SPECIAL APPLICATION OF RELAP4 TO THE POWER BURST FACILITY

The purpose of this paper is to illustrate RELAP4/MOD5 (Ref. 1) applications and adaptability to a proposed Power Burst Facility (PBF) loop modification. These applications of RELAP4 are different from standard blowdown analyses and code development work commonly reported (Ref. 2 through 6). RELAP4 is used to predict loop pressures resulting from thermal swell generated by fuel pin disassembly during a reactivity initiated event. Also, RELAP4 is applied to a blowdown problem requiring several code modifications for modeling specific hydraulic and fuel rod conditions. Thermal hydraulic responses resulting from 1) a design basis fuel pin energy transient and 2) an accidental rapid loop depressurization are presented.

Analyses with RELAP4 of proposed RIA experiments are being conducted in the PBF at the Idaho National Engineering Laboratory. An integral part of the PBF loop coolant system are the two thermal swell accumulators (TSA's) which provide a vapor volume to accomodate the relatively slow thermal expansion of the loop coolant due to the release of large amounts of stored energy. However, the frequency of maintenance repairs and downtime costs associated with the TSA's have necessitated the design of an alternative, economic method for relieving thermal swell. The alternative method which appears most feasible is to isolate the TSA's as blowdown volumes which are separated from the loop by rupture discs. Several accident situations involving this TSA modification have been analyzed using RELAP4/MOD5 to provide the thermal hydraulic results.

The first RELAP4 analysis involved an energy transient modeling thermal swell. The transient was a 50 MW-sec steam fill injection into the core coolant volumes. The test section consisted of 25 rods operating at PWR conditions. The initial RELAP4 run designated the discs to rupture when pressures adjacent to the disc exceeded 2500 psi. Both discs ruptured after 0.30 sec of transient time. Pressure history results showed that the pump discharge pressure exceeded the design limit of 2700 psi. Earlier analyses which studied acoustic responses associated with this transient condition predicted that the acoustic pulse would rupture the disc after 0.02 sec of transient time. This time trip condition was specified in a second RELAP4 run. A plot of test section pressure versus time for both the high pressure trip and time trip condition is illustrated in Figure 1A. Core pressures increased about 350 psi when the thermal swell pressure rise was responsible for rupturing the disc. However, essentially no pressure increase is noticed if the acoustic pulse ruptures the discs.

The second RELAP4 analysis referring to the TSA modification task involved an accidental rupture disc failure resulting in a rapid depressurization of the loop coolant system. The capability of RELAP4 to easily adapt to a special modeling situation proved to be highly worthwhile and essential in the second analysis. A worst case accident was studied in which both discs were simultaneously ruptured thereby blowing down to both TSA volumes. A 25-rod test section operating at a peak power of 16 kW/ft was modeled prior to the transient. The UO_2 average fuel temperature and Zr-4 clad surface temperature as a function of time are illustrated in Figure 1B. Fuel temperatures continually decreased yet clad surface temperature significantly increased and attained a value of 2150 °F, approaching a loss of clad integrity.

Acceptance criteria for ECC's (Ref. 7) designate in Criterion 1 that "the calculated maximum fuel element cladding temperature shall not exceed 2200 °F". Compliance with this criteria and also problems associated with Zr-H_2O reaction when cladding temperatures exceed 1750 °F justified another RELAP4 analysis which involved greater detail of test section conditions. Specifically, two code updates were inserted into RELAP4 in an attempt to better simulate actual test conditions. An investigation of critical heat flux (CHF) correlations applicable to annular low flow conditions was performed. It was concluded that the modified Zuber pool boiling CHF correlation would provide a close approximation for CHF during stagnation and low flow (< 200,000 lbm/hr-ft^2) conditions. This CHF logic was incorporated into the RELAP4 CHF subroutine. Also, earlier PBF LOC-11 blowdown analyses similar to this provided a reliable gap thermal conductivity versus time function. Standard RELAP4 logic requires a conductivity versus temperature input. The necessary RELAP4 code revisions to accept a gap conductance-time function were made and the function was input as data.

Results of the second RELAP4 analysis revealed that test section mass fluxes fluctuated yet remained below 200,000 lbm/hr-ft^2 throughout most of the transient. Again, a plot of average fuel rod temperature and of clad surface temperature is illustrated in Figure 1B. A steady-state average fuel rod temperature of 2425 °F is observed and is significantly less than the fuel rod temperature of the first study. This difference is due to the change in gap conductance which concurs with gap closure effects evident during PBF steady-state operation.

In the first analysis, a CHF condition was achieved earlier and sustained for a longer duration as compared to the CHF history characteristic of the second analysis. Consequently, clad surface temperatures of the second analysis peaked at 1700 °F and are well within ECC limits.

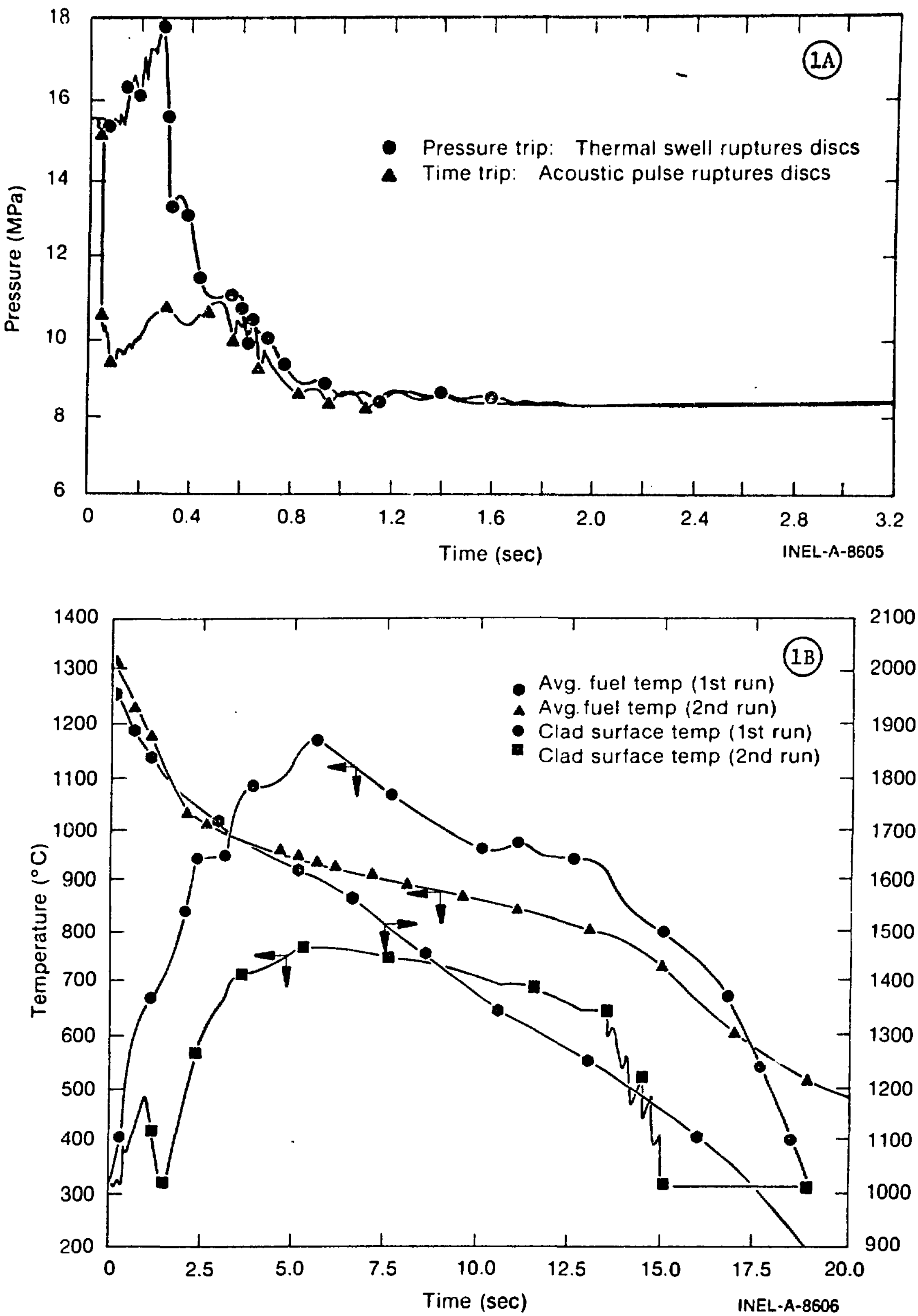
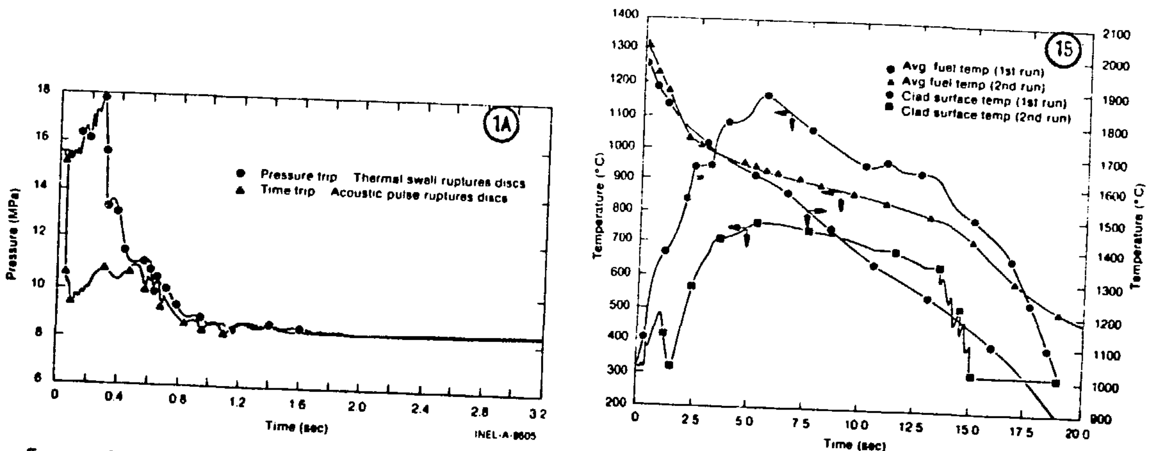


Figure 1: RELAP4 Thermal Hydraulic Results for Evaluation of the PBF TSA Modification



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