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# HEAT TRANSFER CONSIDERATIONS FOR PBF FIRST NUCLEAR BLOWDOWN

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The first PBF-LOCA program nuclear blowdown experiment (LOC-11) consisted of three sequential tests conducted with four separately shrouded PWR 15 x 15 design fuel rods[1,2]. The first test, LOC-11A, was a facility checkout test during which no programmatic information was obtained. The test rod peak power prior to blowdown was 46 kW/m for the LOC-11B test and 68 kW/m for the LOC-11C test. Maximum measured peak surface temperatures were 890 K and 1030 K for LOC-11B and LOC-11C, respectively. RELAP4/MOD6[3][a] posttest analysis of LOC-11B and LOC-11C indicated that accurate predictions of measured peak cladding temperatures required the inclusion of the following models: (1) a low flow CHF prediction model to allow for relatively accurate prediction of the time to CHF, (2) an accurate fuel model to represent the initial stored energy, (3) a radiation heat transfer model to represent the radiant exchange of thermal energy between the fuel rod and the shroud.

The LOC-11 test series was designed such that nuclear fuel rod performance during a simulated PWR blowdown transient could be investigated. For the LOC-11B test, the flow through the fuel rod shrouds was stagnated for ∿ 0.8 second before blowdown in an attempt to obtain an early CHF which would result in relatively high cladding temperatures through most of the transient. Pretest calculations performed at a peak power of 55 kW/m with RELAP4/MOD5[4] with licensing type heat transfer and fuel rod models indicated peak cladding temperatures as high as 1400 K and fuel rod failure. Pretest RELAP4/MOD5[a]

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[a] RELAP4 PBF-LOCA model employs unreleased versions of RELAP4 with configuration control numbers of H00203IB (MOD5) and H00332IB (MOD6).

calculations were performed with best estimate heat transfer and fuel rod models and a low flow CHF correlation (modified Zuber CHF correlation[5]) which indicated a several second delay in CHF and a reduced peak cladding temperature of ($\sim$ 1200 K). The delay in CHF predicted by the modified Zuber CHF correlation is supported by the LOC-11B data displayed in Figure 1.

For LOC-11C the stagnation flow phase prior to the blowdown was eliminated and the rod power was increased. However, the pretest analysis model still over-estimated the stored energy and neglected radiation heat transfer and subsequently overpredicted the peak cladding temperature by $\sim$ 200 K.

For posttest analysis of the LOC-11 tests, a RELAP4/MOD6[3] model of the PBF-LOCA blowdown facility was developed. In order to be able to predict the initial measured centerline temperature of the high pressure fuel rod ($\sim$ 321 psia He prepressurization) with the RELAP4/MOD6 Ross and Stoute[3] best-estimate gap model, it was necessary to model the centerline thermocouple hole and radial pin power profile. With the improved post-CHF heat transfer package of RELAP4/MOD6 and with the improved fuel model the RELAP4 model results showed good agreement with surface thermocouple data earlier in the blowdown. The improved predictions for time greater than $\sim$ 10 seconds were accomplished by the inclusion of a radiation heat transfer model in the LOC-11 RELAP4 model, as illustrated in Figures 1 and 2. The radiation heat transfer model assumed diffuse gray radiation between two infinite concentric cylinders.

Additional sources of discrepancies between data and prediction are: (1) fin cooling of standoff thermocouples, (2) prediction of local properties, (3) prediction of transient gap conductance, (4) prediction of decay heat curve. The results presented here compared with the pretest results illustrate the conservatism of the RELAP4/MOD5 licensing type heat transfer and fuel rod models, as applied to the PBF-LOCA facility.

## REFERENCES


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3. S. R. Fischer, et al., RELAP4/MOD6 A Computer Program for Transient Thermal-Hydraulic Analysis of Nuclear Reactors and Related Systems User's Manual, CDAP-TR-003 (January 1978).
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5. R. A. Smith and P. Griffith, "A Simple Model for Estimating Time to CHF in a PWR LOCA," Transactions of American Society of Mechanical Engineers, Paper No. 76-HT-9 (1976).

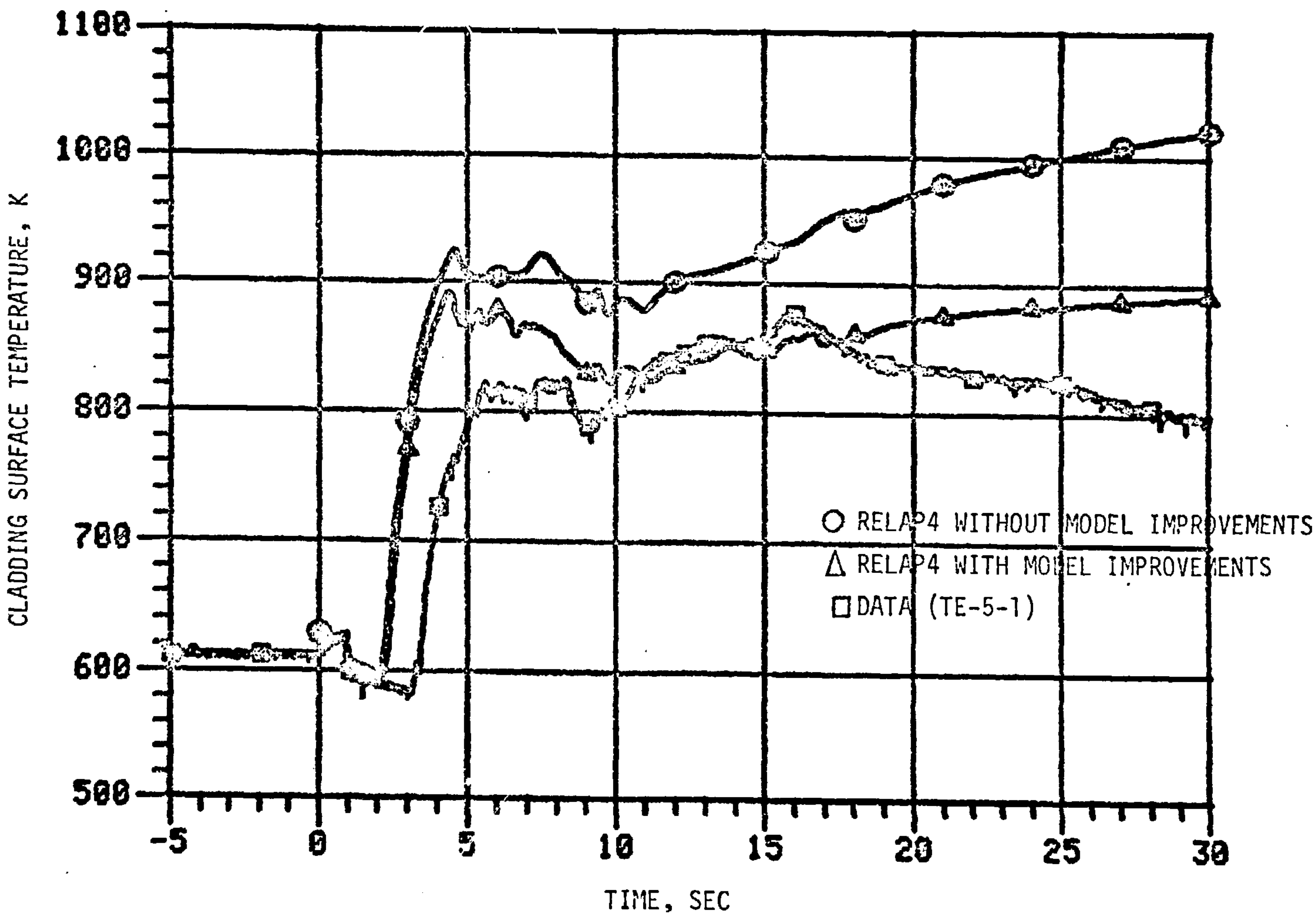


FIGURE 1. LOC-11B MEASURED SURFACE CLADDING TEMPERATURE AT 0.53 METER COMPARED WITH RELAP4 PREDICTION.

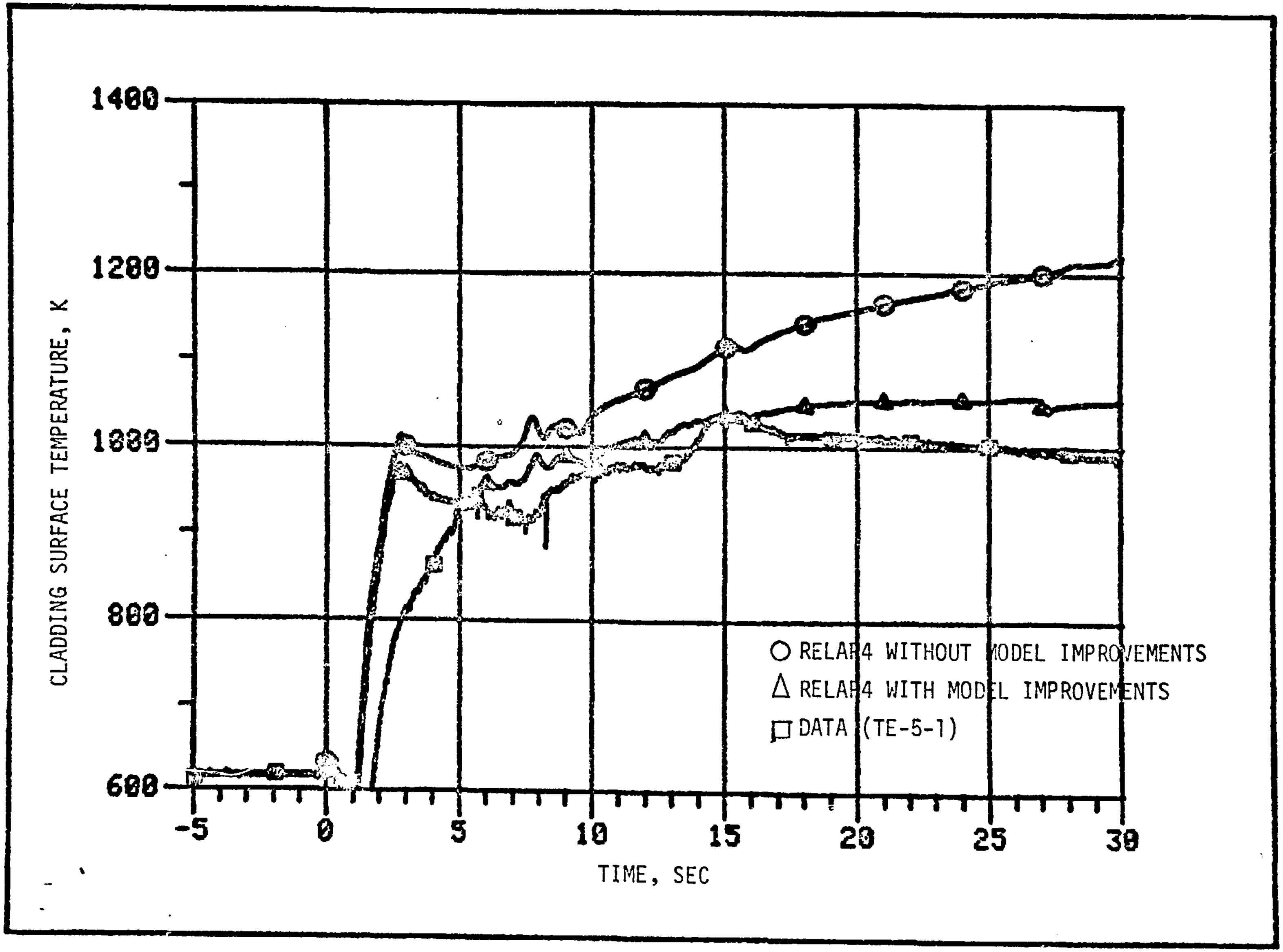


FIGURE 2. LOC-11C MEASURED SURFACE CLADDING TEMPERATURE AT 0.53 METER COMPARED WITH RELAP4 PREDICTION.