

HYDROGEN SOLUBILITY IN VANADIUM ALLOYS, LiCa ALLOYS, AND SnLi ALLOYS*

D.L. Smith (Argonne National Laboratory), R.E. Buxbaum (REB Research), and C.B. Reed (Argonne National Laboratory)

OBJECTIVE

The objective of this program is to provide baseline solubility data for hydrogen in selected vanadium-base alloys, LiCa alloys and SnLi alloys which will provide a basis for determining the equilibrium distribution and hydrogen/tritium inventories in candidate structure/breeder materials systems.

SUMMARY

A systematic study is currently being conducted by Argonne National Laboratory with support from REB Research to provide baseline data on the solubility of hydrogen in selected LiCa, SnLi, and VCrTi alloys. The experimental approach involves charging and degassing of vanadium alloys and vanadium alloy encapsulated LiCa and SnLi specimens to various hydrogen partial pressures while maintaining the system at constant temperature. With this procedure one avoids the problems associated with the rapid redistribution of hydrogen that is typically observed during cool-down of the specimens. Initial tests have been conducted on solid cylindrical specimens of a vanadium alloy. The liquid metal alloys will be contained in vanadium alloy capsules. Preliminary results for the V-4Cr-4Ti alloy (Heat #832665) are reported.

INTRODUCTION

The self-cooled lithium system with a vanadium alloy structure offers a potential for a high performance, environmentally attractive first-wall/blanket system for fusion applications. One of the key issues associated with this system relates to the development of an electrically insulating coating on the vanadium alloy channel walls to mitigate the magnetohydrodynamic (MHD) – induced pressure drop in the recirculating lithium coolant. Calcium oxide-based coatings are a leading candidate for this insulator application. Since tritium production in the lithium is essential for the fuel cycle, hydrogen transmutations will occur in the vanadium alloy structure, and hydrogen isotopes are highly mobile in most materials at elevated temperatures; tritium/hydrogen interactions are an important safety related issue and effects of hydrogen isotopes on the stability of the coating and integrity of the structure are important performance considerations for the V/Li system.

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The Sn-Li alloy has recently been proposed as a possible liquid metal coolant for fusion applications, primarily because of low vapor pressure considerations. An important consideration regarding the potential of this system involves hydrogen/tritium solubility.

A procedure previously used at both ANL and REB Research to accurately determine the hydrogen solubility in metals and alloys involves quantitatively charging and degassing of specimens to various hydrogen partial pressures while maintaining the system at constant temperature. This procedure avoids the difficulties of obtaining accurate data caused by rapid redistribution of the hydrogen during cooling.

This task involves the accurate determination of hydrogen as a function of temperature and pressure in selected vanadium alloys, LiCa alloys and a SnLi alloy. Results for the vanadium alloys are important for evaluating the performance of these alloys in a fusion system, as baseline data for the distribution of hydrogen/tritium in the DHCE experiment to evaluate He effects in neutron irradiation tests, and to provide an accurate blank for the vanadium alloy capsules used for the hydrogen solubility tests for LiCa and SnLi. The effects of Ca in Li on the solubility of hydrogen/tritium are important to evaluate tritium inventory, tritium recovery, and the stability of the CaO coatings in lithium cooled systems. The measurements of hydrogen solubility in SnLi will provide baseline data for further evaluation of this alloy system for fusion applications.

EXPERIMENTAL PROCEDURE

Test specimens are exposed at constant temperature to flowing helium gas containing varying concentrations of hydrogen. Initially the specimens are exposed to pure helium (no hydrogen) to purge the system and degas any hydrogen in the test specimen. The gas exiting the test section is analyzed with a gas chromatograph. Purging of the system is continued until impurities in the helium are reduced to negligible levels.

In the current series of tests cylindrical specimens (~4.75 mm dia x 100 mm long) are used. The test specimens are contained in a cylindrical chamber so that the gas flows axially in an annular region surrounding the test specimen. The test specimens are pre coated with a thin (~1 micron) coating of palladium to facilitate absorption and desorption of hydrogen and to avoid possible surface oxidation of the vanadium during the initial purging of the system. The vanadium alloy specimens are solid cylinders to maximize the volume and the liquid metals (LiCa and SnLi) are contained in thin-walled vanadium alloy capsules of approximately the same geometry.

After the test specimens are completely degassed in the pure helium, a specified H/He mixture is introduced and the concentration of hydrogen exiting the test section is continuously measured. Flow conditions are controlled such that initially most of the hydrogen entering the test section is absorbed by the test specimen. As the test specimen becomes saturated at the set hydrogen pressure, the hydrogen concentration exiting the text section increases until no further absorption

of hydrogen by the test specimen occurs. The total concentration in the test specimen is determined by the difference. This value is then checked by quantitatively degassing the hydrogen from the specimen in pure helium. The reversibility of this process assures an accurate measurement. Subsequent charging/degassing runs on the same specimen can be used to further verify the results. The hydrogen solubility in the test specimens is determined directly from the weight of the specimen. For the cases of the liquid metals, the total hydrogen absorption is corrected by adjusting for the hydrogen concentration in the vanadium alloy capsule.

RESULTS

Preliminary results have been obtained on the solid vanadium alloy (V-4Cr-4Ti). Figure 1 shows a desorption curve for this specimen after equilibration at 360°C in He containing ~400 ppm H. In this particular case the test was prematurely terminated with a small concentration of hydrogen remaining in the specimen as indicated by discontinuity at an elapsed flow of ~130,000 cm³-s.

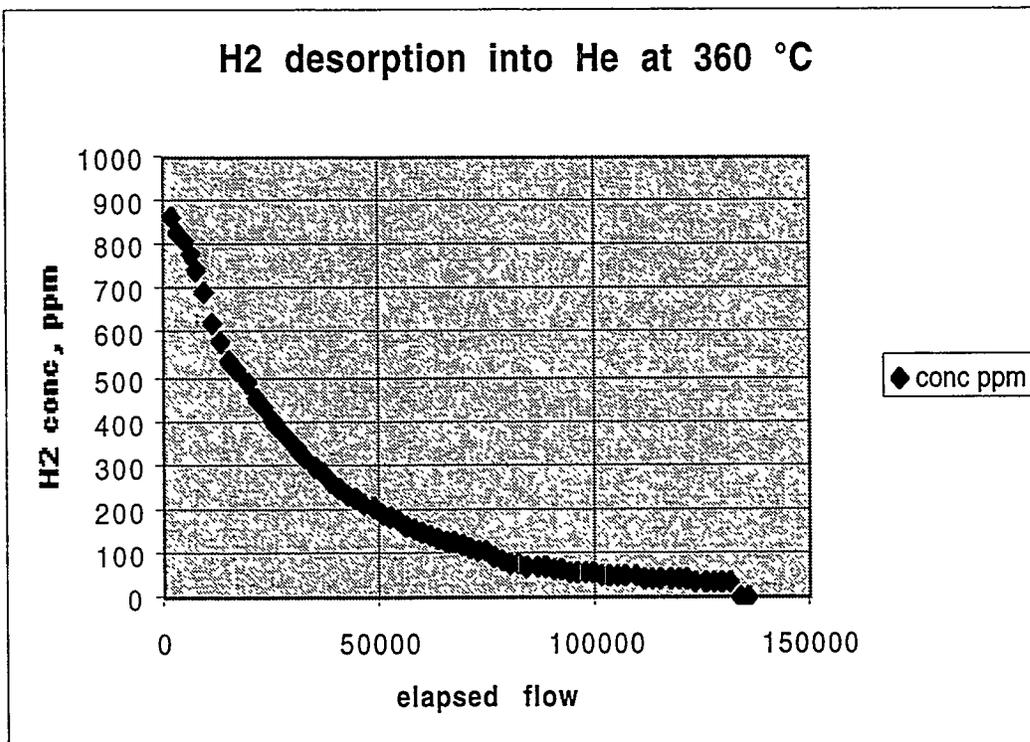


Figure 1. Desorption curve for V-4Cr-4Ti alloys at 360°C.

FUTURE DIRECTIONS

Additional runs will be made on the V-4Cr-4Ti alloy at selected temperatures and pressures. Tests on the LiCa and SnLi specimens will then be tested.