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THE *Marquardt*  
CORPORATION

VAN NUYS, CALIFORNIA

17 SEPTEMBER 1961

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(TITLE -- UNCLASSIFIED)

TENSILE AND CREEP PROPERTIES OF  
0.010 AND 0.020-INCH RENE 41 ALLOY SHEET  
FROM ROOM TEMPERATURE TO 2000°F

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(Title -- Unclassified)  
TENSILE AND CREEP PROPERTIES OF  
0.010 AND 0.050-INCH RENE' 41 ALLOY SHEET  
FROM ROOM TEMPERATURE TO 2000° F

Contract AF 33(657)-8706

Project 281

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I. SUMMARY

A materials testing program was conducted to evaluate the important mechanical properties of Rene' 41 alloy sheet. Two thicknesses of sheet (0.010 and 0.050 inch) were used throughout the program. In addition, several tests were conducted using two different solution heat treatments (2150°F versus 1950°F) to determine their effect on mechanical properties.

Tensile properties were investigated from room temperature to 2000°F. Strain rate sensitivity of tensile properties was also investigated. Creep and rupture properties at temperatures from 1400° to 1800°F were determined for short times of 1 to 1000 seconds and for longer times of 10 to 100 hours.

II. INTRODUCTION

Rene' 41 alloy sheet has received extensive interest and usage from the aerospace industries because of its excellent combination of mechanical properties, oxidation resistance, and reasonable ease of fabrication. This test program was initiated because several specialized mechanical properties that could not be obtained from vendor literature were required by Marquardt designers, for example, the strain rate sensitivity of tensile properties. Therefore, a program was initiated for testing the two most widely used thicknesses of Rene' 41 sheet: 0.010 and 0.050 inch. An additional reason for selecting these two thicknesses was that previous work on superalloys had shown important differences in mechanical properties between these thicknesses.

Two vendor-recommended heat treatments for Rene' 41 alloy sheet exist. One to yield maximum creep properties (2150°F solution anneal) and another for maximum elevated temperature tensile properties (1950°F solution anneal). Both heat treatments were investigated for the two thicknesses of material utilized in the program.

III. OBJECTIVES

A. Tensile Properties

Tensile properties were determined at selected temperatures ranging from room temperature to 2000°F on two thicknesses of Rene' 41 alloy sheet and for two different solution heat treatment temperatures. The effect of various tensile test strain rates on room and elevated temperature tensile properties was determined.

B. Creep Properties

The 1600°, 1800°, and 2000°F creep and rupture data were determined for 0.050-inch thick Rene' 41 alloy sheet solution annealed at 1950°F. The 1400°, 1600°, 1700°, and 1800°F creep and rupture data were determined on 0.050-inch Rene' 41 alloy sheet solution annealed at 2150°F.

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IV. MATERIAL AND HEAT TREATMENTS

The chemical analyses of the three heats of Rene' 41 alloy sheet used in this investigation are listed in Table I. Table I also contains the allowable ranges for chemical composition of Rene' 41 alloy sheet from the General Electric Company specification. All heats of material used in this investigation met the specification. The heat treatments recommended by the General Electric Company are listed in Table II, along with the material heat numbers, thicknesses, and heat treatments used in this investigation.

V. EXPERIMENTAL PROCEDURES AND RESULTSA. Tensile Properties

The tensile specimens which were used had a 0.500-inch width of reduced section and a 2-inch gage length. All room and elevated temperature tensile tests were conducted on the Marquardt TM-1 elevated temperature test machine. Figure 1 is a photograph of this machine and its peripheral equipment. Elevated temperatures are obtained on this machine by resistance heating of the specimen. Three pairs of 36 gage wire thermocouples are welded to the specimen. One thermocouple is used for electronic feedback control of the temperature and the other two thermocouples are used to check and record the thermal gradient along the 2-inch gage length. Strain rates are electronically controlled with feedback from the linear transducer of the extensometer.

The results of tensile tests from room temperature to 2000°F on 0.010 and 0.050-inch thick Rene' 41 alloy sheet for three different strain rates are reported in Tables III through IX. Table X contains a comparison of yield strength with strain rate. Stress-strain curves to beyond 0.2% yield strength for temperatures from room temperature to 2000°F are presented in Figures 2 through 4. The variation of proportional limit, 0.2% yield strength, and ultimate tensile strength with strain rate and temperature are presented in Figures 5 through 7, respectively. Figure 8 illustrates the variation of ultimate tensile strength with temperature and for both thicknesses and heat treatments used in this investigation.

B. Creep Properties

The results of creep tests at 1400°, 1600°, 1800° and 2000°F for two heat treatments on 0.050-inch thick Rene' 41 alloy sheet are tabulated in Tables XI through XIV. These results are shown graphically in Figures 9 through 15.

VI. DISCUSSIONA. Tensile Properties

For 0.050 inch thick Rene' 41 alloy sheet solution heat treated at 1950°F, the proportional limit and yield strength become strain rate sensitive above 1200°F. For 0.010 and 0.050-inch Rene' 41 alloy sheet given a solution heat treatment at 2150°F, the strain rate sensitivity of proportional limit and yield strength does not begin until 1400°F. For 0.050-inch Rene' 41 alloy sheet, the

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tensile strength becomes strain rate sensitive above 1450°F. At temperatures in the 1500°F to 2000°F range, very severe drops in strength can result from using slow strain rates. For example, the yield strength of 0.050-inch Rene' 41 alloy sheet solution heat treated at 1950°F is 107.5 Ksi at 1600°F using a 0.1 in./in./sec strain rate. With a 0.00001 in./in./sec strain rate, the yield strength drops to 56.0 Ksi. Other comparisons of strain rate sensitivity are given in Table X. As expected, the 1950°F solution heat treat temperature gives the 0.050-inch material superior ultimate tensile strength at all temperatures, as compared to a 2150°F solution heat treat temperature. The ultimate tensile strength of 0.010-inch thick Rene' 41 alloy sheet solution annealed at 2150°F is decidedly inferior to that of the 0.050-inch material for the same heat treatment. This behavior is illustrated in Figure 8.

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TABLE I

## CHEMICAL COMPOSITION OF THREE HEATS OF RENE' 41 ALLOY

Element	Heat Number (Haynes)			General Electric Co. Specification B50T59B
	TV707	TV353	TV716	
	0.010 in.	0.050 in.	0.050 in.	
Cr	19.22%	19.25%	19.05%	18.00 to 20.00%
Co	10.98	11.20	10.62	10.00 to 12.00
Mo	10.03	9.85	10.18	9.00 to 10.50
Al	1.45	1.49	1.44	1.40 to 1.60
Ti	3.03	3.15	3.12	3.00 to 3.30
Fe	1.44	0.67	1.48	5.00 max.
C	0.08	0.09	0.09	0.12 max.
Si	0.28	0.14	0.29	0.50 max.
S	0.007	0.005	0.007	0.015 max.
Mn	0.01	0.02	0.03	0.10 max.
B	0.005	0.005	0.005	0.003 to 0.010
Ni	Balance	Balance	Balance	Balance

TABLE II

## HEAT TREATMENTS OF THREE HEATS OF RENE' 41 ALLOY

(All heat treatments were preceded by a mill anneal at 1975°F, RC)

Heat Number (Haynes)	Thickness	Solution Treatment	Aging
TV707	0.010 in.	2150°F (1/2 hr) AC	1650°F (4 hrs)
TV353	0.050	1950°F (1/2 hr) RAC	1400°F (16 hrs)
TV716	0.050	2150°F (1/2 hr) RAC	1650°F (4 hrs)
<u>General Electric Co. Specification</u>			
	B50T59C	1950°F (1/2 hr) AC	1400°F (16 hrs)
	B50T59D	2150°F (1/2 hr) AC	1650°F (4 hrs)







TABLE VI

SHORT-TIME TENSILE TEST RESULTS  
ON RENE' 41 ALLOY SHEET AT AN INTERMEDIATE STRAIN RATE

Thickness = 0.050 in.	Machine = ETIM
Heat Treatment = 2150°F (1/2 hr) RAC + 1650°F (4 hrs)	Method of Heating = Resistance
Heat Number = TV716 (Haynes)	Heating Rate = 200°F/sec
	Hold Time = 5 min
	Strain Rate = 0.001 in./in./sec to YS 0.01 in./in./sec to Rupture
	Gage Length = 2.0 in.

Specimen No.	Test Temperature (°F)	Proportional Limit (Ksi)	0.2% Yield Strength (Ksi)	Ultimate Tensile Strength (Ksi)	Elongation (%)	Modulus of Elasticity
487D	RT	88	112	174	18	$31 \times 10^6$ psi
488D	RT	92	114	172	16	
489D	800	83	104	155	19	29
490D	1000	88	104	153	22	27
491D	1200	85	104	150	26	26
492D	1400	78	102	144	20	25
493D	1600	66	88	112	19	22
494D	1800	38	45	59	21	19

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TABLE VII

SHORT-TIME TENSILE TEST RESULTS  
 ON RENE' 41 ALLOY SHEET AT AN INTERMEDIATE STRAIN RATE

Thickness = 0.050 in.	Machine = ETTM
Heat Treatment = Sol. HT 1950°F (1/2 hr)	Method of Heating = Resistance
RAC & Aged at 1400°F (16 hrs) AC	Heating Rate = 200°F/sec
Heat Number = TV353 (Haynes)	Strain Rate = 0.001 in./in./sec to YS 0.01 in./in./sec to Rupture
	Gage Length = 2.0 in.

Specimen No.	Test Temperature (°F)	Hold Time (min)	Proportional Limit (Ksi)	0.2% Yield Strength (Ksi)	Ultimate Tensile Strength (Ksi)	Elongation (%)	Modulus of Elasticity
923A	RT	--	154.0	151.0	185.0	12	29.5 x 10 <sup>6</sup> psi
924A	RT	--	135.0	154.0	189.0	13	
950A	RT	--	131.0	146.0	187.0	15	
952A	800	2	111.0	131.0	166.0	15	26.0
953A	800	2	116.0	132.0	167.0	16	26.5
954A	800	2	117.0	132.0	171.0	19	27.0
955A	1200	2	108.0	128.0	163.0	18	24.0
956A	1200	2	105.0	129.0	164.0	16	25.0
957A	1200	30	110.0	129.0	163.0	16	23.0
958A	1400	2	96.0	121.0	158.0	12	22.0
959A	1400	2	102.0	123.0	158.0	13	21.0
933A	1600	2	64.0	96.0	114.0	7.5	19.5
934A	1600	2	63.0	92.0	107.0	8	18.0
935A	1600	30	60.0	89.0	108.0	8	19.0
936A	1800	2	22.0	32.0	46.0	17.5	13.0
937A	1800	2	22.0	31.0	45.0	15	12.5
932A	1800	30	17.0	23.0	35.0	19	12.5
925A	2000	2	7.0	9.0	16.5	45	7.5
926A	2000	2	8.0	9.5	16.0	51	6.5
927A	2000	30	7.0	9.0	14.0	30	8.5

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TABLE X

COMPARISON OF AVERAGE TENSILE PROPERTIES FOR RENE' 41 ALLOY SHEET  
 SOLUTION HEAT TREATED AT 1950°F AND AGED AT 1400°F FOR 16 HOURS

Test Temperature	0.2% Yield Strength		Ultimate Strength	Elongation in 2.0 in.
	0.00001 in./in./sec	0.001 in./in./sec	0.01 in./in./sec	
RT	150.0 Ksi	150.0 Ksi	184.0 Ksi	6.5%
1000°F	129.0	129.0	165.0	8.7
1200	126.0	126.0	164.0	8
1400	108.0	122.0	158.0	6
1600	55.0	92.0	110.0	5

## NOTE:

Sheet = 0.050 in. thick, (Heat TV353)

TABLE XI

1600°F TENSILE CREEP-RUPTURE DATA FOR RENE 41' ALLOY SHEET

Heat Treatment = Sol. HT 1950°F (1/2 hr) RAC  
 Age 1400°F (16 hrs) AC  
 Heat Number = TV353  
 Machine = ETIM  
 Heating = Resistance  
 Sheet Thickness = 0.050 in.  
 Gage Length = 2.0 in.

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Specimen No.	Stress Level (Ksi)	Load Extension (%)	Time to Produce Indicated Creep (sec)					Creep In 900 sec (%)	Time To Rupture (sec)	Elongation At Rupture (%)	Residual UTS (Ksi)
			0.05%	0.2%	0.5%	1.0%	2.0%				
990A	90	0.55	--	1.3	3.7	6.6	11	16	18	6	--
991A	90	0.65	0.4	2.0	4.4	8.0	13	16	17.5	4.5	--
994A	90	0.65	0.5	1.5	6.0	10.0	16	22	26	7	--
992A	75	0.20	2.0	9	25	44	71	101	105	5.5	--
993A	75	0.25	3.0	14	31	54	82	113	117	5.5	--
994A	75	0.25	1.4	10	25	40	68	96	104	6	--
995A	60	0.25	10	71	173	281	403	534	545	5	--
996A	60	0.25	11	69	190	316	454	595	617	5	--
997A	60	0.27	11	59	157	260	370	495	545	6	--
3B	45	0.22	40	320	950	--	--	--	900+	7.5	110.0
998A	45	0.22	35	285	710	--	--	--	900+	8	99
999A	45	0.25	22	217	590	850	--	--	900+	7	92
1B	45	0.22	20	270	807	--	--	--	900+	6.5	105
2R	45	0.22	34	260	--	--	--	--	--	--	--
2B1	45	0.22	34	320	--	--	--	--	--	--	--
987A	30	0.10	90	780	--	--	--	--	900+	7.0	100.5
988A	30	0.10	82	935	--	--	--	--	900+	6.5	100.5
989A	30	0.10	55	960	--	--	--	--	900+	6.5	104.0





TABLE XIV

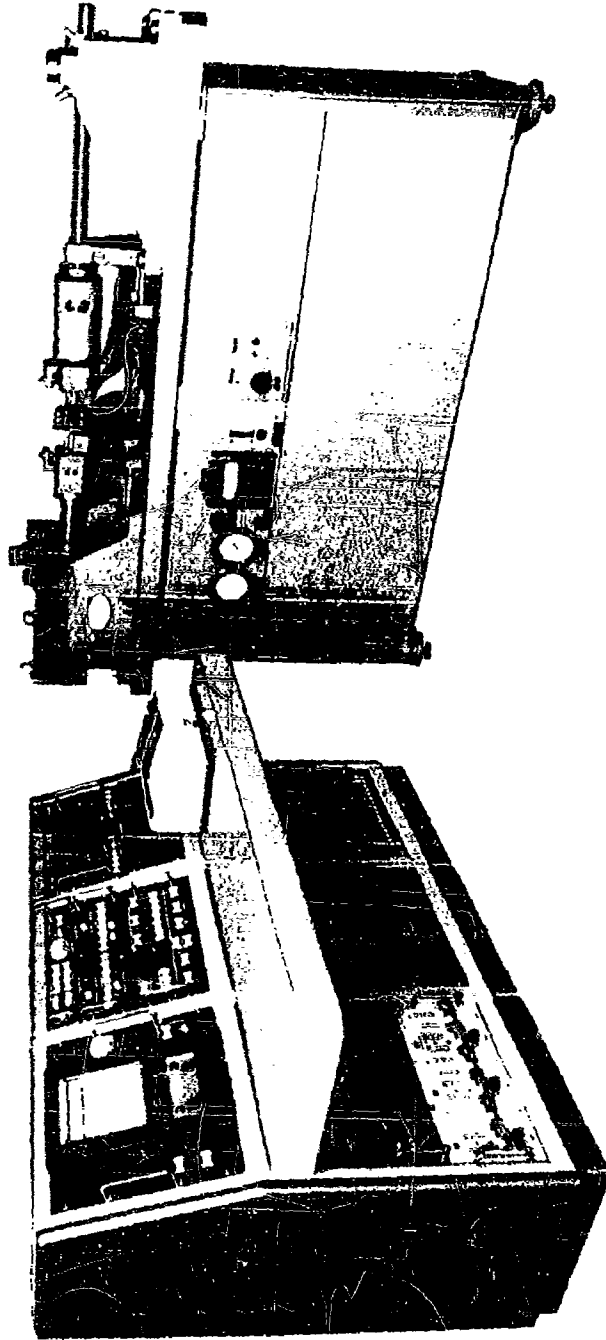
CREEP-RUPTURE DATA FOR RENEE' 41 ALLOY SHEET

Heat Treatment = Sol. HT 2150°F (1/2 hr) AC      Machine = Furnace Heating  
 Age 1650°F (4 hrs) AC      Arc Weld  
 Heat Number = FV716      Sheet Thickness = 0.050 in.

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Specimen No.	Stress Level (Ksi)	Test Temperature (°F)	Time to Produce Indicated Creep (min)					Time to Rupture (min)	Elongation in 2 in. (%)
			0.05%	0.2%	0.5%	1.0%	2.0%		
464D	65	1400	660	1860	3060	--	--	3860	--
466D	65	1400	300	1290	2340	3156	3910	3984	--
500D	80	1400	90	198	333	482	684	729	--
513D	34	1400	--	--	--	--	--	No creep	--
514D	36	1400	--	--	--	--	--	No creep	--
459D	20	1600	444	2070	3828	5200	6216	6252	--
465D	28	1600	432	1000	1620	--	--	2136	--
517D	17	1600	3120	4980	7980	--	--	10,236	--
516D	15	1600	2400	4800	8010	14,520	--	15,534	1
502D	28	1600	24	750	1360	1,896	2010	2,376	9
455D	10	1700	1080	2190	4140	7380	12,636	20,160	3
457D	23	1700	75	300	516	685	855	1,150	8
518D	10	1700	1152	3120	6600	10,800	--	11,340	1
519D	12	1700	1920	3120	4800	6,660	--	11,436	--
467D	6	1800	276	1164	2400	3530	6300	10,893	7
468D	11	1800	320	624	960	--	--	972	--
520D	6	1800	660	1830	3450	5160	7610	9,960	3
521D	8	1800	30	300	780	1270	1900	3,300	9

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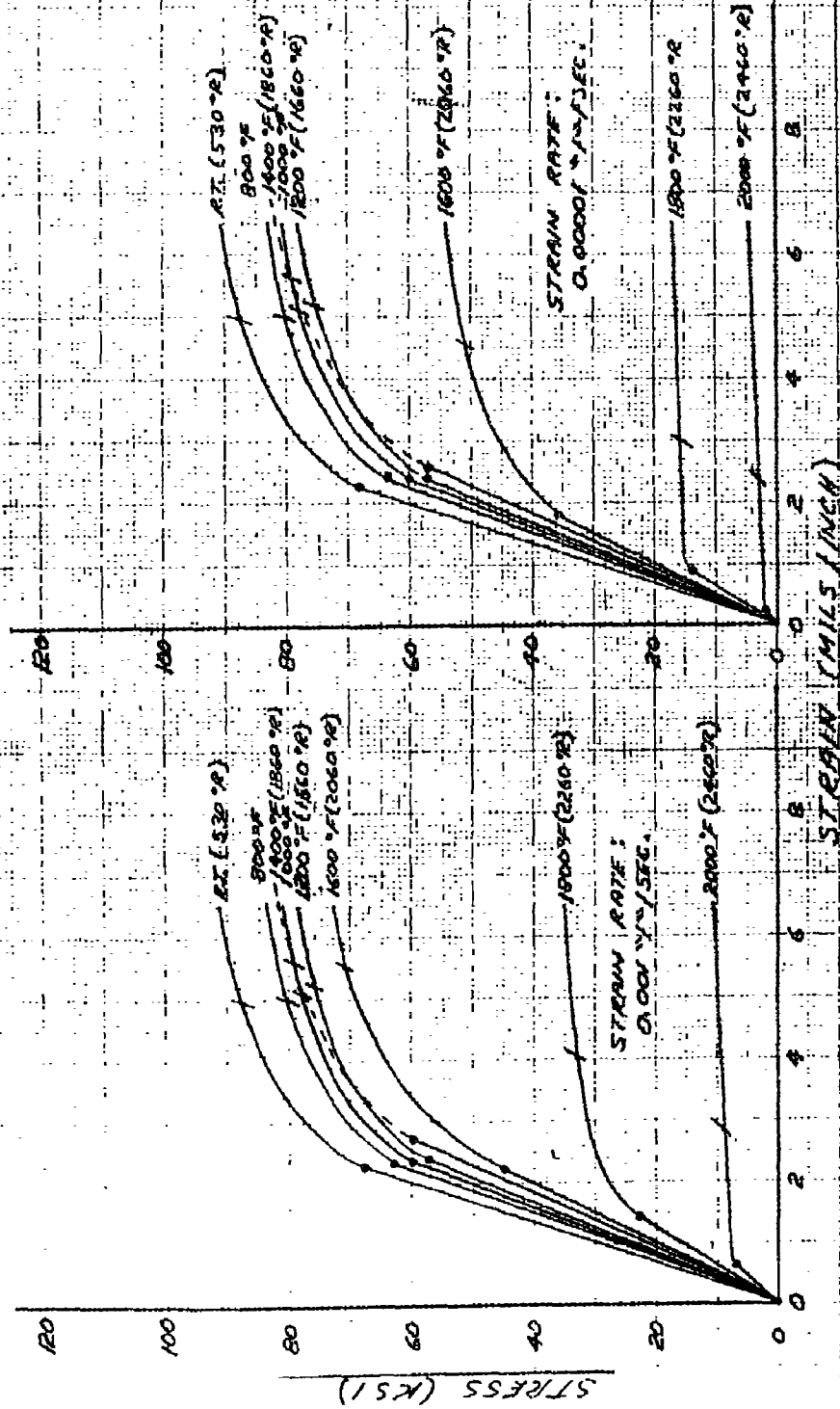
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FIGURE 1 - The Marquardt IM-1A Elevated Temperature Test Machine Assembly

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STRESS - STRAIN CURVES FOR RENE 41 ALLOY SHEET

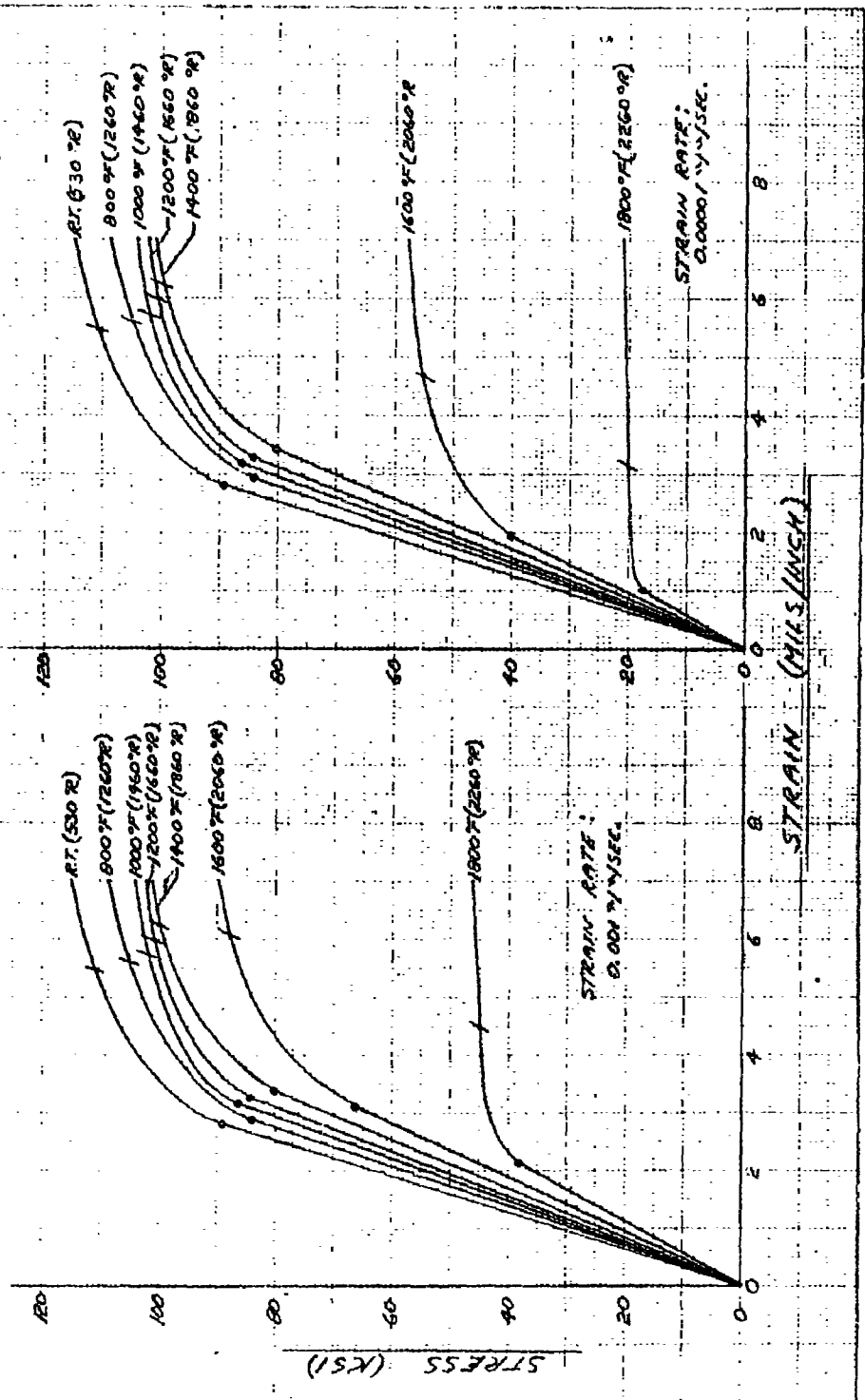
SOL. HT. 2150 °F (1177 °C) AC  
AGED AT 1650 °F (899 °C) AC  
GAGE LENGTH - 2.0 IN.  
HEAT TREAT  
SHEET THICKNESS - 0.010 IN.



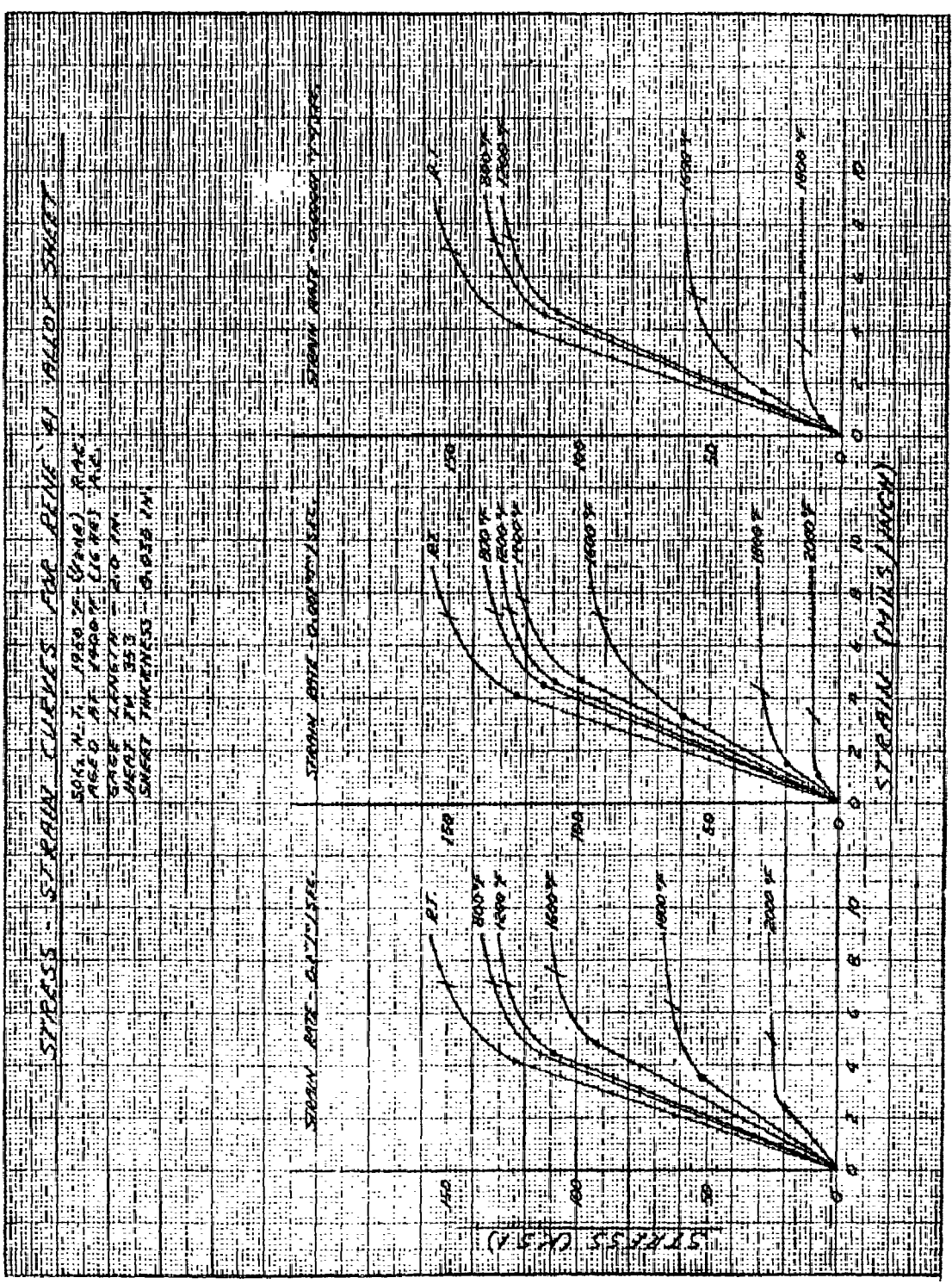
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STRESS - STRAIN CURVES FOR 7075-T6 ALLOY SHEET

SOL. H.T. 2150°F (20mm) R.R.C.  
AGED AT 1850°F (8mm) R.C.  
GAGE LENGTH - 2.0 IN.  
SHEET THICKNESS - 0.020 IN.

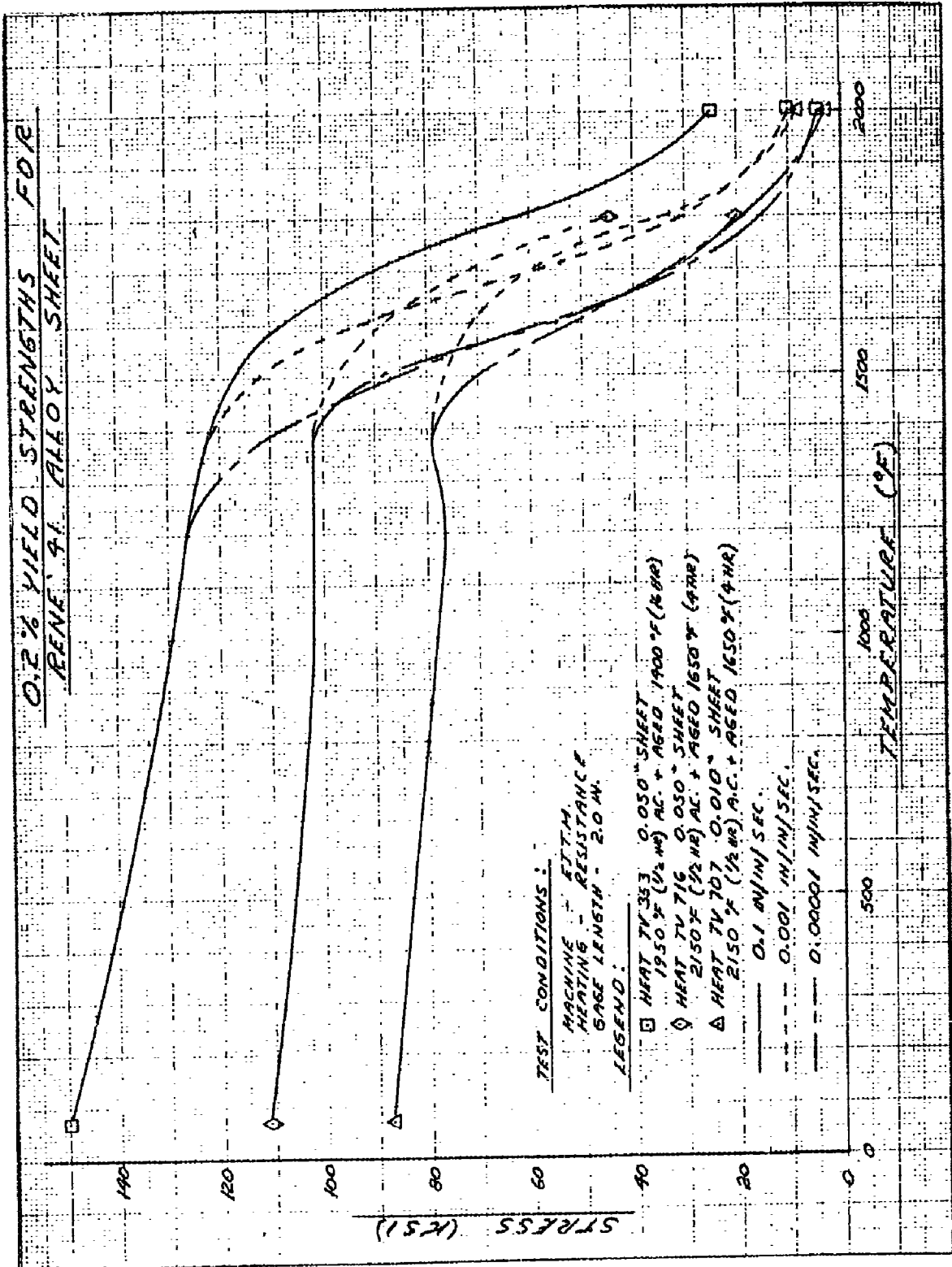


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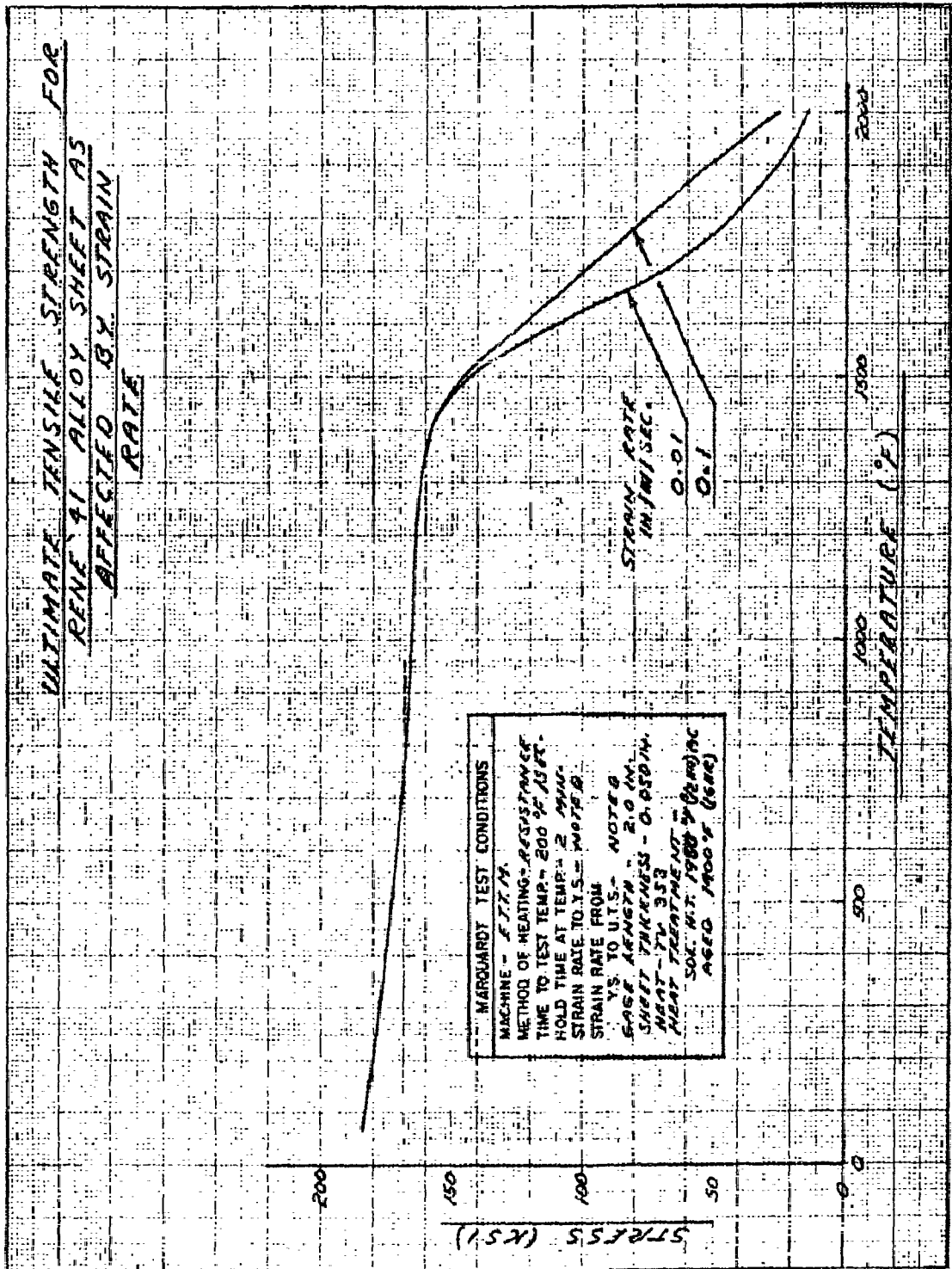
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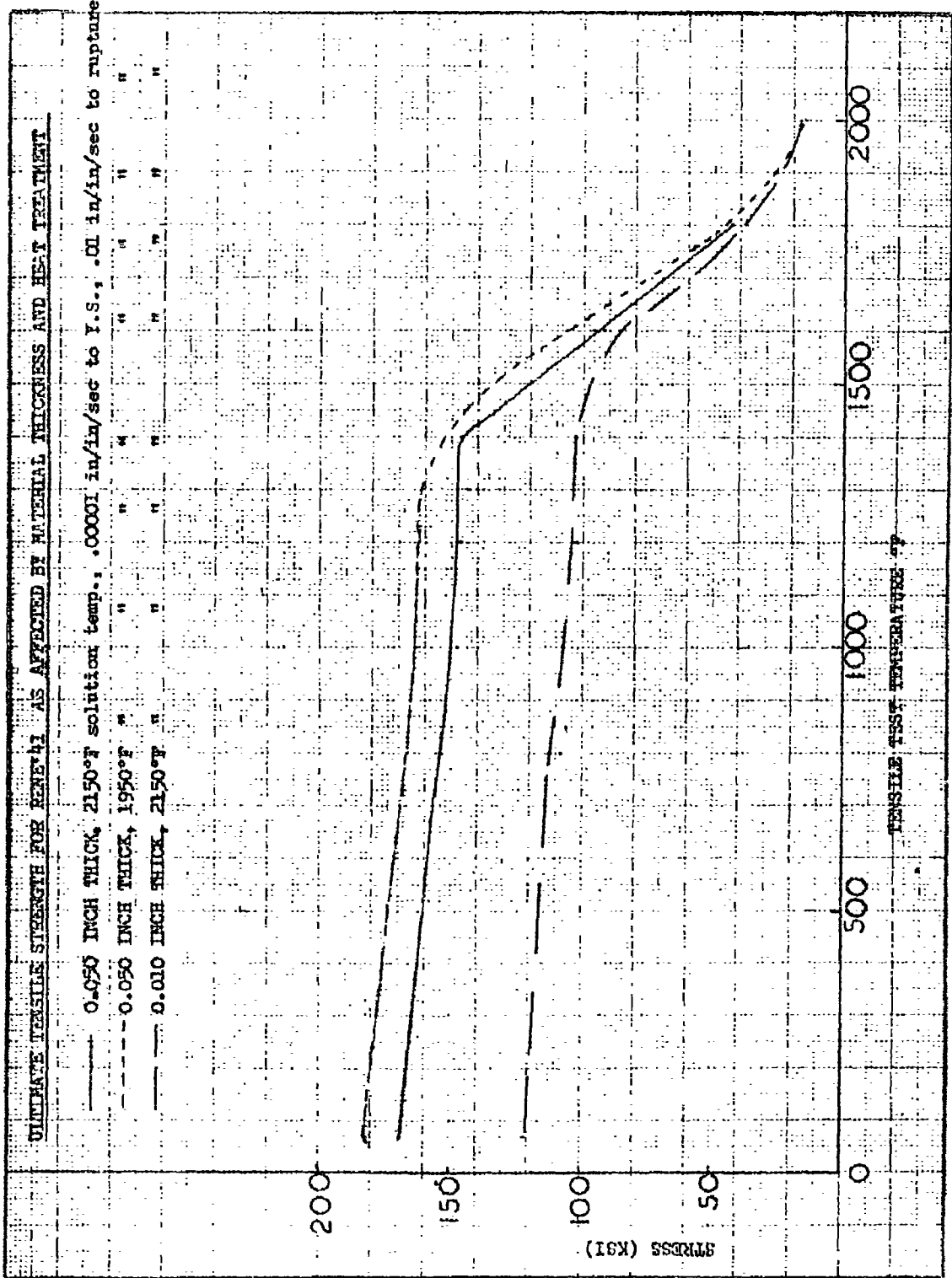
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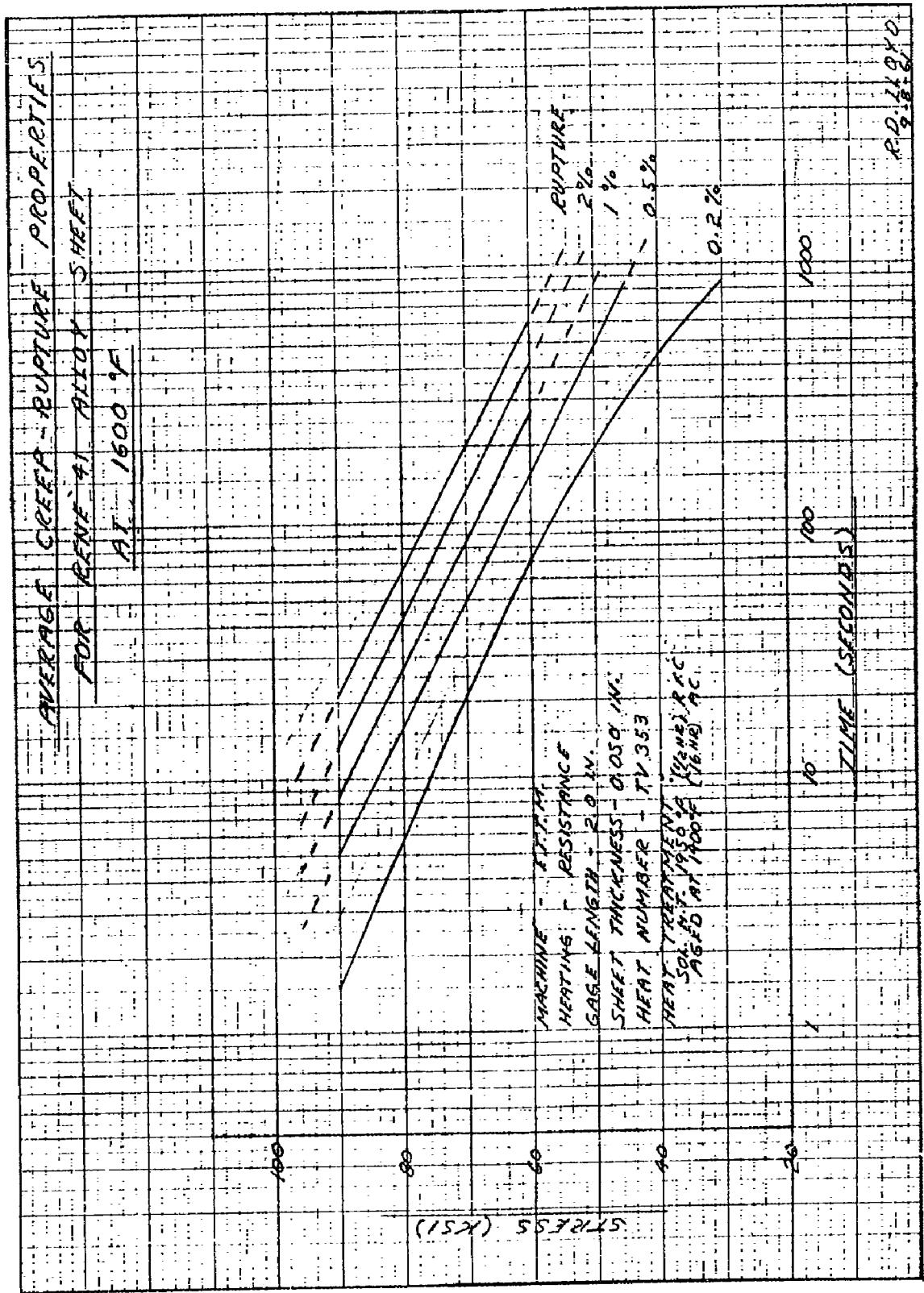
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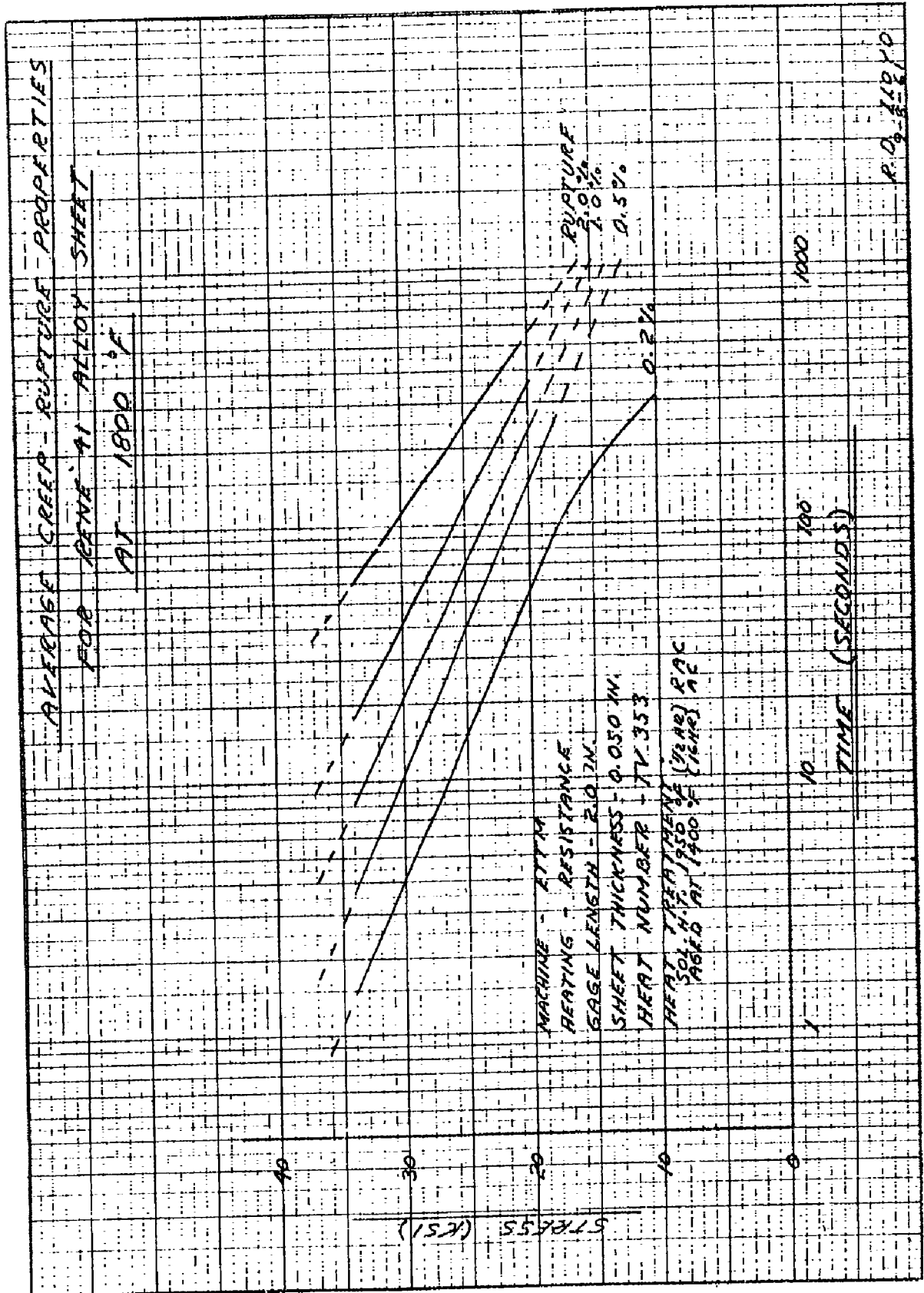
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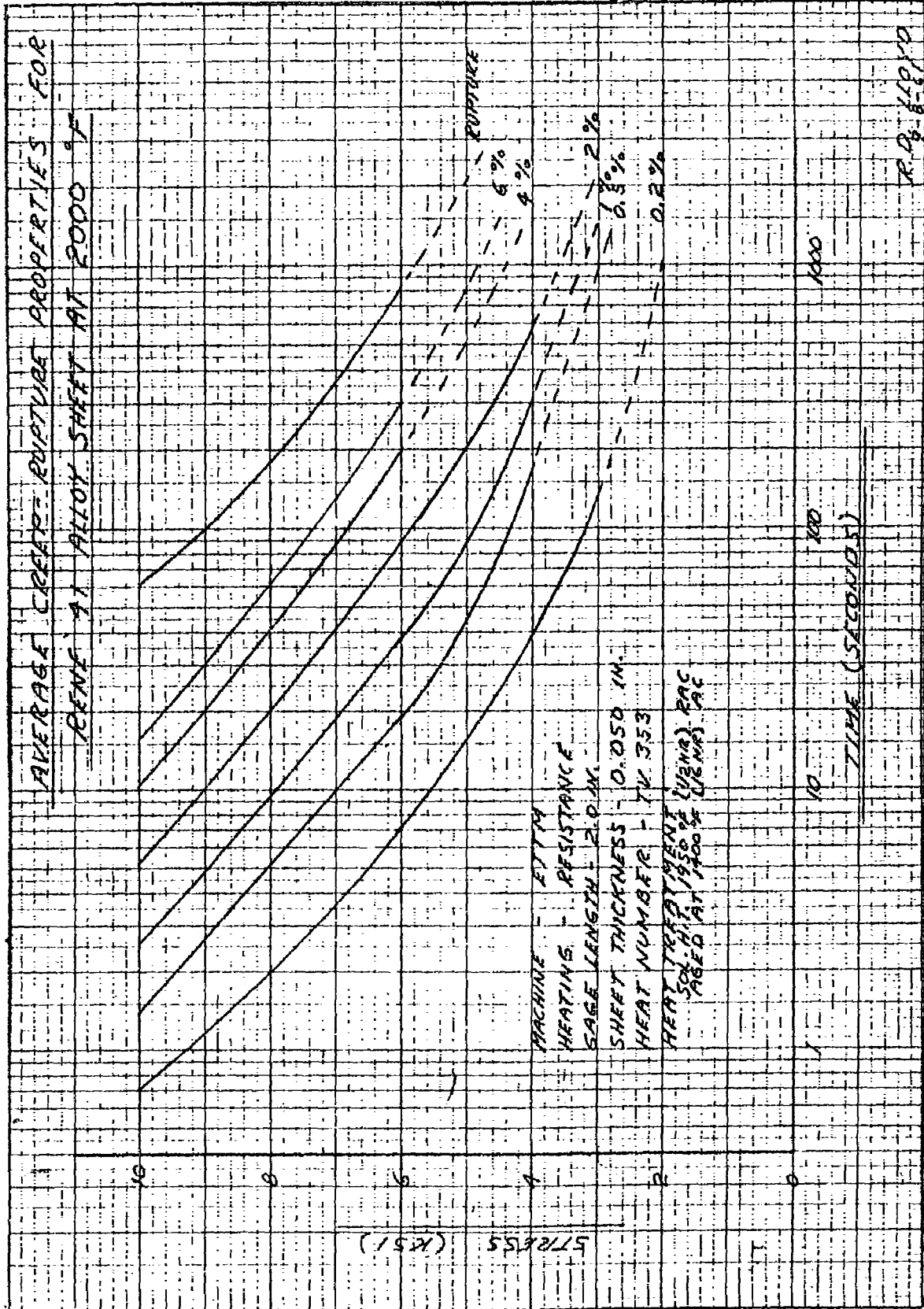


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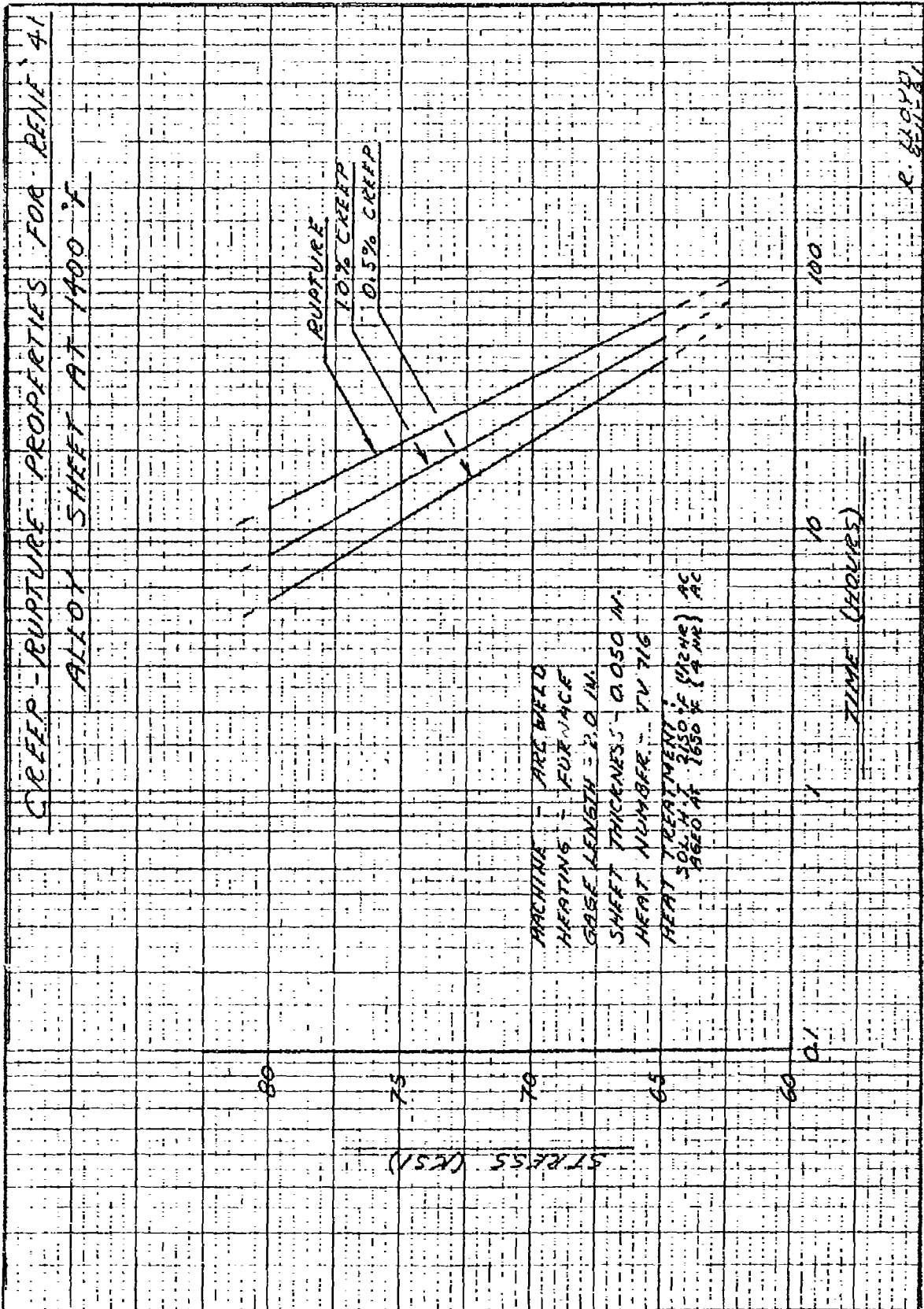
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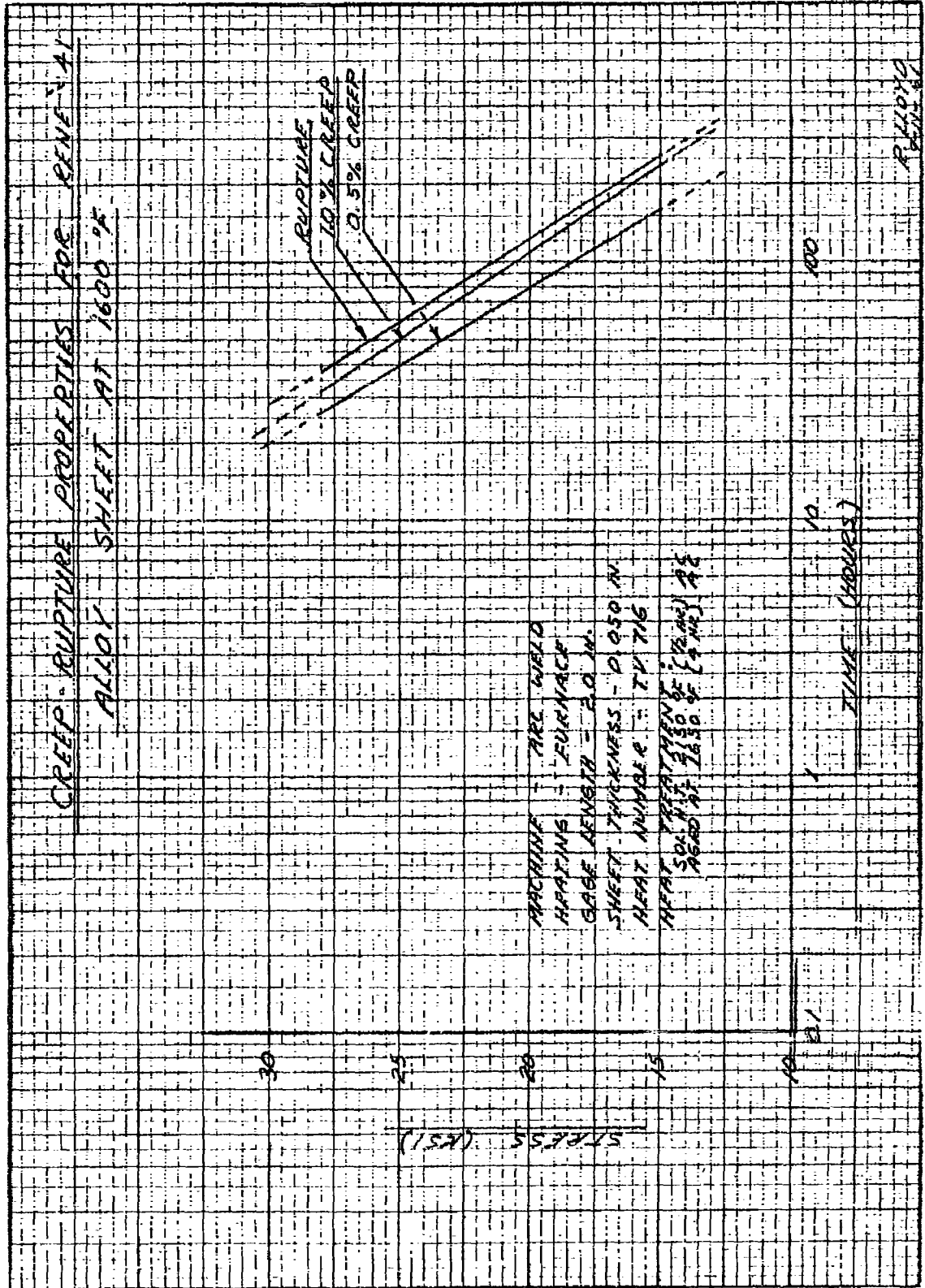




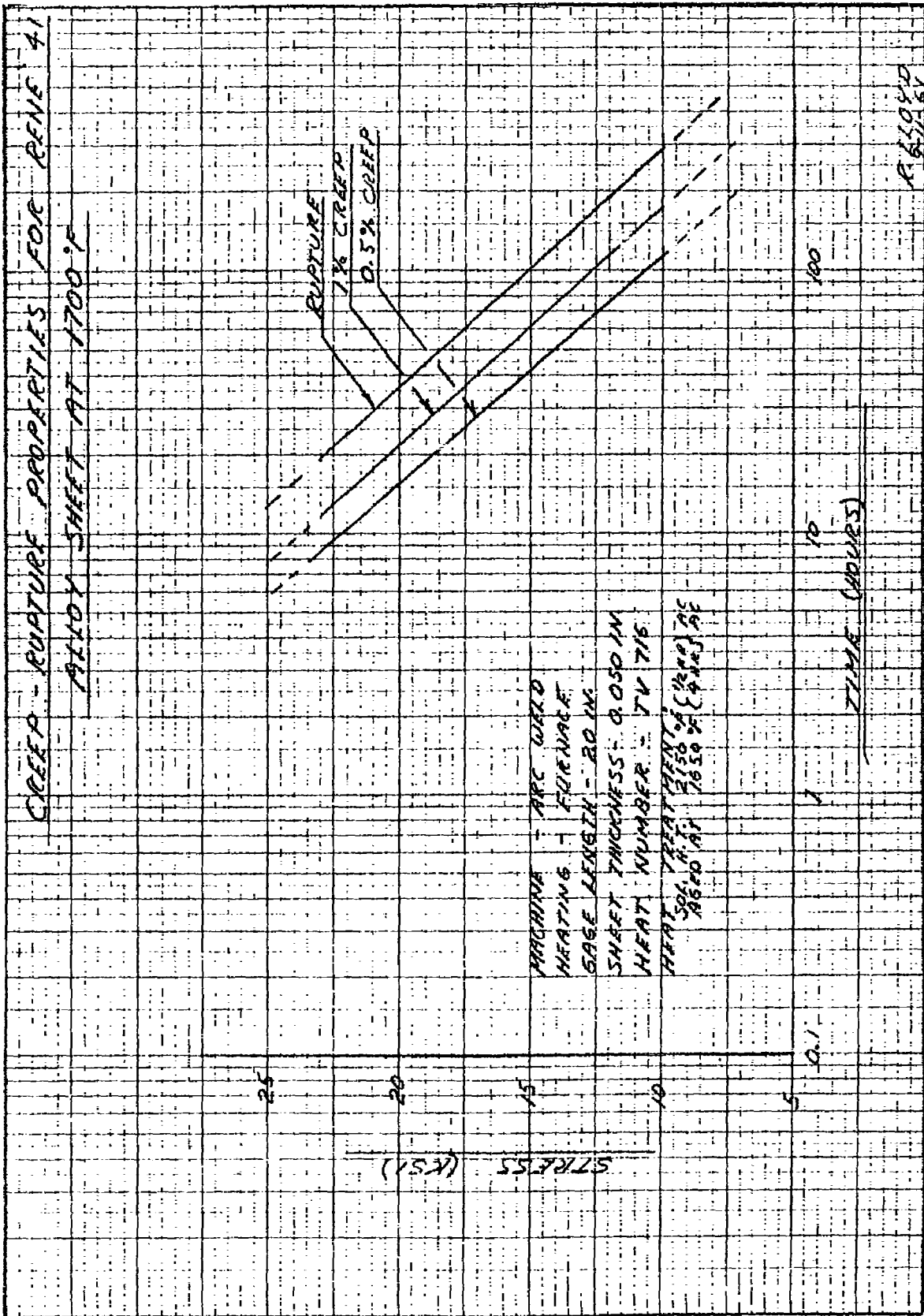
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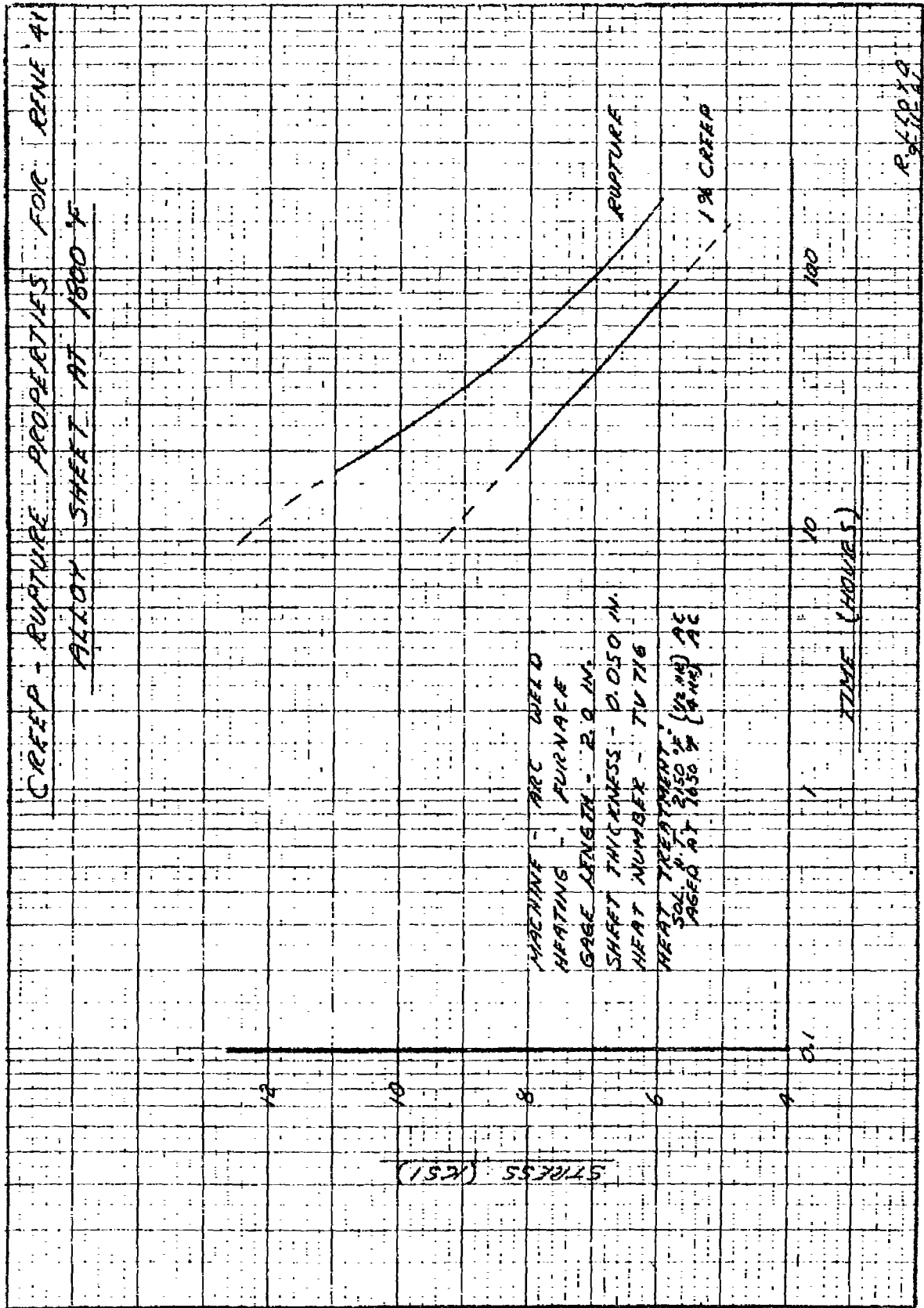


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