CONF-871101--75

For presentation at the November 1987 ANS Meeting in Los Angeles

Comparison of the SASSYS/SAS4A Radial Core Expansion Reactivity Feedback Model and the Empirical Correlation for FFTF*

by

R. A. Wigeland
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

CONF-871101--75

DE88 003036

The submitted manuscript has been authored by a contractor of the U. S. Government under contract No. W-31-109-ENG-38. Accordingly, the U. S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U. S. Government purposes.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

---

*Work supported by the U.S. Department of Energy, Office of Technology Support Programs, under Contract W-31-109-Eng-38.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Comparison of the SASSYS/SAS4A Radial Core Expansion Reactivity Feedback Model and the Empirical Correlation for FFTF

by

R. A. Wigeland

The present emphasis on inherent safety for LMR designs has resulted in a need to represent the various reactivity feedback mechanisms as accurately as possible. The dominant negative reactivity feedback has been found to result from radial expansion of the core for most postulated ATWS events. For this reason, a more detailed model for calculating the reactivity feedback from radial core expansion has been recently developed [1] for use with the SASSYS/SAS4A Code System [2,3]. The purpose of this summary is to present an extension to the model so that it is more suitable for handling a core restraint design as used in FFTF, and to compare the SASSYS/SAS4A results using this model to the empirical correlation presently being used to account for radial core expansion reactivity feedback in FFTF [4].

Model Extension

The initial version of the radial core expansion reactivity feedback model contained provisions for grid plate expansion, the subassembly nozzle/grid plate receptacle characteristics, the above-core load pads and load pads at the top of the subassembly, and a restraint ring (core former ring) around the core at the top load pad elevation. This is the core restraint design currently being described as the "limited free bow" design. However, in some earlier reactors, such as FFTF, there was an additional restraint ring included at the elevation of the above-core load pads. This additional ring was to provide more control over the duct deformation during steady-state and transient operating conditions, and to ensure that all hardware for controlling the reactor and refueling would not be impaired by the duct deformation. The presence of this restraint ring also limits the possible expansion of the core at the above-core load pads. At present, the additional restraint ring has been added to the SASSYS/SAS4A model and is given a fixed dimension based on the core temperatures at nominal power and assuming a suitable clearance. This dimension is not changed for the remainder of any particular transient as SASSYS/SAS4A does not contain a detailed thermal model of the core restraint rings, although this capability is being developed.

Comparison with FFTF Results

From the results of a series of tests in the FFTF reactor, empirical correlations were developed for the reactivity feedback coefficients by HEDL analysts [5]. The correlation for radial core expansion reactivity feedback expresses the reactivity as a function of the normalized power-to-flow ratio. The correlation is shown in Fig. 1 for a range of normalized power-to-flow, $0 \le P/F \le 2.0$.

In order to make a comparison with SASSYS/SAS4A, calculations were performed over the same range of power-to-flow ratio. The default values for the subassembly bending moment were used. The uniform radial core expansion value was -318.9 $/m. The subassembly dimensions were taken from the FFTF design. The clearances between the subassemblies and the restraint rings were estimated from FFTF design information, although they were modified since the SASSYS/SAS4A calculation does not model the restraint rings in detail at present.

The results from the SASSYS/SAS4A calculations are also shown on Fig. 1. The results form three regions on the figure, with each region representing a different loading condition on the subassemblies. In the first region, from $0 \le P/F \le 0.7$, the subassemblies in the active core are all in contact at the above-core load pad region. The top load pad is not yet pushing against the top restraint ring. In this region, the thermal expansion of the load pads is providing negative reactivity feedback as the power-to-flow ratio increases, while the bending of the subassembly due to intra-subassembly temperature gradients results in a smaller, but positive, feedback.

In the second region, for $0.7 \le P/F \le 1.25$, the bending moment is sufficiently large for the top load pad region to have bent outward against the top restraint ring. As a result of this loading condition, both the thermal expansion of the load pads and the thermally-induced bending moment are providing negative reactivity feedback, so that the slope is somewhat steeper in this region. In the third region, $P/F \ge 1.25$ the above-core load pad region has expanded sufficiently to contact the restraint ring at this elevation. As a result, any further thermal expansion of the above-core load pads is stopped, and any further negative contribution to the reactivity feedback is due only to the thermally-induced bending moment.

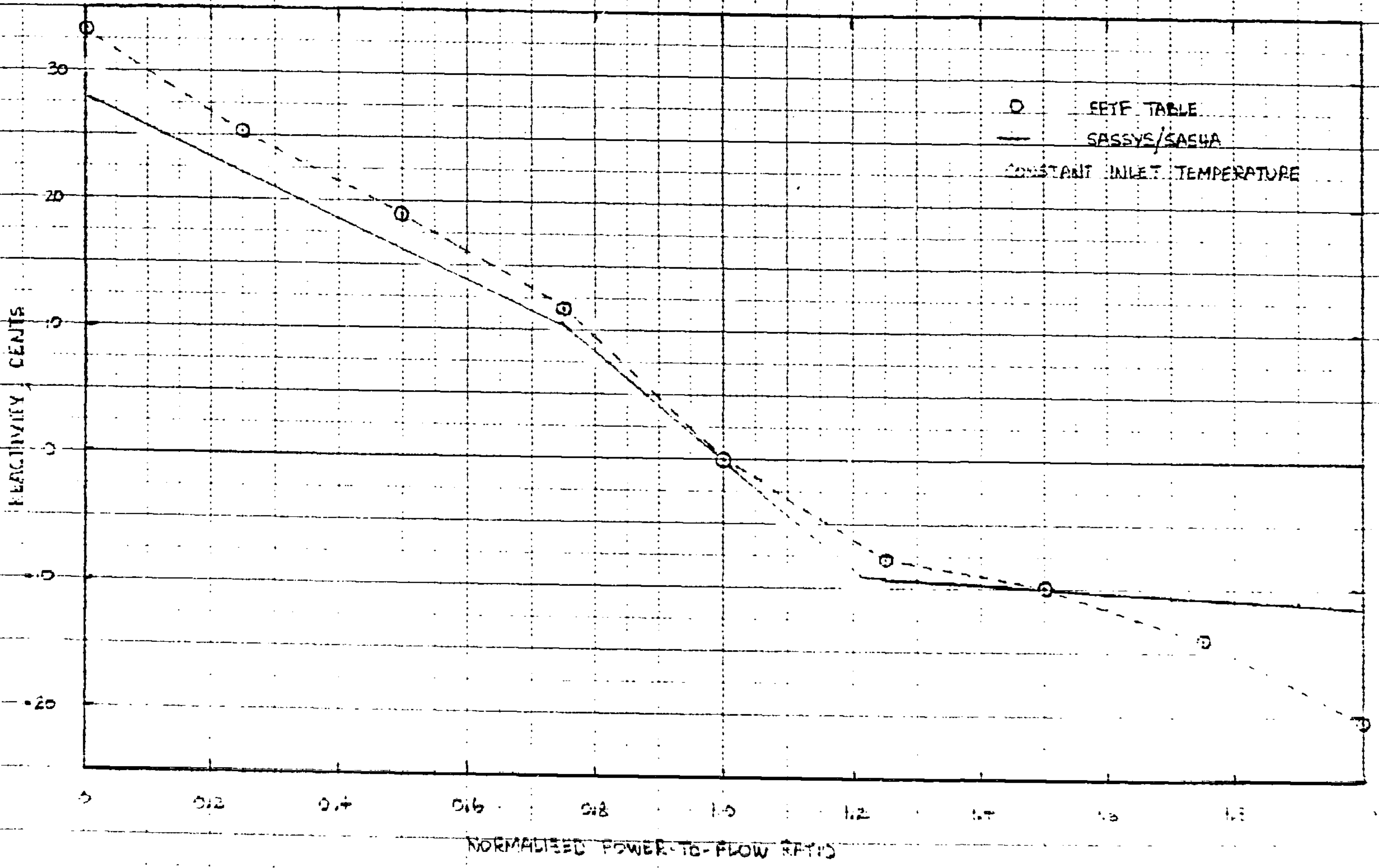
As Figure 1 demonstrates, there is good qualitative agreement between the FFTF correlation and the SASSYS/SAS4A predictions. This is especially true for $P/F \leq 1.25$. There is a discrepancy for $P/F > 1.25$, which increases with increasing power-to-flow ratio. This discrepancy is due to the fixed dimension of the restraint ring in the SASSYS/SAS4A calculation at present. In reality, the restraint ring will also increase in size as the temperature increases, thus allowing some thermal expansion of the above-core load pads, and an increase in the negative contribution to the reactivity feedback.

One interpretation of the present SASSYS/SAS4A model is that it accounts for the feedback from radial core expansion which has a very short time constant, on the order of a few seconds. The restraint ring expansion is a much slower effect, with a thermal time constant of several hundred seconds, based on its size. Thus, the model is probably suitable for the initial rapid transients, but in its present form will underestimate the negative feedback at long times for power-to-flow ratios greater than approximately 1.5.

References

1. R. A. Wigeland, "Effect of a Detailed Radial Core Expansion Reactivity Feedback Model on ATWS Calculations Using SASSYS/SAS4A," Trans. Am. Nucl. Soc., 53, 303 (1986).
2. A. M. Tentner et al., "The SAS4A LMFBR Whole Core Accident Code," Proc. Int. Mtg. Fast Reactor Safety, p. 989, Knoxville, TN (1985).
3. F. E. Dunn et al., "The SASSYS-1 LMFBR Systems Analysis Code," Proc. Int. Mtg. Fast Reactor Safety, p. 999, Knoxville, TN (1985).
4. J. B. Waldo, A. Padilla Jr., D. H. Nguyen, S. W. Claybrook, "Application of the GEM Shutdown Device to the FFTF Reactor," Trans. Am. Nucl. Soc., 53, 312 (1986).
5. Private Communication, A. Padilla, Hanford Engineering Laboratory.

461510


30
20
10
0
-10
-20
REACTIVITY, CENTS
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
NORMALIZED POWER-TO-FLOW RATIO
○ FFTF TABLE
— SASSYS/SAS4A
CONSTANT INLET TEMPERATURE