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*Analysis of Unscrammed Events in PRISM

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The PRISM reactor (Ref. 1) is presently under pre-application licensing review by the NRC (Ref.2), with Brookhaven National Laboratory (BNL) providing technical assistance. The purpose of this paper is to review the current PRISM design and describe the results from the SSC Code (Ref. 3) calculations performed at BNL, for a series of unscrammed accidents.

The metal fuel utilized in PRISM is composed of 27% Pu, 10% Zr, 63% U. The fuel has a small power and temperature defect (~$1.20) as a result of having a small Doppler coefficient and high thermal conductivity. The small Doppler effect is due largely to the hard spectrum found in a metal fuel core. The reactivity feedbacks of the core are engineered to provide a negative response to the thermal expansion of the fuel, control rods, and core radial dimensions. The core restraint system incorporates the limited free bowing feature, which generates an outward bow of the in-core portion of the assemblies when a radial temperature gradient exists. The core also has three Gas Expansion Modules (GEMs) placed around the periphery which, combined, have a net worth of -69 cents of reactivity at operating conditions. The GEMs are hydro-statically connected to the core inlet and function like manometers. When the pressure decreases, a gas bubble (which is normally above the core) expands into the core region and allows neutrons to stream out which normally are reflected back in. The GEMs were added to the design to generate a fast negative feedback, so as to automatically reduce power simultaneously with reduced core flow. This diminishes the potential for sodium voiding in case of a sudden loss in pumping.

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An input deck for SSC was generated to represent the PRISM power module (Figure 1) for the new reference ALMR design. The three unscrammed events that will be discussed in this paper are 1) the loss of flow and loss of heat sink (ULOF/LOHS), 2) loss of flow with and without GEMs (ULOF), and 3) the loss of heat sink (ULOHS).

In the full paper, each of the above listed events will be discussed in detail with the attributes of the metal fuel core emphasized. As a demonstration of a transient, a short description of a ULOF/LOHS will be presented. The postulated event starts with the plant at full power and a simultaneous loss of the intermediate heat exchangers (IHX) and EM pumps. The EM pumps coast down, using the power supplied by the synchronous machines.

The predicted power, shown in Figure 2, decreases due to the negative reactivities generated. The increase in core temperatures, due to the loss of flow, results in a power-flow mismatch, which activates the reactivity feedbacks from the structure and fuel thermal expansion. However, these effects are slow, as shown in Figure 3. The sudden pressure reduction at the core inlet drops the GEMs gas level and starts the power reduction. The GEMs insert -40 cents immediately after the pump trip, and insert the full -69 cents by the termination of the coastdown. The core goes subcritical, and the power reduces to the decay heat level by 500s. The peak fuel and clad temperatures in Figure 4 show that no fuel damage would occur. The margin to sodium boiling is about 230 K at 1000s. Thus, the GEMS effectively limit the peak fuel temperatures to reasonable values during a loss of flow event, and no damage is predicted.

A summary of the pertinent calculations to be presented in the paper are shown in Figure 5. The transient calculations, shown from left to right are: ULOF/LOHS by G.E., ULOF/LOHS, ULOF with 3 GEMs, ULOF without GEMs, and a ULOHS, with the last 4 cases calculated by BNL. The bar chart shows the peak fuel, clad, and coolant temperatures for each transient. Imposed on the graph are temperature limits important to the reactor system. Two of the highest limits are the temperatures where sodium would boil with the pumps on and off, respectively. They should be compared to the peak coolant temperatures on the chart. The top band (between 1700°F and 1880°F) is the expected range for fuel melting, which depends on the local isotope concentrations, which change during the burnup cycle. The isotope migration affects the solidus temperature, depending on the local isotope concentrations. The peak fuel temperature should be compared against this banded region to determine the margin to fuel melting.

The next banded region (extending from roughly 1300° F to 1550°F is the temperature range within which fuel cladding would fail, depending on time spent at the high temperatures. At the top limit it might take a fraction of a second for the eutectic to penetrate the clad while the lower limit would take many hours. The final temperature limit is the "Structural Damage" limit, which applies to the structure temperature and their operating service limits. Generally, the peak structural temperatures would be less than the peak sodium temperatures, especially for there relatively brief unscrammed events.

REFERENCES

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3. Guppy, J.G., "Super System Code (SSC, Rev. 2), An Advanced Thermalhydraulic Simulation Code for Transients in LMFBRs," NUREG-51650, Brookhaven National Laboratory, April 1983.

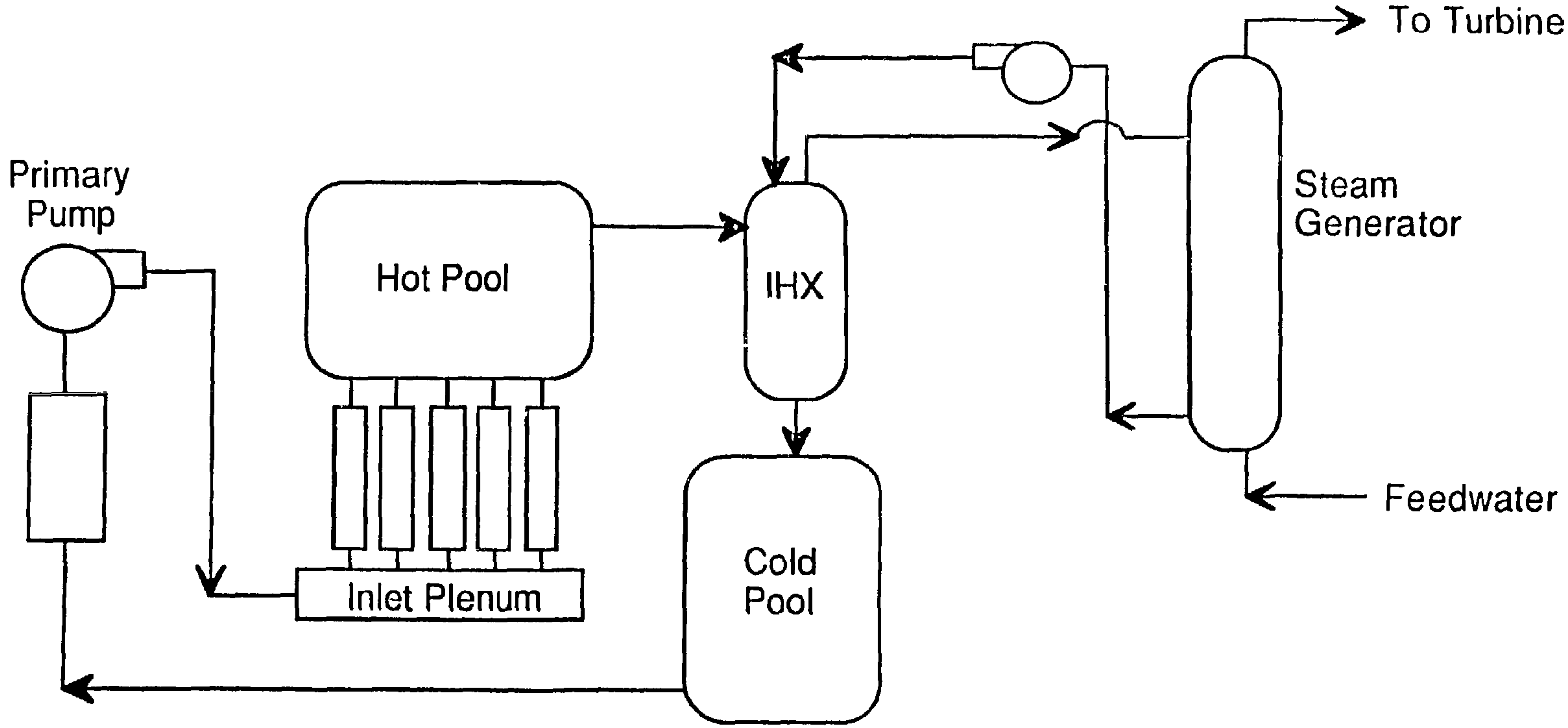

Figure 1. **SSC Representation of the PRISM Reactor Module**

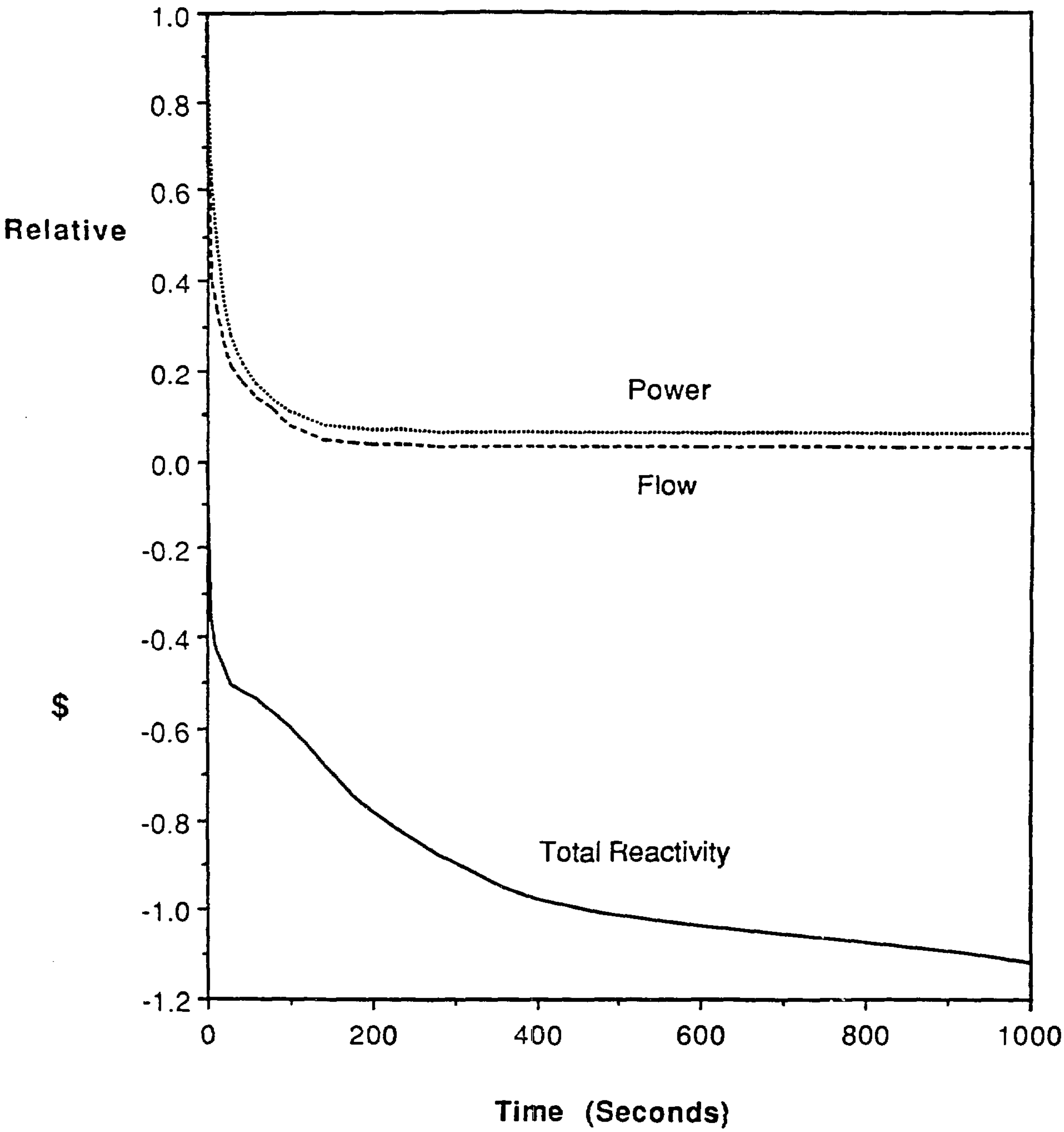

Figure 2. **Relative power and Core Flow Predictions from SSC for a ULOF/LOHS Along with the Total Core Reactivity Feedback Predicted During the Event.**

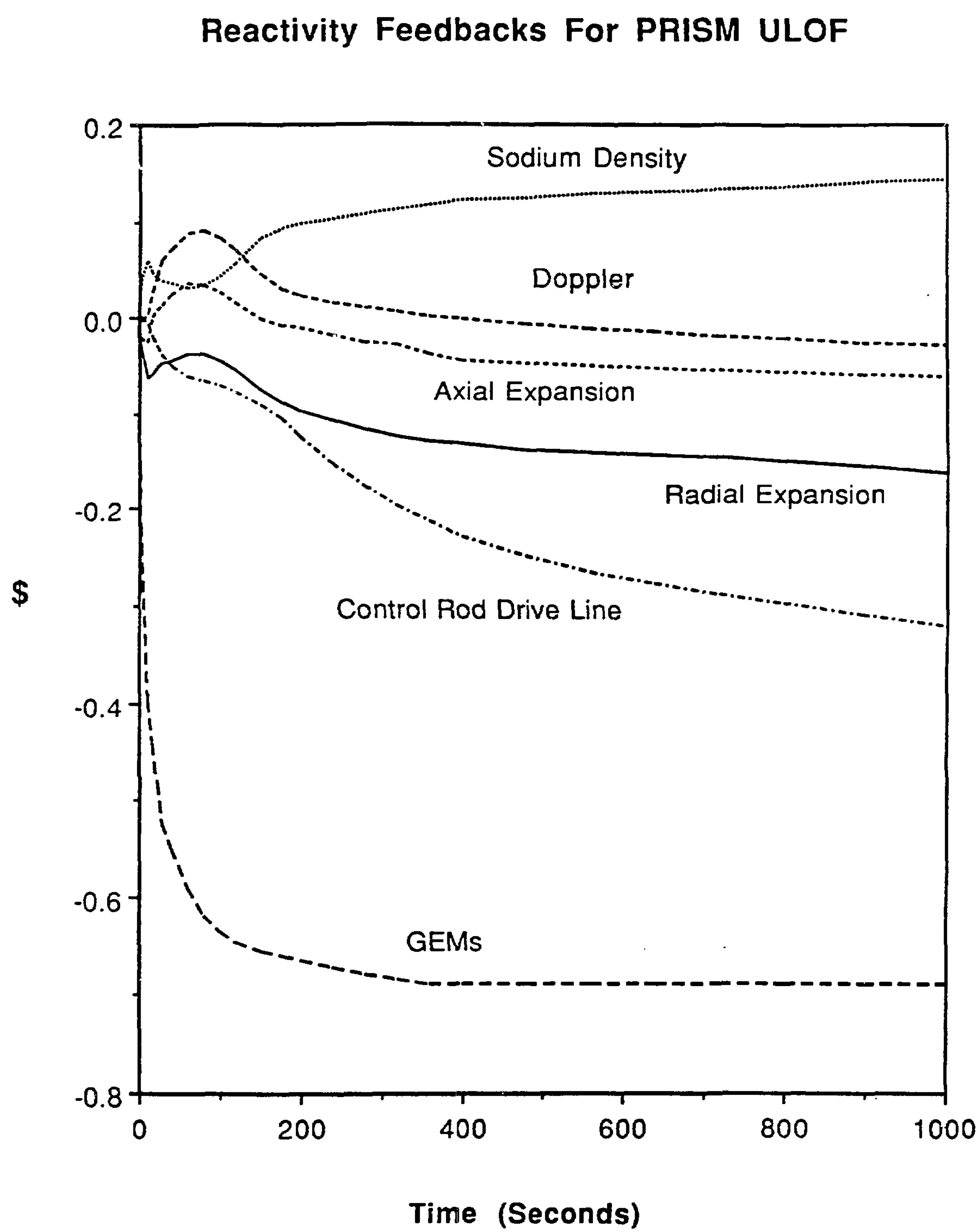

Figure 3. **Predicted Reactivity Feedback Mechanisms Predicted by SSC for a ULOF/LOHS.**

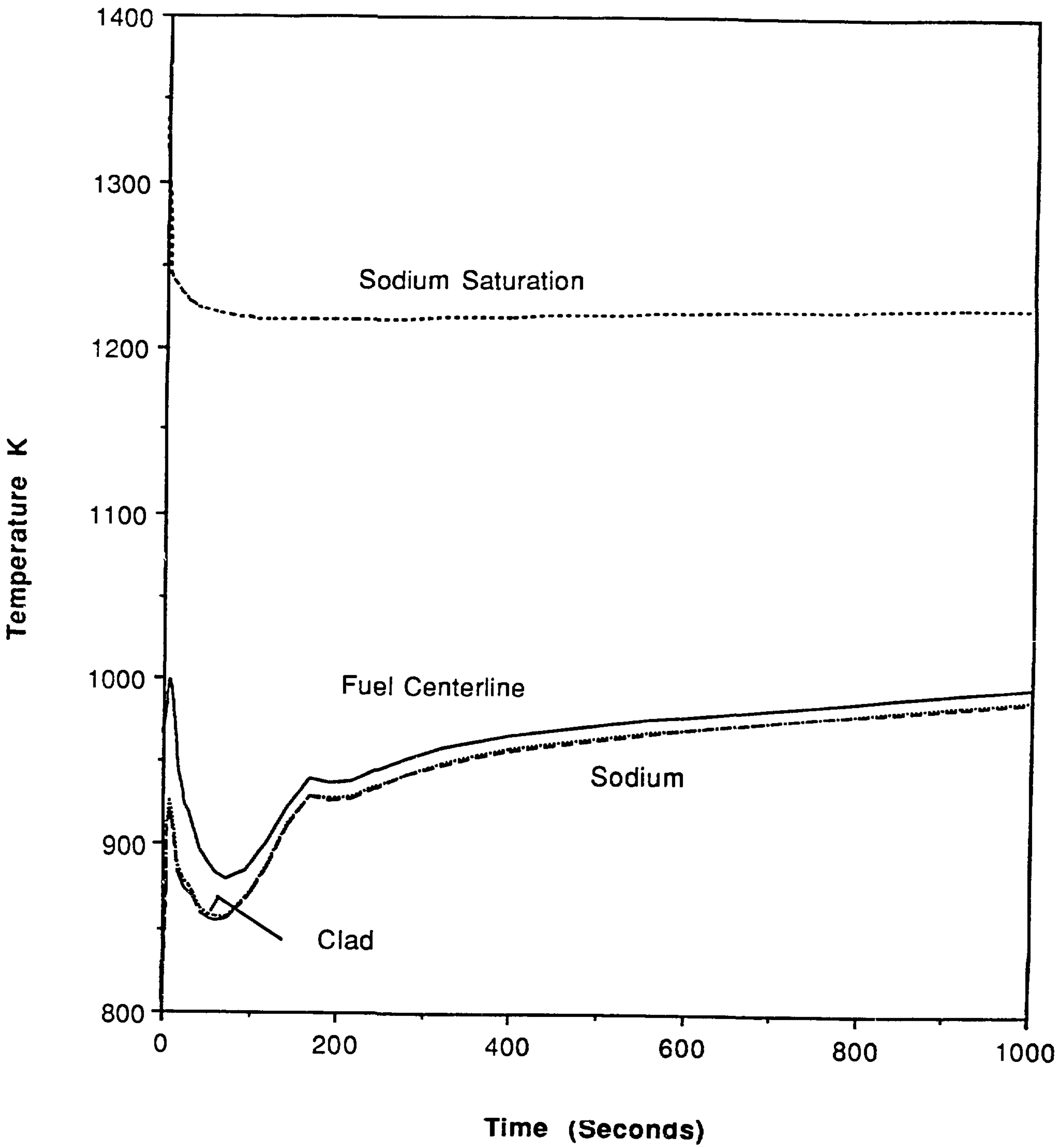

Figure 4. **Peak Fuel, Clad, and Sodium Coolant Temperatures Predicted by SSC for a ULOF/LOHS Along with the Sodium Saturation Temperature.**

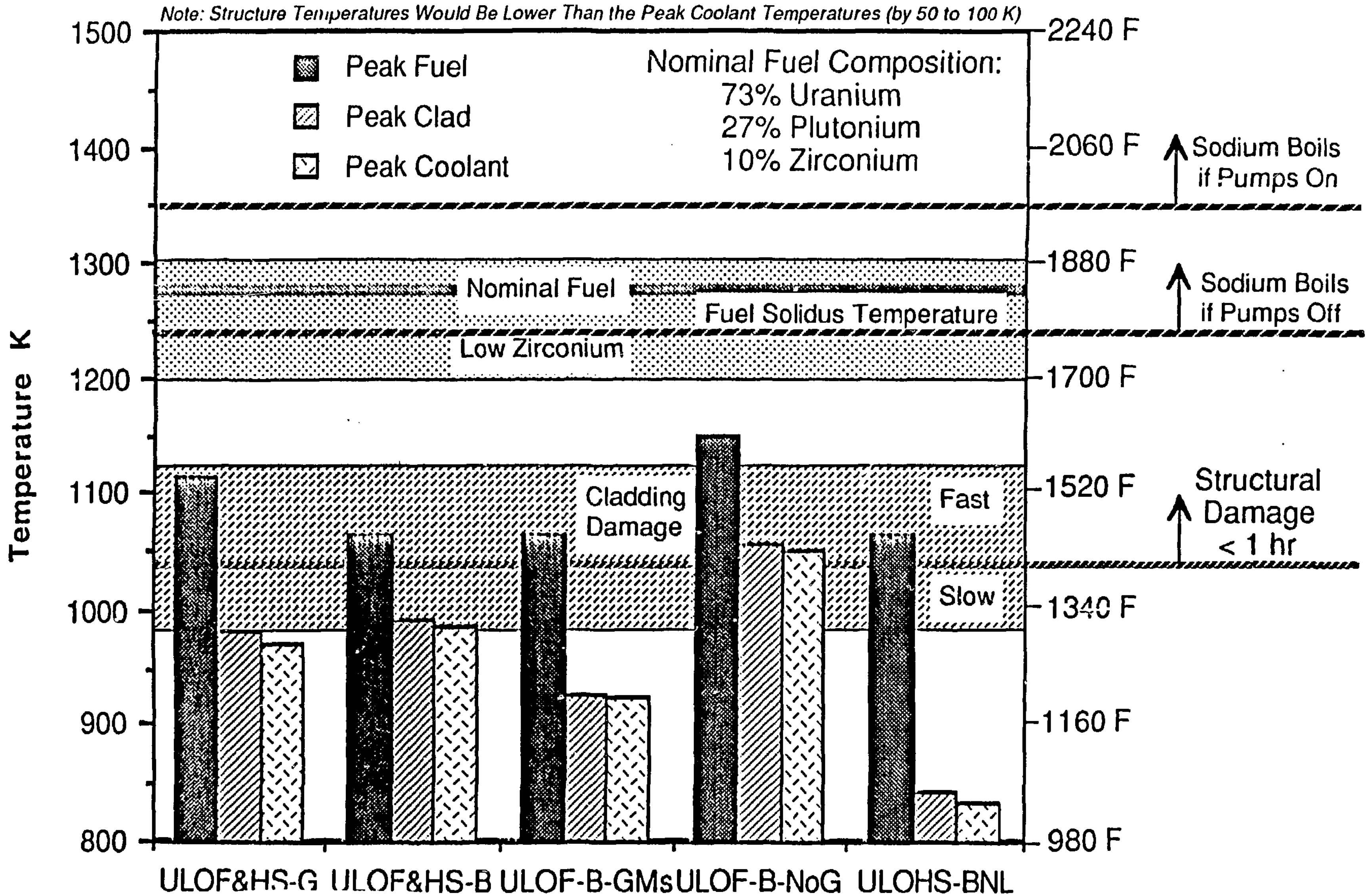

Figure 5. **Peak Fuel, Clad, and Sodium Temperatures for Various Unscrammed Loss of Flow and/or Loss of Heat Sink Events**