TRACE Thermal-Hydraulic Components

Information Systems Laboratories, Inc.

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Objective

Provide basic information about the commonly used components in TRACE.

TRACE Hydrodynamic and Thermal Components

TRACE Thermal-Hydraulic components are the basic building blocks of an input model

There are 22 components available. The most commonly used components include:

- PIPE
- BREAK
- FILL
- VALVE
- PUMP
- TEE
- CONTAN
- HTSTR
- POWER
- CHAN
- JETP
- SEPD
- VESSEL

Dissecting a TRACE Component

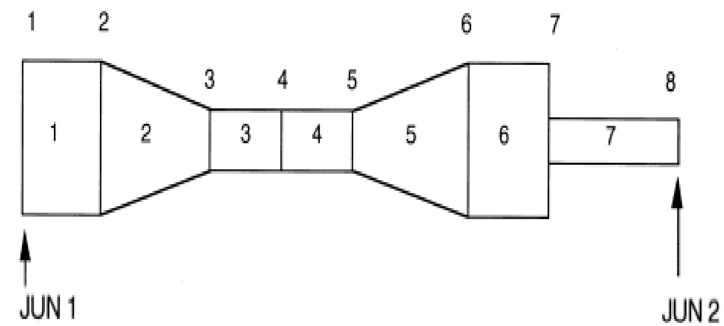
- Common Modeling Capabilities
  - Geometry & Orientation
  - Specifying different working fluids
  - Side junctions
  - Power to the fluid
  - Power to the wall
  - Wall heat transfer
  - Wall Friction and Irrecoverable losses
  - Modeling Flags (Choked Flow, CCFL, CHF, etc)

TRACE Component Control

- Pressure and fluid-state boundary condition.
- Velocity or mass-flow and fluid-state boundary condition.
- Reactor-core programmed reactivity or power.
- Reactor-core axial-power shape.
- Energy deposition directly in the coolant.
- Energy generation in the hydro-component wall.
- Pump-impeller rotational speed.
- Turbine power demand.
- Valve flow-area fraction or relative stem position.

PIPE Component

- Most basic 1D component
  - Allows arbitrary 1D connectivity
  - Single Junction is a PIPE with zero cells (SJC)
  - Abrupt or smooth area changes can be modeled
  - Can model dead-ends
  - Multiple CHF options are available
  - Special modeling options through use of PIPETYPE flag:



- Accumulator
- Rod bundle (reflood)
- Falling film condensation
- Wall condensation as in drywell
- Pressurizer
- Accumulator
- Helical coils
- CANDU horizontal pressure tube fuel bundles

BREAK Component

- Several modeling scenarios
  - Modeling inflow/outflow between a piping system and a large volume
  - Modeling a location in a test section where the pressure distribution is known as a function of time
  - Establishing a pressure difference across a test section or piping network as a means of driving flow across it
  - Modeling a mass flow boundary condition (in combination with an SJC PUMP and use of active break option)

- BREAK Modeling Options
  - Constant Boundary Conditions
  - Table Driven Boundary conditions
  - Control System Driven Boundary Conditions
  - Containment-Coupled BREAK
  - Saturation Temperature Use Option
  - Active BREAK

BREAK Component (continued)

- Calling Choke Flow
  - ICFLOW = 1 will turn on choked flow at all BREAK junctions
  - Default subcoled and saturated discharge coefficients are used (1.0, 1.0)

- A BREAK may not be connected directly to a VESSEL, FILL, or PLENUM component.

FILL Component

- Provides a mass flow boundary condition

- 11 Types that control the FILL Behavior
  - Control System Driven (with or without slip = 1)
  - Constant Velocity/Mass Flow/Generalized State
  - Table-driven Velocity/Mass Flow/Generalized State
  - Trip-controlled Table of Velocity/Mass Flow/Generalized State

- Can be used as a zero-velocity to serve as a dead-end

- Do not directly connect to a VALVE

VALVE Component

- Modeling options
  - Flow area/stem position vs. independent variable
  - Flow area controlled by control system
  - Trip-controlled (open until trip, closed until trip, override trips)
  - Check valves
  - SRV valve banks
  - Motor controlled valves
  - Inertial swing valve
- Be careful – VALVE losses can be tricky
  - Can cause unrealistic un-choking times
  - Internal additive flow loss
- Avoid "chattering" VALVEs!!
  - Possible during slow depressurization transients whereby pressure difference across the valve fluctuates rapidly
  - Use trip setpoint delays
- Valve area action takes place at user specified cell face when ncells is greater than 0 (ncells equal to zero implies an SJC valve).

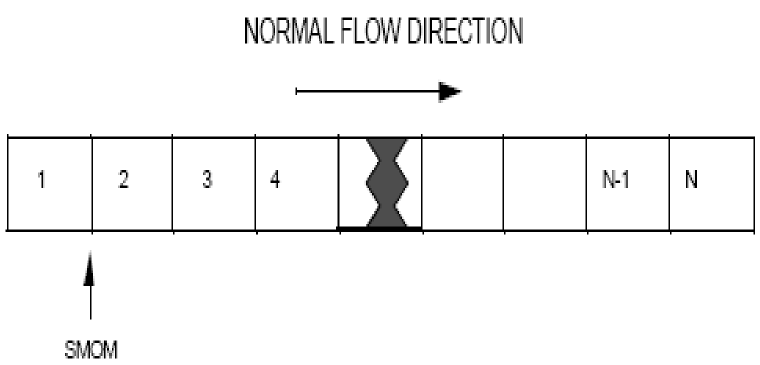
PUMP Component

- Includes fluid cells and internal flow faces, piping wall heat structures, a momentum source at one face, and models for speed control (user-specified speed or inertial coast-down).

- Momentum source term at Face 2 based on pump homologous curves.

- Except for the face with the momentum source, the TRACE PUMP Component features are similar to those of a TRACE PIPE Component.

- PUMP may be modeled using only a single junction (SJC-type component) at which the momentum is added (see IPMPTY 10 and 11 in the manual).



PUMP Component (continued)

- The PUMP component describes the momentum interaction between the rotor and the coolant in a centrifugal pump. The basic TRACE PUMP models are the same as used in the TRAC, RELAP5 and RETRAN pump models.
- The model uses a non-dimensional homologous-curve formulation for the relations between:
  - pump head, speed and flow
  - pump torque, speed and flow
- The user may input homologous curve data for a specific pump or use TRACE built-in homologous curve data for:

  Semiscale Mod-1 pump

  LOFT pump

  PWR Bingham-Wilamette pump

  PWR Westinghouse pump
- Data is also input describing control of the pump speed
- Pump heat (resulting from the work performed on the fluid) is included in the model (except currently for the SJC-type pump configuration)

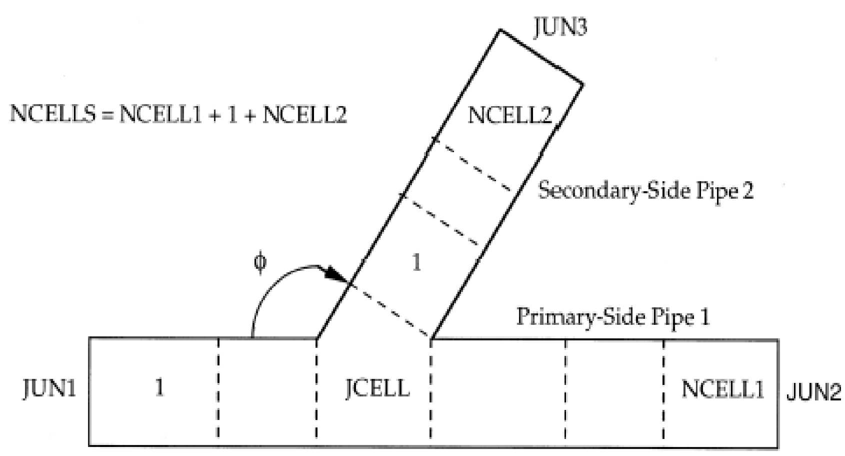
TEE Component

- The TEE component is outdated. Use a PIPE component with side connections as a more flexible approach for flow branch modeling.

- Includes fluid cells and internal faces for a main flow path and a connecting side flow path, and piping wall heat structures for both the main and side paths.

- Junctions to other TRACE components are specified at the two end faces of the main path and at the free end of the side path. The angle between the main and side paths is specified and the momentum solution at the TEE is dependent upon the angle.

Example application: PWR hot leg to pressurizer surge line connection.



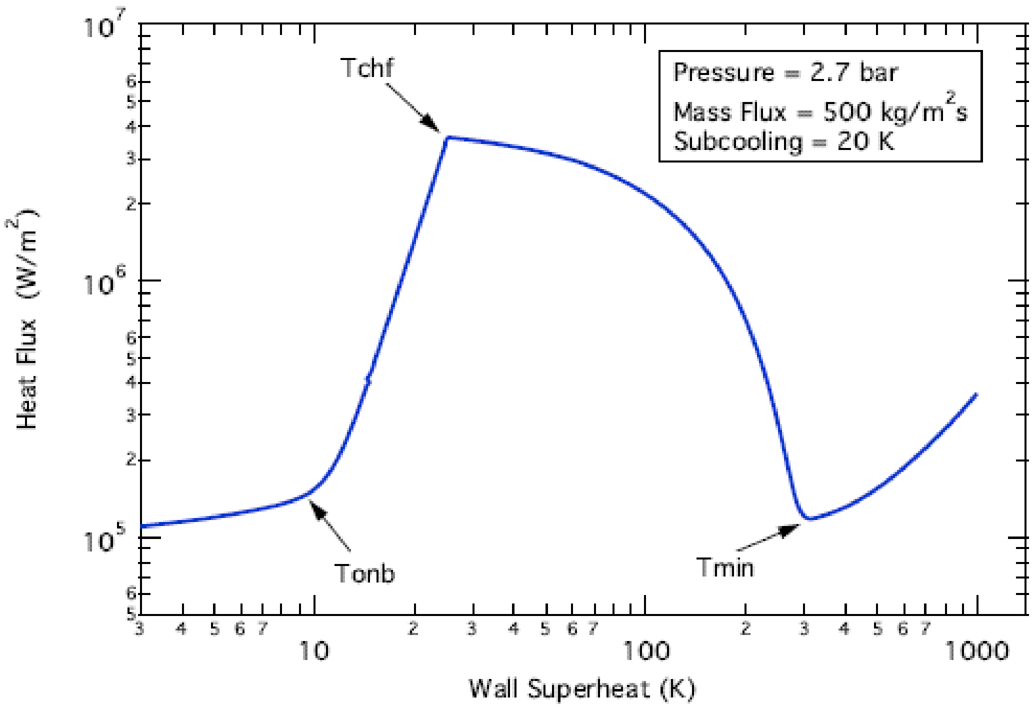
HTSTR Component

- Generic model building block that may be made as specific as needed in order to represent the physical structures of a facility.
- Models heat conduction within structures and can be coupled to fluid components, to other heat structures through radiation, or to specified boundary conditions.
- Lumped parameter or up to 2D conduction in Cartesian, cylindrical, or spherical geometry.
- Fine mesh rezoning based on temperature differences between adjacent mesh cells.
- May be coupled with the POWER component to represent structures with internal heating.
- Can model Zirconium metal-water reaction and fuel cladding interaction gap heat transfer.
- Improved fuel rod models (to be discussed later).
- This structure modeling capability is in addition to existing pipe-wall modeling feature included in many of the TRACE components. It is recommended using the HTSTR component rather than the built-in pipe-wall modeling feature.

Example applications: core fuel rods, piping walls.

HTSTR Component

Heat flux from wall to fluid is calculated using the wall, fluid and saturation temperatures and correlations representing the various regions of the "boiling curve": single phase convection, subcooled nucleate boiling, saturated nucleate boiling, critical heat flux, transition boiling and film boiling.

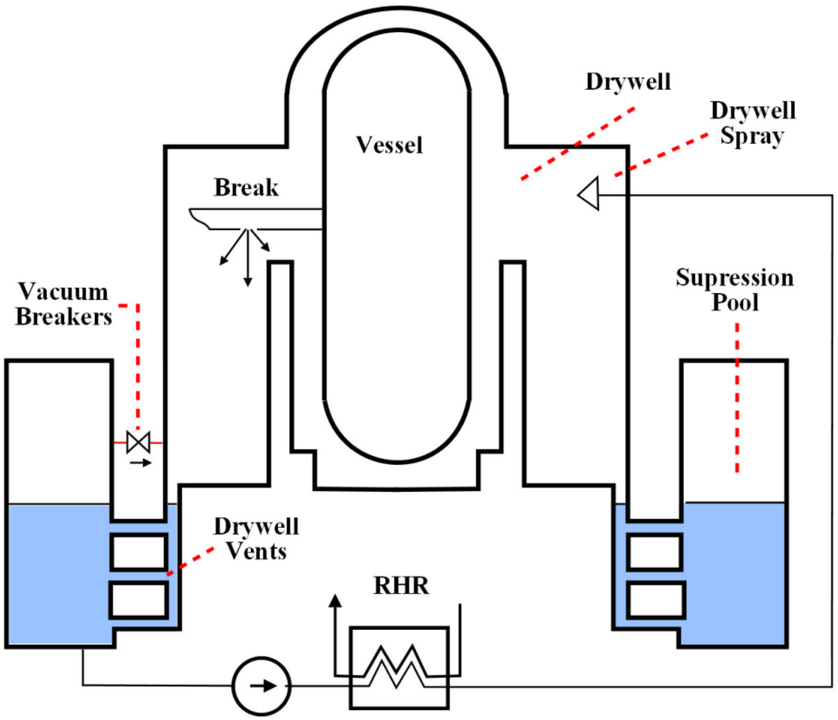


POWER Component

- Supplies power to specified heat structures.
- Can be specified by constant power, time table, control system.
- Point reactor kinetics available.
- ANS 73, 79, and 94 decay heat models available
- Axial power shape can also change in time.
- 3D kinetics available through PARCS

CONTAN Component

- Lumped parameter model,
- Typically used to simulate a BWR containment,
- Models multiple compartments, of a reactor containment,
- Heat structures can be applied to model the physical structures in the containment
- Interacts with the pressure coolant loop via BREAKs and FILLs



CONTAN Component

To simulate the system interactions between the containment and the primary coolant loop (PCL) during a simulated accident, it is necessary to model the mass and energy transport within the containment as well a the PCL. The following physical processes are modeled by the CONTAN component:

a. The pressurization of a large volume due to high-pressure and high temperature fluid discharge,
b. Pressure induced flow among the large containment volumes,
c. Convective heat transfer between containment volumes and the solid surfaces,
d. Interfacial heat transfer between pool and vapor regions by free convection,
e. Interaction between the PCL and containment.

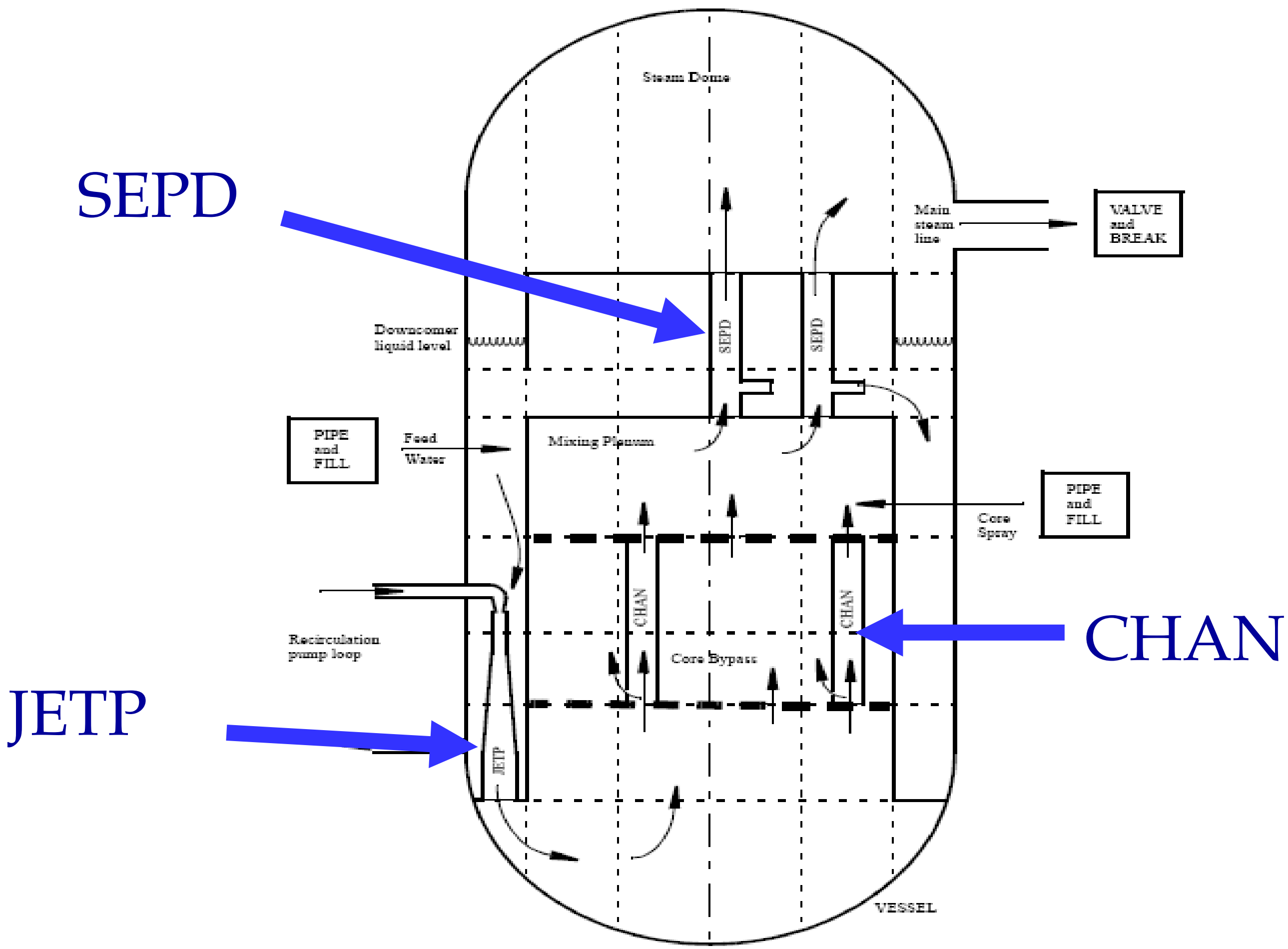
CONTAN Component

The CONTAN component employs the following seven basic component elements to model the containment calculation:

a. Compartment,
b. Heat structure,
c. Cooler,
d. Passive flow junctions,
e. Forced flow junctions,
f. Fan cooler,
g. Source/sink flow junctions

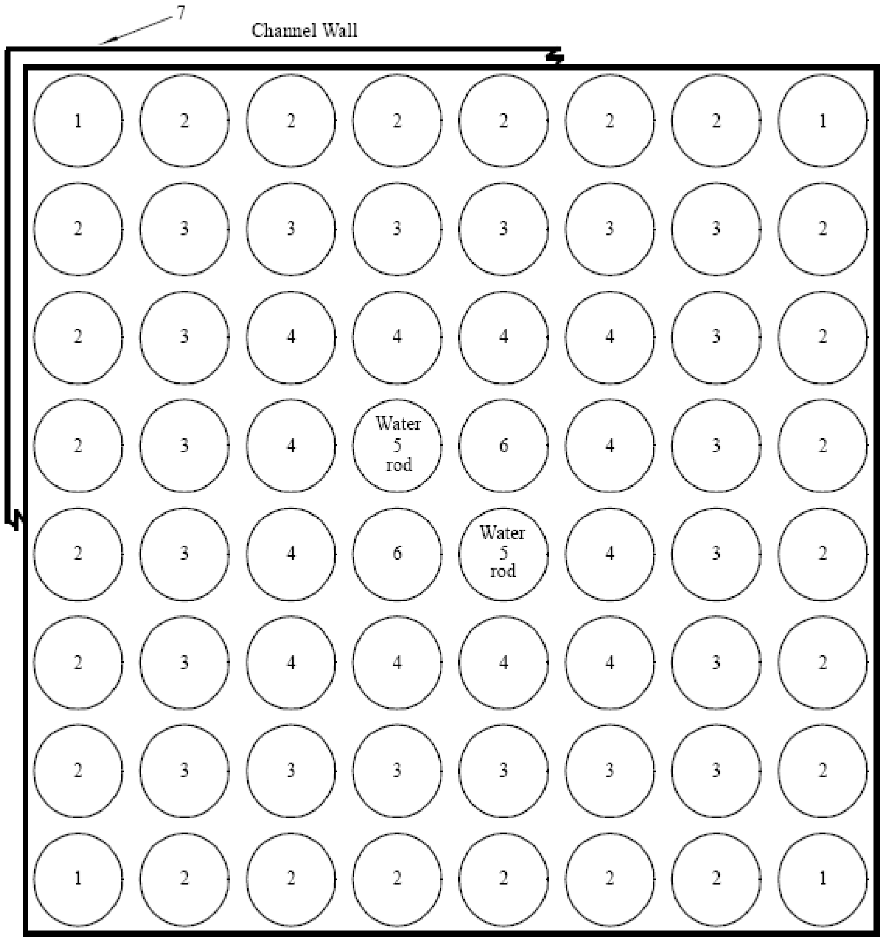
Common BWR Components

- **CHAN**
- **SEPD**
- **JETP**



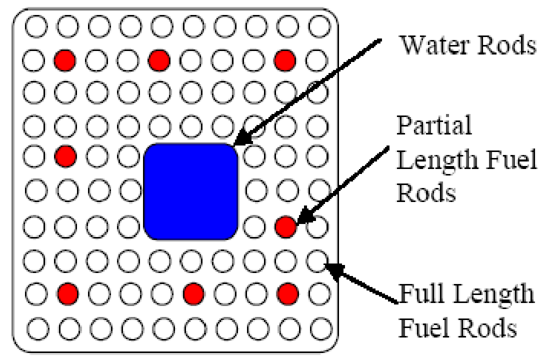
CHAN Component

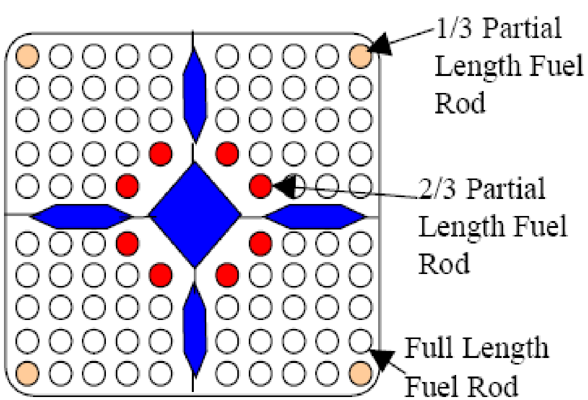
- Models BWR channels.
- Leak paths into bypass region can be modeled
- Automatically computes radiation view factors and path lengths for all BWR channel types
  - Ray tracing method
  - Cross String method

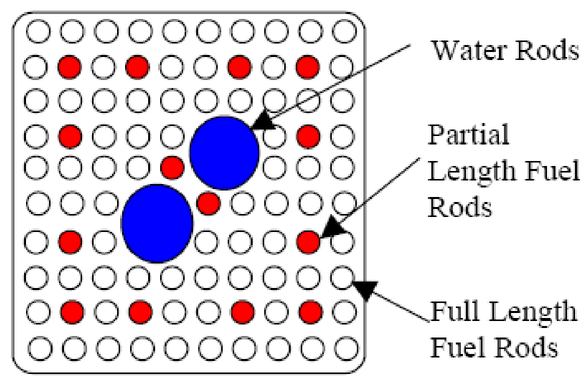


CHAN Component

All modern BWR fuel types are supported by the CHAN component

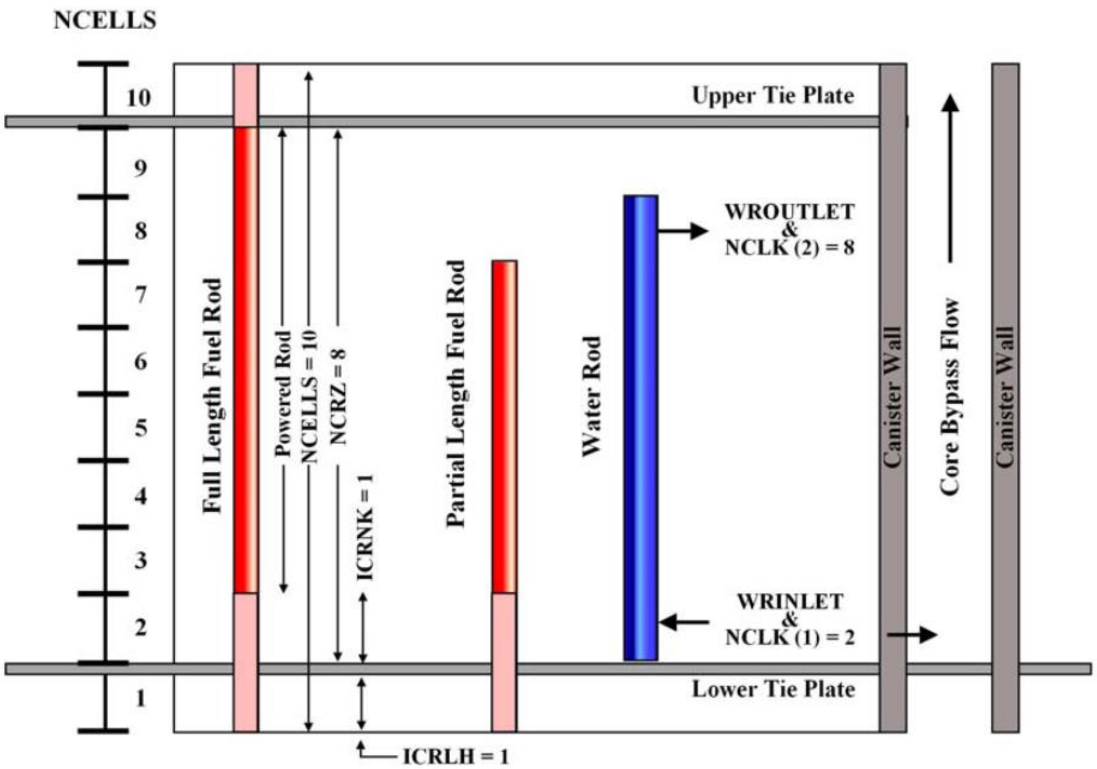






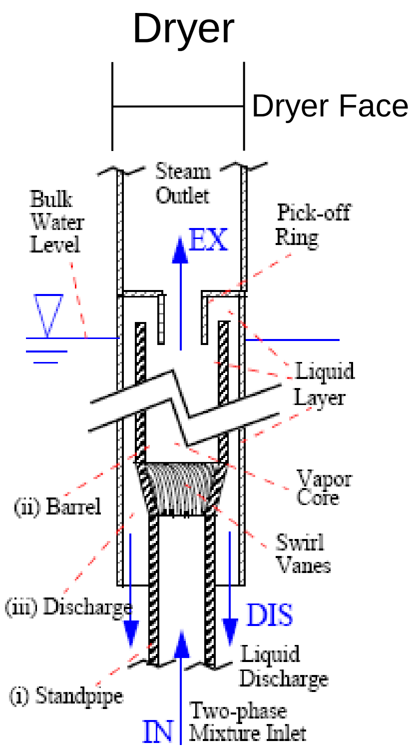
CHAN Component

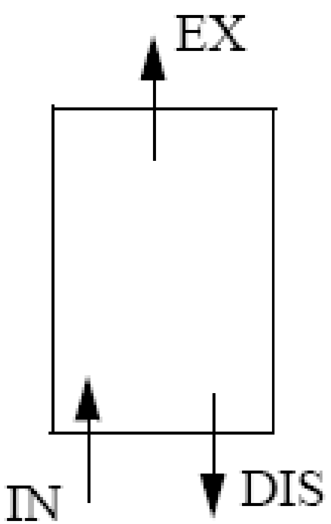
- CHAN is a compound component
  - consists of PIPEs, HTSTRs, and RADENC that are spawned internally
  - Book-keeping of spawned component numbers is important for tracking output



SEPD Component

- Specialized version of the TEE component.
- Separates an incoming steam/water mixture into two streams, one that is vapor-enriched and one that is liquid-enriched.
- Option available allowing user to model:
  - Ideal Separator
  - Two-stage mechanistic separator
  - Three-stage mechanistic separator
  - Dryers in conjunction with separator function





SEPD Component

- Carry-under and carry-over can be set by:
  - Input constants
  - Control System
  - Mechanistic 2 and 3 stage GE Separator model

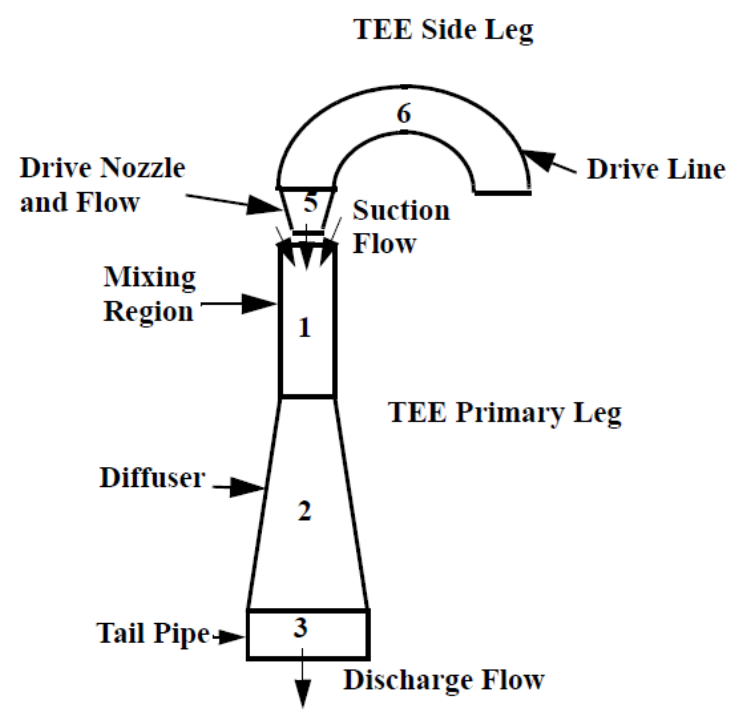
- Separator inlet quality is defined as the ratio of the inlet gas mass flow rate divided by the total inlet mass flow rate.

- Liquid carry-over quality is defined as the ratio of the exit liquid mass flow rate divided by the total exit mass flow rate.

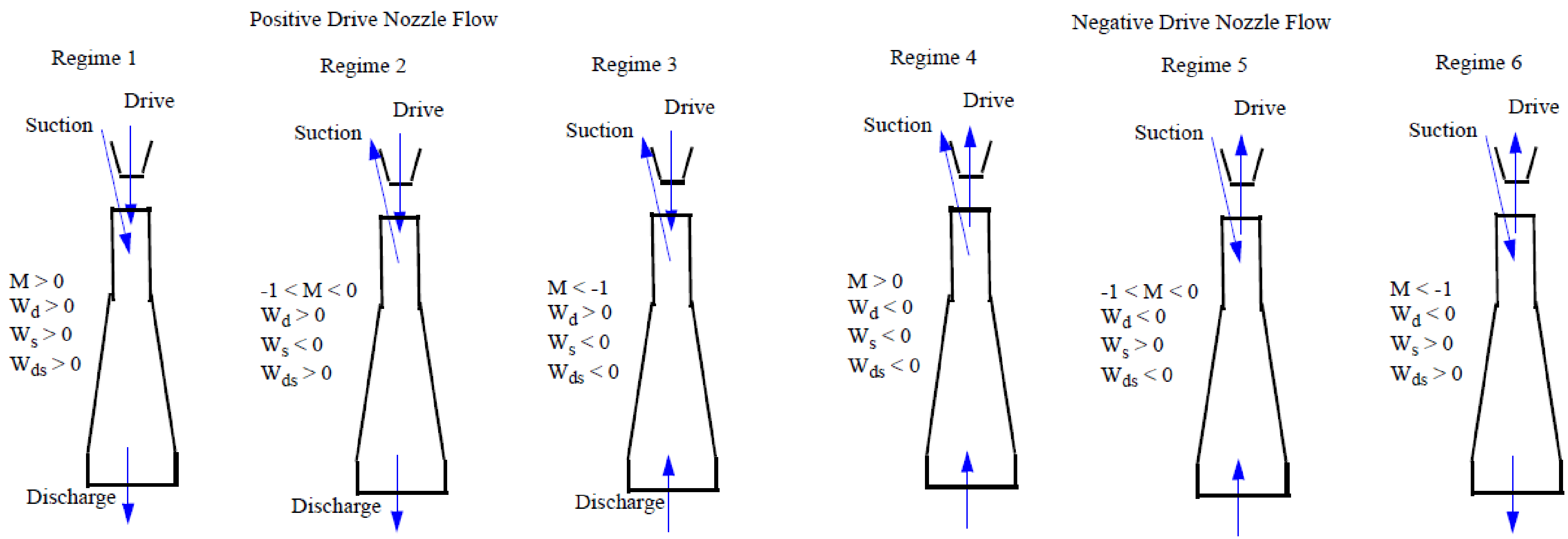
- Vapor carry-under quality is defined as the ratio of the discharge vapor mass flow rate divided by the total discharge mass flow rate.

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



JETP Component

- 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	$\left(\left(\frac{A_s}{A_{ds}}\right)^2 - 1\right)$

JETP Component

- 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,

VESSEL Component

- Models fluid cells laid out using a level, ring and azimuth sector grid arrangement. Connecting junctions (termed vessel source connections) to other TRACE components are specified. Heat structures (such as internals and PWR core fuel rods) are modeled using separate HTSTR components.

- The dimensional grid that is input for the VESSEL defines both the locations of the fluid cells and their dimensions. A Cartesian (X, Y, Z) grid structure is available in addition to a right-circular cylinder (R, Ө, Z) grid structure.

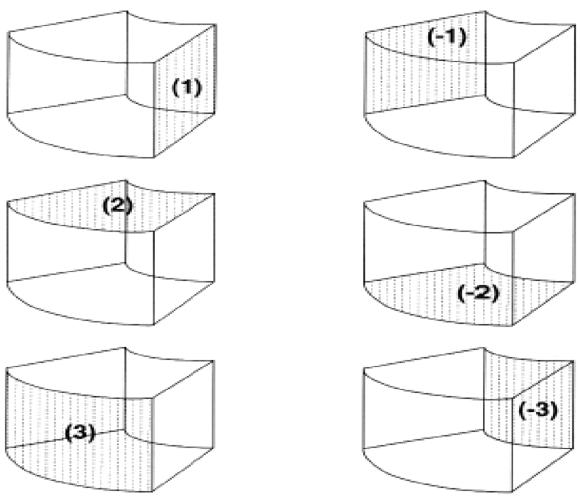
- The cell and cell-face input data (fluid volume, flow area, etc.) are entered as fractions of the full cell or cell-face values.

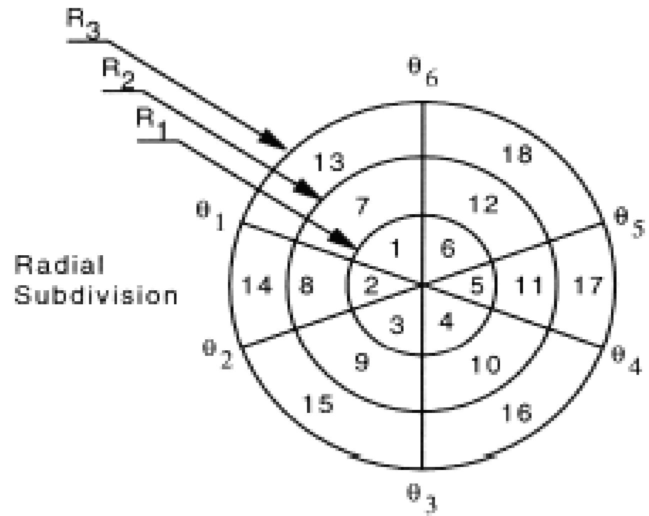
- The volume and flow area fractions typically are the same for regular geometries and typically are different when modeling irregular geometries.

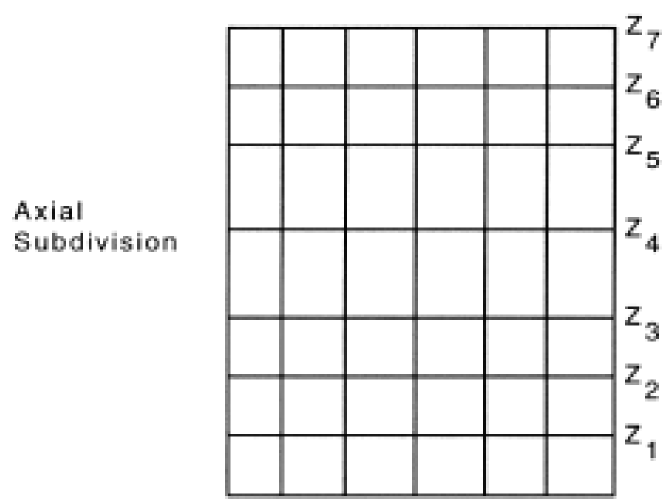
VESSEL Nodalization

Typical Nodalization Layout

Cell face numbering







VESSEL Special Models

- Core Region
  - Bestion correlation is used for interfacial drag
  - Core reflood models

- Downcomer
  - Axial direction interfacial drag is 1/8th of normal interfacial drag. The multiplier was selected based on comparisons to ECC penetration in the UPTF Test 6 series

- Orifice Model
  - Used to suppress transverse momentum from being carried across an orifice (e.g., core support plates)
  - Engage this model by setting a negative value for the axial hydraulic diameter

Questions?

Any questions on TRACE components before moving on?