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WRAP-PWR-EM SYSTEM DEVELOPMENT AND APPLICATIONS

by

F. Beranek

Savannah River Laboratory
E. I. du Pont de Nemours & Co.
Aiken, SC 29801

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SUMMARY

The WRAP-EM system is a complete computational system for analysis of loss-of-coolant accidents (LOCAs) in light-water power reactors. The system has been developed for use by the Nuclear Regulatory Commission in evaluating and interpreting reactor vendor model methods and results.

WRAP-EM has the capability of predicting fuel parameters during the normal operation of a reactor, performing thermal-hydraulic initialization of the reactor system, analysing the behavior of the reactor core during an accident (encompassing the blowdown, refill, and reflood stages), and executing a detailed transient thermal analysis of the hottest pin in the core during the accident. A minimum amount of user intervention is required throughout the analysis.

WRAP-PWR-EM is the integrated system of codes used for the analysis of pressurized water reactors (PWRs). GAPCON-THERMAL-2 is used to initialize fuel parameters as a function of reactor operating time. Both the blowdown and reflood phases of an accident are analyzed by RELAP4/MOD5. The refill calculation is based on a simple accumulator flow model (FLOW4) developed at NRC, and the hot-pin analysis is performed by FRAP-T4-LACE. The automated transfer of relevant data from one code to another is accomplished through interface routines developed at SRL (except RELAP4/MOD5-FLOOD to FRAP).

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Because different fuel models are used in the various codes, it is important to ascertain that the conditions predicted at a given time by two different codes are similar. In particular, at the time of accident initiation, the fuel parameters determined by RELAP and FRAP must be similar to, and more conservative than, the parameters predicted by GAPCON. The conservatism requirement is set for licensing concerns. Results achieved using Zion fuel indicate that fuel temperatures predicted by RELAP and FRAP are more conservative than the GAPCON predictions.

The refill portion of the transient is that time during which the lower plenum is being filled with water until the liquid level reaches the bottom of the core. Analysis of this period by RELAP requires very small calculational time-steps. An alternative technique has been developed based on a simple accumulator flow model. Within the refill period, the core is assumed to heat up adiabatically. The core thermal response is calculated by continuing the RELAP4 calculation with the hydraulics calculation bypassed. The lower plenum subcooling, which is required as input to the flood calculations, is calculated by a mixed-average, bulk-fluid, temperature calculation. Several assumptions relating to heat transfer during this period have been made to decrease the computational time. Results of sensitivity studies to determine conservative estimates of these parameters will be presented.

The system is presently being evaluated by analyzing various LOFT experiments and the Zion reactor. Results of these analyses will be discussed. Future plans include performing pre-test analyses on the LOFT L2 series experiments as well as reference and sensitivity studies regarding the Zion facility.

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WRAP-PWR-EM DEVELOPMENT AND APPLICATIONS

F. BERANEK
SAVANNAH RIVER LABORATORY

OUTLINE

I. System Description

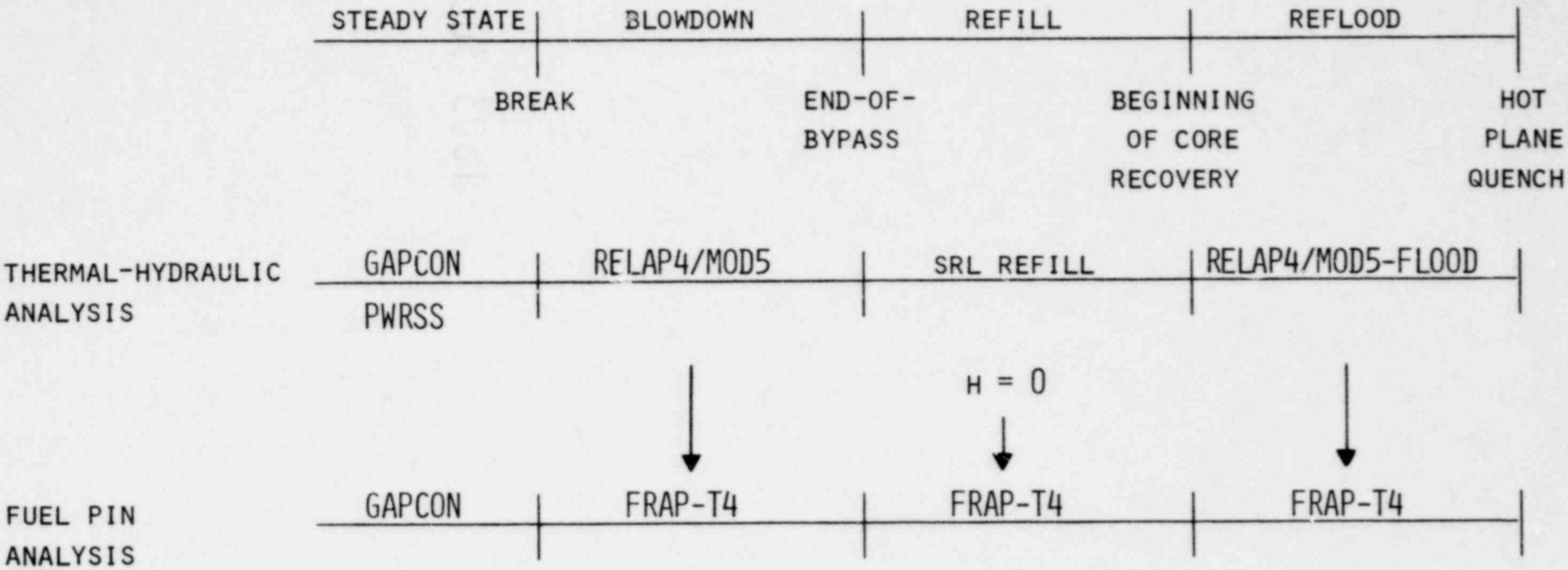
II. Fuel Model Consistency

III. Refill

IV. Analyses
- LOFT
- ZION
- FLOOD Sensitivity

V. Program

PWR ANALYSIS SCHEME



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GAPCON-FRAP CONSISTENCY AT HOTTEST AXIAL NODE

Burnup = 13000 MWD/MT

	GT2[1]	F4L[2]
Centerline Temperature (°F)	3159	3285
Fuel Surface Temperature (°F)	1540	1588
Gap Conductance (BTU/hr-ft^2-°F)	374	356
Gap Pressure (psi)	1204	1238
Stored Energy (BTU/lb)	163	170

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[1] GT2 ≡ GAPCON-THERMAL-2

[2] F4L ≡ FRAP-T4-LACE

GAP CONDUCTANCE

FRAP (Open gap)

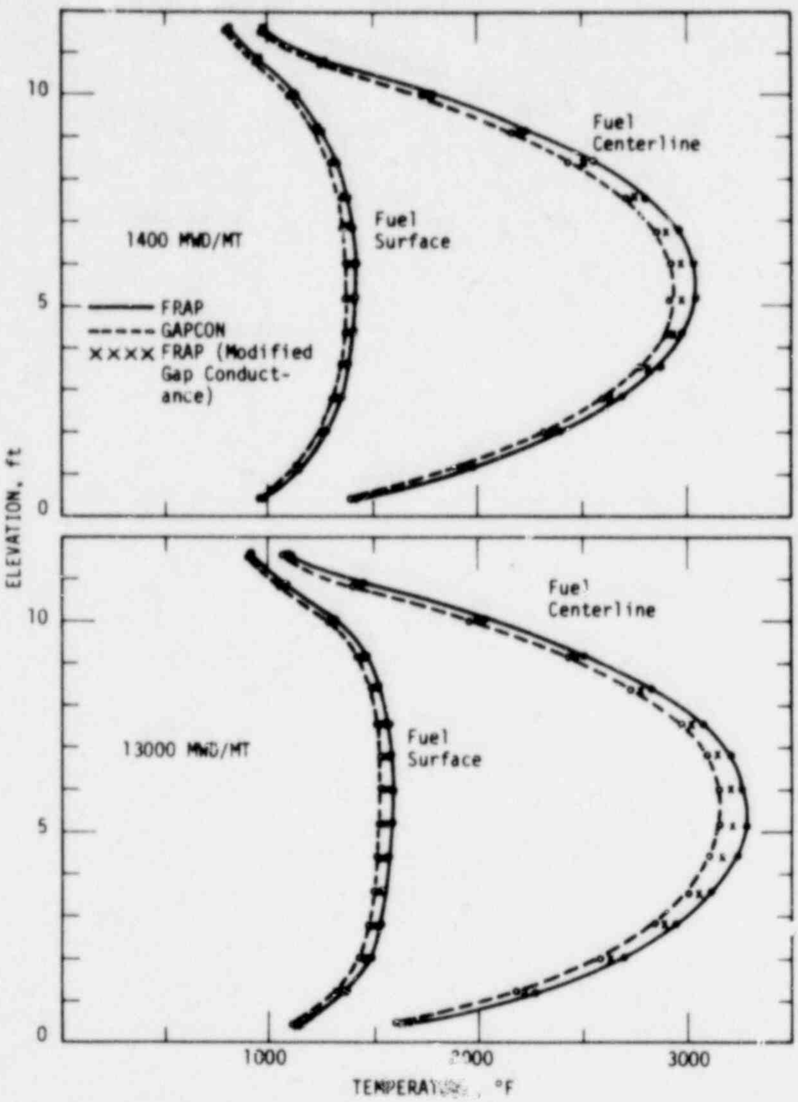
$$h = \frac{k}{\Delta X + g + 1.98R} + h_r$$

GAPCON (Open gap)

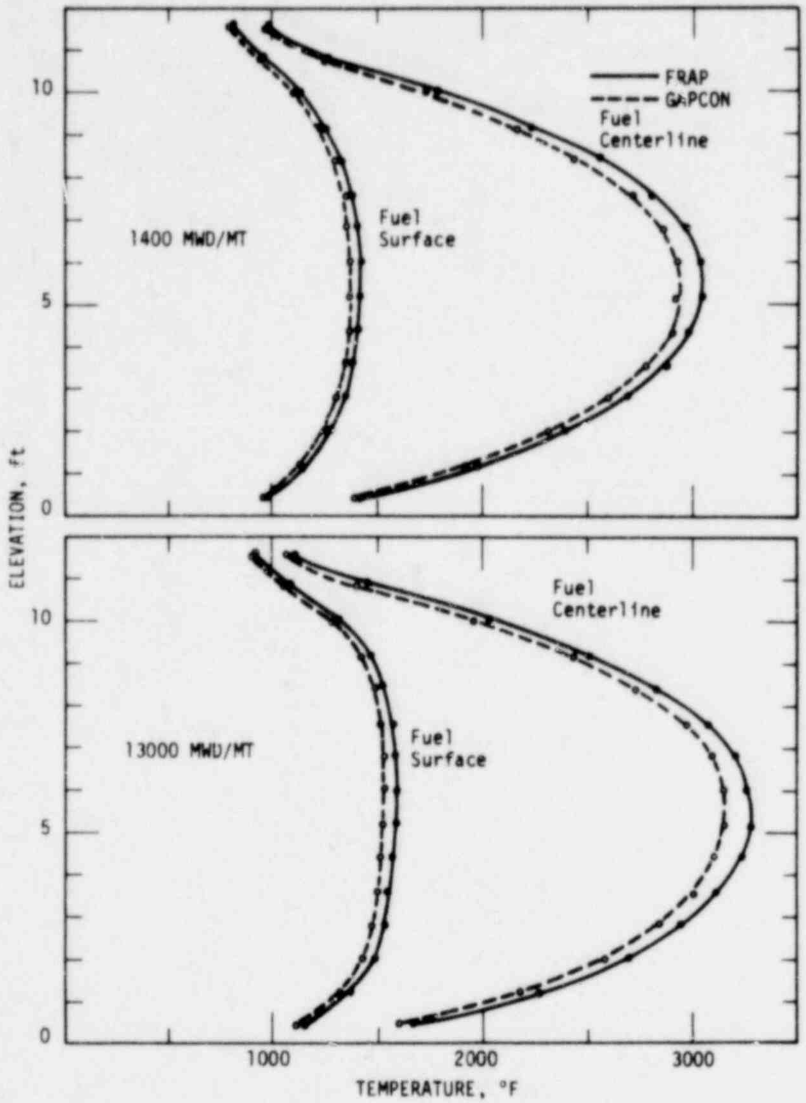
$$h = \frac{k}{\Delta X + g'} + h_r$$

k	$\equiv$	thermal conductivity of gas
g and g'	$\equiv$	temperature jump distances
ΔX	$\equiv$	gap width
R	$\equiv$	average roughness
h_r	$\equiv$	radiation term
h	$\equiv$	gap conductance

GAPCON-FRAP Fuel Temperatures



GAPCON-FRAP Fuel Temperatures



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REFILL

- RELAP calculation prohibitive
- FLOW4 - Simple accumulator flow model
- Core thermal model - Adiabatic heatup
- Mixed average bulk fluid model

GAPCON-FRAP CONSISTENCY AT HOTTEST AXIAL NODE
WITH MODIFIED GAP CONDUCTANCE CORRELATION

Burnup = 13000 MWD/MT

	GT2[1]	F4L[2]	F4LM[3]
Centerline Temperature (°F)	3159	3285	3234
Fuel Surface Temperature (°F)	1540	1588	1550
Gap Conductance (BTU/hr-ft^2-°F)	374	356	372
Gap Pressure (psi)	1204	1238	1222
Stored Energy (BTU/lb)	163	170	166

[1] GT2 ≡ GAPCON-THERMAL-2

[2] F4L ≡ FRAP-T4-LACE

[3] F4LM ≡ FRAP-T4-LACE MODIFIED

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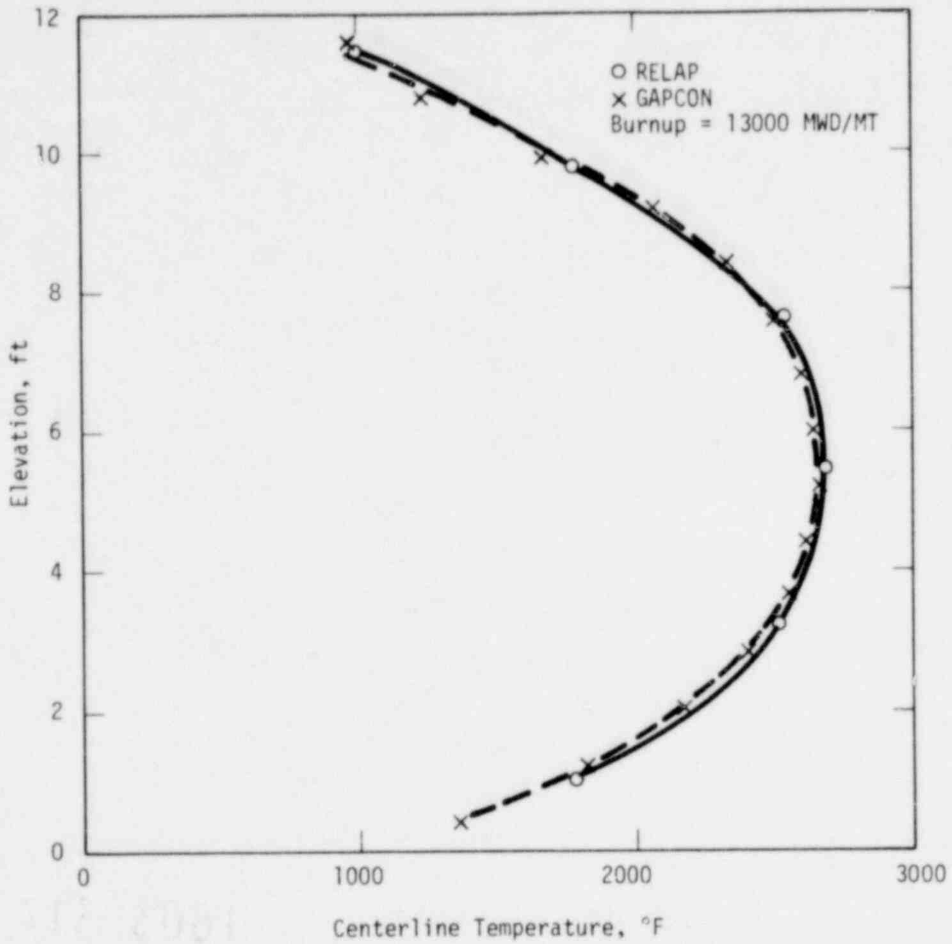
GAPCON-WRAP(RELAP) Fuel Temperature Comparison



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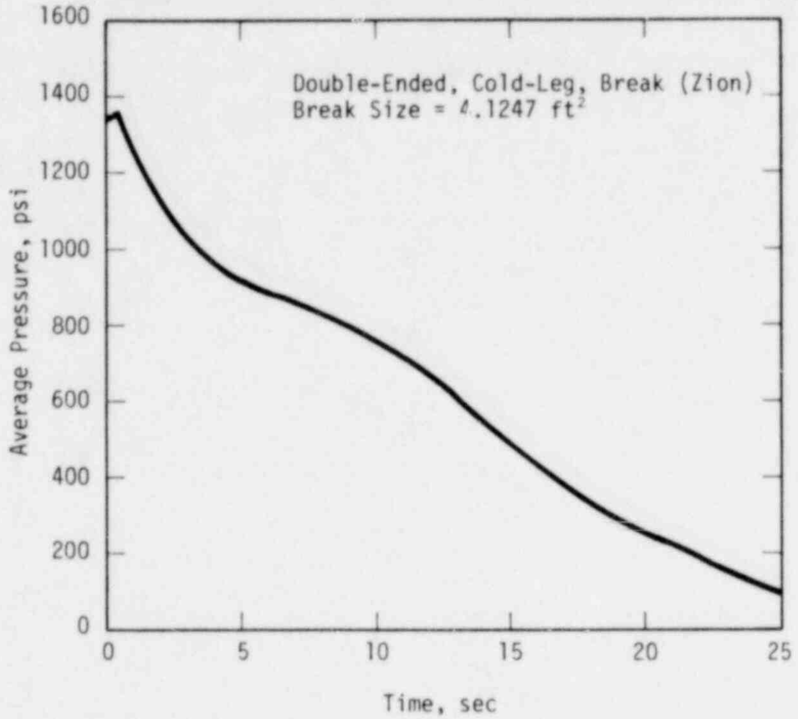
Lower Plenum Pressure



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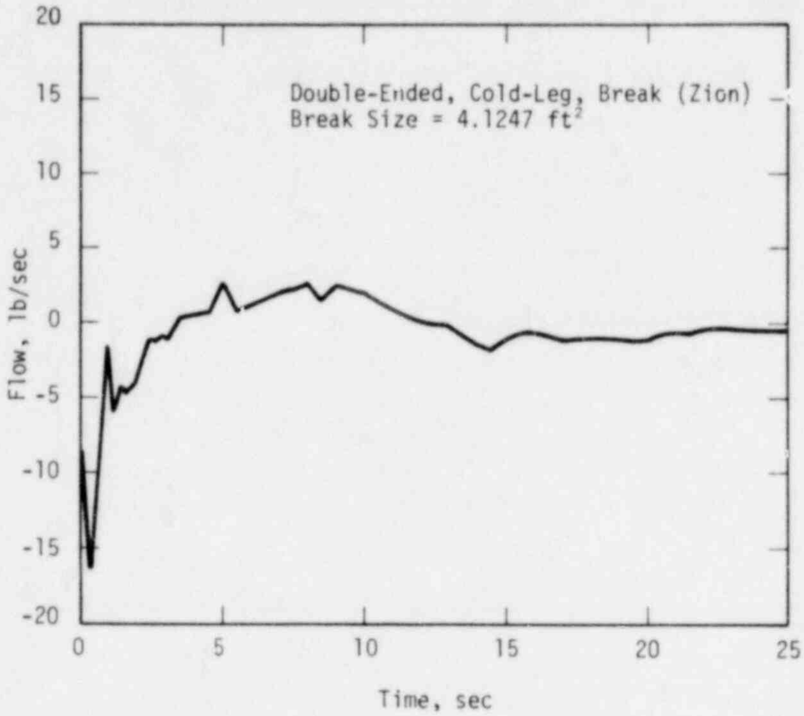
Zion Core Flow



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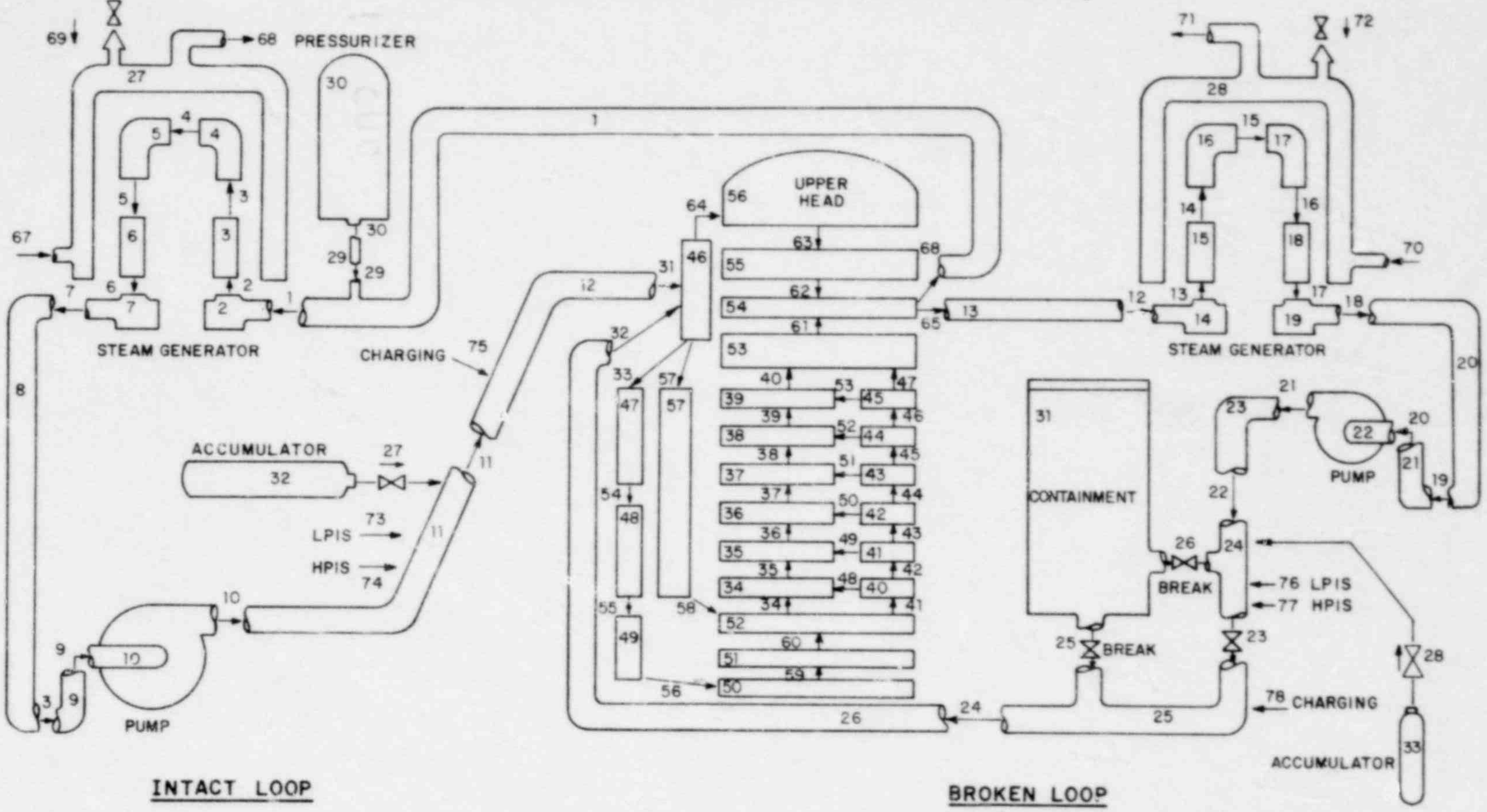
System Nodalization (Zion Plant)



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PROGRAM

- PWR System Checkout and Evaluation
- Verification Studies
  1. LOFT (L1-5 and L2-3)
  2. Semi-scale (S-06-03 and MOD3)
  3. Zion
- WRAP Analysis for NRC
  1. LOFT Pre-test Calculations
  2. Reference and Sensitivity Studies
  3. NRC Licensing Concerns