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NEUTRONIC DATA IN SUPPORT OF SPACE NUCLEAR PROPULSION

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ABSTRACT

The scattering kernel data for ^{7}LiH have been generated for the first time in the temperature range 50-1000 K. This is based on a phonon distribution function derived from both experimental data and theoretical calculations. A detailed study of the variation of the moderator temperature coefficient $\alpha_m(T)$ with temperature, T, is carried out for a typical space nuclear reactor of the particle bed type. It is established that the moderator temperature coefficient is propotional to $T^{-1.65}$ where T is the moderator temperature in Kelvin units.

INTRODUCTON

The thermophysical properties of lithium hydride (^{7}LiH), particularly small density (0.775 gm/cc), high melting point (688° C) and relatively high hydrogen atomic number density makes it an attractive material for use as a neutron moderator and shield (for LiH) in space nuclear thermal propulsion. However, the unavailabilty of neutronic cross section data in the thermal energy range for ^{7}LiH in the ENDF/B library necessitated the generation of the relevant data which is required in criticality studies and for the determination of temperature-dependent feedback coefficients in the moderator and fuel regions.

GENERATION OF THE SCATTERING KERNEL DATA

The phonon frequency distribution function of ^{7}LiH was derived from experimental data as well as theoretical calculations [1] . One interesting feature of this phonon spectrum is the presence of an energy gap between 0.062 and 0.074 eV separating the acoustical and optical phonon modes (Fig. 1). This phonon spectrum, evaluated in the present study, was utilized in GASKET calculations [2] to determine the scattering matrix elements $S(\alpha,\beta)$, the Debye-Waller integrals and the effective temperatures in the temperature range 50-1200° K. Subsequently, the calculated $S(\alpha,\beta)$ values were cast in an ENDF format in order to be processed by the NJOY code[3] which produces files for the MCNP Library (Fig 2).

MODERATOR TEMPERATURE COEFFICIENT

The present results were incorporated in a special Monte Carlo neutron and photon MCNP

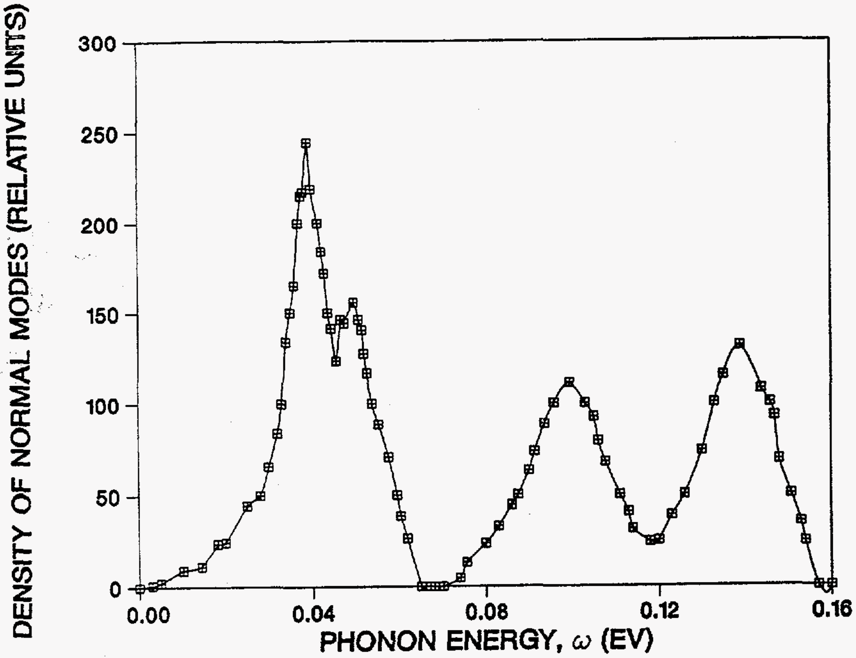

Fig. 1 The Evaluated ^{7}LiH Phonon Frequency Distribution Employed In GASKET.

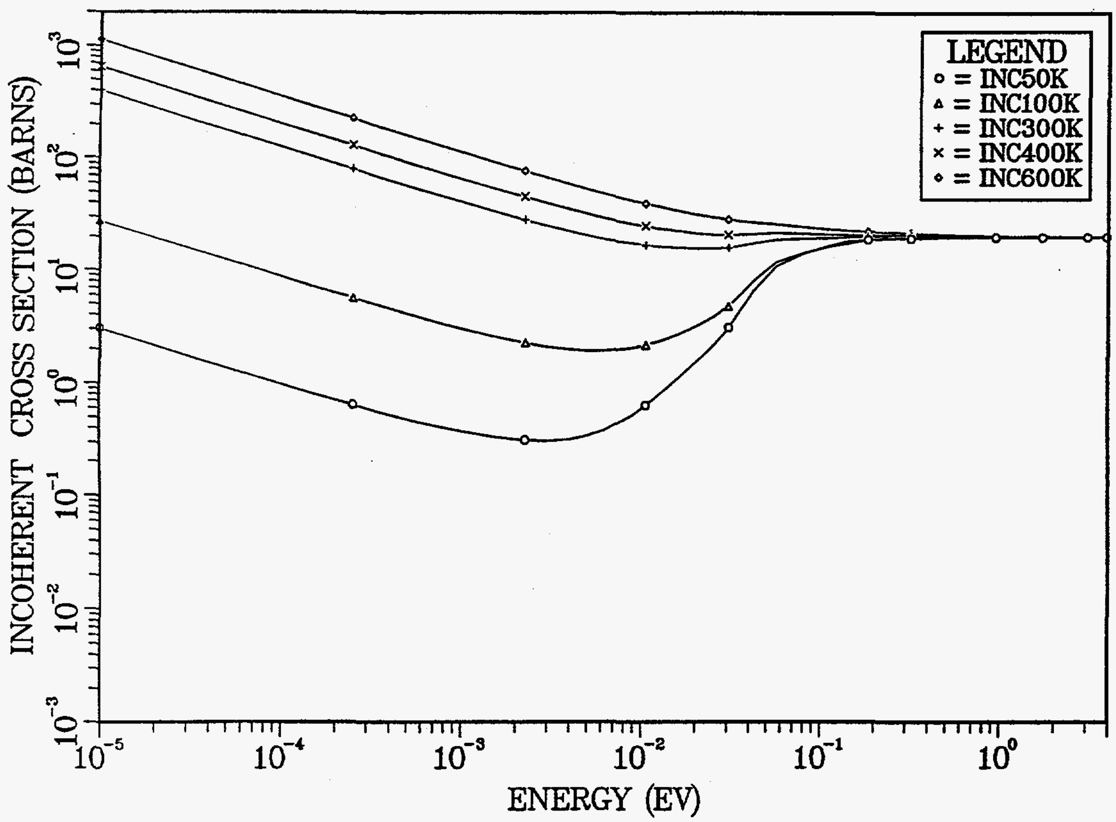

Fig. 2 The Incoherent Cross Sections of ^{7}LiH as Computed by GASKET .

library, and tests were carried out to access the magnitude and temperature dependence of the moderator temperature coefficient for typical nuclear space reactors with lithium hydride as the moderator. A particle bed reactor design [4] with a pitch of 12 cm, height 60 cm, 19 ^{235}U fuel elements with a total fuel volume of 30 liters, side, top, bottom beryllium reflectors (10 cm each) was considered. The reactivity temperature coefficients were determined for this configuration with MCNP computations at various temperatures. From the present and previous results [5] the following dependenee for the moderator temperature coefficient was deduced.

$$\alpha_m(T) = CF_v(H)^{1.6}T^{-1.65} \quad \mathbf{(1)}$$

where $F_v(H)$ is the volume fraction of the hydrogen moderator and C is a normalizing constant which depends on the thermal capture cross section of the moderator under consideration. With the four factor formula, it can be shown that, under the assumption of no change in the fission rate with temperature, the C in Equation 2 is related to the Maxwellian average capture cross section of the moderator[5] . The positive component of the temperature coefficient, which is due to chemical binding effects, can be counteracted by several methods, such as : 1) reduction of the solid hydrogeneous solid moderator, 2) replacement by a moderator with a small thermal neutron capture cross section such as D, ^{9}Be, ^{11}B, ^{12}C, 3) operation of the moderator at a high temperature such as 800° K, 4) change in moderator density due to expansion, and 5). combinations of the above methods. Method 3 provides negative temperature coefficient for some moderators. For ^{7}LiH moderator, density changes of 20% from 800 K to 1000° K results in a large negative reactivity if a mechanism of expansion for the ^{7}LiH out of the moderator region is allowed in a manner similar to a pressurized boiling water reactor. A preliminary estimate of negative reactivity of 2.5% in this temperature range is achieved for this reactor design.

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