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**A RE-EXAMINATION OF THE AUTOCATALYTIC CRITICALITY
PHENOMENA**

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INTRODUCTION

In two recent draft publications a new phenomena referred to as "autocatalytic criticality" has been reported^{1,2} as a potential criticality problem for underground dry storage facilities. Much of the independent research criticizing these results has focused on the nuclear kinetics of the proposed phenomena and the actual magnitude of an underground storage facility's total energy release. It should be noted that if the physical interpretation for the proposed autocatalytic phenomena is accurate, then both the design and analysis of underground dry storage facilities would need to account for the phenomena. Thus, more fundamental than even the system kinetics, risk or probability of an excursion event is the identification of any mechanism that could facilitate the autocatalytic phenomena. The purpose of this analysis is two fold: first, it is to discuss the analysis of the proposed autocatalytic criticality phenomena and demonstrate its limitations; second, it is to present a simple physical model that more accurately demonstrates this criticality phenomena in the more realistic setting of a porous media.

ORIGINAL AUTOCATALYTIC MODEL

The original problem applied the MCNP-4A³ solution on a homogeneous, finite volume sphere with an infinite reflector. The homogeneous core region contained H₂O, SiO₂ and Pu²³⁹ and the reflector region contained only SiO₂. The evaluation was essentially a critical fissile concentration search as a function of the individual material components. The key to understanding the autocatalytic mechanism is in recognizing that the analysis requires the weight fractions of H₂O and SiO₂ to be linearly dependent variables and this can be shown as follows. First, both the volume and density of the system are held constant which implies that the total

mass of the system is constant. With the mass of Pu^{239} held constant during an excursion, then the only trajectories allowed are along lines of constant Pu^{239} weight fraction. The consequence of this is to constrain the linear combination of H_2O and SiO_2 weight fractions as follows:

$$f_{\text{SiO}_2} + f_{\text{H}_2\text{O}} = 1 - f_{\text{Pu}} = \text{Constant} \quad . \quad (1)$$

The mathematics of this material model imply that H_2O is replaced by SiO_2 during the excursion without a constitutive relation governing the transformation. There is no obvious physical explanation for this replacement. A more realistic model would account for water evaporating while at the same time keeping the mass of the rock constant.

A SIMPLE POROUS MEDIA MODEL

For the porous media model MCNP-4A was also used to examine a homogeneous, finite volume sphere with an infinite reflector; however, both the material composition and the constitutive relations were changed in order to provide a simple and more accurate model of the mechanisms which drive the system criticality. First, a Parametric study was performed to determine the eigenvalue response as a function of material composition of the rock matrix. Rock matrix compositions included North American Bedasite, Western Granite, Sand Stone, Nevada Alluvium, Lime stone and Average Granite. These results show that residual components in the rock matrix significantly reduces the eigenvalue. Next, a simple porous media model was employed which accounted for a static porosity of the rock matrix and allowed for a homogeneous water-steam mixture density in the critical system. These results indicate that such a system can not be autocatalytic, and in fact the void coefficient is always negative.

CONCLUSIONS

The proposed autocatalytic criticality phenomena was examined and the implicit mathematical requirements of the model have been identified which explain the deficiencies of the model. A simple porous transport model was developed and used to analyze a parametric series of rock matrix types over a bounding set of expected porosities and water-steam void

fractions. The results provide a simple demonstration that the void coefficient is negative for all of the parametric cases examined. And this is the basis for proving that the autocatalytic criticality is not a concern in repository design or analysis.

REFERENCES

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