THERMAL CREEP OF V-4Cr-4Ti in a Li ENVIRONMENT

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Objective

This investigation is being conducted to evaluate thermal creep behavior under conditions where the oxygen concentration is not increased during the life of the test. This will allow thermal creep to be separated from irradiation and helium effects in DHCE (Dynamic Helium Charging Experiments) experiments and will aid in interpretation of the vacuum thermal creep experiments now being performed.

Summary

Tests of pressurized tube specimens of Wah Chang heat 832665 of V-4Cr-4Ti were exposed to Li at elevated temperatures and the deformation in the tubes monitored periodically by laser profilometry. It was determined that at 665°C deformations were below 0.05% for all stresses in the range of 59-117 MPa effective stress at 1105 hours and below 6% at 765°C at 1927 hours. The deformation was so small at 665°C that the temperature was increased to 700°C. Results from 700 C have not yet been obtained. At both temperatures the duration of the tests is not yet sufficient to make a valid comparison with the vacuum creep tests conducted at PNNL.1

Experimental Modifications

Temperature measurements using a sheathed thermocouple directly in the molten lithium determined that the lithium was about 35°C lower than the temperature measured on the thermocouples placed on the outside of the quartz tube surrounding the retorts. Although a temperature gradient was expected, a difference this great was not anticipated. Temperatures were corrected from 700 to 665 and from 800 to 765°C and stresses corrected as appropriate. The retorts have been redesigned to accommodate a thermocouple well in the liquid lithium to obtain a more accurate temperature measurement. Results from the newly designed retorts will described in the next reporting period.

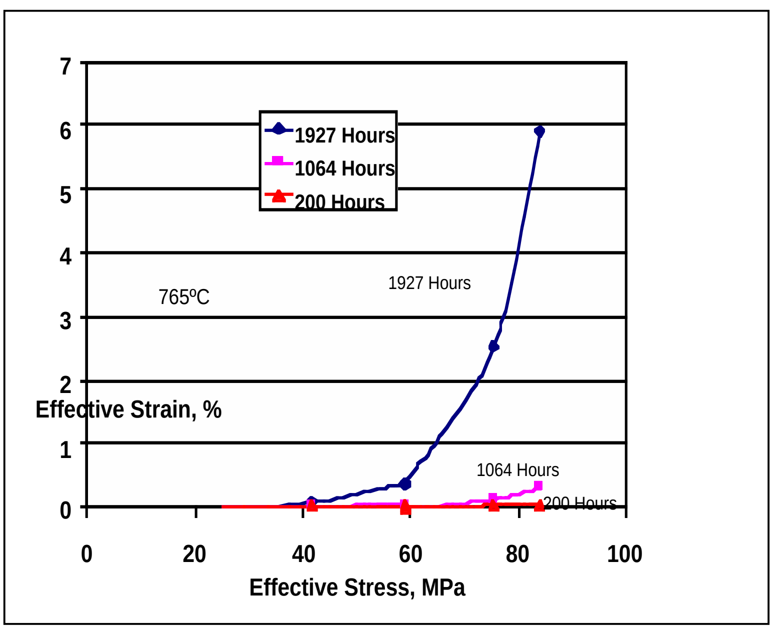
The c-ring type vanadium gaskets originally used on the retorts were found to be unreliable. Internal pressures were monitored so that a leaking gasket could be replaced prior to reaching operating temperature, but numerous delays were experienced. A newer design uses Conflat type flanges with Nb-1Zr gaskets. The newer flange design is much more reliable. However, difficulties are still being experienced in welding flanges to the molybdenum retorts.

Results and Discussion

Table 1 provides results of creep deformation in terms of effective uniaxial strain. For 765°C, effective strain is plotted as a function of stress in Fig. 1. The power law stress behavior is expected, and the stress exponent is found to be in the range of 1-5. Values greater than one are indicative of diffusion-controlled dislocation climb creep.

Table 1. Creep data in terms of effective stress and strain

Specimen	Eff. Stress (MPa)	Effective Strain, %		
		765°C		
		200 Hrs	**1064 Hrs**	**1927 Hrs**
V5	25	-.0037	-.017	-.016
V8	42	.017	.016	.078
V3	59	.027	.039	.38
V10	59	.0007	-.016	.36
V7	75	.033	.13	2.5
V4	84	.031	.30	5.9
		665°C		
		242 Hrs	**1105 Hrs**	
V12	59	.023	.034	
V2	75	.025	.031	
V11	75	.0074	.0022	
V9	83	.027	.040	
V6	100	.022	leaked	
V1	117	-.010	.0044	
V13	133	.014	leaked	



Comparison of 665°C data with results for 700°C in a vacuum, from tests at PNNL, shows larger deformations in the 665°C specimens. This is an unexpected result, but there are large errors associated with the small strains. Longer tests will enable better comparisons to be made. At 765°C the Li exposed specimens show creep deformation similar to the 800°C vacuum tests, allowing for the difference in temperature.

No creep ruptures have been observed at either temperature. A Larson-Miller parameter plot as shown in Fig. 2 compares the creep rupture data from PNNL with the Larson-Miller parameters, $P=T(\log t_r + 20)/1000$ (T is the absolute temperature and t_r is the time to rupture in hours), for Li-exposed specimens that have not yet failed.[2] It can be seen from Fig. 2 that the Li-exposed specimens would not yet be expected to fail.

Biaxial Creep Rupture Data for V-4Cr-4Ti

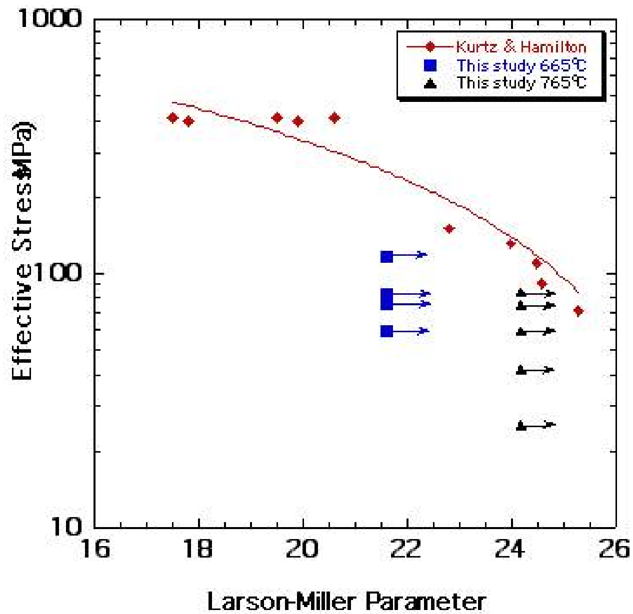


Fig. 2 Larson-Miller type plot comparing creep rupture data from PNNL with tests in progress in the present study.

The activation energy is compared with that of other studies in Table 2. The observed value of 2.8 eV is in close agreement with the value measured in the vacuum experiment of 3.1 eV. It is also in rather close agreement to the value of 2.3 eV observed by Bohm and Schirra in the V-5Ti alloy.[3]

Table 2. Activation energy for creep and self-diffusion

Stress State	Laboratory	Act. Energy, eV
Biaxial	Present Study	2.8
Biaxial	PNNL	3.1
Uniaxial	ANL	5.7
Uniaxial	Bohm and Schirra	2.3
Self-diffusion[4]		3.2

Conclusions

1. An experimental apparatus has been developed for handling liquid lithium for creep testing of pressurized tubes. All metals in contact with Li are refractory metal, including gaskets. It was concluded that a thermocouple well protruding into the liquid lithium is necessary and will be incorporated. Operating experience was also obtained for using a retort with a tritium barrier in anticipation of the next series of experiments.
2. The creep rates observed are consistent with those obtained from specimens in a vacuum environment, with the exception of 665°C where creep rates are higher for the lithium environment. Longer exposures will have to be achieved before confidence can be gained in this observation.
3. At 765°C, no creep failures were observed after an exposure of 1927 hours at effective stress levels up to 87 MPa.
4. Tertiary creep initiates early, with a short region of steady-state creep.
5. The observed activation energy of 2.8 eV is consistent with other measurements and with the activation energy for self-diffusion within experimental error.

References

[1] R.J. Kurtz and M.L. Hamilton, J. Nucl. Mater. 283-287 (2000) 628.
[2] F.R. Larson and J. Miller, Trans. ASME 74 (1952) 765.
[3] H. Bohm and M. Schirra, J. Less Comm. Metals 12 (1967) 280.
[4] R.F. Peart, *Diffusion in Body-Centered Cubic Metals*, Chapter 16, ASM, Metals Park, OH (1965) p. 235.