ANALYSIS OF PRIMARY SIDE FEED AND BLEED OPERATION AT ARMENIAN NPP UNIT 2

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Outline

- Objective
- ANPP Description
- Model Description
- Event Description
- Results
- Conclusions

Objective

- To demonstrate core cooling capability of the plant using the high pressure injection (HPI) system (feed) and pressurizer safety valves (bleed), and to evaluate temperature changes in the borated water supply tank (BWST)

ANPP Unit 2

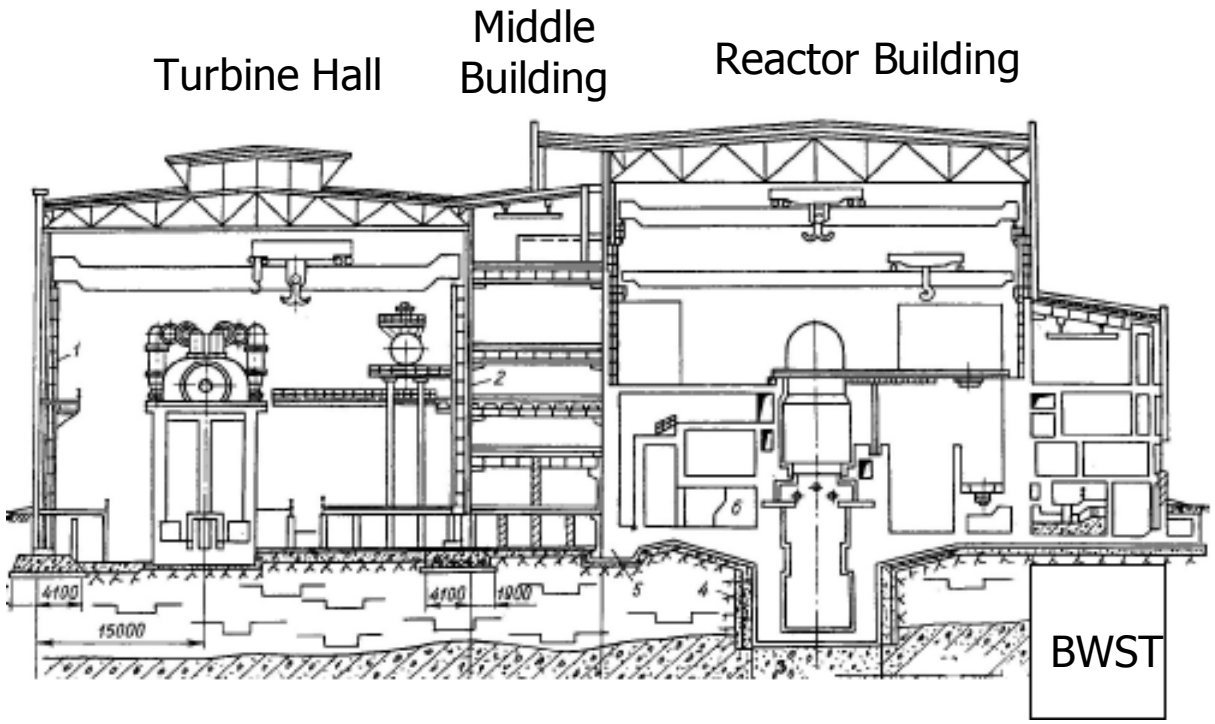
- WWER 440/270
- 6 loops
- Horizontal SGs with large water inventories
- Hot and a cold leg isolation valves
- ECCS: two channels of HPI pumps, BWST
- Two turbine generators
- Low heat production with respect to the fuel weight

ANPP Unit 2 cont'd

- Reactor thermal power: 1375 MWt
- Normal operating pressure at the reactor outlet: 12.26 MPa
- Coolant average temperature: 282 °C
- Number of fuel assemblies: 349

ANPP Unit 2 cont'd

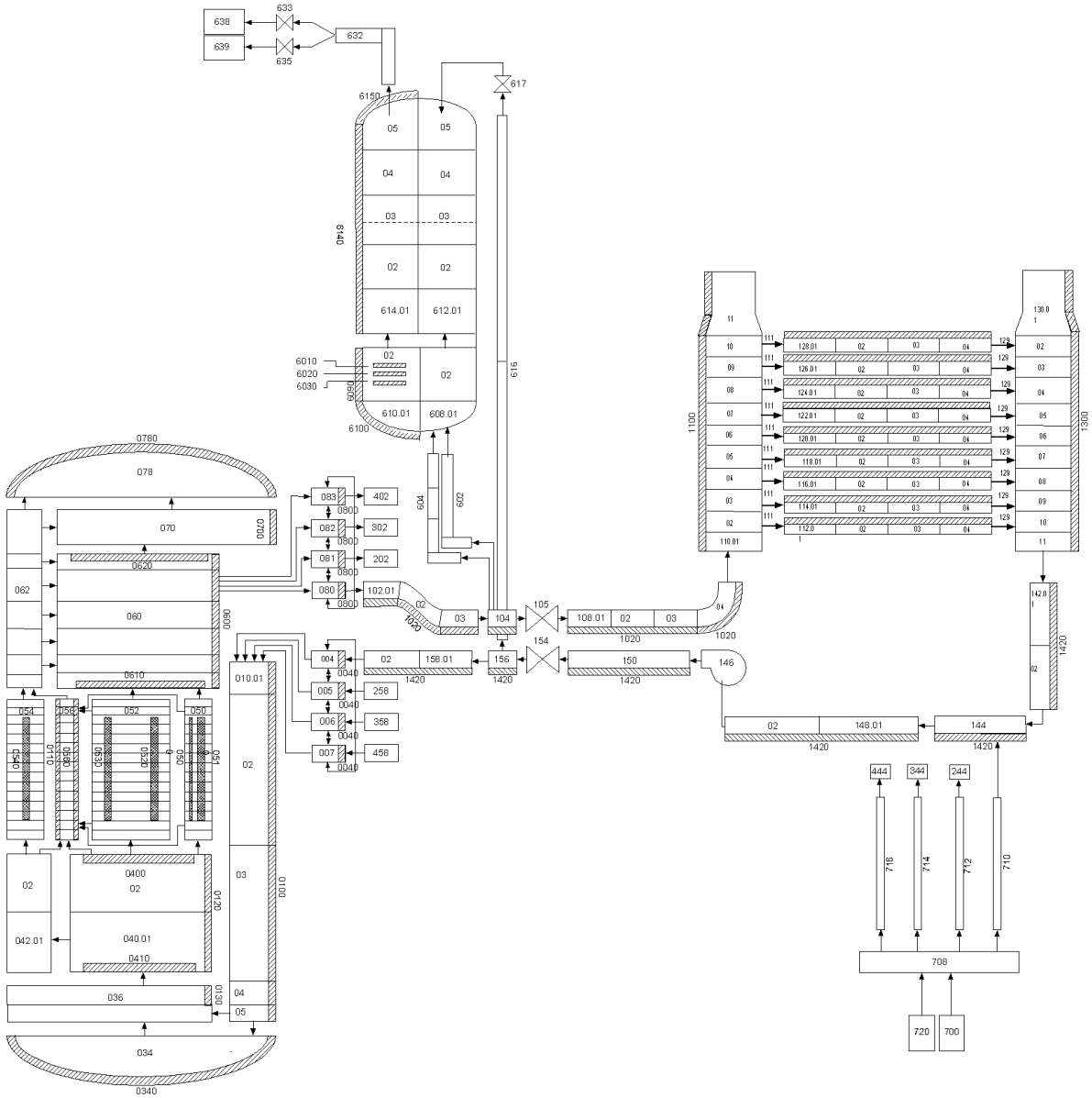
Cross-Sectional View of ANPP Unit 2



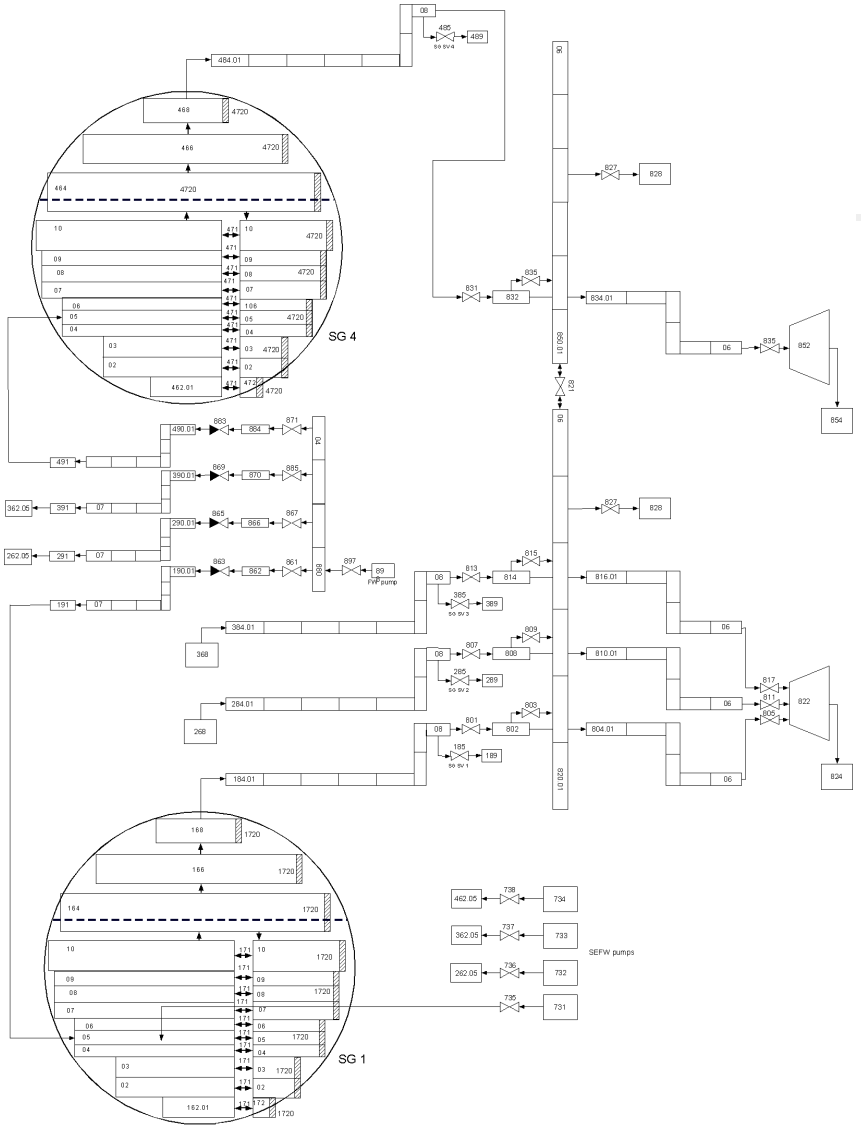
Model Description

- The Mod3.2.2β version of RELAP5 was used for the analysis.
- The six loops of the plant were modeled by 4 loops; three loops represented three individual loops and one loop combined the other three loops.
- The input described the primary and secondary loops in detail as well as all safety systems and most of control systems.

Primary side nodalization



Secondary side nodalization



Model Description cont'd

- The HPI and BWST systems were simulated by a time-dependent junction and a time-dependent volume.
- The HPI injection rate was provided as a function of the primary pressure.
- The HPI water temperature was calculated by solving the energy and mass conservation equations around the BWST and heat exchangers using control variables.

Event Description

- The analysis considered a hypothetical case with a total loss of the SG feedwater.
- The reactor was assumed to be at the EOC condition, with the maximal residual heat generation.

Event Description cont'd

- The analysis was performed in two phases:
  - Pre-F&B Phase:
    - The core was cooled by the natural circulation in the primary loop, which was sustained by the remaining water in the secondary sides of the SGs.
  - F&B Operation Phase:
    - The feed and bleed to remove the decay heat and cool the core. The F&B procedure was initiated by simultaneously opening one PRZ SV and starting one train of HPI (two HPI pumps).

Results

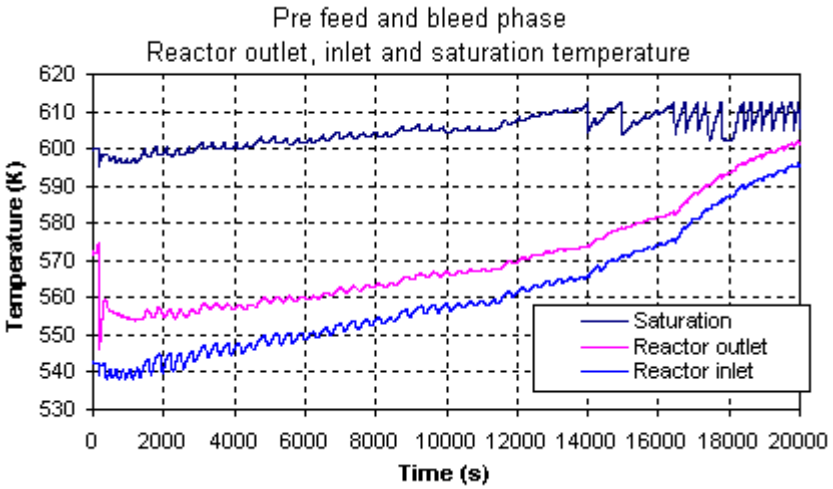
- Pre-F&B Phase
  - The objective was to determine the maximal time reserve that the operator would have during which reliable core cooling could be sustained without F&B.
  - The transient was initiated by a loss of power, which caused a reactor scram, the primary coolant pump coast-down, loss of secondary feedwater and turbine trip. Steam dump systems were not operable.
  - The calculation of this phase was performed up to 2×10^4 seconds.

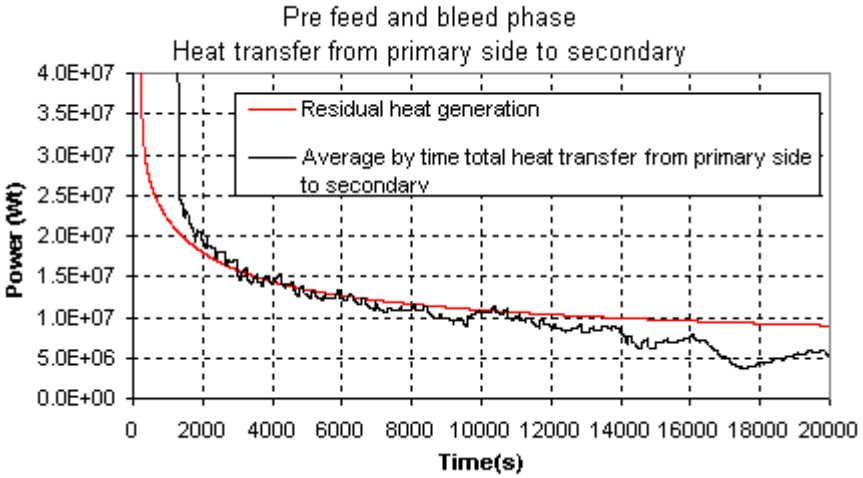
Results cont'd

- Pre-F&B Phase
  - The reactor was cooled by the natural circulation in the primary loop, which was sustained by the remaining water in the secondary sides of the SGs.
  - As the SGs lose water and their levels decreased the heat removal from the primary side through the SGs became degraded due to the decrease of heat exchange surface in the SGs.
  - Eventually, the remaining water in SGs was depleted, and the heat generation rate on the primary side began to exceed the heat removal rate through SGs.

Results cont'd

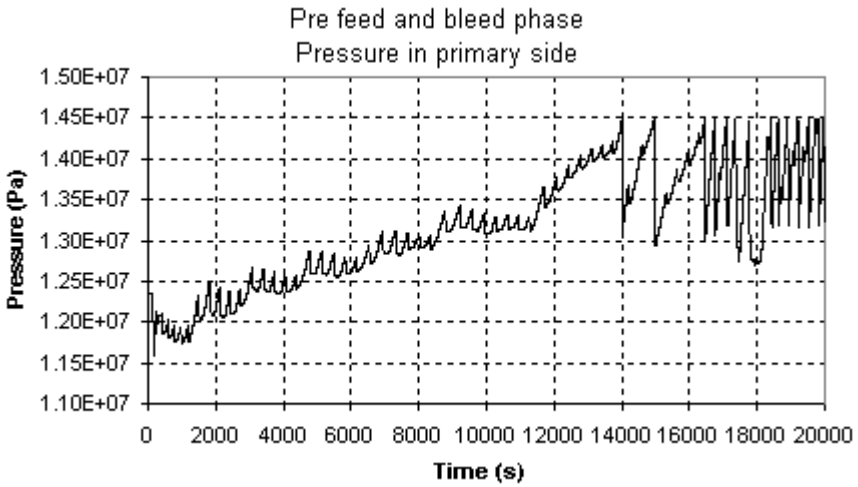
- Pre-F&B Phase

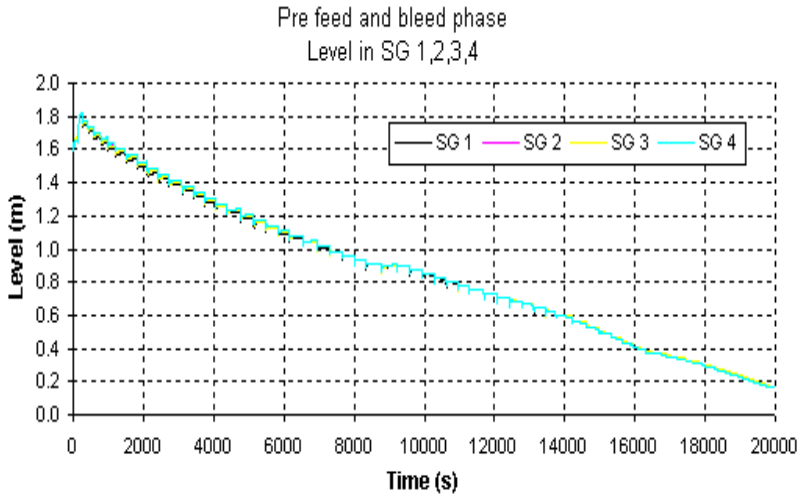




Results cont'd

- Pre-F&B Phase





Results cont'd

- Pre-F&B Phase
  - During the whole period of calculation, the boiling in the reactor was not observed.
  - Hot pin temperature stayed below saturation temperature.
  - The heat generation rate on the primary side began to considerably exceed the heat removal rate through SGs at about 1.1×10^4 sec.
  - The operator should either restore the residual heat removal through the secondary side, or initiate the F&B procedure before this time.

Results cont'd

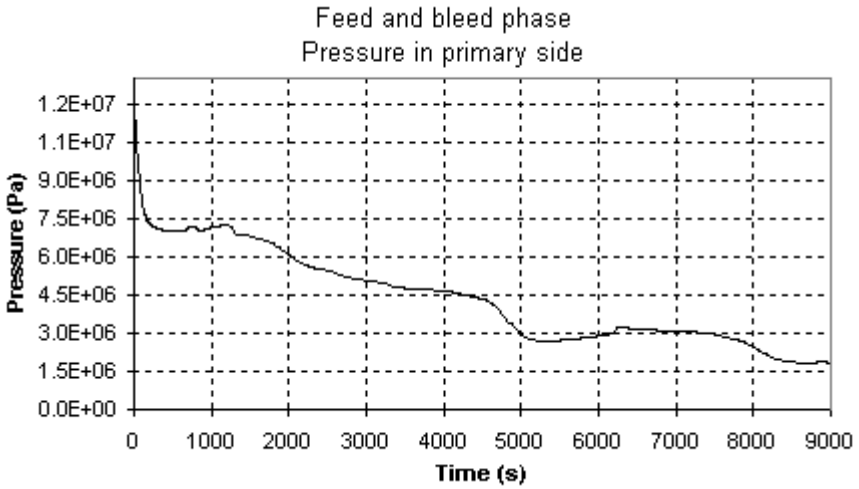
- F&B Phase
  - The F&B operation began at 1.1×10^4 seconds after scram, which was near the point when the remaining water in SGs was depleted and the heat generation on the primary side considerably exceeded the heat transfer through SGs to the secondary sides.
  - The F&B procedure was initiated by simultaneously opening one PRZ SV and starting one train of HPI (two HPI pumps).
  - The calculation was performed for 9×10^3 seconds from the beginning of the F&B procedure.
  - The PRZ SV was constantly in the open state through which the steam-water mixture was discharged into the confinement.

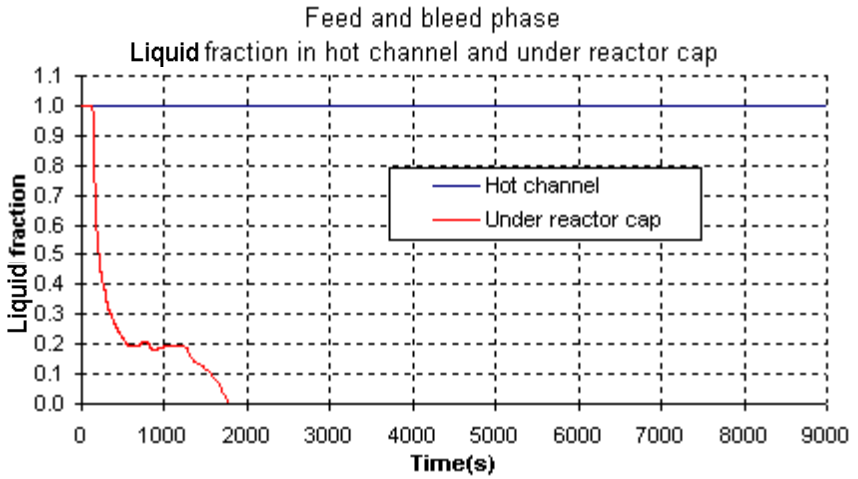
Results cont'd

- F&B Phase
  - Upon beginning of F&B, the primary pressure rapidly decreased as the PRZ SV opened and relieved the steam.
  - The primary pressure and temperature during the F&B continued to decrease until the plant was brought to a safe shutdown condition.

Results cont'd

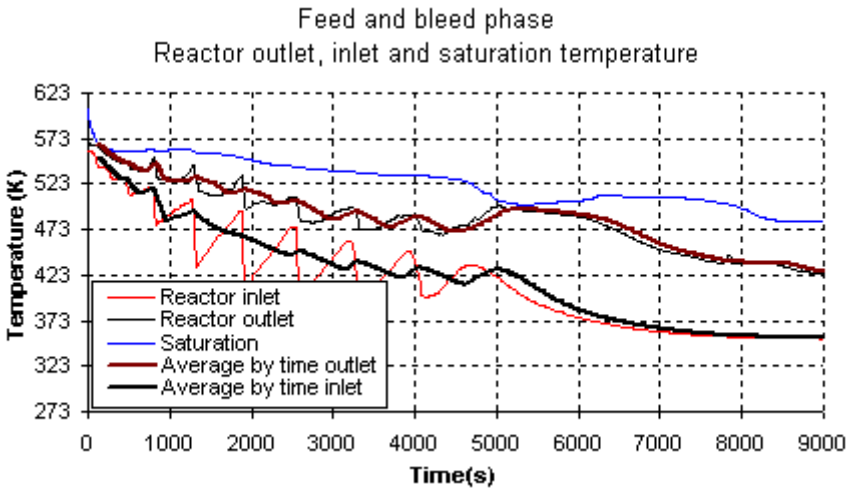
- F&B Phase





Results cont'd

- F&B Phase



- Oscillations of the primary loop temperature and flow rates are observed in the initial 4000 seconds of the F&B phase. They occur when a mixture level in the header of the SGs crosses the node boundary and moves from one node to the next node.
- We believe the oscillations are numerical.

Conclusions

- In the beginning of the transient, the core is cooled by natural circulation in the primary loops supported by the remaining water in the SGs. This state would last more than 3 hours.
- Beyond this period, the F&B operation can sustain the plant cooling for several more hours without the BWST water temperature exceeding the saturation temperature.
- During the F&B operation, the primary pressure and temperature continue to decrease.
- The feed and bleed operation is capable of maintaining the plant in coolable condition for several hours, and the operator would have an adequate time to restore the SG feedwater supply.

Acknowledgment

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