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The SASSYS-1 LMFBR Systems Analysis Code*

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The SASSYS-1 LMFBR systems analysis code has been developed to analyze the consequences of failures in the shutdown heat removal system and to determine whether this system can perform its mission adequately even with some of its components inoperable.

The code is especially intended for analyzing the coolability of the reactor core in cases involving natural circulation flows at decay heat power levels. In addition, the code is also capable of analyzing a wide range of transients, from mild operational transients through more severe transients leading to sodium boiling in the core and possible melting of clad and fuel.

SASSYS-1 provides a detailed thermal-hydraulic analysis of the reactor core, inlet and outlet coolant plenums, primary and intermediate heat transport systems, steam generators, and emergency heat removal systems. The code can handle any LMFBR design, loop, or pool with an arbitrary arrangement of components. Because of efficient numerical methods and coding, the code is fast running, usually faster than real time.

The SASSYS-1 core treatment is taken from the SAS4A accident analysis code (1). This core treatment includes the SAS4A heat transfer, coolant flow, reactor power level, and sodium boiling treatments, with modifications to account for subassembly-to-subassembly heat transfer through the duct walls and the interstical sodium. Also, for more severe accidents, SASSYS-1 can couple directly to the SAS4A modules for fuel pin mechanics and for the motion of molten fuel and cladding.

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SASSYS-1 uses a point kinetics treatment for the neutron flux and fission power level. Reactivity changes are computed for control rod scram, the Doppler effect in the fuel, sodium voiding or density changes, fuel and cladding thermal expansion, core radial expansion, and thermal expansion of the control rod drives. Also, decay-heat power levels are computed. The time-dependent decay heat power level either can be supplied by the user or it can be computed internally by the code as a function of burnup and power history.

For the primary and intermediate loop thermal hydraulics calculations, SASSYS uses a generalized geometry as indicated in Fig. 1. A number of compressible volumes are connected by liquid or gas segments, and each liquid segment can contain one or more elements. This treatment allows SASSYS to be used for an arbitrary arrangement of components, since compressible volumes and segments can be connected in an arbitrary manner.

The elements in liquid segments represent components such as pipes, pump impellers, valves, the shell or tube side of an IHX or an emergency cooling heat exchanger, and the reactor core. Liquid segments are characterized by incompressible flow, with the possible exception of the core element. The reactor core is a special element handled by the detailed core treatment. Gas segments represent pipes between cover gas volumes. Compressible volumes represent items such as the coolant inlet and outlet plenums, pump bowls, and expansion tanks. Compressible volumes are characterized by pressures which drive the flows through the liquid and gas segments. If a compressible volume does not contain a cover gas, then the liquid is treated as compressible.

SASSYS-1 contains temperature calculations for pipe coolant and walls, intermediate heat exchangers, and air draft heat exchangers. It also contains a uniform mixing thermal model that can be used for inlet and outlet plenums and pools. A PLENUM-2A type model (2) can be used to account for thermal stratification in the outlet plenum. In addition, the code accounts for component-to-component heat transfer, such as hot pool to cold pool heat transfer or pipe wall to surrounding air heat transfer.

SASSYS-1 contains a moderately detailed steam generator model developed by R. May and B. Singer (3), using an approach similar to that of Bein and Yahalom (4). This model uses moving boundaries separating the subcooled region, the nucleate boiling (pre-D_{NB}) region, film boiling region, and superheated region. Each axial node represents a well defined physical region with smooth, slowly varying water properties within the region. This method provides reasonably accurate results with only a few axial nodes and only a moderate amount of computing time.

Shutdown heat removal transients are often long, slow transients lasting hundreds or thousands of seconds. In order to reduce the computer time required to run such a case, it is usually desirable to take large time steps for the calculation of flows, pressures, and temperatures. Although most of the equations solved by SASSYS-1 are non-linear, they are linearized for a time step. The linearized equations are solved directly, without iteration, using semi-implicit or fully implicit finite differencing in time. For slow transients, it is possible to obtain stable and accurate results using long time steps with these numerical methods.

As a demonstration of SASSYS's capability for modeling plant-wide transients under both forced and natural circulation, consider simulating the following transient. A large-pool plant operating at steady state power experiences a total loss of electric power. The plant response to this event is a reactor scram and coastdown of centrifugal pumps. The mechanical louvers on the natural draft chimney are opened and this initiates primary system cooling via natural circulation in the decay heat removal system. Proper simulation of this transient requires adequate treatment of buoyancy forces and pressure losses in the primary, intermediate, and decay heat removal coolant paths. Important items in getting this correct are the representation of turbulent to laminar transition in the core and locked pumps, flow redistribution within the core, pipe and vessel wall heat capacity, pump coastdown characteristics, and air circulation through the air blast heat exchanger and natural draft chimney.

The loss of electric transient was run with SASSYS and invoked the following model features. The intermediate system representation included a steam generator model, while the natural draft chimney and the air blast heat exchanger in the SHRS-WC were represented. Circulation of coolant through flow paths and storage of coolant energy in pipes and structure walls along the flow paths are standard features of the code. A representative fuel assembly and blanket assembly were included to account for flow redistribution in the core at low flow. Interassembly heat transfer is a feature of the code, but it was not used here. Turbulent and laminar friction factor correlations were used in each core channel along with logic to select the appropriate correlation based on the flow condition. Pump coastdown and locked rotor behavior were explicitly modeled using a homologous pump model. The response of the hot pool is shown in Fig. 1.

References

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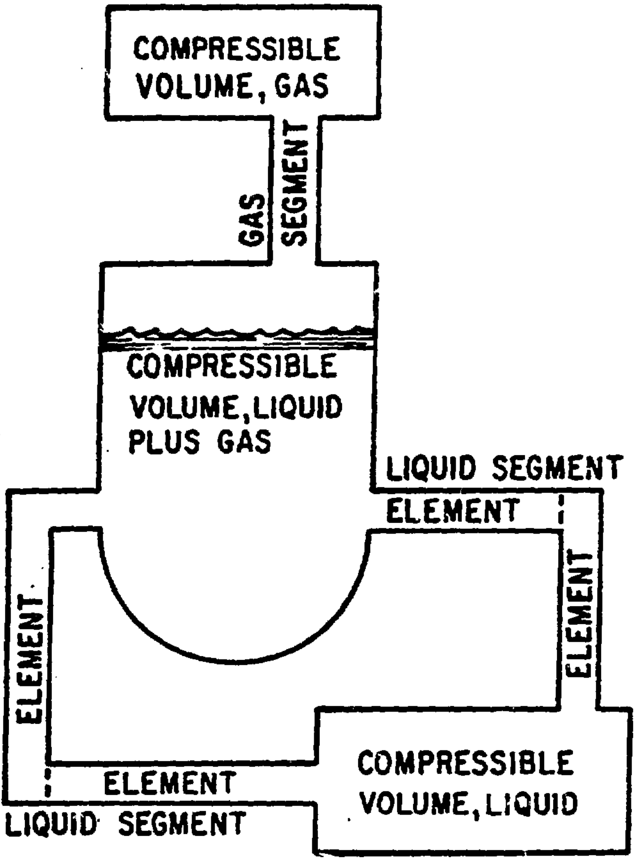

Fig. 1. General Heat Transport System Geometry Used in SASSYS.

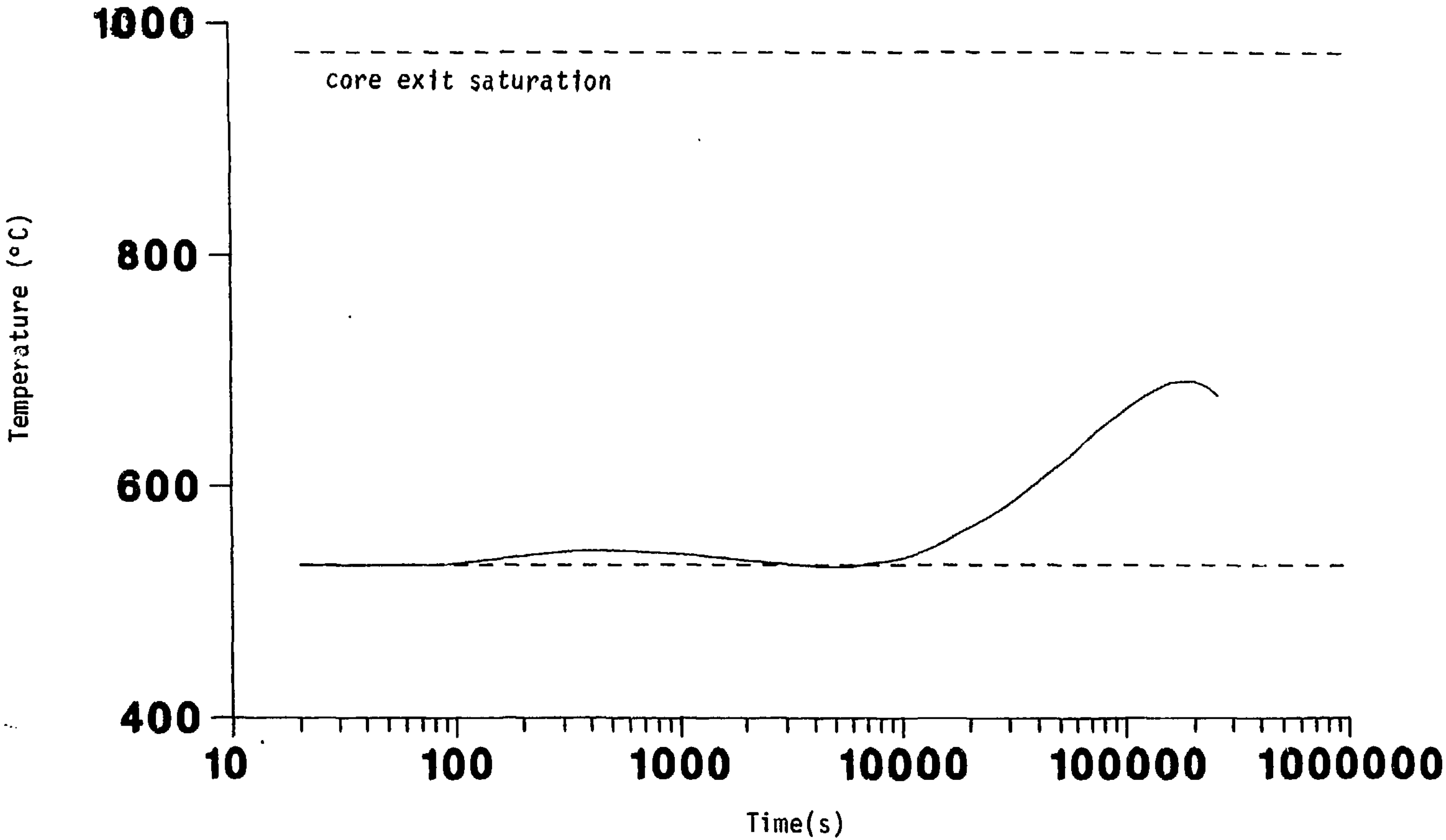

Fig. 2. Hot Pool Temperature for Large Pool Plant Following Total Loss of Electric Power Event.