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RESEARCH MEMORANDUM

STATIC SHEAR STRENGTH OF 2117-T4 (A17S-T4) ALUMINUM-ALLOY RIVETS AT ELEVATED TEMPERATURES

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Aluminum Company of America

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SUMMARY

Static single shear tests were made of 3/16-inch-diameter 2117-T4 (A17S-T4) aluminum-alloy rivets at elevated temperatures. The maximum test temperature employed was 800° F, and the time at temperature prior to testing ranged from 1/2 hour to 720 hours.

INTRODUCTION

Extensive work has been done at the Aluminum Research Laboratories on the effect of elevated temperatures on the tensile properties of aluminum-alloy products. None of this work has included rivets, however. A number of inquiries have been received concerning this subject, and a modest investigation was therefore undertaken to determine the effects of elevated temperatures on the shear strength of 2117-T4 (A17S-T4) rivets.

This work has been made available to the National Advisory Committee for Aeronautics for publication because of its general interest.

MATERIAL

The material used in this investigation was some 0.091-inch-thick, 2024-T4 (24S-T4) sheet, joined by 3/16-inch-diameter 2117-T3 (A17S-T3) button-head rivets.

SPECIMEN

The tests were made of static single shear specimens of the type shown in figure 1 wherein 2024-T4 sheet, 0.091 inch thick, was joined by 3/16-inch-diameter rivets. Only one 2117-T3 rivet was driven in each specimen before the heating was completed, since the fully assembled specimens were too long for the heating ovens. Prior to testing, each specimen was completed by placing a 3/16-inch-diameter steel bolt in the remaining rivet hole.

The 2117-T3 rivets were squeeze driven by means of a subpress in a 40,000-pound-capacity Amsler universal testing machine.[1] A load of about 3,700 pounds was required to form flat heads approximately 17/64 inch in diameter (1.4D).

PROCEDURE

The following tabulation indicates the number of tests made for each heating condition:

Temp., °F	Time at temp., hr				
	1/2	6	24	144	720
212	2	—	—	2	1
300	2	1	2	2	1
400	2	1	2	2	1
500	2	1	2	2	1
600	2	1	2	—	—
800	2	—	—	—	—

The specimens to be heated for only 1/2 hour were heated in the furnace of the testing machine. Heating for longer periods was done in other furnaces, after which the specimens were cooled in still air to room temperature; later they were reheated to their former temperature in the furnace of the testing machine and tested after temperature conditions had become stable (about 1/2 hour).

The tests were made in a 30,000-pound-capacity Baldwin-Southwark testing machine equipped with a Marshall furnace for holding the specimen at the required temperature during testing. The Baldwin-Southwark testing machine equipped with the furnace for making tests at elevated temperatures is shown in figure 2.

Inasmuch as grips for flat specimens are too large to fit inside the furnace of the testing machine, it was necessary to use long enough specimens that they extended beyond the ends of the furnace. These ends

[1]Type 20ZBDA, serial number 4318.

were then gripped with Templin-type self-equalizer grips. A thermocouple attached to the specimen beside the 2117-T6 rivet was used to maintain the proper temperature in the testing area.

In all tests the load was increased gradually until failure occurred, the movement of the head of the testing machine being about 0.1 inch per minute. All failures were by shearing of the rivets. Shear strengths were determined by dividing the ultimate load by the rivet shear area based on the hole diameter.

DISCUSSION OF TEST RESULTS

Results of the individual static shear tests and the average results where duplicate tests were made are presented in table I. These results are also plotted in figure 3. In this plotting, only the averages are shown where duplicate tests were made.

The average of the two tests made at room temperature was 35,200-psi shear strength for these 2117-T4 rivets. This value is 6.7 percent above the average shear strength of 33,000 psi given for these rivets (ref. 1).

Examination of the test results of table I and of the curves in figure 3 shows that a reduction in shear strength consistently occurred with each rise in temperature. The loss in shear strength of the 2117-T4 rivets heated 1/2 hour at the various temperatures ranges from 13 percent for those tested at 212° F to 93 percent for the specimens tested at 800° F. However, 63 percent of the original shear strength is retained at 400° F if the heating period does not exceed 1/2 hour and 42 percent is still retained at this temperature after 720 hours of heating.

The test results at 212° F indicate that 720 hours at this temperature is not enough to induce artificial aging. The curves of figure 3 show that the artificial aging results in increases in shear strength. This can be expected for 2117-T4 and at 300° F reaches its peak after about 50 hours at this temperature, after which overaging reduces the shear strength. The reduction is such that after about 500 hours at 300° F the shear strength is about equal to that after 1/2 hour at this temperature. A decrease in shear strength occurred for each increase in heating time from 1/2 hour to 720 hours for the rivets tested at temperatures of 400° F and above.

The test results as shown in the curves of figure 3 have been replotted in figure 4 against temperature for each of the time periods used for the tests. This plotting clearly shows the effects of artificial aging.

The curves of figure 4 have been replotted in figure 5 to show shear strength at the various temperatures in percent of the shear strength at room temperature. Since this plotting is in terms of percent values, it is directly applicable to minimum properties in design. In plotting these curves, those portions of the curves falling above the 1/2-hour curve have been omitted inasmuch as they are of little or no importance in design.

In a previous investigation, the effects of elevated temperatures on the tensile properties of 2117-T4 were determined. The tensile strengths expressed in percentages of room-temperature strength, as determined in that investigation, are shown in table II together with similar values for shear strengths taken from the curves of figure 3. The percentage values for tensile strength and shear strength agree closely except for periods of 100 and 1,000 hours at 400° F. Since the shear data are based on only one lot of material and the same is true for the tensile data, the two discrepancies mentioned probably do not represent significant differences. The results of this investigation substantiate the previous reasoning that shear strength is reduced by the same percentages as is tensile strength.

CONCLUSIONS

The results of static shear tests of 3/16-inch-diameter 2117-T4 aluminum-alloy rivets at room temperature and at elevated temperatures seem to warrant the following conclusions:

1. The room temperature tests of the 2117-T4 rivets reveal an average shear strength of 35,200 psi for this sample. This is about 7 percent higher than the average value obtained elsewhere.

2. The shear strength of 2117-T4 rivets decreases as the temperature increases from room temperature up to 800° F. However, 63 percent of the original shear strength is retained at 400° F if the heating period does not exceed 1/2 hour and 42 percent is still retained at this temperature after 720 hours of heating.

3. The length of heating time at 212° F has no effect on the shear strength through 720 hours. At 300° F, the shear strength after about 500 hours is also approximately the same as that after 1/2-hour heating. For intermediate periods at 300° F, artificial aging results in somewhat increased shear strength. The results indicate that heating for periods longer than 720 hours at this temperature would result in lower shear strengths.

4. A decrease in shear strength occurred for each increase in heating time from 1/2 hour to 720 hours for the rivets tested at temperatures of 400° F and above.

5. The previous assumption that the percentage decrease in shear strength at elevated temperatures is similar to that for tensile strength under the same heating conditions is substantiated.

Aluminum Research Laboratories,
Aluminum Company of America,
New Kensington, Pa., March 21, 1955.

REFERENCE

1. Anon.: Riveting Alcoa Aluminum. Aluminum Co. of Am. (Pittsburgh), 1953.

TABLE I

RESULTS OF STATIC SHEAR TESTS ON 3/16-INCH-DIAMETER 2117-T4 RIVETS

AT ELEVATED TEMPERATURES

Time at temp., hr	Ultimate load, lb	Shear strength,[a] hr	Average shear strength, psi
Room temperature			
---	1,015	35,000	35,200
---	1,044	35,400	
212° F			
1/2	895	30,900	31,000
1/2	905	31,200	
144	869	30,000	30,600
144	911	31,200	
720	893	30,300	30,300
300° F			
1/2	756	26,200	26,200
1/2	758	26,200	
6	813	27,800	27,800
24	862	29,500	29,600
24	869	29,800	
144	835	28,300	28,500
144	838	28,700	
720	748	25,600	25,600
400° F			
1/2	672	23,000	22,100
1/2	620	21,200	
6	638	21,600	21,600
24	552	18,900	18,800
24	546	18,800	
144	491	16,800	16,700
144	483	16,600	
720	424	14,500	14,500
500° F			
1/2	472	16,200	15,600
1/2	438	15,000	
6	354	12,100	12,100
24	301	10,300	10,000
24	285	9,800	
144	256	8,800	8,600
144	241	8,300	
720	197	6,700	6,700
600° F			
1/2	270	9,200	8,700
1/2	240	8,200	
6	203	7,000	7,000
24	156	5,300	5,500
24	165	5,700	
800° F			
1/2	70	2,400	2,400
1/2	66	2,300	

[a]Shear area based on hole diameter, $\frac{\pi}{4}D^2$.

TABLE II

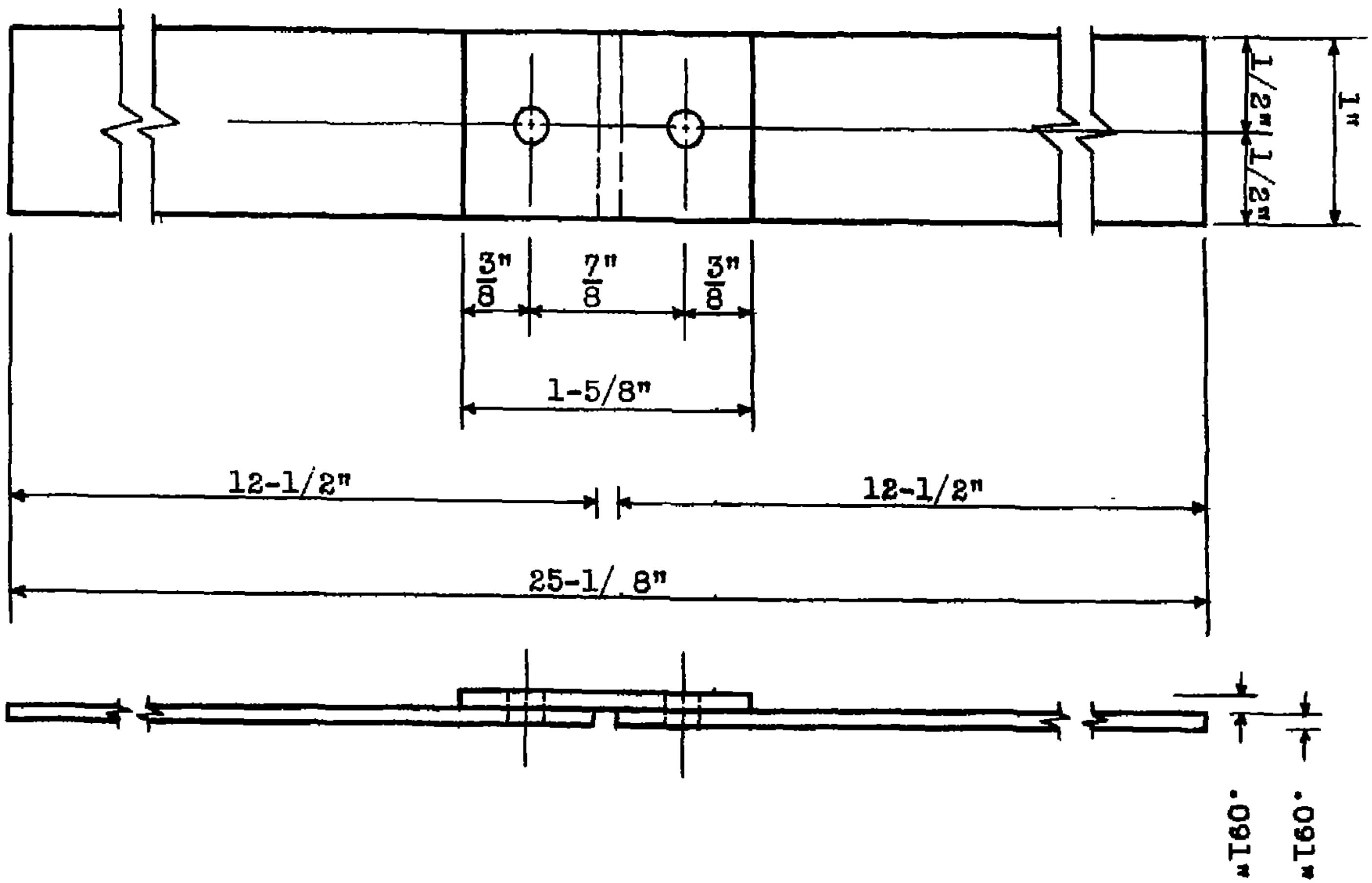
TENSILE STRENGTH OF RIVET STOCK AND SHEAR STRENGTH OF DRIVEN RIVETS

OF 2117-T4 AT ELEVATED TEMPERATURES EXPRESSED AS

PERCENTAGE OF ROOM-TEMPERATURE VALUES

[Where 1/2-hr values are lower than those for longer times the 1/2-hr values are shown instead of the higher values]

Temp., °F	1/2 hr		10 hr		100 hr		1,000 hr	
	Tensile strength, percent	Shear strength, percent	Tensile strength, percent	Shear strength, percent	Tensile strength, percent	Shear strength, percent	Tensile strength, percent	Shear strength, percent
75	100	100	100	100	100	100	100	100
212	85	87	85	87	85	87	85	87
300	73	76	73	76	73	76	73	70
400	59	63	59	58	59	48	53	40
500	42	44	32	34	28	25	20	18
600	24	25	18	18	13	14	12	---



Drill Holes 0.191-in. (No. 11 Drill)

Figure 1.- Single shear specimen for testing 3/16-inch-diameter rivets at elevated temperatures.

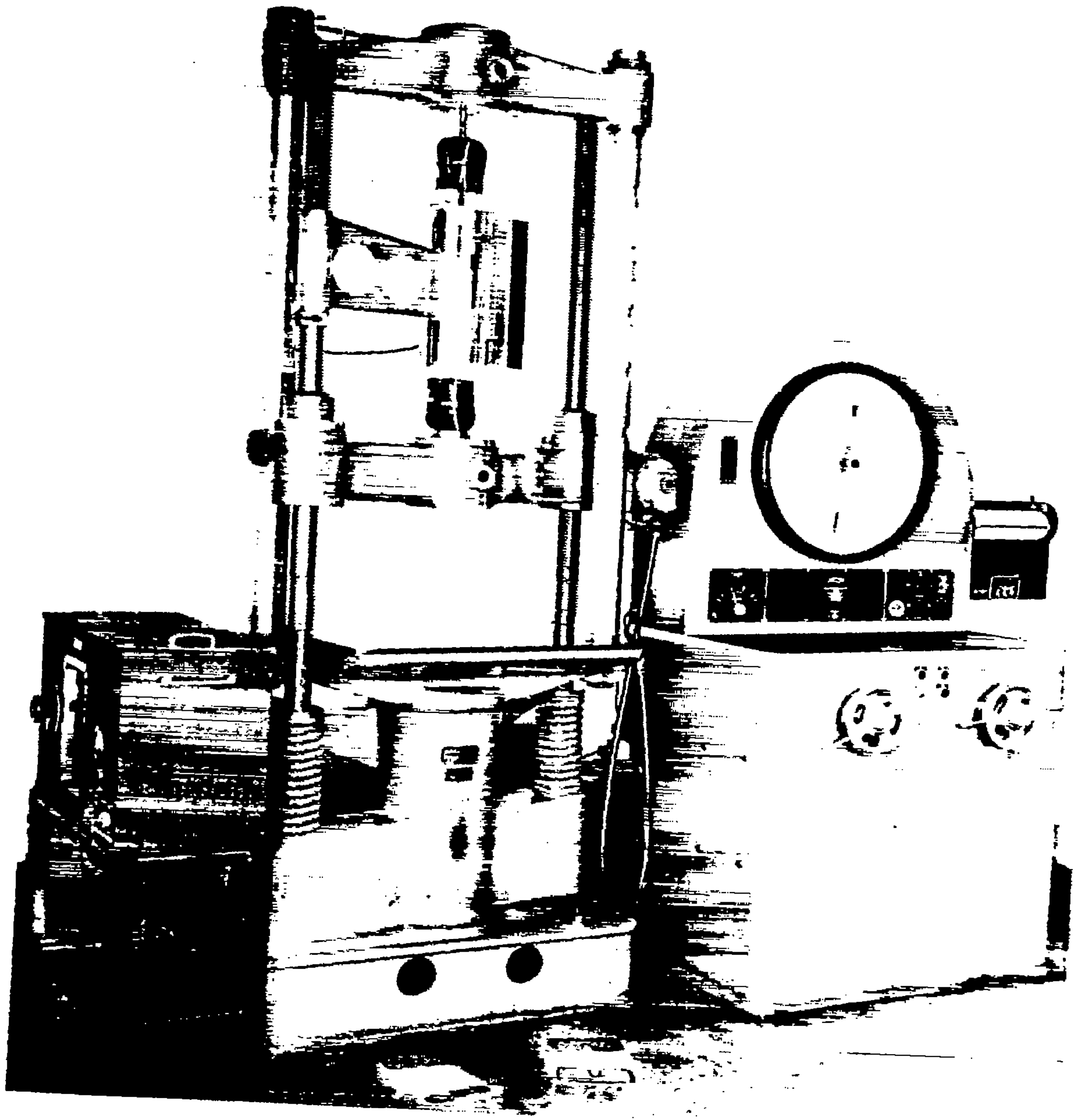


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Figure 2.- Baldwin-Southwark 30,000-pound-capacity testing machine equipped with furnace for making shear tests of rivets at elevated temperatures.

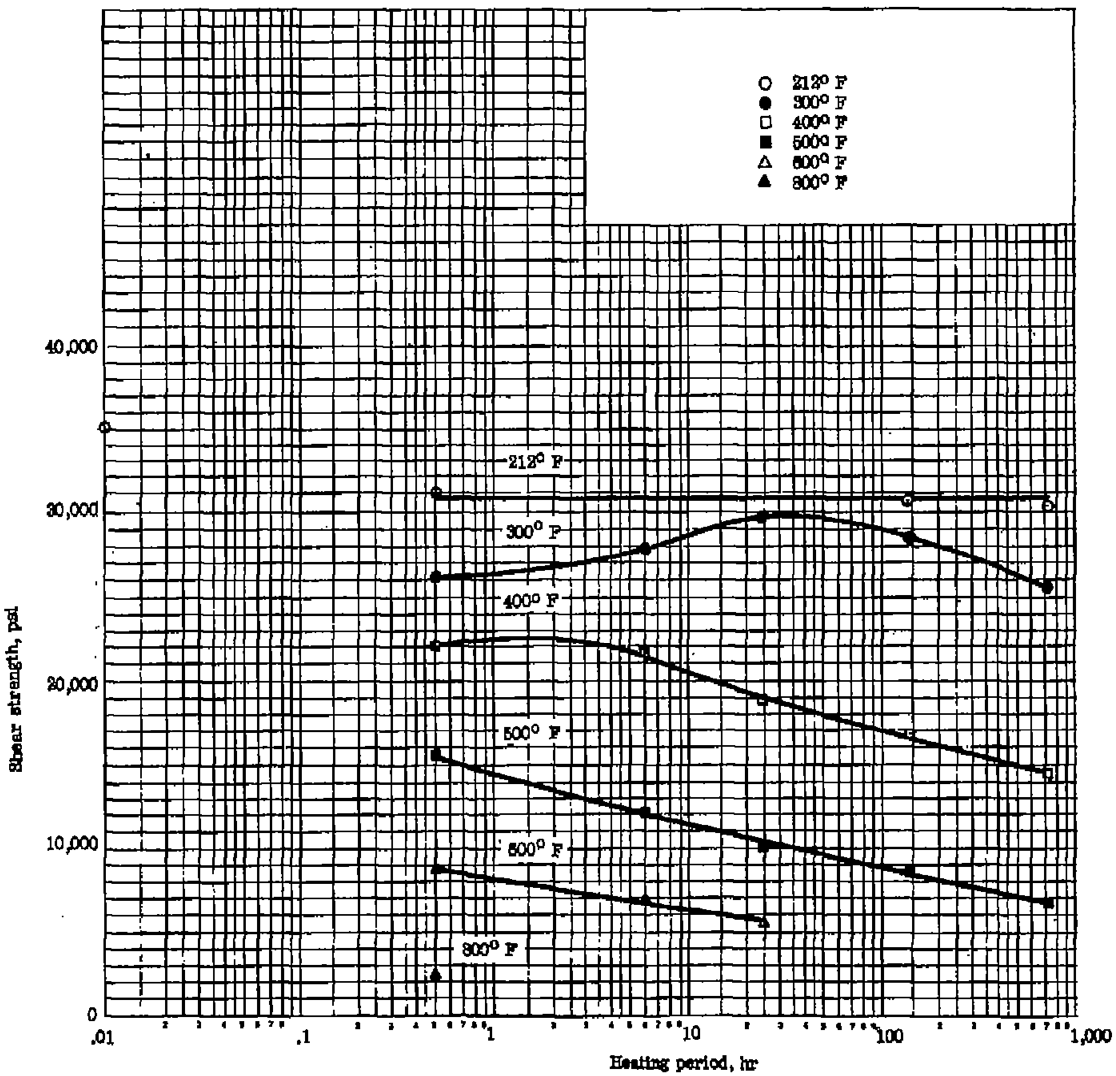

Figure 3.- Shear strength of 2117-T4 aluminum-alloy rivets versus heating period for various temperatures.

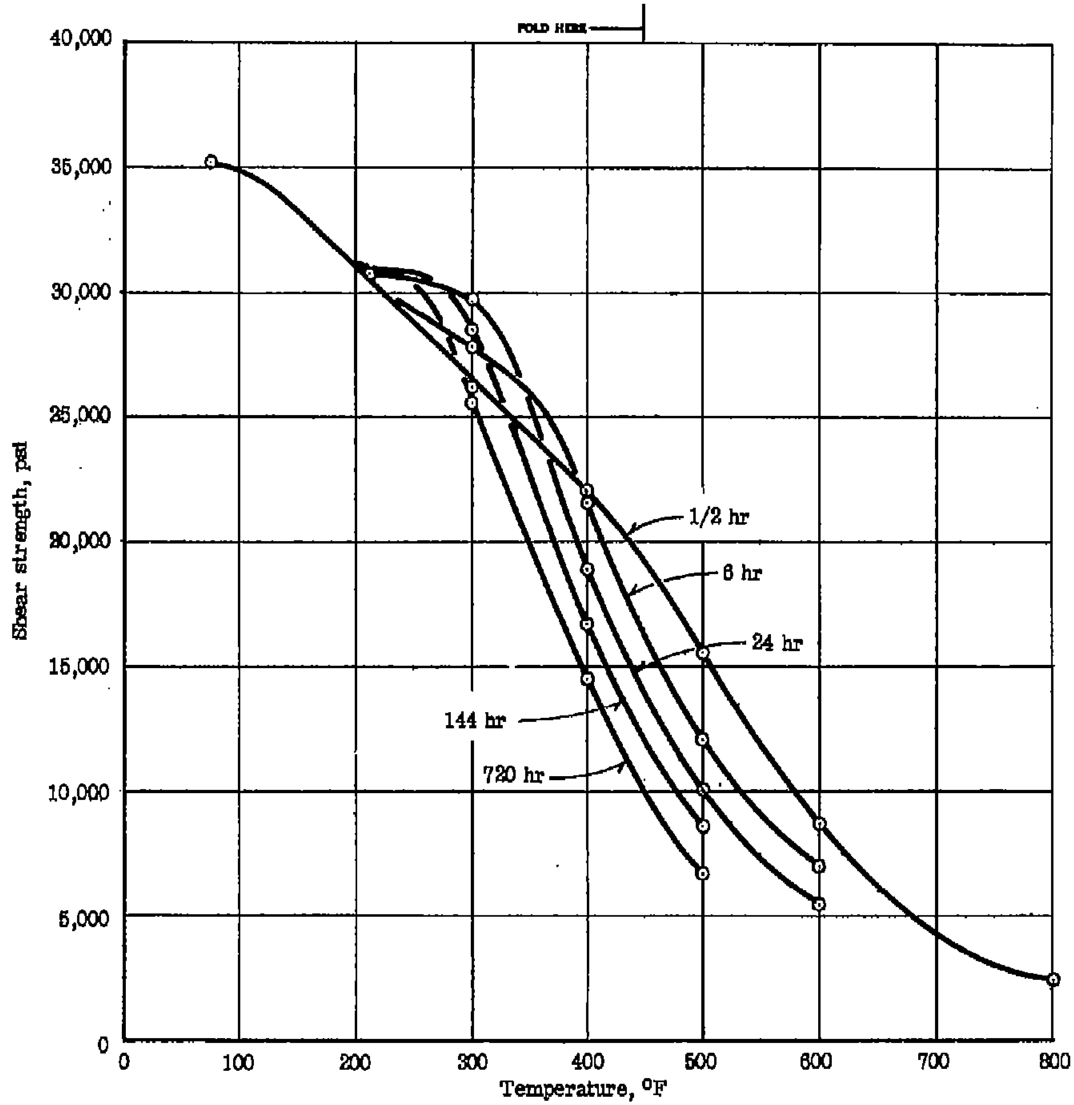

Figure 4.- Shear strength of 2117-T4 aluminum-alloy rivets versus temperature for various heating periods.

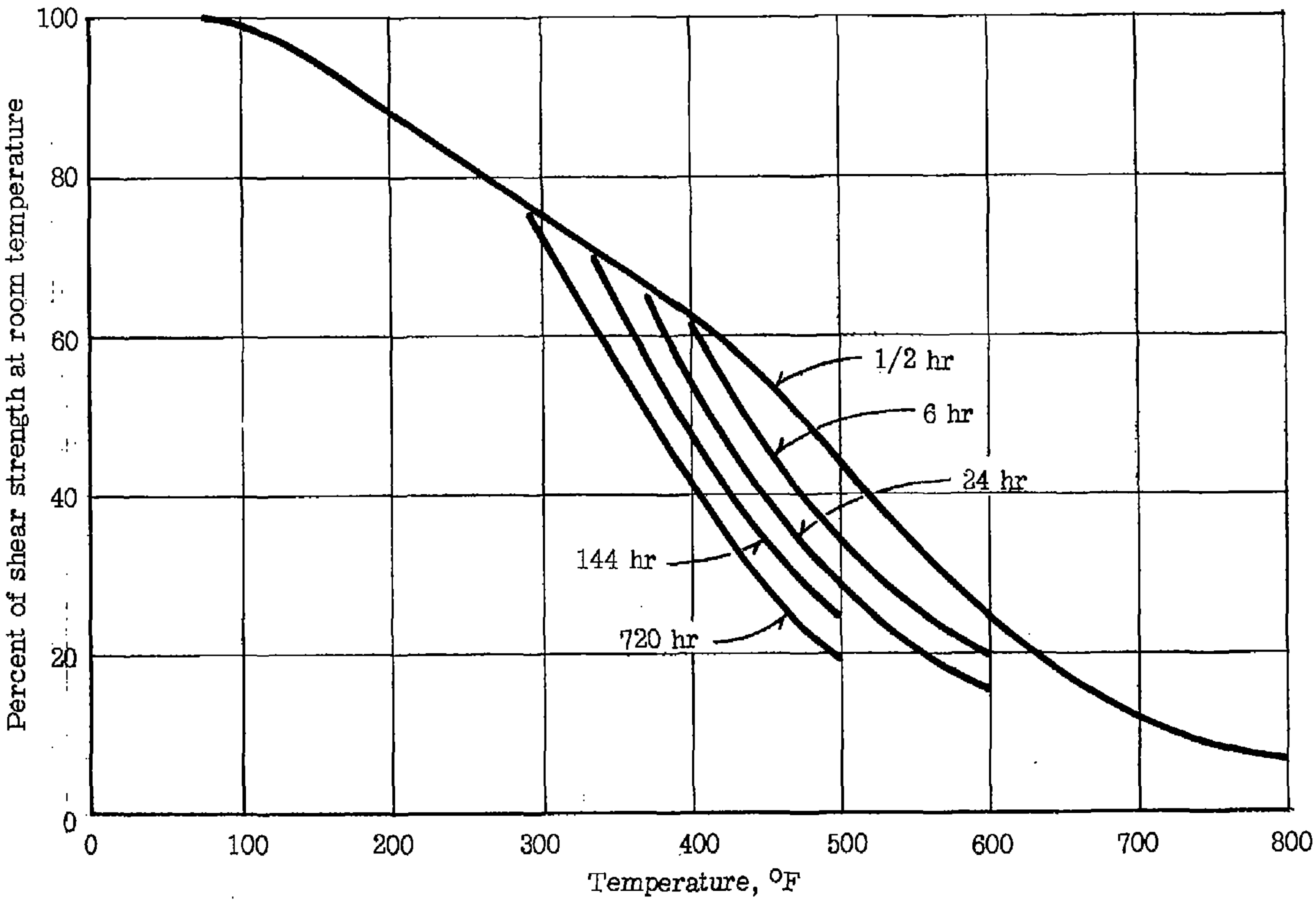

Figure 5.- Percentage of shear strength of 2117-T4 aluminum-alloy rivets at room temperature versus temperature for various heating periods. Portions of curves above that for 1/2 hour have been omitted.