SEVENTH PROGRESS REPORT

EFFECT OF 12,000-HOUR CREEP EXPOSURE ON STRUCTURAL SHEET MATERIALS

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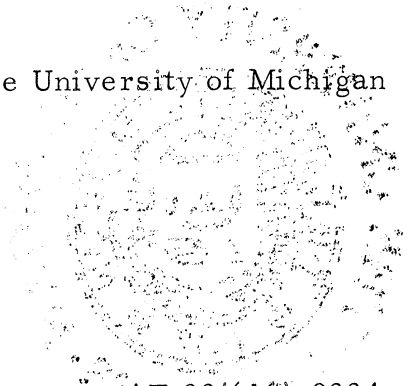

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INTRODUCTION

This research investigation was initiated in June, 1961, with the objective of determining the influence of exposure at 550°F on the mechanical properties of vacuum melted AM350 sheet material. The data obtained in this program are to be used in the evaluation of alloys for possible use in the supersonic transport. It is anticipated that the principles developed in this investigation regarding the influence of exposure on the strength of properties of this alloy can be extended to other alloys of a similar type.

AM350 sheet steel in the SCT condition and in the CRT condition is being exposed at 550°F under a stress of 67,000 psi. This stress was selected on the basis of being representative of the most probable design stress for the aircraft. Specimens are being and have been exposed for time periods of 2,000, 5,000, 12,000 and 30,000 hours to evaluate the effects of exposure time on mechanical properties. The exposures for time periods of 12,000 hours and less have been completed and the mechanical properties of the specimens measured. In addition to these a limited number of tests have been included in the program to evaluate the possibility of using shorter-duration higher temperature exposures to predict changes in mechanical properties to be expected during the service life of the aircraft.

EXPERIMENTAL PROGRAM

The test materials have been described in full in previous progress reports. The same is true for the experimental procedures followed in this program. For this reason these sections will not be repeated in the present report.

The program will evaluate the influence of exposure at 550°F for 30,000 hours under a stress of 67,000 psi on the mechanical properties of the AM 350 sheet material. This will be accomplished by observing the change in the short-time tensile strength of both smooth and edge-notched ($K_t = 3$) specimens at room temperature and 550°F. The edge-notches are intended to

simulate an area of stress concentration in the material. In addition, an objective of the investigation is to measure the ability of the alloy to withstand very sharp notches ($K_t > 20$) introduced after exposure. This research was included in the program on the basis that changes in the alloy during exposure might severely limit its ability to withstand cracks or sharp notches which might be encountered during the service life of the aircraft.

In order to provide factual interim data without the necessity of waiting 30,000 hours for an indication of the influence of exposure, shorter duration exposures of 2,000, 5,000 and 12,000 hours have also been included in the program. In addition, these tests will provide data for a study of possible methods of predicting the influence of long-time exposure from short-time tests. These shorter duration exposures included both smooth and edge-notched specimens which were tensile tested at both room temperature and 550°F after completion of the exposure.

A limited study of the influence of stress during exposure on the properties of the alloy in both the SCT and the CRT condition is being made by the inclusion of a few specimens which have no applied stress. Exposure times of 30,000, 12,000 and 5,000 hours are being evaluated, with the subsequent tensile tests conducted at room temperature.

Based on the assumption that the mechanical property changes induced by exposure to elevated temperatures should involve reactions of the type obeying the Arrhenius rate equation, exposures at 600°, 650° and 700°F were included in the program. These exposures should induce equivalent property changes to those occurring in 30,000 hours at 550°F.

PRESENT STATUS OF THE PROGRAM

The 2,000, 5,000 and 12,000 hour exposures of the AM 350 sheet material in both the SCT and the CRT conditions have been finished and the tensile tests on the exposed samples completed. In addition, the accelerated exposures at 600°, 650° and 700°F have been run and the tensile tests on these specimens completed. The results of these tests are reported in Table I.

The 30,000 hour exposures have now been in progress for time periods of between 16,000 and 20,000 hours. The status of these exposures is shown in Table II.

RESULTS TO DATE

The results obtained from the completed tensile tests along with the hardness data are reported in Table I. In Figure 1 the ultimate tensile strengths at 550°F and at room temperature, together with the elongation of the unnotched specimens, are plotted as a function of exposure time at 550°F. The following trends have been revealed by study of these data:

Properties of the Unexposed Material

(1) The alloy in the SCT condition is slightly weaker than the alloy in the CRT condition at room temperature. At 550°F, however, it is considerably stronger.

(2) The notches of the intermediate acuity (K_t = 3) raised the net-section strength at 550°F and at room temperature for the alloy in the SCT condition. The alloy in the CRT condition also exhibited an increase in notch strength at 550°F. At room temperature there was very little influence of notches of intermediate acuity on the net-section strength of the CRT material.

(3) Sharp edge-notches reduced the net-section strength of the AM350 alloy in the SCT condition by approximately 35,000 psi. The alloy in the CRT condition had approximately the same net-section strength as the unnotched material at both room temperature and at 550°F.

Properties of the Alloy as Influenced by Exposure

(1) In both the CRT and the SCT conditions the strength properties of the material have probably not been significantly changed as the result of stressed or unstressed exposure at 550°F for time periods up to 12,000 hours. A slight increase in strength was noted after exposure for 12,000 hours. This increase amounted to about two percent of the original strength of the alloy.

(2) There does not appear to be any appreciable change in the elongation of the unnotched specimens of the alloy in either the SCT or the CRT condition as the result of exposure for times up to 12,000 hours, although, as was the case with the tensile strength of the material, a very slight increase in elongation was noted after 12,000 hours of exposure.

(3) The accelerated, equivalent time exposures carried out at 600°, 650° and 700°F caused no appreciable changes in the strength properties or in the elongation of the AM350 sheet material in either the SCT or the CRT condition.

(4) The yield strength and hardness data reported in Table I show that little change occurred in either property as the result of exposure at 550°F. Earlier in the investigation it was thought that unstressed exposure at 550°F of the SCT material may have caused a drop in subsequent room temperature yield strength. This drop, however, was not evident after 12,000 hours of exposure. This indicates that the observed decrease in yield strength after 5,000 hours of exposure was due to either material variability or to difficulties encountered during the testing of that specimen.

Creep measurements taken during the exposures indicate that little strain has occurred. These measurements indicate that most of the specimens have contracted very slightly during the first 18,000 hours of exposure. The amounts of contraction range from 0% to 0.03%. It is likely that no significant amount of "creep" has taken place in the alloy in either the SCT or the CRT condition.

TABLE I

RESULTS OF TENSILE TESTS FOR AM 350 SHEET

Exposure Conditions			Test	Subsequent Tests on Unnotched Specimens							Notched (K_t=3)	[a]Sharp Edge Notches		
Temp.	Stress	Time	Temp.	P.L.	Offset Yield Strengths (ksi)			Tensile	Elongation(%)		Tensile Strength	Rockwell "45N" Hardness		Tensile
(°F)	(ksi)	(hrs.)	(°F)	(ksi)	0.02%	0.1%	0.2%	Strength (ksi)	Per 2"	Per 0.5"	(ksi)	Before Exp.	After Exp.	Strength (ksi)
							CRT Condition							
None			Room	93	122	168	185.5	218.5	28	--	225.5	51	--	214
None			Room	100	126	165	191	217	16.5	--	---	51.5	--	215.1
None			Room	110	137	171.5	182	224.2	23.5	--	---	--	--	---
550	40	2000	Room	89	107	155	178	212.5	21	34	---	--	--	---
550	67	2000	Room	--	---	---	[b](178)	221.8	22	--	220	52	51.5	212
550	90	2000	Room	119	142.5	154.5	186	221.4	16.5	--	---	--	--	---
550	150	2000	Room	145	174	198	208	221.7	19.5	--	---	--	--	---
550	0	5000	Room	120	140.5	170	178.5	219	20	--	---	--	--	---
550	67	5000	Room	150	174	182	185.5	222.2	19	--	223.8	53.5	51.5	213
550	0	12000	Room	136	156	183	193	230	24.7	--	---	49	49.8	---
550	67	12000	Room	91	120	165	187	227	22.7	--	230.5	49	--	---
600	67	2000	Room	114	139	168	181	217.8	17	28	---	--	--	---
700	67	200	Room	70	111	158	183	215.8	--	--	---	52.5	52	211.4
700	67	200	Room	---	---	---	---	---	--	--	---	52	51	209.8
None			550	95	120	144	153	169	4	--	185	50.5	--	172.1
None			550	96	115	143	153	168.8	4.5	--	---	50.5	--	166.8
550	0	2000	550	89	112.5	135.5	147.5	171.2	4	10	---	--	--	---
550	67	2000	550	85	105	132	141	163.5	2	6	178.2	52	--	160
550	67	5000	550	110	126	144	151	168.6	2	--	181.8	53.5	51.5	170.5
550	0	12000	550	95	109	139	150	173	4.3	--	---	49	50.3	---
550	67	12000	550	95	108	137	151	171.5	4.3	--	183	49	50.7	---
600	67	2000	550	92	113	141	153	172	5	--	175.7	--	--	---
650	67	200	550	85	101	139	154	170.8	4	8	---	--	--	---
700	67	20	550	80	97	130	145	170.7	4	6	---	--	--	---
700	67	200	550	95	104	140	152.5	188	4.5	--	---	52	51	[c](>151)
700	67	200	550	103	117	139	150.5	171.2	4	8	---	52.5	52	172
							SCT Condition							
None			Room	113	143	170	185.3	214.9	17	32	241.5	--	--	216
None			Room	119	139	165	178	213.1	12	26	---	--	--	208.3
None			Room	105	129	162	176	214	16.5	32	---	--	--	---
550	67	2000	Room	---	---	---	---	---	--	--	238.8	54	52.5	196.5
550	67	2236	Room	123	146.8	170	179	212	18	--	237.5	--	--	---
550	0	5000	Room	90	103	136	159	214.5	14	--	---	--	--	---
550	67	5000	Room	120	137	163	176	216	13.5	--	238.5	53.5	53.5	209.4
550	0	12000	Room	117	158	177	189	223	20.0	--	---	53.5	50.8	---
550	67	12000	Room	116	130	159	176.5	224	17.7	--	247	54.0	--	---
700	67	200	Room	---	---	---	---	---	--	--	---	53.5	52	208.8
None			550	70	89	119	135	193.6	5	12	210	--	--	159.3
None			550	80	98	126.9	141	194.4	6.5	12	---	--	--	159
550	67	2000	550	95	113.5	138	150	195.9	8.5	16	---	54.5	55	159.2
550	0	2236	550	70	92.3	125.5	142	199.5	7.5	--	---	--	--	---
550	67	2236	550	80	106	132	147.5	199	7.5	--	206.1	--	--	---
550	67	5000	550	110	114	134	145	193.5	4.5	--	208	53	52	161.5
550	0	12000	550	100	119	141	154	198.9	6.7	--	---	53.5	51.8	---
550	67	12000	550	115	125	137	151	198.8	7.3	--	213.5	53.5	52.6	---
600	67	2000	550	81	101	132	145.5	198.5	5.5	--	---	--	--	---
650	67	200	550	75	95	122	140	195.8	6	12	---	--	--	---
700	67	20	550	87	101	131	146	200.3	5.5	--	---	53.5	51	163
700	67	200	550	96	118	141	151.5	201.2	6	--	---	--	--	---

a) Exposed unnotched. Sharp edge notches added before tensile test
b) By "drop of needle"; extensometer erratic
c) Specimen shoulder tore; no fracture at the notch

TABLE 2

STATUS OF 30,000 HOUR EXPOSURE TESTS AT 550°F

Specimen Code	Specimen Type [a]	Alloy Condition [b]	Accumulated Time to Date (Hours)	Estimated Completion	Stress (psi)
E-6	W	SCT	18648	7/17/65	67,000
E-7	W	SCT	18648	7/17/65	67,000
E-4	U	SCT	18384	7/28/65	67,000
C-6	U	SCT	18384	7/28/65	None
E-1	U	SCT	18744	7/13/65	67,000
C-3	U	SCT	18744	7/13/65	None
C-1	U	SCT	16728	10/ 4/65	67,000
E-2	U	SCT	16728	10/ 4/65	67,000
D-4	U	SCT	16728	10/ 4/65	None
37	W	CRT	18552	7/21/65	67,000
55	U	CRT	18648	7/17/65	None
36	U	CRT	18384	7/28/65	67,000
56	U	CRT	18552	7/21/65	None
32	U	CRT	19152	6/26/65	67,000
52	U	CRT	19152	6/26/65	67,000
53	U	CRT	19152	6/26/65	None
41	U	CRT	18744	7/13/65	67,000
E-4	N	SCT	18552	7/28/65	67,000
E-1	N	SCT	18744	7/13/65	67,000
C-1	N	SCT	16728	10/ 4/65	67,000
E-2	N	SCT	16728	10/ 4/65	67,000
36	N	CRT	18552	7/28/65	67,000
32	N	CRT	19152	6/26/65	67,000
52	N	CRT	19152	6/26/65	67,000
41	N	CRT	18774	7/13/65	67,000

a) U = Unnotched, 0.350-inch gage width; N = Notched; $K_t = 3$; W = Wide unnotched during exposure, sharp edge notches for tensile tests.

b) CRT = Cold rolled 20 percent plus three hours at 850°F.
SCT = Annealed at 1950°F, conditioned for 10 minutes at 1710°F, A.C., held three hours at -100°F and tempered three hours at 850°F.

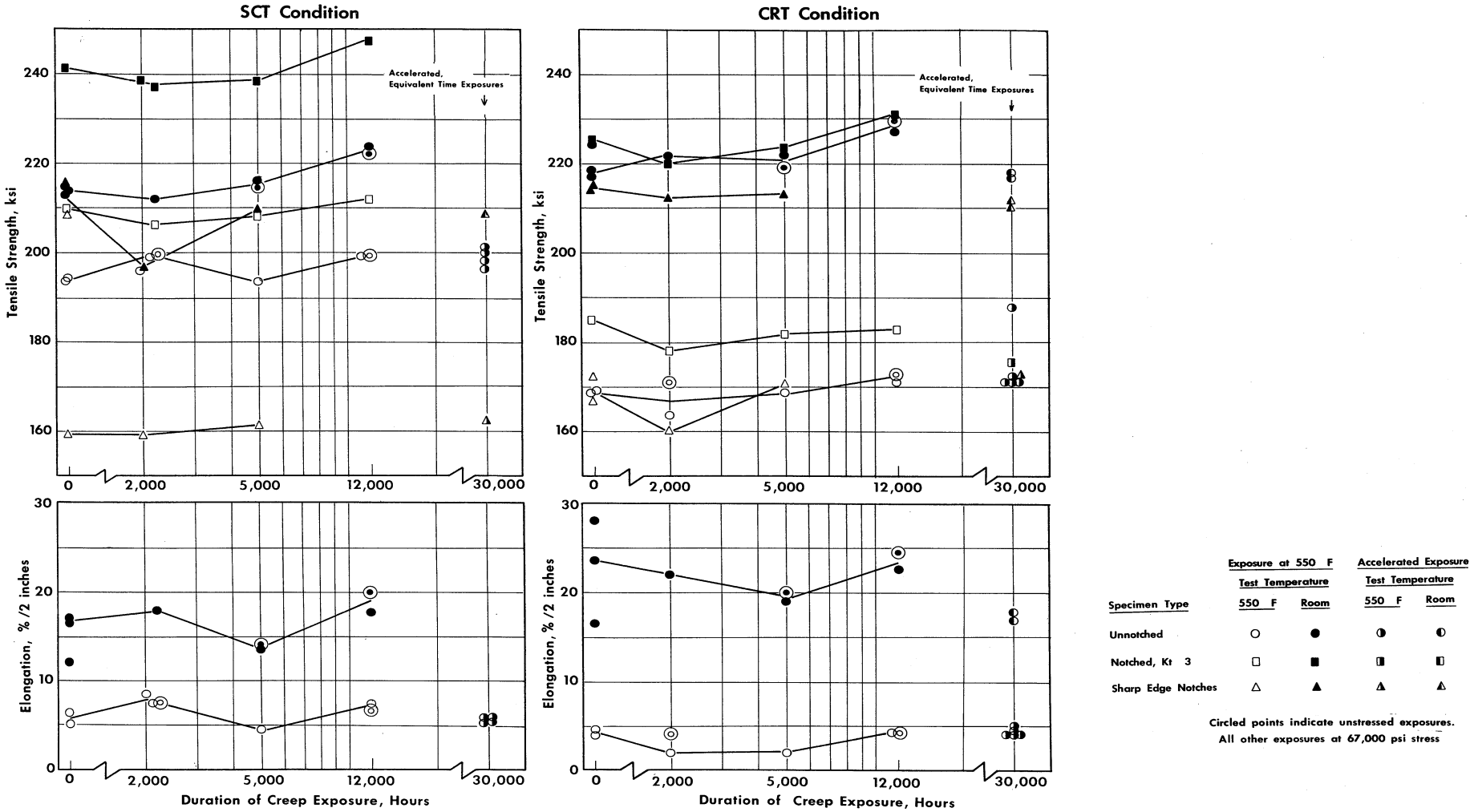

Figure 1. Effect of Exposure at 550° on Tensile Strength and Ductility of Vacuum-Melted AM350 Sheet at 550° F and at Room Temperature. Predicted Strengths and Ductilities Based on the Results of Accelerated Tests Conducted at 600°, 650°, and 700° F Are Plotted at an Equivalent Exposure Time of 30,000 Hours.