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A Detailed Analysis of the ANO-2 Turbine Trip Test

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A RELAP5/MOD1 (Cycle 18)[1] computer code simulation of the ANO-2 turbine trip test from 98 percent power level was performed for use in vendor code qualification studies. Results focused on potential improvements to simulation capabilities and plant data acquisition systems to provide meaningful comparisons between the calculations and the test data.[2,3] The turbine trip test was selected because it resulted in an unplanned sequence of events that broadly affected the plant process systems and their controls.[4,5] The pressurizer spray valve stuck open at an undetermined flow area, and an atmospheric dump valve remained stuck fully open while several atmospheric dump and secondary side safety valves were unavailable throughout. Thus, although the plant remained always in a safe condition, this transient potentially provided an unusual set of data against which the fidelity of a NSSS simulation by RELAP5/MOD1 along with certain vendor analysis codes might be judged.

The detailed model of the ANO-2 plant includes all four cold legs and pumps, both hot legs and all significant heat structures on the primary side. Additionally, the pressurizer spray flow lines are modeled from their cold leg take-offs and the main steam lines are modeled from the steam generator outlets to the turbine. The resultant input model contains 215 volumes, 221 junctions, 171 heat slabs having 937 mesh points, 63 control variables and a large number of general tables and trips. A somewhat reduced version of the model was also developed to observe the effects of some of the lesser important heat structures as well as the necessity for inclusion of certain features such as the pressurizer sprays and heaters and the detailed modeling of the main steam lines to the turbine.

The plant responded asymmetrically early in the transient due to the asymmetric valve availability but in a symmetric fashion later thereby indicating communication between the two secondary sides. This was modeled by "sharing" certain dump valves between steam lines (the cross-connect not appearing in "as built" drawings available at CE, could not be modeled precisely, but its effect could be so included[6]). Secondary side valves were sized for several design pressures and parametrically studied with respect to this early asymmetry. In this regard, we point out that most "design" values of such valves are simply guarantees of at least so much flow at a prescribed pressure. Further, real plant operation flow information is necessary to improve the understanding of the test.

The steady state initial conditions listed in reference 4 were matched reasonably well (data for steady state were inconsistent to a degree). During the transient the primary side flowrates and pump action (all tripped off at about 200 s into the transient) and secondary side feedwater flowrates were controlled to match data. However, lack of information on the auxiliary feedwater flowrate and inlet enthalpy as well as take-off flows to drive turbine pumps for AFW and MFW required that many parametric variations be performed.

As a result of these multitudinous variations in the calculations performed the RELAP5 code can perform a relatively close approximation to portions of the ANO-2 turbine trip test. The cold leg temperature traces in Figure 1 are in reasonable agreement. However, this may be largely due to the lack of constraining test data. Inability to satisfactorily model the repressurization phase seems likely due to dead volume flashing in the lower portion of the pressurizer below its inlet volume and code difficulties as the level crosses pressurizer volume boundaries as well as a lack of certainty in plant data and response. From this lack of constraining data ANL concluded that the ANO-2 series of start-up tests were not appropriate for use in code verification.

References

1. "RELAP5/MOD1 Code Manual," V. H. Ransom, et al., 3 volumes, NUREG/CR-1826, Nov. 1980.

2. "Evaluation of ANO-2 Test Series as a Code Verification Tool," T. A. McDonald, et al., ANL/LWR/NRC 83-1, Jan. 1983.

3. Private communication, Abramson (ANL) to Guttmann (NRC), Oct. 10, 1982.

4. "NSSS Design and Cycle 1 Operating History Data for Arkansas Nuclear One, Unit 2, P. A. Gague, EPRI NP-1707, March 1981.

5. "NSSS Transient Tests at ANO-2," D. P. Sioka, EPRI NP-1708, May 1981.

6. Phone conversation, T. A. McDonald (ANL) with G. Maxx (CE), Nov. 24, 1982.

Figure 1: Cold Leg Temperatures for ANO-2 Turbine Trip Test.

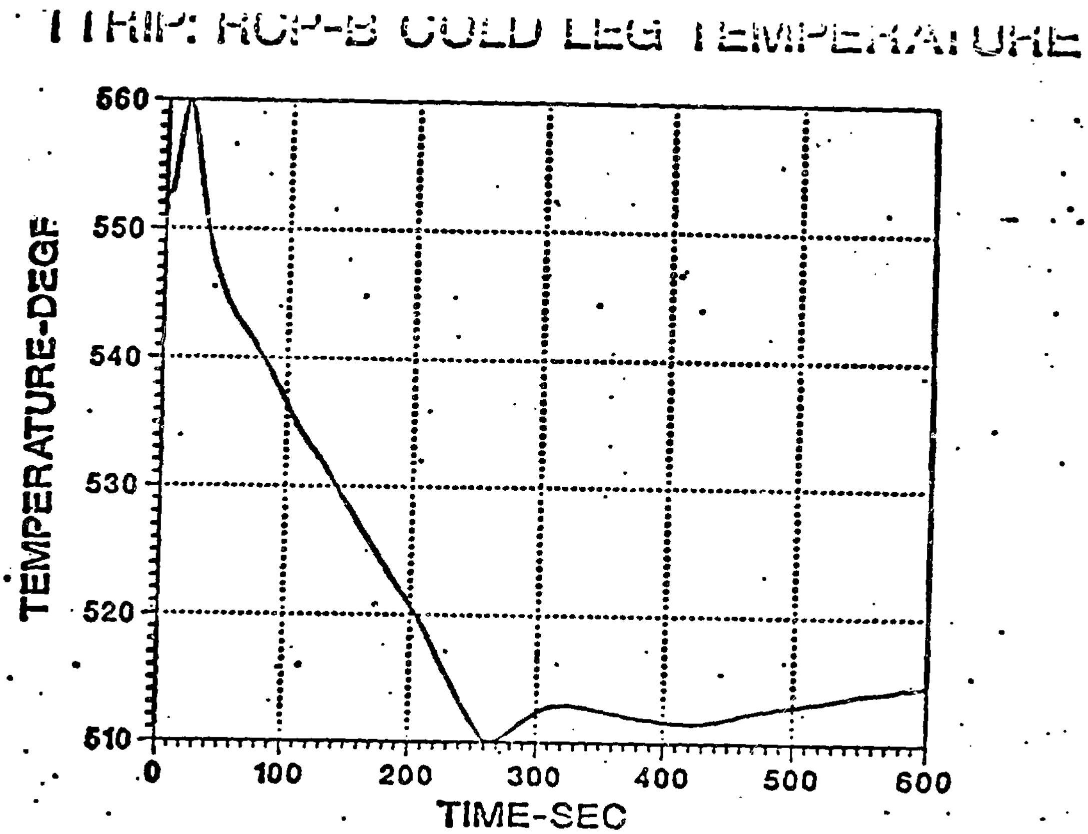

Fig. 2. ANO-2 Turbine Trip Test Cold Leg Temperature from Data Tape.

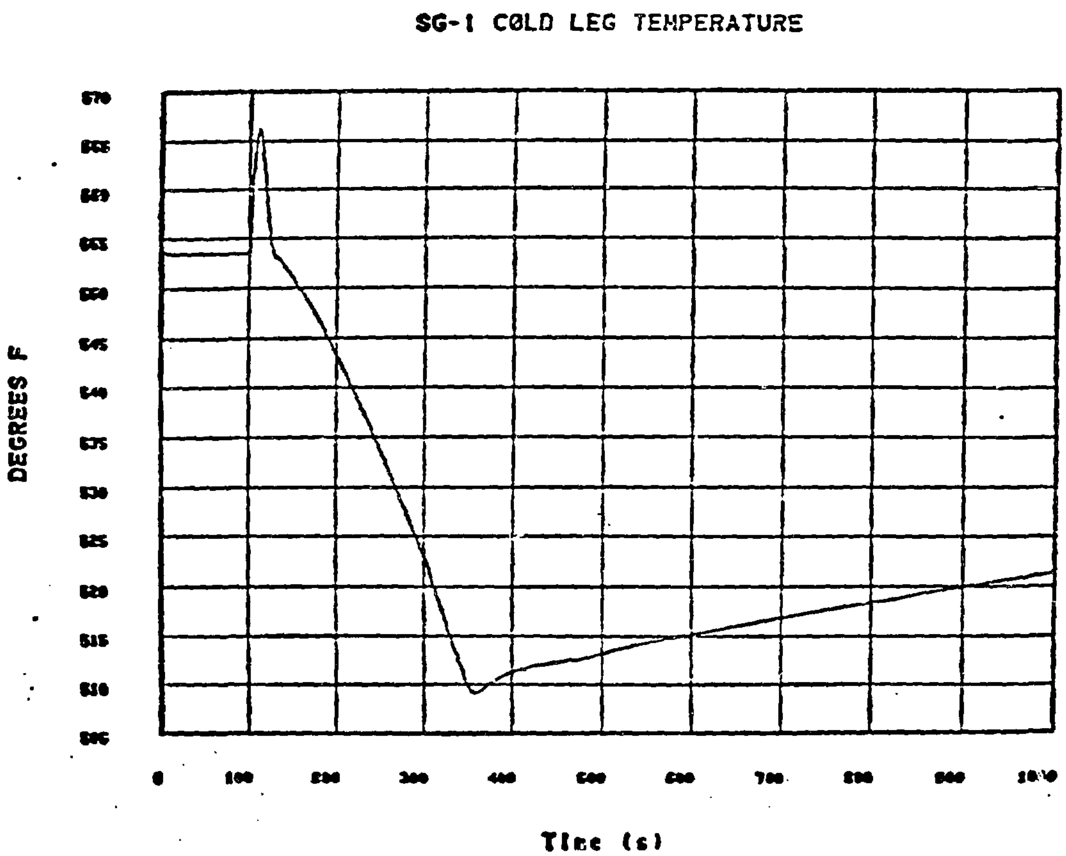

Fig. 3. ANO-2 Turbine Trip Test Cold Leg Temperature from RELAP5 Calculation.

Note: being combined by draftsman into one plot.

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