Modeling of Boiling Water Reactors

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Organization

BWR Modeling and Model Assessment Session Agenda

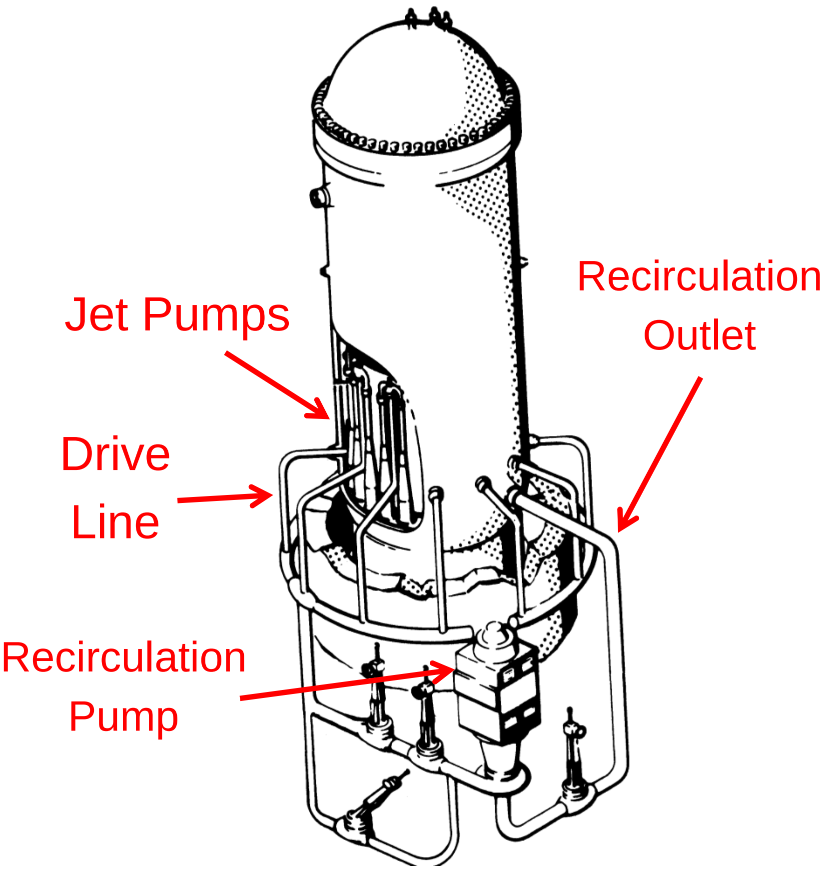
1. Model Overview
2. Determining Key Analysis Parameters
3. Important BWR Phenomena
4. BWR Specific Components
5. Steady State Model
6. LBLOCA Simulation

Jet Pumps

Jet Pumps are used in operating BWR plants to drive recirculation flow in the vessel. BWR/3 through BWR/6 designs use jet pumps. A typical BWR has 20 jet pumps split between two recirculation loops.

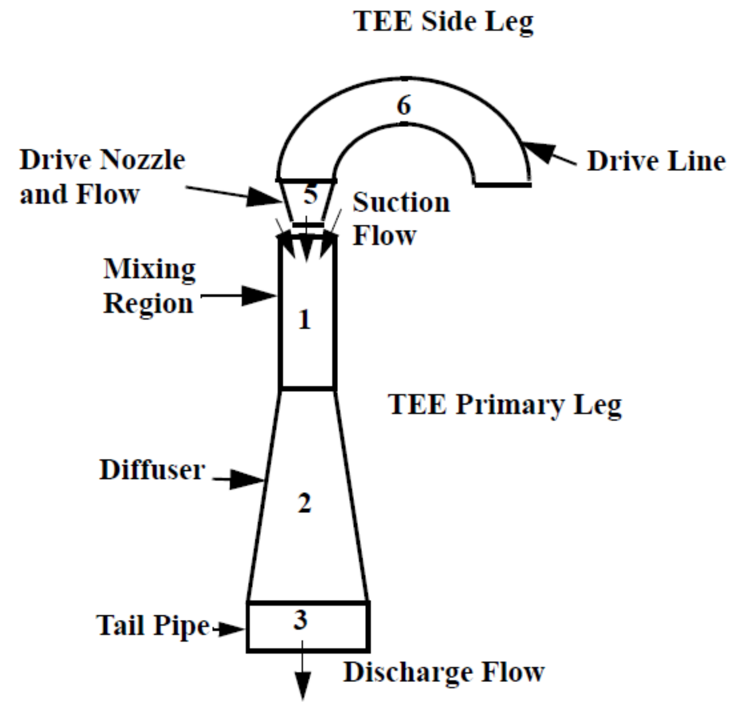
The vessel downcomer is isolated from the lower plenum. The jet pumps penetrate the downcomer plate. Thus flow from the downcomer must flow through the jet pumps to enter the downcomer.

Flow through the jet pumps comes through the drive line and is maintained by the recirculation pump.

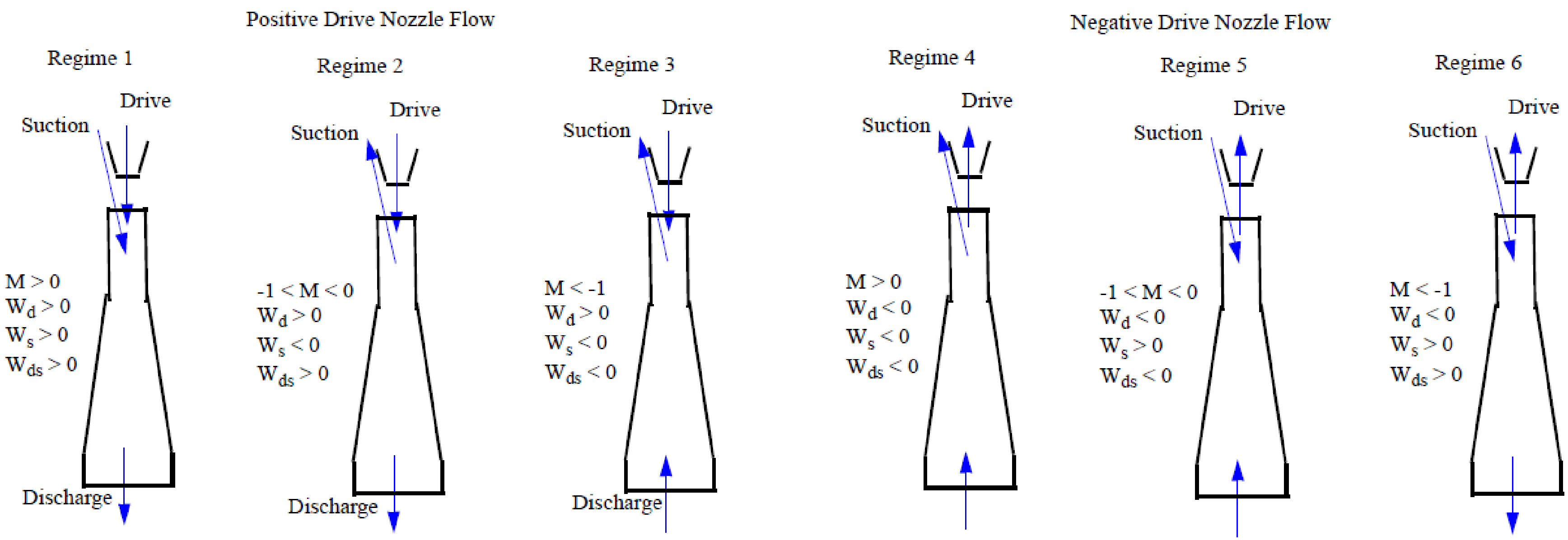


JETP Component

- Special case of a TEE component
- Internal models for simulating flow losses, mixing losses, and pressure recovery
- Diffuser expansion loss and Nozzle contraction loss models are applied at all internal edges, user inputs are overwritten
- User input losses applied at the external edges of the JETP and are not overwritten



JETP Modes of Operation



Jet Pumps

- JETP Additive Losses

Regime	Mixing Losses $\frac{\Delta P}{\rho(V_d)^2}$	Nozzle Losses $\frac{\Delta P}{\rho(V_d)^2}$	Suction $\frac{\Delta P}{\rho(V_s)^2}$
1	0	0	0
2	$-0.3 \cdot M^2$	$[M \cdot (0.08 \cdot M - 0.06)]$	0
3	$-(0.1 - 0.0333 \cdot M)$	$Min[2.5\ ,\ M \cdot (0.08 \cdot M - 0.06)]$	0
4	0	$Max[0\ ,\ 0.48 - M \cdot (0.33 - 0.055 \cdot M)]$	0
5	0	$[0.48 - M \cdot (0.33 - 1.74 \cdot M)]$	$\left(\left(\frac{A_s}{A_{ds}}\right)^2 - 1\right)$
6	0	2.55	$\left(\left(\frac{A_s}{A_{ds}}\right)^2 - 1\right)$

Jet Pumps

- M Ratio

$$M = \frac{W_s}{W_d}$$

Where,

W_s = Suction mixture mass flow rate,
W_d = Drive mixture mass flow rate

- N Ratio

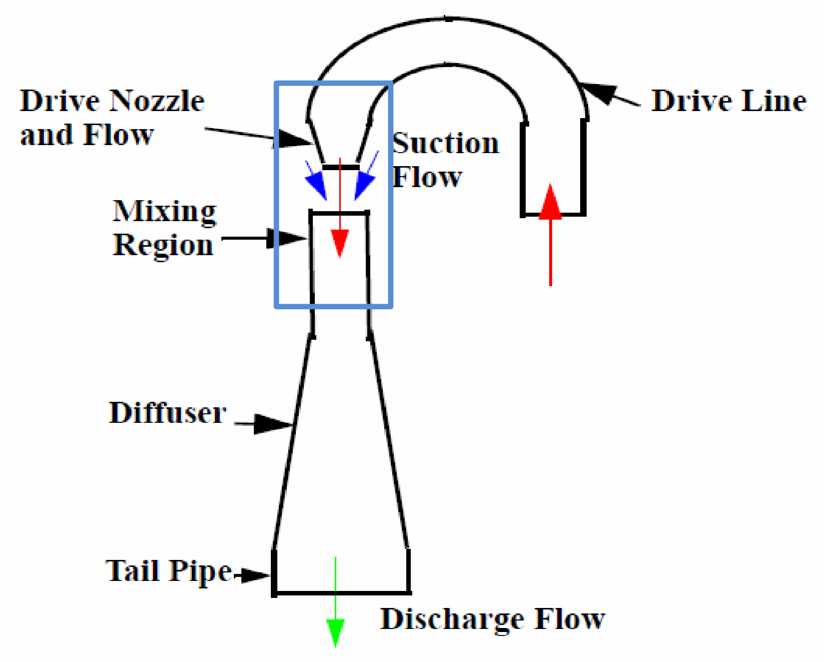
$$N = \frac{P_{ds} - P_s}{P_d - P_{ds} + rho * V_d^2}$$

Where,

P_{ds} = pressure in the discharge of the jet pump,
P_d = pressure in the drive line of the jet pump,
P_s = pressure in the suction of the jet pump,
V_d = velocity in the drive nozzle,
ρ = density in the drive nozzle,

Jet Pumps

Forward and Reverse flow losses and critical flow (likely through the nozzle in the broken loop) were ranked as being of high importance in the PIRT for LOCAs.



Jet Pumps Losses

The TRACE jet pump model calculates K loss coefficients internally for the nozzle and diffuser based on Idel'Chik irreversible loss factors for contraction and expansion through a smooth area change.

Expansion Losses

$$K_E = C_E (\tan\alpha)^{1.5} (1 - A^*)$$

Contraction Losses

$$K_C = C_C \sin\alpha (1 - A^*)$$

$$K_E \ \& \ K_C = Expansion \ \& \ Contraction \ \ K \ Loss \ Factor$$

$$C_E \ \& \ C_C = Expansion \ \& \ Contraction \ \ Const. \ (TRACE \ \ Inputs)$$

$$\alpha \qquad = Expansion \, / \, Contraction \ \ Angle$$

$$A^* \qquad = Area \ Ratio \ of \ \ Outlet \ (A_o) \ to \ Inlet \ (A_i) \ Flow \ Areas \ (where \ A_o \le A_i)$$

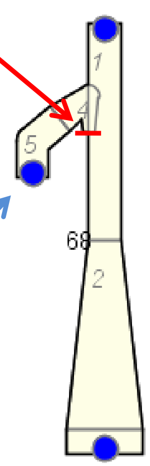
The nozzle and diffuser each have an expansion and contraction constant C_E and C_C. These are called Forward and Reverse Formloss in SNAP. A suction formloss and Discharge formloss are also specified. These are direct K loss values.

Jet Pumps Inputs

In the Jet Pump model, user defined K losses specified via the ‘Friction’ dialog in SNAP are ignored at all internal edges. K losses can be set at the inlet, outlet and recirculation boundary edges (identified by blue circles below). Choking should be set at the jet pump nozzle edge for LOCA events.

Vessel Downcomer

Nozzle Edge Set Choking Flag for LOCAs



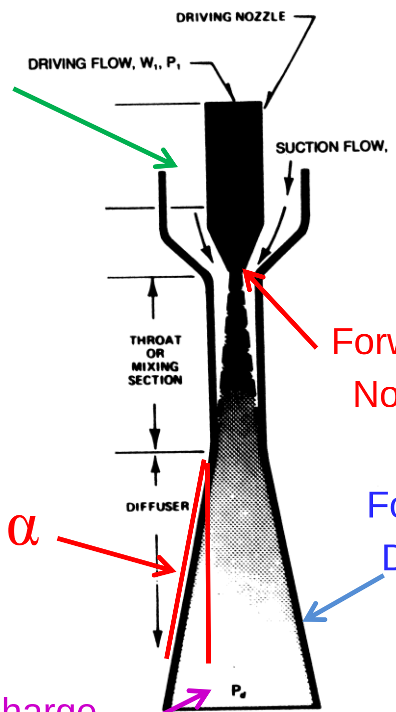
Recirculation Loop

Vessel Lower Plenum

JetPump 68 (loop b jet pumps)

Number Of Jetpumps	10	
Forward Diffuser Formloss	5.5	(-)
Reverse Diffuser Formloss	0.38	(-)
Forward Nozzle Formloss	5.5	(-)
Reverse Nozzle Formloss	3.5	(-)
Suction Formloss	0.04	(-)
Discharge Formloss	0.45	(-)

Suction Formloss



Forward & Reverse Nozzle Formloss

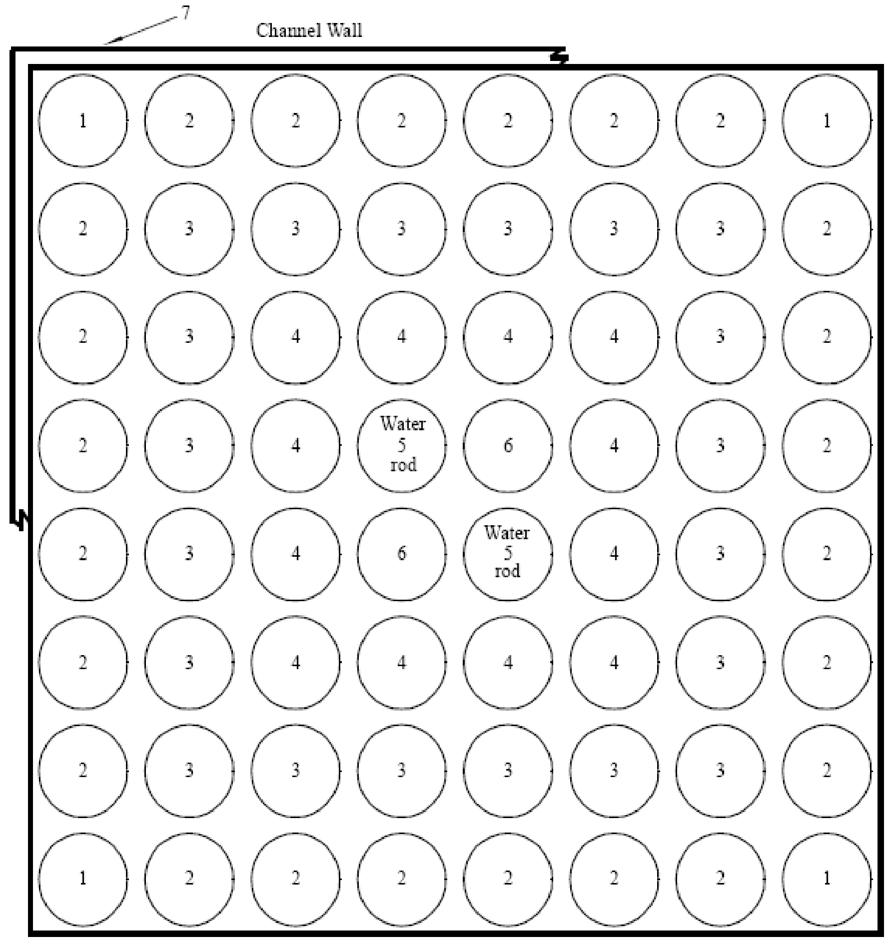
α

Forward & Reverse Diffuser Formloss

Discharge Formloss

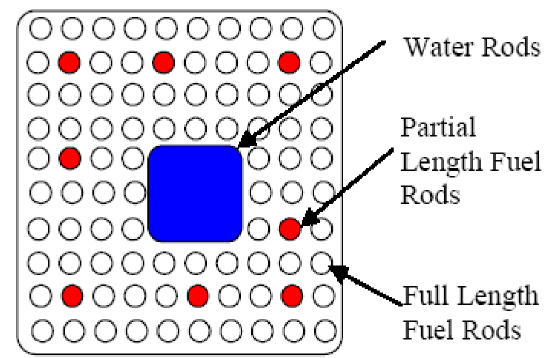
CHAN Component

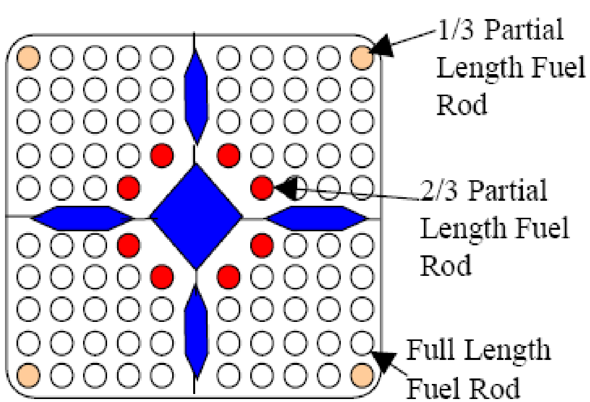
- Models BWR channels.
- Leak paths into bypass region can be modeled
- Automatically computes radiation view factors and path lengths for all BWR channel types
    - Ray tracing method
    - Cross String method

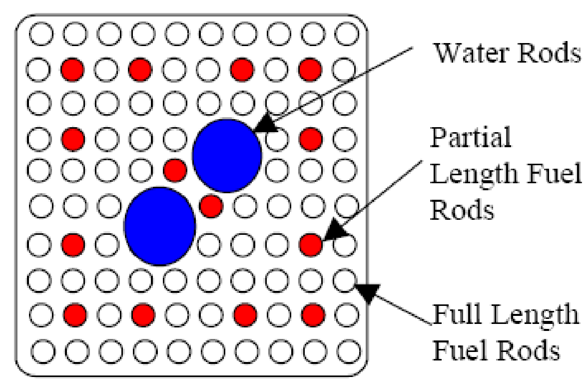


CHAN Component

All modern BWR fuel types are supported by the CHAN component

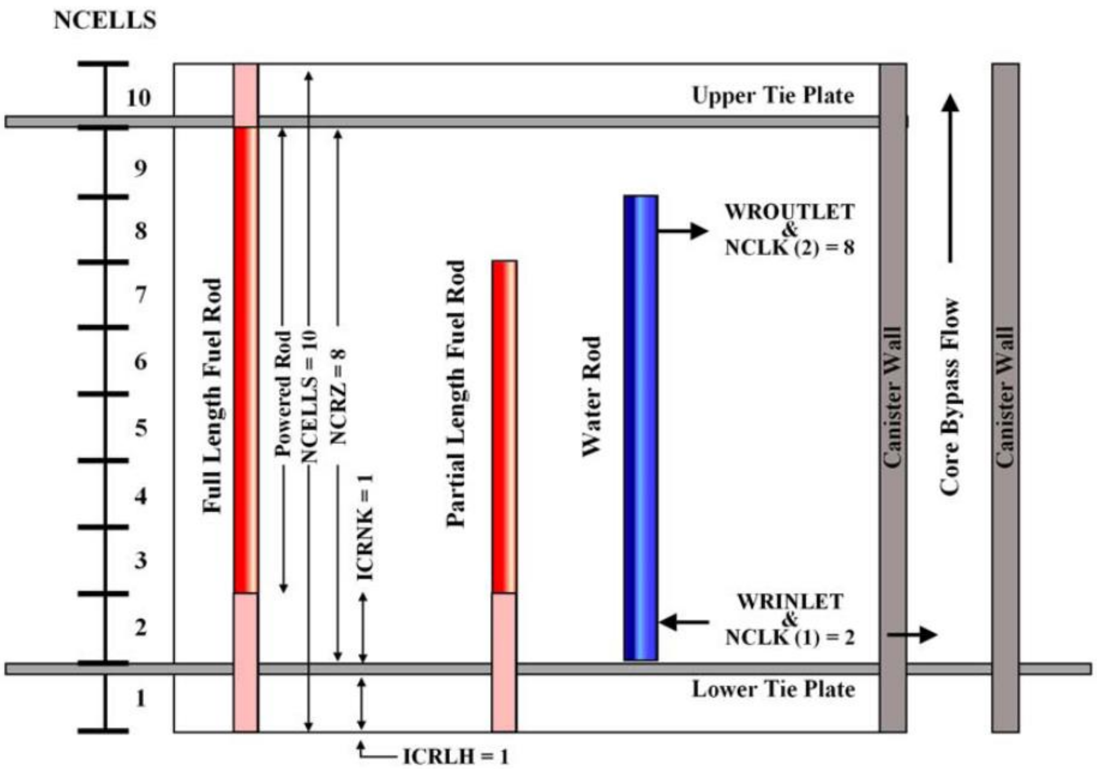






CHAN Component

- CHAN is a compound component
  - consists of PIPEs, HTSTRs, and RADENC that are spawned internally
  - Book-keeping of spawned component numbers is important for tracking output



CHAN Component

In the previous exercise, a Radial Power Profile and radiation properties were configured for the core. The CHAN also supports configuration for advanced fuels through the addition of **water rods** and **partial length rods**.

For partial length rods, the highest numbered axial cell where power is applied is specified in the rod group.

When TRACE is coupled with PARCS, **gamma direct heating** to the channel flow, water rod flow, and bypass flow can be specified.

Exercise

Do the‘**Modeling Jet Pump Losses and Advanced Fuels**’ exercise (BWR-4-Exercise.pdf).