delay in plastic flow can be brought about by the presence of residual strain-hardening (or cold-work) in the structure. At room temperature the 10 per cent cold-worked material had a yield stress 100 per cent higher than the annealed material. At 1600 F, the increase in yield strength was 48 per cent.

2 Structural components can be fabricated with residual cold-work and higher design strengths using controlled working and thermal cycles.

3 For short times, on the order of 2 min, at high temperatures, stresses approaching the tensile strength can be sustained with less than 10 per cent elongation.

4 The effect of welding is to lower the ductility appreciably; however, strength properties are, in general, not lowered.

5 A definite stress-strain relation exists for the Type 316 stainless-steel alloy to 2300 F with a tensile strength of approximately 2500 psi.

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The authors wish to express their appreciation to Mr. Clement Theberge for his assistance with the experimental work.

DISCUSSION

Robert A. Bareiss[5]

The authors have demonstrated that, for environments combining a short time at load with a high ambient temperature, designers might well consider using one of the more common and readily available structural materials such as Type 316 stainless steel. The work appears to be well done and is certainly well reported.

The authors may wish to give further consideration to their third conclusion, namely that "for short times . . . . at high temperatures, stresses approaching the tensile strength can be sustained with less than 10 per cent elongation." It does not seem appropriate to compare directly the creep and tensile strength data reported here since there is a wide variation in the time at temperature for the two test conditions. In the case of the tensile tests, the time to reach temperature and complete a test was approximately thirty minutes while, for the creep tests, this time was about eight–nine minutes. Since time at temperature has an important bearing on strength through stress relief and recrystallization processes, it might not be unreasonable to assume that higher tensile strengths would be obtained for an eight–nine minute test duration.

Those desiring to obtain more data of this nature may wish to refer to another report[6] showing creep data for times as small as 10 seconds on a number of materials including stainless Type 321 and 410.

[5] Vice President, Lessells and Associates, Inc., Boston, Mass. Mem. ASME.

Authors' Closure

The data reported in the paper were for a missile re-entry time-temperature cycle and, as pointed out by Mr. Bareiss and in the paper, the effect of time and temperature is not evident. Since the paper was written, high heat rate equipment has been designed and constructed that will record and control all variables for heating rates up to 1000 F per second. Tests have been conducted recently on the original and one additional heat of stainless steel.

Materials	Time at temperature, sec	Yield strength (0.2 per cent offset) at temperature, psi			
		RT	1400 F	1600 F	1800 F
		annealed			
Composition in paper	1800	34,000	15,600	14,050	7,700
		10 per cent cold work			
Composition in paper	1800	69,500	30,250	19,700	9,850
	30	69,500	29,700	17,100	8,500*
		annealed			
Composition different from above	30	34,700	16,600		
		10 per cent cold work			
	30	66,000	27,300		

* Slightly lower strain rates (standard 0.005 per minute) probably accounted for lower strengths.

The data clearly indicate that the times at temperature from 30 seconds to 30 minutes (1800 seconds) does not affect the high-temperature strength of cold-worked Type 316 stainless steel. Evidently for 10 per cent cold-work and at temperatures up to 1800 F for up to 30 minutes' soak time, recrystallization and grain growth does not lower the strength. These short-time heating data clearly indicate that the two-minute creep curves in the paper would apply also to heating time of 30 to 1800 seconds.

[6] J. S. Ives, Jr., "Ultra-Short-Time Creep Rupture," WADC Technical Report 59-762 Part II.