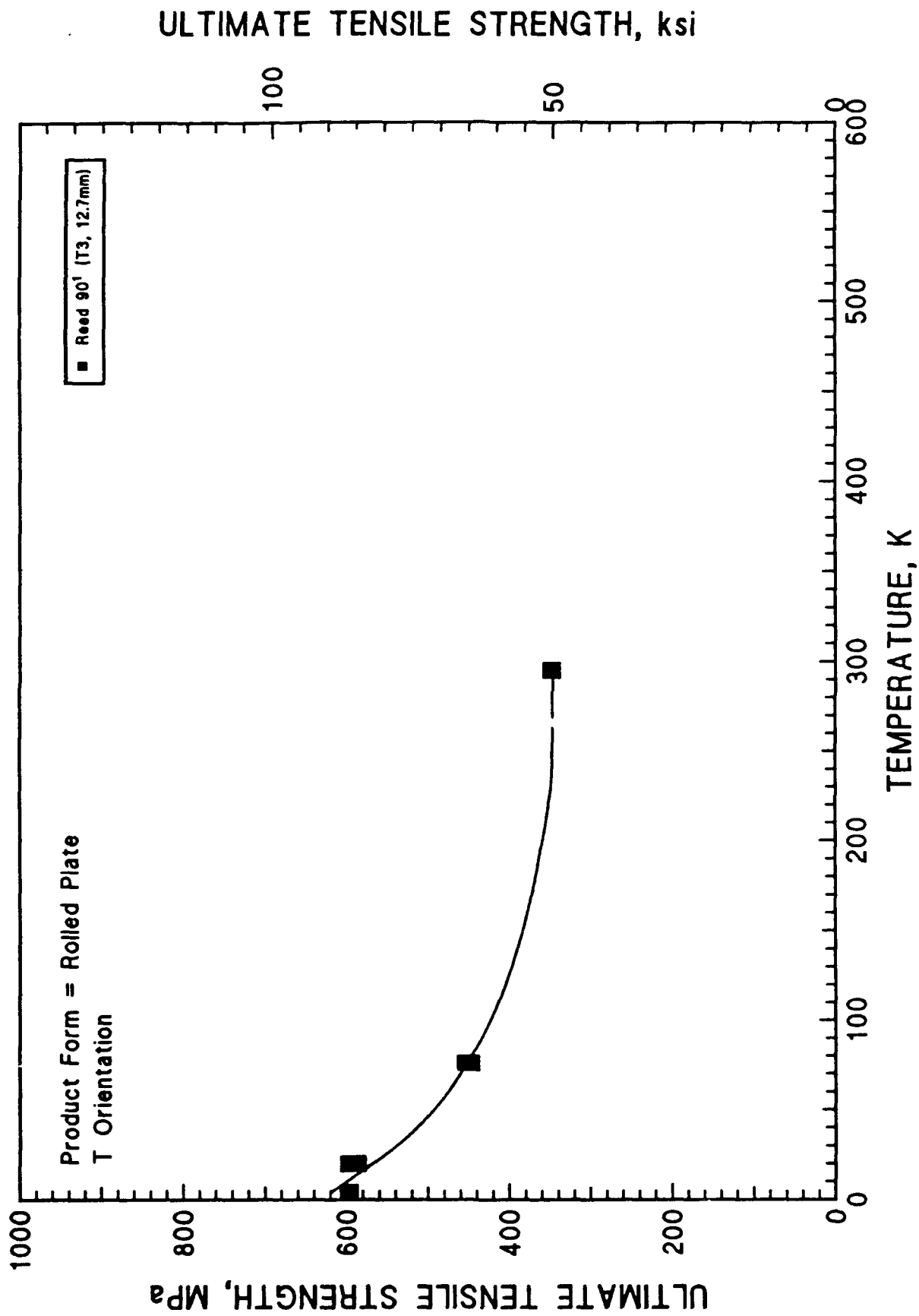
8090-T3



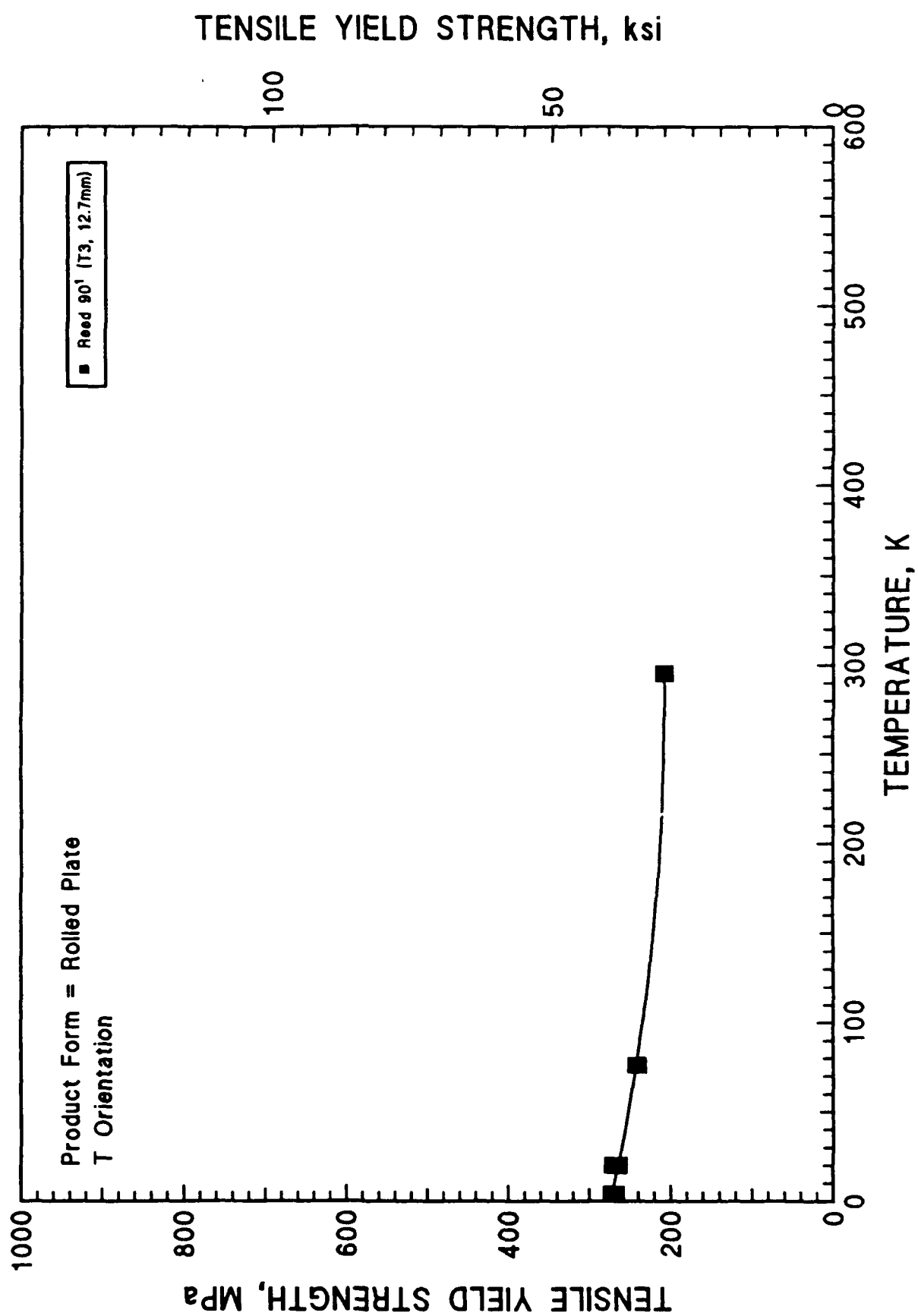
8090-T3



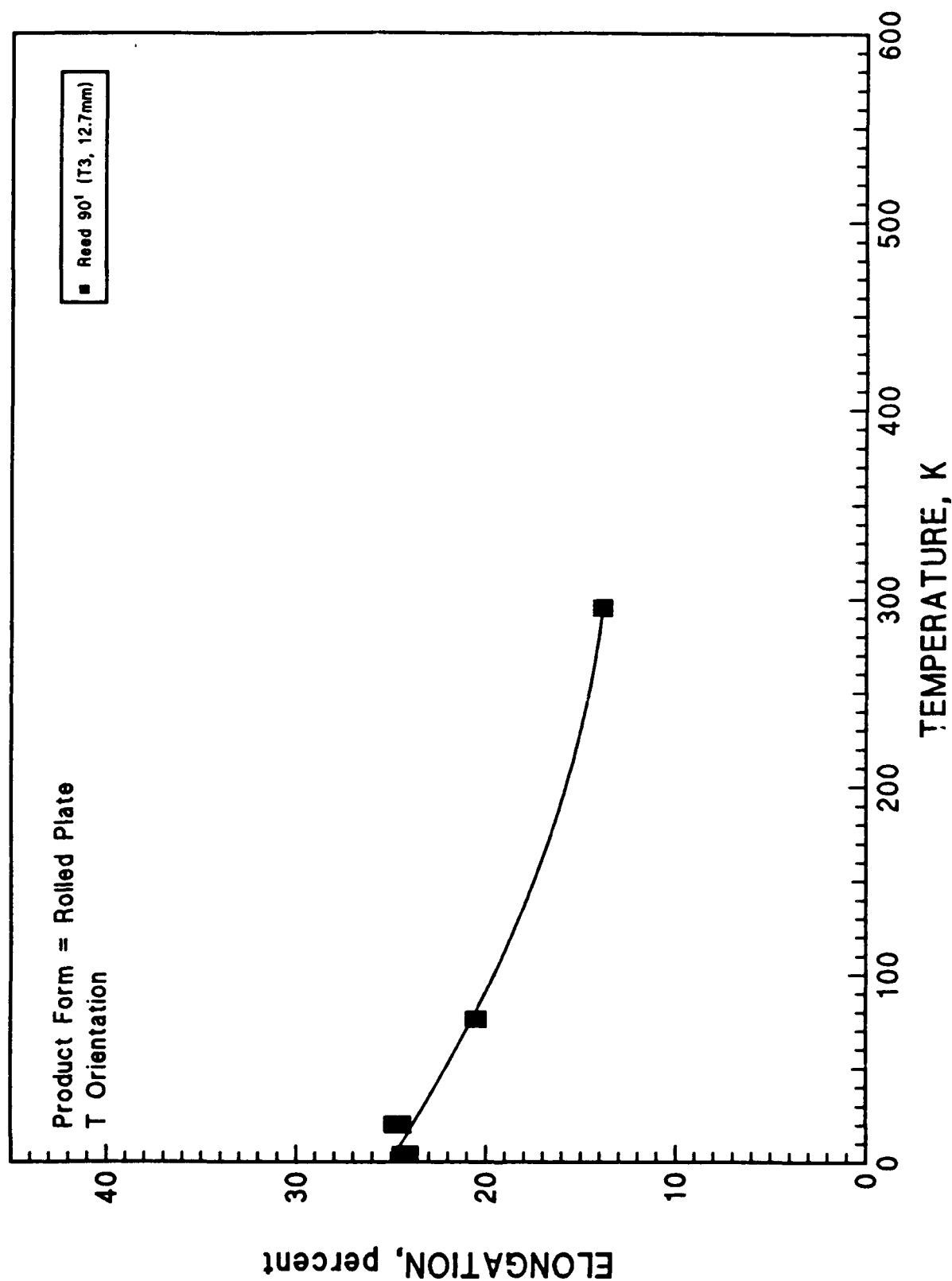
8090-T3



8090-T3



8090-T3



Al-Li ALLOY 8090

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper °C	Product			Aging			Soln. Treat.			Quench Cond.	Grain Size μm	Hardness	No. of Tests/Data Pt
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h						
1A	295	567.	509.	4.1	6.4	L	T8771	Rolled Plate	12.7	NA	NA	6	NA	NA	NA	NA	NA	NA	1	
1A	295	567.	514.	2.4	4.8	L	T8771	Rolled Plate	12.7	NA	NA	6	NA	NA	NA	NA	NA	NA	1	
1A	76	701.	546.	11.4	11.	L	T8771	Rolled Plate	12.7	NA	NA	6	NA	NA	NA	NA	NA	NA	1	
1A	76	697.	538.	NA	NA	L	T8771	Rolled Plate	12.7	NA	NA	6	NA	NA	NA	NA	NA	NA	1	
1A	20	708.	570.	13.2	11.7	L	T8771	Rolled Plate	12.7	NA	NA	6	NA	NA	NA	NA	NA	NA	1	
1A	20	709.	571.	14.2	14.1	L	T8771	Rolled Plate	12.7	NA	NA	6	NA	NA	NA	NA	NA	NA	1	
1A	4	802.	569.	12.6	13.2	L	T8771	Rolled Plate	12.7	NA	NA	6	NA	NA	NA	NA	NA	NA	1	
1A	4	811.	578.	13.7	17.1	L	T8771	Rolled Plate	12.7	NA	NA	6	NA	NA	NA	NA	NA	NA	1	
3A	533	161.	NA	19.	82.7	L	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	NA	1	
3A	533	212.	NA	10.5	81.9	L	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	NA	1	
3A	478	340.	338.	10.3	51.4	L	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	NA	1	
3A	478	336.	333.	10.4	61.7	L	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	NA	1	
3A	478	346.	338.	17.5	58.6	L	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	NA	1	
3A	367	507.	476.	7.7	10.2	L	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	NA	1	
3A	367	497.	439.	7.6	11.1	L	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	NA	1	
3A	367	505.	465.	6.8	15.1	L	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	NA	1	
3A	293	503.	448.	6.	9.4	L	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	NA	1	
3A	293	513.	445.	7.9	6.5	L	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	NA	1	

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient.	Temper	Product		Aging		Soln. Treat.		Quench	Grain Size μm	Hardness	No. of Tests/Data Pt	
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C					Time h
3A	203	515.	477.	7.2	9.4	L	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	200	526.	427.	8.4	11.0	L	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	200	532.	492.	8.1	9.2	L	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	200	516.	456.	5.8	13.1	L	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	78	635.	520.	8.5	3.2	L	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	78	604.	486.	7.9	127.	L	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	78	639.	516.	8.3	7.7	L	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	4	683.	NA	6.4	12.6	L	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	4	635.	NA	6.8	16.3	L	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	4	641.	NA	8.7	18.3	L	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
7A	203	440.	361.	8.5	NA	L	T8771	Roller Plate	100	170	16.	NA	NA	NA	NA	NA	NA	*
7B	203	455.	397.	5.	NA	L	T8771	Roller Plate	100	170	16.	NA	NA	NA	NA	NA	NA	*
5A	436	408.	397.	16.	NA	L	T8511	Extrusion	6.35	149	96.	3.5-4.0	545	1.	HQ	NA	NA	1
5A	436	402.	390.	13.	NA	L	T8511	Extrusion	6.35	149	96.	3.5-4.0	545	1.	HQ	NA	NA	1
5A	380	459.	398.	10.	NA	L	T8511	Extrusion	6.35	149	96.	3.5-4.0	545	1.	HQ	NA	NA	1
5A	380	459.	403.	9.	NA	L	T8511	Extrusion	6.35	149	96.	3.5-4.0	545	1.	HQ	NA	NA	1
5A	325	511.	427.	6.	NA	L	T8511	Extrusion	6.35	149	96.	3.5-4.0	545	1.	HQ	NA	NA	1
5A	325	521.	434.	5.	NA	L	T8511	Extrusion	6.35	149	96.	3.5-4.0	545	1.	HQ	NA	NA	1
5A	255	513.	412.	7.	NA	L	T8511	Extrusion	6.35	149	96.	3.5-4.0	545	1.	HQ	NA	NA	1

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient.	Temper	Product		Aging		Soln. Treat.		Grain Size μm	Hardness	No. of Tests/Data Pt	
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C				Time h
5A	255	524.	427.	7.	NA	L	T8511	Extrusion	6.35	149	96.	3.5-4.0	545	1.	HQ	NA	1
5A	186	489.	392.	8.	NA	L	T8511	Extrusion	6.35	149	96.	3.5-4.0	545	1.	HQ	NA	1
5A	186	487.	393.	9.	NA	L	T8511	Extrusion	6.35	149	96.	3.5-4.0	545	1.	HQ	NA	1
5A	116	523.	396.	10.	NA	L	T8511	Extrusion	6.35	149	96.	3.5-4.0	545	1.	HQ	NA	1
5A	116	550.	414.	11.	NA	L	T8511	Extrusion	6.35	149	96.	3.5-4.0	545	1.	HQ	NA	1
1C	295	473.	401.	4.9	3.8	L	T8151	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1C	295	475.	403.	4.2	4.5	L	T8151	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1C	76	633.	411.	9.4	9.7	L	T8151	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1C	76	633.	412.	11.	7.7	L	T8151	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1C	20	720.	445.	10.4	5.7	L	T8151	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1C	20	778.	454.	14.8	12.7	L	T8151	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1C	4	767.	452.	16.7	14.1	L	T8151	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1C	4	771.	452.	14.1	13.1	L	T8151	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
4A	298	534.	482.	6.	NA	L	T8X	Rolled Plate	11-16	190	16.	3	NA	NA	L:1500; T:350; S:40	NA	1
6A	300	456.	387.	9.4	NA	L	T8X	Rolled Plate	25	190	4.	2-2.5	NA	NA	NA	NA	1
6A	300	464.	406.	9.4	NA	L	T8X	Rolled Plate	25	190	8.	2-2.5	NA	NA	NA	NA	1
6A	77	542.	392.	16.	NA	L	T8X	Rolled Plate	25	190	4.	2-2.5	NA	NA	NA	NA	1
6A	77	566.	411.	16.	NA	L	T8X	Rolled Plate	25	190	8.	2-2.5	NA	NA	NA	NA	1
8A	195	495.	450.	6.	NA	L	T651	Rolled Plate	6.35-38.1	NA	NA	NA	NA	NA	NA	NA	*

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. T	Temper Form	Product		Aging Temp. °C	Time h	Stretch		Temp. °C	Time h	Quench Cond.	Grain Size µm	Hardness	No. of Tests/ Data Pt
								Thickness mm	Product			z	z						
1E	297	328.	218.	11.7	18.7	L	T3	12.7	Rolled Plate	NA	NA	NA	NA	NA	NA	NA	NA	118.5	1
1E	297	328.	218.	13.1	17.4	L	T3	NA	Rolled Plate	NA	NA	NA	NA	NA	NA	NA	NA	118.5	1
1E	76	437.	248.	19.6	29.8	L	T3	12.7	Rolled Plate	NA	NA	NA	NA	NA	NA	NA	NA	118.5	1
1E	76	460.	248.	23.4	24.7	L	T3	12.7	Rolled Plate	NA	NA	NA	NA	NA	NA	NA	NA	118.5	1
1E	20	610.	270.	28.1	26.5	L	T3	12.7	Rolled Plate	NA	NA	NA	NA	NA	NA	NA	NA	118.5	1
1E	20	607.	272.	27.	24.3	L	T3	12.7	Rolled Plate	NA	NA	NA	NA	NA	NA	NA	NA	118.5	1
1E	4	604.	278.	26.8	30.	L	T3	12.7	Rolled Plate	NA	NA	NA	NA	NA	NA	NA	NA	118.5	1
1E	4	608.	283.	26.3	27.5	L	T3	12.7	Rolled Plate	NA	NA	NA	NA	NA	NA	NA	NA	118.5	1
1A	295	567.	489.	5.2	11.	T	T8771	12.7	Rolled Plate	NA	NA	6	6	NA	NA	NA	NA	NA	1
1A	295	566.	502.	6.4	12.6	T	T8771	12.7	Rolled Plate	NA	NA	6	6	NA	NA	NA	NA	NA	1
1A	76	682.	NA	NA	NA	T	T8771	12.7	Rolled Plate	NA	NA	6	6	NA	NA	NA	NA	NA	1
1A	76	679.	537.	8.	5.6	T	T8771	12.7	Rolled Plate	NA	NA	6	6	NA	NA	NA	NA	NA	1
1A	20	772.	570.	9.8	9.5	T	T8771	12.7	Rolled Plate	NA	NA	6	6	NA	NA	NA	NA	NA	1
1A	20	768.	575.	7.7	7.2	T	T8771	12.7	Rolled Plate	NA	NA	6	6	NA	NA	NA	NA	NA	1
1A	4	764.	578.	NA	NA	T	T8771	12.7	Rolled Plate	NA	NA	6	6	NA	NA	NA	NA	NA	1
1A	4	768.	570.	7.2	7.2	T	T8771	12.7	Rolled Plate	NA	NA	6	6	NA	NA	NA	NA	NA	1
3A	534	182.	NA	21.	74.9	T	T8771	25.4-50.8	Rolled Plate	179	96.	4-6	4-6	545	0.5	WQ	NA	NA	1
3A	534	196.	NA	21.1	70.7	T	T8771	25.4-50.8	Rolled Plate	179	96.	4-6	4-6	545	0.5	WQ	NA	NA	1
3A	478	331.	328.	15.6	53.1	T	T8771	25.4-50.8	Rolled Plate	179	96.	4-6	4-6	545	0.5	WQ	NA	NA	1

*See Comments

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper Form	Product Thickness mm	Aging		Soln. Treat.		Grain Size μm	Hardness	No. of Tests/Data Pt		
									Temp. °C	Time h	Stretch %	Temp. °C				Time h	Quench Cond.
3A	478	341.	339.	17.7	54.8	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	478	334.	332.	19.6	59.6	T	T8771	Roller Plate	25.4-50.8	179	96.	4-8	545	0.5	HQ	NA	1
3A	367	492.	438.	9.1	14.6	T	T8771	Roller Plate	25.4-50.8	176	96.	4-6	545	0.5	HQ	NA	1
3A	367	496.	439.	8.8	14.	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	367	471.	398.	10.5	26.6	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	293	513.	476.	7.5	6.7	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	293	483.	432.	6.4	11.2	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	293	510.	474.	6.6	5.1	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	200	530.	432.	10.9	6.4	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	200	532.	442.	10.1	7.8	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	200	496.	392.	7.	5.5	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	78	622.	461.	10.3	7.3	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	78	620.	459.	10.3	7.2	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	78	598.	482.	7.9	12.7	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	4	670.	NA	8.5	16.5	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	4	629.	NA	8.7	17.8	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
3A	4	707.	NA	5.8	10.1	T	T8771	Roller Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	1
7C	293	430.	310.	9.8	NA	T	T8771	Roller Plate	100	NA	NA	NA	NA	NA	NA	NA	*
7D	293	437.	335.	7.8	NA	T	T8771	Roller Plate	100	NA	NA	NA	NA	NA	NA	NA	*

*See Comments

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. T	Temper Form	Product		Aging		Soln. Treat.		Quench Cond.	Grain Size μm	Hardness	No. of Tests/ Data Pt
								Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h				
9A	293	448.	379.	4.	NA	T	T8771	Roller Plate	6.35-38.1	NA	NA	NA	NA	NA	NA	NA	1
5C	436	386.	314.	8.	NA	T	T852	Forging	254	149	96.	4*	545	1.	WQ	NA	1
5C	436	395.	321.	10.	NA	T	T852	Forging	254	149	96.	4*	545	1.	WQ	NA	1
5C	380	434.	345.	5.	NA	T	T852	Forging	254	149	96.	4*	545	1.	WQ	NA	1
5C	380	450.	342.	7.	NA	T	T852	Forging	254	149	96.	4*	545	1.	WQ	NA	1
5C	325	463.	340.	5.	NA	T	T852	Forging	254	149	96.	4*	545	1.	WQ	NA	1
5C	325	458.	351.	6.	NA	T	T852	Forging	254	149	96.	4*	545	1.	WQ	NA	1
5C	255	465.	340.	6.	NA	T	T852	Forging	254	149	96.	4*	545	1.	WQ	NA	1
5C	255	464.	343.	6.	NA	T	T852	Forging	254	149	96.	4*	545	1.	WQ	NA	1
5C	186	461.	343.	5.	NA	T	T852	Forging	254	149	96.	4*	545	1.	WQ	NA	1
5C	186	468.	343.	5.	NA	T	T852	Forging	254	149	96.	4*	545	1.	WQ	NA	1
5C	116	473.	361.	3.	NA	T	T852	Forging	254	149	96.	4*	545	1.	WQ	NA	1
5C	116	473.	360.	3.	NA	T	T852	Forging	254	149	96.	4*	545	1.	WQ	NA	1
1C	295	507.	403.	6.6	7.1	T	T8151	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1C	295	508.	407.	4.8	5.9	T	T8151	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1C	76	642.	413.	10.9	10.5	T	T8151	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1C	76	643.	417.	10.7	10.	T	T8151	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1C	20	752.	453.	12.	9.5	T	T8151	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1C	20	760.	453.	11.7	11.4	T	T8151	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. I	Temper T	Product		Aging		Soln. Treat.		Quench Cond.	Grain Size μm	Hardness	No. of Tests/ Data Pt
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C				
1C	4	778.	462.	14.	14.7	T	T8151	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1C	4	783.	464.	14.8	14.3	T	T8151	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
5B	436	416.	391.	11.	NA	T	T8	Sheet	1.78	149	96.	2.5-3.0	545	1.	HQ	NA	1
5B	436	407.	388.	13.	NA	T	T8	Sheet	1.78	149	96.	2.5-3.0	545	1.	HQ	NA	1
5B	380	494.	479.	9.	NA	T	T8	Sheet	1.78	149	96.	2.5-3.0	545	1.	HQ	NA	1
5B	380	499.	443.	8.	NA	T	T8	Sheet	1.78	149	96.	2.5-3.0	545	1.	HQ	NA	1
5B	325	534.	456.	7.	NA	T	T8	Sheet	1.78	149	96.	2.5-3.0	545	1.	HQ	NA	1
5B	325	514.	434.	6.	NA	T	T8	Sheet	1.78	149	96.	2.5-3.0	545	1.	HQ	NA	1
5B	255	532.	448.	6.	NA	T	T8	Sheet	1.78	149	96.	2.5-3.0	545	1.	HQ	NA	1
5B	255	526.	441.	7.	NA	T	T8	Sheet	1.78	149	96.	2.5-3.0	545	1.	HQ	NA	1
5B	186	535.	460.	4.	NA	T	T8	Sheet	1.78	149	96.	2.5-3.0	545	1.	HQ	NA	1
5B	186	532.	454.	5.	NA	T	T8	Sheet	1.78	149	96.	2.5-3.0	545	1.	HQ	NA	1
5B	116	582.	468.	6.	NA	T	T8	Sheet	1.78	149	96.	2.5-3.0	545	1.	HQ	NA	1
5B	116	581.	463.	7.	NA	T	T8	Sheet	1.78	149	96.	2.5-3.0	545	1.	HQ	NA	1
8A	295	480.	420.	7.	NA	T	T651	Roller Plate	25-40	190	6.	0	NA	NA	NA	NA	*
1E	297	347.	209.	13.8	24.5	T	T3	Roller Plate	12.7	NA	NA	2	NA	NA	NA	118.5	1
1E	297	349.	207.	13.6	28.8	T	T3	Roller Plate	12.7	NA	NA	2	NA	NA	NA	118.5	1
1E	76	454.	240.	20.6	37.3	T	T3	Roller Plate	12.7	NA	NA	2	NA	NA	NA	118.5	1
1E	76	447.	243.	20.4	36.9	T	T3	Roller Plate	12.7	NA	NA	2	NA	NA	NA	118.5	1

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. T	Temper Form	Product		Aging Temp. °C	Time h	Stretch		Temp. °C	Time h	Quench Cond.	Grain Size µm	Hardness	No. of Tests/ Data Pt
								Thickness mm	Form			z	z						
1E	20	598.	264.	24.9	29.2	T	T3	12.7	Roll Plate	NA	NA	2	2	NA	NA	NA	NA	118.5	1
1E	20	586.	271.	24.4	28.1	T	T3	12.7	Roll Plate	NA	NA	2	2	NA	NA	NA	NA	118.5	1
1E	4	596.	273.	24.	29.7	T	T3	12.7	Roll Plate	NA	NA	2	2	NA	NA	NA	NA	118.5	1
1E	4	598.	267.	24.5	28.5	T	T3	12.7	Roll Plate	NA	NA	2	2	NA	NA	NA	NA	118.5	1
10A	293	302.	142.	23.	40.	T	O	11	Roll Plate	NA	NA	0	0	520	NA	W	NA	NA	1
10A	273	283.	140.	25.5	50.1	T	O	11	Roll Plate	NA	NA	0	0	520	NA	W	NA	NA	1
10A	258	271.	140.	25.	59.5	T	O	11	Roll Plate	NA	NA	0	0	520	NA	W	NA	NA	1
10A	238	262.	142.	24.5	57.8	T	O	11	Roll Plate	NA	NA	0	0	520	NA	W	NA	NA	1
10A	218	250.	140.	26.5	65.6	T	O	11	Roll Plate	NA	NA	0	0	520	NA	W	NA	NA	1
10A	198	254.	142.	27.5	68.5	T	O	11	Roll Plate	NA	NA	0	0	520	NA	W	NA	NA	1
10A	173	257.	146.	30.	68.7	T	O	11	Roll Plate	NA	NA	0	0	520	NA	W	NA	NA	1
10A	153	257.	150.	30.	63.	T	O	11	Roll Plate	NA	NA	0	0	520	NA	W	NA	NA	1
10A	78	352.	187.	41.5	49.9	T	O	11	Roll Plate	NA	NA	0	0	520	NA	W	NA	NA	1
3A	534	163.	NA	14.6	84.9	45°	T8771	25.4-50.8	Roll Plate	179	96.	4-6	4-6	545	0.5	HQ	NA	NA	1
3A	534	172.	NA	16.3	85.1	45°	T8771	25.4-50.8	Roll Plate	179	96.	4-6	4-6	545	0.5	HQ	NA	NA	1
3A	534	210.	NA	26.4	77.	45°	T8771	25.4-50.8	Roll Plate	179	96.	4-6	4-6	545	0.5	HQ	NA	NA	1
3A	478	332.	319.	21.1	62.1	45°	T8771	25.4-50.8	Roll Plate	179	96.	4-6	4-6	545	0.5	HQ	NA	NA	1
3A	478	352.	335.	25.6	58.5	45°	T8771	25.4-50.8	Roll Plate	179	96.	4-6	4-6	545	0.5	HQ	NA	NA	1
3A	478	334.	326.	18.8	64.7	45°	T8771	25.4-50.8	Roll Plate	179	96.	4-6	4-6	545	0.5	HQ	NA	NA	1

*See Comments

Ref & Note No.	Temp. K	I.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. °	Temper °C	Product		Aging Temp. °C	Aging Time h	Stretch %	Soln. Treat.		Quench Cond.	Grain Size µm	Hardness	No. of Tests/ Data Pt
								Form	Thickness mm				Temp. °C	Time h				
3A	367	458.	363.	12.4	27.9	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	367	457.	364.	11.8	28.5	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	367	456.	362.	12.1	28.7	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	293	476.	365.	11.3	18.9	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	293	473.	363.	12.	12.4	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	293	479.	364.	12.8	20.	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	200	485.	372.	11.5	12.5	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	200	482.	365.	9.9	13.7	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	200	485.	365.	10.1	11.1	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	78	559.	392.	14.3	11.4	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	78	562.	387.	15.3	18.4	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	78	558.	387.	12.3	11.2	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	4	662.	NA	12.8	19.4	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	4	654.	NA	13.5	19.4	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
3A	4	652.	NA	11.6	19.4	45°	T8771	Rolled Plate	25.4-50.8	179	96.	4-6	545	0.5	HQ	NA	NA	1
1B	295	558.	NA	NA	NA	S	T8771	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
1B	295	567.	NA	NA	NA	S	T8771	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
1B	76	626.	NA	NA	NA	S	T8771	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
1B	76	600.	NA	NA	NA	S	T8771	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. S	Temper Form	Product Thickness mm	Aging		Soln. Treat.		Quench Cond.	Grain Size μ m	Hardness	No. of Tests/ Data Pt
									Temp. °C	Time h	Temp. °C	Time h				
1B	4	664.	NA	NA	NA	S	T6771 Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1B	4	637.	NA	NA	NA	S	T6771 Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
3B	534	159.	NA	8.7	36.7	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	534	149.	NA	9.6	31.5	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	534	159.	NA	10.	23.1	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	478	304.	279.	5.3	22.7	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	478	328.	296.	5.	24.8	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	478	330.	304.	4.4	15.8	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	367	447.	339.	5.4	13.7	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	367	474.	365.	4.4	3.6	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	367	463.	351.	3.9	12.2	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	293	456.	350.	2.7	11.3	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	293	476.	368.	2.	8.4	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	293	454.	348.	2.8	11.9	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	200	439.	349.	1.9	12.3	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	200	438.	327.	1.3	11.8	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	200	465.	303.	1.8	14.5	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	78	487.	368.	1.5	6.	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1
3B	78	477.	355.	2.	9.7	S	T6771 Rolled Plate	25.4-50.8	179	96.	545	0.5	HQ	NA	NA	1

*See Comments

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper °C	Product		Aging		Soln. Treat.		Grain Size µm	Hardness	No. of Tests/ Data Pt	
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C				Time h
3B	4	487.	NA	1.	1.	S	T8771	Rollled Plate	25.4-50.8	178	96.	4-6	545	0.5	HQ	NA	1
3B	4	546.	NA	2.6	1.2	S	T8771	Rollled Plate	25.4-50.8	178	96.	4-6	545	0.5	HQ	NA	1
3B	4	546.	NA	8.6	2.1	S	T8771	Rollled Plate	25.4-50.8	178	96.	4-6	545	0.5	HQ	NA	1
7E	293	442.	320.	7.	NA	S	T8771	Rollled Plate	100	NA	NA	NA	NA	NA	NA	NA	*
7F	293	410.	283.	5.	NA	S	T8771	Rollled Plate	100	NA	NA	NA	NA	NA	NA	NA	*
9B	293	421.	338.	1.5	NA	S	T8771	Rollled Plate	25.4-50.8	NA	NA	NA	NA	NA	NA	NA	*
1D	295	483.	NA	NA	NA	S	T8151	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1D	295	473.	NA	NA	NA	S	T8151	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1D	76	548.	NA	NA	NA	S	T8151	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1D	76	539.	NA	NA	NA	S	T8151	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1D	4	582.	NA	NA	NA	S	T8151	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1D	4	586.	NA	NA	NA	S	T8151	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
8B	293	435.	365.	2.	NA	S	T651	Rollled Plate	25-40	NA	NA	NA	NA	NA	NA	NA	*

*See Comments

Comments from the Al-Li Alloy 809C Data Table

Reference and
Note Number

3A-B--Temper T851 appears to be T8771, and is reported here as such.

5C--Cold work is in compression.

8A--Values reported are "typical" properties.

9A--Values reported are "minimum" properties.

TEST PARAMETERS
AL-L1 ALLOY 8090

Ref & Strain Note No.	Rate 10 ⁻⁴ /s	Specimen			Specimen Location	Expo Time min	Supplier	Yr. Prod.	Lot No.	Product L(m) X W(m)	Major Elements wt%							Minor Elements wt%
		Type	Diam mm	Thick mm	G.L. mm						Li	Cu	Mg	Zr	Si	Fe	Ag	
1A	2.2	Round	6.35	NA	25.4	Mid-Plane	5.	Alcan	1989	3503302A	1.635 X 0.925	2.36	1.2	0.7	0.11	0.02	0.06	NA
1B	2.2	Round	2.5	NA	25.4	Random	5.	Alcan	1989	3503302A	1.635 X 0.925	2.36	1.2	0.7	0.11	0.02	0.06	NA
1C	2.2	Round	6.35	NA	25.4	Mid-plane	5.	Alcan	1989	35712859	1.533 X 0.925	2.36	1.2	0.7	0.11	0.02	0.06	NA
1D	2.2	Round	2.5	NA	25.4	Random	5.	Alcan	1989	35712859	1.533 X 0.925	2.36	1.2	0.7	0.11	0.02	0.06	NA
1E	2.2	Round	6.35	NA	25.4	Mid-plane	5.	Alcan	1989	3518302A	0.254 X 0.254	2.34	1.2	0.6	0.12	0.03	0.05	NA
3A	8.3	Round	12.7	NA	50.8	NA	2.	Alcan	1987	NA	NA	2.4*	1.3	0.8	0.12	0.1	0.3	NA
3B	8.3	Round	12.7	NA	50.8	NA	2.	Alcan	1987	NA	NA	2.4*	1.3	0.8	0.12	0.1	0.3	NA
4A	8.3	Round	12.7	NA	50.8	NA	2.	Alcan	1987	NA	NA	2.4*	1.3	0.8	0.12	0.1	0.3	NA
5A	0.83	NA	NA	NA	NA	Random	30.	Alcan	NA	NA	NA	2.5*	1.2	0.7	0.12	0.04	0.08	NA:0.001
5C	0.83	NA	NA	NA	NA	Random	30.	Alcan	NA	NA	0.46 X 0.25	2.5*	1.2	0.7	0.12	0.04	0.08	NA:0.001
6A	1.0	Round	NA	NA	NA	NA	15.	Alcan	NA	NA	NA	2.28	0.9	0.9	0.13	0.06	0.13	NA
5B	0.83	NA	NA	NA	NA	NA	30.	Alcan	NA	NA	1.22 X 3.66	2.5*	1.2	0.7	0.12	0.04	0.08	NA:0.001
7A	NA	NA	NA	NA	NA	4 the thickness	NA	Alcan	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7B	NA	NA	NA	NA	NA	4 the thickness	NA	Alcan	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7C	NA	NA	NA	NA	NA	4 the thickness	NA	Alcan	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7D	NA	NA	NA	NA	NA	4 the thickness	NA	Alcan	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7E	NA	NA	NA	NA	NA	4 the thickness	NA	Alcan	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7F	NA	NA	NA	NA	NA	4 the thickness	NA	Alcan	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Ref & Strain Note No.	Rate 10 ⁻⁴ /s	Type	Specimen			G.L. mm	Specimen Location	Expo Time min	Supplier	Yr. Prod	Lot No.	Product L(m) X W(m)	Major Elements							Minor Elements wt%
			Diam mm	Thick mm									Li	Cu	Mg	Zr wt%	Si	Fe	Ag	
8A	NA	NA	NA	NA	NA	NA	NA	NA	Alcan	NA	NA	NA	2.5*	1.3	0.7	0.12	0.1	0.2	NA	NA
8B	NA	NA	NA	NA	NA	NA	NA	NA	Alcan	NA	NA	NA	2.5*	1.3	0.7	0.12	0.1	0.2	NA	Na:0.001
9A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.5*	1.2	0.7	0.09	0.04	0.08	NA	Na:0.001
9B	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.5*	1.2	0.7	0.09	0.04	0.08	NA	Na:0.001
10A	4.6	Round	5	NA	36	NA	NA	NA	Alcan	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Comments from the Al-Li Alloy 8090 Test Parameter Table

Reference and
Note Number

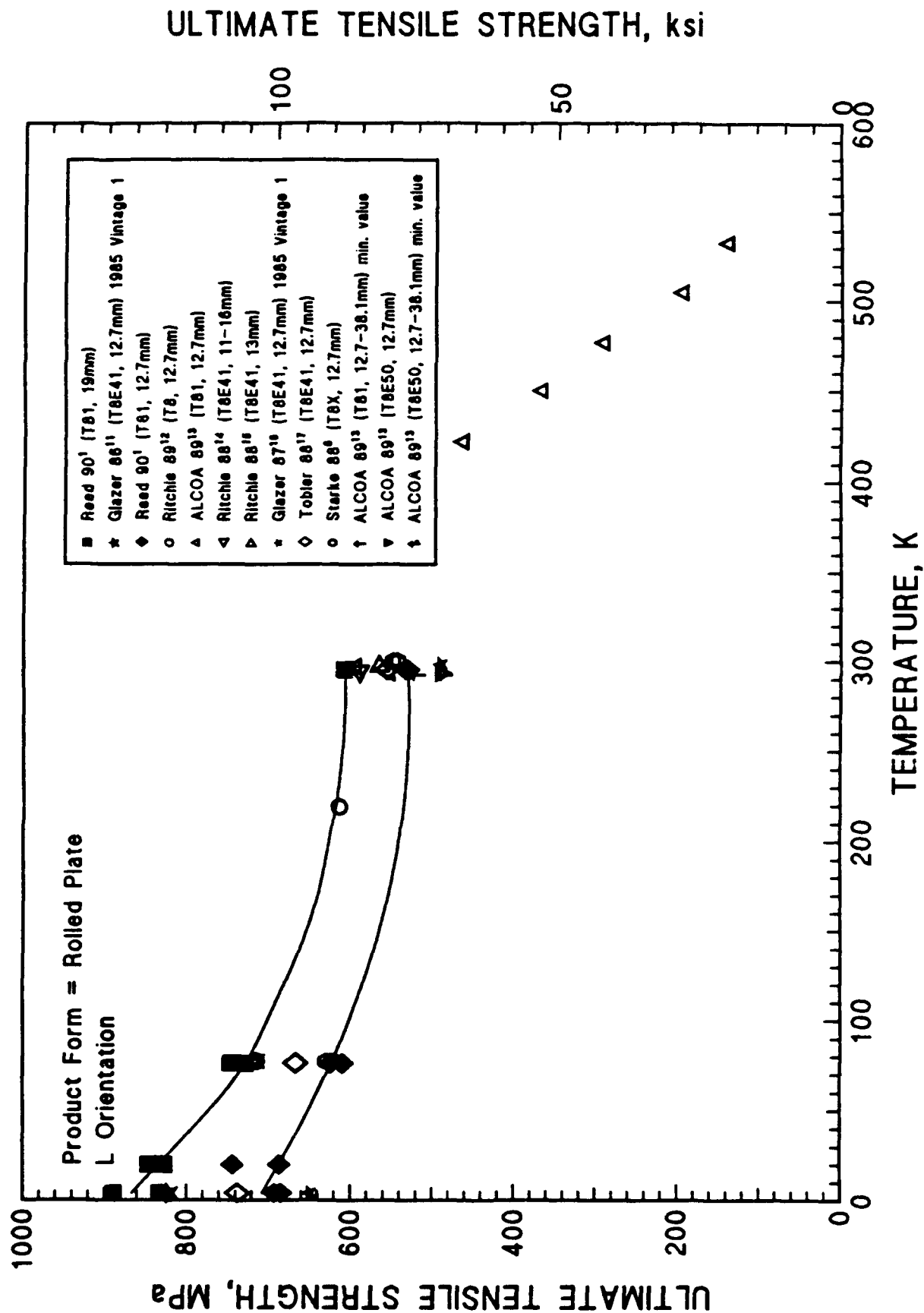
3A-B--Reported composition is based on typical values.

4A--Reported composition is based on nominal values.

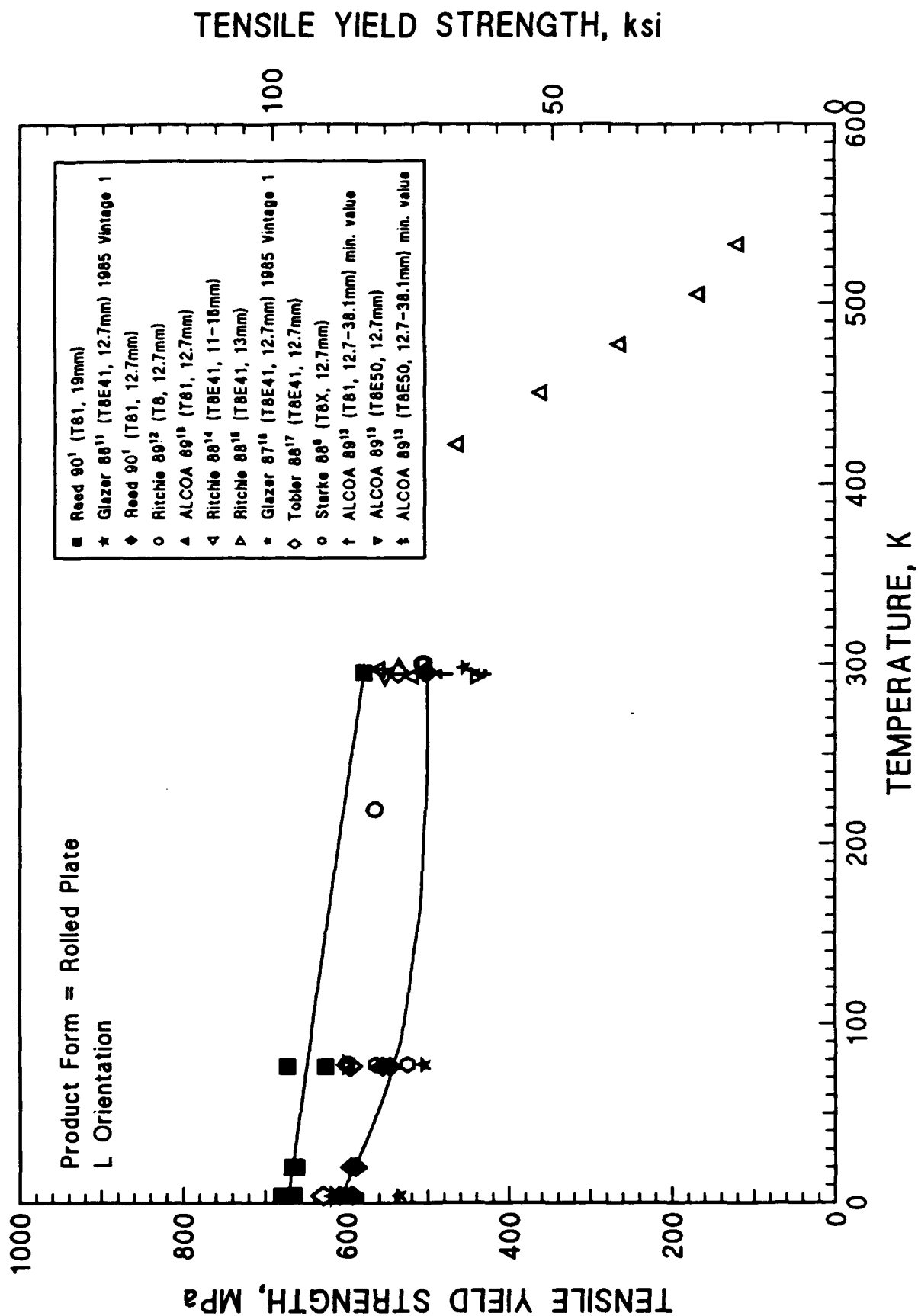
5A-C--Reported composition is the average of the range provided for in the Lockheed requirements.

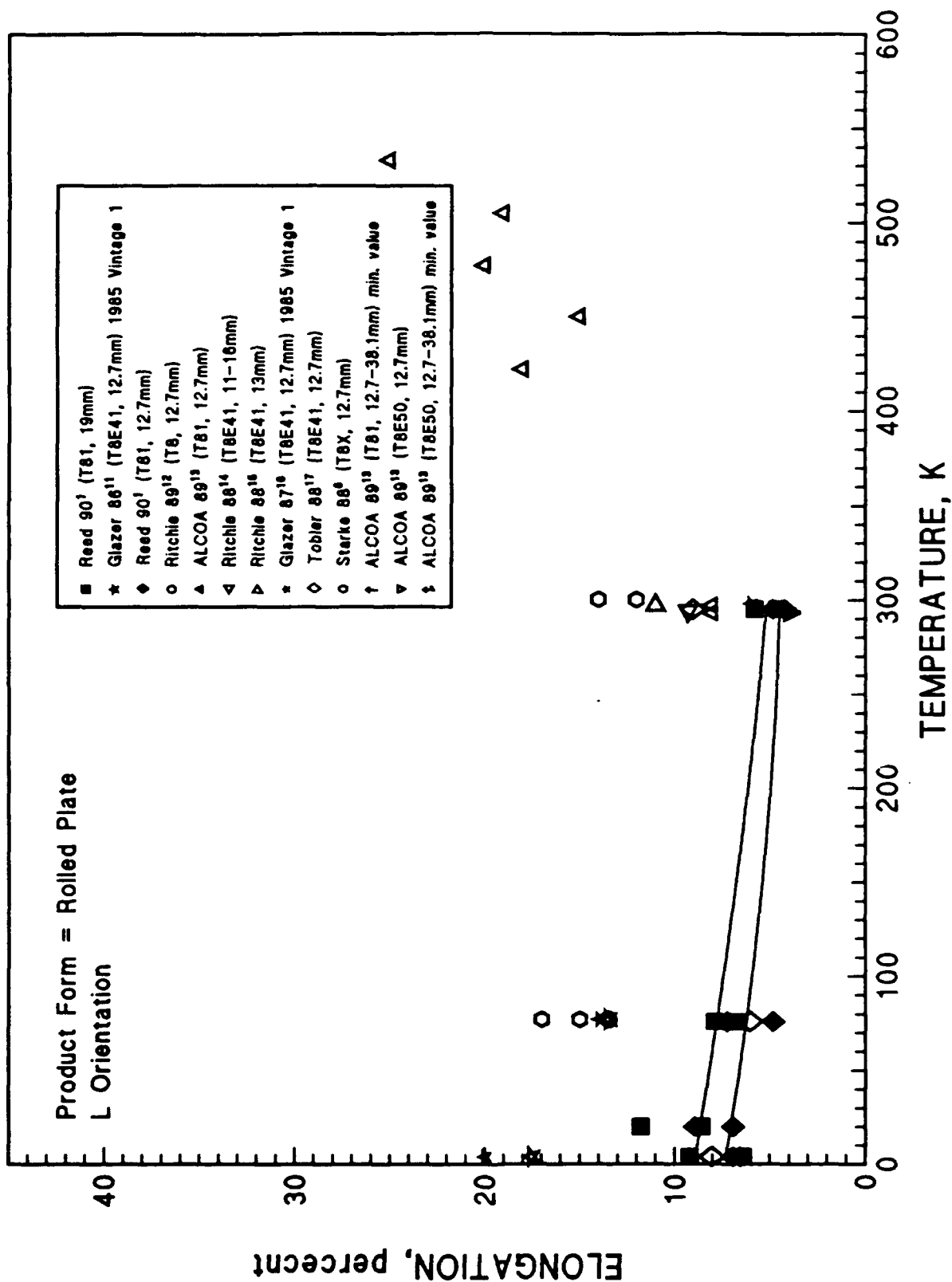
8A--Reported composition is based on nominal values.

9A-B--Reported composition is the average of the range provided for in the Lockheed requirements.

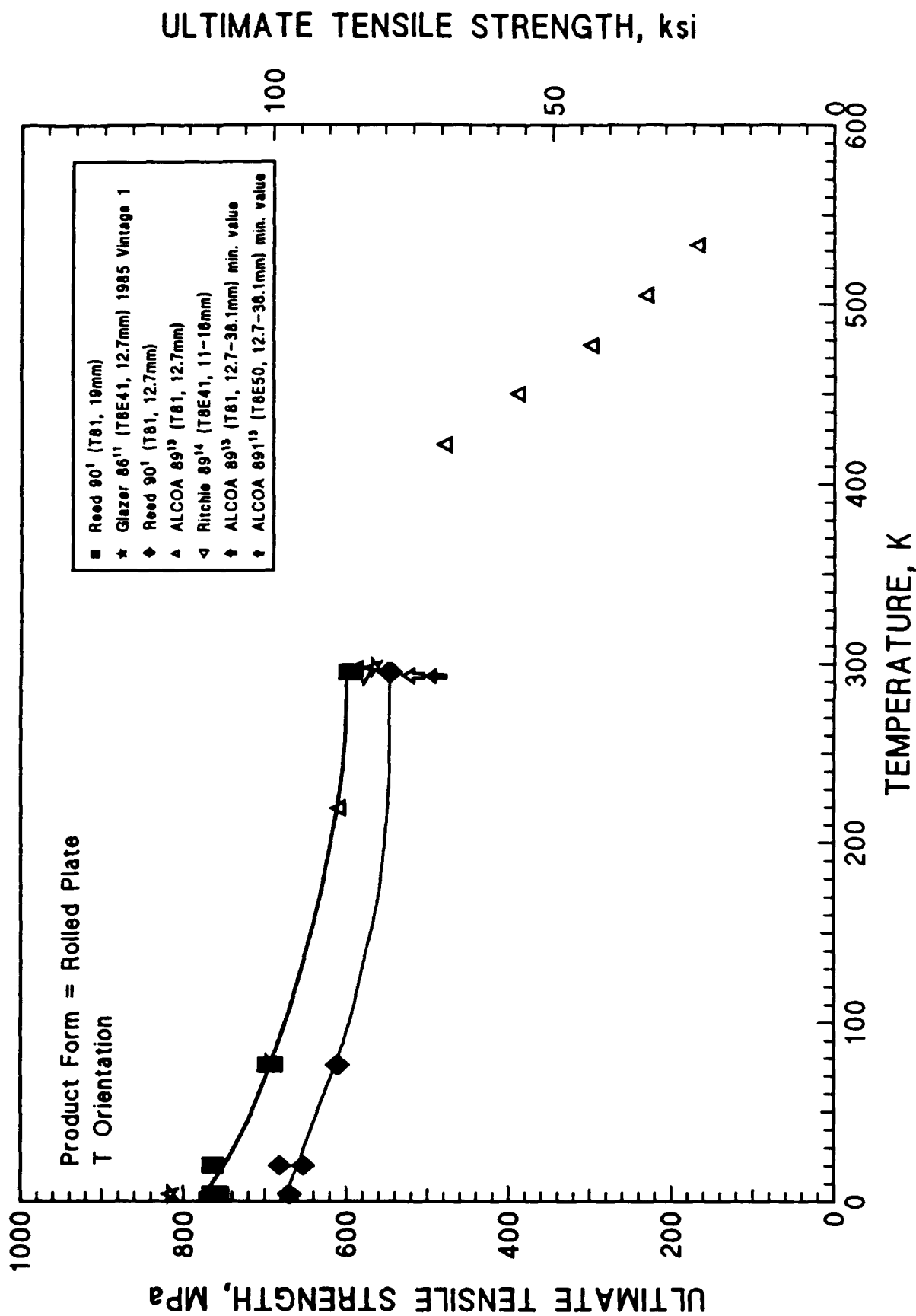


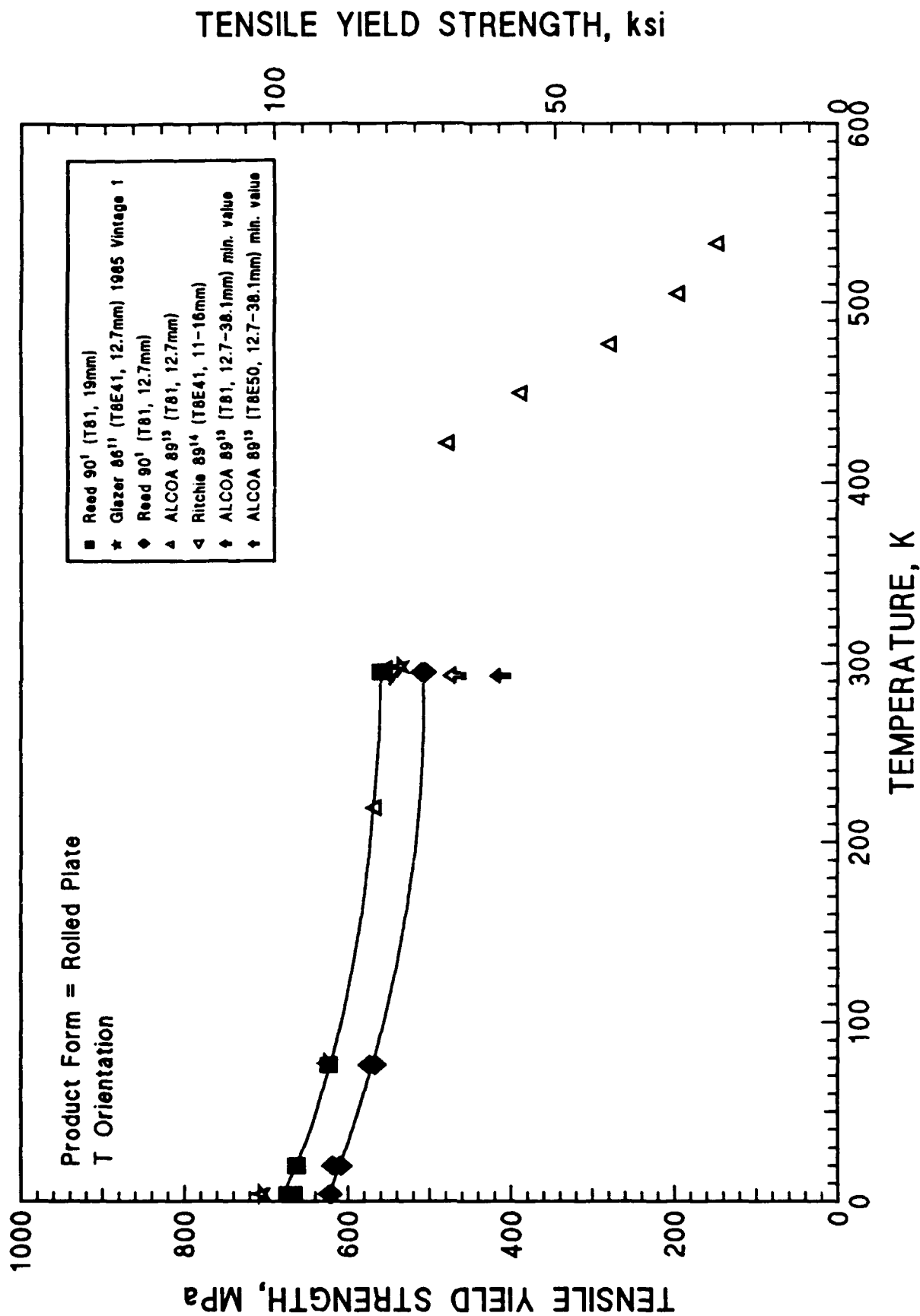
2090-T8



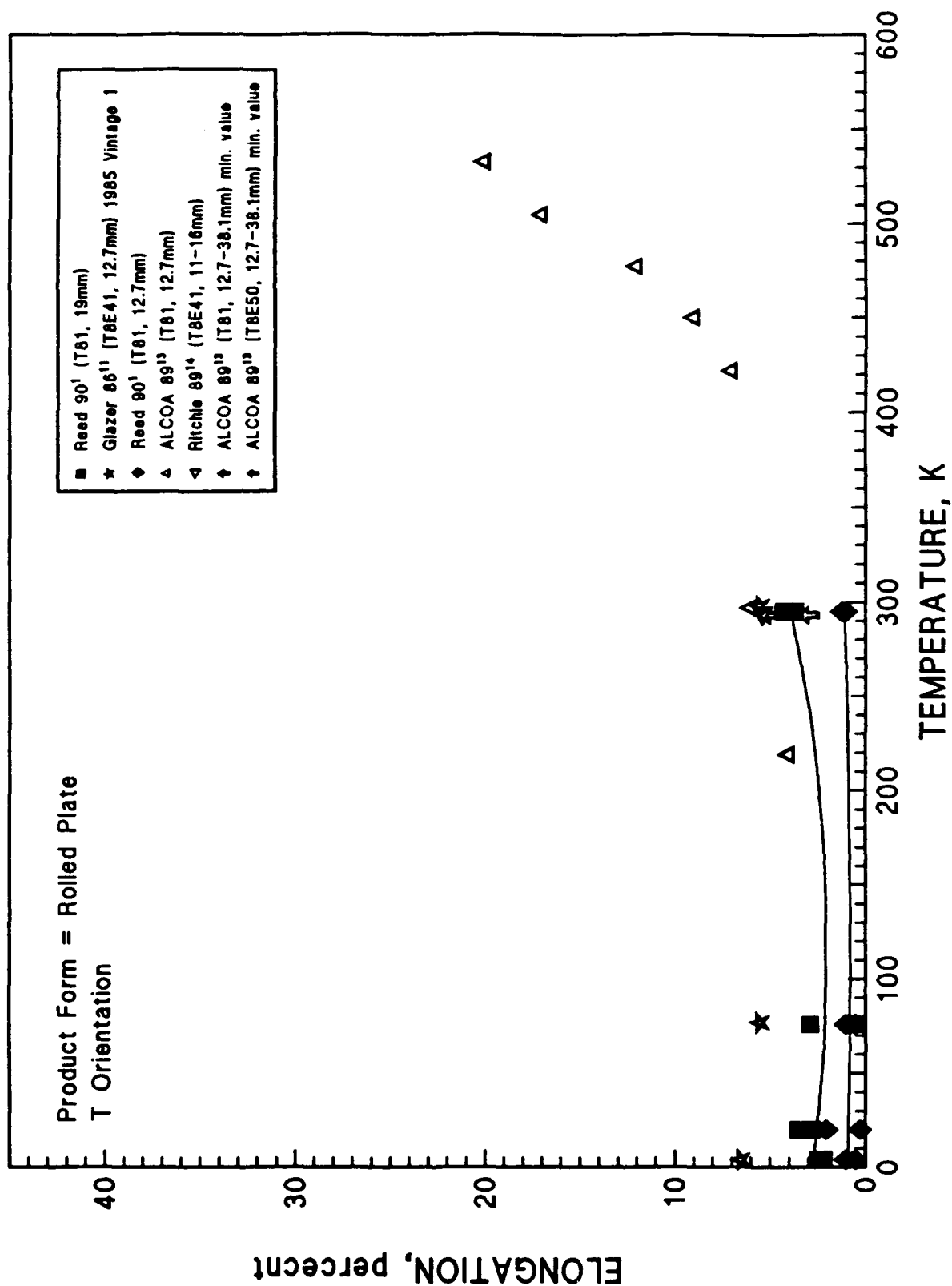


2090-T8

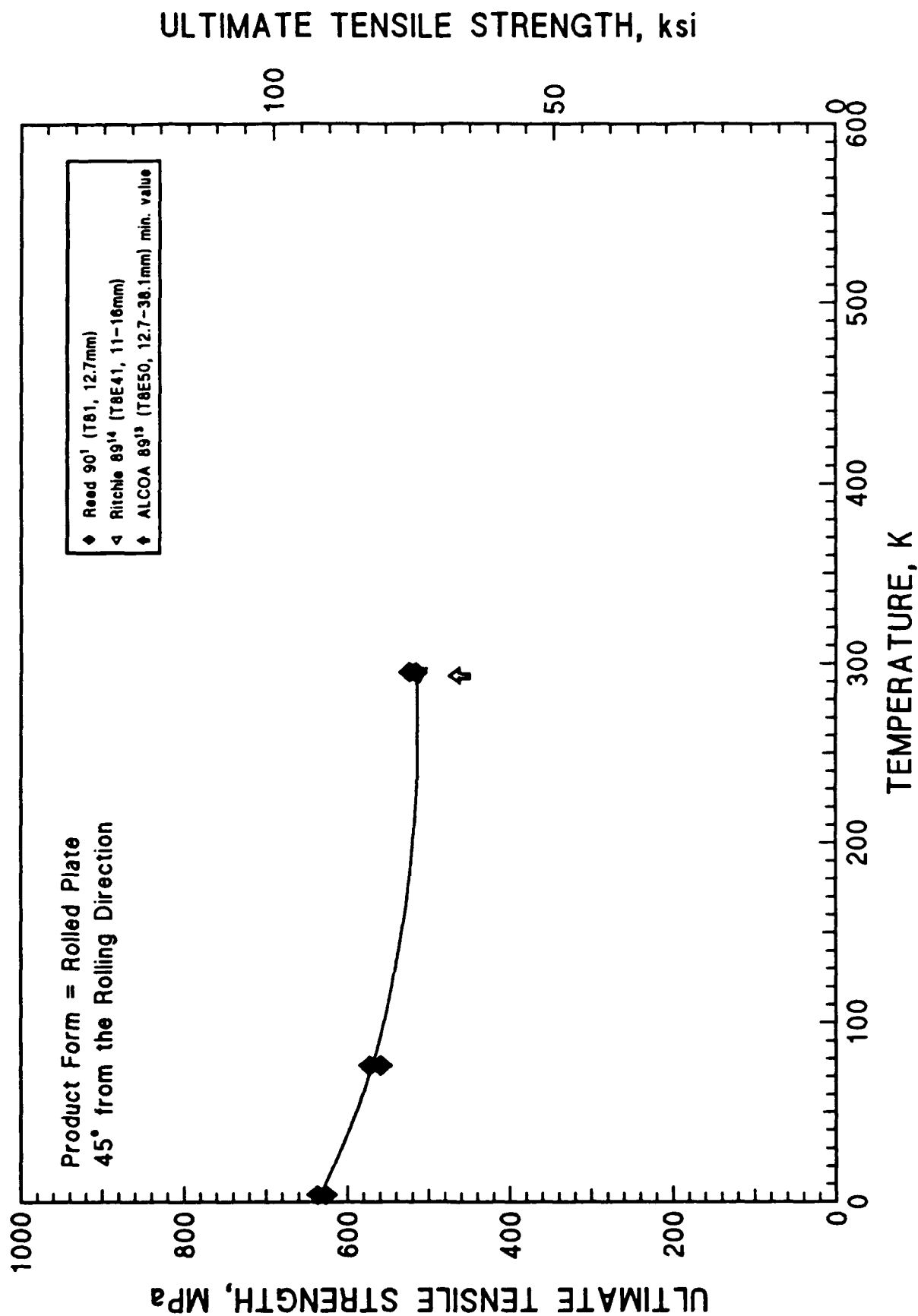




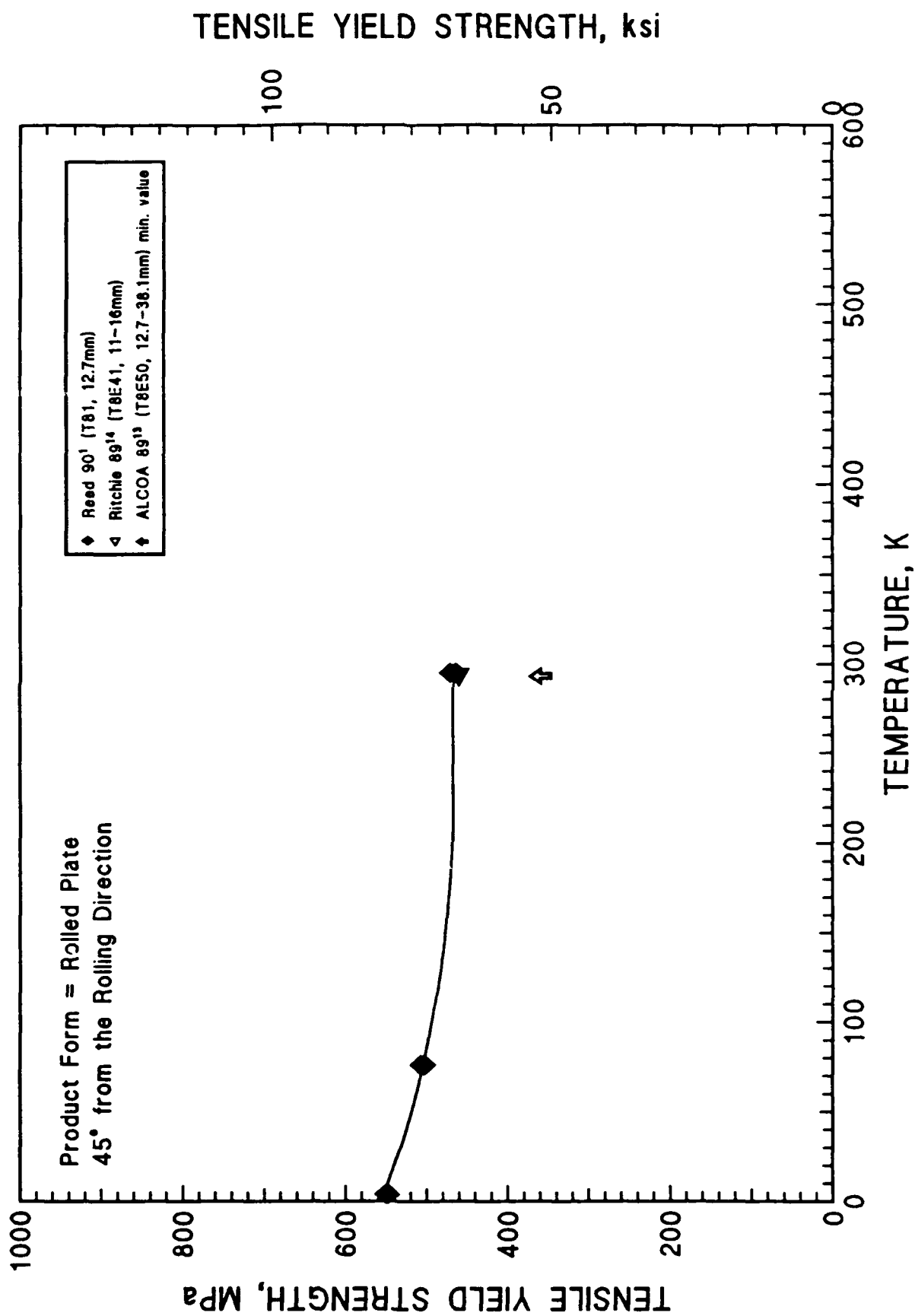
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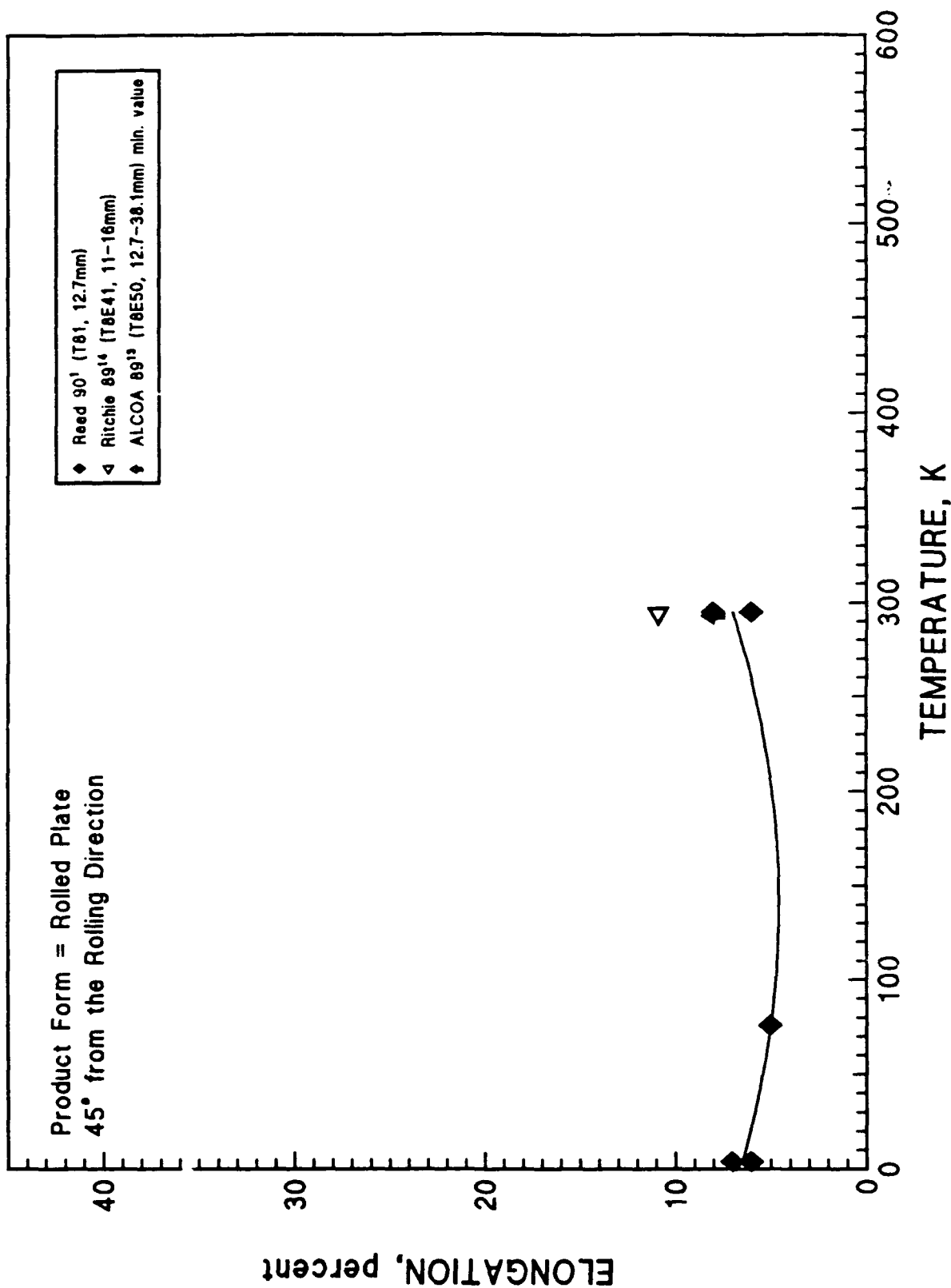


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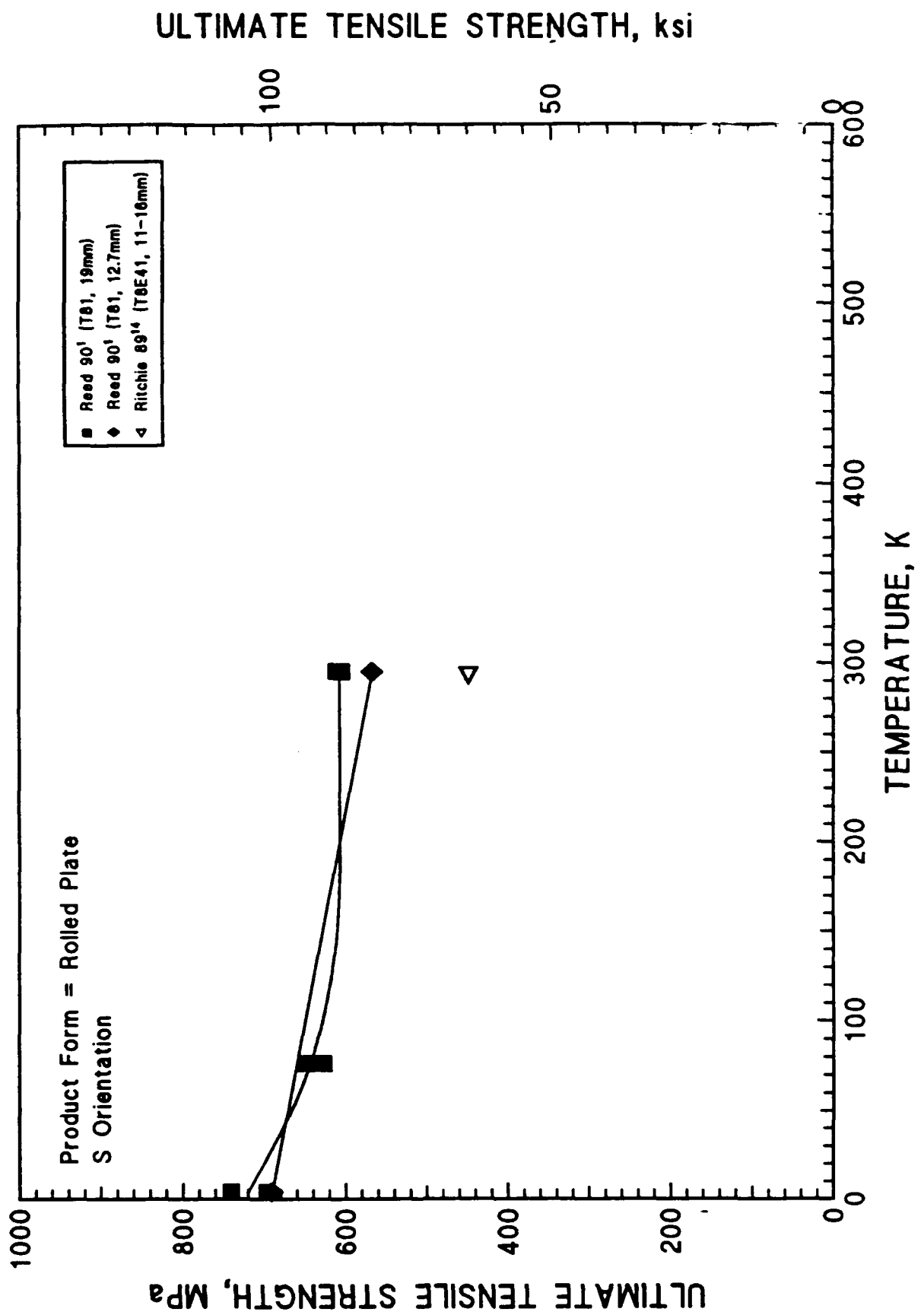


2090-T8

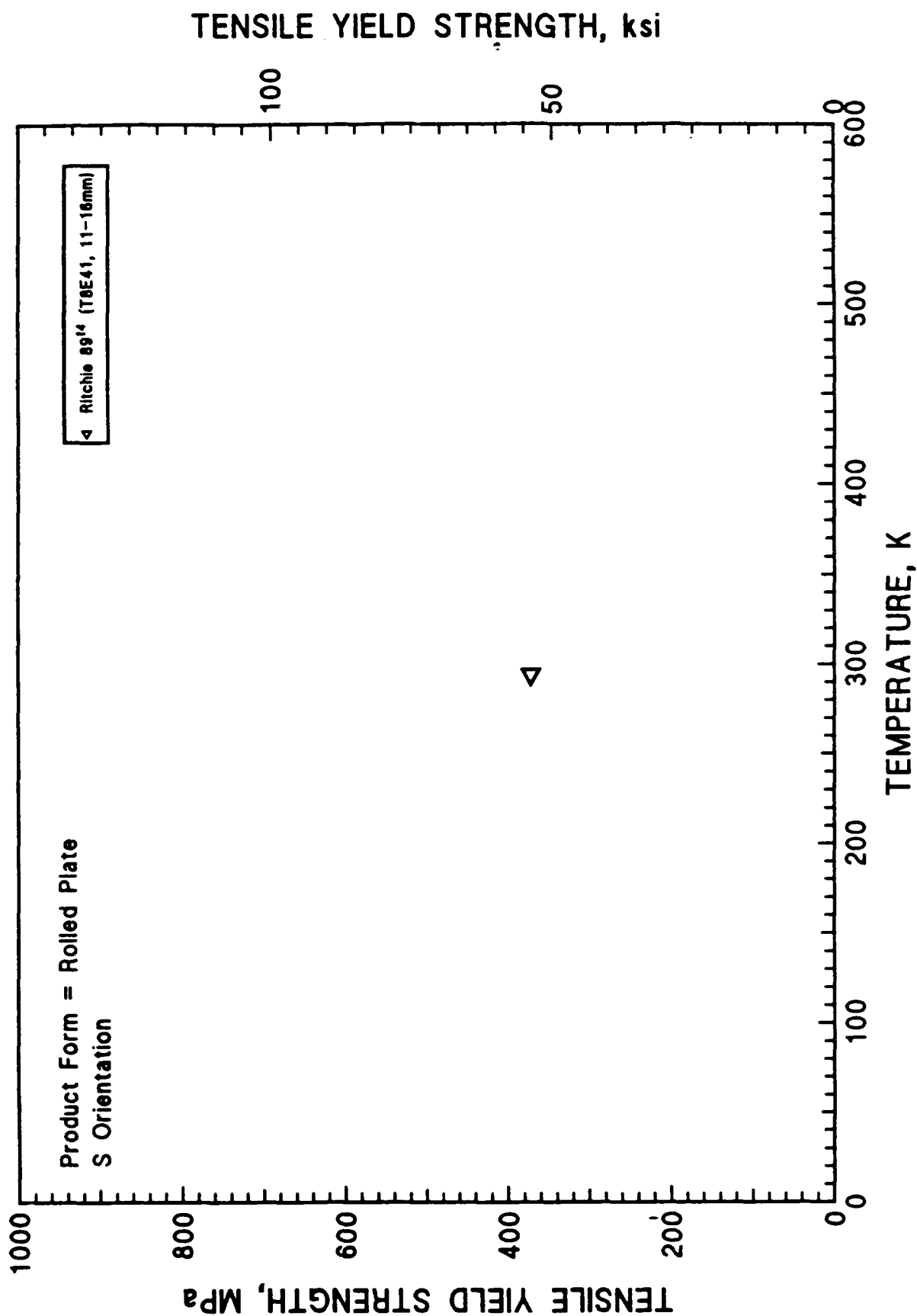




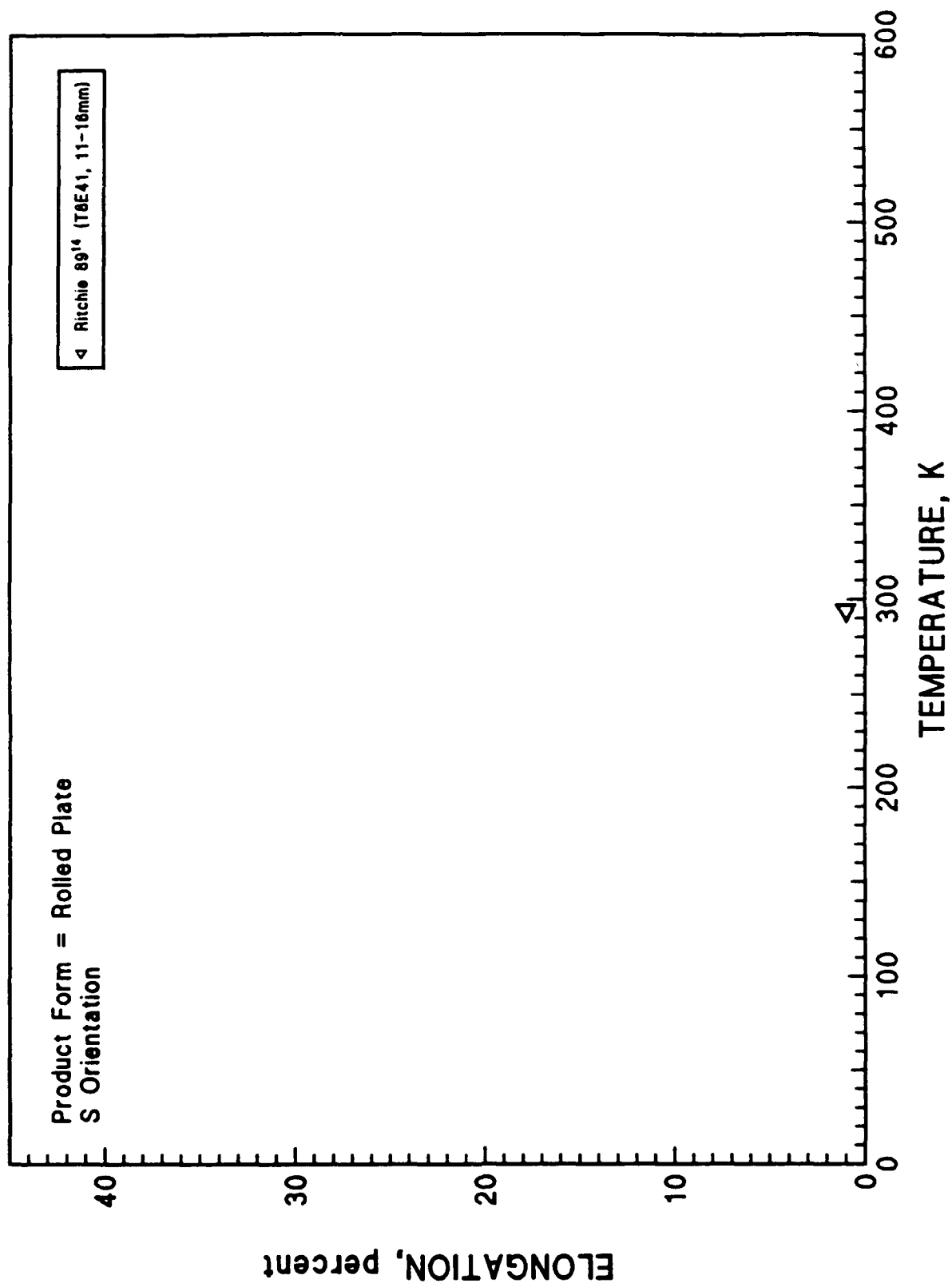
2090-T8



2090-T8



2090-T8



Al-Li ALLOY 2090

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. I	Temper T01	Product		Aging Temp. °C	Time h	Stretch %	Soln. Treat. Temp. °C	Time h	Quench Cond.	Grain Size µm	Hardness	No. of Tests/ Data Pt
								Form	Thickness mm									
1F	295	608.	578.	4.6	17.6	L	T01	Rollled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	108.3	1
1F	295	608.	578.	5.8	17.4	L	T01	Rollled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	108.3	1
1F	76	746.	673.	8.8	3.45	L	T01	Rollled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	108.3	1
1F	76	730.	628.	7.9	6.72	L	T01	Rollled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	108.3	1
1F	20	846.	667.	11.8	13.	L	T01	Rollled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	108.3	1
1F	20	827.	662.	8.6	9.7	L	T01	Rollled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	108.3	1
1F	4	833.	665.	9.2	7.28	L	T01	Rollled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	108.3	1
1F	4	889.	680.	6.4	7.35	L	T01	Rollled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	108.3	1
1H	295	532.	502.	4.8	6.9	L	T01	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	108.3	1
1H	295	529.	500.	4.2	11.6	L	T01	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	108.3	1
1H	76	823.	555.	7.2	7.9	L	T01	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	108.3	1
1H	76	609.	546.	4.8	10.6	L	T01	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	108.3	1
1H	20	666.	586.	6.9	11.9	L	T01	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	108.3	1
1H	20	743.	594.	8.9	8.86	L	T01	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	108.3	1
1H	4	692.	608.	6.5	20.3	L	T01	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	108.3	1
1H	4	684.	592.	6.9	13.7	L	T01	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	108.3	1
13A	293	552.	517.	8.	NA	L	T01	Rollled Plate	6.35-50.8	NA	NA	NA	NA	NA	NA	NA	NA	•
13B	533	138.	117.	25.	NA	L	T01	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. I	Temper °C	Product		Aging Temp. °C	Aging Time h	Stretch %	Soin. Treat.		Quench Cond.	Grain Size µm	Hardness	No. of Tests/ Data Pt
								Form	Thickness mm				Temp. °C	Time h				
13B	505	193.	165.	19.	NA	L	T81	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
13B	477	280.	262.	20.	NA	L	T81	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	2
13B	450	365.	359.	15.	NA	L	T81	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
13B	422	462.	462.	19.	NA	L	T81	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
13B	297	593.	558.	8.	NA	L	T81	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
13C	293	517.	493.	4.	NA	L	T81	Rolled Plate	12.7-38.1	NA	NA	NA	NA	NA	NA	NA	NA	*
12A	219	614.	565.	NA	NA	L	T8	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
12A	77	715.	600.	13.5	NA	L	T8	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
13A	293	490.	441.	4.	NA	L	T8E50	Rolled Plate	6.35-50.8	NA	NA	NA	NA	NA	NA	NA	NA	*
13C	293	490.	434.	5.	NA	L	T8E50	Rolled Plate	12.7-38.1	NA	NA	NA	NA	NA	NA	NA	NA	*
11A	77	715.	600.	13.5	NA	L	T8E41	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
11A	4	820.	615.	17.5	NA	L	T8E41	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
14A	293	589.	552.	9.3	NA	L	T8E41	Rolled Plate	11-16	163	24.	6	NA	NA	NA	L: 2500*; T: 500; S: 50	NA	1
15A	298	565.	535.	11.	NA	L	T8E41	Rolled Plate	13	163	24.	6	NA	NA	NA	L: 2500*; T: 500; S: 50	NA	1
16A	298	490.	455.	6.	NA	L	T8E41	Rolled Plate	12.7	NA	NA	6	NA	NA	NA	NA	NA	1
16A	77	625.	505.	14.	NA	L	T8E41	Rolled Plate	12.7	NA	NA	6	NA	NA	NA	NA	NA	1
16A	4	650.	535.	20.	NA	L	T8E41	Rolled Plate	12.7	NA	NA	6	NA	NA	NA	NA	NA	1
17A	295	555.	535.	9.	15.	L	T8E41	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
17A	76	666.	595.	6.	8.	L	T8E41	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. I	Product Form	Product Thickness mm	Aging Temp. °C	Aging Time h	Stretch %	Soln. Temp. °C	Time h	Quench Cond.	Grain Size µm	Hardness	No. of Tests/Data Pt
17A	4	737.	620.	8.	11.	L	T8E41 Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
6B	300	546.	503.	14.	NA	L	T6X Rolled Plate	12.7	190	4.	2	550	1.	NA	NA	NA	1
6B	300	542.	507.	12.	NA	L	T6X Rolled Plate	12.7	190	8.	2	550	1.	NA	NA	NA	1
6B	77	630.	564.	15.	NA	L	T6X Rolled Plate	12.7	190	8.	2	550	1.	NA	NA	NA	1
6B	77	619.	525.	17.	NA	L	T6X Rolled Plate	12.7	190	4.	2	550	1.	NA	NA	NA	1
16B	298	270.	120.	19.	NA	L	T4 Rolled Plate	3.2	NA	NA	NA	550	0.5	WQ	NA	NA	1
16B	77	350.	155.	29.	NA	L	T4 Rolled Plate	3.2	NA	NA	NA	550	0.5	WQ	NA	NA	1
16B	4	435.	190.	25.	NA	L	T4 Rolled Plate	3.2	NA	NA	NA	550	0.5	WQ	NA	NA	1
1F	295	595.	557.	3.7	12.5	T	T61 Rolled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	198.3	1
1F	295	600.	561.	4.3	13.3	T	T61 Rolled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	198.3	1
1F	76	686.	624.	0.4	3.51	T	T61 Rolled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	198.3	1
1F	76	698.	623.	2.9	5.16	T	T61 Rolled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	198.3	1
1F	20	761.	684.	3.5	7.53	T	T61 Rolled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	198.3	1
1F	20	767.	682.	2.8	5.97	T	T61 Rolled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	198.3	1
1F	4	754.	666.	2.2	5.56	T	T61 Rolled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	198.3	1
1F	4	767.	675.	2.5	3.84	T	T61 Rolled Plate	19.05	NA	NA	NA	NA	NA	NA	NA	198.3	1
1H	295	544.	509.	1.	3.04	T	T61 Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	198.3	1
1H	295	548.	505.	1.2	6.12	T	T61 Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	198.3	1
1H	76	611.	573.	1.	4.93	T	T61 Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	198.3	1

*See Comments

Ref. & Note	Temp. K	I.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper	Product		Aging		Soln. Treat.		Grain Size μm	Hardness	No. of Tests/ Data Pt
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h	Quench Cond.	
1H	76	609.	566.	0.5	3.28	T	T81	Rollled Plate	12.7	NA	NA	NA	NA	NA	198.3	1
1H	20	652.	618.	2.	2.09	T	T81	Rollled Plate	12.7	NA	NA	NA	NA	NA	198.3	1
1H	20	691.	608.	0.25	2.98	T	T81	Rollled Plate	12.7	NA	NA	NA	NA	NA	198.3	1
1H	4	668.	620.	0.5	3.68	T	T81	Rollled Plate	12.7	NA	NA	NA	NA	NA	198.3	1
1H	4	670.	622.	1.	3.91	T	T81	Rollled Plate	12.7	NA	NA	NA	NA	NA	198.3	1
13B	533	185.	145.	20.	NA	T	T81	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
13B	505	228.	193.	17.	NA	T	T81	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
13B	477	296.	276.	12.	NA	T	T81	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	2
13B	450	476.	386.	9.	NA	T	T81	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
13B	422	476.	386.	7.	NA	T	T81	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
13B	297	586.	552.	6.	NA	T	T81	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	4
13B	219	607.	565.	4.	NA	T	T81	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	2
13E	293	517.	469.	3.	NA	T	T81	Rollled Plate	12.7-38.1	NA	NA	NA	NA	NA	NA	*
13C	293	490.	414.	5.	NA	T	T8E50	Rollled Plate	12.7-38.1	NA	NA	NA	NA	NA	NA	*
11B	298	565.	535.	5.5	NA	T	T8E41	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
11B	77	695.	625.	5.5	NA	T	T8E41	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
11B	4	815.	705.	6.5	NA	T	T8E41	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
14A	293	579.	548.	5.4	NA	T	T8E41	Rollled Plate	11-16	163	24.	6	NA	NA	L:2500*; T:500; S:50	1
1H	295	515.	463.	4.	9.	45°	T81	Rollled Plate	12.7	NA	NA	NA	NA	NA	198.3	1

*See Comments

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. Z	Temper Form	Product		Aging		Soln. Treat.		Grain Size µm	Hardness	No. of Tests/ Data Pt
								Thickness mm	Time h	Temp. °C	Stretch %	Time h	Quench Cond.			
1H	293	523.	470.	6.	11.	45°	T81	12.7	NA	NA	NA	NA	NA	NA	198.3	1
1H	76	558.	502.	3.	7.	45°	T81	12.7	NA	NA	NA	NA	NA	NA	198.3	1
1H	76	572.	508.	4.	7.	45°	T81	12.7	NA	NA	NA	NA	NA	NA	198.3	1
1H	4	636.	550.	5.	8.	45°	T81	12.7	NA	NA	NA	NA	NA	NA	198.3	1
1H	4	626.	547.	5.	10.	45°	T81	12.7	NA	NA	NA	NA	NA	NA	198.3	1
13C	293	462.	359.	8.	NA	45°	T8E50	12.7-38.1	NA	NA	NA	NA	NA	NA	NA	*
14A	293	514.	460.	10.9	NA	45°	T8E41	11-16	163	24.	6	NA	NA	L: 2500*; T: 500; S: 50	NA	1
1G	293	604.	NA	NA	NA	S	T81	19.05	NA	NA	NA	NA	NA	NA	198.3	1
1G	293	611.	NA	NA	NA	S	T81	19.05	NA	NA	NA	NA	NA	NA	198.3	1
1G	76	627.	NA	NA	NA	S	T81	19.05	NA	NA	NA	NA	NA	NA	198.3	1
1G	76	649.	NA	NA	NA	S	T81	19.05	NA	NA	NA	NA	NA	NA	198.3	1
1G	4	741.	NA	NA	NA	S	T81	19.05	NA	NA	NA	NA	NA	NA	198.3	1
1G	4	697.	NA	NA	NA	S	T81	19.05	NA	NA	NA	NA	NA	NA	198.3	1
1I	293	566.	NA	NA	NA	S	T81	12.7	NA	NA	NA	NA	NA	NA	198.3	1
1I	4	690.	NA	NA	NA	S	T81	12.7	NA	NA	NA	NA	NA	NA	198.3	1
14B	293	448.	372.	1.	NA	S	T8E41	11-16	163	24.	6	NA	NA	L: 2500*; T: 500; S: 50	NA	1

*See Comments

Comments from the Al-Li Alloy 2090 Data Table

Reference and
Note Number

13A--Values reported are "typical" properties.

13C--Values reported are "minimum" properties.

13E--Values reported are "minimum" properties.

14A--Value reported is the average of the range of grain sizes.

14B--Value reported is the average of the range of grain sizes.

15A--Value reported is the average of the range of grain sizes.

TEST PARAMETERS
Al-Li ALLOY 2090

Ref & Strain Note		Specimen				Expo Time min	Supplier	Yr. Prod.	Lot No.	Product L(m) X W(m)	Major Elements							Minor Elements wt%	
		Type	Diam mm	Thick mm	G.L. mm						Specimen Location	Li	Cu	Mg	Zr wt%	Si	Fe		Ag
1F	2.2	Round	6.35	NA	25.4	Mid-plane	5.	Alcoa	1989	103299	1.22 X 2.44	2.3	2.6	0.1	0.1	NA	0.07	NA	NA
1G	2.2	Round	2.5	NA	25.4	Random	5.	Alcoa	1989	103299	1.22 X 2.44	2.3	2.8	0.1	0.1	NA	0.07	NA	NA
1H	2.2	Round	6.35	NA	25.4	Mid-plane	5.	Alcoa	1989	103301	1.22 X 2.44	2.3	2.7	0.	0.12	NA	0.08	NA	NA
1I	2.2	Round	2.5	NA	25.4	Random	5.	Alcoa	1989	103301	1.22 X 2.44	2.3	2.7	NA	0.12	NA	0.08	NA	NA
6B	1.0	Round	NA	NA	NA	NA	15.	Alcoa	NA	NA	NA	2.53	1.8	0.5	0.13	0.3	0.3	NA	NA
11A	NA	Round	NA	NA	25.4	NA	NA	Alcoa	NA	NA	NA	2.2*	2.7	NA	0.12	NA	NA	NA	NA
11B	NA	Round	NA	NA	25.4	NA	NA	Alcoa	NA	NA	NA	2.2*	2.7	NA	0.12	NA	NA	NA	NA
12A	NA	NA	NA	NA	NA	NA	NA	Alcoa	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
13A	NA	Flat	NA	NA	NA	Random	NA	Alcoa	NA	NA	NA	2.3*	2.7	0.3	0.12	0.1	0.12	NA	Ti:0.15;Zn:0.10;Cr:0.05
13B	NA	Flat	NA	NA	NA	Random	NA	Alcoa	NA	NA	2.54	2.3*	2.7	0.3	0.12	0.1	0.12	NA	Ti:0.15;Zn:0.10;Cr:0.05
13C	NA	Flat	NA	NA	NA	Random	NA	Alcoa	NA	NA	NA	2.3*	2.7	0.3	0.12	0.1	0.12	NA	Ti:0.15;Zn:0.10;Cr:0.05
14A	NA	Round	6.4	NA	25.	Mid-plane	NA	Alcoa	NA	NA	NA	2.1*	2.9	0.	0.12	E-2	0.02	NA	Zn:0.005; Ti:0.02
14B	NA	Round	6.4	NA	25.	Mid-plane	NA	Alcoa	NA	NA	NA	2.1*	2.9	0.	0.12	E-2	0.02	NA	Zn:0.005; Ti:0.02
15A	NA	NA	NA	NA	NA	NA	NA	Alcoa	NA	NA	NA	2.05	2.9	0.	0.12	E-2	0.02	NA	Mn:0.05; Ti:0.02
16A	8.0	Flat	9.5	3.2	41.	4 the thickness	NA	Alcoa	NA	NA	NA	2.05	2.9	NA	0.12	NA	NA	NA	NA
16B	8.0	Flat	9.5	3.2	41.	4 the thickness	NA	Alcoa	NA	NA	NA	2.05	2.9	NA	0.12	NA	NA	NA	NA
17A	2.2	Round	6.35	NA	25.4	NA	5.	Alcoa	NA	NA	1.22 X 1.22	2.05	2.9	NA	0.12	NA	NA	NA	NA

Comments from the Al-Li Alloy 2090 Test Parameter Table

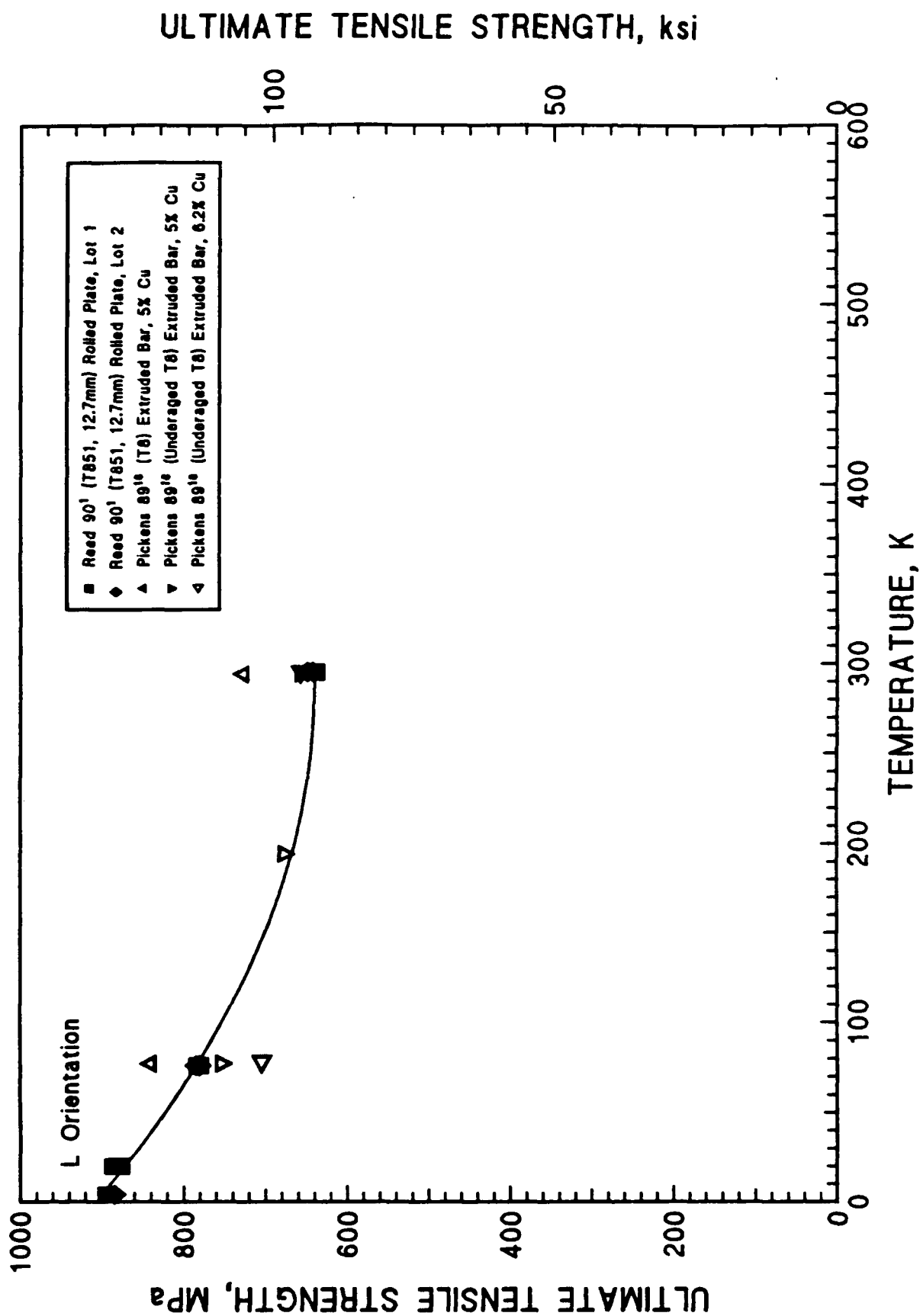
Reference and
Note Number

11A--Reported composition is based on nominal values.

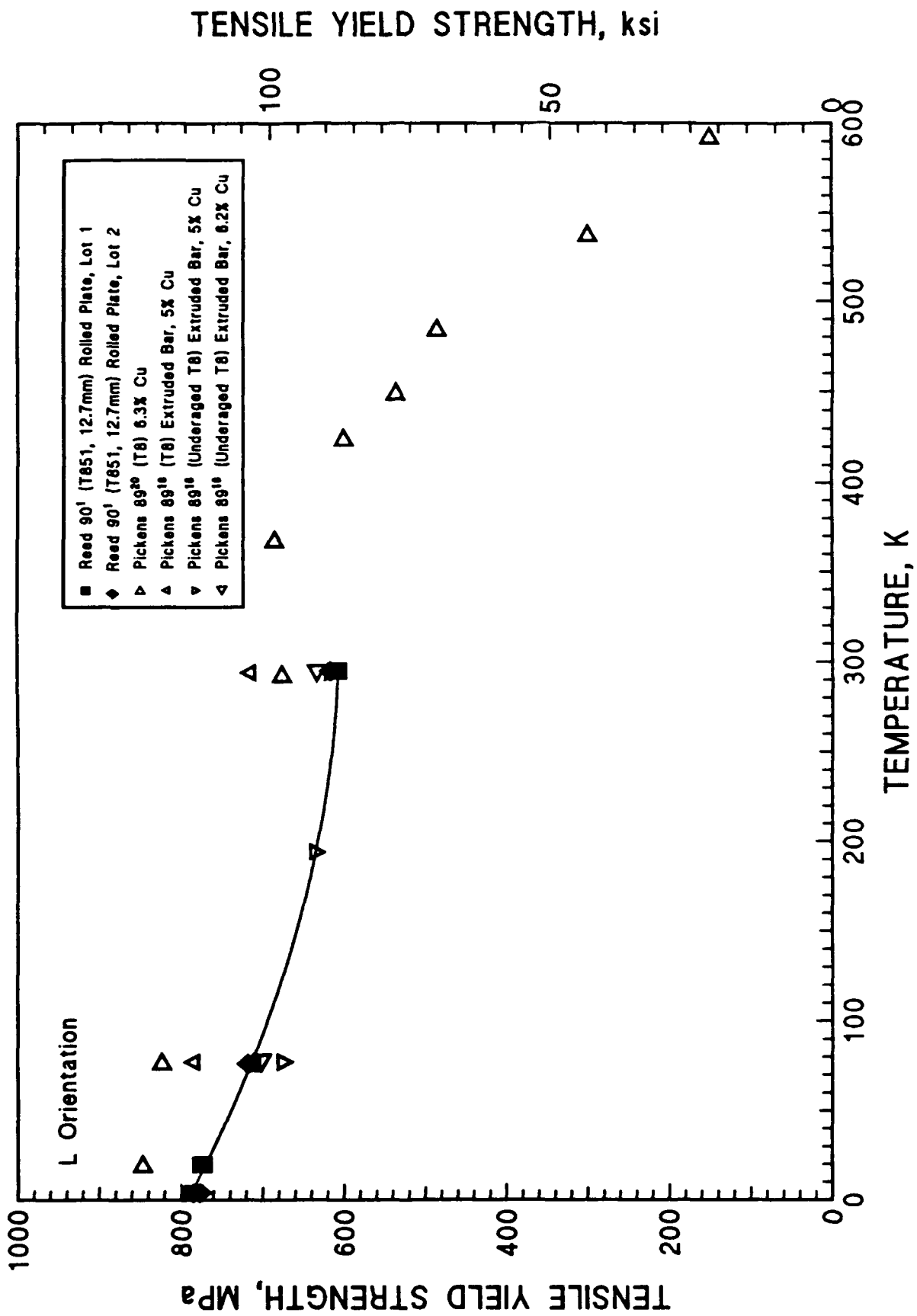
13A-C--Reported composition is the average of the minimum and maximum values.

14A--Reported composition is based on nominal values.

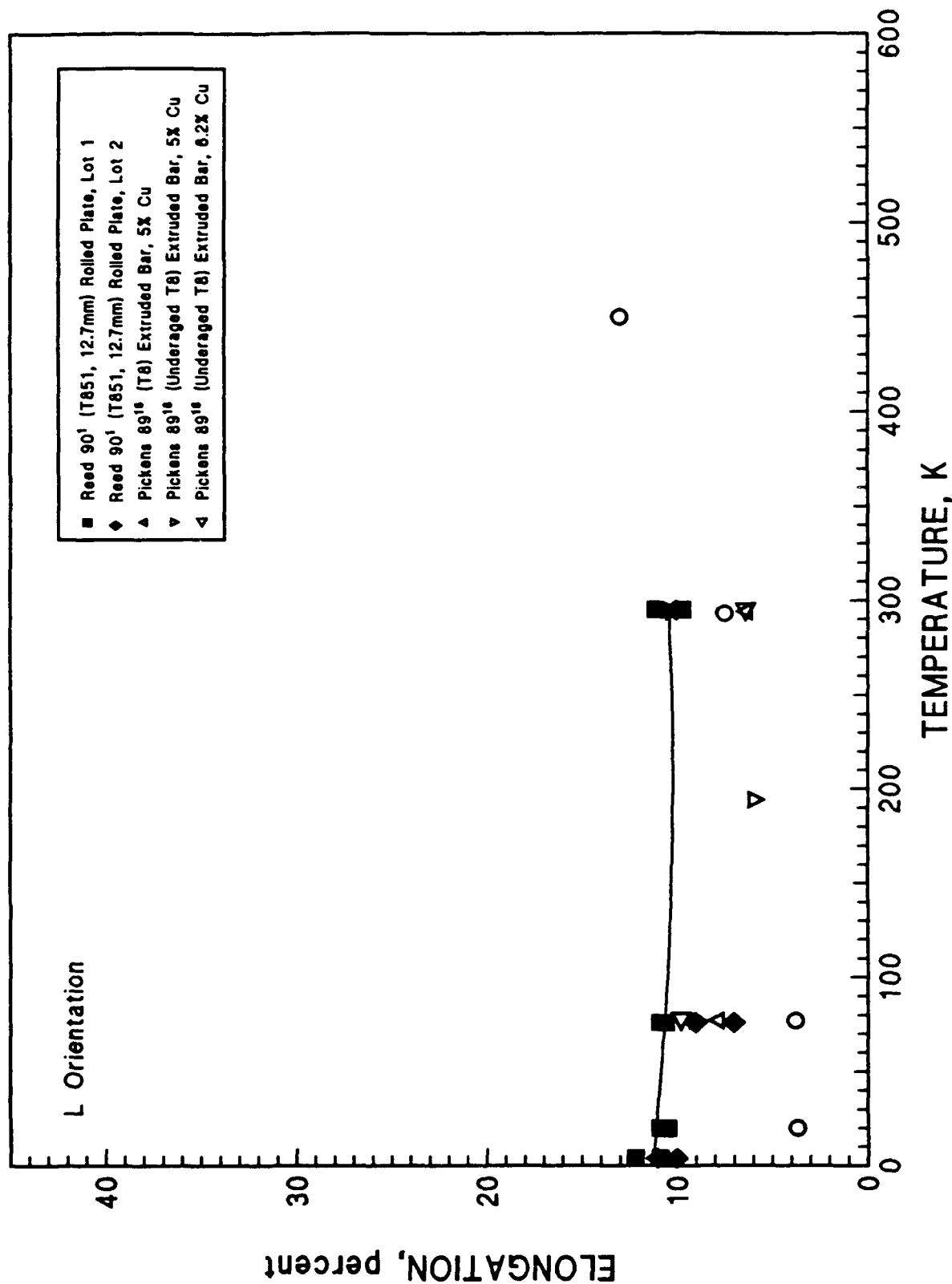
WL049-T8



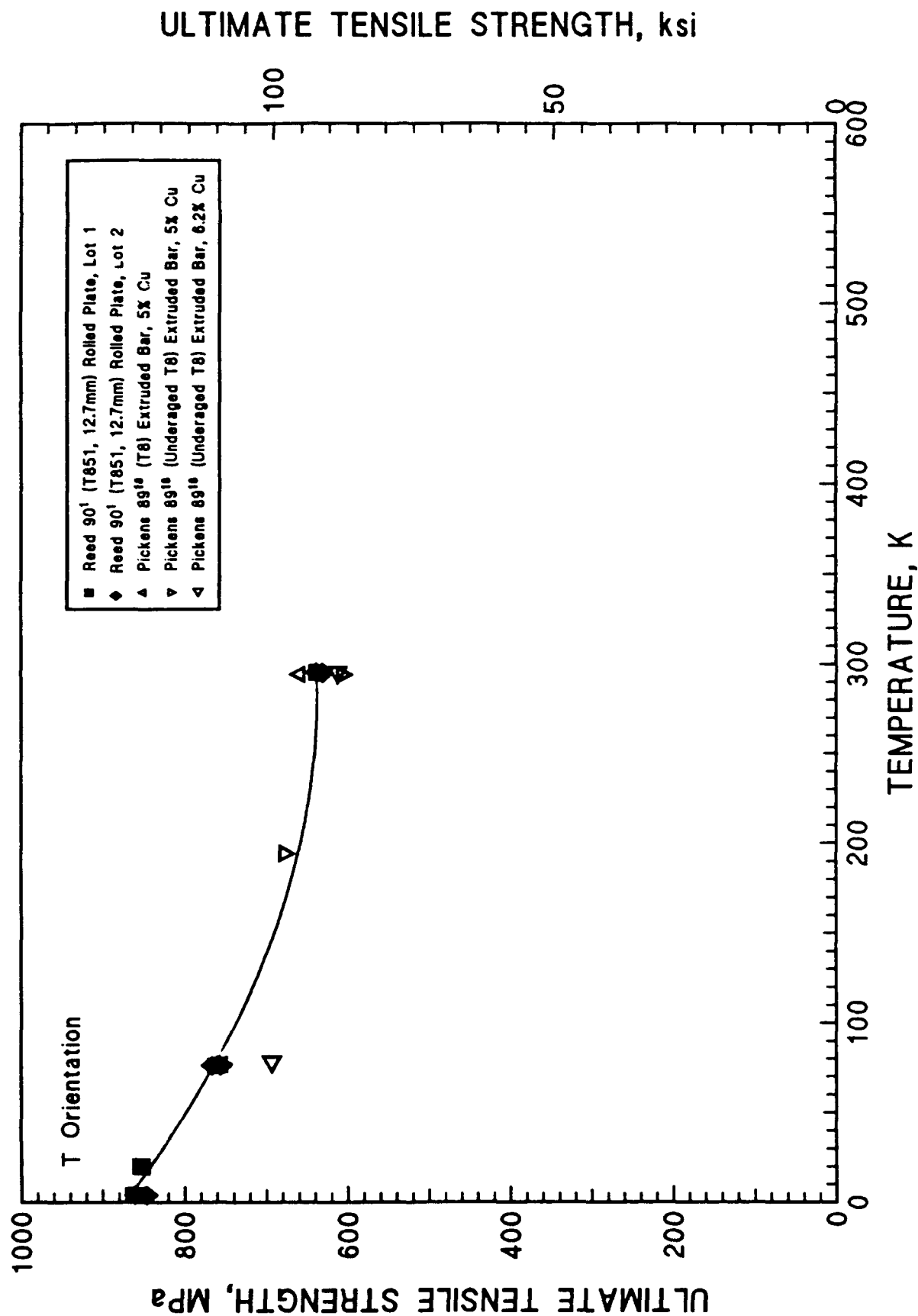
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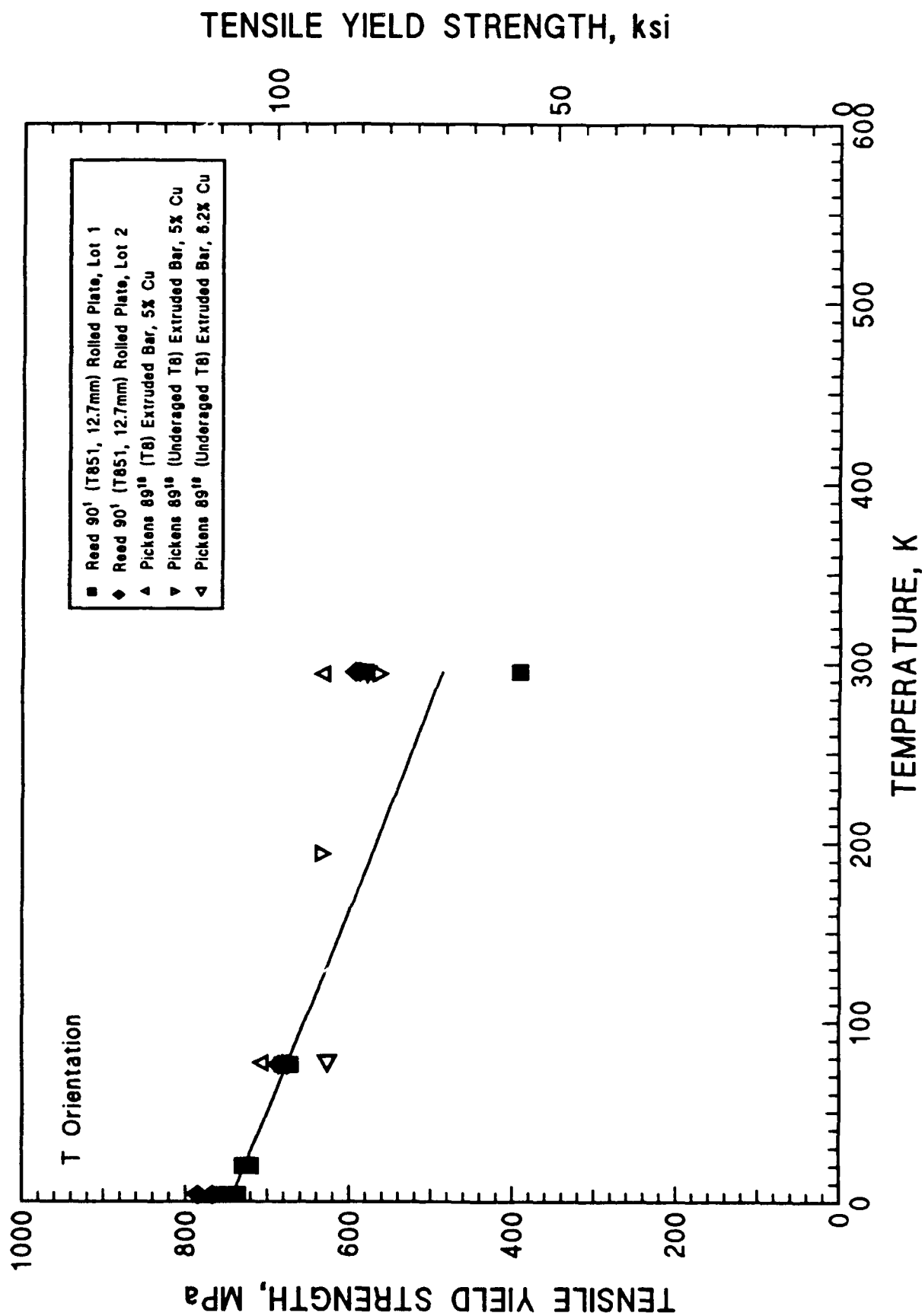
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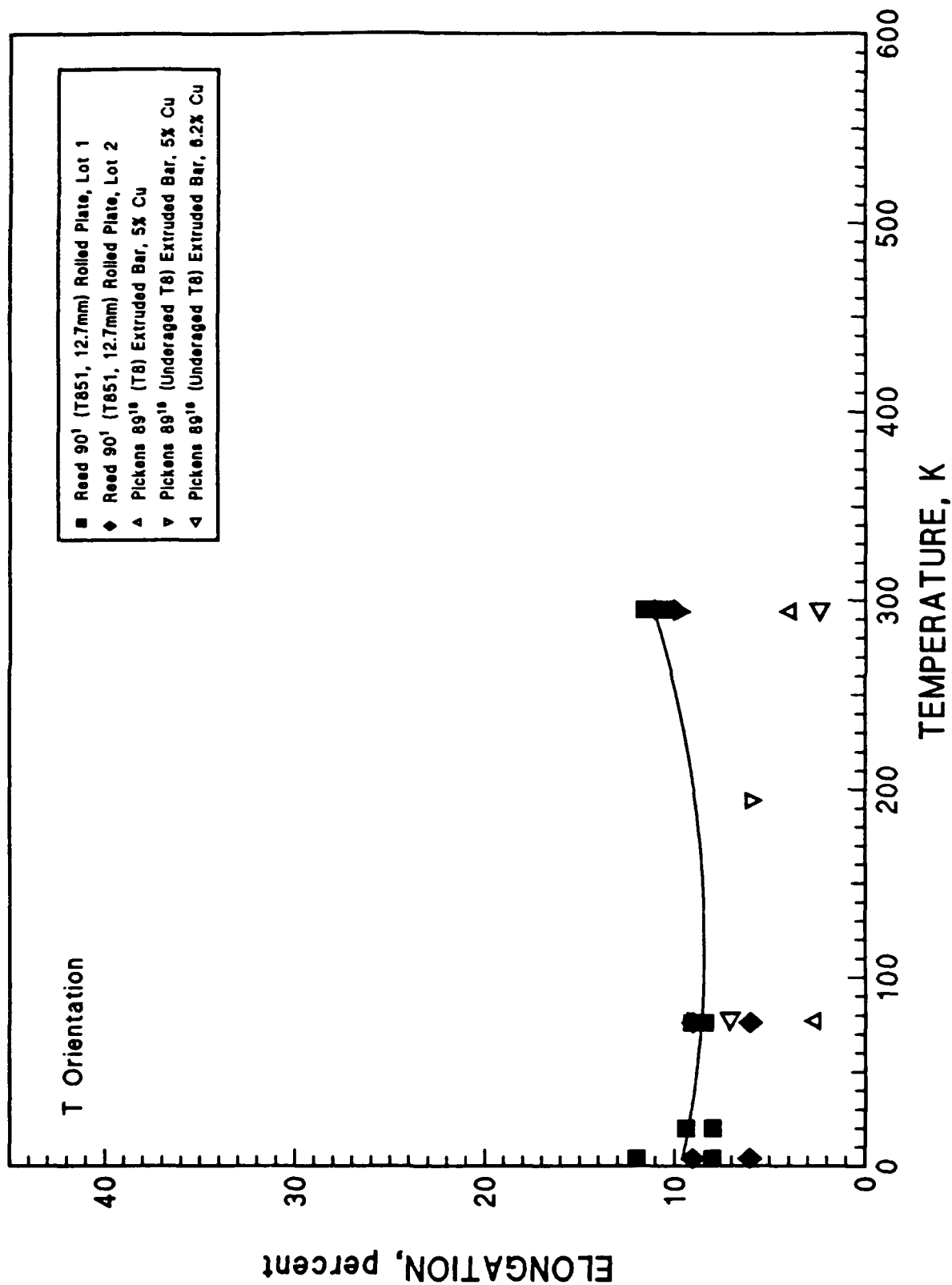
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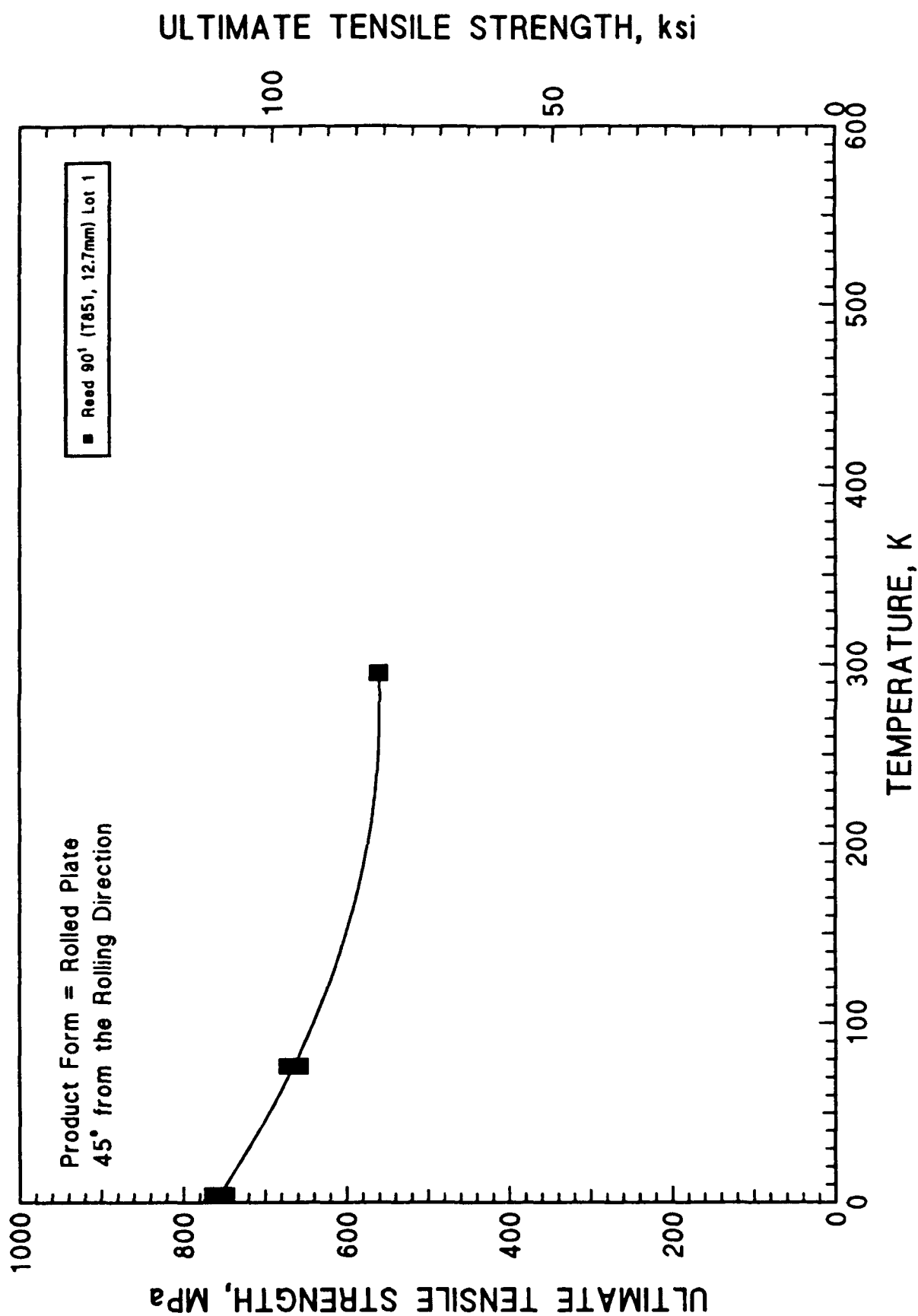
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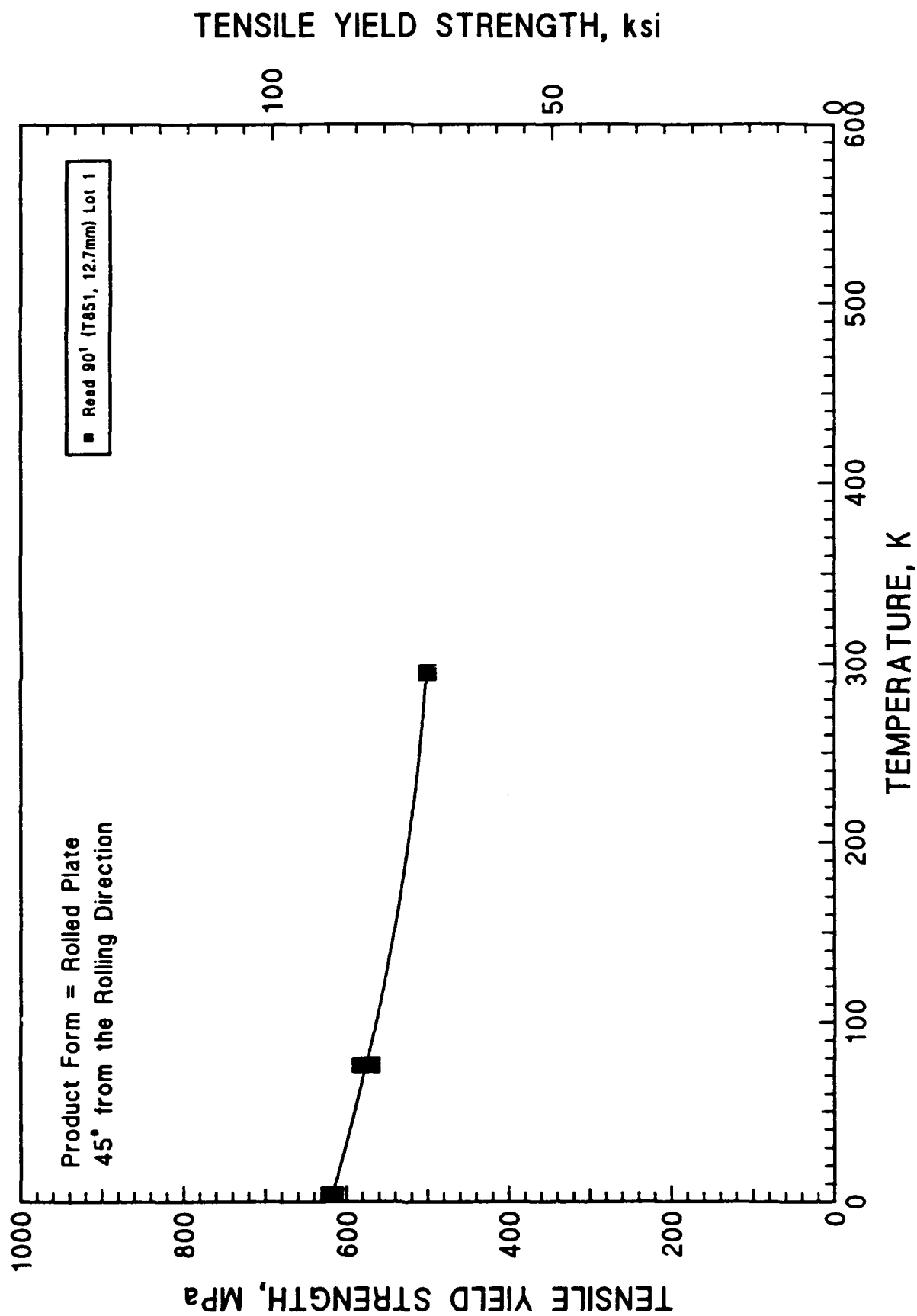
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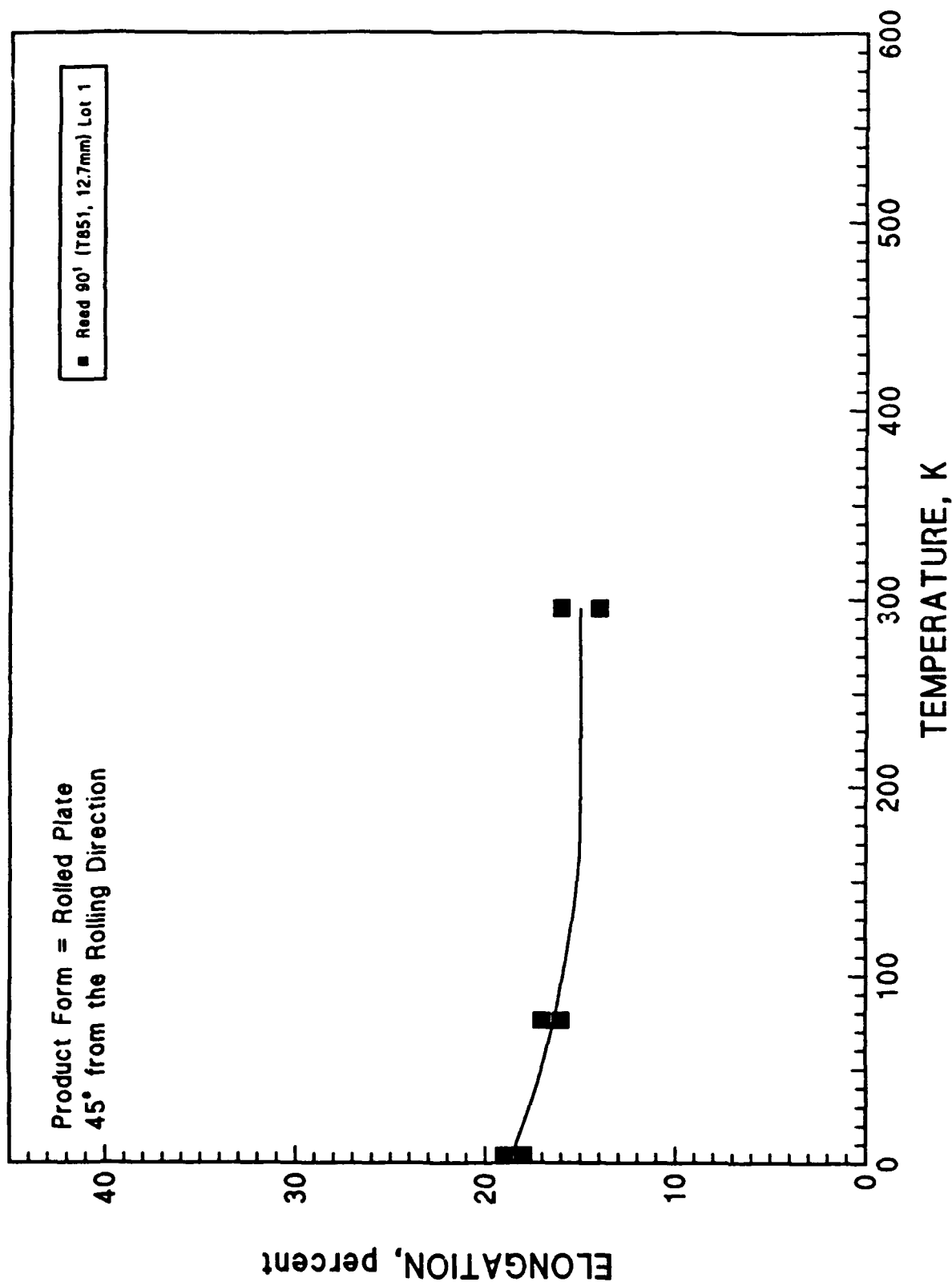
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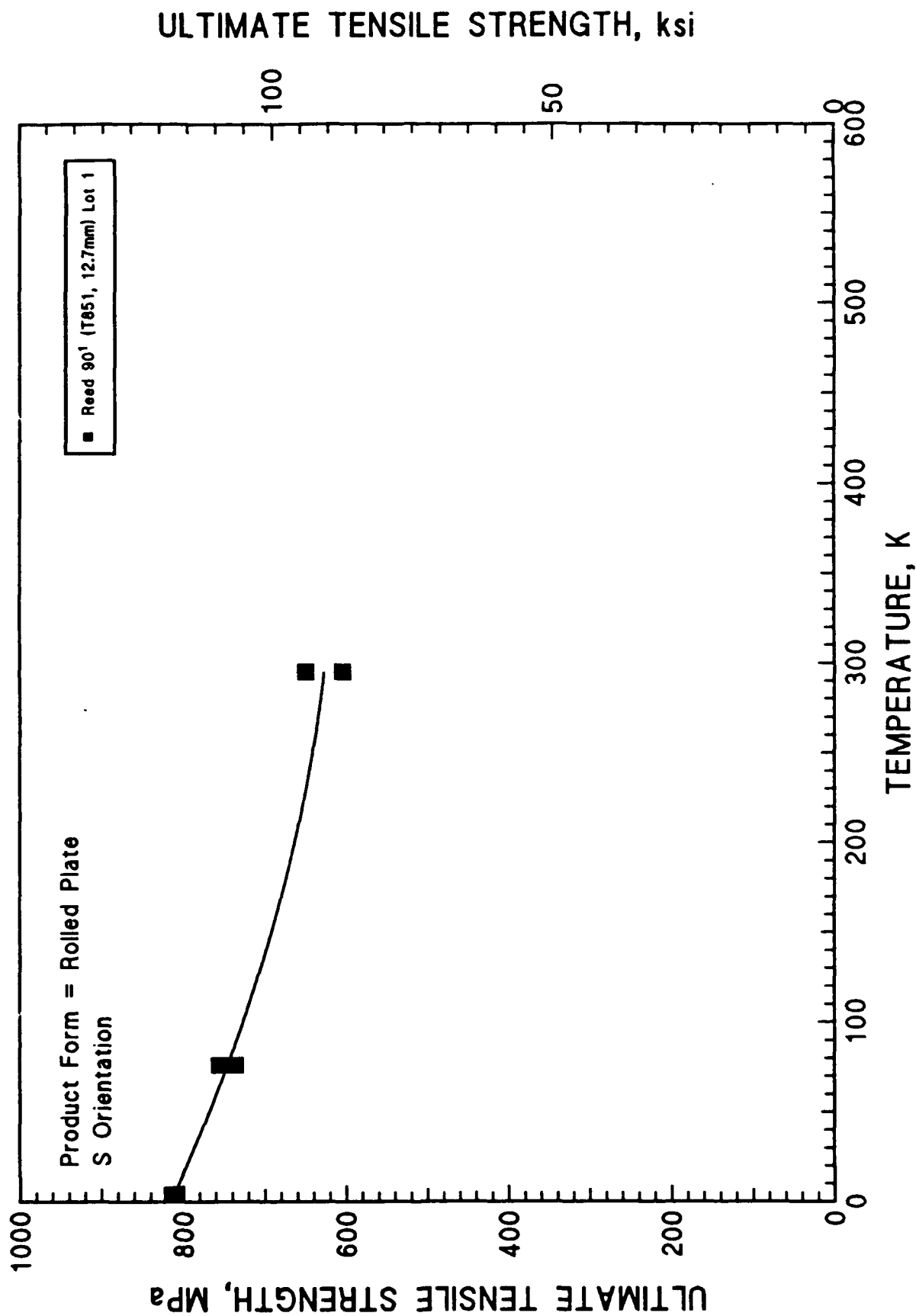
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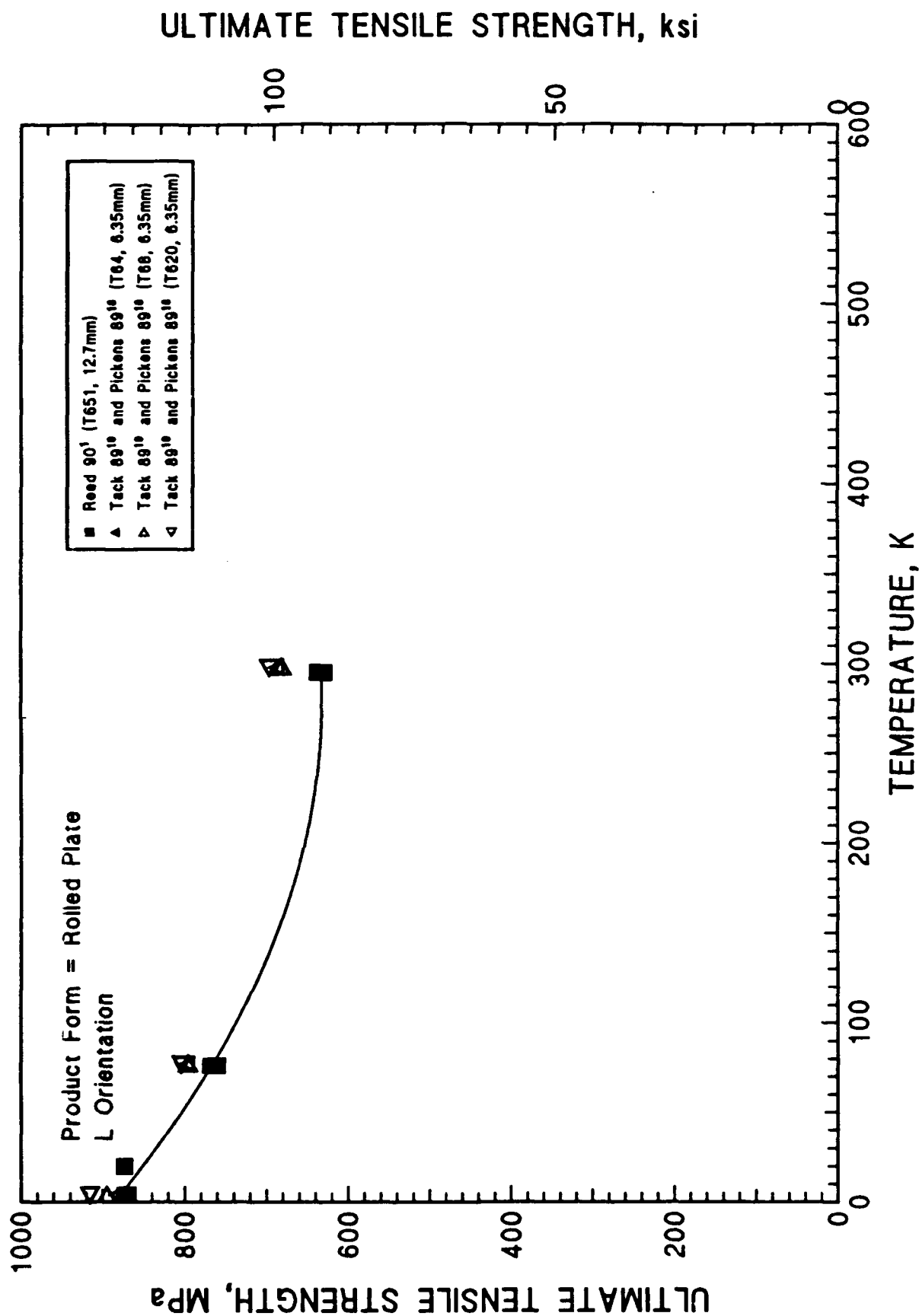
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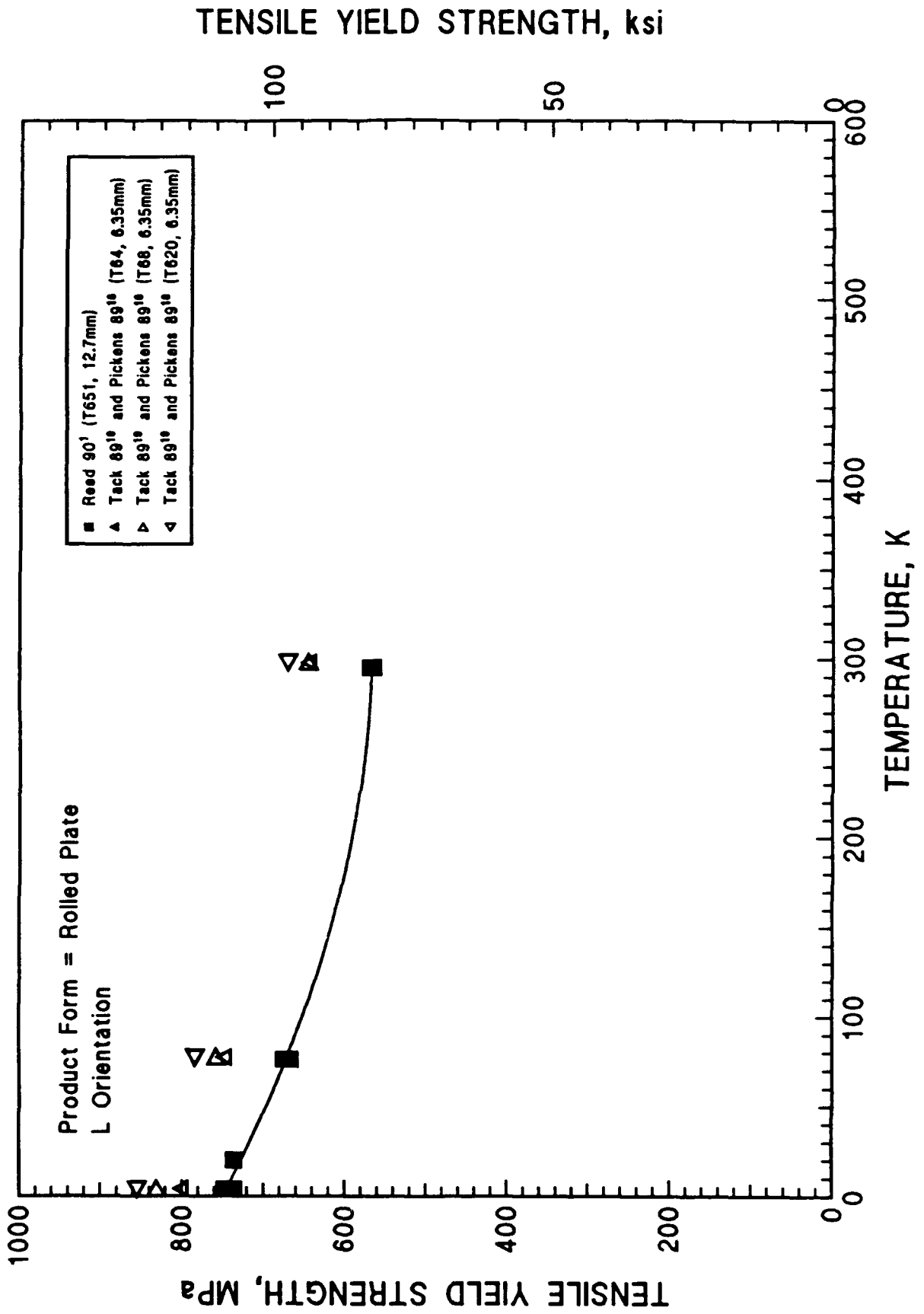
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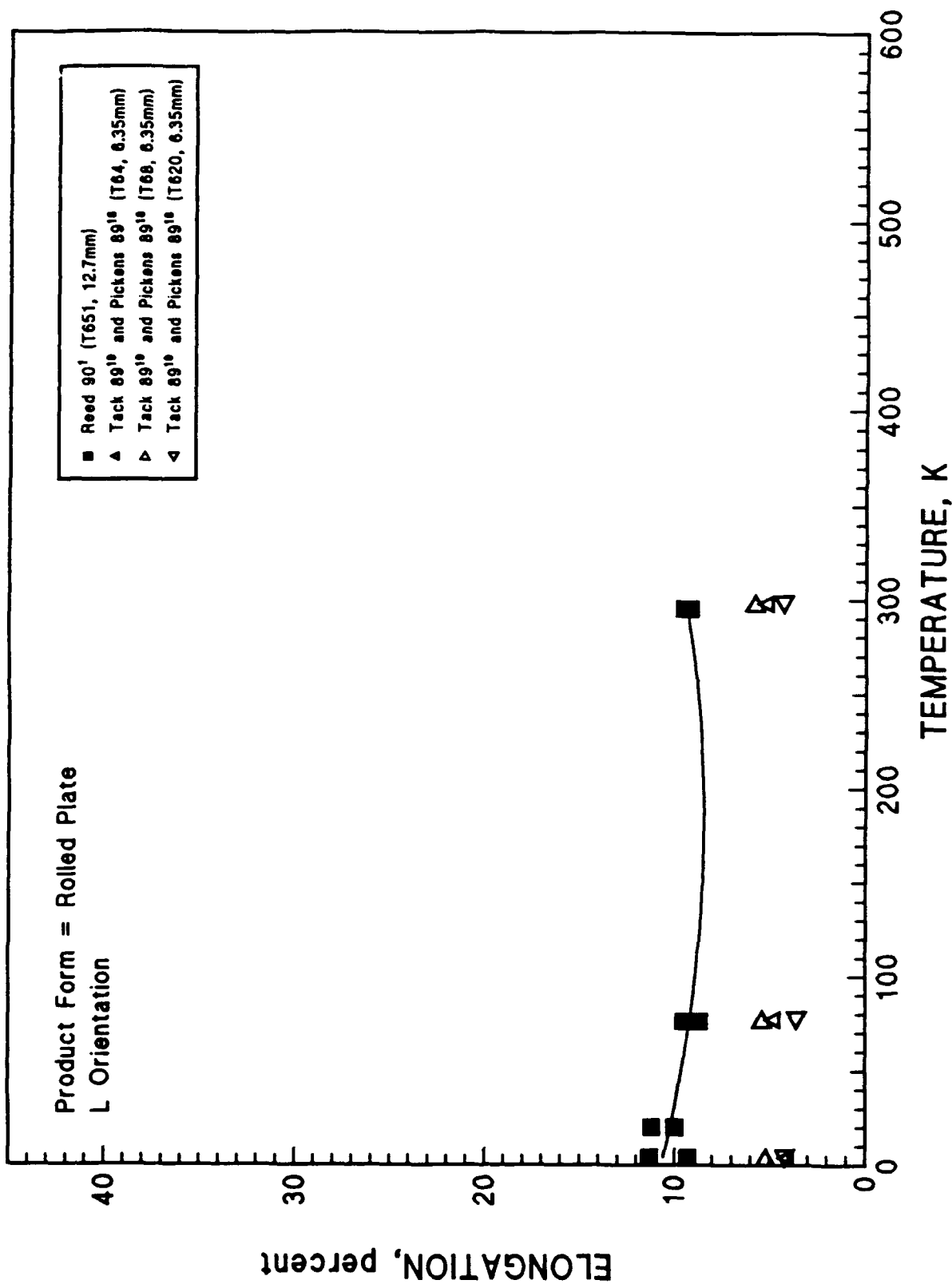
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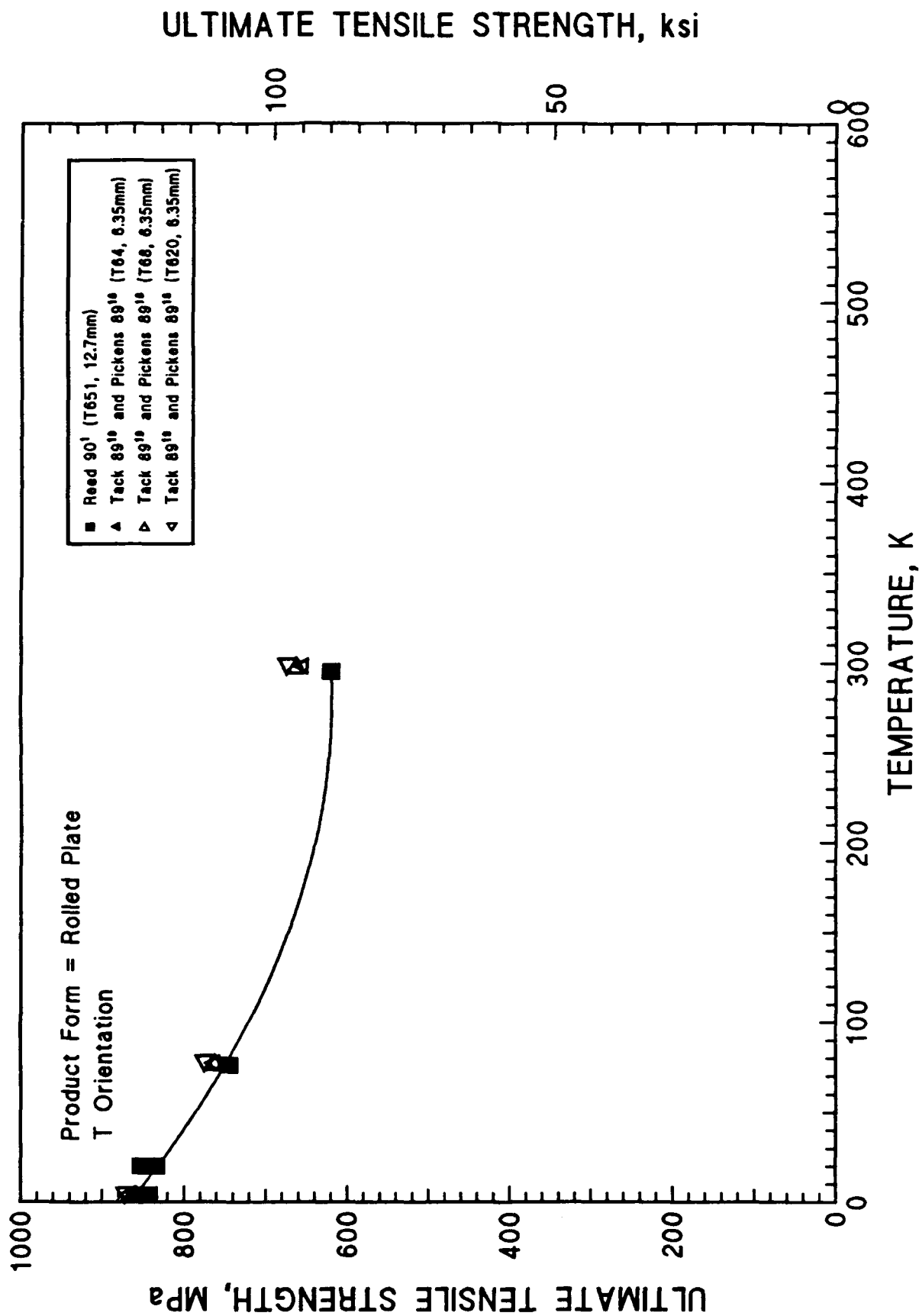
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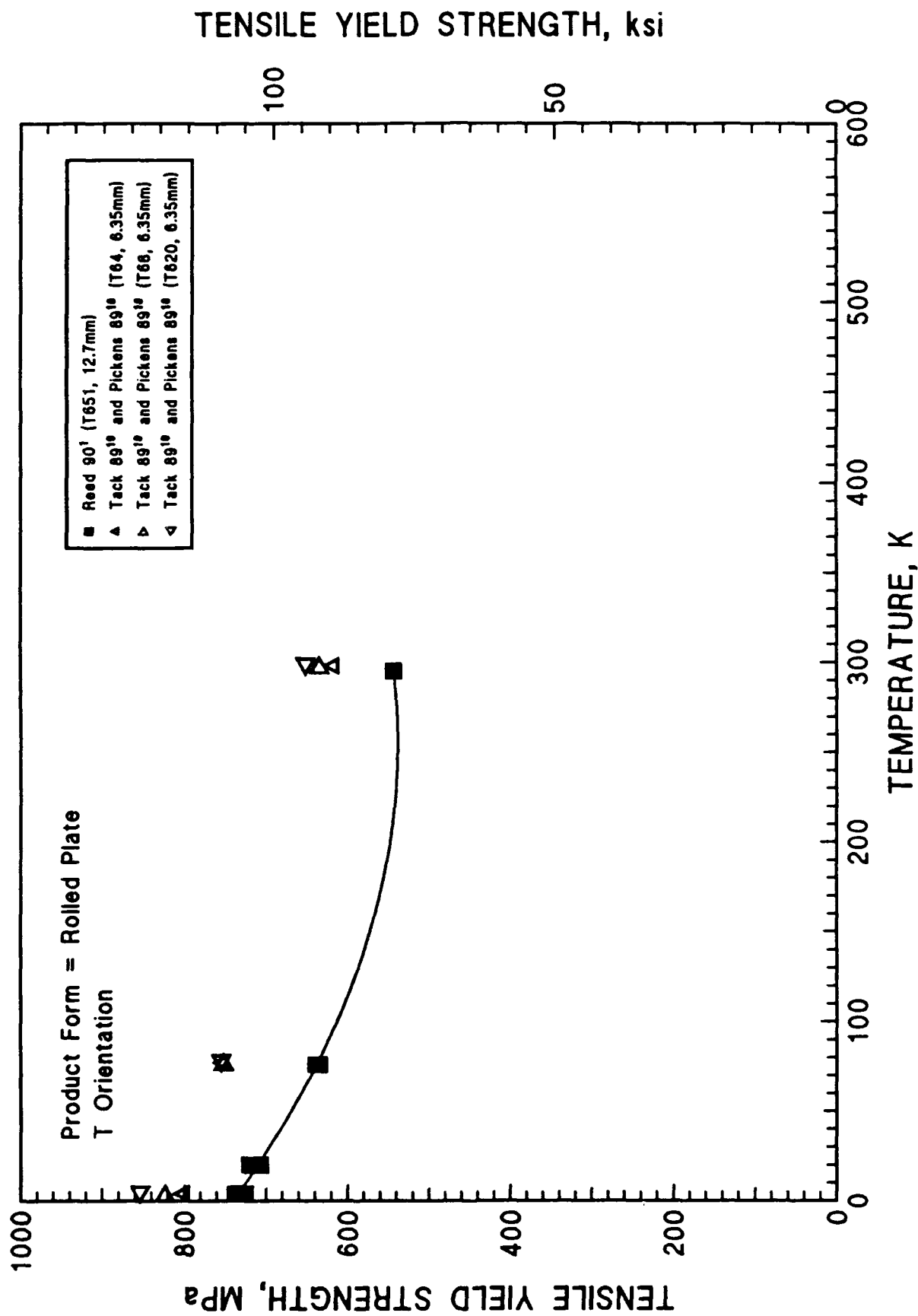
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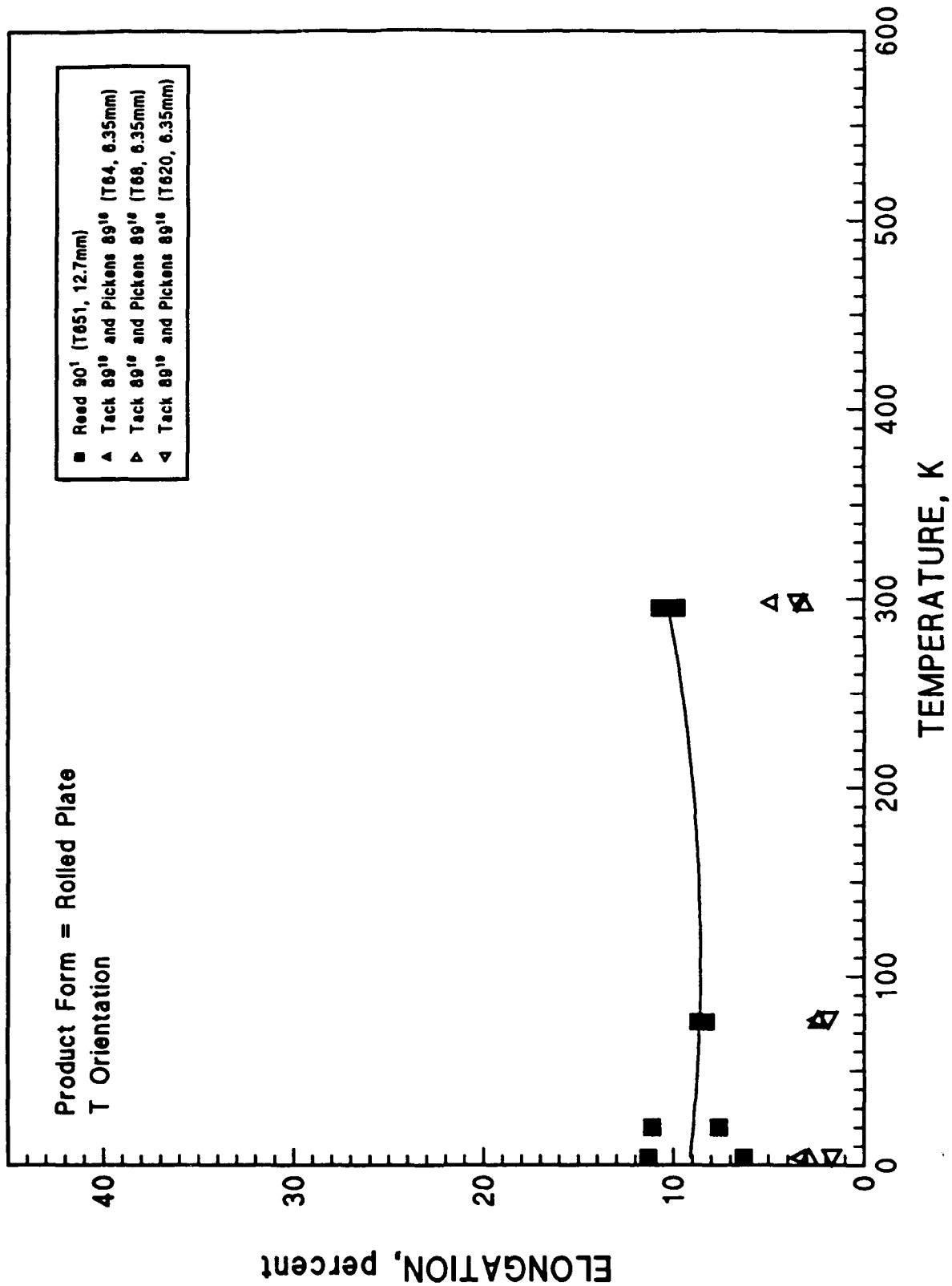
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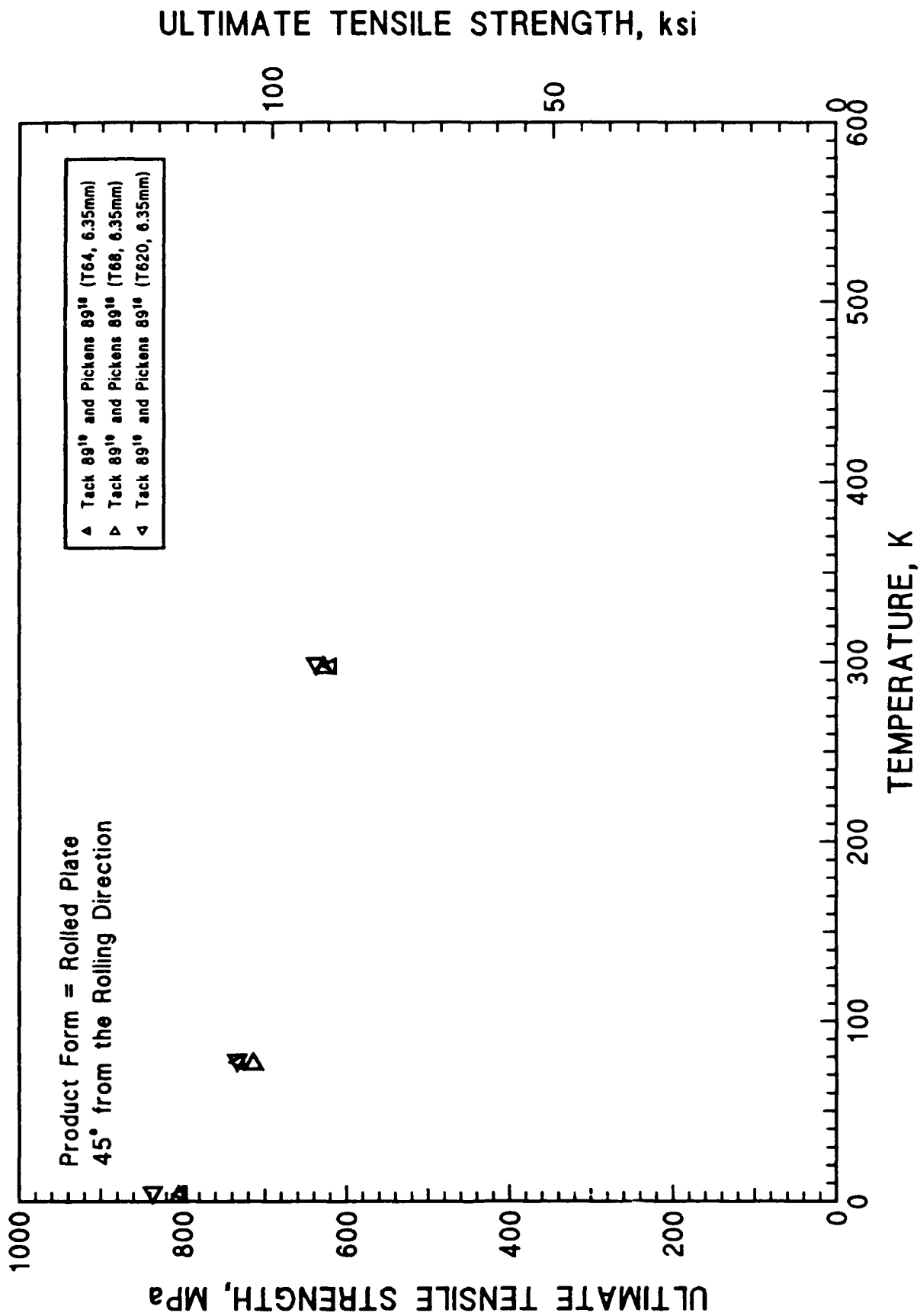
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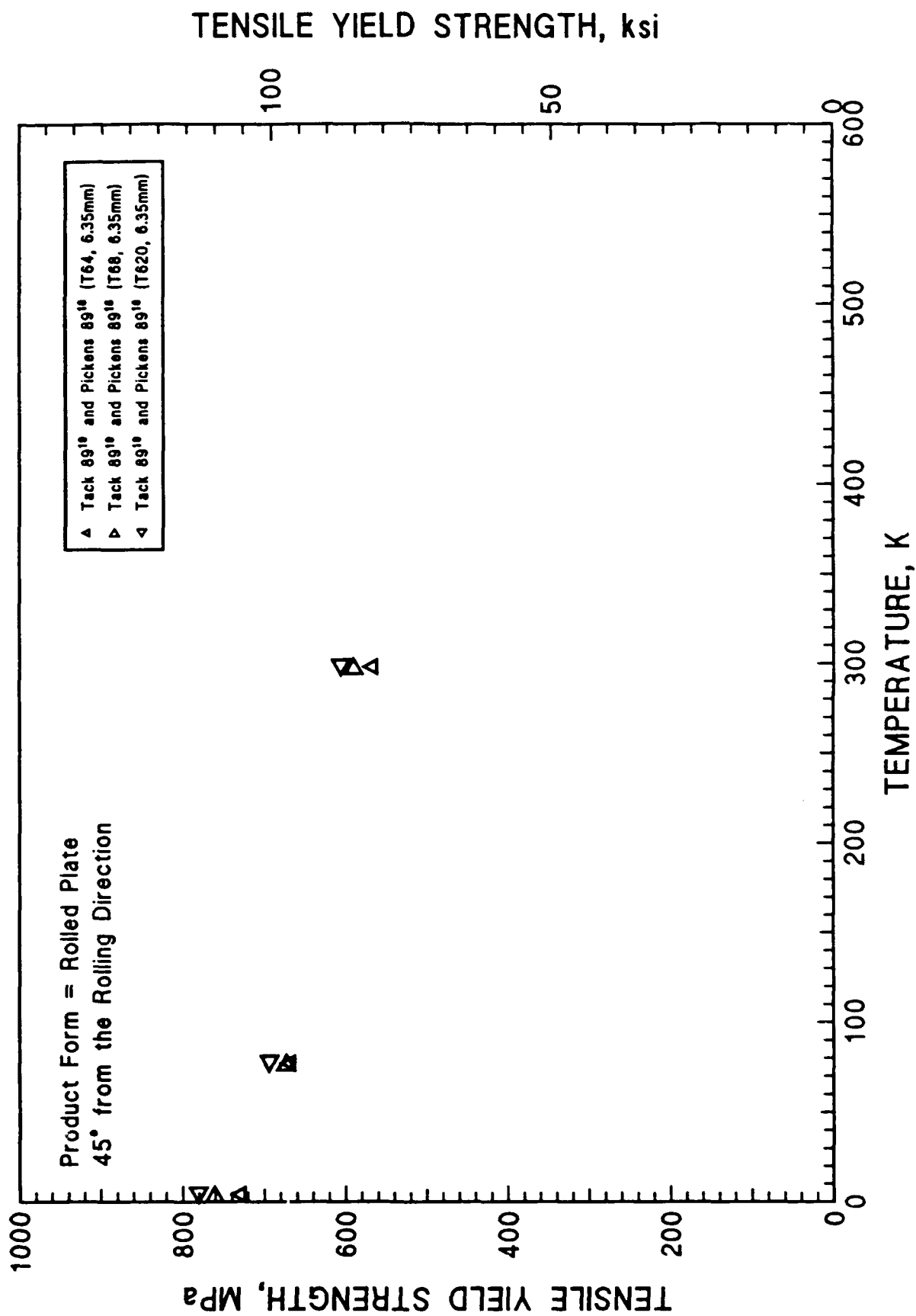
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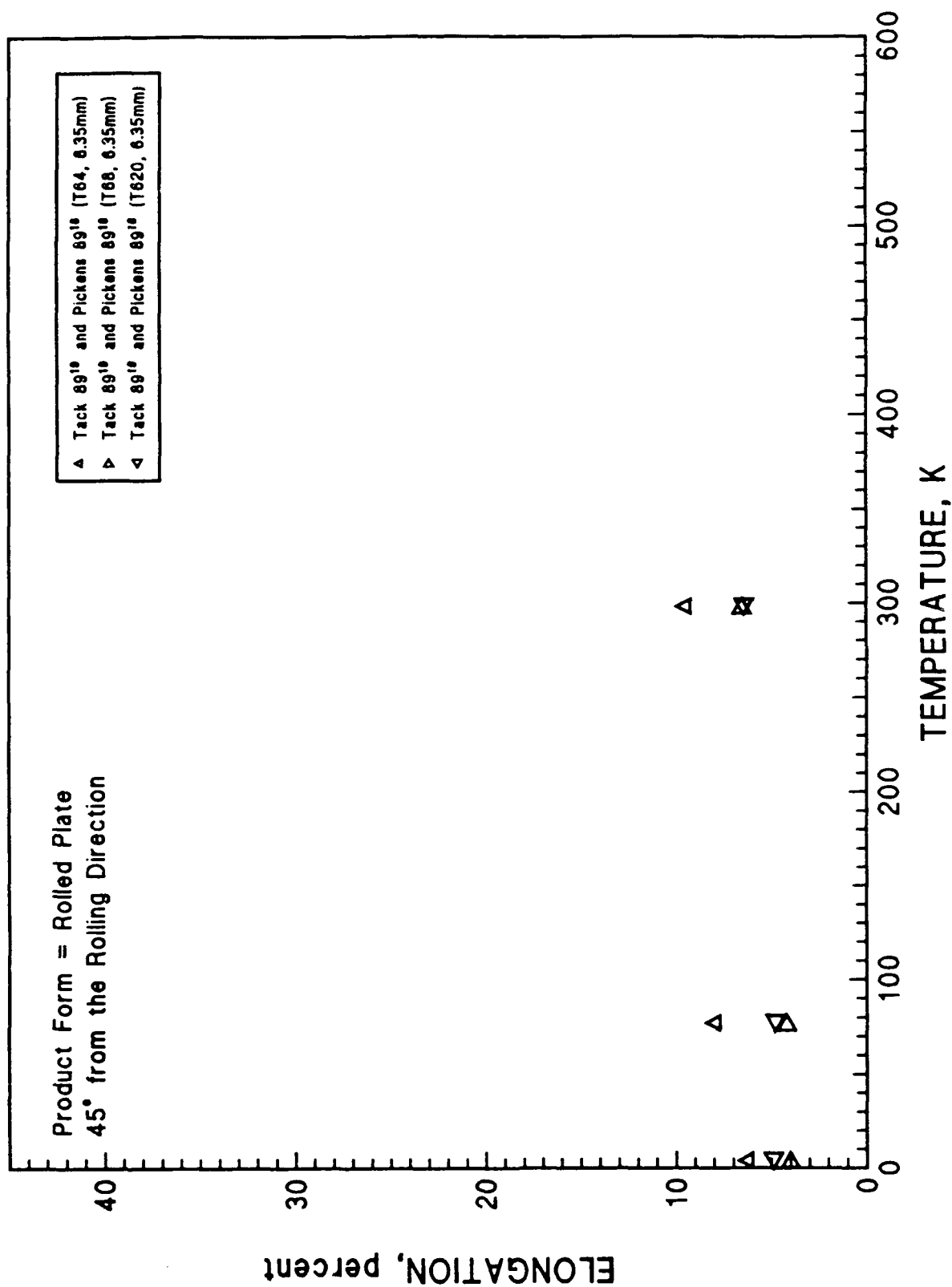
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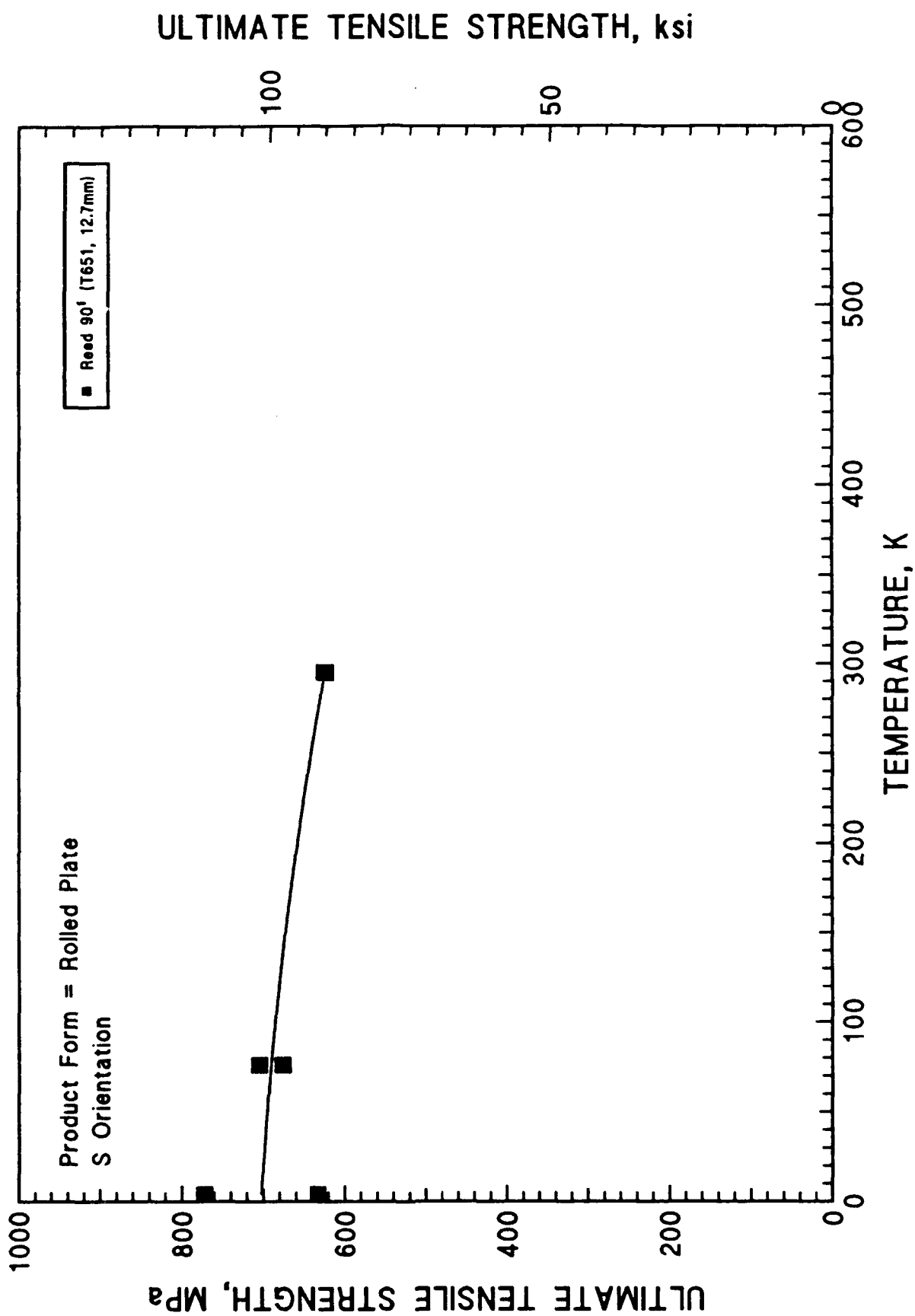
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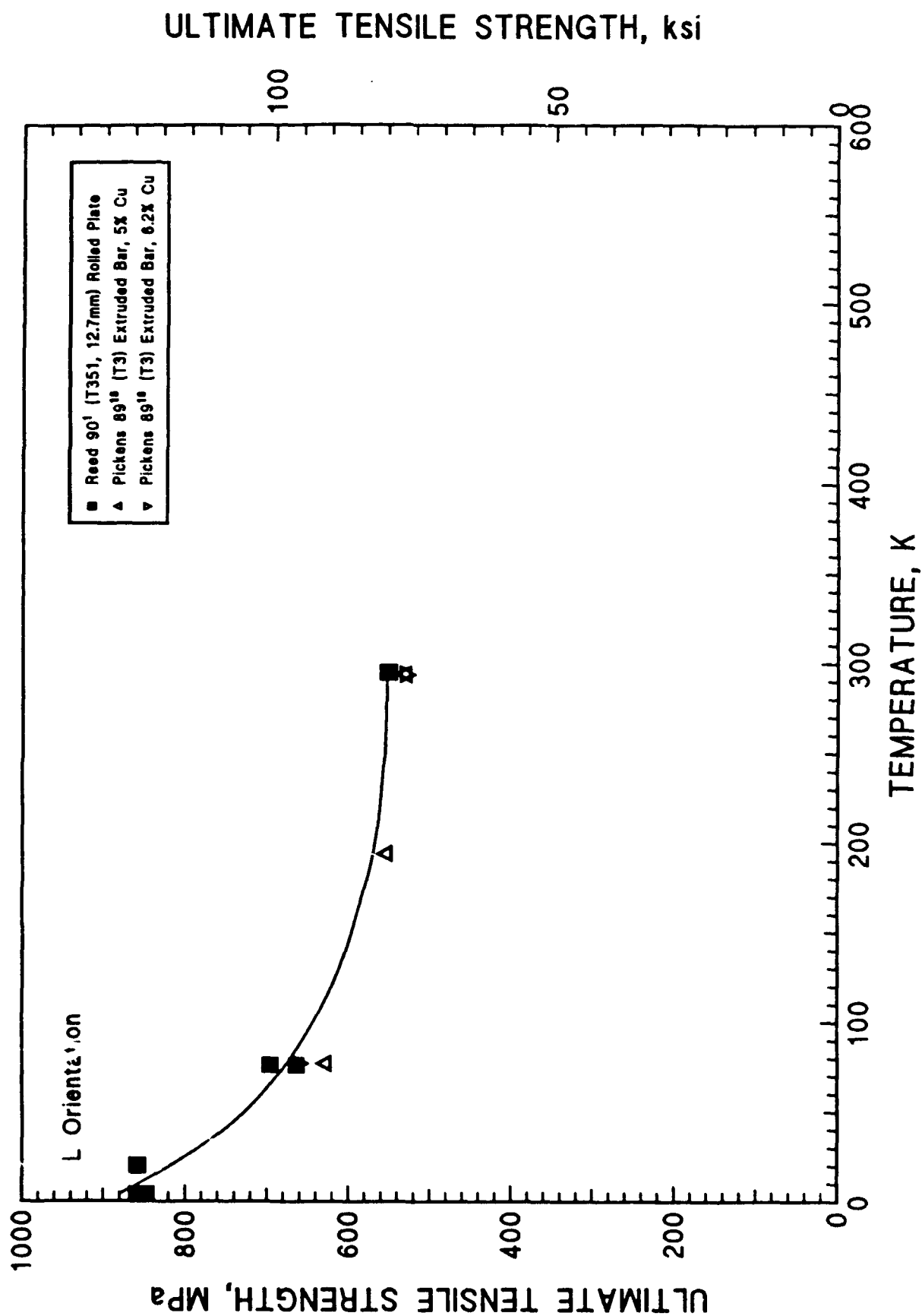
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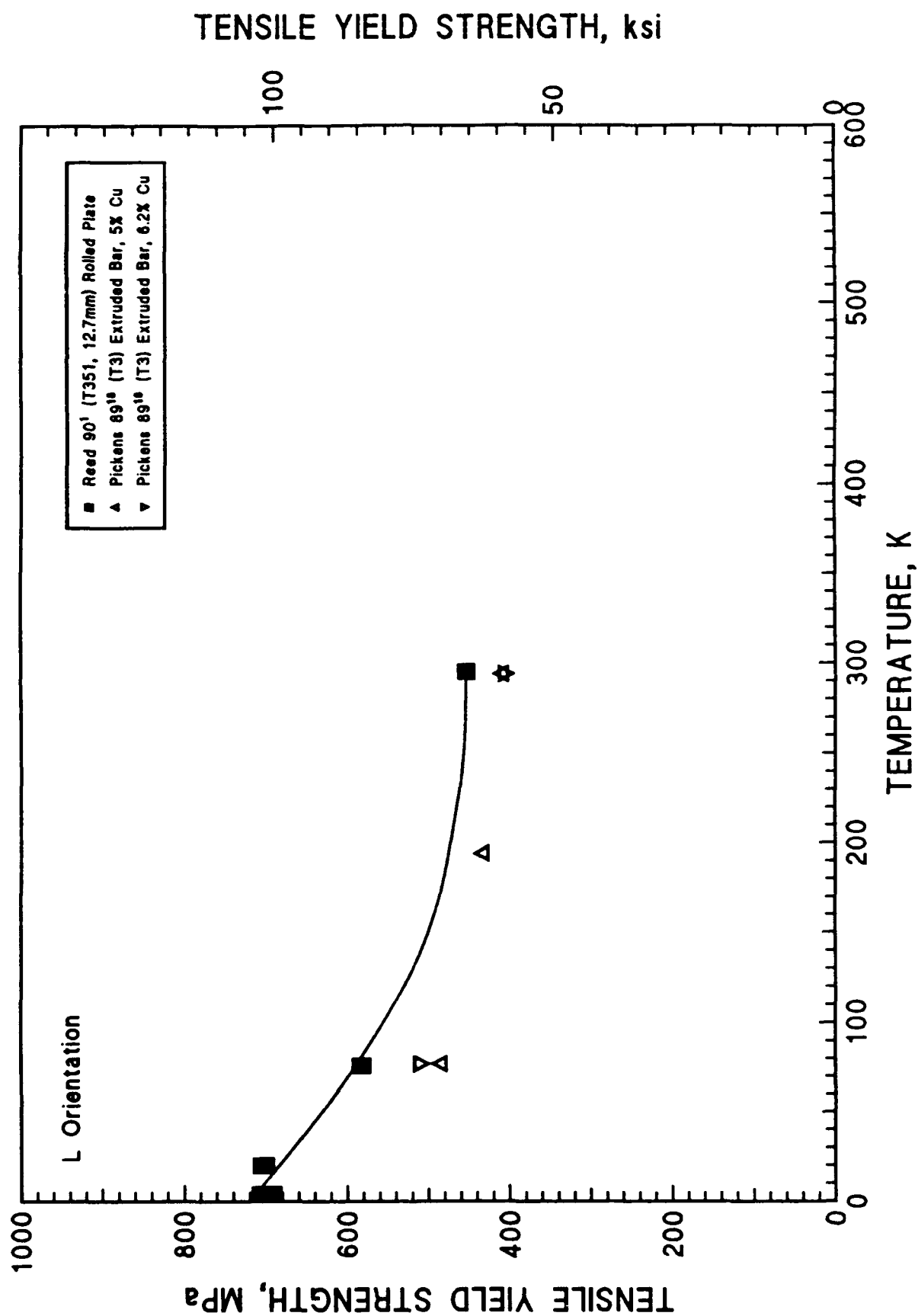
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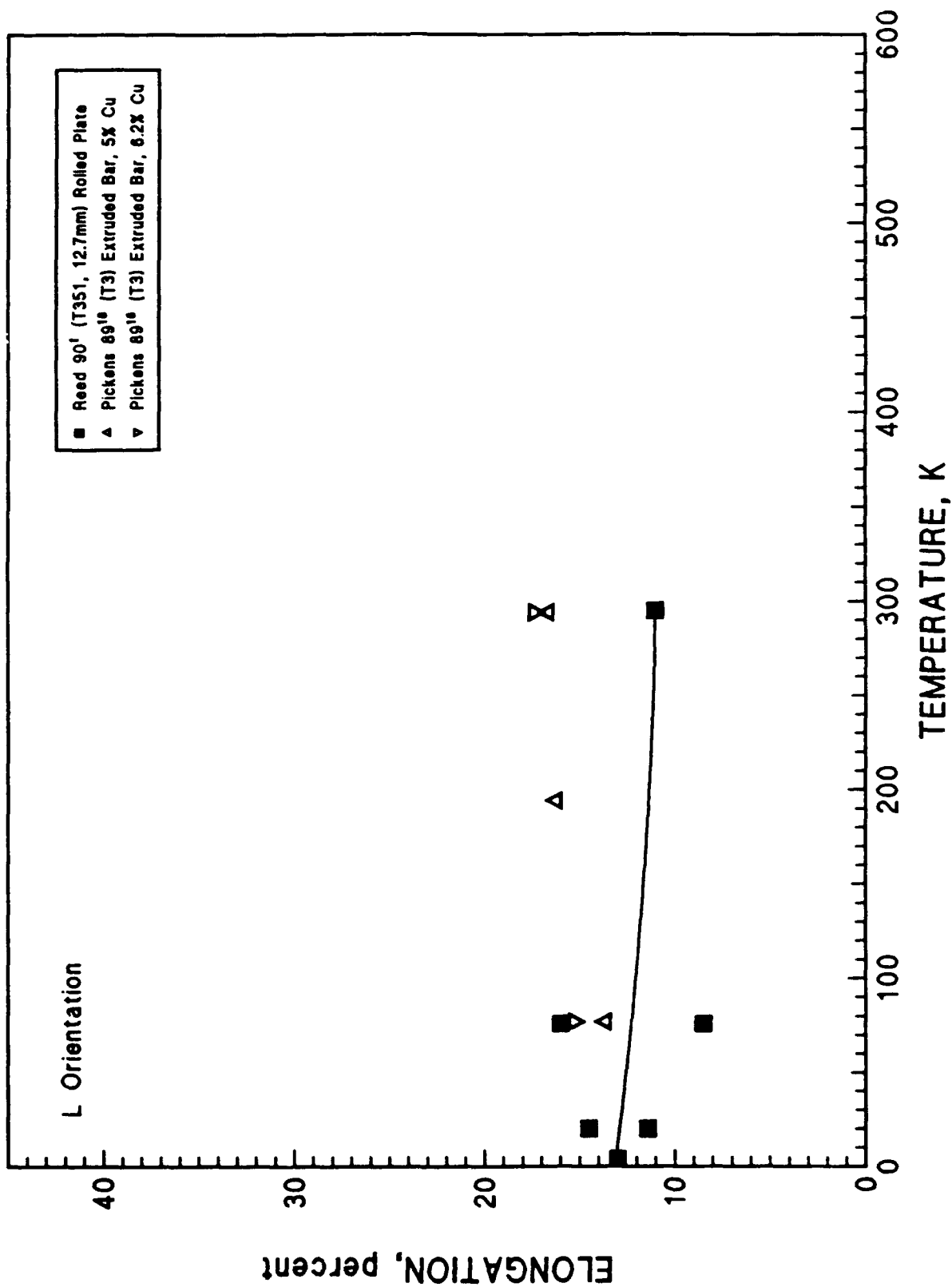
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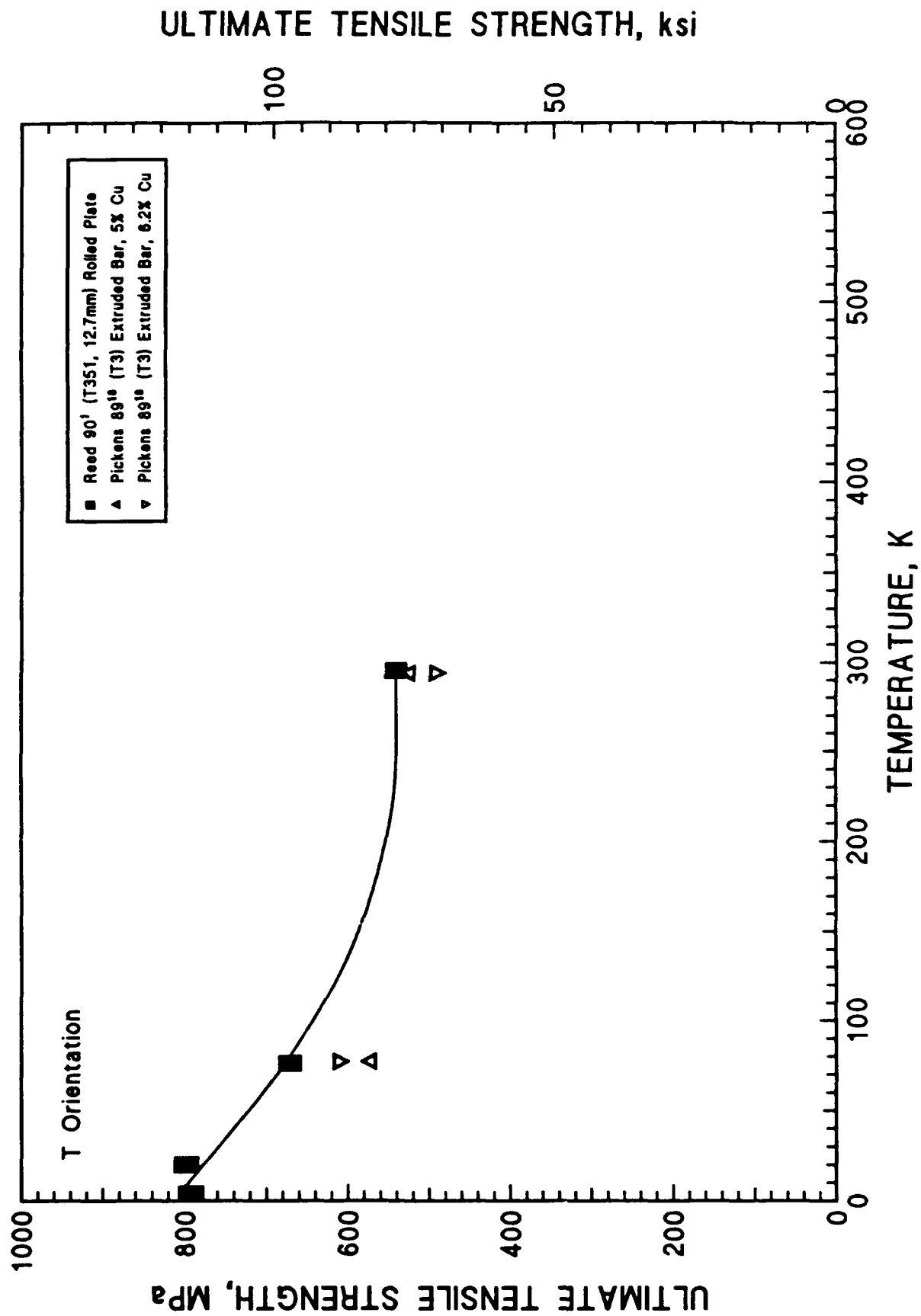
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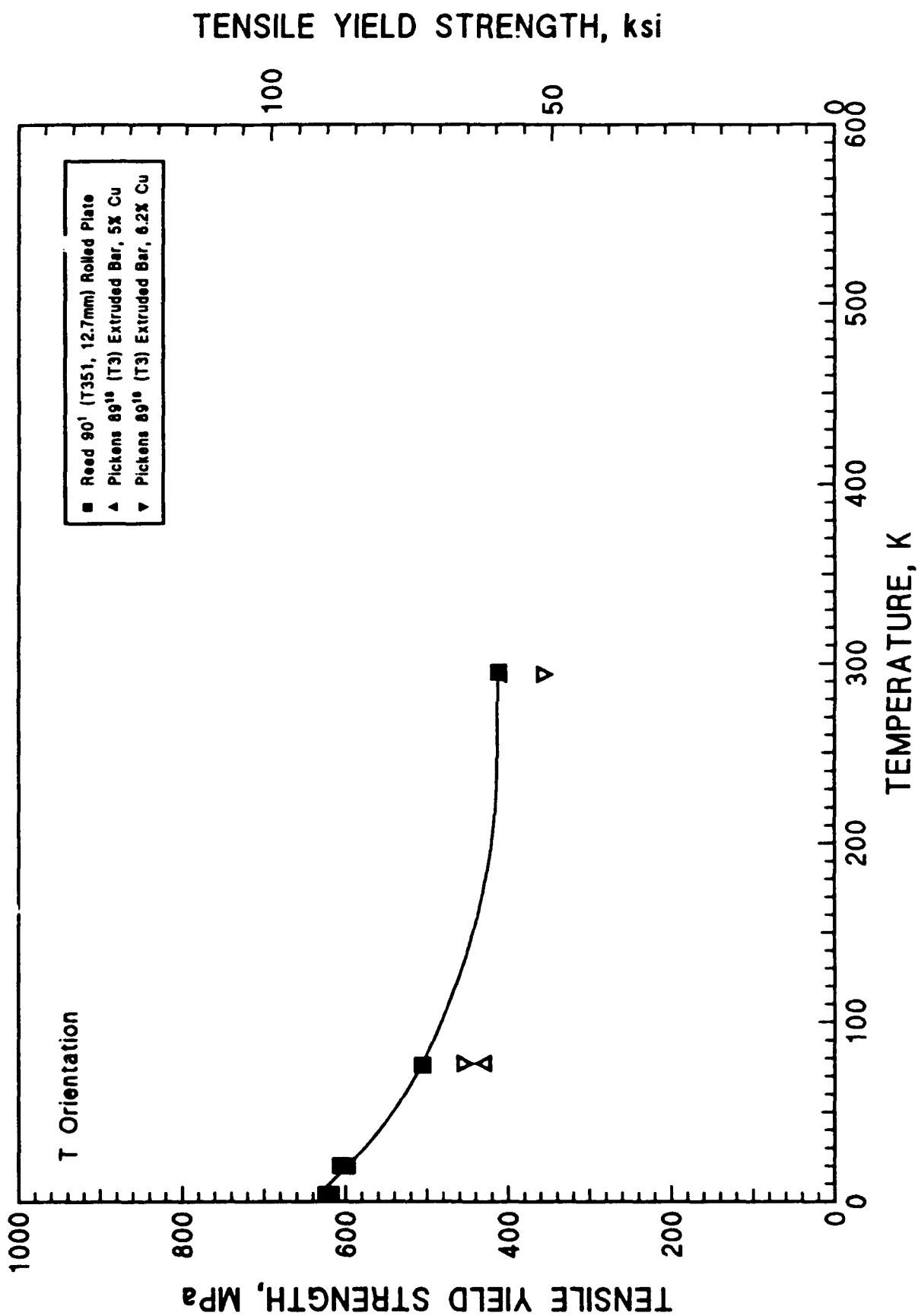
WL049-T3



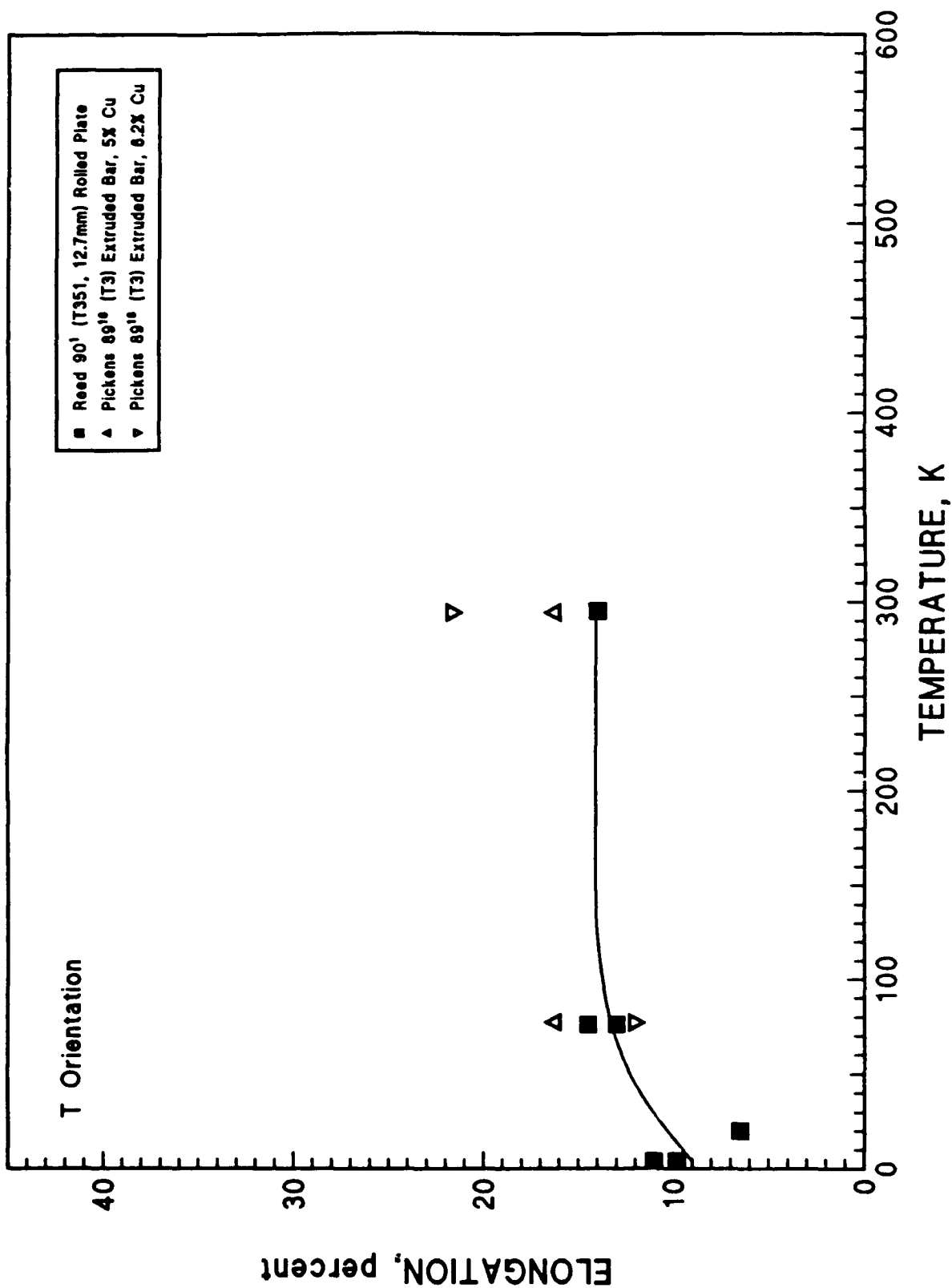
WL049-T3



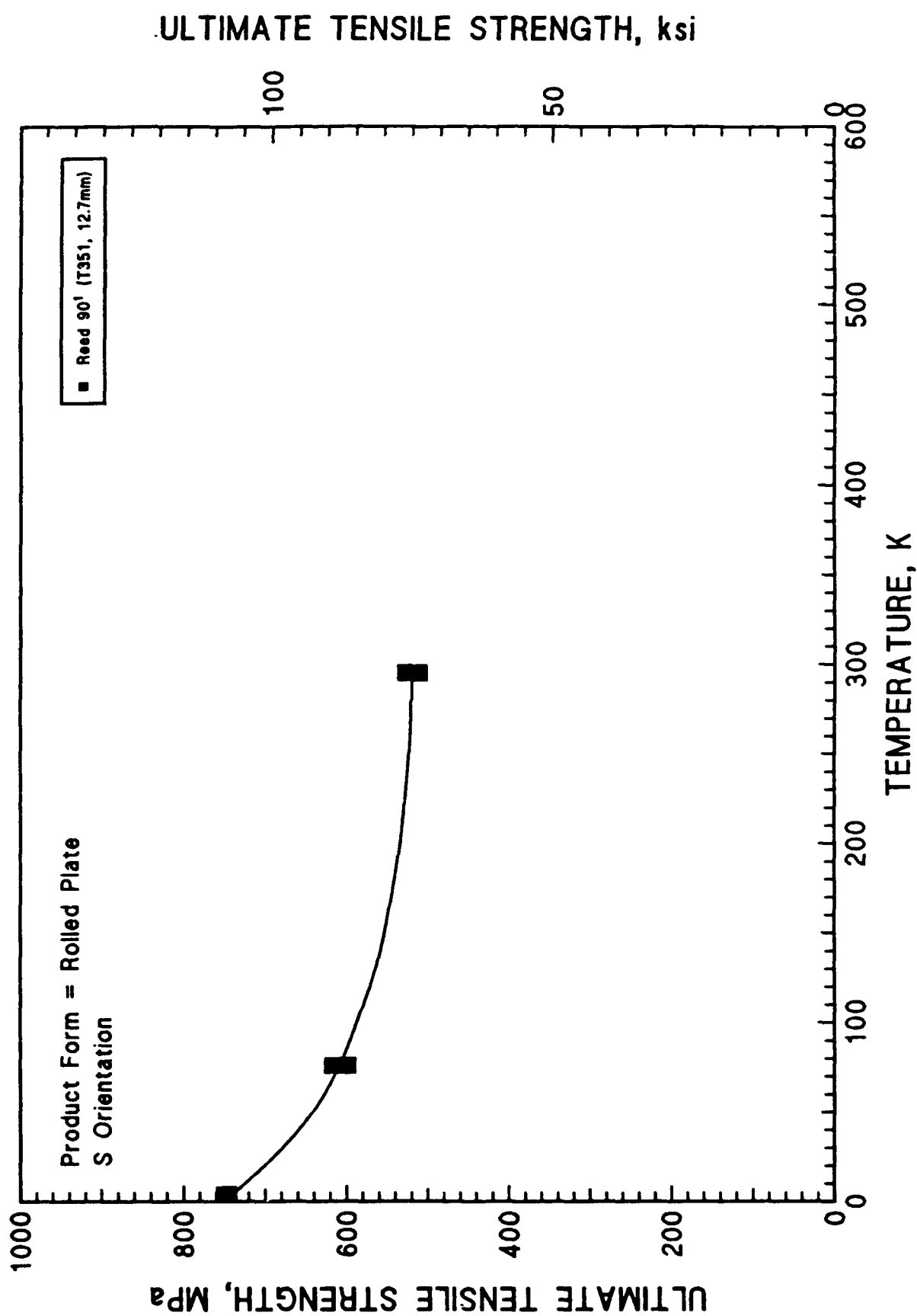
WL049-T3



WL049-T3



WLO49-T3



Al-Li ALLOY WL049

Ref & Note	Temp. K	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper	Product		Aging		Soln. Treat.		Quench	Grain Size μm	Hardness	No. of Tests/ Data Pt
							Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h			
1J	295	636	606	11.1	21	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	295	643	608	9.71	20	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	76	780	712	10.6	15	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	76	784	712	10.9	14	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	20	887	772	10.9	11	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	20	876	776	10.5	15	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	4	895	783	12.2	14	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	4	892	787	10.9	12	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1L	295	648	615	10	23	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1L	295	641	616	10	24	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1L	76	784	717	9	17	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1L	76	780	717	7	7	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1L	4	884	784	11	14	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1L	4	884	776	10	10	L	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
18A	294	727	714	6.3	NA	L	T8	Extruded Bar	19.05	NA	NA	NA	NA	NA	NA	1
18A	77	840	783	7.6	NA	L	T8	Extruded Bar	19.05	NA	NA	FA	NA	NA	NA	1
20B	593	NA	150	NA	NA	L	T8	NA	NA	NA	3	NA	NA	NA	NA	NA
20B	593	NA	150	NA	NA	L	T8	NA	NA	NA	3	NA	NA	NA	NA	NA

*See Comments

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper Form	Product Thickness mm	Aging Temp. °C	Time h	Stretch %	Temp. °C	Time h	Quench Cond.	Grain Size µm	Hardness	No. of Tests/ Data Pt
20B	538	NA	300.	NA	NA	L	T8	NA	NA	NA	3	NA	NA	NA	NA	NA	NA
20B	485	NA	485.	NA	NA	L	T8	NA	NA	NA	3	NA	NA	NA	NA	NA	NA
20B	450	NA	536.	NA	NA	L	T8	NA	NA	NA	3	NA	NA	NA	NA	NA	NA
20B	425	NA	600.	NA	NA	L	T8	NA	NA	NA	3	NA	NA	NA	NA	NA	NA
20B	368	NA	685.	NA	NA	L	T8	NA	NA	NA	3	NA	NA	NA	NA	NA	NA
20B	293	NA	676.	NA	NA	L	T8	NA	NA	NA	3	NA	NA	NA	NA	NA	NA
20B	77	NA	847.	NA	NA	L	T8	NA	NA	NA	3	NA	NA	NA	NA	NA	NA
20B	20	NA	847.	NA	NA	L	T8	NA	NA	NA	3	NA	NA	NA	NA	NA	NA
16A	294	658.	618.	10.3	NA	L	UAT8	Extruded Bar	19.05	NA	NA	NA	NA	NA	NA	NA	1
16A	194	678.	638.	6.	NA	L	UAT8	Extruded Bar	19.05	NA	NA	NA	NA	NA	NA	NA	1
18A	77	755.	676.	9.1	NA	L	UAT8	Extruded Bar	19.05	NA	NA	NA	NA	NA	NA	NA	1
18B	294	657.	633.	6.4	NA	L	UAT8	Extruded Bar	19.1	NA	NA	NA	NA	NA	NA	NA	NA
18B	77	705.	701.	9.8	NA	L	UAT8	Extruded Bar	19.1	NA	NA	NA	NA	NA	NA	NA	NA
1M	295	637.	569.	5	17.8	L	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1M	295	629.	565.	8.7	15.5	L	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1M	76	768.	675.	7.2	11.	L	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1M	76	760.	667.	6.6	13.3	L	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1M	20	873.	738.	9.55	11.8	L	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1M	20	873.	738.	10.5	11.	L	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. Z	Temper Form	Product		Aging		Soln. Treat.		Grain Size μm	Hardness	No. of Tests/ Data Pt
								Thickness mm	Stretch %	Temp. °C	Time h	Temp. °C	Time h			
1M	4	869.	736.	7.55	11.	L	T651	12.7	NA	NA	NA	NA	NA	NA	NA	1
1M	4	873.	748.	8.35	11.8	L	T651	12.7	NA	NA	NA	NA	NA	NA	NA	1
18B	4	895.	831.	5.2	NA	L	T6	6.35	NA	180	8.	504	1.	NA	NA	3
18B	4	916.	855.	4.2	NA	L	T6	6.35	NA	180	20.	504	1.	NA	NA	3
18B	4	880.	788.	4.	NA	L	T6	6.35	NA	180	4.	504	1.	NA	NA	3
18A	298	696.	670.	4.3	NA	L	T6	6.35	NA	180	20.	504	1.	NA	NA	3
18A	298	684.	641.	5.1	NA	L	T6	6.35	NA	180	4.	504	1.	NA	NA	3
18A	298	681.	645.	5.8	NA	L	T6	6.35	NA	180	8.	504	1.	NA	NA	3
18A	77	796.	738.	5.4	NA	L	T6	6.35	NA	180	8.	504	1.	NA	NA	3
18A	77	804.	784.	3.6	NA	L	T6	6.35	NA	180	20.	504	1.	NA	NA	3
18A	77	794.	745.	4.7	NA	L	T6	6.35	NA	180	4.	504	1.	NA	NA	3
20A	293	563.	398.	16.3	NA	L	T4	9.5	0	NA	1300.	504	0.8	NA	NA	1
20A	77	734.	552.	13.6	NA	L	T4	9.5	0	NA	4300.	504	0.8	NA	NA	1
10	295	552.	454.	NA	NA	L	T351	12.7	NA	NA	NA	NA	NA	NA	NA	1
10	295	550.	452.	9.65	10.9	L	T351	12.7	NA	NA	NA	NA	NA	NA	NA	1
10	76	696.	581.	11.6	13.9	L	T351	12.7	NA	NA	NA	NA	NA	NA	NA	1
10	76	664.	584.	8.5	13.2	L	T351	12.7	NA	NA	NA	NA	NA	NA	NA	1
10	20	859.	700.	11.4	11.7	L	T351	12.7	NA	NA	NA	NA	NA	NA	NA	1
10	20	858.	706.	14.5	11.	L	T351	12.7	NA	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref # Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper.	Product Form	Product Thickness mm	Aging		Soln. Treat.		Grain Size μ m	Hardness	No. of Tests/ Data Pt
										Temp. °C	Time h	Temp. °C	Time h			
10	4	847.	708.	13.	14.7	L	T351	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
10	4	859.	691.	13.	15.3	L	T351	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
18A	294	529.	407.	16.8	MA	L	T3	Extruded Bar	19.05	NA	NA	NA	NA	NA	NA	1
18A	194	553.	431.	16.2	MA	L	T3	Extruded Bar	19.05	NA	NA	NA	NA	NA	NA	1
18A	77	627.	483.	13.6	MA	L	T3	Extruded Bar	19.05	NA	NA	NA	NA	NA	NA	1
18G	294	531.	407.	17.4	MA	L	T3	Extruded Bar	19.1	NA	NA	NA	NA	NA	NA	NA
18G	77	663.	512.	15.3	MA	L	T3	Extruded Bar	19.1	NA	NA	NA	NA	NA	NA	NA
18A	294	487.	330.	21.5	MA	L	Rev	NA	NA	NA	NA	NA	NA	NA	NA	1
18A	194	454.	315.	19.	MA	L	Rev	NA	NA	NA	NA	NA	NA	NA	NA	1
18A	77	577.	404.	25.2	MA	L	Rev	NA	NA	NA	NA	NA	NA	NA	NA	1
1J	295	638.	391.	10.6	20.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	295	638.	581.	11.6	23.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	76	762.	682.	8.4	12.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	76	760.	672.	9.1	12.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	20	852.	720.	8.	9.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	20	854.	730.	9.4	10.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	4	863.	752.	8.7	12.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	4	855.	736.	6.5	8.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1L	295	637.	592.	11.	27.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient.	Temper	Product		Aging Temp. °C	Time h	Stretch %	Soln. Treat.		Grain Size µm	Hardness	No. of Tests/ Data Pt
								Form	Thickness mm				Temp. °C	Time h			
1L	205	630.	587.	10.	27.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1L	76	755.	675.	6.	7.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1L	76	765.	685.	9.	15.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1L	4	846.	766.	6.	8.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1L	4	860.	784.	9.	14.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
18C	294	658.	630.	3.9	NA	T	T8	Extruded Bar	9.53	NA	NA	NA	NA	NA	NA	NA	1
18D	77	753.	705.	2.62	NA	T	T8	Extruded Bar	19.05	NA	NA	NA	NA	NA	NA	NA	1
18D	294	607.	566.	9.8	NA	T	UAT8	Extruded Bar	19.05	NA	NA	NA	NA	NA	NA	NA	1
18D	194	678.	636.	6.	NA	T	UAT8	Extruded Bar	19.05	NA	NA	NA	NA	NA	NA	NA	1
18D	77	755.	576.	9.1	NA	T	UAT8	Extruded Bar	19.05	NA	NA	NA	NA	NA	NA	NA	1
18H	294	612.	578.	2.4	NA	T	UAT8	Extruded Bar	19.1	NA	NA	NA	NA	NA	NA	NA	NA
18H	77	693.	627.	7.1	NA	T	UAT8	Extruded Bar	19.1	NA	NA	NA	NA	NA	NA	NA	NA
1M	295	621.	543.	9.4	17.8	T	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1M	295	619.	543.	7.8	16.3	T	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1M	76	744.	638.	5.3	11.6	T	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1M	76	744.	635.	6.3	10.2	T	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1M	20	853.	720.	NA	NA	T	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1M	20	833.	707.	5.3	8.7	T	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
1M	4	860.	726.	8.9	8.7	T	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. Z	Temper	Product Form	Product Aging		Soln. Treat.		Quench Cond.	Grain Size μm	Hardness	No. of Tests/Data Pt	
									Thickness mm	Temp. °C	Time h	Stretch %					Temp. °C
1M	4	842.	738.	NA	NA	T	T651	rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1	
18E	4	867.	800.	3.3	NA	T	T6	Roller Plate	6.35	180	4.	0	504	1.	HQ	NA	3
18E	4	872.	854.	1.7	NA	T	T6	Roller Plate	6.35	180	20.	0	504	1.	HQ	NA	3
18E	4	859.	823.	2.9	NA	T	T6	Roller Plate	6.35	180	8.	0	504	1.	HQ	NA	3
18B	200	674.	651.	3.5	NA	T	T6	Roller Plate	6.35	180	20.	0	504	1.	HQ	NA	3
19B	200	654.	616.	4.8	NA	T	T6	Roller Plate	6.35	180	4.	0	504	1.	HQ	NA	3
19B	200	663.	634.	3.2	NA	T	T6	Roller Plate	6.35	180	8.	0	504	1.	HQ	NA	3
19B	77	775.	755.	1.9	NA	T	T6	Roller Plate	6.35	180	20.	0	504	1.	HQ	NA	3
19B	77	762.	752.	2.4	NA	T	T6	Roller Plate	6.35	180	8.	0	504	1.	HQ	NA	3
19B	77	762.	752.	2.4	NA	T	T6	Roller Plate	6.35	180	4.	0	504	1.	HQ	NA	3
10	295	544.	412.	14.	23.	T	T351	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
10	295	538.	412.	14.	22.	T	T351	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
10	76	667.	506.	13.	12.9	T	T351	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
10	76	675.	505.	NA	13.2	T	T351	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
10	20	793.	598.	NA	NA	T	T351	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
10	20	803.	606.	NA	13.2	T	T351	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
10	4	787.	618.	9.8	15.	T	T351	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
10	4	798.	624.	11.	16.3	T	T351	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	1
18D	294	523.	408.	16.2	NA	T	T3	Extruded Bar	19.05	NA	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. °	Temper °C	Product		Aging		Soin. Treat.		Grain Size µm	Hardness	No. of Tests/ Data Pt
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h	Quench Cond.	
18D	77	371.	427.	16.2	NA	T	T3	Extruded Bar	10.05	NA	NA	NA	NA	NA	NA	1
18G	294	493.	359.	21.7	NA	T	T3	Extruded Bar	10.1	NA	NA	NA	NA	NA	NA	NA
18G	77	612.	452.	12.1	NA	T	T3	Extruded Bar	10.1	NA	NA	NA	NA	NA	NA	NA
1J	295	562.	502.	16.	37.	45°	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	295	559.	500.	14.	37.	45°	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	76	657.	569.	16.	32.	45°	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	76	673.	583.	17.	28.	45°	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	4	785.	814.	19.	22.	45°	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1J	4	746.	622.	16.	21.	45°	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
18F	4	801.	729.	6.2	NA	45°	T6	Rolled Plate	6.35	180	4.	4	504	1.	HQ	3
18F	4	837.	781.	4.9	NA	45°	T6	Rolled Plate	6.35	180	20.	4	504	1.	HQ	3
18F	4	805.	761.	4.	NA	45°	T6	Rolled Plate	6.35	180	8.	4	504	1.	HQ	3
19C	298	618.	566.	9.4	NA	45°	T6	Rolled Plate	6.35	180	4.	4	504	1.	HQ	3
19C	298	637.	606.	6.4	NA	45°	T6	Rolled Plate	6.35	180	20.	4	504	1.	HQ	3
19C	298	628.	590.	6.5	NA	45°	T6	Rolled Plate	6.35	180	8.	4	504	1.	HQ	3
19C	77	714.	673.	4.2	NA	45°	T6	Rolled Plate	6.35	180	8.	4	504	1.	HQ	3
19C	77	734.	694.	4.8	NA	45°	T6	Rolled Plate	6.35	180	20.	4	504	1.	HQ	3
19C	77	731.	668.	7.9	NA	45°	T6	Rolled Plate	6.35	180	4.	4	504	1.	HQ	3
1K	295	604.	NA	NA	NA	S	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper	Product			Aging			Soln. Treat.			Grain Size μ m	Hardness	No. of Tests/ Data Pt
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h	Quench Cond.				
1K	295	649.	NA	NA	NA	S	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1K	76	755.	NA	NA	NA	S	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1K	76	736.	NA	NA	NA	S	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1K	4	809.	NA	NA	NA	S	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1K	4	814.	NA	NA	NA	S	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1N	295	623.	NA	NA	NA	S	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1N	295	625.	NA	NA	NA	S	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1N	76	676.	NA	NA	NA	S	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1N	76	705.	NA	NA	NA	S	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1N	4	772.	NA	NA	NA	S	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1N	4	633.	NA	NA	NA	S	T651	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1P	295	511.	NA	NA	NA	S	T351	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1P	295	527.	NA	NA	NA	S	T351	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1P	76	617.	NA	NA	NA	S	T351	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1P	76	599.	NA	NA	NA	S	T351	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1P	4	750.	NA	NA	NA	S	T351	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
1P	4	745.	NA	NA	NA	S	T351	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	

*See Comments

TEST PARAMETERS
AL-LI ALLOY WL049

Ref & Strain Note		Specimen				Expo Time min	Supplier	Yr. Prod.	Lot No.	Product L(m) X W(m)	Major Elements										Minor Elements wt%
		Type	Diam mm	Thick mm	G.L. mm						Location	Li	Cu	Mg	Zr	Si	Fe	Ag			
1J	2.2	Round	6.35	NA	25.4	Mid-plate	5.	Reynolds	1989	0387250A	1.22 X 1.22	0.38	4.7	0.4	0.12	0.02	0.03	0.37	NA		
1K	2.2	Round	2.5	NA	25.4	Random	5.	Reynolds	1989	0387250A	1.22 X 1.22	0.38	4.7	0.4	0.12	0.02	0.03	0.37	NA		
1L	2.2	Round	6.35	NA	25.4	Mid-plate	5.	Reynolds	1989	9002311A	1.22 X 1.22	0.38	4.7	0.4	0.12	0.02	0.03	0.37	NA		
1M	2.2	Round	6.35	NA	25.4	Mid-plane	5.	Reynolds	1989	0387240A	1.22 X 1.22	1.28	4.7	0.4	0.12	0.02	E-3	0.35	NA		
1N	2.2	Round	2.5	NA	25.4	Random	5.	Reynolds	1989	0387240A	1.22 X 1.22	1.28	4.7	0.4	0.12	0.02	0.03	0.35	NA		
1O	2.2	Round	6.35	NA	25.4	Mid-plane	5.	Reynolds	1989	0387230A	1.22 X 1.22	1.28	4.7	0.4	0.12	0.02	0.03	0.35	NA		
1P	2.2	Round	2.5	NA	25.4	Random	5.	Reynolds	1989	0387230A	1.22 X 1.22	1.28	4.7	0.4	0.12	0.02	0.03	0.35	NA		
18A	4	Round	6.35	NA	25.4	Mid-plane	15.	M.M.	NA	MA	0.102	1.3	5.	0.4	0.14	NA	NA	0.4	Ti: 0.03		
18B	1.67	Round	NA	NA	12.7	NA	NA	Reynolds	NA	NA	NA	1.3*	5.4	0.4	0.14	NA	NA	0.4	NA		
18C	4	Round	6.35	NA	25.4	Mid-plane	15.	M.M.	NA	MA	0.102	1.3	5.	0.4	0.14	NA	NA	0.4	Ti: 0.03		
18D	4	Round	6.35	NA	25.4	Mid-plane	15.	M.M.	NA	NA	0.051	1.3	5.	0.4	0.14	NA	NA	0.4	Ti: 0.03		
18E	1.67	Round	NA	NA	12.7	NA	NA	Reynolds	NA	NA	NA	1.3*	5.4	0.4	0.14	NA	NA	0.4	NA		
18F	1.67	Round	NA	NA	12.7	NA	NA	Reynolds	NA	NA	NA	1.3*	5.4	0.4	0.14	NA	NA	0.4	NA		
18G	4	Round	6.35	NA	25.4	Mid-plane	15.	M.M.	NA	MA	50.8	1.3	6.2	0.4	0.14	NA	NA	0.4	Ti: 0.03		
18H	4	Round	6.35	NA	25.4	Mid-plane	15.	M.M.	NA	MA	50.8	1.3	6.2	0.4	0.14	NA	NA	0.4	Ti: 0.03		
19A	1.67	Round	NA	NA	12.7	NA	NA	Reynolds	NA	NA	NA	1.3*	5.4	0.4	0.14	NA	NA	0.4	NA		
19B	1.67	Round	NA	NA	12.7	NA	NA	Reynolds	NA	NA	NA	1.3*	5.4	0.4	0.14	NA	NA	0.4	NA		
19C	1.67	Round	NA	NA	12.7	NA	NA	Reynolds	NA	NA	NA	1.3*	5.4	0.4	0.14	NA	NA	0.4	NA		

Ref & Strain		Specimen			Expo		Major Elements												
Note	Rate	Type	Diam	Thick	G.L.	Specimen Location	Time min	Supplier	Yr. Prod.	Lot No.	Product	Li	Cu	Mg	Zr wt%	Si	Fe	Ag	Minor Elements wt%
No.	10-4/s		mm	mm	mm						L(m) X W(m)								
20A	NA	NA	NA	NA	NA	NA	NA	Reynolds	NA	NA	0.102	1.19	4.8	0.4	0.16	NA	NA	0.36	NA
20B	4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.3	6.2	0.4	0.14	NA	NA	0.4	Ti: 0.03

Comments from the Al-Li Alloy WL049 Test Parameter Table

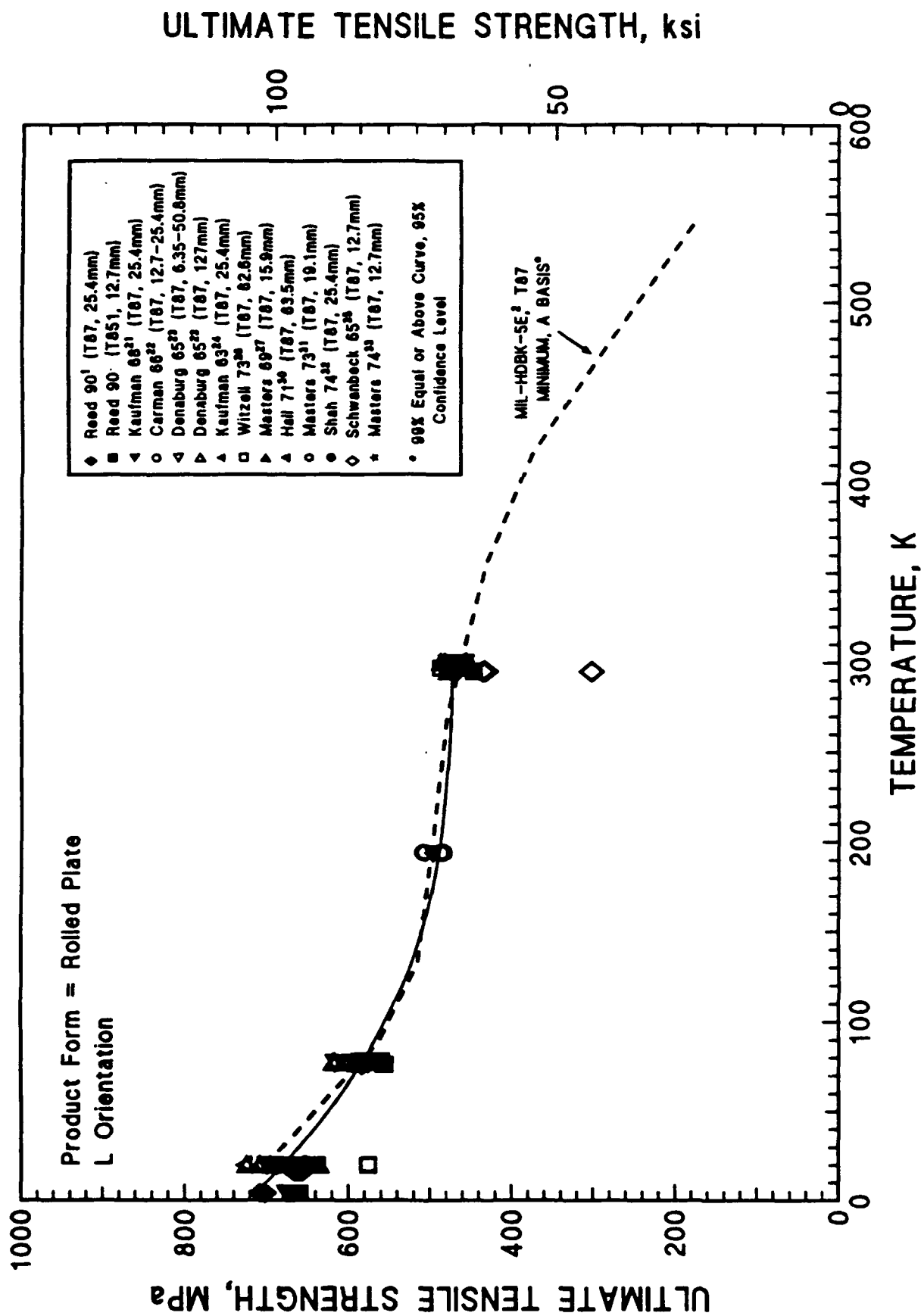
Reference and
Note Number

18B--Reported composition is based on nominal values.

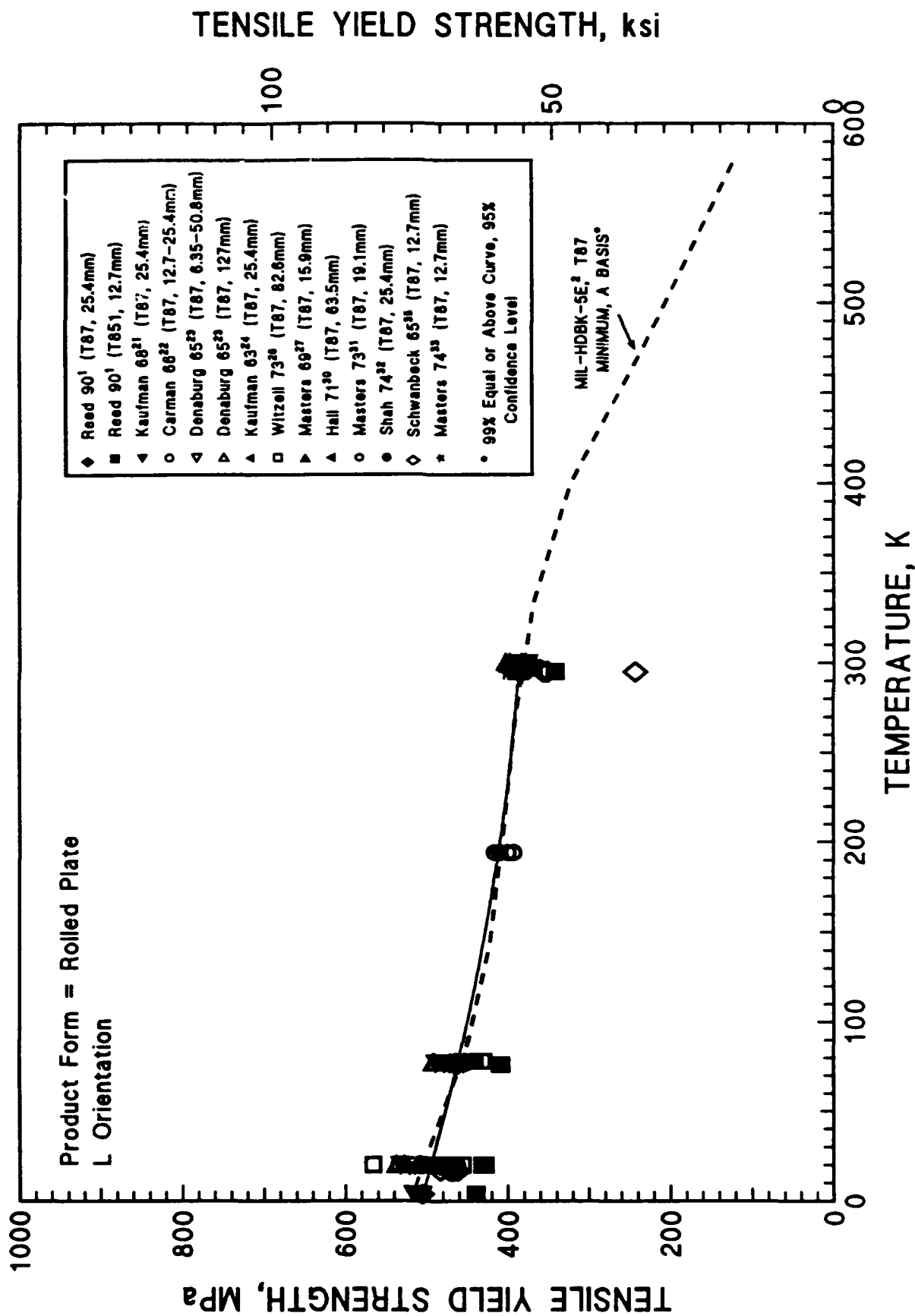
18E--Reported composition is based on nominal values.

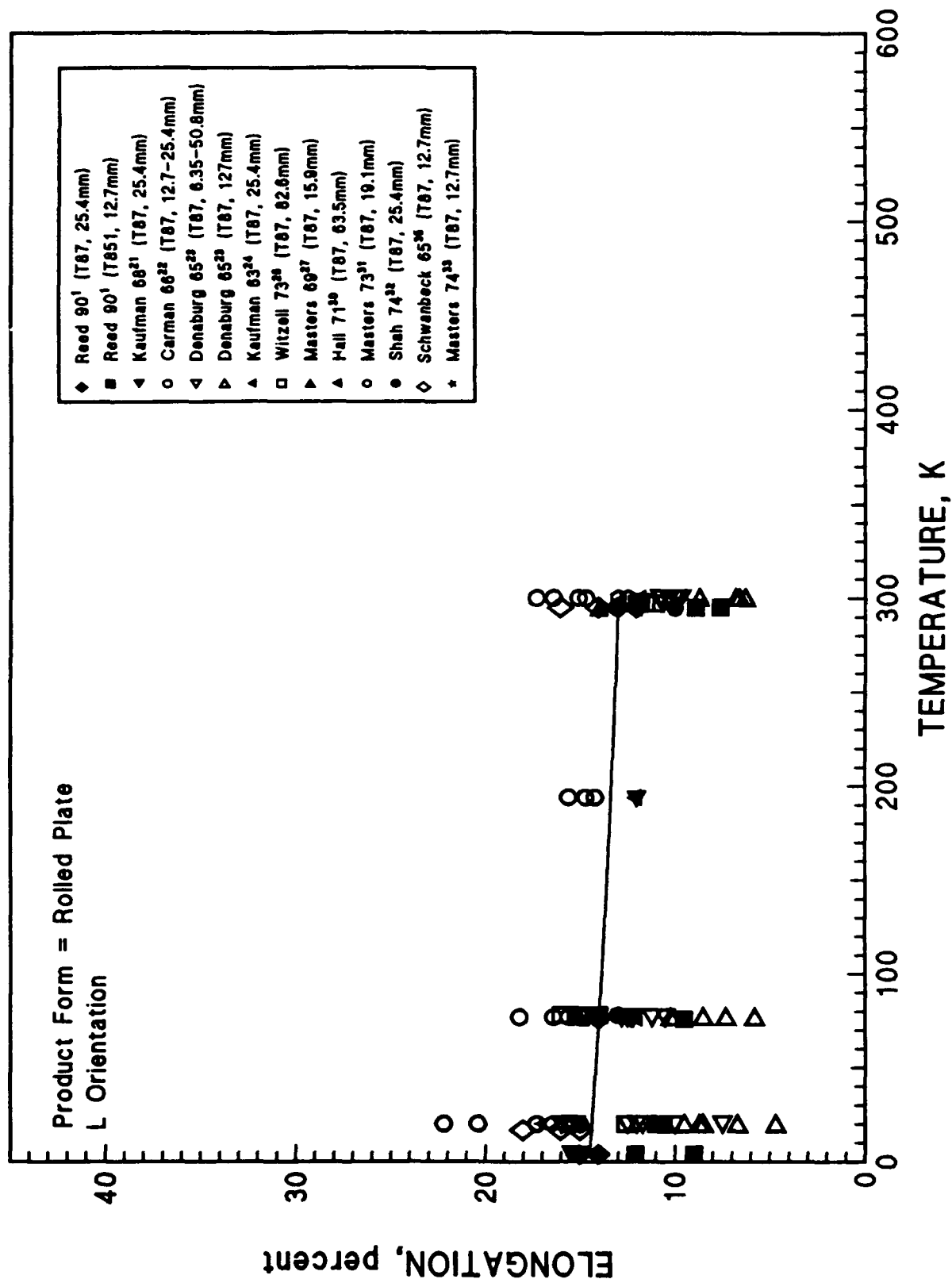
18F--Reported composition is based on nominal values.

19A-C--Reported composition is based on nominal values.

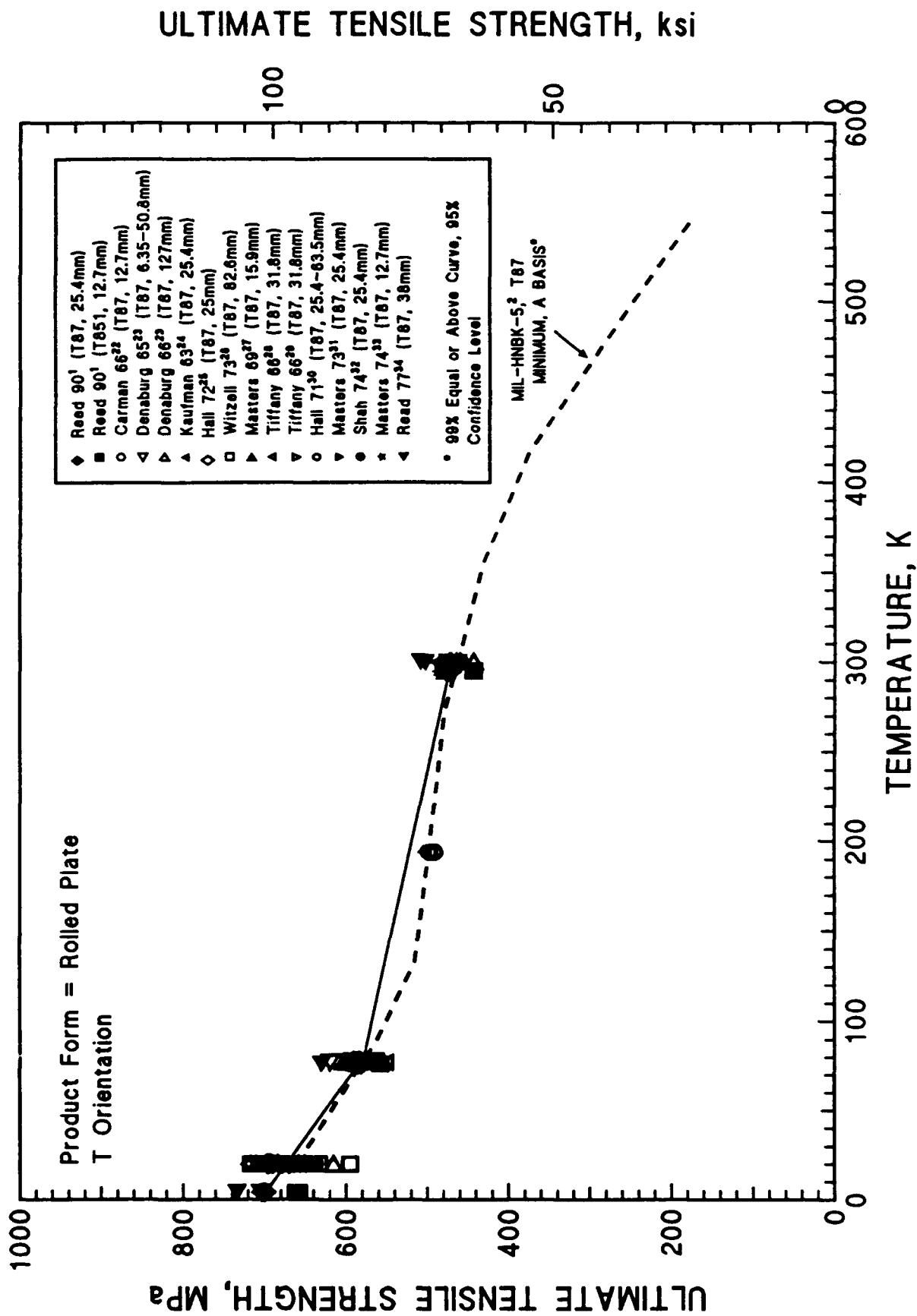


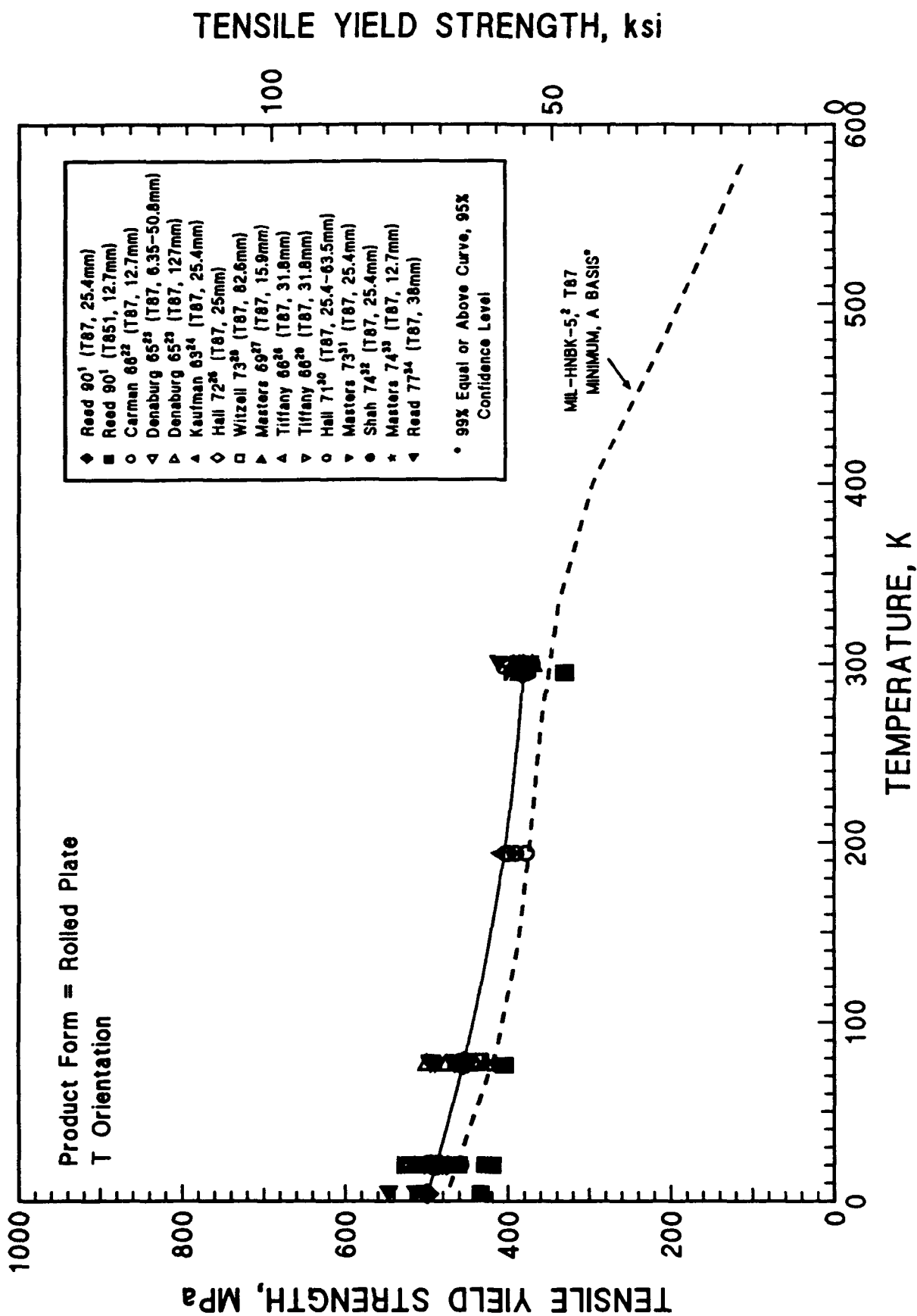
2219-T8



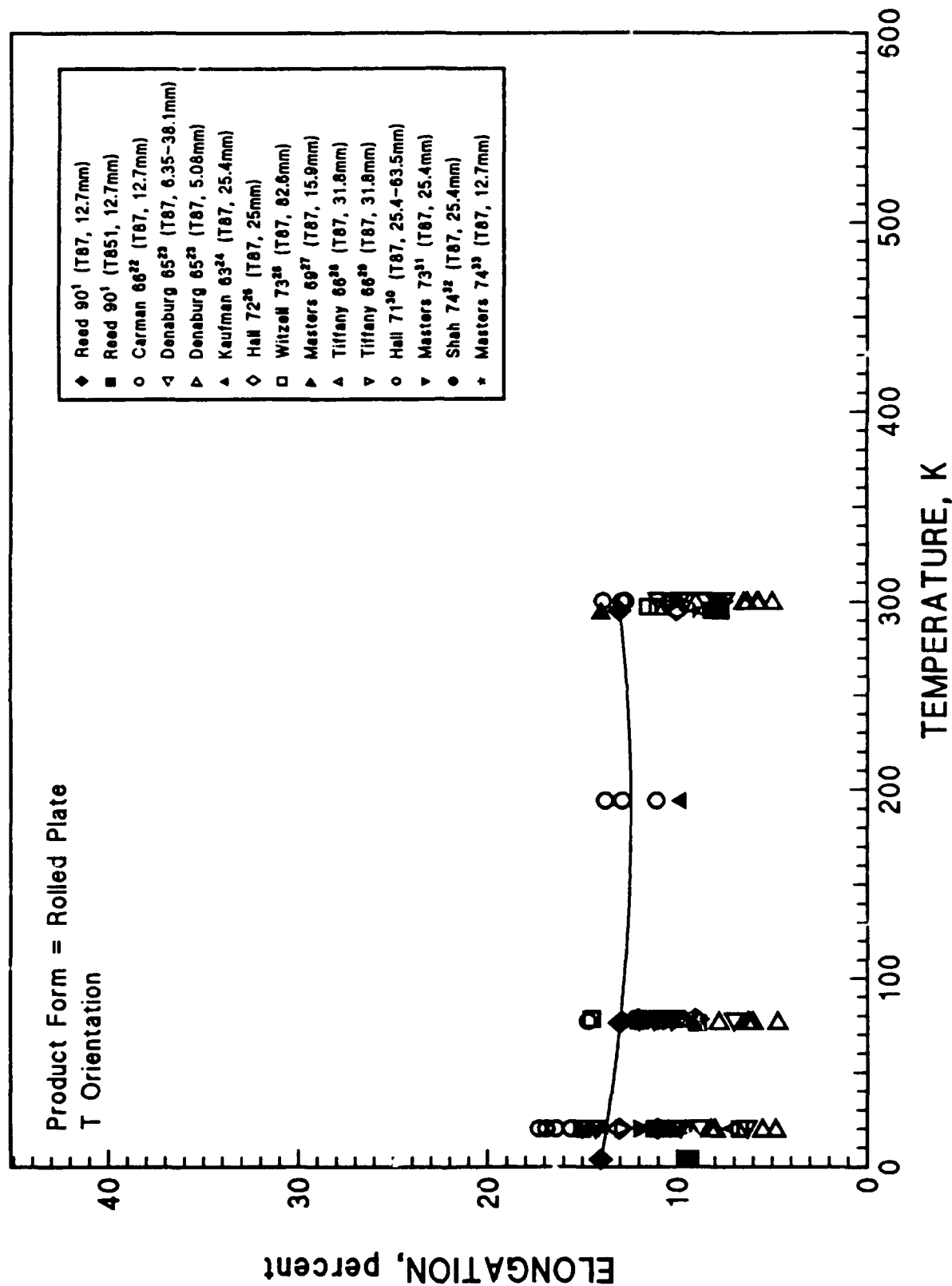


2219-T8

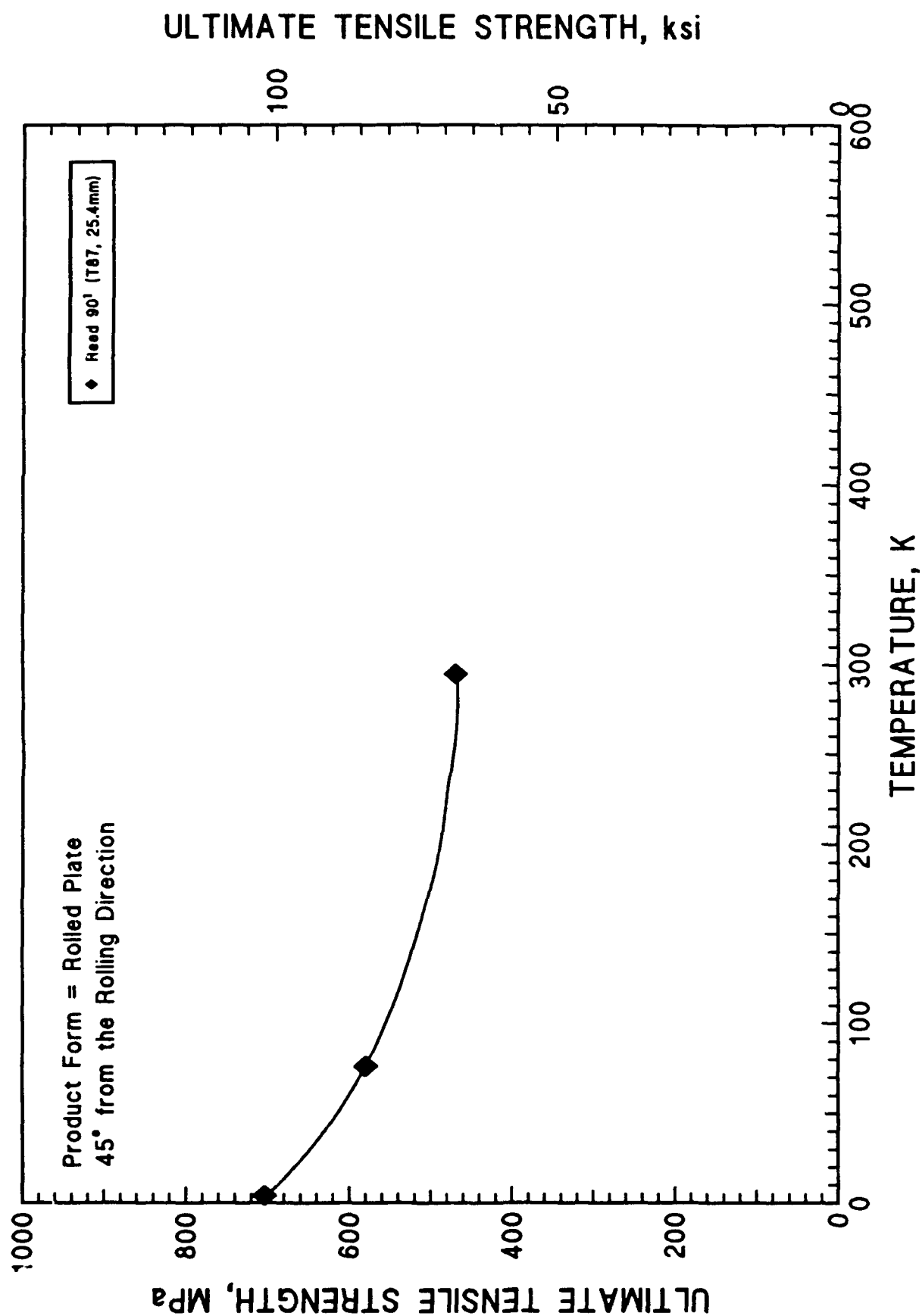




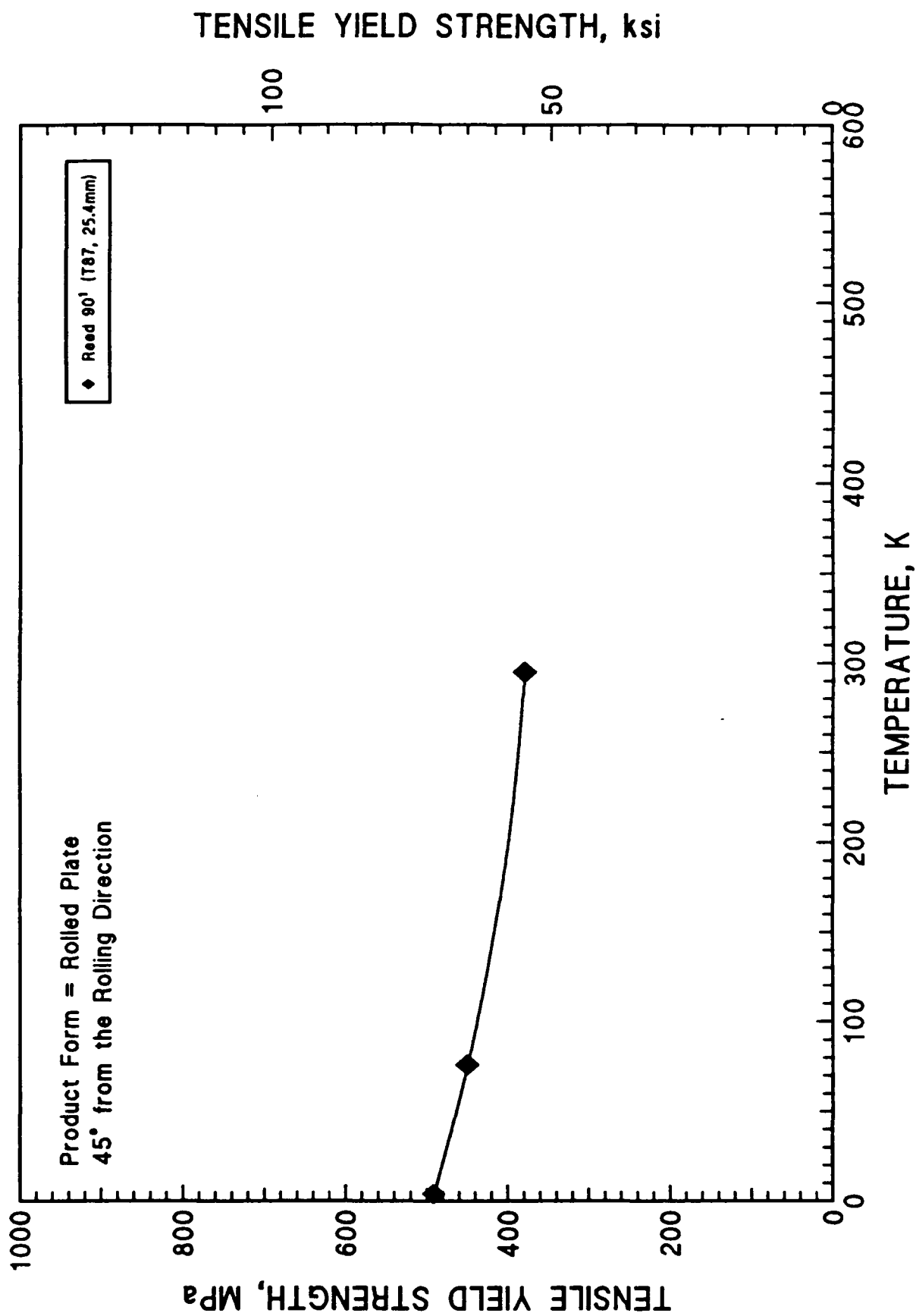
2219-T8

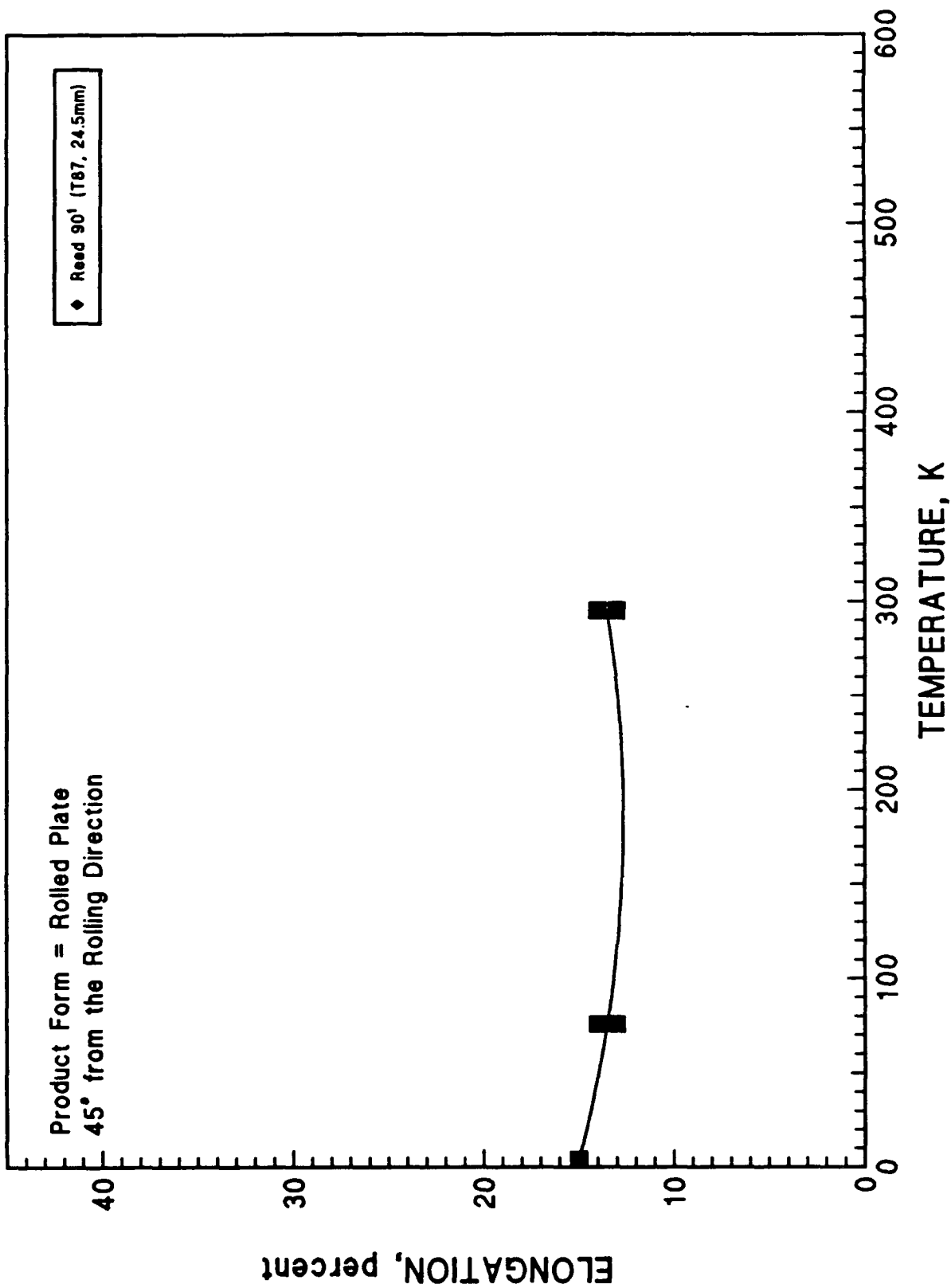


2219-T8

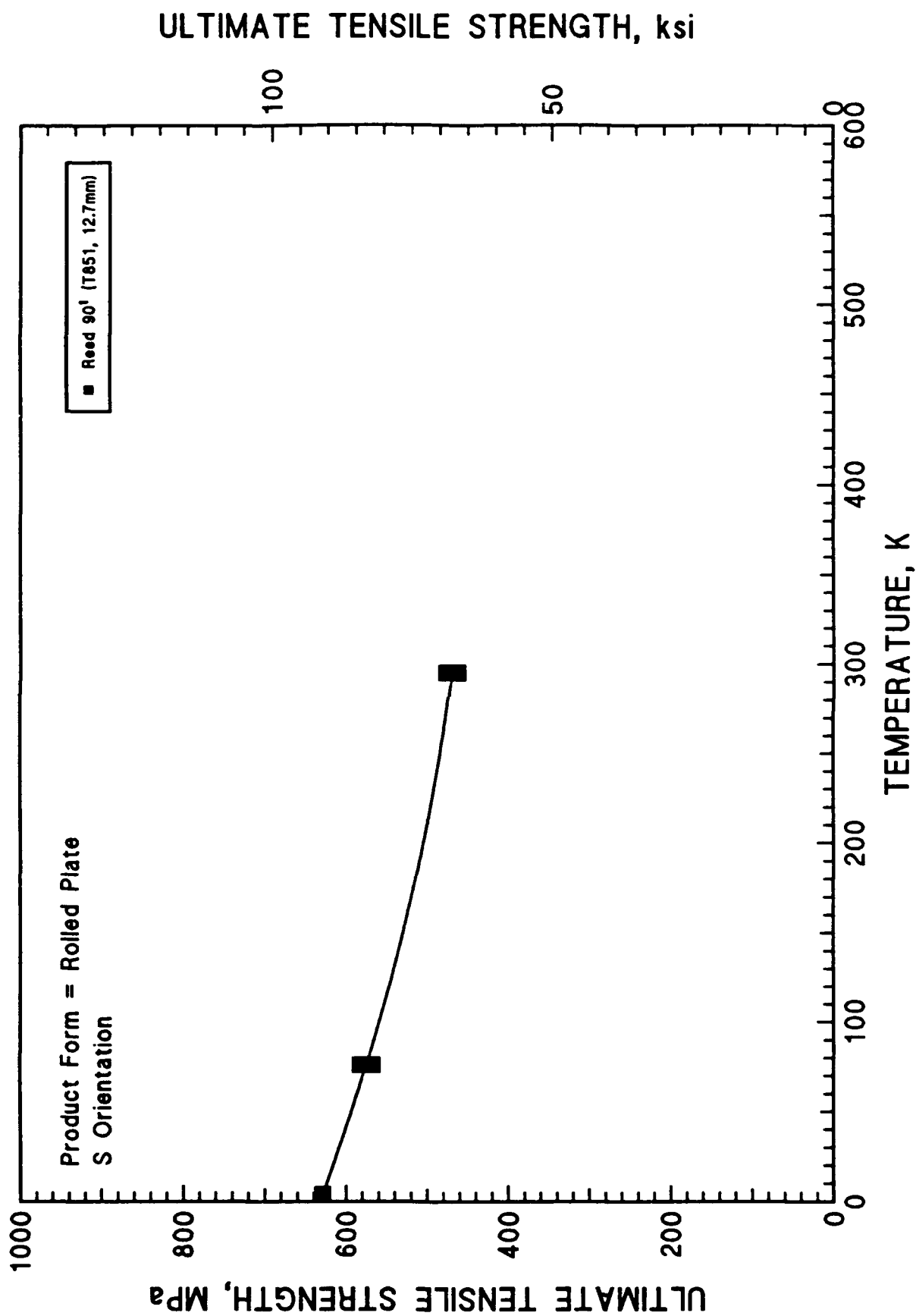


2219-T8

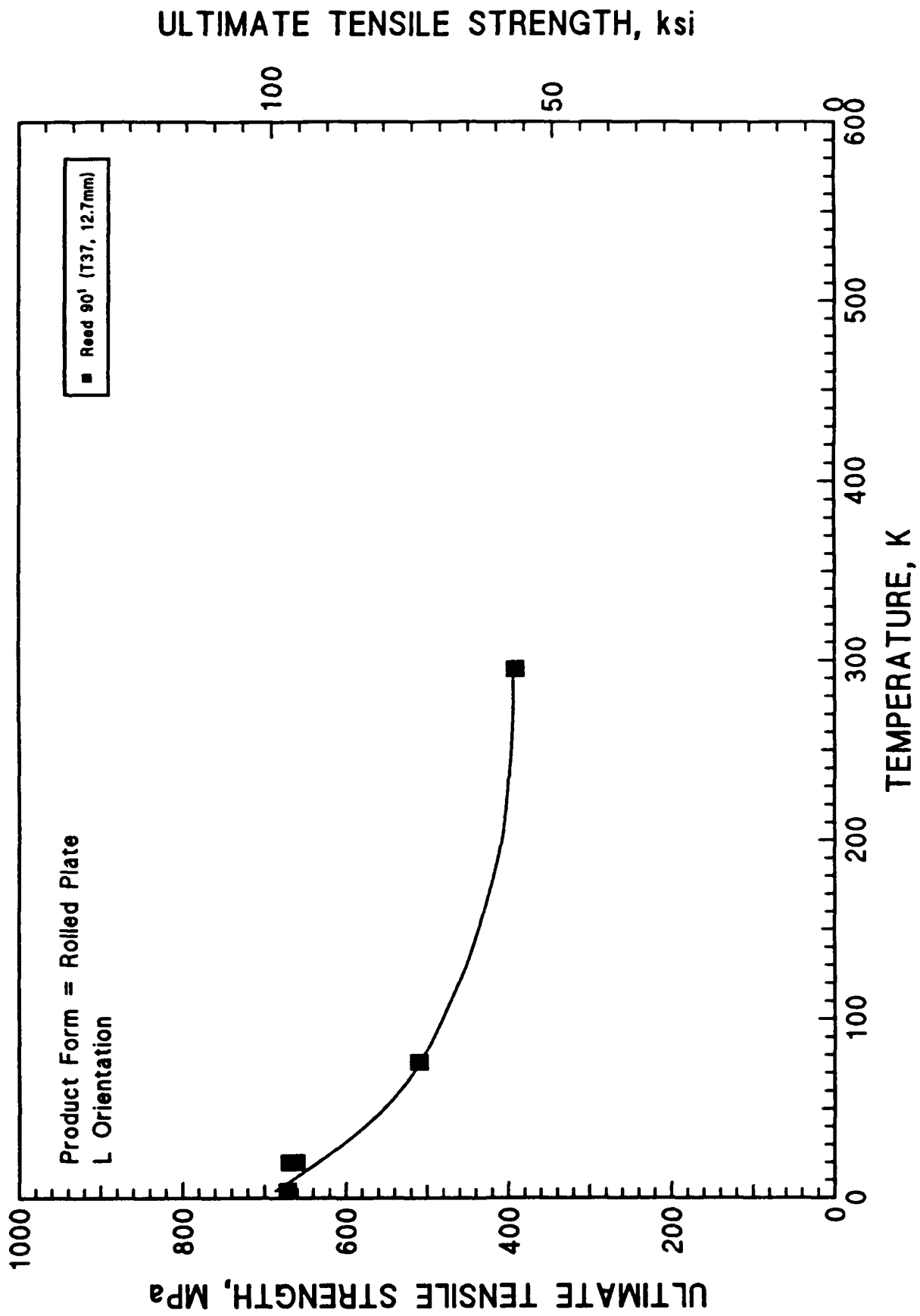




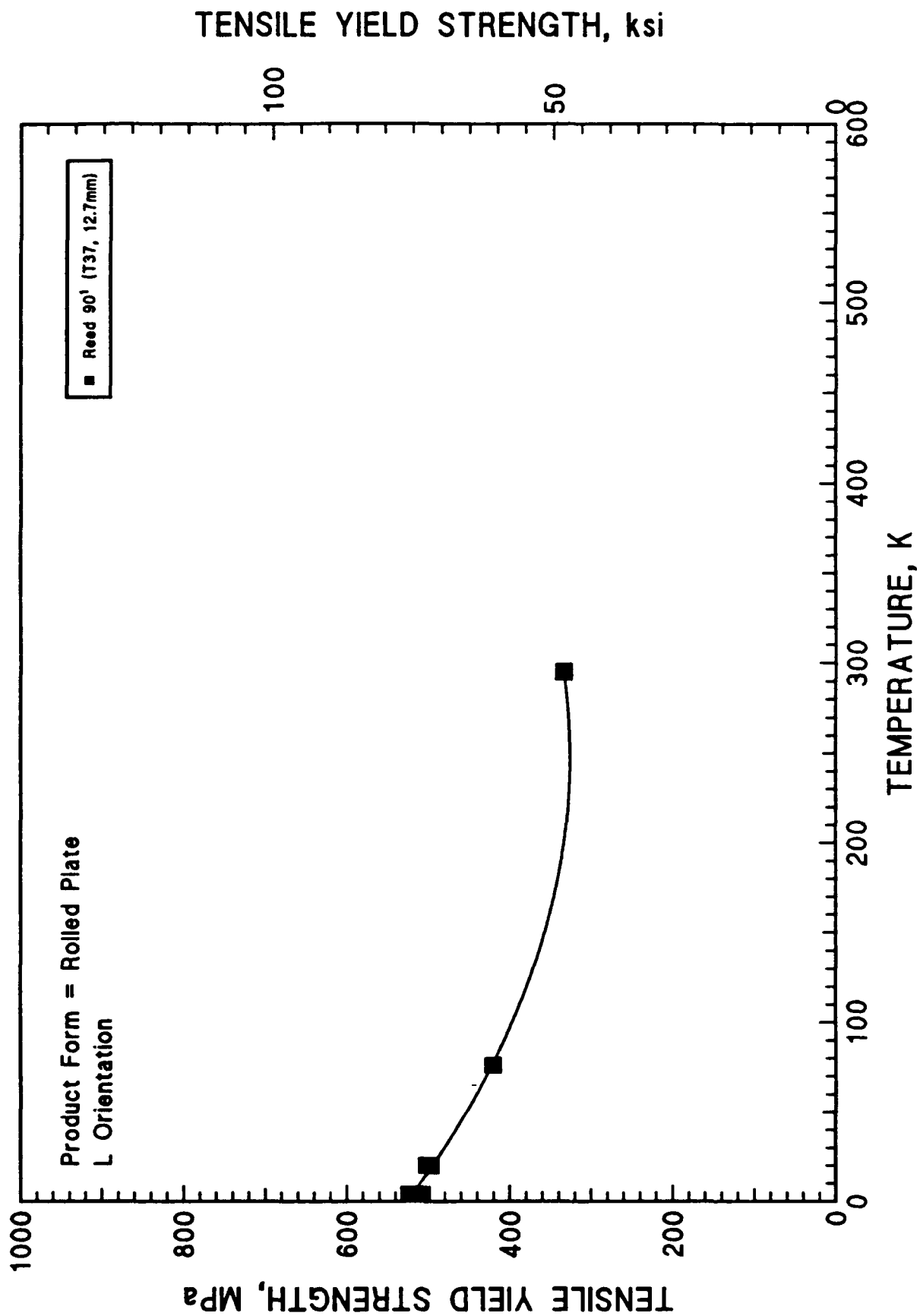
2219-T8



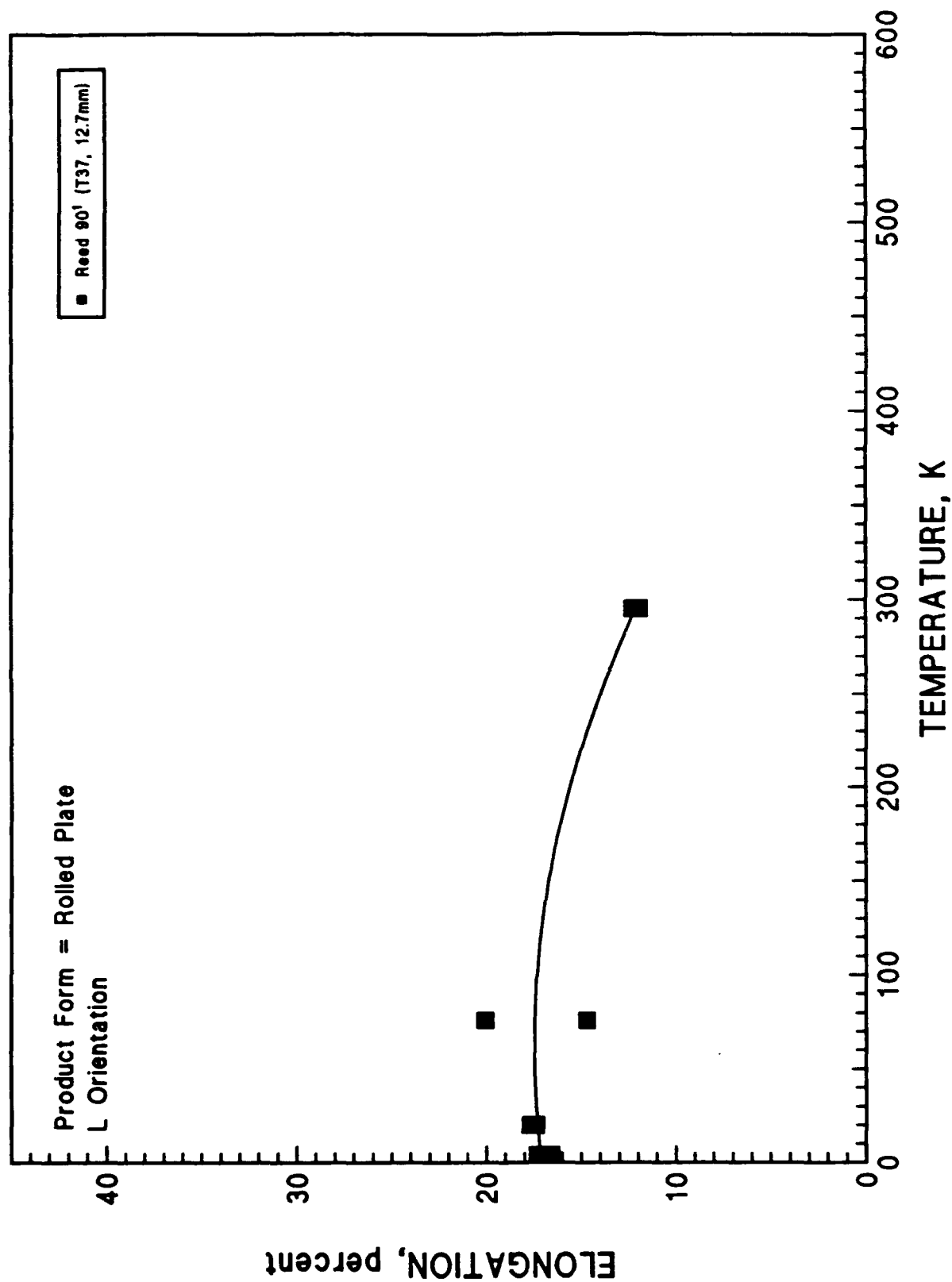
2219-T3



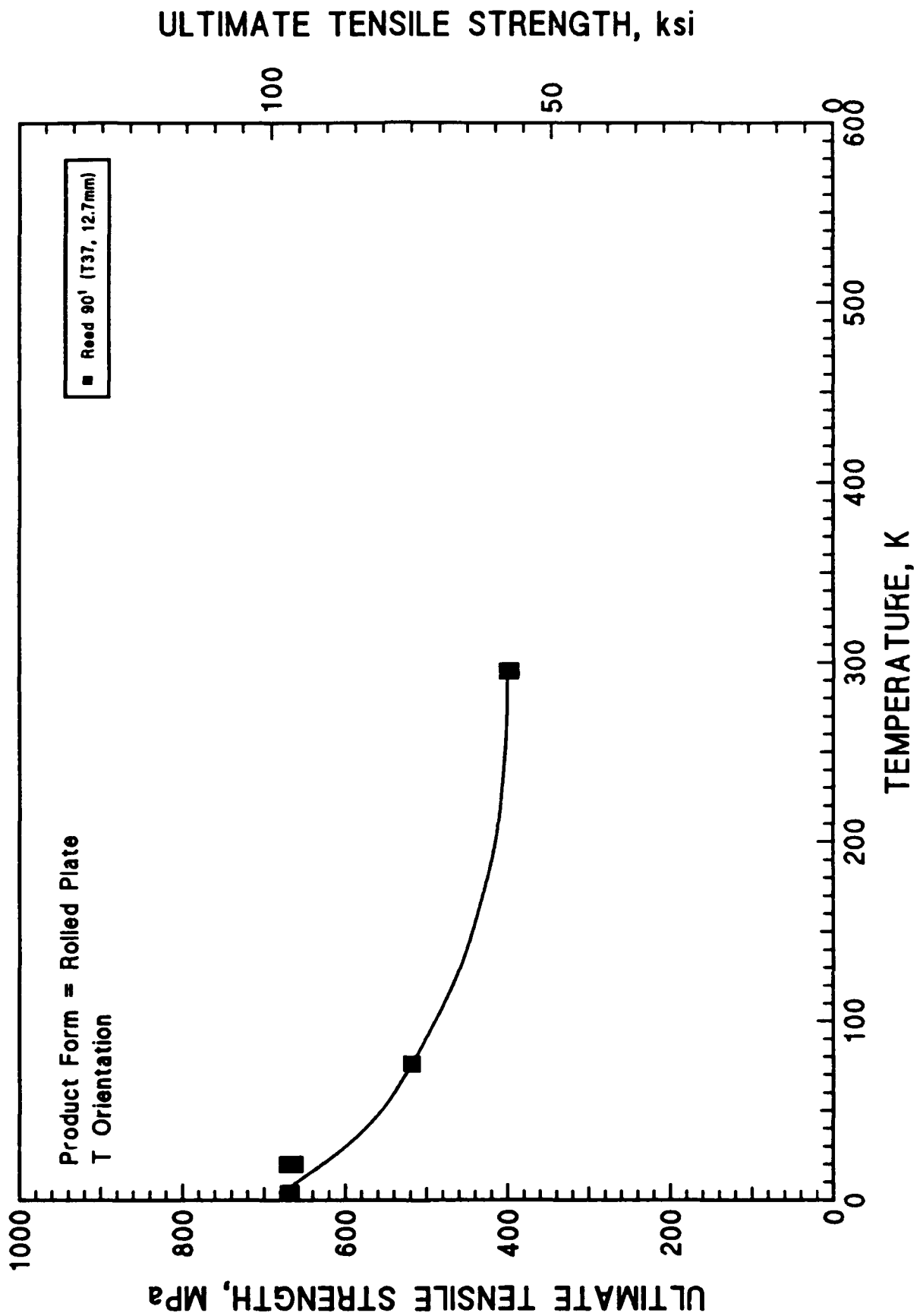
2219-T3



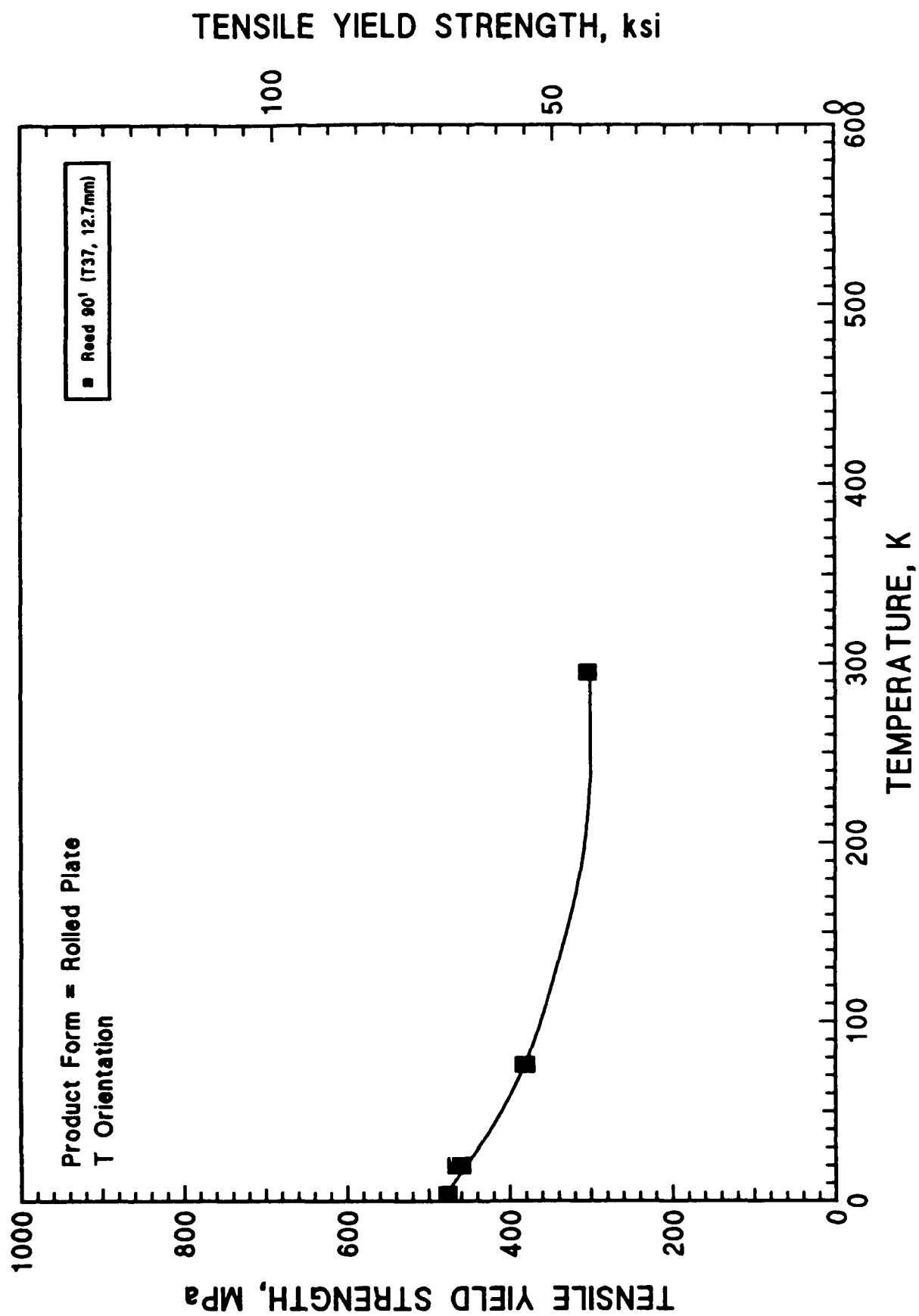
2219-T3



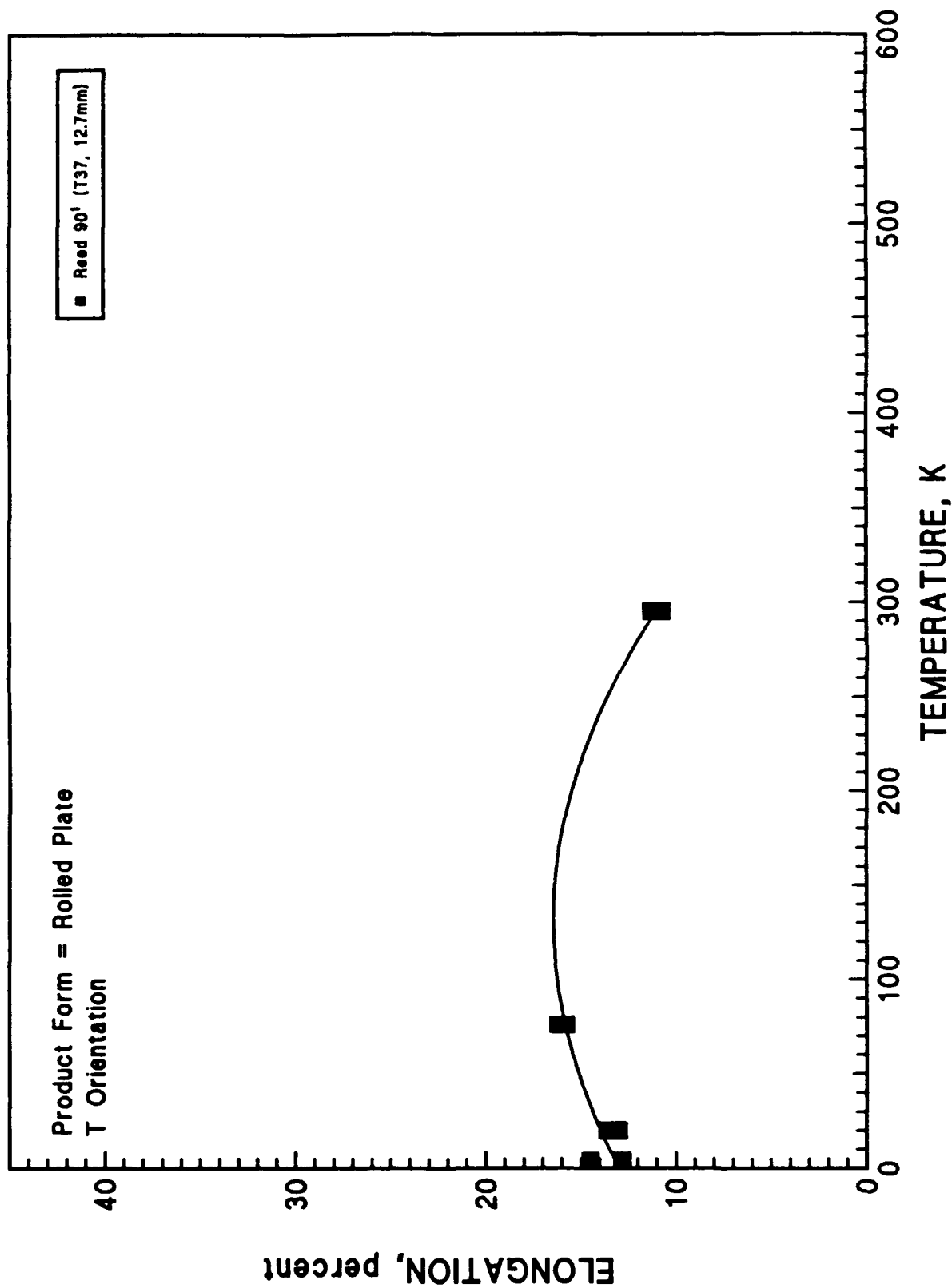
2219-T3



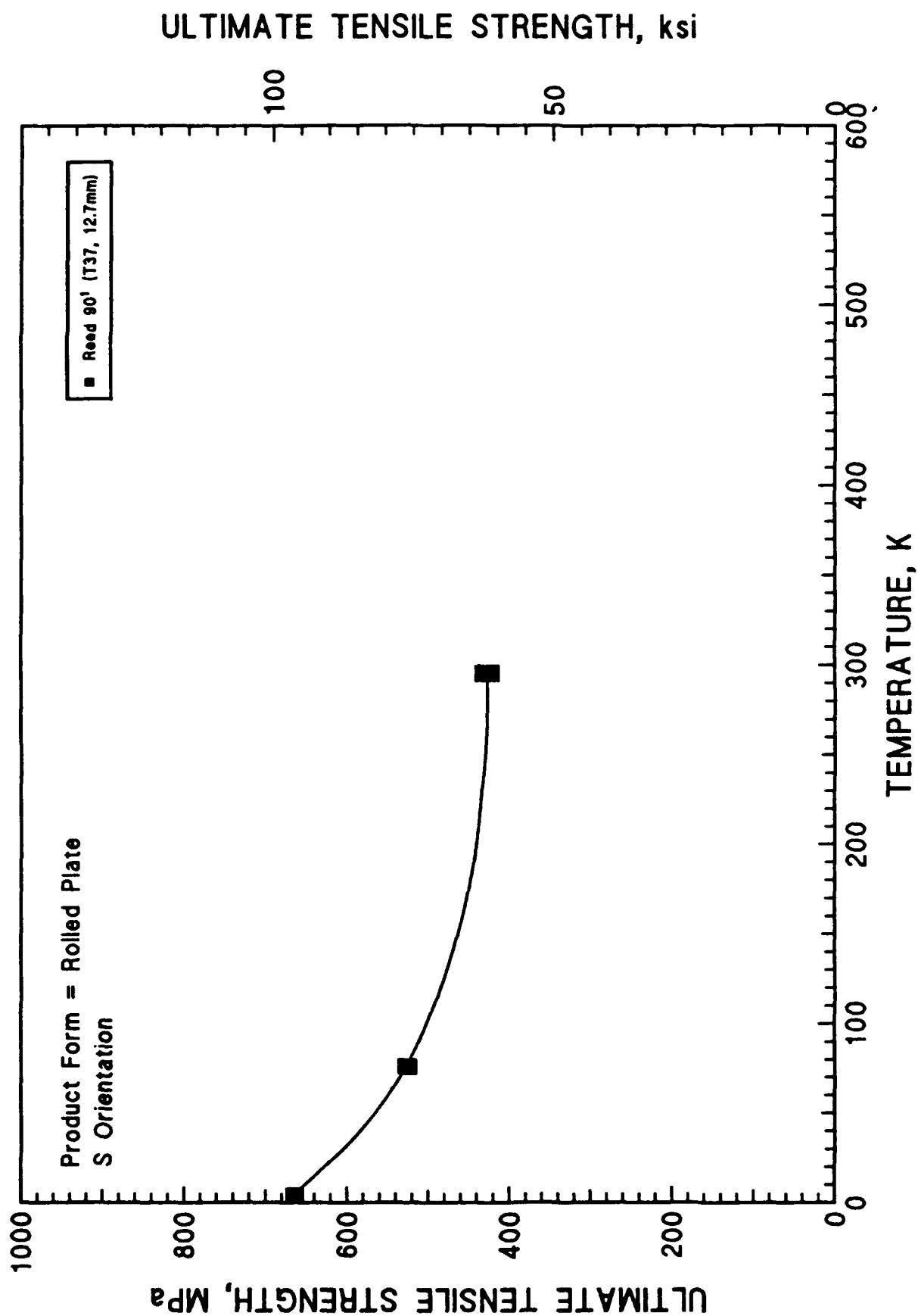
2219-T3



2219-T3



2219-T3



AL-L4 ALLOY 2219

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper	Product		Aging		Soln. Treat.		Grain Size μm	Hardness	No. of Tests/ Data Pt
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h	Quench Cond.	
1Q	295	472.	385.	13.	33.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
1Q	295	472.	387.	13.	31.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
1Q	76	582.	461.	14.	31.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
1Q	76	583.	464.	14.	31.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
1Q	4	707.	504.	15.	28.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
1Q	4	701.	508.	14.	29.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
21A	298	465.	383.	11.8	28.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
21A	193	496.	413.	12.	28.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
21A	77	576.	462.	14.	28.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
21A	20	680.	499.	15.2	21.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
21A	4	676.	518.	15.5	24.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
21A	4	672.	505.	15.	22.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	300	463.	376.	17.3	30.9	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	300	463.	395.	16.4	29.9	L	T87	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
22A	300	456.	374.	14.7	28.9	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	300	476.	390.	15.1	29.9	L	T87	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
22A	194	509.	410.	14.7	28.9	L	T87	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
22A	194	487.	400.	14.7	26.5	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper Form	Product		Aging		Soln. Treat.		Grain Size μm	Hardness	No. of Tests/ Data Pt
								Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h			
22A	104	483.	393.	14.2	27.9	L	T87	Rollled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	104	507.	416.	15.6	27.9	L	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
22A	77	565.	462.	18.2	30.9	L	T87	Rollled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	77	578.	465.	15.6	28.9	L	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
22A	77	578.	457.	16.4	28.9	L	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
22A	77	563.	452.	16.4	28.9	L	T87	Rollled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	20	655.	491.	22.2	28.9	L	T87	Rollled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	20	663.	502.	17.3	27.9	L	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
22A	20	639.	487.	0.	27.9	L	T87	Rollled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	20	703.	534.	20.4	25.5	L	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
23A	300	469.	385.	10.8	0.	L	T87	Rollled Plate	6.35	NA	NA	NA	NA	NA	NA	1
23A	300	458.	376.	10.7	0.	L	T87	Rollled Plate	6.35	NA	NA	NA	NA	NA	NA	1
23A	77	578.	454.	12.8	0.	L	T87	Rollled Plate	6.35	NA	NA	NA	NA	NA	NA	1
23A	77	581.	461.	12.2	0.	L	T87	Rollled Plate	6.35	NA	NA	NA	NA	NA	NA	1
23A	20	676.	485.	16.	0.	L	T87	Rollled Plate	6.35	NA	NA	NA	NA	NA	NA	1
23A	20	665.	489.	12.5	0.	L	T87	Rollled Plate	6.35	NA	NA	NA	NA	NA	NA	1
23B	300	469.	386.	9.8	0.	L	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
23B	77	592.	470.	11.2	0.	L	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
23B	20	687.	476.	10.	0.	L	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper °C	Product		Aging		Soln. Treat.		Grain Size µm	Hardness	No. of Tests/ Data Pt
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h	Quench Cond.	
23C	300	479.	382.	10.	0.	L	T87	Rolled Plate	50.8	NA	NA	NA	NA	NA	NA	1
23C	300	473.	393.	9.7	0.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
23C	77	601.	479.	12.5	0.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
23C	77	616.	489.	10.5	0.	L	T87	Rolled Plate	50.8	NA	NA	NA	NA	NA	NA	1
23C	20	673.	532.	12.	0.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
23C	20	700.	521.	7.5	0.	L	T87	Rolled Plate	50.8	NA	NA	NA	NA	NA	NA	1
23D	300	469.	388.	10.3	0.	L	T87	Rolled Plate	38.1	NA	NA	NA	NA	NA	NA	1
23D	77	594.	472.	12.3	0.	L	T87	Rolled Plate	38.1	NA	NA	NA	NA	NA	NA	1
23D	20	691.	514.	11.7	0.	L	T87	Rolled Plate	38.1	NA	NA	NA	NA	NA	NA	1
23E	300	455.	379.	6.3	0.	L	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	300	456.	379.	6.6	0.	L	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	300	482.	398.	8.7	0.	L	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	300	487.	403.	8.7	0.	L	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	300	457.	383.	6.6	0.	L	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	77	592.	471.	7.3	0.	L	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	77	591.	463.	7.3	0.	L	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	77	576.	466.	5.8	0.	L	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	77	619.	492.	10.2	0.	L	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	77	616.	490.	8.5	0.	L	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper Form	Product		Aging		Soln. Treat.		Grain Size μm	Hardness	No. of Tests/ Data Pt
								Thickness mm	Form	Temp. °C	Time h	Stretch %	Temp. °C	Time h	Quench Cond.	
23E	20	532.	507.	6.7	0.	L	T87	127	Rolled Plate	NA	NA	NA	NA	NA	NA	1
23E	20	703.	527.	8.52	0.	L	T87	127	Rolled Plate	NA	NA	NA	NA	NA	NA	1
23E	20	696.	510.	6.7	0.	L	T87	127	Rolled Plate	NA	NA	NA	NA	NA	NA	1
23E	20	725.	538.	9.5	0.	L	T87	127	Rolled Plate	NA	NA	NA	NA	NA	NA	1
24A	300	465.	388.	11.8	28.	L	T87	25.4	Rolled Plate	NA	NA	NA	NA	NA	NA	1
24A	194	496.	413.	12.	28.	L	T87	25.4	Rolled Plate	NA	NA	NA	NA	NA	NA	1
24A	78	576.	462.	14.	28.	L	T87	25.4	Rolled Plate	NA	NA	NA	NA	NA	NA	1
26A	297	476.	378.	12.	18.4	L	T87	82.6	Rolled Plate	NA	NA	NA	NA	NA	NA	1
26A	297	487.	368.	11.5	15.1	L	T87	82.6	Rolled Plate	NA	NA	NA	NA	NA	NA	1
26A	297	473.	372.	11.5	10.3	L	T87	82.6	Rolled Plate	NA	NA	NA	NA	NA	NA	1
26A	297	487.	382.	11.	15.1	L	T87	82.6	Rolled Plate	NA	NA	NA	NA	NA	NA	1
26A	78	560.	430.	15.	29.4	L	T87	82.6	Rolled Plate	NA	NA	NA	NA	NA	NA	1
26A	78	563.	432.	16.	28.8	L	T87	82.6	Rolled Plate	NA	NA	NA	NA	NA	NA	1
26A	78	587.	444.	14.	19.1	L	T87	82.6	Rolled Plate	NA	NA	NA	NA	NA	NA	1
26A	20	658.	586.	12.6	16.9	L	T87	82.6	Rolled Plate	NA	NA	NA	NA	NA	NA	1
26A	20	647.	490.	15.5	13.4	L	T87	82.6	Rolled Plate	NA	NA	NA	NA	NA	NA	1
26A	20	576.	456.	15.5	17.4	L	T87	82.6	Rolled Plate	NA	NA	NA	NA	NA	NA	1
27A	295	477.	387.	14.	29.	L	T87	15.9	Rolled Plate	NA	NA	NA	NA	NA	NA	1
27A	295	479.	386.	14.	31.	L	T87	15.9	Rolled Plate	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref. & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. I	Temper	Product		Aging		Soln. Treat.		Grain Size μm	Hardness	No. of Tests/ Data Pt
								Form	Thickness mm	Temp. °C	Time h	Temp. °C	Time h			
27A	77	592.	482.	15.	29.	L	T87	Rolled Plate	15.9	NA	NA	NA	NA	NA	NA	1
27A	77	587.	483.	15.	29.	L	T87	Rolled Plate	15.9	NA	NA	NA	NA	NA	NA	1
27A	20	635.	485.	0.	21.	L	T87	Rolled Plate	15.9	NA	NA	NA	NA	NA	NA	1
27A	20	647.	501.	0.	22.	L	T87	Rolled Plate	15.9	NA	NA	NA	NA	NA	NA	1
30A	295	476.	393.	12.	0.	L	T87	Rolled Plate	63.5	NA	NA	NA	NA	NA	NA	1
30A	77	600.	483.	12.	0.	L	T87	Rolled Plate	63.5	NA	NA	NA	NA	NA	NA	1
30A	20	724.	510.	11.	0.	L	T87	Rolled Plate	63.5	NA	NA	NA	NA	NA	NA	1
31A	300	471.	382.	13.	27.6	L	T87	Rolled Plate	19.1	NA	NA	NA	NA	NA	NA	1
31A	300	470.	381.	12.5	24.6	L	T87	Rolled Plate	19.1	NA	NA	NA	NA	NA	NA	1
31A	78	574.	439.	14.	25.3	L	T87	Rolled Plate	19.1	NA	NA	NA	NA	NA	NA	1
31A	78	583.	452.	15.	25.4	L	T87	Rolled Plate	19.1	NA	NA	NA	NA	NA	NA	1
31A	20	682.	470.	16.5	20.	L	T87	Rolled Plate	19.1	NA	NA	NA	NA	NA	NA	1
31A	20	683.	476.	16.5	18.5	L	T87	Rolled Plate	19.1	NA	NA	NA	NA	NA	NA	1
32A	285	469.	378.	10.	28.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
32A	78	572.	448.	13.	22.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
32A	20	669.	462.	15.	0.	L	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
33A	295	479.	403.	12.	28.	L	T87	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
33A	295	477.	397.	12.	30.	L	T87	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
33A	20	693.	497.	17.	22.	L	T87	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper °C	Product		Aging Temp. °C	Aging Time h	Stretch %	Soin. Treat.		Quench Cond.	Grain Size µm	Hardness	No. of Tests/ Date Pt
								Form	Thickness mm				Temp. °C	Time h				
33A	20	690.	492.	17.	24.	L	787	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
35A	295	432.	350.	16.	37.	L	787	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	128 RB	1
35A	295	432.	357.	16.	34.	L	787	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	128 RB	1
35A	295	435.	354.	14.	31.	L	787	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	128 RB	1
35A	295	435.	352.	13.	31.	L	787	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	128 RB	1
35A	295	301.	243.	12.	28.	L	787	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	128 RB	1
35A	17	665.	483.	18.	27.	L	787	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	128 RB	1
35A	17	665.	472.	18.	31.	L	787	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	128 RB	1
35A	17	661.	466.	16.	23.	L	787	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	128 RB	1
35A	17	657.	460.	15.	28.	L	787	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1
35A	17	656.	461.	15.	27.	L	787	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	128 RB	1
1R	297	447.	340.	8.9	17.5	L	7851	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	154.8	1
1R	297	447.	343.	7.6	20.2	L	7851	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	154.8	1
1R	76	556.	411.	9.5	18.4	L	7851	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	154.8	1
1R	76	557.	407.	9.5	23.6	L	7851	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	154.8	1
1R	20	639.	427.	11.	19.5	L	7851	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	154.8	1
1R	20	647.	432.	10.6	14.9	L	7851	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	154.8	1
1R	4	659.	438.	9.	17.	L	7851	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	154.8	1
1R	4	664.	441.	9.3	13.6	L	7851	Roller Plate	12.7	NA	NA	NA	NA	NA	NA	NA	154.8	1

*See Comments

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper. °C	Product			Aging			Soln. Treat.			Grain Size μm	Hardness	No. of Tests/ Data Pt
								Product Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h	Quench Cond.				
1T	295	390.	333.	11.9	30.7	L	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	142.9	1	
1T	295	392.	333.	12.3	26.5	L	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	142.9	1	
1T	76	511.	420.	20.1	29.4	L	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	142.9	1	
1T	76	509.	421.	14.7	25.7	L	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	142.9	1	
1T	20	670.	497.	17.7	16.2	L	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	142.9	1	
1T	20	661.	502.	17.4	22.9	L	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	142.9	1	
1T	4	672.	524.	17.3	20.6	L	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	142.9	1	
1T	4	671.	508.	16.6	24.3	L	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	142.9	1	
1Q	295	471.	380.	13.	27.	T	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	NA	NA	1	
1Q	295	472.	382.	13.	29.	T	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	NA	NA	1	
1Q	76	584.	457.	13.	23.	T	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	NA	NA	1	
1Q	76	580.	454.	13.	24.	T	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	NA	NA	1	
1Q	20	717.	526.	15.	13.4	T	T87	Rolled Plate	82.6	NA	NA	NA	NA	NA	NA	NA	NA	1	
1Q	4	702.	498.	14.	22.	T	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	NA	NA	1	
1Q	4	699.	500.	14.	23.	T	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	NA	NA	1	
22A	300	465.	375.	13.9	20.1	T	T87	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
22A	300	460.	380.	12.9	23.5	T	T87	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	1	
22A	300	460.	379.	12.9	21.1	T	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	NA	NA	1	
22A	300	465.	371.	12.7	0.	T	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	NA	NA	1	

*See Comments

Ref & Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. T	Temper T	Product		Aging		Soln. Treat.		Grain Size μm	Hardness	No. of Tests/ Date Pt
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h	Quench Cond.	
22A	104	491.	378.	11.1	19.1	T	T87	Rollled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	104	491.	391.	11.1	16.7	T	T87	Rollled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	104	497.	403.	13.8	19.1	T	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
22A	104	499.	400.	12.9	24.5	T	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
22A	77	579.	456.	12.9	21.1	T	T87	Rollled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	77	565.	445.	14.7	22.5	T	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
22A	77	573.	455.	12.9	24.5	T	T87	Rollled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	20	663.	525.	16.9	24.5	T	T87	Rollled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	20	662.	469.	16.4	19.1	T	T87	Rollled Plate	25.4	NA	NA	NA	NA	NA	NA	1
22A	20	638.	459.	15.6	26.5	T	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
22A	20	663.	462.	17.3	23.5	T	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
23A	300	471.	381.	9.8	NA	T	T87	Rollled Plate	6.35	NA	NA	NA	NA	NA	NA	1
23A	300	464.	374.	11.3	NA	T	T87	Rollled Plate	9.525	NA	NA	NA	NA	NA	NA	1
23A	77	594.	460.	9.8	NA	T	T87	Rollled Plate	6.35	NA	NA	NA	NA	NA	NA	1
23A	77	585.	449.	11.2	NA	T	T87	Rollled Plate	9.525	NA	NA	NA	NA	NA	NA	1
23A	20	690.	485.	14.3	NA	T	T87	Rollled Plate	6.35	NA	NA	NA	NA	NA	NA	1
23A	20	676.	476.	15.	NA	T	T87	Rollled Plate	9.525	NA	NA	NA	NA	NA	NA	1
23B	300	468.	377.	8.5	NA	T	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1
23B	77	585.	466.	10.3	NA	T	T87	Rollled Plate	12.7	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note No.	Temp. K	I.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. I	Temper I	Product		Aging		Soln. Treat.		Grain Size μm	Hardness	No. of Tests/ Data Pt
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h	Quench Cond.	
23B	20	606.	496.	9.6	NA	T	T87	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
23C	300	489.	385.	9.5	NA	T	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
23C	300	472.	385.	8.	NA	T	T87	Rolled Plate	50.8	NA	NA	NA	NA	NA	NA	1
23C	77	619.	495.	7.	NA	T	T87	Rolled Plate	50.8	NA	NA	NA	NA	NA	NA	1
23C	77	597.	465.	9.3	NA	T	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
23C	20	606.	496.	14.3	NA	T	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
23C	20	682.	503.	6.3	NA	T	T87	Rolled Plate	50.8	NA	NA	NA	NA	NA	NA	1
23D	300	484.	380.	7.5	NA	T	T87	Rolled Plate	38.1	NA	NA	NA	NA	NA	NA	1
23D	77	592.	451.	7.	NA	T	T87	Rolled Plate	38.1	NA	NA	NA	NA	NA	NA	1
23D	20	670.	481.	8.8	NA	T	T87	Rolled Plate	38.1	NA	NA	NA	NA	NA	NA	1
23E	300	480.	381.	5.7	NA	T	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	300	443.	370.	5.	NA	T	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	300	484.	386.	6.3	NA	T	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	300	473.	393.	6.5	NA	T	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	300	471.	393.	5.8	NA	T	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	77	580.	500.	6.2	NA	T	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	77	581.	500.	6.	NA	T	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	77	603.	476.	7.8	NA	T	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1
23E	77	554.	427.	4.7	NA	T	T87	Rolled Plate	127	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref. & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. T	Temper. °C	Product		Aging		Soln. Treat.		Grain Size μm	Hardness	No. of Tests/Data Pt
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h	Quench Cond.	
23E	77	594.	461.	6.3	NA	T	T87	Roller Plate	127	NA	NA	NA	NA	NA	NA	1
23E	20	658.	482.	5.5	NA	T	T87	Roller Plate	127	NA	NA	NA	NA	NA	NA	1
23E	20	616.	474.	4.6	NA	T	T87	Roller Plate	127	NA	NA	NA	NA	NA	NA	1
23E	20	651.	497.	5.5	NA	T	T87	Roller Plate	127	NA	NA	NA	NA	NA	NA	1
23E	20	692.	502.	6.2	NA	T	T87	Roller Plate	127	NA	NA	NA	NA	NA	NA	1
23E	20	684.	500.	6.	NA	T	T87	Roller Plate	127	NA	NA	NA	NA	NA	NA	1
24A	300	470.	388.	10.	19.	T	T87	Roller Plate	25.4	NA	NA	NA	NA	NA	NA	1
24A	194	501.	410.	9.6	16.	T	T87	Roller Plate	25.4	NA	NA	NA	NA	NA	NA	1
24A	78	585.	465.	11.6	20.	T	T87	Roller Plate	25.4	NA	NA	NA	NA	NA	NA	1
25A	295	473.	383.	10.	16.	T	T87	Roller Plate	25	NA	NA	NA	NA	NA	NA	1
25A	295	474.	383.	10.	13.	T	T87	Roller Plate	25	NA	NA	NA	NA	NA	NA	1
25A	78	583.	454.	9.	14.	T	T87	Roller Plate	25	NA	NA	NA	NA	NA	NA	1
25A	78	590.	452.	12.	15.	T	T87	Roller Plate	25	NA	NA	NA	NA	NA	NA	1
25A	20	696.	488.	13.	14.	T	T87	Roller Plate	25	NA	NA	NA	NA	NA	NA	1
25A	20	694.	494.	11.	12.	T	T87	Roller Plate	25	NA	NA	NA	NA	NA	NA	1
26A	297	478.	377.	11.5	9.6	T	T87	Roller Plate	82.6	NA	NA	NA	NA	NA	NA	1
26A	297	481.	378.	11.	9.7	T	T87	Roller Plate	82.6	NA	NA	NA	NA	NA	NA	1
26A	297	476.	381.	11.	15.5	T	T87	Roller Plate	82.6	NA	NA	NA	NA	NA	NA	1
26A	78	563.	434.	14.5	25.1	T	T87	Roller Plate	82.6	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Product Form	Product		Aging		Soin. Treat.		Quench Cond.	Grain Size μm	Hardness	No. of Tests/ Data Pt
								Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h				
26A	78	592.	439.	11.	12.9	T	T07	82.6	NA	NA	NA	NA	NA	NA	NA	NA	1
26A	78	581.	453.	12.5	15.1	T	T07	82.6	NA	NA	NA	NA	NA	NA	NA	NA	1
26A	78	592.	439.	10.	16.5	T	T07	82.6	NA	NA	NA	NA	NA	NA	NA	NA	1
26A	20	595.	485.	11.	11.1	T	T07	82.6	NA	NA	NA	NA	NA	NA	NA	NA	1
26A	20	633.	461.	6.7	13.	T	T07	82.6	NA	NA	NA	NA	NA	NA	NA	NA	1
27A	295	478.	387.	14.	20.	T	T07	15.9	NA	NA	NA	NA	NA	NA	NA	NA	1
27A	295	478.	388.	14.	31.	T	T07	15.9	NA	NA	NA	NA	NA	NA	NA	NA	1
27A	77	598.	450.	12.	18.	T	T07	15.9	NA	NA	NA	NA	NA	NA	NA	NA	1
27A	77	599.	456.	12.	19.	T	T07	15.9	NA	NA	NA	NA	NA	NA	NA	NA	1
27A	20	654.	0.	0.	18.	T	T07	15.9	NA	NA	NA	NA	NA	NA	NA	NA	1
27A	20	0.	492.	0.	16.	T	T07	15.9	NA	NA	NA	NA	NA	NA	NA	NA	1
28A	300	483.	399.	10.5	16.	T	T07	31.75	NA	NA	NA	NA	NA	NA	NA	NA	1
28A	77	547.	456.	9.5	18.	T	T07	31.75	NA	NA	NA	NA	NA	NA	NA	NA	1
28A	20	697.	494.	7.	19.	T	T07	31.75	NA	NA	NA	NA	NA	NA	NA	NA	1
28A	20	716.	521.	9.5	25.	T	T07	31.75	NA	NA	NA	NA	NA	NA	NA	NA	1
28A	300	479.	388.	10.5	0.	T	T07	31.75	NA	NA	NA	NA	NA	NA	NA	NA	1
28A	300	480.	392.	10.	0.	T	T07	31.75	NA	NA	NA	NA	NA	NA	NA	NA	1
29A	77	591.	468.	10.	0.	T	T07	31.75	NA	NA	NA	NA	NA	NA	NA	NA	1
29A	77	592.	467.	10.5	0.	T	T07	31.75	NA	NA	NA	NA	NA	NA	NA	NA	1

*See Comments

Ref & Note	Temp. K	Y.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. %	Temper Form	Product		Aging		Soln. Treat.		Grain Size μm	Hardness	No. of Tests/ Data Pt
								Thickness mm	Time h	Temp. °C	Time h	Temp. °C	Quench Cond.			
29A	20	683.	470.	13.	0.	T	T87	31.75	MA	MA	NA	NA	NA	NA	NA	1
29A	20	711.	530.	12.	0.	T	T87	31.75	MA	MA	NA	NA	NA	NA	NA	1
30A	295	476.	375.	10.	0.	T	T87	63.5	MA	MA	NA	NA	NA	NA	NA	1
30A	295	476.	386.	8.	0.	T	T87	25.4	MA	MA	MA	NA	NA	MA	MA	1
30A	77	593.	455.	12.	0.	T	T87	25.4	MA	MA	MA	NA	NA	MA	MA	1
30A	77	593.	462.	11.	MA	T	T87	63.5	MA	MA	MA	NA	NA	MA	MA	1
30A	20	690.	476.	11.	0.	T	T87	25.4	MA	MA	MA	NA	NA	MA	MA	1
30A	20	696.	503.	10.	MA	T	T87	63.5	MA	MA	MA	NA	NA	MA	MA	1
31A	300	472.	374.	80.	10.4	T	T87	19.1	MA	MA	MA	NA	NA	MA	MA	1
31A	300	474.	378.	7.5	11.9	T	T87	19.1	MA	MA	MA	NA	NA	MA	MA	1
31A	78	504.	464.	10.5	12.0	T	T87	19.1	MA	MA	MA	NA	NA	MA	MA	1
31A	78	565.	455.	11.	13.3	T	T87	19.5	MA	MA	MA	NA	NA	MA	MA	1
31A	20	700.	498.	12.	11.6	T	T87	19.1	MA	MA	MA	NA	NA	MA	MA	1
31A	20	693.	494.	14.5	14.8	T	T87	19.1	MA	MA	MA	NA	NA	MA	MA	1
32A	295	476.	386.	8.	15.	T	T87	25.4	MA	MA	MA	NA	NA	MA	MA	1
32A	78	593.	455.	12.	14.	T	T87	25.4	MA	MA	MA	NA	NA	MA	MA	1
32A	20	690.	476.	11.	13.	T	T87	25.4	MA	MA	MA	NA	NA	MA	MA	1
33A	295	485.	402.	9.	19.	T	T87	12.7	MA	MA	MA	NA	NA	MA	MA	1
33A	295	485.	399.	9.	17.	T	T87	12.7	MA	MA	MA	NA	NA	MA	MA	1

*See Comments

Ref 4		Product												Soln. Treat.		Grain Size		Hardness		No. of	
Note No.	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. I	Temper. °C	Product Form	Thickness mm	Aging Temp. °C	Time h	Stretch %	Temp. °C	Time h	Quench Cond.	µm				Tests/	Data Pt
33A	20	700.	502.	15.	16.	T	T87	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
33A	20	702.	502.	14.	17.	T	T87	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
34A	300	503.	412.	NA	NA	T	T87	Rolled Plate	38.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
34A	300	509.	411.	NA	NA	T	T87	Rolled Plate	38.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
34A	76	630.	490.	NA	NA	T	T87	Rolled Plate	38.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
34A	76	630.	486.	NA	NA	T	T87	Rolled Plate	38.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
34A	4	706.	514.	NA	NA	T	T87	Rolled Plate	38.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
34A	4	734.	547.	NA	NA	T	T87	Rolled Plate	38.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
1R	297	444.	332.	7.7	13.6	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	154.8	154.8	1	1
1R	297	443.	330.	8.2	18.3	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	154.8	154.8	1	1
1R	76	559.	403.	9.	14.6	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	154.8	154.8	1	1
1R	76	557.	406.	8.0	17.2	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	154.8	154.8	1	1
1R	20	658.	429.	10.5	15.8	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	154.8	154.8	1	1
1R	20	641.	419.	11.2	18.	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	154.8	154.8	1	1
1R	4	663.	435.	9.6	15.8	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	154.8	154.8	1	1
1R	4	658.	433.	9.3	13.6	T	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	154.8	154.8	1	1
1T	295	306.	303.	11.3	25.	T	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	142.9	142.9	1	1
1T	295	400.	304.	10.7	24.3	T	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	142.9	142.9	1	1
1T	76	518.	383.	16.2	20.	T	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	NA	NA	142.9	142.9	1	1

*See Comments

Ref & Note	Temp. K	T.S. MPa	Y.S. MPa	Elong. %	R.A. %	Orient. °	Temper °C	Product		Aging		Soin. Treat.		Grain Size µm	Hardness	No. of Tests/ Data Pt
								Form	Thickness mm	Temp. °C	Time h	Stretch %	Temp. °C	Time h	Quench Cond.	
1T	76	516.	379.	15.6	22.	T	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1T	20	671.	467.	13.6	19.9	T	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1T	20	662.	459.	13.	16.2	T	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1T	4	667.	476.	12.8	17.2	T	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1T	4	670.	478.	14.5	15.4	T	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	NA	1
1Q	295	469.	379.	13.	30.	45°	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
1Q	295	468.	378.	14.	33.	45°	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
1Q	76	578.	449.	14.	29.	45°	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
1Q	76	580.	450.	13.	28.	45°	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
1Q	4	704.	491.	15.	27.	45°	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
1Q	4	702.	491.	15.	28.	45°	T87	Rolled Plate	25.4	NA	NA	NA	NA	NA	NA	1
1S	295	476.	NA	NA	NA	S	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	154.8	1
1S	295	462.	NA	NA	NA	S	T851	Rolled Plate	12.7	NA	NA	NA	NA	NA	154.8	1
1U	295	432.	NA	NA	NA	S	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	142.9	1
1U	295	422.	NA	NA	NA	S	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	142.9	1
1U	76	524.	NA	NA	NA	S	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	142.9	1
1U	76	527.	NA	NA	NA	S	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	142.9	1
1U	4	663.	NA	NA	NA	S	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	142.9	1
1U	4	665.	NA	NA	NA	S	T37	Rolled Plate	12.7	NA	NA	NA	NA	NA	142.9	1

*See Comments

TEST PARAMETERS
Al-Li ALLOY 2219

Ref & Strain		Specimen				Expo	Major Elements				Minor Elements							
		Type	Dim	Thick	G.L.							Specimen						
Note	Rate					Time	Supplier	Yr.	Lot	Product	Li	Cu	Mg	Zr	Si	Fe	Ag	wt%
No.	10-4/s		mm	mm	mm	min		Prod.	No.	L(m) X W(m)				wt%				
1Q	2.2	Round	6.35	NA	25.4	Mid-plane	5.	NASA	1990	484881	0.307 X 0.307	NA	5.7	NA	0.01	0.07	0.02	NA
1R	2.2	Round	6.35	NA	25.4	Mid-plane	5.	Kaiser	1989	429881	1.02 X 1.02	NA	5.7	0.	0.15	0.07	0.02	NA
1S	2.2	Round	2.5	NA	25.4	Random	5.	Kaiser	1989	429881	1.02 X 1.02	NA	5.7	NA	0.15	0.07	0.02	NA
1T	2.2	Round	6.35	NA	25.4	Mid-plane	5.	Kaiser	1989	486341	1.02 X 1.02	NA	5.7	0.	0.15	0.07	0.02	NA
1U	2.2	Round	2.5	NA	25.4	Random	5.	Kaiser	1989	486341	1.02 X 1.02	NA	5.7	NA	0.15	0.07	0.02	NA
21A	7.4	NA	12.7	NA	57.	NA	15.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
22A	NA	Round	4.06	NA	NA	NA	NA	NA	NA	NA	NA	6.3	0.	0.18	0.2	0.3	NA	NA
23A	NA	NA	NA	NA	50.8	NA	NA	NA	NA	NA	NA	6.3	0.	0.17	0.2	0.3	NA	NA
23B	NA	Flat	12.7	3.175	50.8	NA	NA	NA	NA	NA	NA	6.3	0.	0.17	0.2	0.3	NA	NA
23C	NA	Flat	25.4	3.175	50.8	NA	NA	NA	NA	NA	NA	6.3	0.	0.17	0.2	0.3	NA	NA
23D	NA	Flat	19.	3.175	50.8	NA	NA	NA	NA	NA	NA	6.3	0.	0.17	0.2	0.3	NA	NA
23E	NA	Flat	25.4	NA	50.8	NA	NA	NA	NA	NA	NA	6.3	0.	0.17	0.2	0.3	NA	NA
24A	NA	Flat	12.7	NA	50.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
25A	NA	Flat	13.	9.52	50.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
27A	NA	Round	12.8	NA	50.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
27A .003	Flat	15.9	12.7	50.8	NA	NA	NA	NA	NA	NA	NA	6.3	0.	0.17	0.2	0.3	NA	NA
28A .003	Plate	12.7	NA	50.8	NA	NA	NA	NA	NA	NA	NA	6.3	0.	0.17	0.2	0.3	NA	NA
29A .003	Plate	12.7	NA	50.8	NA	NA	NA	NA	NA	NA	NA	6.3	0.	0.17	0.2	0.3	NA	NA

Ref & Strain Note No.	Rate 10 ⁻⁴ /s	Specimen			Specimen Location	Expo Time min	Supplier	Yr. Prod.	Lot No.	Product L(m) X W(m)	Major Elements							Minor Elements wt%
		Type	Diam	Thick	G.L.						Li	Cu	Hg	Zr	Si	Fe	Ag	
			mm	mm	mm									wt%				
30A	.003	Flat	12.7	MA	50.8	MA	NA	NA	NA	NA	NA	6.3	0.	0.17	0.2	0.3	NA	NA
30B	.003	Flat	12.7	12.7	50.8	MA	NA	NA	NA	NA	NA	6.3	0.	0.17	0.2	0.3	NA	NA
31A	.003	Flat	19.1	12.7	50.8	MA	NA	NA	NA	NA	NA	6.3	0.	0.17	0.2	0.3	NA	NA
32A	.003	MA	MA	MA	50.8	MA	NA	NA	NA	NA	NA	6.3	0.	0.17	0.2	0.3	NA	NA
33A	.002	Flat	12.7	7.62	50.8	MA	NA	NA	NA	NA	NA	5.9	003	0.12	0.12	0.25	NA	NA
34A	NA	MA	MA	MA	MA	MA	NA	NA	NA	NA	NA	NA	NA	MA	MA	NA	NA	NA
35A	MA	MA	3.17	MA	12.7	MA	NA	NA	NA	NA	NA	NA	NA	NA	MA	MA	NA	NA

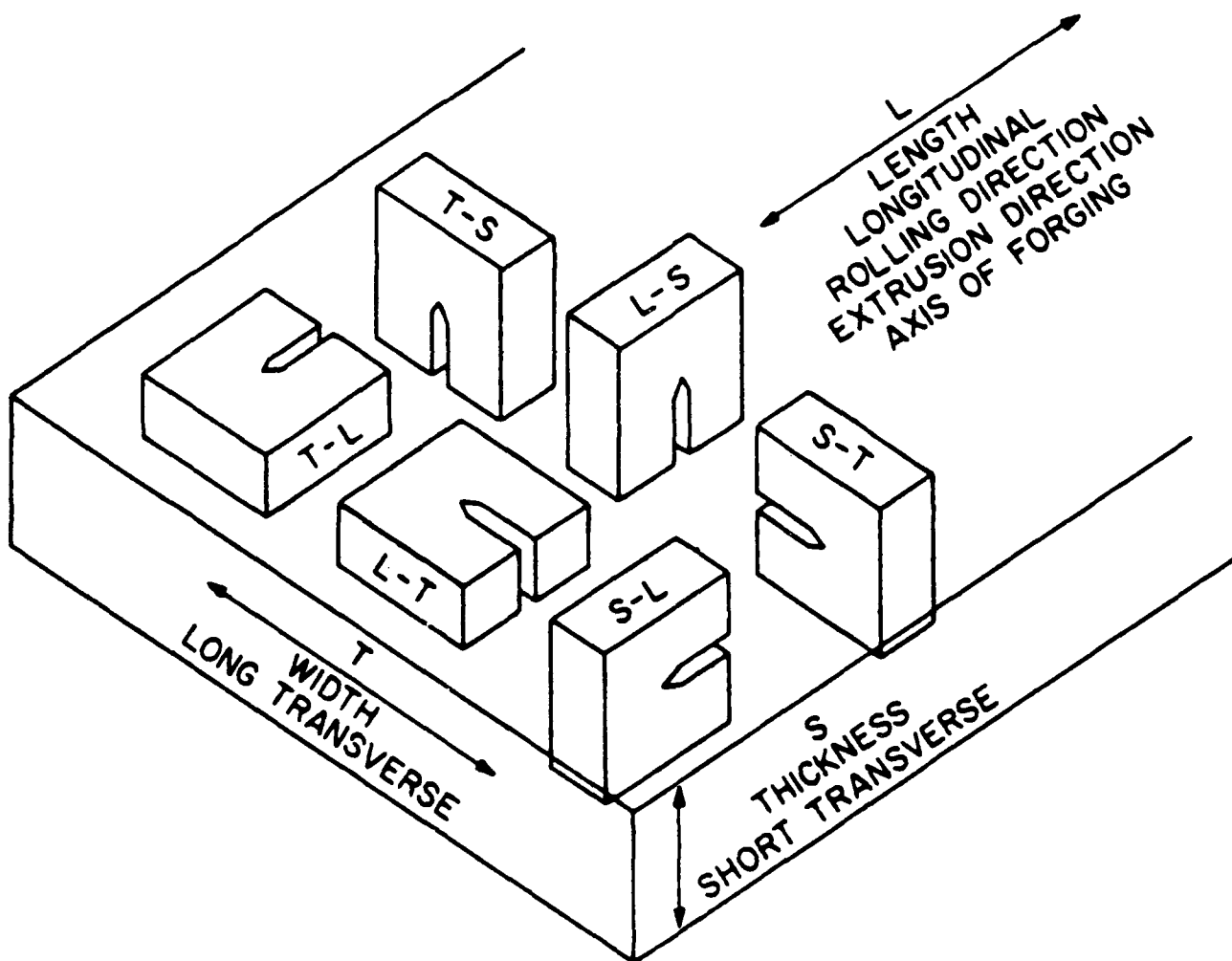
2. FRACTURE TOUGHNESS

2.1. Introduction to Graphs

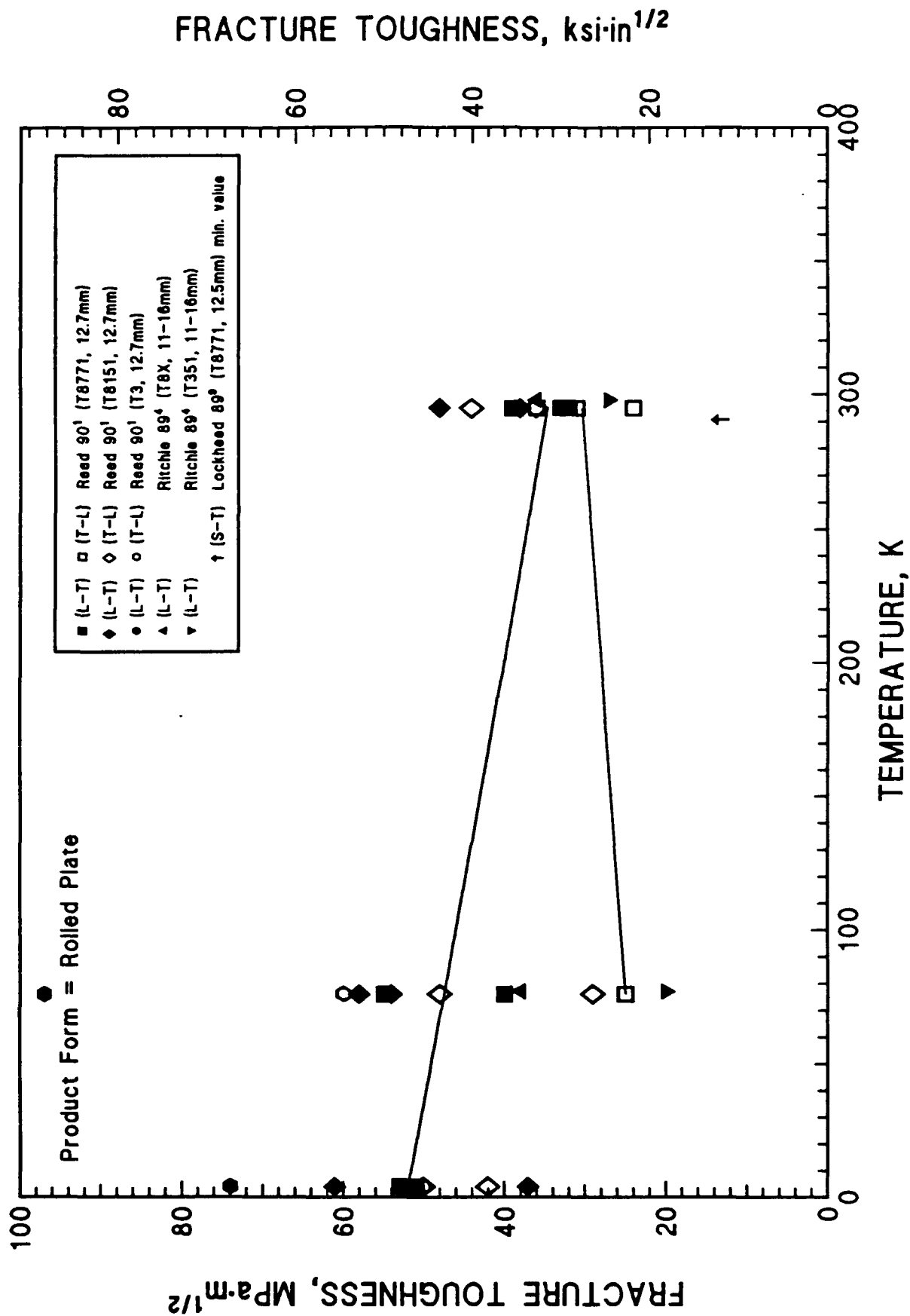
Fracture toughness data at room temperature are presented (with few exceptions) only when measurements at cryogenic temperatures are part of the data set. Thus, only K_{IC} data on CT (compact tension) specimens are presented in this review. These data are currently available because measurements are relatively easy to carry out in conventional cryostats compared with wide-panel center-crack or part-through crack tests. Most of the measurements on current production vintages and tempers were carried out during the last year at NIST. These measurements are discussed more fully, including fracture mode and microstructural considerations, in another NIST report¹ on comparative cryogenic mechanical properties. A figure showing the possible specimen orientations with respect to the rolling direction precedes the graphs of fracture toughness data. The fracture toughness is presented graphically both as a function of temperature and as a function of yield strength.

All graphical data are presented and referenced in tables following the graphs. The properties presented in the data tables are the fracture toughness and yield strength, along with temper, product information, thermomechanical processing, grain size, hardness, number of tests per data point, and the reference and note number. The reference and note number is a guide to the accompanying test conditions table, which gives information on the specimen type and dimensions, precrack conditions, existence of side grooves or multiple specimens, invalidating criterion, chemistry, and procedures, including the test standard used. A list of comments follows the fracture toughness data table and the fracture toughness test conditions table for each alloy where necessary.

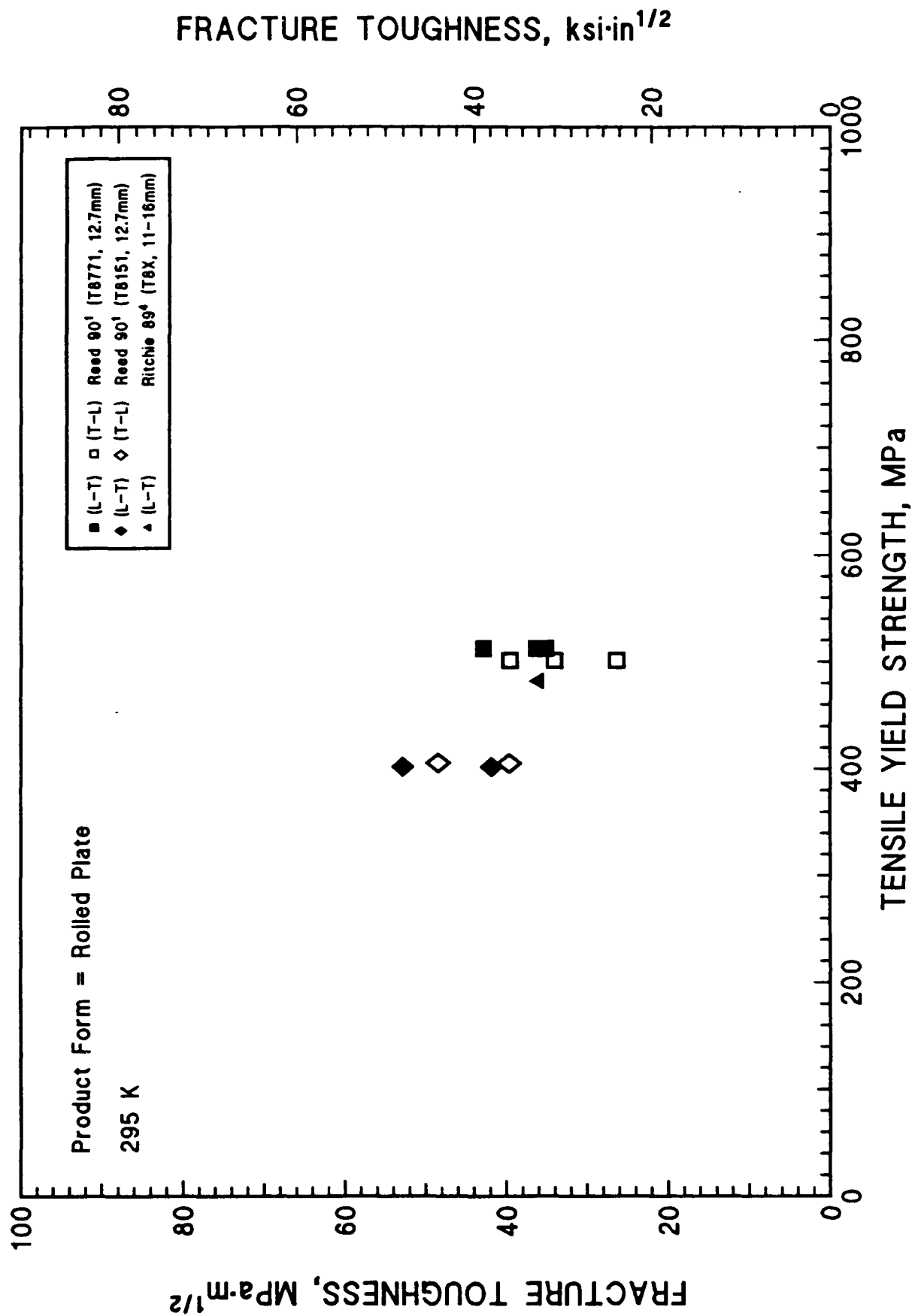
NIST is currently engaged in a program to expand the cryogenic fracture toughness database by testing 102-mm (4.0-in) panels with part-through cracks. The type of fracture toughness data presented in this new program is determined by design needs of the ALS program, where these alloys are under consideration for use in cryogenic tankage. Generally, a leak is equivalent to failure, so part-through cracks in wide panel testing are more relevant than center-crack tests. Wide panel testing at temperatures of 20 and 4 K is quite limited, and there are no data to report at present.



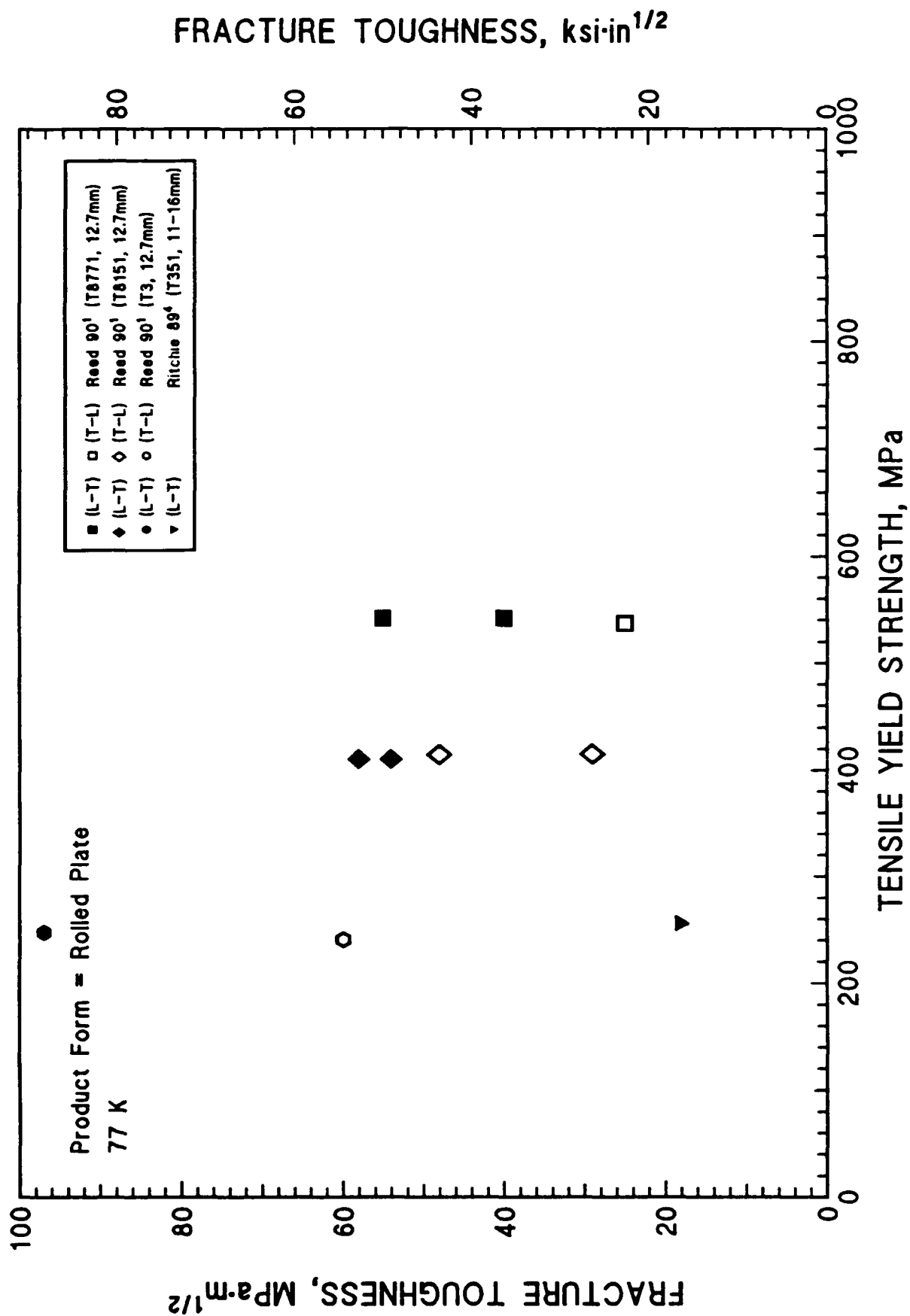
8090



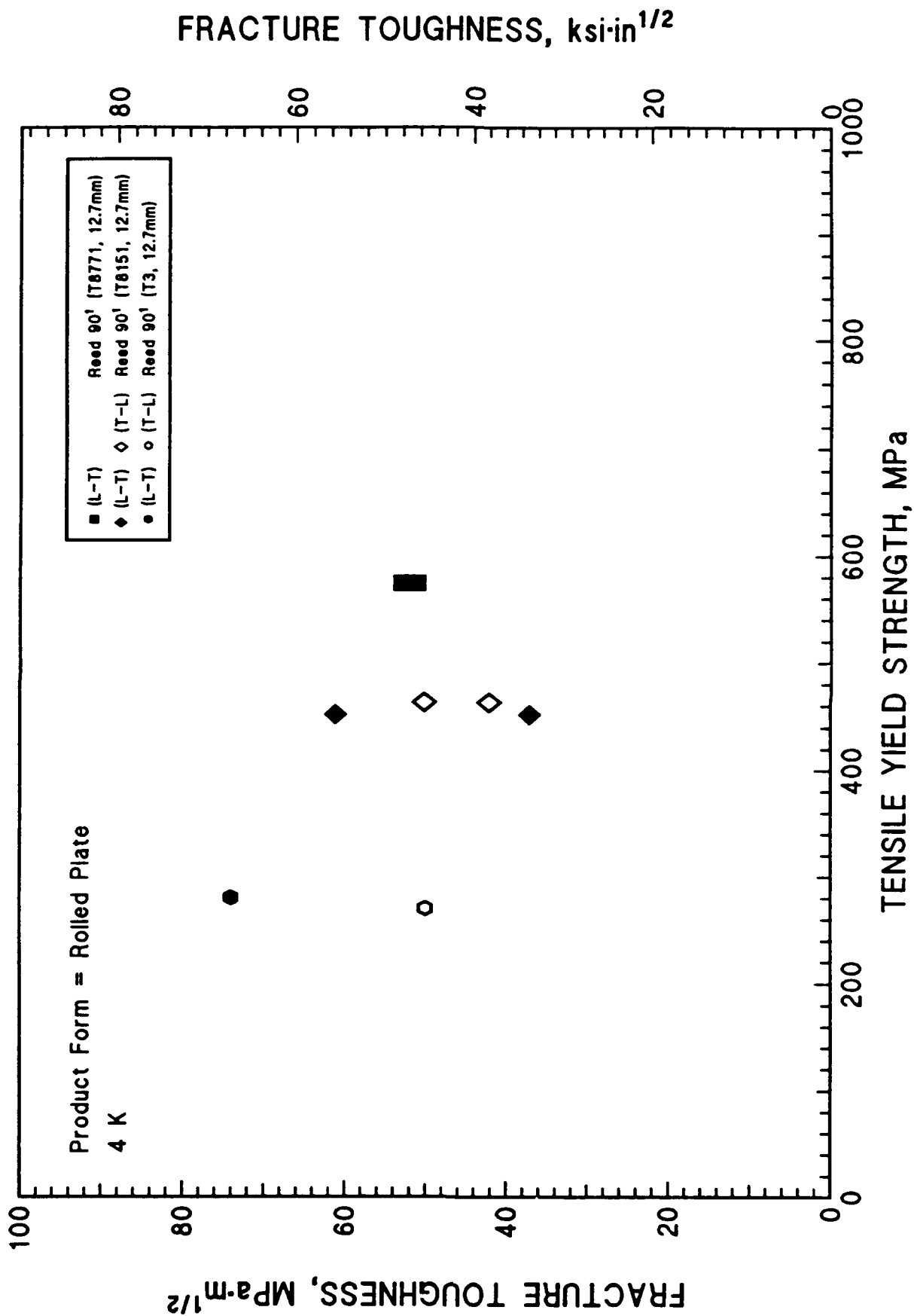
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Fracture Toughness
Alloy 8080

Ref & Note No.	Temp. K	K MPa/m	Y.S. MPa	Orient.	Temper	Product Form	Product Thickness mm	Supplier; Year; Lot Number	Aging Temp. °C	Time h	Cold Work %	Soln Treat. Temp. °C	Time h	Quench Cond.	Grain Size			Hardness	No. of Tests/ Data Pt
															L	X	T X ST µm		
1A	295	39.	512.	L-T	T8771	Rollled Plate	12.7	ALCAN; '89 ;3503302B	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	1
1A	295	32.	512.	L-T	T8771	Rollled Plate	12.7	ALCAN; '89 ;3503302B	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	1
1A	295	33.	512.	L-T	T8771	Rollled Plate	12.7	ALCAN; '89 ;3503302B	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	1
1B	76	40.	542.	L-T	T8771	Rollled Plate	12.7	ALCAN; '89 ;3503302B	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	1
1B	76	55.	542.	L-T	T8771	Rollled Plate	12.7	ALCAN; '89 ;3503302B	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	1
1B	4	53.	574.	L-T	T8771	Rollled Plate	12.7	ALCAN; '89 ;3503302B	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	1
1B	4	51.	574.	L-T	T8771	Rollled Plate	12.7	ALCAN; '89 ;3503302B	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	1
1C	295	38.	402.	L-T	T8151	Rollled Plate	12.7	ALCAN; '89 ;35712859	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
1C	295	48.	402.	L-T	T8151	Rollled Plate	12.7	ALCAN; '89 ;35712852	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
1D	76	58.	411.	L-T	T8151	Rollled Plate	12.7	ALCAN; '89 ;35712859	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
1D	76	54.	411.	L-T	T8151	Rollled Plate	12.7	ALCAN; '89 ;35712852	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
1D	4	61.	452.	L-T	T8151	Rollled Plate	12.7	ALCAN; '89 ;35712852	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
1D	4	37.	452.	L-T	T8151	Rollled Plate	12.7	ALCAN; '89 ;35712852	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
4B	298	36.	482.	L-T	T8X	Rollled Plate	12.7	ALCAN ;NA	180	16.	3	NA	NA	NA	1500	350	40	NA	1
4C	77	38.	NA	L-T	T8X	Rollled Plate	12.7	ALCAN ;NA	180	16.	3	NA	NA	NA	1500	350	40	NA	1
4A	77	20.	256.	L-T	T351	Rollled Plate	12.7	ALCAN ;NA	NA	NA	3	NA	NA	NA	1500	350	40	NA	1
1E	76	97.	248.	L-T	T3	Rollled Plate	12.7	ALCAN; '89 ;3518302A	NA	NA	2	NA	NA	NA	600	NA	20	118.5, V	1
1E	4	74.	280.	L-T	T3	Rollled Plate	12.7	ALCAN; '89 ;3518302A	NA	NA	2	NA	NA	NA	600	NA	20	118.5, V	1

Ref & Note No.	Temp. K	K MPa/mm	Y.S. MPa	Orient.	Temper	Product Form	Product Thickness mm	Supplier;		Product Thickness mm	Aging Temp. °C	Time h	Cold Work %	Soln Treat.		Quench Cond.	Grain Size					Hardness	No. of Tests/ Data Pt
								Year;	Lot Number					Temp. °C	h		Temp. °C	h	L	X	T		
1A	295	31.	501.	T-L	T8771	Rolled Plate	12.7	ALCAN; '89	; 3503302B	NA	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	NA	1	
1A	295	36.	501.	T-L	T8771	Rolled Plate	12.7	ALCAN; '89	; 3503302B	NA	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	NA	1	
1A	295	24.	501.	T-L	T8771	Rolled Plate	12.7	ALCAN; '89	; 3503302B	NA	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	NA	1	
1B	76	25.	537.	T-L	T8771	Rolled Plate	12.7	ALCAN; '89	; 3503302B	NA	NA	NA	6	NA	NA	NA	NA	NA	NA	NA	NA	1	
1C	295	36.	405.	T-L	T8151	Rolled Plate	12.7	ALCAN; '89	; 35712850	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	
1C	295	44.	405.	T-L	T8151	Rolled Plate	12.7	ALCAN; '89	; 35712852	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	
1D	76	29.	415.	T-L	T8151	Rolled Plate	12.7	ALCAN; '89	; 35712852	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	
1D	76	48.	415.	T-L	T8151	Rolled Plate	12.7	ALCAN; '89	; 35712852	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	
1D	4	42.	463.	T-L	T8151	Rolled Plate	12.7	ALCAN; '89	; 35712852	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	
1D	4	50.	463.	T-L	T8151	Rolled Plate	12.7	ALCAN; '89	; 35712852	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	
1E	76	60.	241.	T-L	T3	Rolled Plate	12.7	ALCAN; '89	; 3518302A	NA	NA	NA	2	NA	NA	NA	NA	600	NA	20	118.5, V	1	
1E	4	50.	270.	T-L	T3	Rolled Plate	12.7	ALCAN; '89	; 3518302A	NA	NA	NA	2	NA	NA	NA	NA	600	NA	20	118.5, V	1	
9A	295	13.2	NA	T-S	T8771	Rolled Plate	12.7	NA	; NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	*	

Comments from the Al-Li Alloy 8090 Data Table

Reference and
Note Number

9A--Values reported are "minimum" properties.

Fracture Toughness
Test Conditions
Alloy 8090

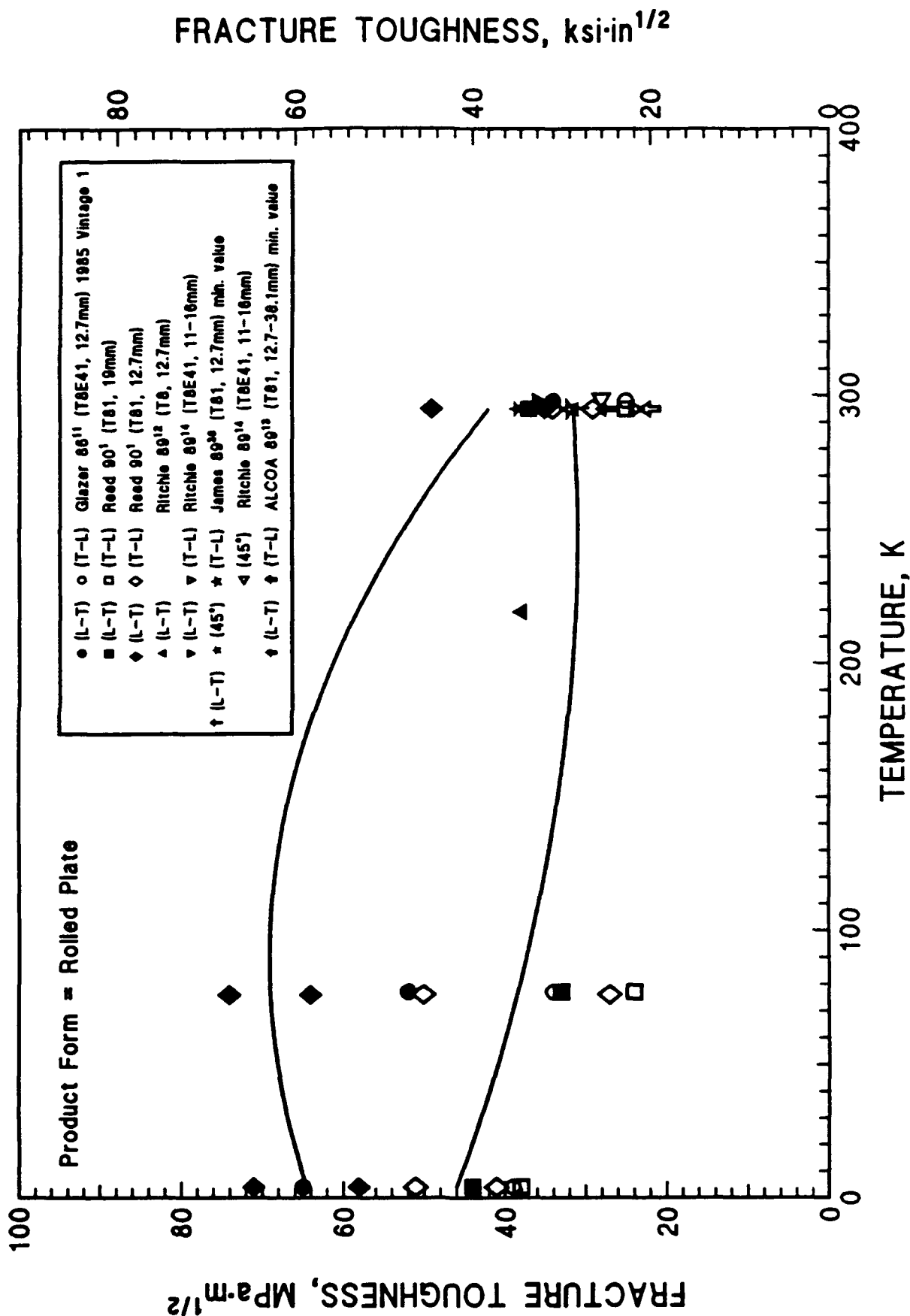
Ref & Note	Specimen Type	Specimen Dimensions				Precrack		Side- Groove	Multi- Spec. no/#	Invalidating Criterion	Major Elements								Procedures
		B	W	a/W	Other	Temp K	Freq Hz				Li	Cu	Mg	Zr	Si	Fe	Ag		
No.			mm								wt%								
1A	CT	12.7	50.8	NA	NA	295	20.	no	no	NA		2.36	1.2	0.7	0.11	0.02	0.06	NA	ASTM E813
1B	CT	12.7	50.8	NA	NA	76	20.	no	no	NA		2.36	1.2	0.7	0.11	0.02	0.06	NA	ASTM E813
1C	CT	12.7	50.8	NA	NA	295	20.	no	no	NA		2.36	1.2	0.7	0.11	0.02	0.06	NA	ASTM E813
1D	CT	12.7	50.8	NA	NA	76	20.	no	no	NA		2.36	1.2	0.7	0.11	0.02	0.06	NA	ASTM E813
1E	CT	12.7	50.8	NA	NA	76	20.	no	no	NA		2.34	1.2	0.6	0.12	0.03	0.03	NA	ASTM E813
4A	CT	7.6	NA	0.5	NA	NA	NA	NA	NA	NA		2.50	1.3	0.7	0.12	0.1	0.2	NA	ASTM E399-83
4B	CT	7.6	NA	0.5	NA	NA	NA	NA	NA	NA		2.50	1.3	0.7	0.12	0.1	0.2	NA	ASTM E399-83
4C	CT	7.6	NA	0.5	NA	NA	NA	NA	NA	NA		2.5	1.3	0.7	0.12	0.1	0.2	NA	ASTM E399-83
9A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA

Comments from the Al-Li Alloy 8090 Test Conditions Table

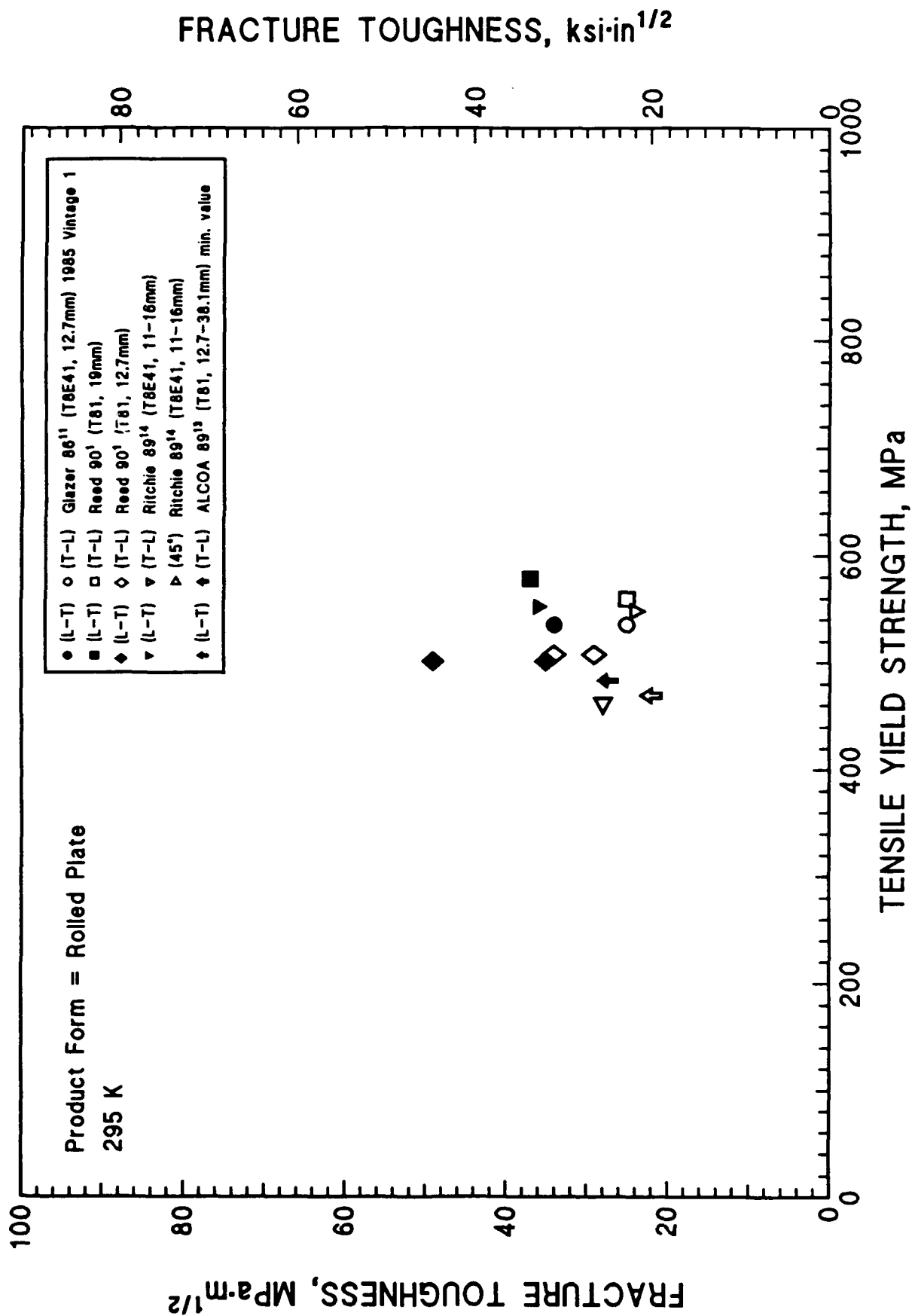
Reference and
Note Number

9A--Reported composition is the average of the range provided for in the Lockheed requirements.

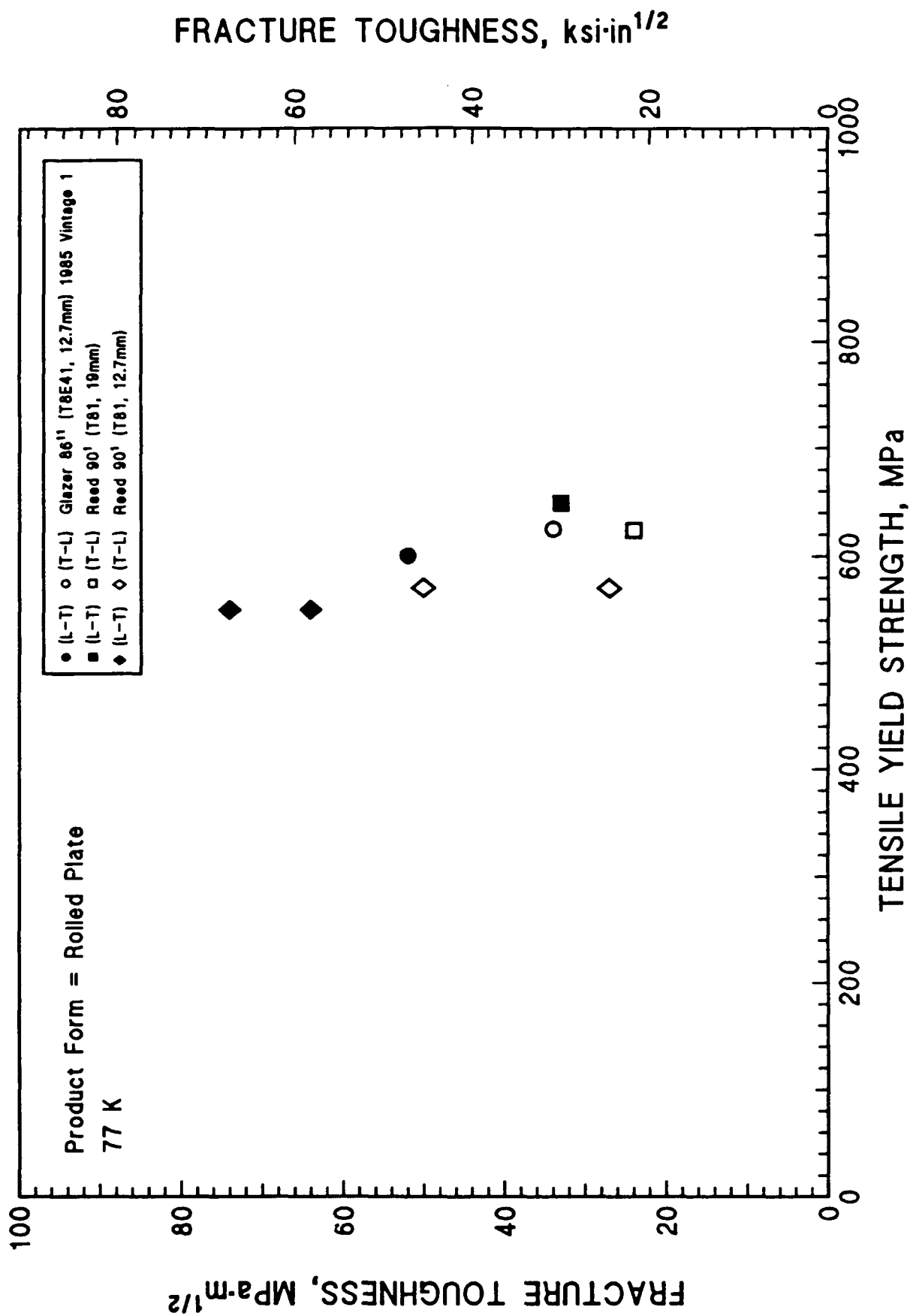
2090



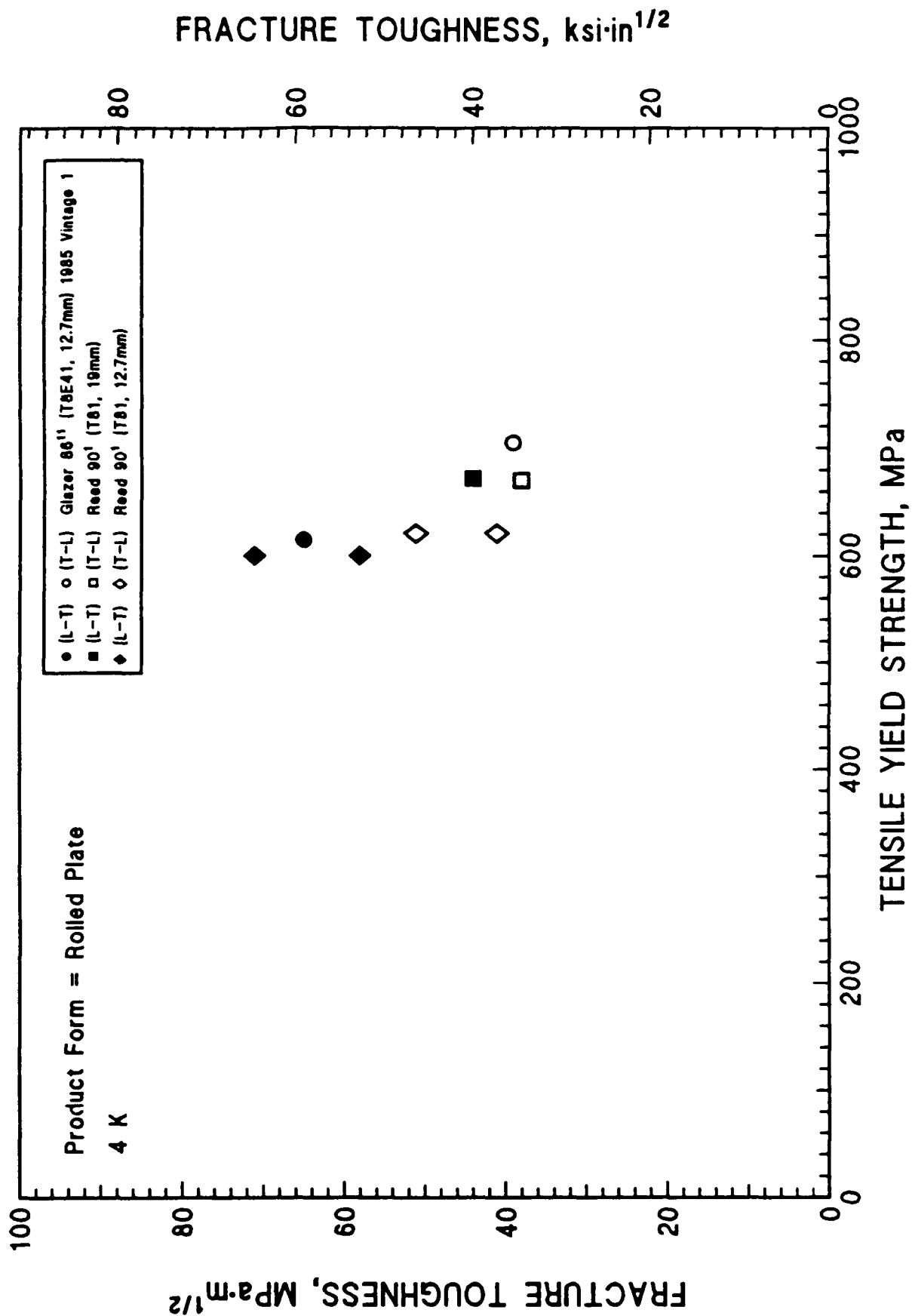
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Fracture Toughness
Alloy 2090

Ref & Note No.	Temp. K	K MPa/m	Y.S. MPa	Orient. Temp	Product Form	Product Thickness mm	Supplier; Year; Lot Number	Aging Temp. °C	h	Cold Work Z	Soln Treat. Temp. °C	Time h	Quench Cond.	Grain Size			Hardness	No. of Tests/ Data Pt
														L	X	T X ST µm		
1F	295	49.	501.	L-T	781	781	ALCOA; '89 ;103301	NA	NA	NA	NA	NA	NA	2000	NA	200	198.3, V	1
1F	295	35.	501.	L-T	781	781	ALCOA; '89 ;103301	NA	NA	NA	NA	NA	NA	2000	NA	200	198.3, V	1
1G	77	64.	550.	L-T	781	781	ALCOA; '89 ;103301	NA	NA	NA	NA	NA	NA	2000	NA	200	198.3, V	1
1G	77	74.	550.	L-T	781	781	ALCOA; '89 ;103301	NA	NA	NA	NA	NA	NA	2000	NA	200	198.3, V	1
1G	4	71.	600.	L-T	781	781	ALCOA; '89 ;103301	NA	NA	NA	NA	NA	NA	2000	NA	200	198.3, V	1
1G	4	58.	600.	L-T	781	781	ALCOA; '89 ;103301	NA	NA	NA	NA	NA	NA	2000	NA	200	198.3, V	1
1H	295	37.	578.	L-T	781	781	ALCOA; '89 ;103299	NA	NA	NA	NA	NA	NA	2000	NA	100	198.3, V	1
1I	77	33.	649.	L-T	781	781	ALCOA; '89 ;103299	NA	NA	NA	NA	NA	NA	2000	NA	100	198.3, V	1
1I	4	44.	672.	L-T	781	781	ALCOA; '89 ;103299	NA	NA	NA	NA	NA	NA	2000	NA	100	198.3, V	1
12A	219	38.	565.	L-T	781	781	ALCOA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
13A	295	27.5	483.	L-T	781	781	25.4 NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	*
36B	295	27.5	NA	L-T	781	781	12.7 NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	*
11A	298	34.	535.	L-T	78E41	78E41	ALCOA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
11A	77	52.	600.	L-T	78E41	78E41	ALCOA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
11A	4	65.	615.	L-T	78E41	78E41	ALCOA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
14A	298	36.	552.	L-T	78E41	78E41	ALCOA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
1F	295	34.	507.	T-L	781	781	ALCOA; '89 ;103301	NA	NA	NA	NA	NA	NA	2000	NA	200	198.3, V	1
1F	295	28.	507.	T-L	781	781	ALCOA; '89 ;103301	NA	NA	NA	NA	NA	NA	2000	NA	200	198.3, V	1

Ref & Note No.	Temp. K	K MPa/m	Y.S. MPa	Orient.	Temper	Product Form	Product Thickness mm	Supplier; Year; Lot Number	Aging		Cold Work %	Soln Treat.		Grain Size				Hardness	No. of Tests/ Data Pt
									Temp. °C	Time h		Temp. °C	Time h	L	X	T	X	ST	
1G	77	27.	570.	T-L	T81	Rolled Plate	12.7	ALCOA; '89 ; 103301	NA	NA	NA	NA	NA	2000	NA	200	NA	198.3, V	1
1G	77	50.	570.	T-L	T81	Rolled Plate	12.7	ALCOA; '89 ; 103301	NA	NA	NA	NA	NA	2000	NA	200	NA	198.3, V	1
1G	4	41.	621.	T-L	T81	Rolled Plate	12.7	ALCOA; '89 ; 103301	NA	NA	NA	NA	NA	2000	NA	200	NA	198.3, V	1
1H	295	25.	559.	T-L	T81	Rolled Plate	19.05	ALCOA; '89 ; 103299	NA	NA	NA	NA	NA	2000	NA	100	NA	198.3, V	1
1G	4	51.	621.	T-L	T81	Rolled Plate	12.7	ALCOA; '89 ; 103301	NA	NA	NA	NA	NA	2000	NA	200	NA	NA	1
1I	77	24.	624.	T-L	T81	Rolled Plate	19.05	ALCOA; '89 ; 103299	NA	NA	NA	NA	NA	2000	NA	100	NA	198.3, V	1
1I	4	38.	670.	T-L	T81	Rolled Plate	19.05	ALCOA; '89 ; 103299	NA	NA	NA	NA	NA	2000	NA	100	NA	198.3, V	1
13A	295	22.	469.	T-L	T81	Rolled Plate	25.4	NA ; NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
36A	295	31.9	NA	T-L	T81	Rolled Plate	12.7	ALCOA ; 400-011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
11A	298	25.	535.	T-L	T8E41	Rolled Plate	12.7	ALCOA ; NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
11A	77	34.	625.	T-L	T8E41	Rolled Plate	12.7	ALCOA ; NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
11A	4	39.	705.	T-L	T8E41	Rolled Plate	12.7	ALCOA ; NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
14A	298	24.	548.	T-L	T8E41	Rolled Plate	12.7	ALCOA ; NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
36A	295	39.5	NA	45°	T81	Rolled Plate	12.7	ALCOA ; 400-011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
14A	298	28.	460.	45°	T8E41	Rolled Plate	12.7	ALCOA ; NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1

Comments from the Al-Li Alloy 2090 Data Table

Reference and
Note Number

37B--Value reported is a proposed minimum value.

13A--Value reported are "minimum" properties.

Fracture Toughness
Test Conditions
Alloy 2090

Ref & Note	Specimen Type	Specimen Dimensions				Precrack		Multi- Spec. no/#	Invalidating Criterion	Major Elements							Procedures																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
		B	W	a/W	Other	Temp K	Freq Hz			Side- Groove	Li	Cu	Mg	Zr	Si	Fe		Ag																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
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Comments from the Al-Li Alloy 2090 Test Conditions Table

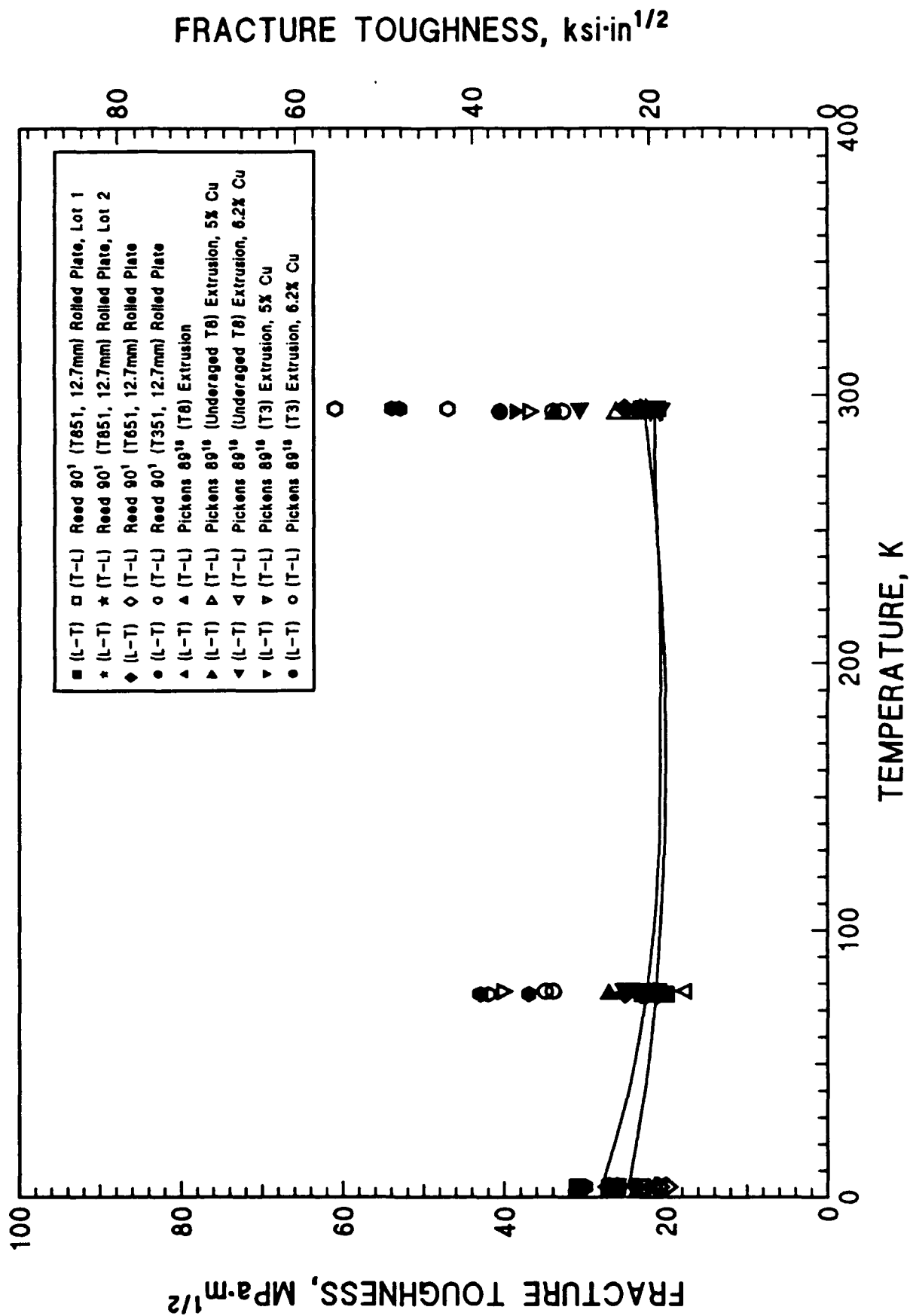
Reference and
Note Number

11A--Reported composition is based on nominal values.

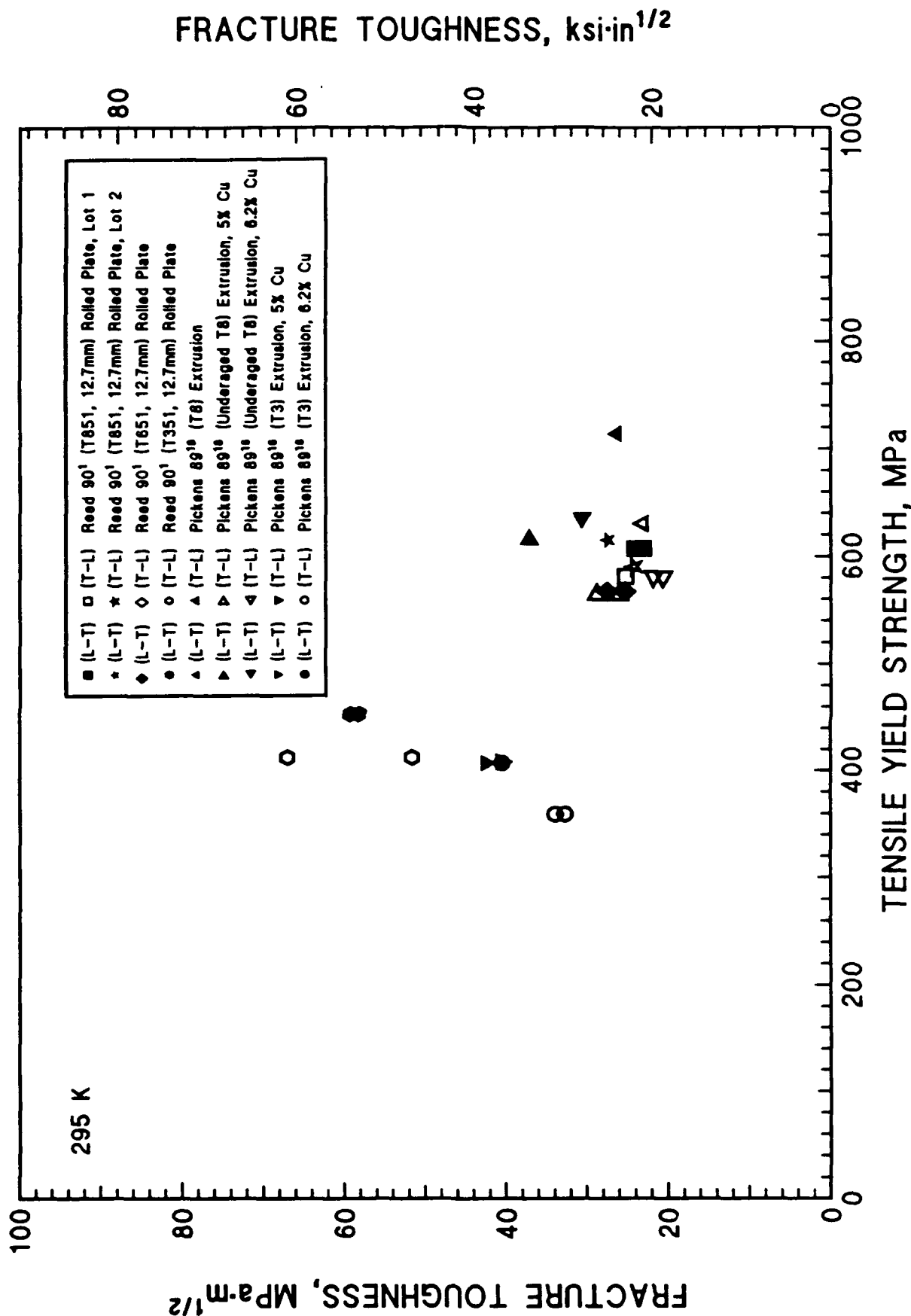
13A--Reported composition is the average of the minimum and maximum values.

18A--Reported composition is based on nominal values.

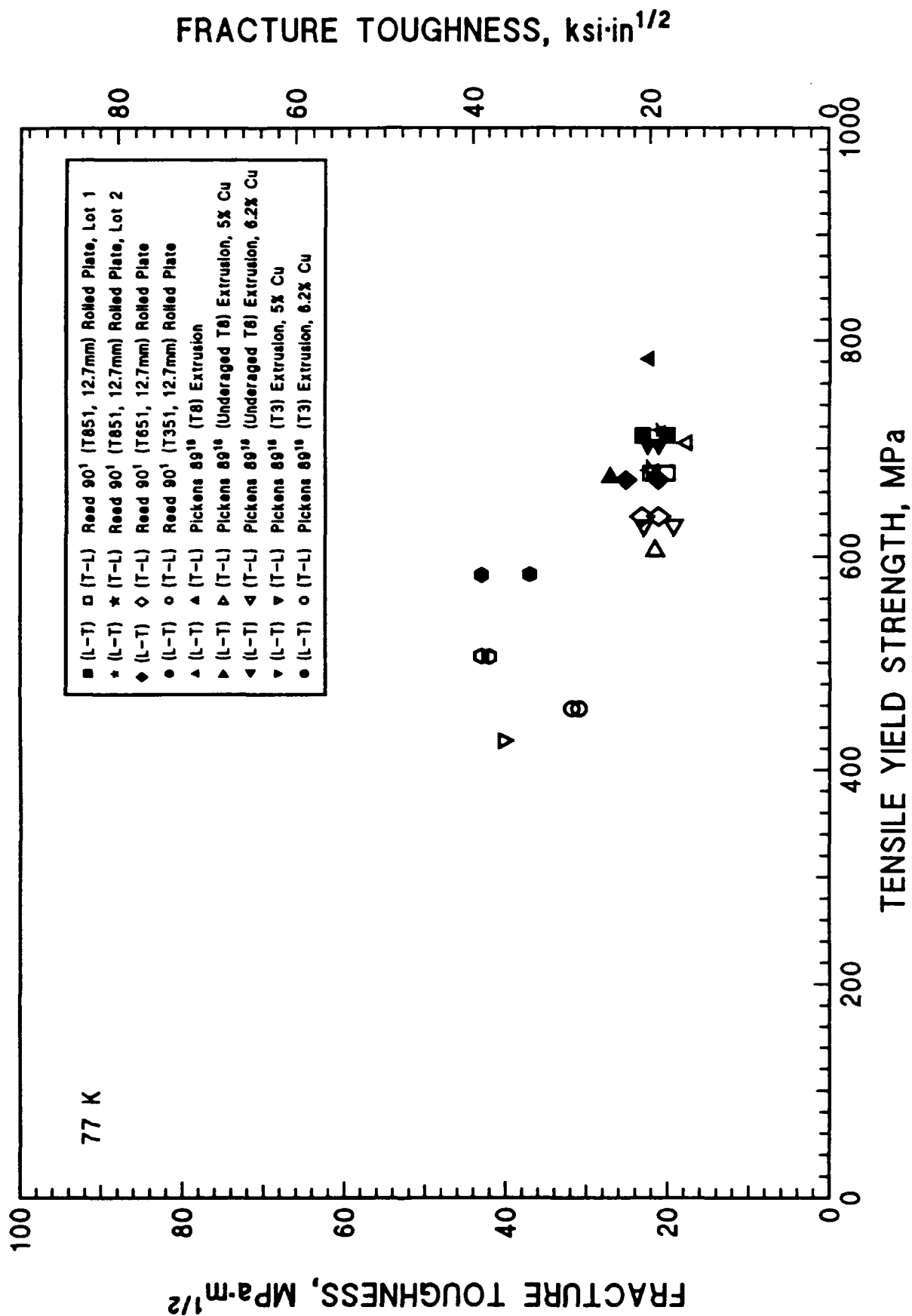
WL049



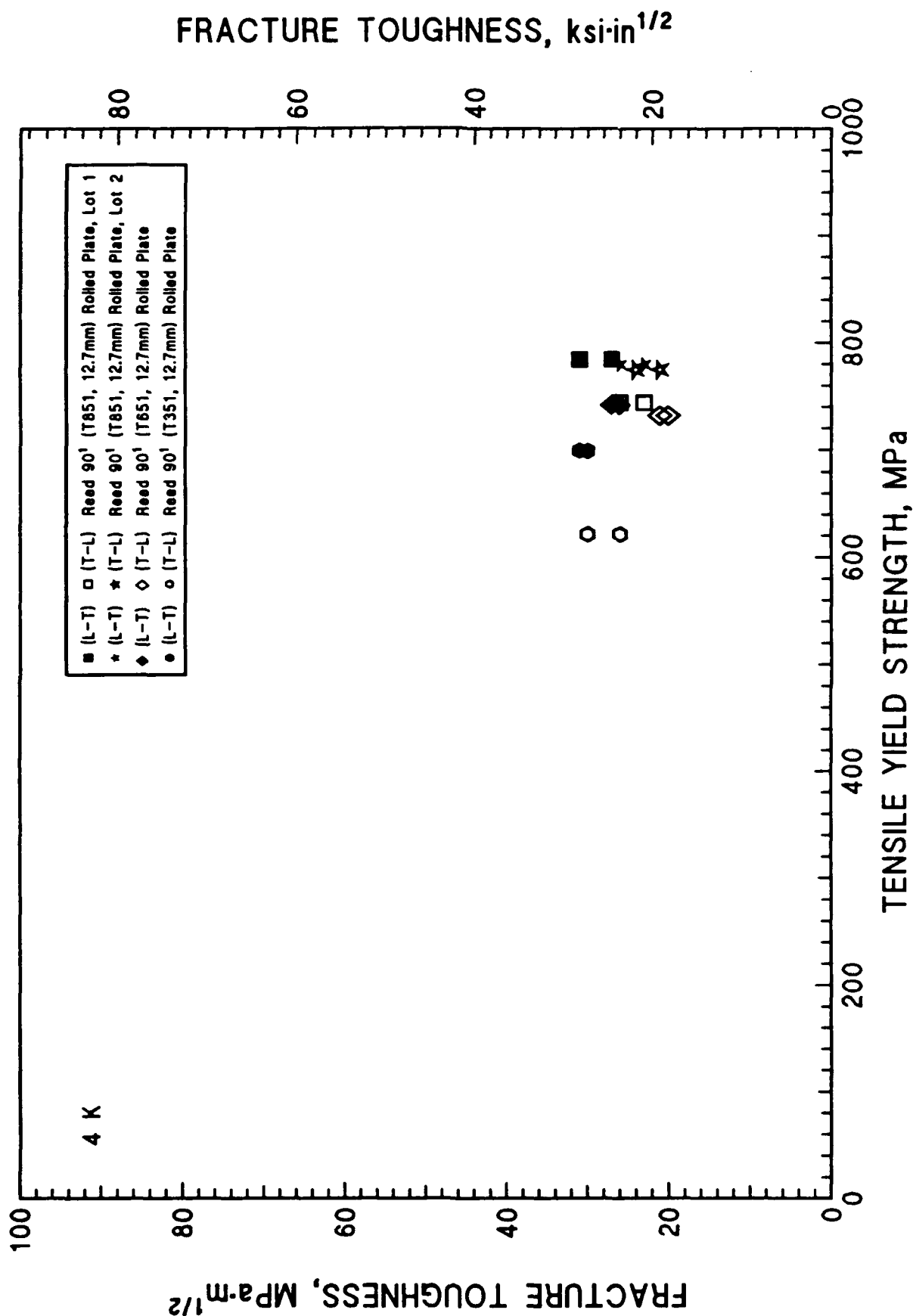
WL049



WL049



WLO49



Fracture Toughness
Alloy WL049

Ref & Note	Temp. K	K MPa/m	Y.S. MPa	Orient.	Temper	Product Form	Product Thickness mm	Supplier; Year; Lot Number	Aging Temp. °C	Time h	Cold Work %	Soln Treat. Temp. °C	Time h	Quench Cond.	Grain Size			Hardness	No. of Tests/ Data Pt
															L	X	T X ST µm		
1J	295	21.	607.	L-T	T851	Rolled Plate	12.7	Reynolds; '89; 0387250A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1
1J	295	22.	607.	L-T	T851	Rolled Plate	12.7	Reynolds; '89; 0387250A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1
1K	76	23.	712.	L-T	T851	Rolled Plate	12.7	Reynolds; '89; 0387250A	NA	NA	NA	NA	NA	NA	4000	1000	NA	NA	1
1K	76	20.	712.	L-T	T851	Rolled Plate	12.7	Reynolds; '89; 0387250A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1
1K	4	27.	785.	L-T	T851	Rolled Plate	12.7	Reynolds; '89; 0387250A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1
1K	4	31.	785.	L-T	T851	Rolled Plate	12.7	Reynolds; '89; 0387250A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1
1V	295	23.	615.	L-T	T851	Rolled Plate	12.7	Reynolds; '80; 9002311A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1
1W	4	26.	780.	L-T	T851	Rolled Plate	12.7	Reynolds; '80; 9002311A	NA	NA	NA	NA	NA	NA	4000	1000	NA	NA	1
1W	4	23.	780.	L-T	T851	Rolled Plate	12.7	Reynolds; '80; 9002311A	NA	NA	NA	NA	NA	NA	4000	1000	NA	NA	1
1W	76	21.	717.	L-T	T651	Rolled Plate	12.7	Reynolds; '80; 9002311A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1
18A	294	24.	714.	L-T	T8	Extruded Bar	19.05	M.M.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18A	77	22.3	783.	L-T	T8	Extruded Bar	19.05	M.M.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18B	294	33.8	618.	L-T	UAT8	Extruded Bar	19.05	M.M.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18B	77	27.	676.	L-T	UAT8	Extruded Bar	19.05	M.M.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18E	294	27.9	633.	L-T	UAT8	Extruded Bar	19.1	M.M.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18E	77	22.4	701.	L-T	UAT8	Extruded Bar	19.1	M.M.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18E	77	21.	701.	L-T	UAT8	Extruded Bar	19.1	M.M.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
1L	295	25.	567.	L-T	T651	Rolled Plate	12.7	Reynolds; '89; 0387240A	NA	NA	NA	NA	NA	NA	1000	500	NA	NA	1

Ref & Note No.	Temp. K	K	Y.S. MPa	Orient.	Temper	Product Form	Product Thickness mm	Supplier: Year; Lot Number	Aging		Cold Work %	Soln Treat.		Quench Cond.	Grain Size					Hardness	No. of Tests/Data Pt
									Temp. °C	Time h		Temp. °C	Time h		L	X	T	X	ST		
1L	295	23	567	L-T	T651	Rollod Plate	12.7	Reynolds; '89;0387240A	NA	NA	NA	NA	NA	NA	1000	500	NA	NA	1		
1M	76	25	671	L-T	T651	Rollod Plate	12.7	Reynolds; '89;0387240A	NA	NA	NA	NA	NA	NA	1000	500	NA	NA	1		
1M	76	21	671	L-T	T651	Rollod Plate	12.7	Reynolds; '89;0387240A	NA	NA	NA	NA	NA	NA	1000	500	NA	NA	1		
1M	4	26	742	L-T	T651	Rollod Plate	12.7	Reynolds; '89;0387240A	NA	NA	NA	NA	NA	NA	1000	500	NA	NA	1		
1M	4	27	742	L-T	T651	Rollod Plate	12.7	Reynolds; '89;0387240A	NA	NA	NA	NA	NA	NA	1000	500	NA	NA	1		
1N	295	53	453	L-T	T351	Rollod Plate	12.7	Reynolds; '89;0387230A	NA	NA	NA	NA	NA	NA	800	400	NA	NA	1		
1N	295	54	453	L-T	T351	Rollod Plate	12.7	Reynolds; '89;0387230A	NA	NA	NA	NA	NA	NA	800	NA	400	NA	1		
1O	77	37	583	L-T	T351	Rollod Plate	12.7	Reynolds; '89;0387230A	NA	NA	NA	NA	NA	NA	800	NA	400	NA	1		
1O	76	43	583	L-T	T351	Rollod Plate	12.7	Reynolds; '89;0387230A	NA	NA	NA	NA	NA	NA	800	NA	400	NA	1		
1O	4	30	699	L-T	T351	Rollod Plate	12.7	Reynolds; '89;0387230A	NA	NA	NA	NA	NA	NA	800	NA	400	NA	1		
1O	4	31	699	L-T	T351	Rollod Plate	12.7	Reynolds; '89;0387230A	NA	NA	NA	NA	NA	NA	800	NA	400	NA	1		
1OC	294	38.7	407	L-T	T3	Extruded Bar	10.05	H.M. ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1		
1OD	294	36.9	407	L-T	T3	Extruded Bar	10.1	H.M. ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1		
1J	295	23	581	T-L	T651	Rollod Plate	12.7	Reynolds; '89;0387250A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1		
1J	295	23	581	T-L	T651	Rollod Plate	12.7	Reynolds; '89;0387250A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1		
1K	76	22	677	T-L	T651	Rollod Plate	12.7	Reynolds; '89;0387250A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1		
1K	76	20	677	T-L	T651	Rollod Plate	12.7	Reynolds; '89;0387250A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1		
1K	4	26	744	T-L	T651	Rollod Plate	12.7	Reynolds; '89;0387250A	NA	NA	NA	NA	NA	NA	4000	1000	NA	NA	1		
1K	4	23	744	T-L	T651	Rollod Plate	12.7	Reynolds; '89;0387250A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1		

Ref & Note	Temp. K	K MPa/m	Y.S. MPa	Orient.	Temp	Product Form	Product Thickness mm	Supplier; Year; Lot Number	Aging		Cold Work %	Soln Treat.		Grain Size				Hardness	No. of Tests/ Data Pt
									Temp. °C	Time h		Temp. °C	Time h	Quench Cond.	L	X	T X ST μm		
1V	285	22.	590.	T-L	T851	Rolled Plate	12.7	Reynolds; '80; 9002311A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1
1W	4	24.	775.	T-L	T851	Rolled Plate	12.7	Reynolds; '80; 9002311A	NA	NA	NA	NA	NA	NA	4000	1000	NA	NA	1
1W	76	22.	680.	T-L	T851	Rolled Plate	12.7	Reynolds; '80; 9002311A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1
1W	4	21.	775.	T-L	T851	Rolled Plate	12.7	Reynolds; '80; 9002311A	NA	NA	NA	NA	NA	NA	4000*	1000	NA	NA	1
18A	284	21.	630.	T-L	T8	Extruded Bar	19.05	M.H. ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18A	77	17.5	705.	T-L	T8	Extruded Bar	19.05	M.H. ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18B	294	26.2	566.	T-L	UA78	Extruded Bar	19.05	M.H. ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18B	284	23.7	566.	T-L	UA78	Extruded Bar	19.05	M.H. ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18B	77	21.5	607.	T-L	UA78	Extruded Bar	19.05	M.H. ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18E	294	18.8	579.	T-L	UA78	Extruded Bar	19.1	M.H. ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18E	294	19.9	579.	T-L	UA78	Extruded Bar	19.1	M.H. ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18E	77	22.9	627.	T-L	UA78	Extruded Bar	19.1	M.H. ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18E	77	19.2	627.	T-L	UA78	Extruded Bar	19.1	M.H. ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
1M	76	21.	637.	T-L	T851	Rolled Plate	12.7	Reynolds; '89; 0387240A	NA	NA	NA	NA	NA	NA	1000	500	NA	NA	1
1M	76	23.	637.	T-L	T851	Rolled Plate	12.7	Reynolds; '89; 0387240A	NA	NA	NA	NA	NA	NA	1000	500	NA	NA	1
1M	4	21.	732.	T-L	T851	Rolled Plate	12.7	Reynolds; '89; 0387240A	NA	NA	NA	NA	NA	NA	1000	500	NA	NA	1
1M	4	20.	732.	T-L	T851	Rolled Plate	12.7	Reynolds; '89; 0387240A	NA	NA	NA	NA	NA	NA	1000	500	NA	NA	1
1N	295	61.	412.	T-L	T351	Rolled Plate	12.7	Reynolds; '89; 0387230A	NA	NA	NA	NA	NA	NA	800	400	NA	NA	1
1N	295	47.	412.	T-L	T351	Rolled Plate	12.7	Reynolds; '89; 0387230A	NA	NA	NA	NA	NA	NA	800	NA	400	NA	1

Ref & Note No.	Temp. K	K MPa/m	Y.S. MPa	Orient. T-L	Temper T3	Product Form	Product Thickness mm	Supplier:		Cold Work Z	Solv. Treat.		Quench				Grain Size				Hardness	No. of Tests/ Data Pt
								Year;	Lot Number		Temp. °C	Time h	Temp. °C	Time h	Cond.		L	X	T	X	SI	
10	77	43.	506.	T-L	T351	Rollled Plate	12.7	Reynolds;	'89;0387230A	NA	NA	NA	NA	NA	NA	NA	800	NA	400	NA	NA	1
10	76	42.	506.	T-L	T351	Rollled Plate	12.7	Reynolds;	'89;0387230A	NA	NA	NA	NA	NA	NA	NA	800	NA	400	NA	NA	1
10	4	26.	621.	T-L	T351	Rollled Plate	12.7	Reynolds;	'89;0387230A	NA	NA	NA	NA	NA	NA	NA	800	NA	400	NA	NA	1
10	4	30.	621.	T-L	T351	Rollled Plate	12.7	Reynolds;	'89;0387230A	NA	NA	NA	NA	NA	NA	NA	800	NA	400	NA	NA	1
18C	294	37.7	408.	T-L	T3	Extruded Bar	19.05	M.M.	;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18C	77	40.3	427.	T-L	T3	Extruded Bar	19.05	M.M.	;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18D	294	29.6	359.	T-L	T3	Extruded Bar	19.1	M.M.	;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18D	294	30.9	359.	T-L	T3	Extruded Bar	19.1	M.M.	;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18D	77	31.6	457.	T-L	T3	Extruded Bar	19.1	M.M.	;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
18D	77	30.9	457.	T-L	T3	Extruded Bar	19.1	M.M.	;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1

Comments from the Al-Li Alloy WL049 Data Table

Reference and
Note Number

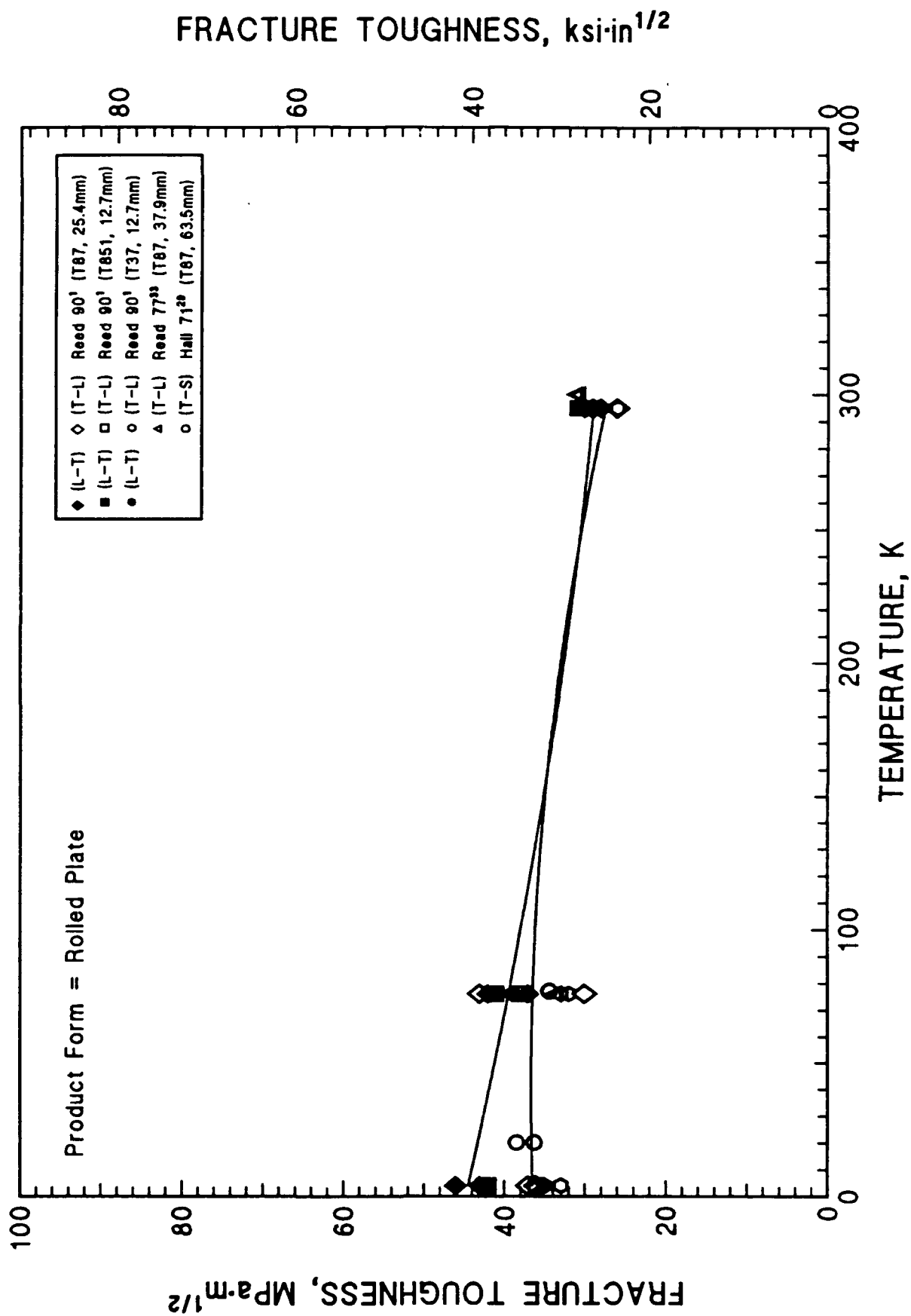
1J-K--Values reported are the average of the range of grain sizes.

18A-E--Under the supplier column, M.M. = Martin Marietta.

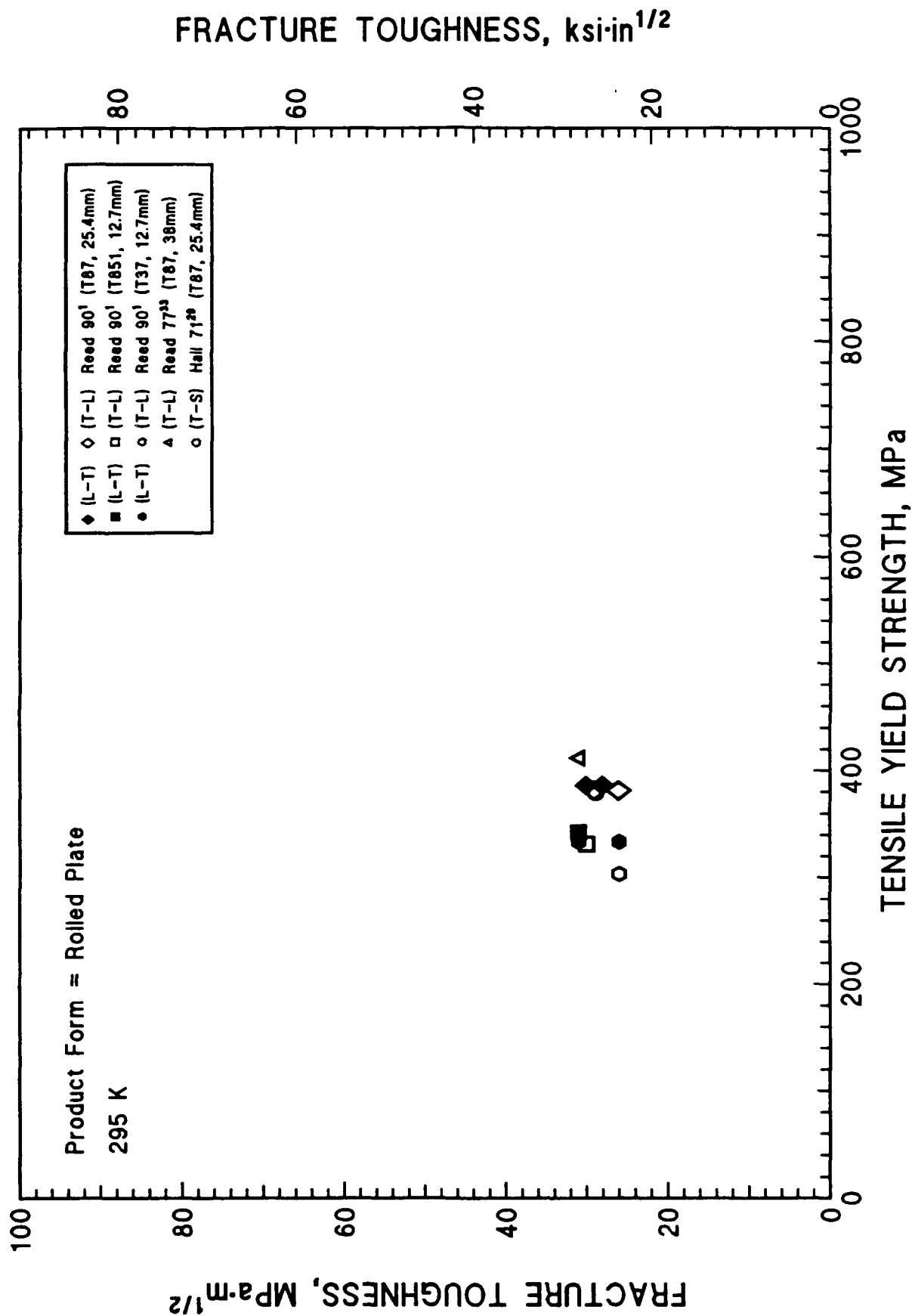
Fracture Toughness
Test Conditions
Alloy WL049

Ref & Note	Specimen Type	Specimen Dimensions			Precrack		Side- Groove	Multi- Spec. no/#	Invalidating Criterion	Major Elements							Procedures		
		B	W	e/W mm	Temp K	Freq Hz				Li	Cu	Mg	Zr	Si	Fe	Ag			
No.										wt%									
1J	CT	12.7	50.8	NA	295	20.	no	no	NA		0.38	4.7	0.4	0.12	0.02	0.03	0.37	ASTM E813	
1K	CT	12.7	50.8	NA	76	20.	no	no	NA		0.38	4.7	0.4	0.12	0.02	0.03	0.37	ASTM E813	
1L	CT	12.7	50.8	NA	295	20.	no	no	NA		1.28	4.7	0.4	0.12	0.02	0.03	0.35	ASTM E813	
1M	CT	12.7	50.8	NA	76	20.	no	no	NA		1.28	4.7	0.4	0.12	0.02	0.03	0.35	ASTM E813	
1N	CT	12.7	50.8	NA	295	20.	no	no	NA		1.28	4.7	0.4	0.12	0.02	0.03	NA	ASTM E813	
1O	CT	12.7	50.8	NA	76	20.	no	no	NA		1.28	4.7	0.4	0.12	0.02	0.03	NA	ASTM E813	
16A	CT	NA	NA	NA	NA	NA	NA	NA	NA		1.3	5.	0.4	0.14	NA	NA	0.4	ASTM E399	
16B	CT	NA	NA	NA	NA	NA	NA	NA	NA		1.3	5.	0.4	0.14	NA	NA	0.4	ASTM E399	
16C	CT	NA	NA	NA	NA	NA	NA	NA	NA		1.3	5.	0.4	0.14	NA	NA	0.4	ASTM E399	
16D	CT	NA	NA	NA	NA	NA	NA	NA	NA		1.4	6.2	0.4	0.14	NA	NA	0.4	ASTM E399	
16E	CT	NA	NA	NA	NA	NA	NA	NA	NA		1.4	6.2	0.4	0.14	NA	NA	0.4	ASTM E399	

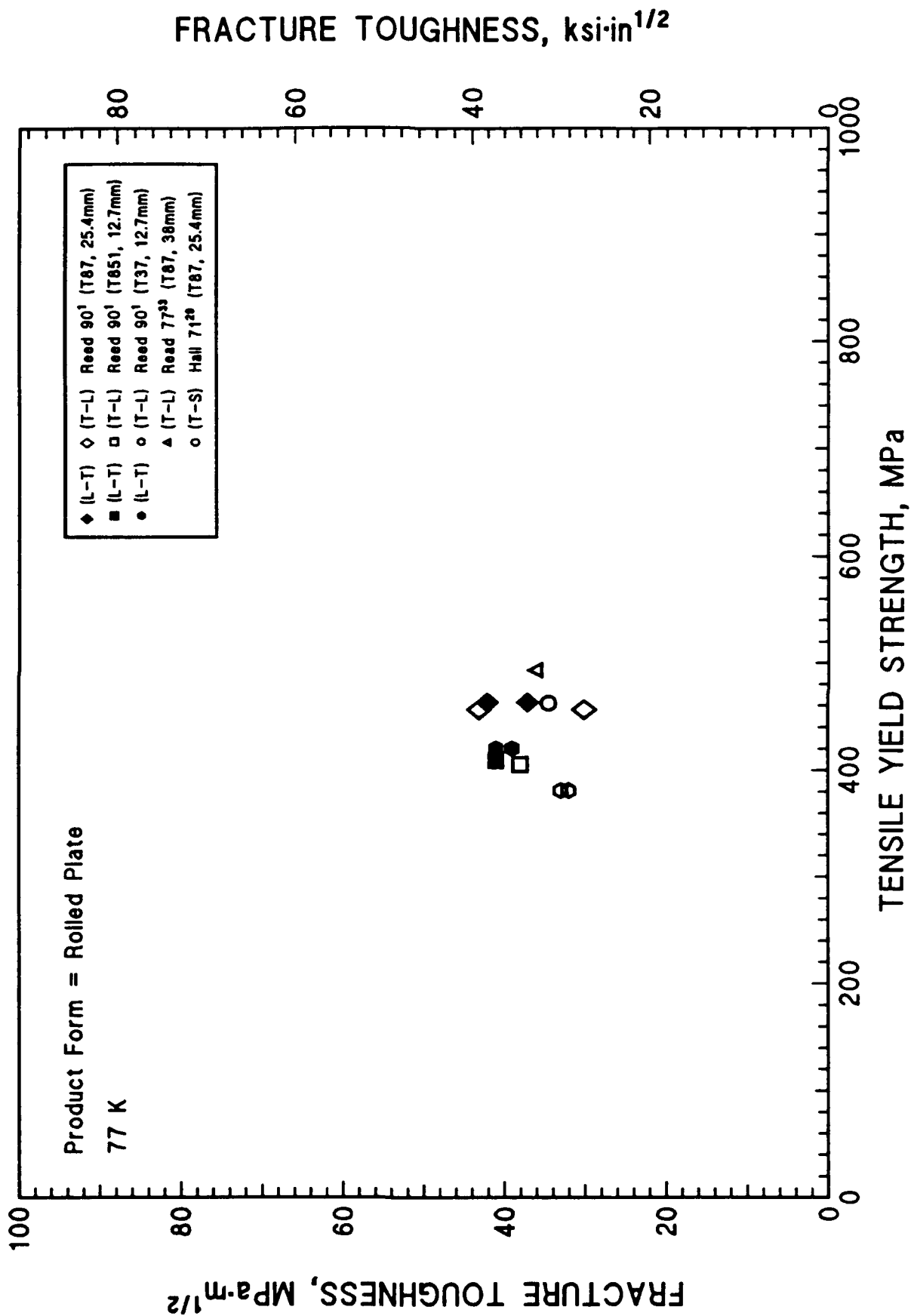
2219



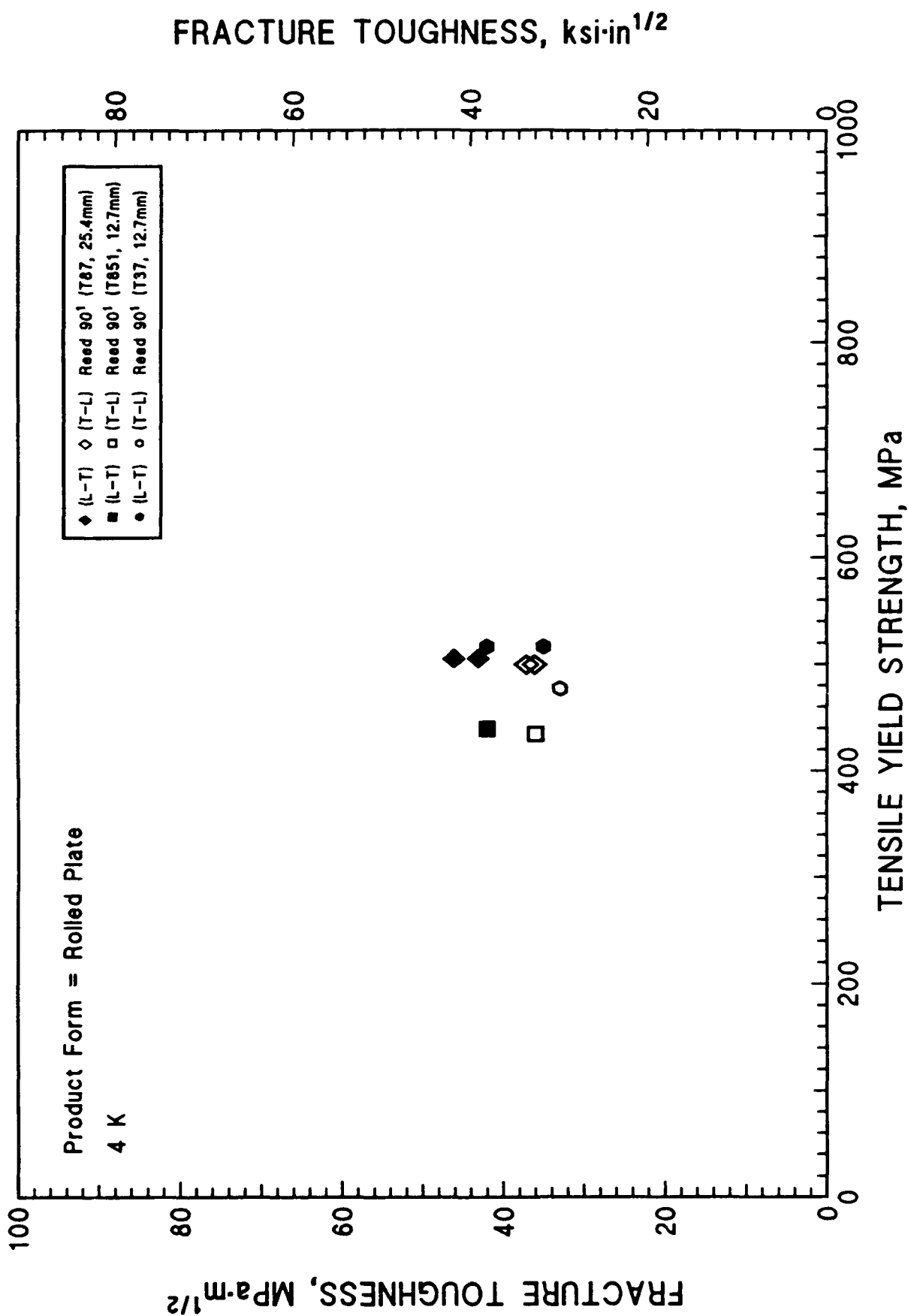
2219



2219



2219



Fracture Toughness
Alloy 2219

Ref & Note No.	Temp. K	K MPa/m	Y.S. MPa	Orient.	Temper	Product Form	Product Thickness mm	Supplier; Year; Lot Number	Aging Temp. °C	h	Cold Work %	Soln Treat. Temp. °C	Time h	Quench Cond.	Grain Size			Hardness	No. of Tests/ Data Pt
															L	T	X ST µm		
1P	295	30.	366.	L-T	T87	Rolled Plate	25.4	NASA; '90 ; 484881	NA	NA	NA	NA	NA	NA	300	50	NA	NA	1
1P	295	28.	386.	L-T	T87	Rolled Plate	25.4	NASA; '90 ; 484881	NA	NA	NA	NA	NA	NA	300	50	NA	NA	1
1Q	77	42.	463.	L-T	T87	Rolled Plate	25.4	NASA; '90 ; 484881	NA	NA	NA	NA	NA	NA	300	50	NA	NA	1
1Q	77	37.	463.	L-T	T87	Rolled Plate	25.4	NASA; '90 ; 484881	NA	NA	NA	NA	NA	NA	300	50	NA	NA	1
1Q	4	46.	505.	L-T	T87	Rolled Plate	25.4	NASA; '90 ; 484881	NA	NA	NA	NA	NA	NA	300	50	NA	NA	1
1Q	4	43.	505.	L-T	T87	Rolled Plate	25.4	NASA; '90 ; 484881	NA	NA	NA	NA	NA	NA	300	50	NA	NA	1
1R	295	31.	342.	L-T	T851	Rolled Plate	12.7	Kaiser; '89 ; 429881	NA	NA	NA	NA	NA	NA	175	NA	50	154.8, V	1
1S	76	41.	409.	L-T	T851	Rolled Plate	12.7	Kaiser; '89 ; 429881	NA	NA	NA	NA	NA	NA	175	NA	50	154.8, V	1
1S	4	42.	439.	L-T	T851	Rolled Plate	12.7	Kaiser; '89 ; 429881	NA	NA	NA	NA	NA	NA	175	NA	50	154.8, V	1
1T	295	26.	333.	L-T	T37	Rolled Plate	12.7	Kaiser; '89 ; 486341	NA	NA	NA	NA	NA	NA	175	NA	50	142.9, V	1
1T	295	31.	333.	L-T	T37	Rolled Plate	12.7	Kaiser; '89 ; 486342	NA	NA	NA	NA	NA	NA	175	NA	50	142.9, V	1
1U	76	39.	420.	L-T	T37	Rolled Plate	12.7	Kaiser; '89 ; 486341	NA	NA	NA	NA	NA	NA	175	NA	50	142.9, V	1
1U	76	41.	420.	L-T	T37	Rolled Plate	12.7	Kaiser; '89 ; 486342	NA	NA	NA	NA	NA	NA	175	NA	50	142.9, V	1
1U	4	42.	516.	L-T	T37	Rolled Plate	12.7	Kaiser; '89 ; 486342	NA	NA	NA	NA	NA	NA	175	NA	50	142.9, V	1
1U	4	35.	516.	L-T	T37	Rolled Plate	12.7	Kaiser; '89 ; 486342	NA	NA	NA	NA	NA	NA	175	NA	50	142.9, V	1
1P	295	26.	381.	T-L	T87	Rolled Plate	25.4	NASA; '90 ; 484881	NA	NA	NA	NA	NA	NA	300	50	NA	NA	1
1P	295	29.	381.	T-L	T87	Rolled Plate	25.4	NASA; '90 ; 484881	NA	NA	NA	NA	NA	NA	300	50	NA	NA	1
1Q	76	43.	456.	T-L	T87	Rolled Plate	25.4	NASA; '90 ; 484881	NA	NA	NA	NA	NA	NA	300	50	NA	NA	1

Ref & Note No.	Temp. K	K MPa/mm	Y.S. MPa	Orient.	Temp.	Product Form	Product Thickness mm	Supplier; Year; Lot Number	Aging Temp. °C	h	Cold Work %	Soln Treat. Temp. °C	Time h	Quench Cond.	Grain Size			Hardness	No. of Tests/ Data Pt
															L	X	T X ST µm		
1Q	76	30.	456.	T-L	T87	Rollled Plate	25.4	NASA;'80 ;484881	NA	NA	NA	NA	NA	NA	300	50	NA	NA	1
1Q	4	37.	489.	T-L	T87	Rollled Plate	25.4	NASA;'80 ;484881	NA	NA	NA	NA	NA	NA	300	50	NA	NA	1
1Q	4	36.	489.	T-L	T87	Rollled Plate	25.4	NASA;'80 ;484881	NA	NA	NA	NA	NA	NA	300	50	NA	NA	1
33A	300	30.6	412.	T-L	T87	Rollled Plate	38.	NA ;NA	NA	NA	NA	NA	NA	NA	NA	3000	NA	B 81.1	1
33A	300	31.	412.	T-L	T87	Rollled Plate	38.	NA ;NA	NA	NA	NA	NA	NA	NA	NA	3000	NA	B 81.1	1
33A	76	33.5	483.	T-L	T87	Rollled Plate	38.	NA ;NA	NA	NA	NA	NA	NA	NA	NA	3000	NA	B 81.1	1
33A	76	37.2	483.	T-L	T87	Rollled Plate	38.	NA ;NA	NA	NA	NA	NA	NA	NA	NA	3000	NA	B 81.1	1
1R	295	30.	331.	T-L	T851	Rollled Plate	12.7	Kaiser;'89 ;429881	NA	NA	NA	NA	NA	NA	175	NA	50	154.8, V	1
1S	76	38.	405.	T-L	T851	Rollled Plate	12.7	Kaiser;'89 ;429881	NA	NA	NA	NA	NA	NA	175	NA	50	154.8, V	1
1S	4	36.	434.	T-L	T851	Rollled Plate	12.7	Kaiser;'89 ;429881	NA	NA	NA	NA	NA	NA	175	NA	50	154.8, V	1
1T	295	26.	303.	T-L	T37	Rollled Plate	12.7	Kaiser;'89 ;486341	NA	NA	NA	NA	NA	NA	175	NA	50	142.9, V	1
1T	295	26.	303.	T-L	T37	Rollled Plate	12.7	Kaiser;'89 ;486342	NA	NA	NA	NA	NA	NA	175	NA	50	142.9, V	1
1U	4	33.	477.	T-L	T37	Rollled Plate	12.7	Kaiser;'89 ;486341	NA	NA	NA	NA	NA	NA	175	NA	50	142.9, V	1
1U	76	32.	381.	T-L	T37	Rollled Plate	12.7	Kaiser;'89 ;486342	NA	NA	NA	NA	NA	NA	175	NA	50	142.9, V	1
1U	76	33.	381.	T-L	T37	Rollled Plate	12.7	Kaiser;'89 ;486342	NA	NA	NA	NA	NA	NA	175	NA	50	142.9, V	1
1U	4	33.	477.	T-L	T37	Rollled Plate	12.7	Kaiser;'89 ;486342	NA	NA	NA	NA	NA	NA	175	NA	50	142.9, V	1
29A	295	29.	378.	T-S	T87	Rollled Plate	63.5	NA ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
29A	295	28.7	378.	T-S	T87	Rollled Plate	63.5	NA ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
29A	77	34.5	462.	T-S	T87	Rollled Plate	63.5	NA ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1

Ref & Note No.	Temp. K	K MPa/mm	Y.S. MPa	Orient. T-S	Temper	Product Form	Product Thickness mm	Supplier; Year; Lot Number	Aging Temp. °C	h	Cold Work %	Solv Treat. Temp. °C	Time h	Quench Cond.	Grain Size			Hardness	No. of Tests/ Data Pt
															L	X	T X ST µm		
29A	77	34.4	462.	T-S	T87	Roller Plate	63.5	MA ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
29A	20	36.3	503.	T-S	T87	Roller Plate	63.5	MA ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
29A	20	38.5	503.	T-S	T87	Roller Plate	63.5	MA ;NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1

Fracture Toughness
Test Conditions
Alloy 2219

Ref & Note	Specimen No.	Type	Specimen Dimensions			Precrack Temp K	Freq Hz	Side- Groove	Multi- Spec. no/#	Invalidating Criterion	Li	Major Elements					Ag	Procedures
			B	W	e/W	Other						Cu	Mg	Zr	Si	Fe		
				mm										wt%				
6P	CT		12.7	50.8	NA	NA	295	20.	no	NA	NA	5.7	NA	0.15	0.07	0.02	NA	ASTM E813
6Q	CT		12.7	50.8	NA	NA	76	20.	no	NA	NA	5.7	NA	0.15	0.07	0.02	NA	ASTM E813
6R	CT		12.7	50.8	NA	NA	295	20.	no	NA	NA	5.7	NA	0.08	0.04	0.02	NA	ASTM E813
6S	CT		12.7	50.8	NA	NA	76	20.	no	NA	NA	5.7	NA	0.08	0.04	0.02	NA	ASTM E813
6T	CT		12.7	50.8	NA	NA	295	20.	no	NA	NA	5.7	NA	0.03	0.04	0.02	NA	ASTM E813
6U	CT		12.7	50.8	NA	NA	76	20.	no	NA	NA	5.7	NA	0.03	0.04	0.02	NA	ASTM E813
29A	CT		31.8	50.8	NA	NA	295	NA	no	NA	NA	6.3	NA	0.18	0.2	0.3	NA	ASTM E399-70T
33A	CT		NA	NA	NA	NA	NA	NA	NA	NA	NA	6.4	NA	0.16	0.15	0.2	NA	ASTM E399-74

3. ELASTIC CONSTANTS

3.1. Introduction to Graphs

3.1.1. Temperature Dependence

Cryogenic elastic constant data are available only for 2090-T81 (Young's modulus, E , and Poisson's ratio, ν) and 2219-T87 (E , ν , bulk modulus, B , and shear modulus, G). These data are presented as a functions of temperature in four graphs and a table following this discussion. The reason that different values of E (77.7 and 74.7 GPa) were obtained for 2219-T87 at ambient temperature in the same laboratory is not understood. It is likely that the values reported in the earlier measurements are too systematically too high, but the temperature dependence has not been remeasured. (A later measurement at room temperature gave a value of 74.8 GPa.) The value given in MIL-HNBK-5E² for E for alloy 2219 plate is 72.4 GPa. There is considerable disagreement in the literature about the correct value of E at ambient temperature for pure Al and therefore, for Al alloyed with small ($\leq 5\%$) amounts of other elements (see Section 3.1.2. below). Because there is so much uncertainty in the literature, and because so little cryogenic data are available, a table of ambient-temperature values of elastic constants from various sources for the Al-Li alloys 8090, 2090, and WL049, and alloy 2219 follows the presentation of the cryogenic data. After a value of E at ambient temperature is chosen, the following equation may be used to estimate values for $4 \text{ K} \leq T \leq 295 \text{ K}$:

$$E(T) = E(295 \text{ K}) [1.1 + 1.2 \times 10^{-4}T - 4.0 \times 10^{-6}T^2 + 1.1 \times 10^{-8}T^3 - 1.2 \times 10^{-11}T^4] \quad (1)$$

Values derived from Equation (1) should be used with caution because it is based on the one set of measurements available for 2090.³⁷

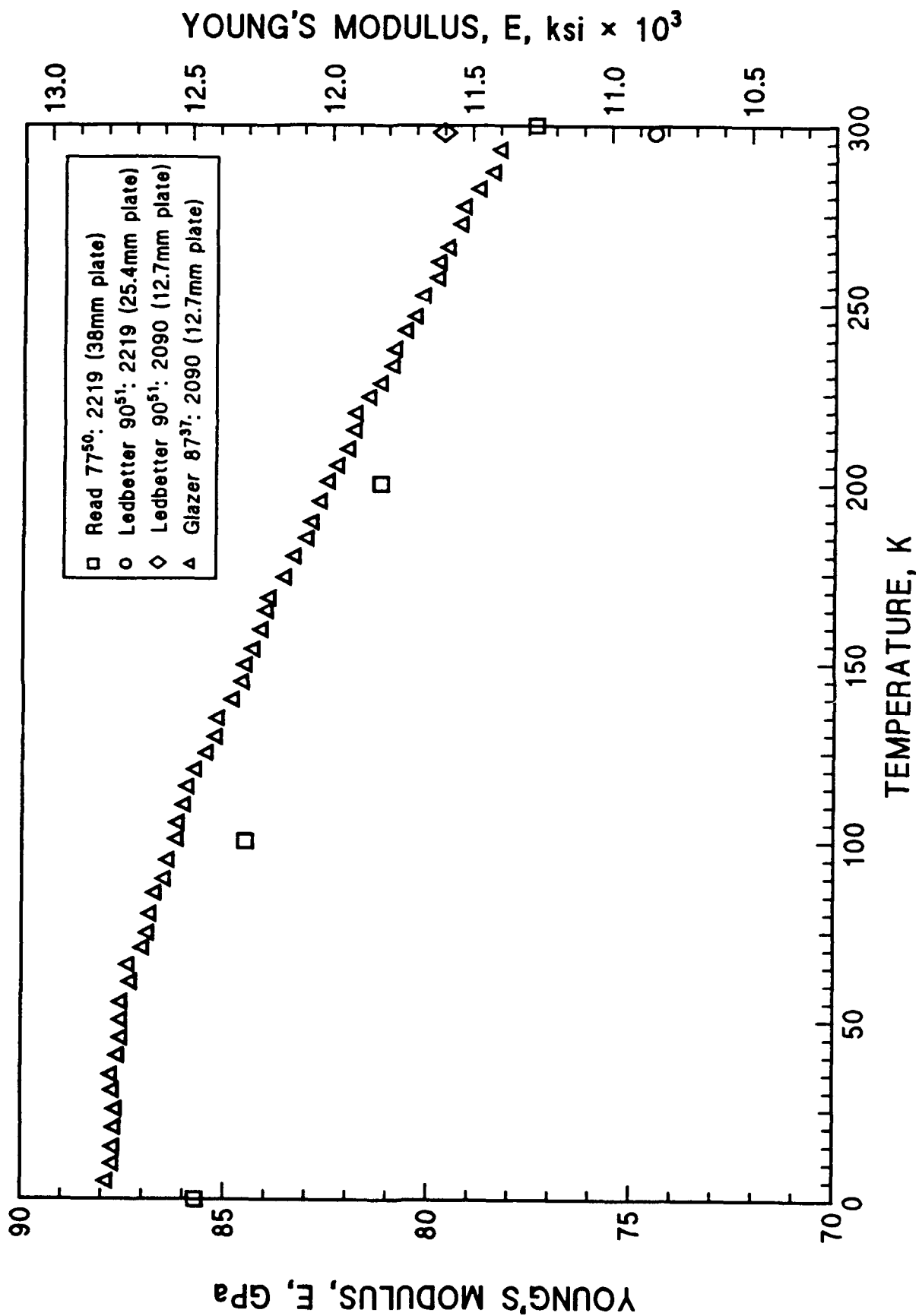
3.1.2. Effects of Alloying Elements, Cold Work, and Other Factors

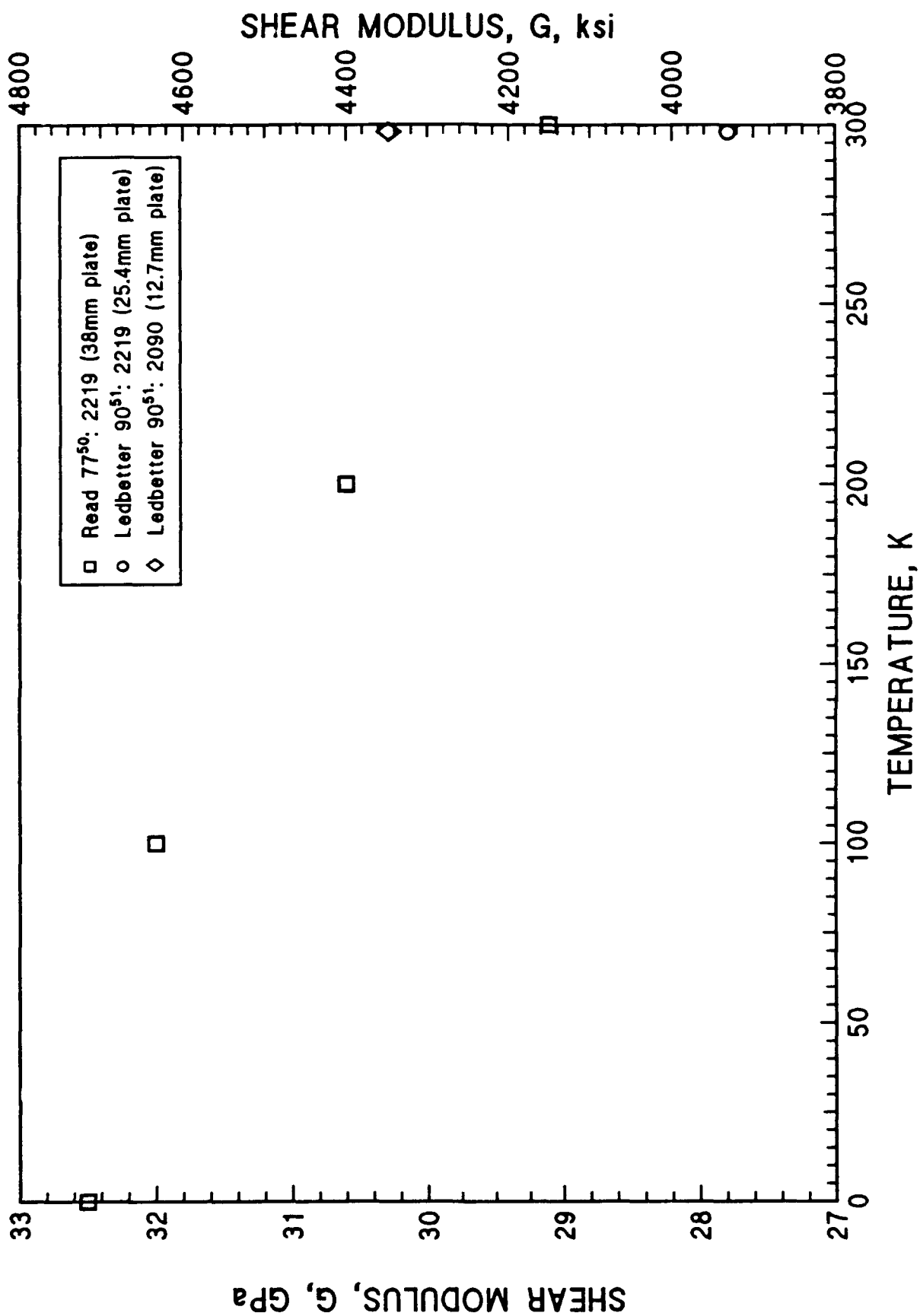
Several sets of static measurements are available on the increase in E with alloying additions of Li;^{38,39} Li and Mg;³⁸ and Li and Cu.³⁹ References 38 and 39 give 66 and 62 GPa, respectively, as the ambient temperature value of E for high purity Al. Measured values of E for Al-2%Li were 79 GPa³⁸ and 73 GPa.³⁹ E was found to be 82 GPa³⁹ for Al-2024-2%Li. The composition of Al-alloy 2024 (4.5Cu, 1.5Mg, 0.6Mn) is very similar to the composition of Al-alloy 2219 (5.8-6.8Cu, 0.2-0.4Mn). However, values of E for pure Al in the literature derived from the single crystal elastic constants measured by dynamic methods are usually about 10% higher than the values in these two references,^{38,39} averaging around 70 to 72 GPa. (Values of Al-Li and Al-Cu-Li alloys would be expected to be correspondingly higher.) Reed⁴⁰ presents a table of Al single-crystal elastic constants from several sources and uses the average of these constants to calculate an E of 70.4 GPa. The calculation is based on a formula presented by Hill⁴¹ in the early 1950s. The discrepancy between values calculated from single-crystal elastic constants using the Hill formula and static measurements of Noble³⁸ was noted by Muller et al.,⁴² but the explanation advanced, microplasticity, may not be sufficient to explain such a large disparity in the values. To validate his formula, Hill used a set of measurements on elastic constants of four common elements (including Al) whose origin is not well-documented. Several dynamic measurements^{43,44,45} not based

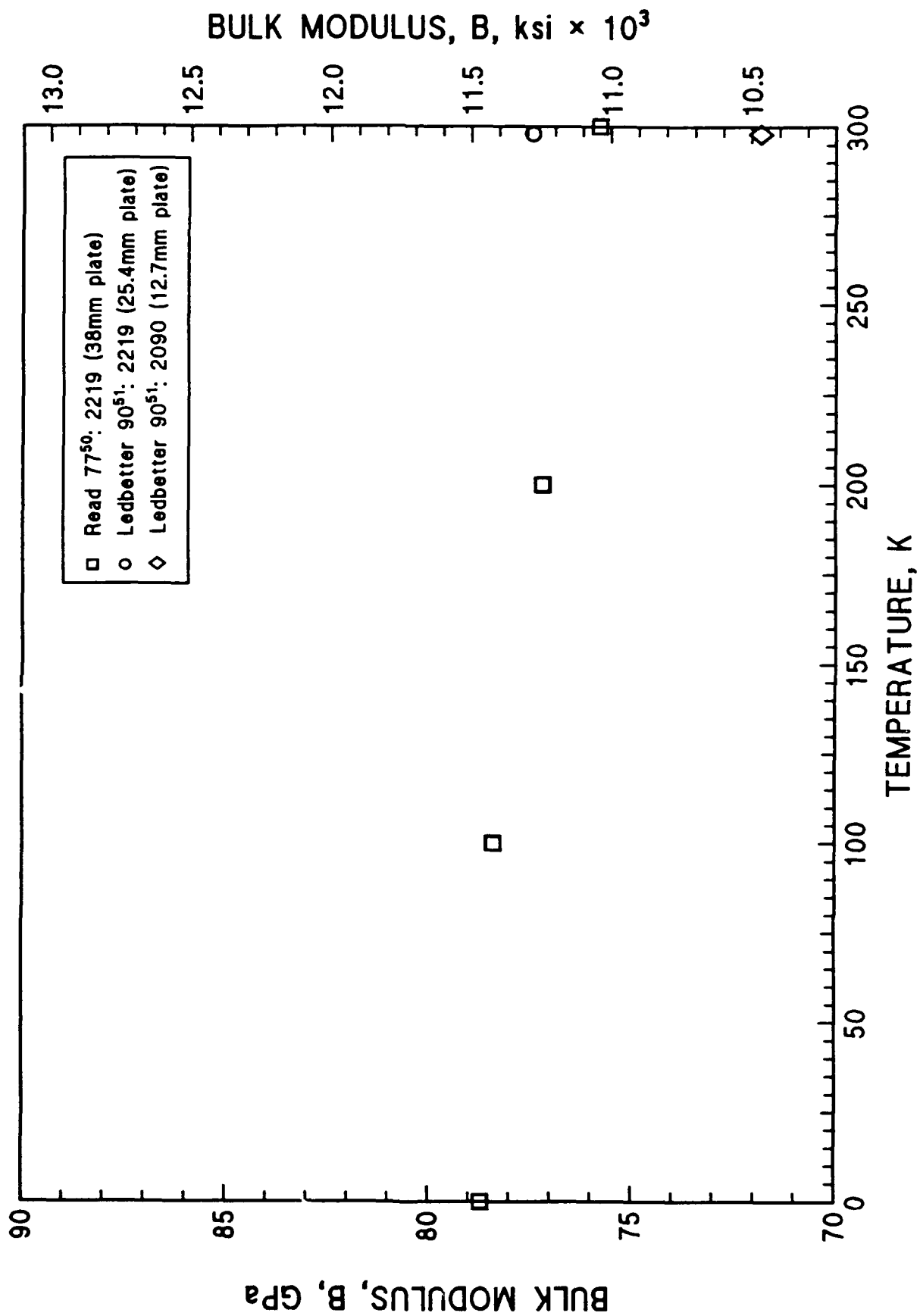
on single-crystal elastic constants and the Hill formula give about 70 GPa for E of pure Al. This disagrees with values of 66, 64, and 65 GPa obtained by static measurements⁴⁶ on commercially pure Al (99.5%) as well as the values quoted above,^{38,39} which are also derived from static measurements. Differences between static and dynamic measurements should be only about a percent,⁴⁷ and so the discrepancy should not be attributable to dissimilar measurement techniques. The Hill formula is frequently employed in the literature of basic science to calculate polycrystalline elastic constant values from single-crystal measurements. However, to our knowledge, it has not been tested against carefully evaluated measurements on polycrystalline specimens of a wide variety of elements. Furthermore, the disagreement of predicted values of E with static measurements (commonly used in the aerospace industry) has not been widely recognized.

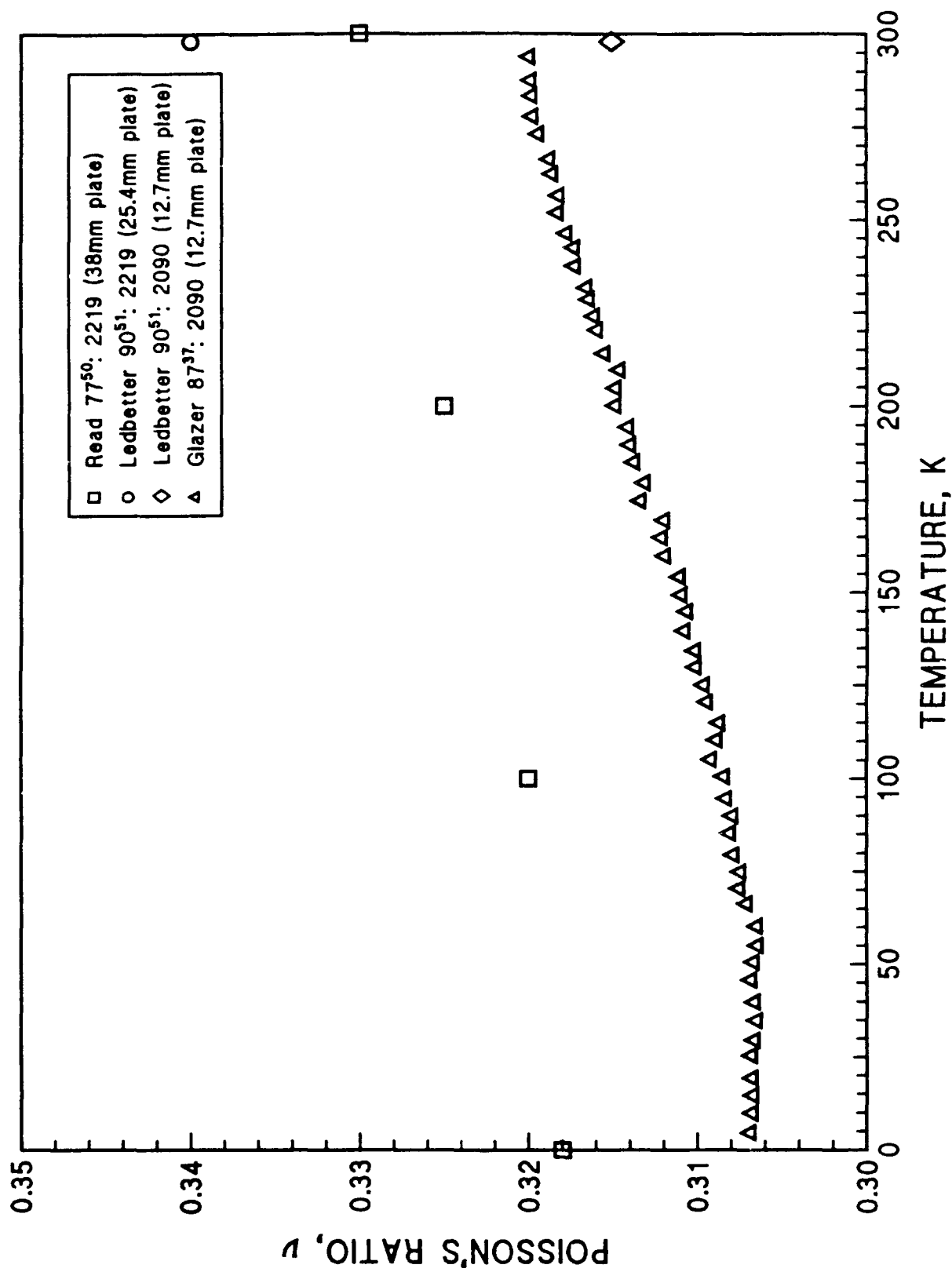
A calculation by Wawra⁴⁸ for Al gives a directional dependence for E of pure Al, such that $E_{111} = 73.8$ GPa and $E_{100} = 63.2$ GPa, which is approximately the size of the discrepancy in the measurements. Most polycrystalline Al is probably not strongly textured, however, and texture has not been reported with the measurements of E . Warwa⁴⁸ also reports a decrease of E of up to $\approx 3\%$ over a range of cold work from 0 to 100%. Decreasing the purity of the Al from 99.99 to 99.6% increased E ⁴⁸ by about 3% to a value of 72.8 GPa. These latter effects do not appear large enough to explain the discrepancy.

Varying the aging time of Al-Li alloys also has an effect on E .⁴⁹ Effects were less than 2% for aging temperature of 230, 210, and 190 °C with aging times of up to 1000 h. This work was carried out on a binary Al-2.5wt%Li alloy using an ultrasonic measurement technique. Another recent paper⁴⁷ also presents results of aging treatment and specimen thickness on E and other elastic constants of 2090-T8E50 as a function of the angle from rolling direction. Effects again are small, $\approx 2-3\%$, but the anisotropy in E can be as much as 6% at 45° from the rolling direction.









Density and Elastic Constants of Al-Li Alloys and Alloy 2219 at Ambient Temperature.

Alloy	Density, kg/m ³ × 10 ³	Young's Modulus, E, GPa	Shear Modulus, G, GPa	Bulk Modulus, B, GPa	Poisson's Ratio, ν	Ref. No.	Method of Analysis
8090-T8771	--	79.3	--	--	0.292	5	1
2090-T81	2.60	79.65	30.28	71.83	0.3152	51	2
2090-T81	2.59	78.28	29.65	72.56	0.320	37	2
2090-T8E50	--	78.60	--	--	--	47	2
2090-T83	--	73.3	--	--	0.35	36	1
WLO49-T851	2.71	76.60	28.83	74.46	0.3285	51	2
WLO49-T851	2.70	77.9	--	--	--	52	2
2219-T87	2.82	74.46	27.79	77.45	0.3398	51	2
2219-T87	--	77.4	29.1	75.8	0.330	33	2

1 Static measurement.

2 Dynamic measurement.

Elastic Constants of Al-Li Alloys and Alloy 2219 at Low Temperatures.

Alloy	Temp., K	Young's Modulus, E, GPa	Shear Modulus, G, GPa	Bulk Modulus, B, GPa	Poisson's Ratio, ν	Ref. No.	Method of Analysis
2219	0	85.7	32.5	78.7	0.318	50	2
	100	84.5	32.0	78.4	0.320	50	2
	200	81.2	30.6	77.2	0.325	50	2
	300	77.4	29.1	75.8	0.330	50	2
2219	298	74.5	27.8	77.5	0.340	51	2
2090	298	79.7	30.3	71.8	0.315	51	2
2090	5	87.8	--	--	0.307	37	2
	10	87.7	--	--	0.307	37	2
	15	87.7	--	--	0.307	37	2
	20	87.7	--	--	0.307	37	2
	25	87.6	--	--	0.307	37	2
	30	87.7	--	--	0.307	37	2
	35	87.7	--	--	0.306	37	2
	40	87.6	--	--	0.307	37	2
	45	87.5	--	--	0.307	37	2
	50	87.5	--	--	0.307	37	2
	55	87.5	--	--	0.306	37	2
	60	87.3	--	--	0.306	37	2
	65	87.3	--	--	0.307	37	2
	70	87.0	--	--	0.307	37	2
	75	86.9	--	--	0.307	37	2
	80	86.8	--	--	0.308	37	2
	85	86.7	--	--	0.308	37	2
	90	86.5	--	--	0.308	37	2
	95	86.4	--	--	0.308	37	2
	100	86.1	--	--	0.308	37	2
	105	86.1	--	--	0.309	37	2
	110	86.0	--	--	0.309	37	2
	115	85.9	--	--	0.309	37	2
	120	85.7	--	--	0.309	37	2
	125	85.4	--	--	0.310	37	2
	130	85.2	--	--	0.310	37	2
	135	85.2	--	--	0.310	37	2
	140	84.8	--	--	0.311	37	2
	145	84.5	--	--	0.311	37	2
	150	84.5	--	--	0.311	37	2
	155	84.3	--	--	0.311	37	2
	160	84.1	--	--	0.312	37	2
	165	84.0	--	--	0.312	37	2
	170	83.9	--	--	0.312	37	2
	175	83.5	--	--	0.313	37	2
	180	83.3	--	--	0.313	37	2
	185	83.0	--	--	0.314	37	2
	190	82.9	--	--	0.314	37	2
	195	82.7	--	--	0.314	37	2

1 Static measurement.

2 Dynamic measurement.

4. THERMAL PROPERTIES

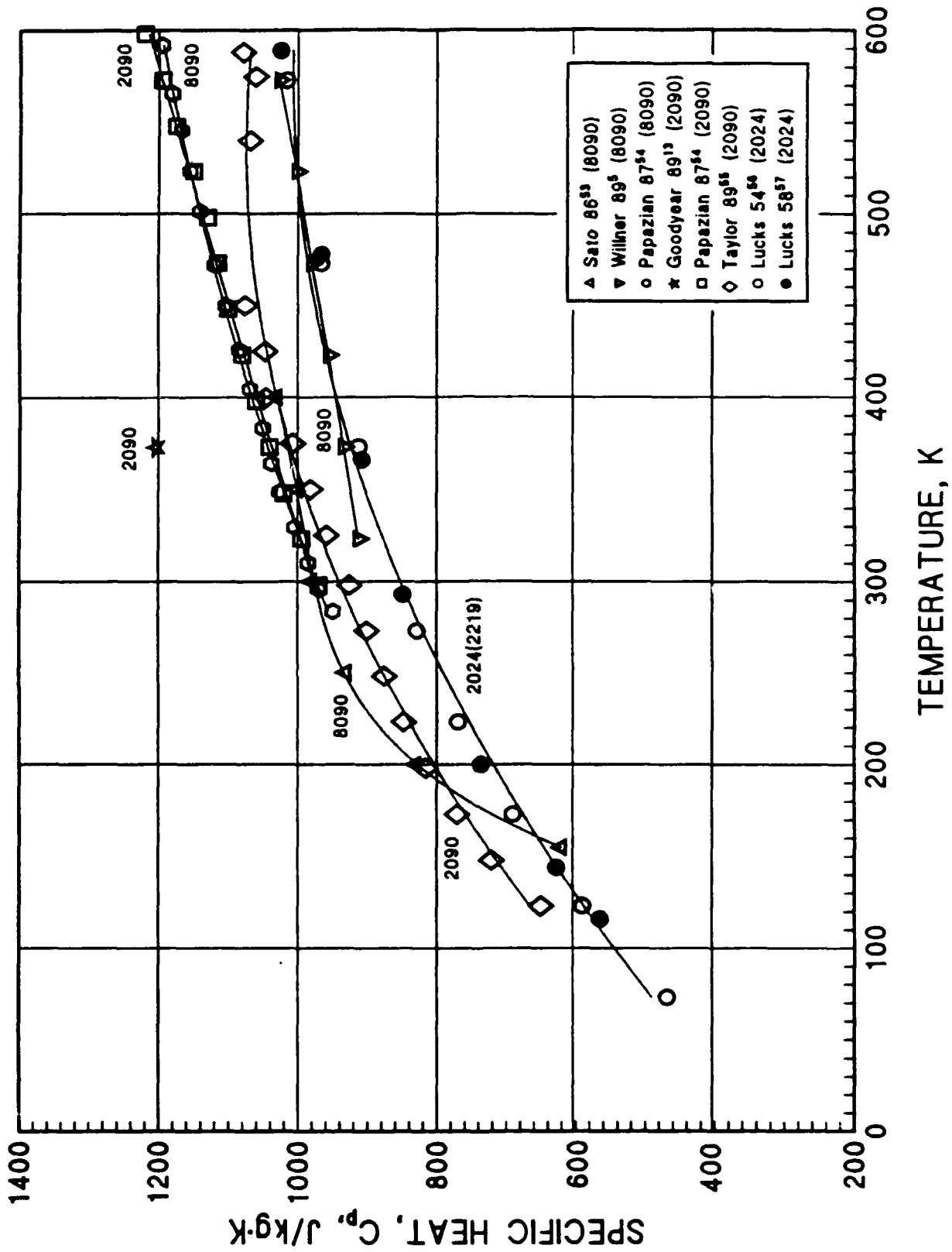
4.1. Specific Heat

4.1.1. Introduction to Graph

The available specific heat (C_p) data from cryogenic temperatures to the melting point are presented in the figure and table. Measurements are available only on alloys 8090 and 2090 between 123 and 598 K. Some of these data were obtained by differential scanning calorimetry to indicate the dissolution temperature of precipitates produced by various aging treatments and the formation of subsequent phases. These are shown in a smoothed form,^{53,54,55} or are omitted⁵³ above 400 K. As shown by Papazian,⁵⁴ changes in the aging treatment move the position of the peaks and valleys along the curve to higher and lower temperatures. Taylor⁵⁵ identified the peak at ≈ 510 K in his specific heat data as the melting point of Li. However, a peak at this position is not observed in the other specific heat measurements of alloy 2090, and it seems more probable that peaks can be identified with the aging treatment. Consult the original references, which specify aging treatments, for specific heat data on alloys 8090 and 2090 with the fine structure in the curves (important only above 400 K).

At present, there are no specific heat data for alloys WL049 or 2219 in the cryogenic temperature range. The curve for the specific heat of alloy 2219 vs. temperature presented in Figure 3.2.6.0. of MIL-HDBK 5E² appears to be based upon data from Al-alloy 2024.^{56,57} The composition of alloy 2024 (4.5Cu, 1.5Mg, and 0.6Mn), is similar to the composition of alloy 2219 (5.8-6.8Cu, and 0.2-0.4Mn). These data, labeled 2024(2219), are also given in the figure.

The specific heat of an alloy can be approximated, near ambient temperature, by a linear combination of the specific heats of the constituent elements.⁵⁸ Because the specific heat of Li is about 4 times larger than the specific heat of Al, and about 9 times larger than that of Cu, the specific heats of alloys 8090 and 2090 should be about 10% higher than that of alloy 2219. This is similar to what is shown in the specific heat figure for the data of Sato⁵³ on alloy 8090 and Papazian⁵⁴ on alloy 2090. However, the higher temperature data on alloy 8090⁴ appear quite similar to that of alloy 2024(2219), and, therefore, are probably too low. Variations in aging conditions and chemistry for individual heats can result in changes in the fine structure of a specific heat curve for Al-Li alloys, especially above ambient temperatures. This could account for this apparent discrepancy, and perhaps, also for one unexpectedly high value of specific heat¹² at 100 °C. More measurements of the specific heat on current production heats of Al-Li alloys would be very desirable.



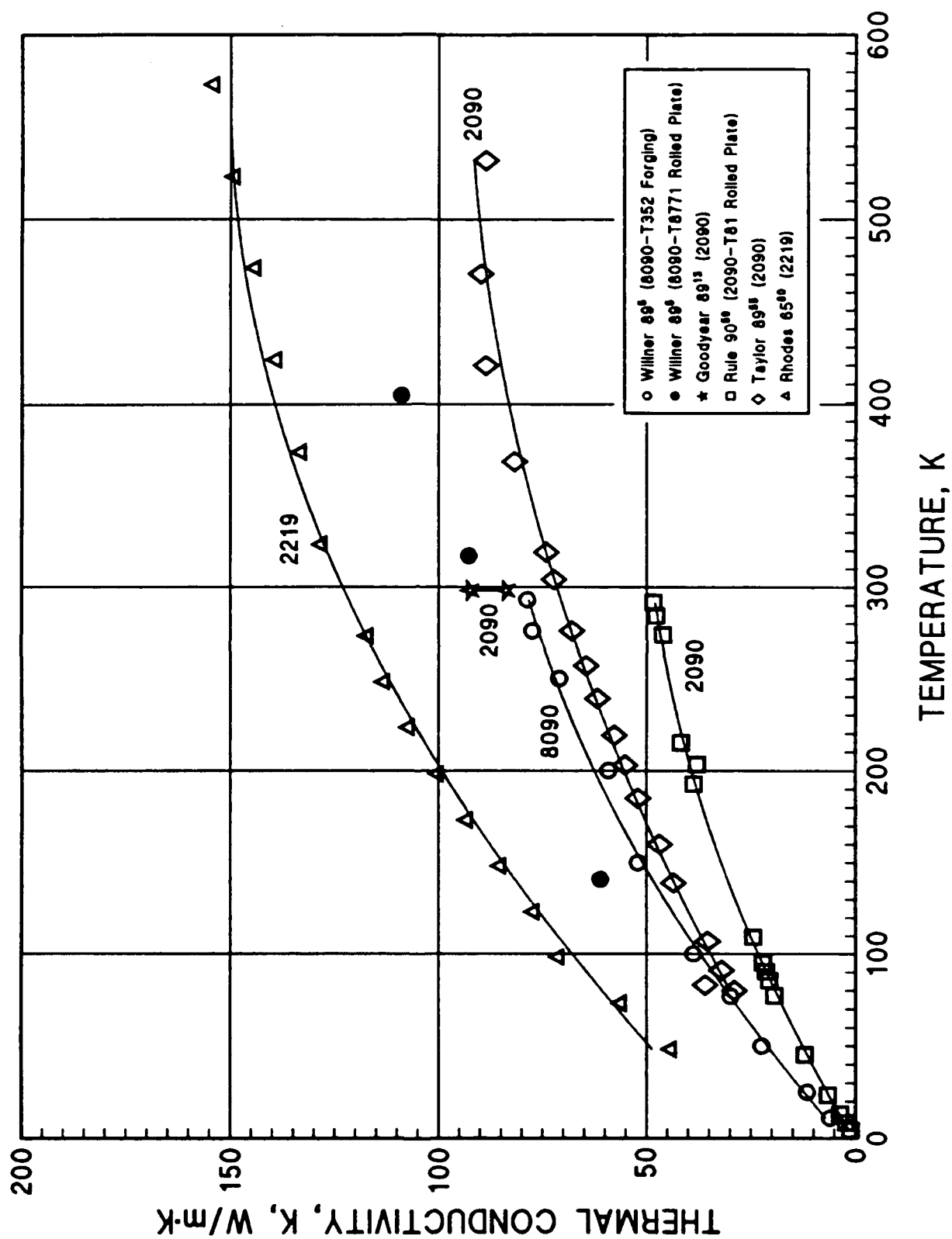
Specific Heat of Al-Li Alloys and Alloy 2219.

Alloy	Temp., K	C _p , J/kg·K	Ref. No.	Alloy	Temp., K	C _p , J/kg·K	Ref. No.
8090	155	620	54	2090	123	649	56
	200	830	54		148	720	56
	250	930	54		173	770	56
	300	980	54		198	815	56
	350	1000	54		223	847	56
	400	1030	54		248	875	56
8090	323	913	5		273	900	56
	373	934	5		298	925	56
	423	956	5		325	958	56
	473	980	5		350	981	56
	523	1002	5		375	1006	56
	573	1027	5		400	1045	56
8090	623	1047	5		425	1046	56
	673	1070	5		450	1075	56
	284	949	55		480	1068	56
	296	969	55		505	1060	56
	310	985	55		530	1078	56
	329	1005	55	2024(2219)	73	469	57
8090	349	1026	55		123	590	57
	364	1038	55		173	690	57
	383	1051	55		223	770	57
	404	1069	55		273	828	57
	426	1085	55		323	912	57
8090	450	1104	55		373	967	57
	472	1120	55		423	1017	57
	501	1141	55	2024(2219)	573	1017	57
	523	1155	55		116	565	58
	546	1168	55		144	628	58
	566	1181	55		200	736	58
8090	592	1195	55		293	849	58
	373	1203	13		366	908	58
2090	298	970	55		478	966	58
	323	995	55		589	1025	58
	348	1020	55				
	373	1040	55				
	398	1060	55				
	423	1080	55				
2090	448	1100	55				
	473	1115	55				
	498	1130	55				
	523	1150	55				
	548	1175	55				
	573	1195	55				
	598	1220	55				

4.2. Thermal Conductivity

4.2.1. Introduction to Graph

Thermal conductivity (K) data for alloys 8090, 2090, and 2219 between 4 and 573 K are given in the accompanying thermal conductivity figure and table. No data on WL049 are currently available. The solid lines shown in the figure represent the fit of second-order polynomials to the alloy 8090,⁴ alloy 2090,^{53,59} and alloy 2219⁶⁰ data. The data of Rule⁵⁹ appear to be anomalously low. However, thermal conductivity of Al alloys at low temperatures is composition and cold-work sensitive.⁶¹



Thermal Conductivity of Al-Li Alloys and Alloy 2219.

Alloy	Temp., K	K, W/m·K	Ref. No.	Alloy	Temp., K	K, W/m·K	Ref. No.
8090-T352	11	6.1	5	2090	80	28.8	56
	25	11.6	5		83	35.8	56
	50	22.5	5		91	31.9	56
	77	29.9	5		107	35.2	56
	100	38.8	5		139	43.4	56
	150	52.1	5		160	46.7	56
	200	59.2	5		185	51.9	56
	250	71.0	5		203	55.0	56
	276	77.5	5		219	57.6	56
	293	78.7	5		239	61.7	56
	317	92.8	5		257	64.4	56
	404	109.	5		276	67.8	56
8090-T8771	141	61.1	5		304	72.2	56
	298	87.9	13		319	74.0	56
	298	87.9	13		368	81.6	56
2090 2090-T81	4	1.1	60		420	88.5	56
	8	2.2	60		470	89.7	56
	13	3.6	60		532	88.5	56
	23	6.6	60	2219	48	44	61
	45	12.1	60		73	56	61
	77	19.4	60		98	71	61
	85	20.6	60		123	77	61
	90	21.4	60		148	85	61
	95	22.1	60		173	93	61
	109	24.4	60		198	100	61
	193	38.6	60		223	107	61
	203	37.9	60		248	113	61
	215	41.7	60		273	117	61
	274	46.1	60		323	128	61
	284	47.7	60		373	133	61
	292	48.4	60		423	139	61
					473	144	61
					523	149	61
					573	154	61

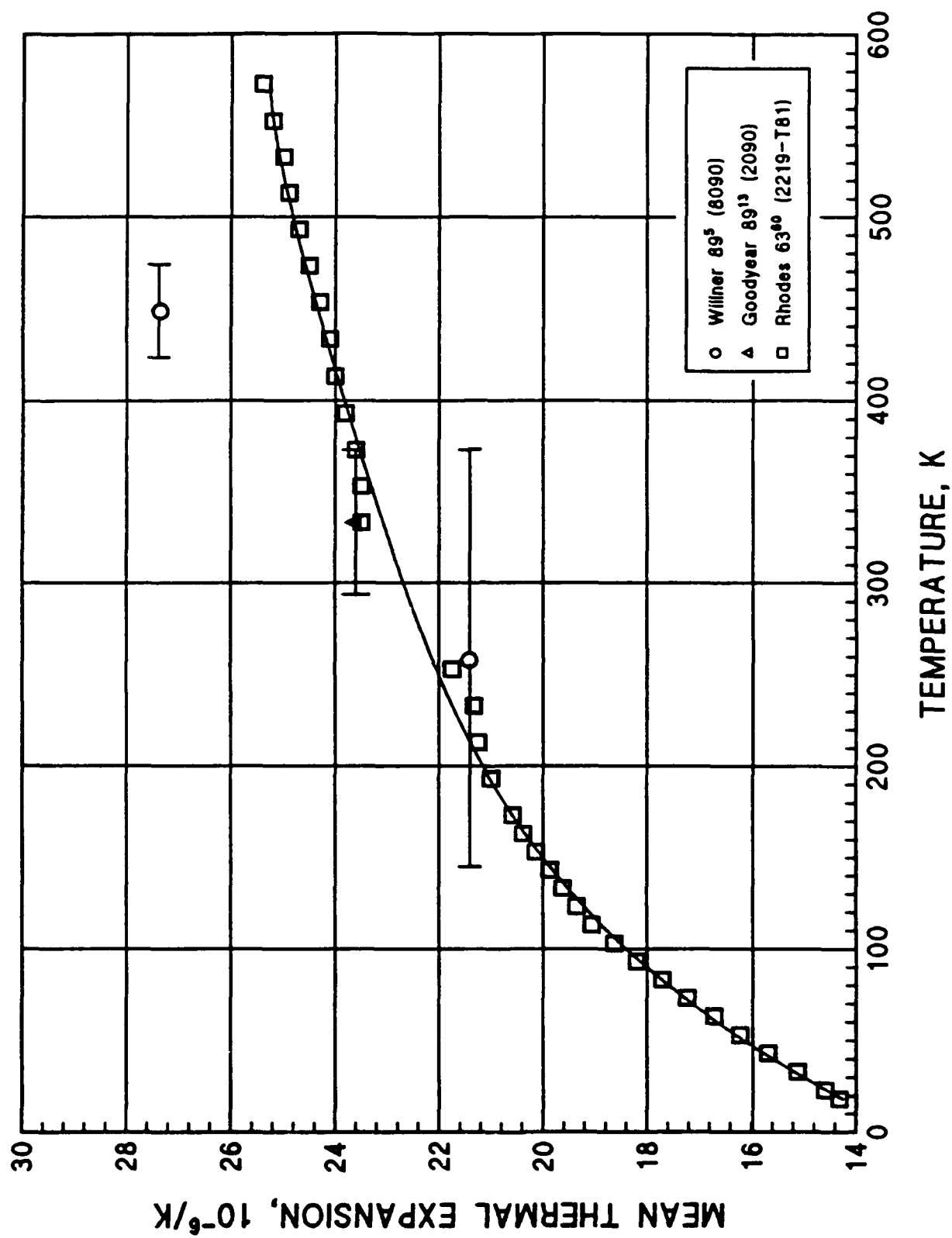
4.3. Mean Thermal Expansion

4.3.1. Introduction to Graph

The figure on mean thermal expansion presents the data available on the property, defined as:

$$\Delta L/L \cdot \Delta T = [L(293 \text{ K}) - L(T)]/[L(293 \text{ K}) (293 \text{ K} - T)].$$

Only data for alloy 2219-T87 are available over a wide temperature range, from 18 to 573 K. The values presented for alloys 8090 and 2090 are averages obtained over the temperature range indicated in the graph. Near 293 K, the quantity $\Delta L/L \cdot \Delta T$ becomes less accurate, because a smaller length change is measured. Mean thermal expansion data for alloy 2219 near 293 K were eliminated if a wide degree of scatter was evident. Although only one set of thermal expansion data for alloy 2219 is available, that data set is in reasonable agreement with several sets of data for alloy 6061 (0.6 Si, 0.27 Cu, 1.0 Mg, 0.2 Cr) over a similar temperature range. The data are also presented in the thermal expansion table that follows the graph.



Mean Thermal Expansion of Al-Li Alloys and Alloy 2219.

Alloy	Temp., K	$\frac{1}{L} \frac{\Delta L}{\Delta T},$ $10^{-5} K^{-1}$	Ref. No.
8090	258	27.4	5
	448	21.4	5
2090	333	23.6	13
2219-T81	18	14.3	61
	23	14.6	61
	33	15.1	61
	43	15.7	61
	53	16.2	61
	63	16.7	61
	73	17.2	61
	83	17.7	61
	93	18.2	61
	103	18.6	61
	113	19.1	61
	123	19.4	61
	133	19.6	61
	143	19.9	61
	153	20.1	61
	163	20.4	61
	173	20.6	61
	193	21.0	61
	213	21.3	61
	233	21.3	61
	253	21.8	61
	333	23.5	61
	353	23.5	61
	373	23.6	61
	393	23.8	61
	413	24.0	61
	433	24.1	61
	453	24.3	61
	473	24.5	61
	493	24.7	61
	513	24.9	61
	533	25.0	61
	553	25.2	61
	573	25.4	61

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