EFFECT OF LiOT ON TRITIUM INVENTORY OF Li_2O SOLID BREEDER

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INTRODUCTION

The tritium transport and inventory in Li_2O solid breeder of the fusion blanket have been affected by the oxygen bearing molecules in the purge gas as well as the solubility of tritium in Li_2O as LiOT. The capability of predicting the LiOT precipitation and the effect on tritium inventory were tested using a new version of MISTRAL code[1]. However, the recent tritium inventory analyses in Li_2O solid breeder under steady state and pulsed operating conditions shows significant differences between the code predictions and thermodynamic correlation.

In this study, a logic for predicting LiOT formation and decomposition in Li_2O solid breeder is developed *and* integrated in the MISTRAL code based on the available thermodynamics and kinetics data. The logic is based on comparison between the local concentration of tritium in the grain and the LiOT solubility limit at the breeder temperature. With this logic, the code is used to analyze tritium inventories in Li_2O under steady and transient conditions. Using a transient temperature scenario in which breeder temperature varied over a wide range from 600 °C to 100 °C and several tritium generation rates in the range of 1×10^{18} to 1×10^{21} atoms/m^3-s, the temperature limits for formation and decomposition of LiOT and the temperature regimes, over which each of the three forms of tritium inventory (grain, surface and precipitation) is dominant, are determined as a function of tritium generation rate.

DESCRIPTION

LiOT solubility in Li_2O increases with increase in temperature and becomes the dominant contributor to the tritium inventory. The solubility limit is obtained by combining the partial pressure of water over the two phase system[2,3] and the solubility of LiOT in Li_2O[4]. The following logic is added to the MISTRAL code to model the LiOT formation and decomposition:

1. Find the solubility limit, C_{sl}, for the local temperature.
2. Calculate the total tritium concentration, C_{tot}, in each local location by adding the grain tritium concentration obtained by solving the diffusion equation and the LiOT concentration from the previous step ($C_{tot} = C_g + C_{LiOT}$).
3. Compare the total grain tritium concentration calculated in step 2 with the solubility limit calculated in step 1 and obtain the new concentrations of tritium in the grain and as LiOT, as follows:

$$\text{if}(C_{tot} > C_{sl}) \qquad C_g = C_{sl}, \qquad C_{LiOT} = C_{tot} - C_{sl}$$
$$\text{if}(Ctot < Csl) \qquad C_g = C_{tot}, \qquad C_{LiOT} = C_{tot} - C_{sl}$$

Preliminary calculations on the candidate Li_2O solid breeder blankets considered for ITER indicated that under the proposed ITER pulsed environment no LiOT would precipitate, due to the relatively high breeder temperatures and low tritium concentrations. On the other hand, no experimental data on the tritium release from Li_2O in the regime of LiOT formation is available. Therefore, to examine the effect of LiOT precipitation on the tritium inventory behavior in Li_2O, an arbitrary operation scenario is considered, in which the tritium generation rate remains at a constant value of G atoms/m^3-s and the breeder temperature follows the history consisting of a 600 °C for 1000 s followed by 1000 s ramp-down to 100 °C and a 1000 s ramp-up to the original temperature of 600 °C as shown in Figure 1. By repeating the calculations for the same temperature history and values of generation rates in the range of 1×10^{18} - 1×10^{21} atoms/m^3-s, the breeder temperature window in which LiOT as a second phase forms as a function of tritium generation rate is determined.

RESULTS

The given breeder temperature and tritium generation rate history were used as input to MISTRAL to calculate the tritium inventory in Li_2O. The results of the calculations in terms of tritium inventory (wppm) for a generation rate of 1x10^{20} are shown in Figure 1. During the initial high temperature period, the inventory as LiOT is zero and the grain (diffusive plus solubility) inventory is dominant. As the breeder temperature drops during the ramp-down, due to lower solubility, the grain inventory decreases and the surface inventory increases. At a temperature of about 290 °C, LiOT begins to form and the tritium inventory as LiOT starts to increase as the temperature is further reduced. With the start of formation of LiOT both the grain and the surface inventories decreases. As the temperature increases during the ramp-up, the LiOT is decomposed and the tritium inventory as LiOT goes down while the grain and surface inventories go up. About a temperature of 310 °C, all LiOT precipitate is decomposed. Figure 1 clearly shows three temperature regimes. In the high temperature regime of 600 °C, due to high solubility the grain inventory is dominant. In the intermediate regime of 290 - 600 °C, the surface inventory becomes dominant. Finally, the inventory due to LiOT precipitation dominates over a narrow temperature range of 215 - 250 °C. For the different generation rates the same general inventory behavior as for the previous case is shown. The temperature range for formation of LiOT, however, changes as the generation rate varies, such as 215 - 250 °C for G = 1x10^{18}, 250 - 285 °C for G = 1x10^{19}, and 330 °C for G = 1x10^{21}. Figure 2 shows the domain of breeder temperature and tritium generation rate over which LiOT precipitation is significant. The maximum and minimum limit appear due to non-symmetry concentration profile in the grain. Therefore, LiOT precipitation is important tritium transport mechanism in Li_2O solid breeder under any pulsed operation within the hatched region.

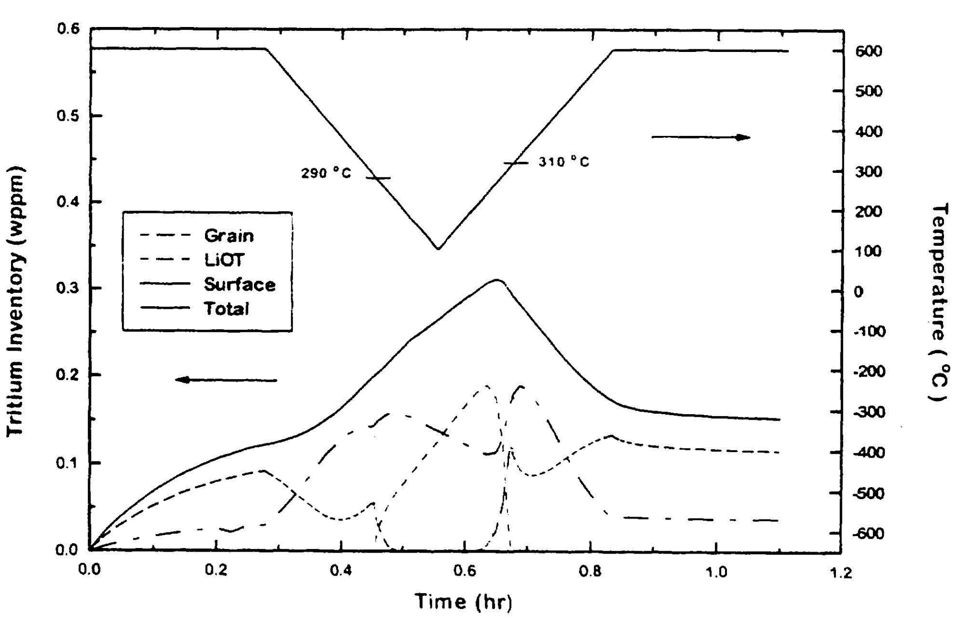

Figure 1 Tritium Inventory Histories and Temperature Profile for G = 1x10^{20} atoms/m^3-s

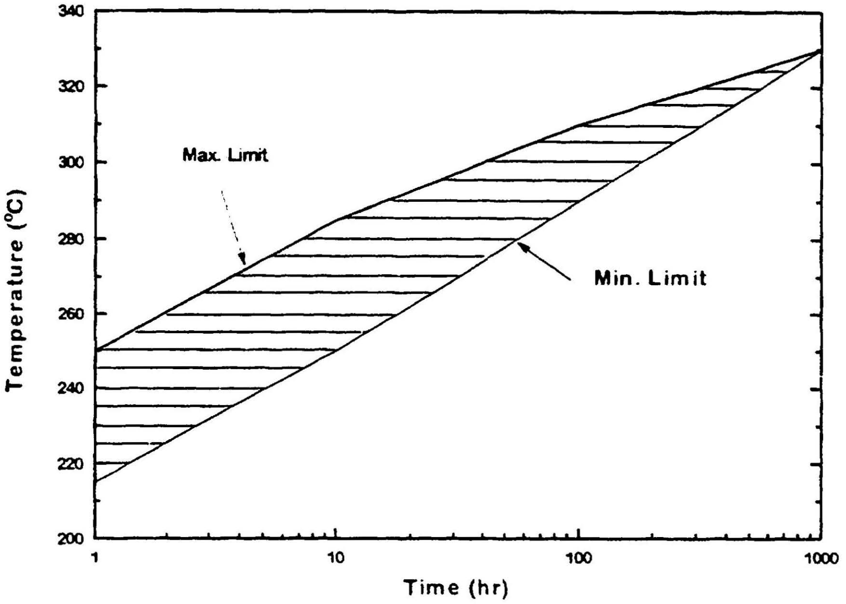

Figure 2 Region of LiOT Precipitation in Li_2O Ceramics

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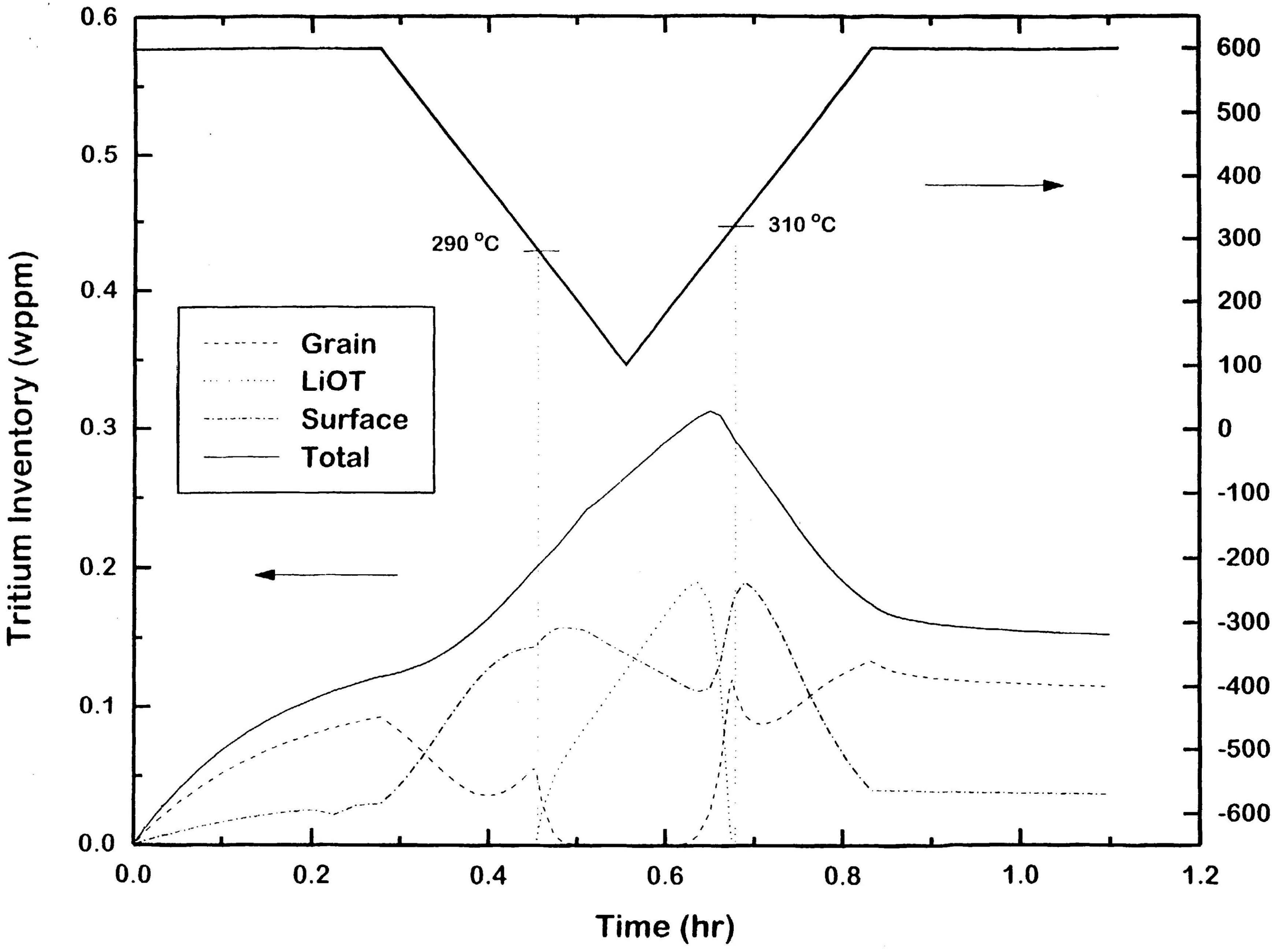

Figure 1

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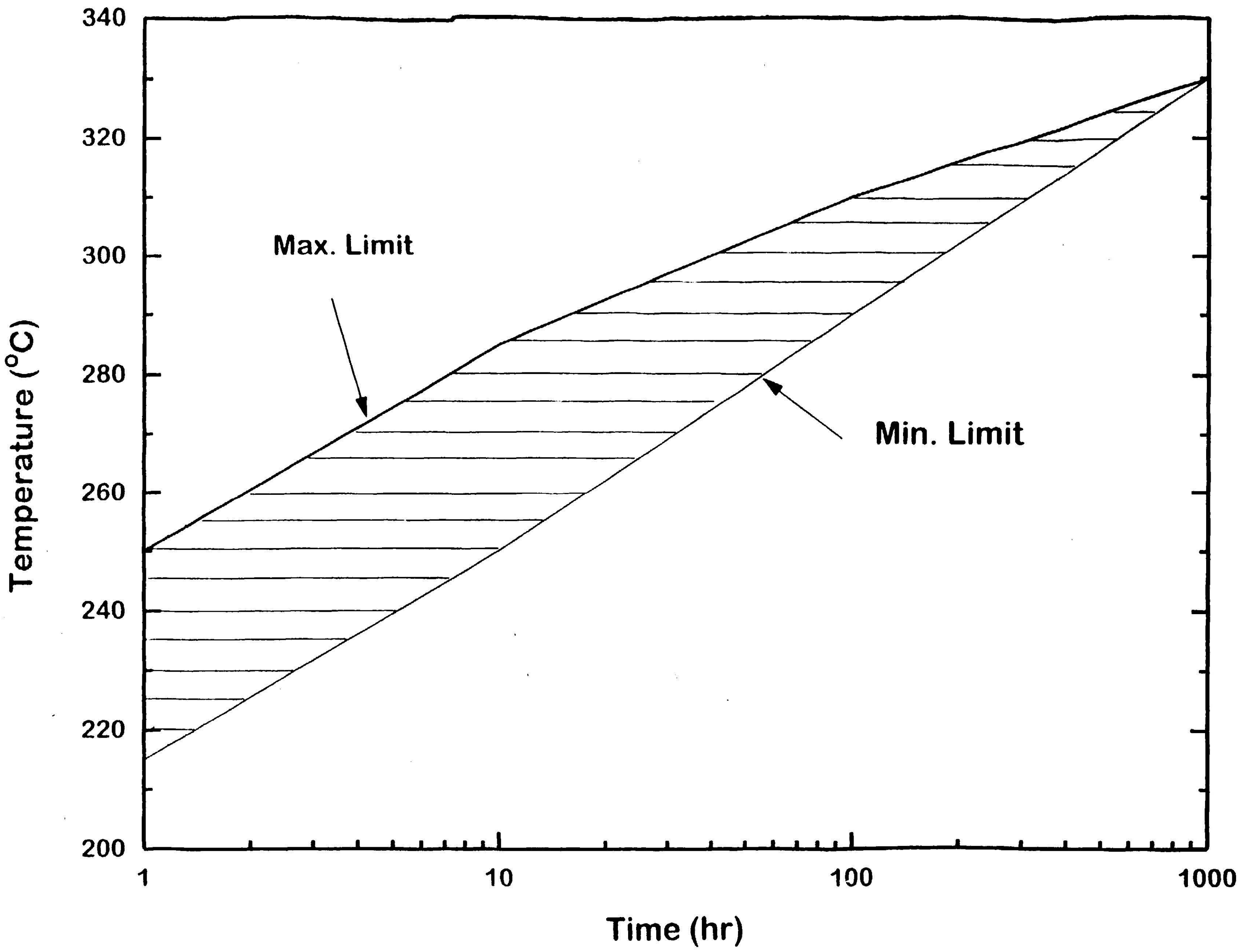

Figure 2

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