TRACE Component Introduction – Part 3

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Objective

In preparation for the exercise that follows, provide the third set of basic information about the TRACE components used for building system models ………

Outline

- VESSEL Component
- POWER Component and Powered Heat Structures
- Point Reactor Kinetics Basics
- Fuel Rod Modeling
- CHAN Component
- CONTAN Component

VESSEL Component

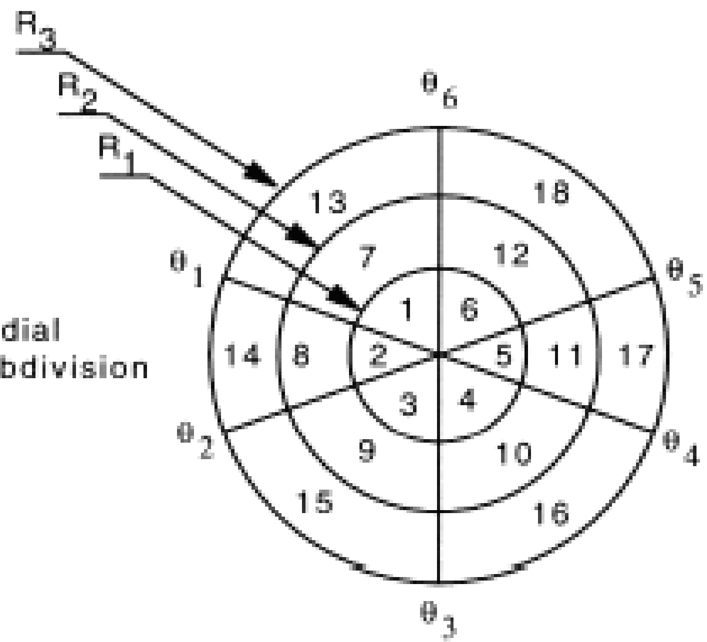
The VESSEL component models reactor pressure vessels using fluid cells laid using a grid structure. Junctions connecting VESSEL components to other TRACE components are made using “source connections”. Structures (such as vessel walls, internals and PWR core fuel rods) are modeled using separate HTSTR components.

The user specifies the cylindrical (R, ϴ, Z) grid structure and its dimensions (radial rings, azimuth sectors and axial levels). A Cartesian (X, Y, Z) grid structure is also available.

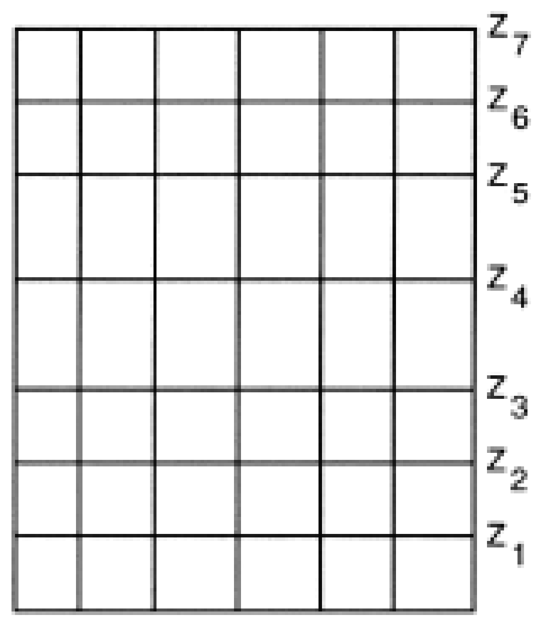
The VESSEL component cell and cell-face input data (fluid volume, flow area, etc.) are entered as fractions of the full cell or cell-face values.

The VESSEL flow model is not fully three-dimensional CFD! TRACE assumes that wall and interfacial drag dominate the flows. Interfacial shear between fluids in adjacent cells is not included in the flow model.

Radial Subdivision



Axial Subdivision



VESSEL Grid Structure Guidance

General Considerations for Layout of VESSEL Grid (R, ϴ, Z)

Axial detail sufficient for representing core, upper plenum and upper head behavior (downcomer axial behavior typically of secondary importance)

Radial detail sufficient for separating the core and downcomer regions, with multiple core rings as needed for the specific application (barrel-baffle core bypass region, core radial power distribution, upper plenum flow split among broken and intact loops)

Downcomer azimuth detail as needed for the specific application (different broken and intact loop behavior, local effects under cold leg and/or ECCS penetrations)

Core azimuth detail typically of secondary importance

VESSEL Grid Structure Numbering

VESSEL Input and Printed Output Numbering Conventions

VESSEL Cell Numbering Conventions

- Levels are numbered from 1 (lowest) to NASX (highest)
- Rings are numbered from 1 (inner) to NRSX (outer)
- Azimuth sectors are numbered from 1 (with the first non-zero angle) to NTSX, in the counterclockwise direction looking downward at the top of the VESSEL

VESSEL Cell Face Numbering Conventions

- Axial direction face data is presented from the top of Level 1 to the top of Level NASX (no data given for for bottom faces of Level 1)
- Radial direction face data is presented from outer face of Ring 1 to outer face of ring NRSX (no data given for inner symmetry face of Ring 1)
- Azimuth direction face data is presented from outlet face of Sector 1 to the outlet face of sector NTSX.

VESSEL Grid Structure Numbering

VESSEL Plotted Output Numbering Conventions

VESSEL data accessed using code of CCCAaaRrrTtt where CCC is the VESSEL component number, aa is the axial level, rr is the radial ring and tt is the azimuth sector

Axial direction face data is presented from the bottom of Level 1 to the top of Level NASX (Aaa = A01 to NASX + 1).

Radial direction face data is presented from inner face of Ring 1 to outer face of ring NRSX (Rrr = R01 to NRSX + 1).

Azimuth direction face data is presented from outlet face of Sector 1 to the outlet face of sector NTSX (Ttt = T01 to NTSX).

For example, “pn-135A02R01T03” is the pressure in Vessel Component 135, Level 2, Ring 1, Sector 3.

VESSEL Region Input

The Modeler Defines the Core and Downcomer Regions

(With SNAP, these are "Boundary Interfaces" Input Parameters)

The core region is located within the VESSEL grid structure by input parameters:

ICRU	Axial level number for which the top faces are the core top elevation
ICRL	Axial level number for which the top faces are the core bottom elevation
ICRR	Radial ring number for which the outer faces are outer radial boundary of the core (the core is assumed to occupy the radial space from the VESSEL centerline to the outside of ring ICRR)

The upper and lower core support plates are located within the VESSEL grid structure by input parameters:

IUCSP	Axial level number for which the upper core support plate is located at the top faces
ILCSP	Axial level number for which the lower core support plate is located at the top faces

VESSEL Region Input

The Modeler Defines the Core and Downcomer Regions (continued)

The downcomer region is located within the VESSEL grid structure by input parameters:

IDCU	Axial level number for which the top faces are the downcomer top elevation
IDCL	Axial level number for which the top faces are the downcomer bottom elevation
IDCR	Radial ring number for which the outer faces are the inner radial boundary of the downcomer (and the outer surface of the outer VESSEL ring is assumed to be the outer radial boundary of the downcomer region)

Specifying the core and downcomer regions also locates the lower plenum region within the VESSEL. TRACE allows use of a special interphase drag model for representing downward flow of cold ECC water against an upward flow of steam in the specific geometries of the downcomer and lower plenum regions. To activate this interphase drag model (Blasius correlation) the user must specify NAMELIST parameter IBLAUS = 1.

TRACE by default removes all flow paths specified using area fractions at the VESSEL downcomer inside radial faces (even though such flow paths otherwise appear to be open based upon the input). Flows through these faces are typically needed to represent various core bypass flow paths. These radial flow paths may be reactivated by specifying NAMELIST parameter IGEOM3 =1.

VESSEL Source Connection Input

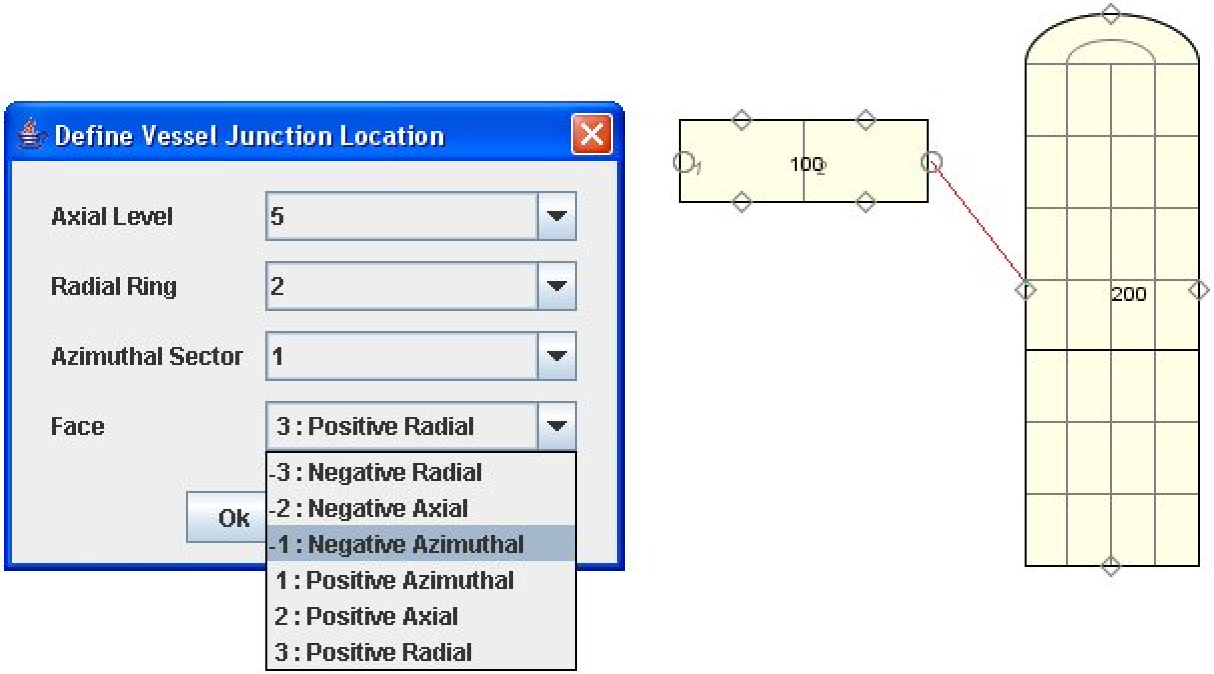
Connections from other TRACE components to a VESSEL component are made only using VESSEL “Source Connections”

The VESSEL source connection input includes the specification of the cell and face to which the connection is made and the associated junction number.

TRACE then connects the VESSEL to the other TRACE component for which with the same junction number has been specified.

VESSEL Source Connection Input

With SNAP, the user is prompted for the VESSEL cell and face to which the connection is made



VESSEL Source Connection Input

For ASCII input, the source connection is illustrated using the following example (in which the VESSEL is assumed to have 20 axial levels, four radial rings and six azimuth sectors):

```
*
* loop 1 hot-leg connection
*        lisrl          lisrc          lisrf         ljuns
           16             13             3             10
*    (axial level)  (relative cell)    (face)      (junction)
*
```

The VESSEL source connection for the Loop 1 hot leg is made by Junction 10 (parameter LJUNS).

The connection is made at the elevation of VESSEL Level 16 (parameter LISRL).

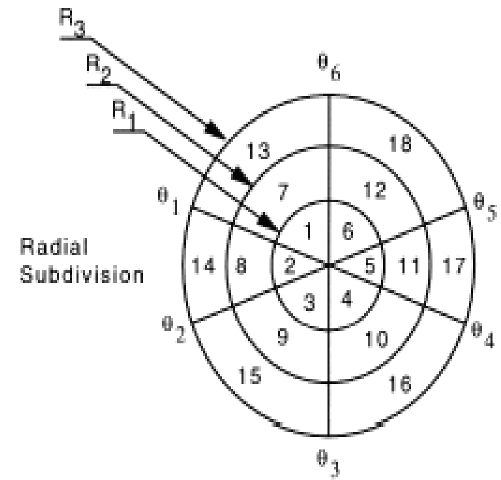
VESSEL Source Connection Input

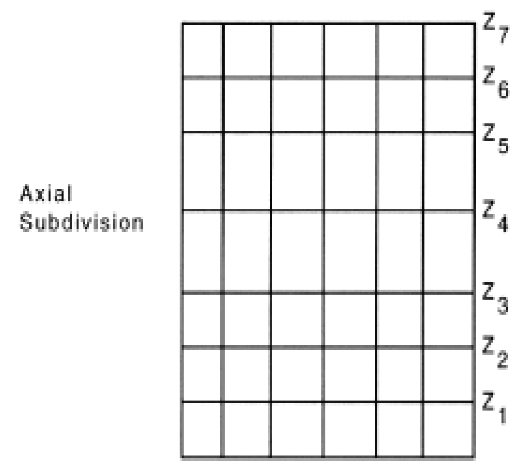
The connection is made to the cell on Level 16 with a relative number of 13 (parameter LISRC). The relative number is determined as follows.

Start counting at the first azimuth sector in Ring 1 (the sector input with the smallest non-zero angle).

Proceed counting counterclockwise (looking downward) completely around Ring 1. Then move to Ring 2 and continue counting in the same manner.

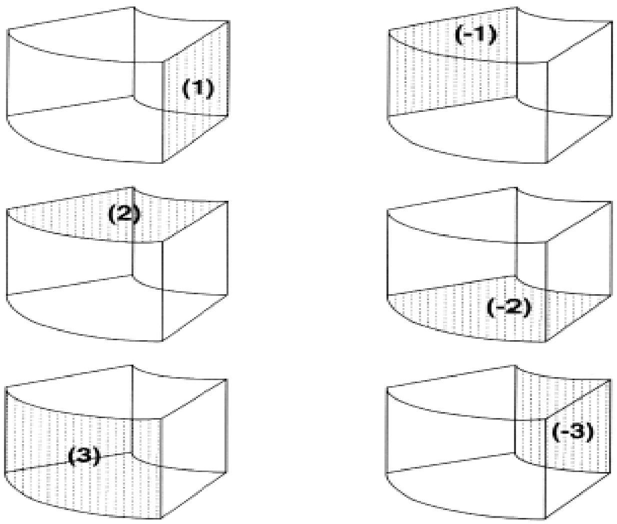
Because there are 6 azimuth sectors per ring, LISRC = 13 indicates that the connection will be to the cell at Azimuth Sector 1 (= 13 - 6 - 6) of Ring 3.





VESSEL Source Connection Input

The connection is made to the face with identifier 3 (parameter LISRF). The face identifiers for ASCII input have the same meanings as described above for SNAP input:



Therefore, for the ASCII input example the Loop 1 hot leg connects via Junction 10 to the outward radial face of Azimuth Cell 1 in Ring 3 of the VESSEL

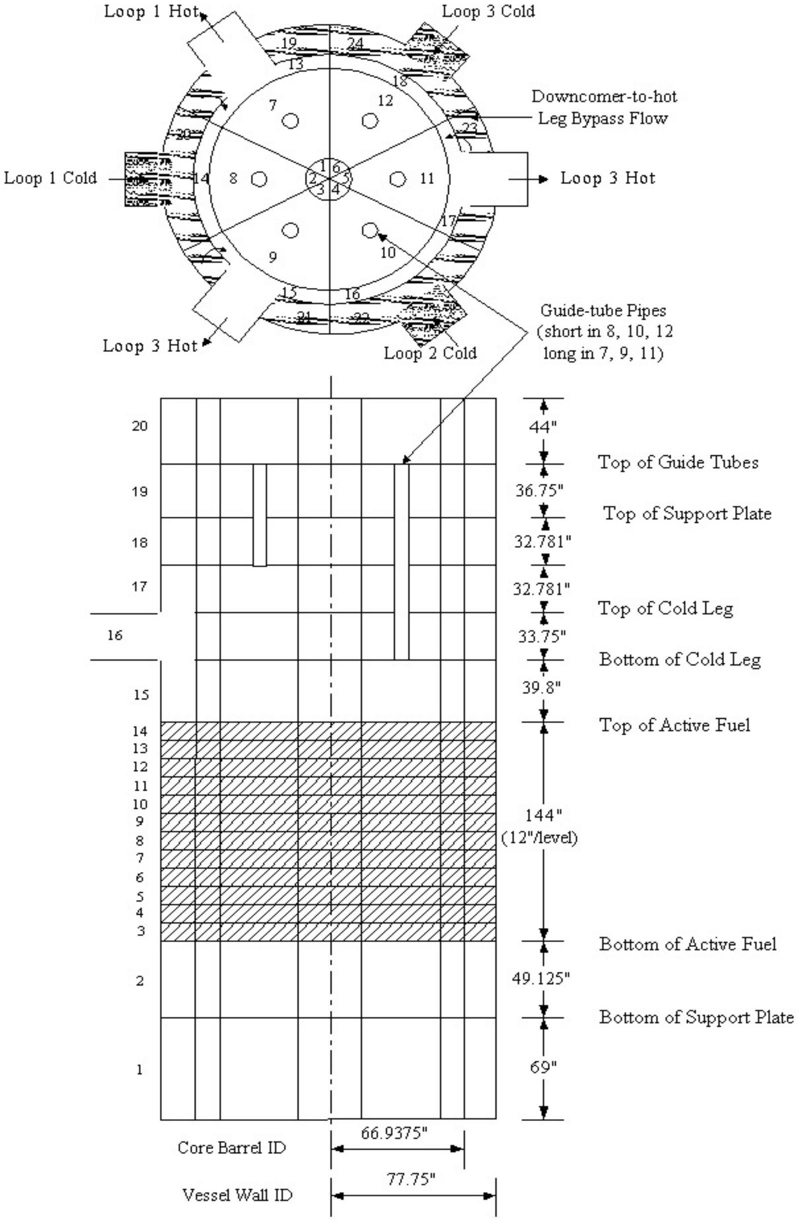
Example PWR VESSEL Grid Structure

Westinghouse three-loop PWR

Nodalization employs 20 axial levels, four radial rings and six azimuth sectors

Suitable for modeling a variety of accidents and transients

Source connections for guide tubes, hot legs and cold legs



Example PWR VESSEL Grid Structure

The VESSEL levels have been defined so as to provide:

1. A moderately-detailed axial representation of the fluid behavior within the core region (12 one-foot vertical nodes),
2. Two levels below the core to provide for modeling the turning of the downcomer flow below the elevation of the bottom of the downcomer skirt, losses of the radially-inward flow through the core support columns and losses of the upward flow through the lower core support plate,
3. Two levels above the core and below the coolant loop nozzles to allow for fluid separation in that region, and
4. Sufficient levels in the vessel upper plenum and upper head regions to permit realistic modeling of the guide tube flows and the fluid temperature response (which is important for the fluid flashing behavior).

Example PWR VESSEL Grid Structure

The VESSEL rings have been defined so as to provide:

1. One radial region for the downcomer, which has distinctly different flow characteristics and behavior than does the core region,
2. Three radial regions within the core, permitting the modeling of a core radial power profile and providing a capability for simulating circulating flows patterns within the core, and
3. Sufficient radial noding detail at Level 16, where the hot and cold legs connect, to permit simulation of asymmetric behavior among the coolant loop pipes.

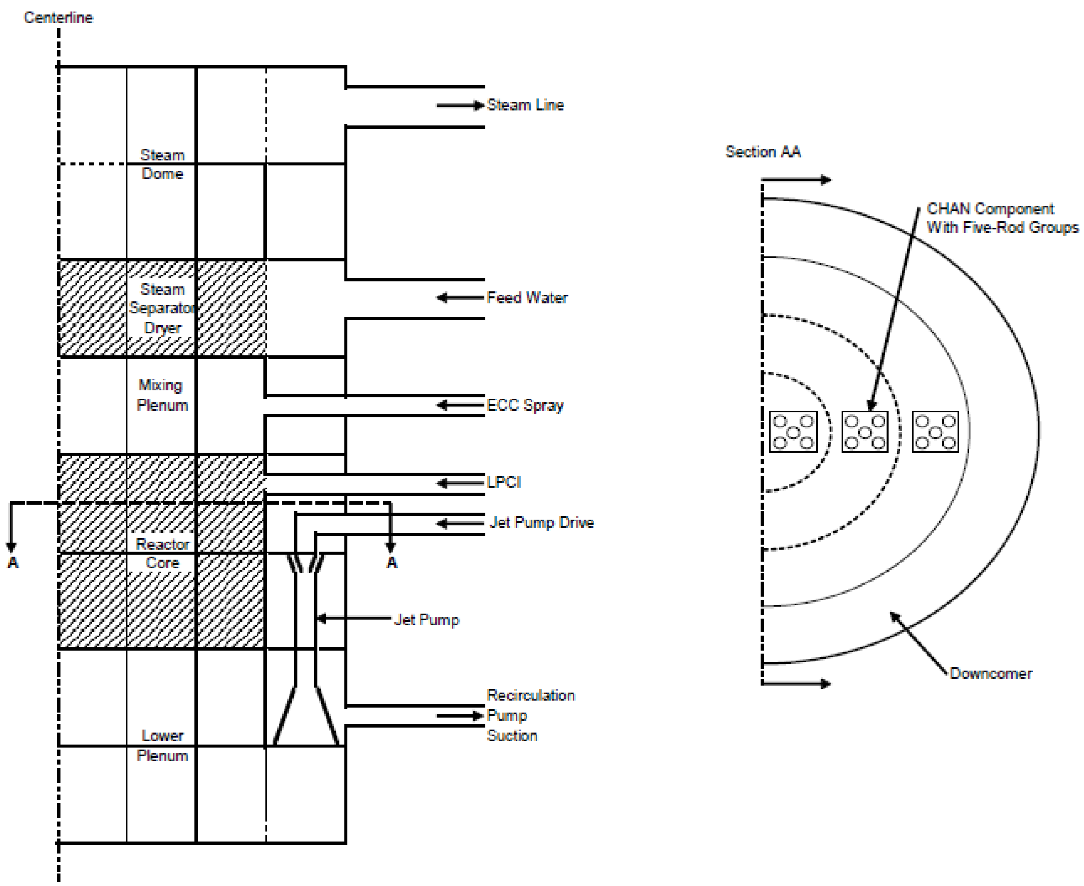
Example PWR VESSEL Grid Structure

The VESSEL azimuth sectors have been defined so as to provide:

1. One sector for each cold leg connection and one sector for each hot leg connection (based on geometry considerations, four-loop PWRs would better be modeled with eight, rather than six azimuth sectors).
2. Vertical channels situated in the downcomer below each cold leg, permitting modeling of asymmetries related to ECCS injection effects, including “buffer” vertical channels between them where mixing can take place.
3. Sufficient rotational noding to permit modeling of the flow behavior through guide tubes of different lengths and locations.

Example BWR VESSEL Grid Structure

- Most BWR models use a two-dimensional VESSEL (one azimuth sector)
- Core fuel region modeled using CHAN components
- Jet pumps and separators modeled using JETP and SEPD components
- CHAN, JETP, and SEPD components connected to the VESSEL via source connections
- Other source connections for feedwater, steam, ECC and recirculation pump suction lines



POWER Component and Powered HTSTRs

- Used to supply power in TRACE facility models
  - Identifies the HTSTR components into which power is deposited and the distributions of the power among and within them

- Can specify power:
  - As a constant
  - From a table that is a function of time
  - From the output of a control system that includes influences of parameter changes elsewhere in the model
  - From the TRACE point reactor kinetics model
  - From a PARCS three-dimensional reactor kinetics model

- Can specify a heat structure power shape that changes as a function of time

POWER Component and Powered HTSTRs

The following example illustrates use of POWER components and their interaction with HTSTR components

The example discussion has been abbreviated for this workshop so as to highlight the major modeling concepts; for a complete discussion, see “POWER Component” in the TRACE User’s Guide, Volume 2

In this example, the fuel rods of a PWR are modeled using four HTSTRs (Components 140, 171, 172 and 173)

The core power is calculated from a table as a function of time and is distributed to the four HTSTRs by POWER Component 174

The example HTSTR component models are discussed first, followed by the corresponding example POWER component model

POWER Component and Powered HTSTRs

The PWR reactor vessel is modeled using VESSEL 26 and the core is located within Ring 1, Azimuth Sectors 1 through 4, Axial Levels 3, 4 and 5

HTSTRs 140, 171, 172 and 173 each represent 9843 fuel rods and are modeled in VESSEL Azimuth Sectors 1, 2, 3 and 4, respectively

The radial and axial nodalizations for the four HTSTRs are identical

Input for one of the fuel rod heat structures (HTSTR 172, located in Azimuth Sector 3 of the VESSEL) is discussed as follows……..

POWER Component and Powered HTSTRs

```
*       type        num       id     ctitle
htstr               172       172    $172$  reactor-core fuel rods
*     nzhtstr       ittc      hscyl      ichf
          3          0          1          1
*      nopowr       plane       liqlev      iaxcnd
          0          3           1          0
*      nmwrx       nfci       nfcil       hdri         hdro
          1          1          1      0.0000E+00   1.3000E-02
*       nhot       nodes       fmon       nzmax     refloodon
          1          8           0          0          0
*      dtxht1        dtxht2         dznht         hgapo          shelv
   4.0000E+00    5.0000E+01    5.0000E-03    6.0000E+03    2.9750E+00
*      idbciN
f          0e
*      idbcoN
f          2e
*     qflxbci
   0.0000E+00e
   0.0000E+00e
   0.0000E+00e
*      nhcomo       nhcelio       nhceljo       nhcelko
         26           1            3            3e
         26           1            3            4e
         26           1            3            5e
*     dhtstrz
   1.2141E+00    1.2141E+00    1.2141E+00e
```

HTSTR 172

3 axial levels

1 hot rod included with this HTSTR

8 radial nodes within the fuel rod

Connected to VESSEL 26 Ring 1, Azimuth 3, Levels 3, 4 and 5

1.2141-m (4-foot) height within each axial level

POWER Component and Powered HTSTRs

```
*        rdx
   9.8430E+03e
*      radrd
   0.0000E+00   2.0000E-03   3.0000E-03   4.0000E-03   4.6427E-03s
   4.7422E-03   5.0500E-03   5.3594E-03e
*      matrd
        1            1            1            1            3s
        2            2e
*        nfax
        0            0            0e
*        rftn
   5.5000E+02   5.5000E+02   5.5000E+02   5.5000E+02s
   5.5000E+02   5.5000E+02   5.5000E+02   5.5000E+02s
   5.5000E+02   5.5000E+02   5.5000E+02   5.5000E+02   5.5000E+02s
   5.5000E+02   5.5000E+02   5.5000E+02   5.5000E+02   5.5000E+02s
   5.5000E+02   5.5000E+02   5.5000E+02   5.5000E+02   5.5000E+02s
   5.5000E+02   5.5000E+02   5.5000E+02   5.5000E+02   5.5000E+02s
   5.5000E+02   5.5000E+02   5.5000E+02   5.5000E+02s
   5.5000E+02   5.5000E+02   5.5000E+02   5.5000E+02s
   5.5000E+02   5.5000E+02   5.5000E+02   5.5000E+02e
*
```

← Number of fuel rods modeled

← 8 radial node dimensions inside fuel rod

← Materials for the 7 radial intervals inside fuel rod, UO2, gap, cladding

POWER Component and Powered HTSTRs

```
*        fpuo2
f    0.0000E+00e
*         ftd
f    9.4500E-01e
*         gmix
     1.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00s
     0.0000E+00    0.0000E+00e
*         gmles
f    0.0000E+00e
*         pgapt
f    1.0000E+07e
*         plvol
f    0.0000E+00e
*         pslen
f    0.0000E+00e
*         clenn
f    0.0000E+00e
*         burn
     1.5400E+04    1.5400E+04    1.5400E+04e
```

Fuel pellet specification and performance data, fuel rod gas volume and gas species data

POWER Component and Powered HTSTRs

The POWER component is set up to deliver the core power using a desired distribution of the power among the fuel rod HTSTR components

Input for the POWER component must be consistent with the radial and axial nodalizations of the fuel rod HTSTR components

In this example, the required input for the POWER 174 is relatively simple because:

- The core power is specified using a table rather than the reactor kinetics model
- The radial and axial nodalizations for the four fuel rod HTSTRs are identical

The input for POWER 174 is discussed as follows……..

POWER Component and Powered HTSTRs

```
*       type        num       id      ctitle
power               174       174     Power Comp for reactor power
*       npwr
        4
*       htnid
        140         171       172       173e
*       irpwty      ndgx      ndhx      nrts       nhist
        6           0         0         10         0
*       irpwtr      irpwsv    nrpwtb    nrpwsv     nrpwrf
        0           1         20        0          0
*       izpwtr      izpwsv    nzpwtb    nzpwsv     nzpwrf
        0           1         1         0          0
*       ipwrad      ipwdep    fissheat  decaheat   wtbypass
        0           0         0.0       0.0        0.0
*       nzpwz       nzpwi     nfbpwt    nrpwr      nrpwi
        0           0         0         1          0
*       react       tneut       rpwoff      rrpwmx      rpwscl
    0.0000E+00  0.0000E+00  0.0000E+00  1.0000E+20  1.0000E+00
*       rpowri      zpwin       zpwoff      rzpwmx
    3.2500E+09  0.0000E+00  0.0000E+00  0.0000E+00
*       extsou      pldr        pdrat       fucrac
    0.0000E+00  0.0000E+00  1.3340E+00  1.0000E+00
```

POWER 174

Power to HTSTRs 140, 171, 172 and 173

POWER Type 6, Power Table Lookup Independent variable in the table is irpwsv =1 (Signal Variable 1 = problem time). Table has nrpwtb = 20 (time, power) pairs

Initial power is 3250 MW

POWER Component and Powered HTSTRs

```
*       rdpwr
 1.2109E+00   1.2371E+00   1.2703E+00   1.3201E+00   1.3823E+00s
 0.0000E+00   0.0000E+00   0.0000E+00e
*       cpowr
 1.0000E+00   1.0000E+00   1.0000E+00   1.0000E+00e
*       rpkf
   1.1          1.2          1.3          1.4e
*       zpwtb
  0.93748       1.20535        0.83715e
*       rpwtb
 0.0000E+00   3.2500E+09   1.0000E-01   2.2700E+08   1.0000E+00s
 1.9500E+08   2.0000E+00   1.8800E+08   5.0000E+00   1.7500E+08s
 1.0000E+01   1.6200E+08   1.5000E+01   1.5200E+08   2.0000E+01s
 1.4600E+08   5.0000E+01   1.2300E+08   7.5000E+01   1.1300E+08s
 1.0000E+02   1.0700E+08   1.2500E+02   1.0400E+08   1.5000E+02s
 1.0000E+08   2.0000E+02   9.4000E+07   2.5000E+02   8.8000E+07s
 3.0000E+02   8.4000E+07   3.5000E+02   8.0000E+07   4.0000E+02s
 7.7000E+07   5.0000E+02   7.2500E+07   9.0000E+02   5.5000E+07e
```

Relative radial power distribution across the 8 fuel rod nodes

Relative radial power distribution among the 4 HTSTRs

Power peaking factors for the hot rods in the 4 HTSTRs

Relative axial power distribution among the three levels in each HTSTR

20 (time, power) pairs providing the total transient core power in Watts

Point Reactor Kinetics Basics

For transients where modeling the core power using a table is not acceptable, TRACE can calculate transient core power based on a point reactor kinetics formulation

With the point kinetics model, the core power is based on total reactivity, delayed neutron fraction and effective prompt neutron lifetime

The formulation includes a six-group equation with calculated powers and decay constants for each neutron group

Reactivity feedback is included based on changes in fuel temperature (Doppler), moderator temperature, moderator void fraction (or moderator density), and boron concentration

Typically, the calculated core power is deposited into the HTSTR components representing the core fuel rods, and the reactivity feedback is caused by the resulting influence on the core fuel and fluid temperatures and the core fluid void fraction

Point Reactor Kinetics Basics

A basic limitation of all point kinetics models is that the core axial power shape is known ahead of time and cannot vary with time

This assumption may be acceptable for simulating:

- Minor reactivity events
- System calculations for which the distribution of core power is not a significant parameter
- Transients for which no large variations in axial and radial core power distributions are expected over the course of the calculation
- Transients that may be analyzed in a step-wise manner using different axial power shapes for each step

The PARCS code (now included as an integral part of TRACE) can be employed for calculating core power for situations where significant changes in core power distributions are anticipated

Point Reactor Kinetics Basics

TRACE Point Reactor Kinetics Model Features

Fission Product Decay Options:

- ANS-73, ANS-79, or ANS-94 with or without Actinide decay
- Set Namelist variable R5dh = 1 to use ANS-94

TRACE Allows Four Forms for Reactivity Coefficients:

- $\Delta K_{eff}/\Delta X$, $X(\Delta K_{eff}/\Delta X)$, $(X/K_{eff})(\Delta K_{eff}/\Delta X)$, in addition to the usual $(1/K_{eff})(\Delta K_{eff}/\Delta X)$

  where X is T_{fuel}, α or density, $T_{moderator}$, or boron concentration

- Set Namelist variable R5fdbk = 1 for X = density

Point Reactor Kinetics Basics

TRACE Point Reactor Kinetics Model Features (continued)

Four-Dimensional Table of Coefficients (1 fuel temparature, 2 moderator temperature, 3 void fraction or density, 4 boron concentration

Reactivity Weighting

- Power weighted and volume averaged over the core region
  - Power Exponent is user-specified

Reactivity Coefficient Input

- Best to do in SNAP, manual table input is very cumbersome
- Demonstration of reactivity coefficient input preparation is a subject more suitable for a TRACE advanced course

Fuel Rod Modeling

Fuel Rod Construction

- Cylindrical UO_2 pellets
- Inert gas gap between pellets and cladding
- Zirconium cladding

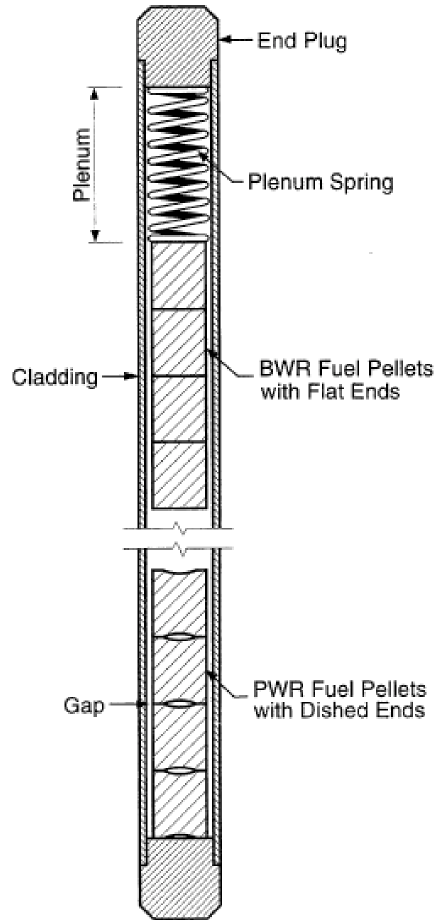


Figure. 2-55. Typical Fuel Rod Geometry.

Fuel Rod Modeling

Key Parameters and Processes Affecting Fuel Rod Modeling

- Core power, initial and during transient events (102% to account for uncertainty)
- Radial power shape within fuel pellets (affects pellet nodalization selection)
- Axial power shape from core bottom to core top (affects core hydro and heat structure nodalization selection)
- Radial power shape from core centerline to core periphery (affects core hydro nodalization selection)
- Conductance across gas gap (dynamic conductance model available)
- Initial stored energy (peak operating fuel temperature often cited in plant data)
- Metal water reaction (between coolant and cladding) models available

Fuel Rod Modeling

Key Parameters and Processes Affecting Fuel Rod Modeling (continued)

Hot rod behavior

Typical TRACE plant models represent the behavior of average fuel assemblies within each core region (ring, azimuth sector and axial level)

An average fuel assembly represents all fuel rods in all assemblies interacting with the average fluid conditions within the core region

Hot rod model is available for representing fuel rods in the average assembly with the highest peaking factor. These "supplemental rods":

(1) Do <u>not</u> influence the hydro solution, and

(2) Operate against the average hydro conditions, and so do <u>not</u> represent a true hot rod calculation, which would require a fuel assembly sub-channel model

Fuel Rod Modeling

Key Parameters and Processes Affecting Fuel Rod Modeling (continued)

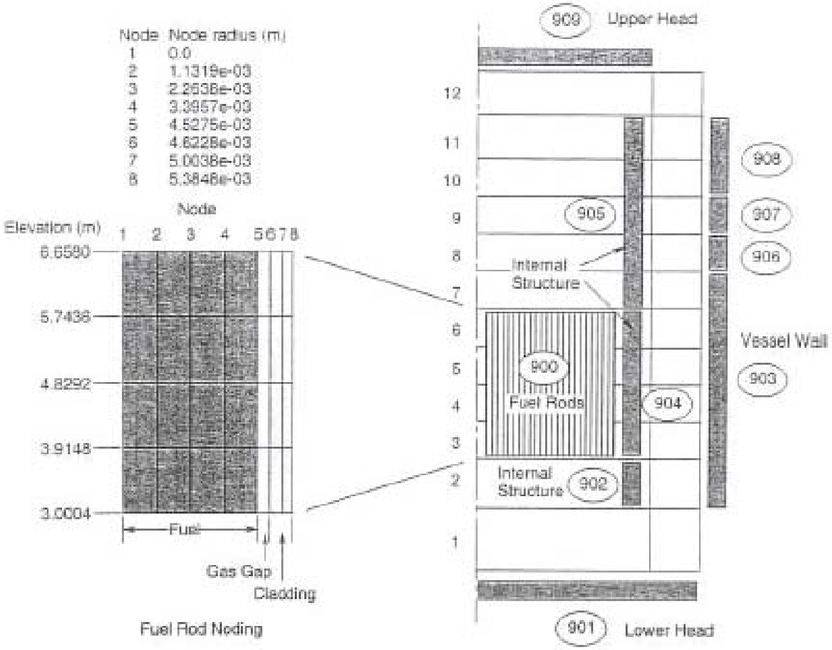
- Reflood modeling
  - Additional modeling detail needed to address reflood behavior
  - Large axial gradients in void fraction and heat transfer in vicinity of the quench fronts (bottom and/or top)
  - Modeling detail must follow quench front as it traverses up and down the fuel rod bundle
  - TRACE provides reflood modeling capabilities for this purpose

Fuel Rod Modeling

Example HTSTR input for fuel rods provided in TRACE User's Manual, Volume 2, Modeling Guidelines, Page 136

Also see guidelines for fuel rod nodalization in TRACE User's Manual, Volume 2, Modeling Guidelines, Page 13

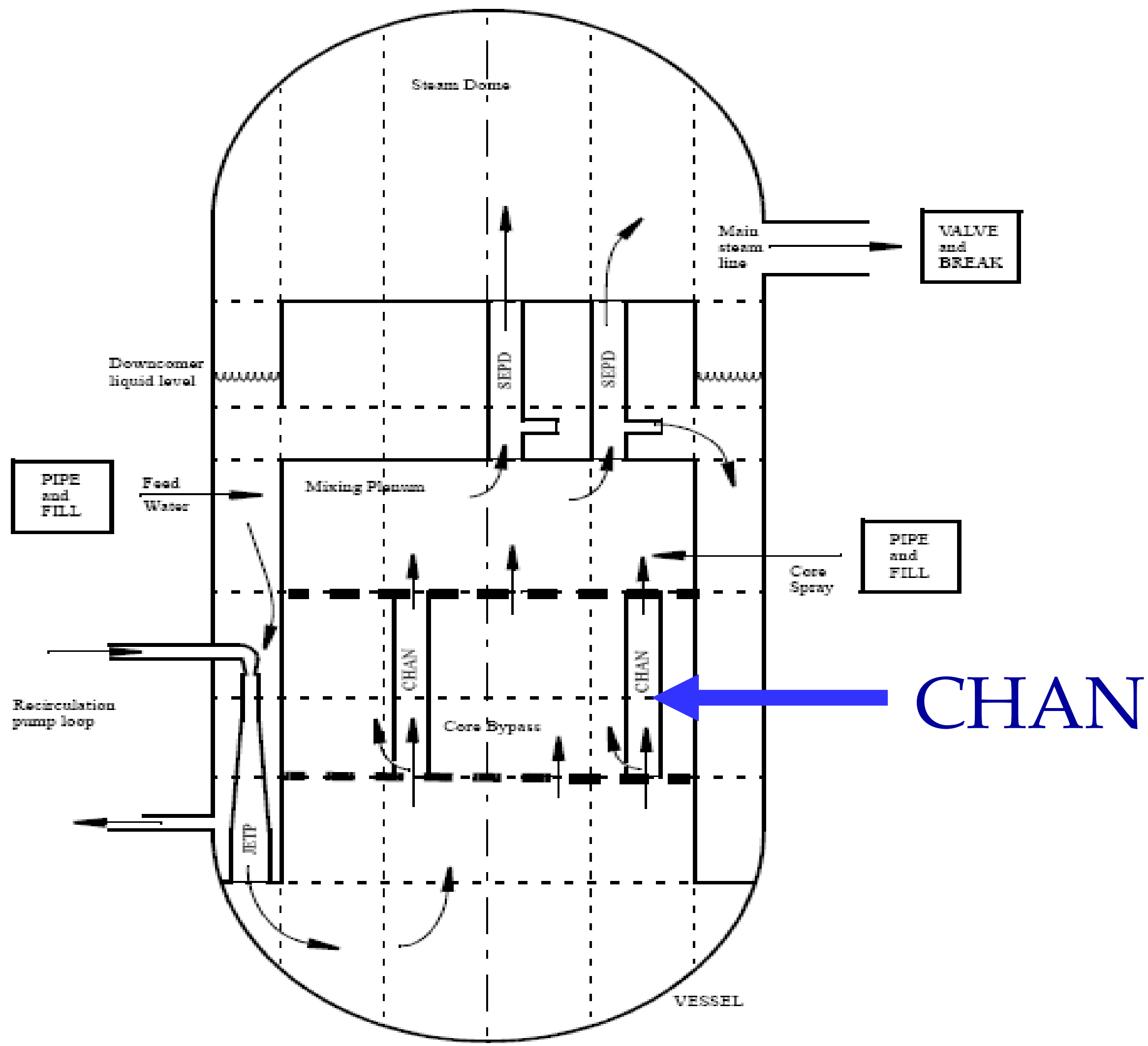
An exercise later in this workshop session will provide experience with fuel rod HTSTR modeling and renodalization



CHAN Component

- The CHAN component is used for representing BWR reactor core fuel regions

- The features of BWR fuel assemblies are combined together into a single CHAN component

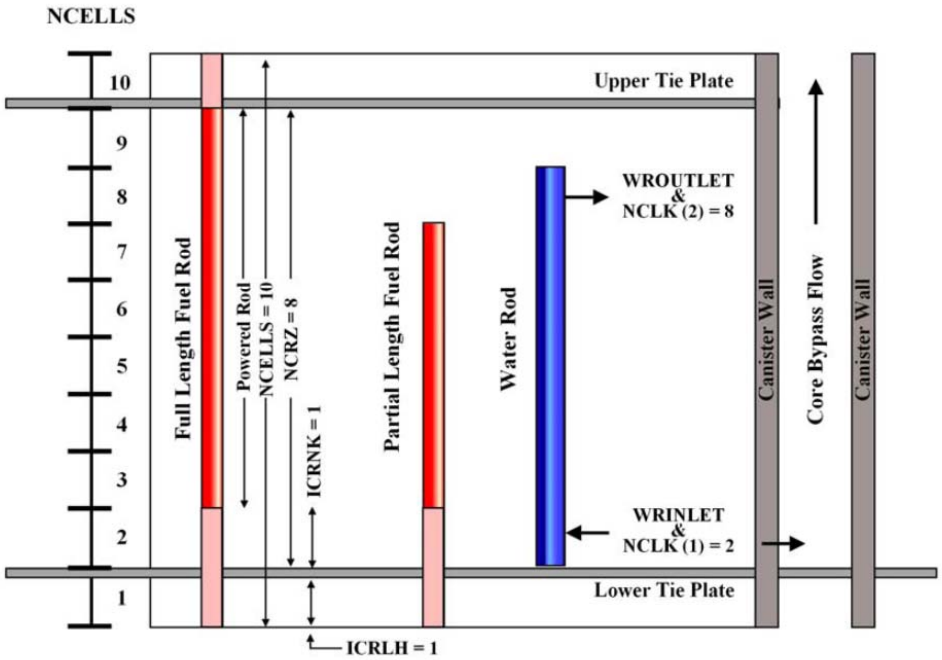


CHAN Component

CHAN components include multiple axial fluid cells and connecting faces, specification of connecting junctions at the bottom and top faces, fuel rod heat structures, water rod heat structures, channel box wall heat structure, leakage paths from the channel box into the core bypass region

The CHAN consists of PIPEs, HTSTRs, and RADENCs that are spawned internally based on user input

Bookkeeping of spawned component numbers is important for tracking the code output



CHAN Component

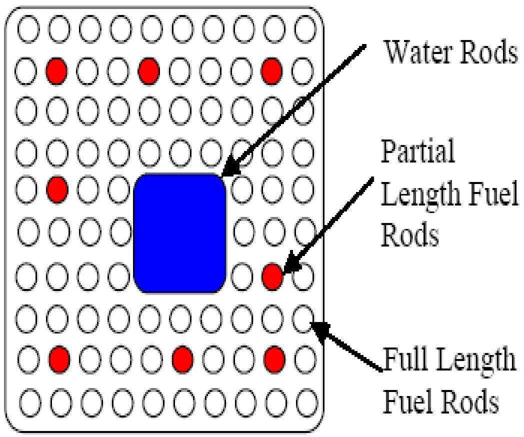
The CHAN component supports configurations for advanced fuels through the addition of water rods and partial length rods

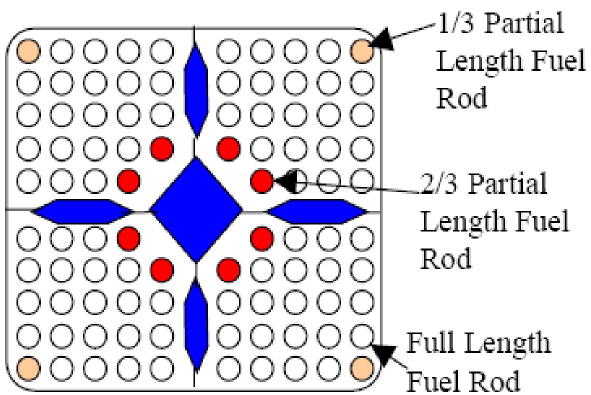
For partial length rods, the highest numbered axial cell where power is applied is specified in the rod group

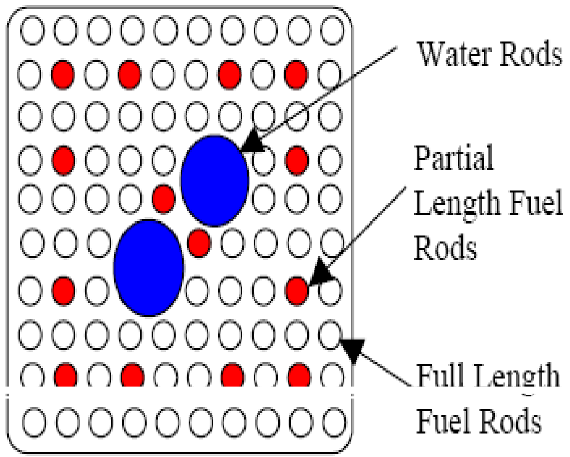
When TRACE is coupled with PARCS, gamma direct heating to the channel flow, water rod flow, and bypass flow can be specified

CHAN Component

Modeling for all modern BWR fuel types is supported by the CHAN component







CONTAN Component

The TRACE CONTAN Component provides a set of models that may be used to represent behavior of reactor containment regions

The containment models used for thermal hydraulic analysis typically don’t need to be as detailed as primary and secondary coolant system models

CONTAN models are therefore generally lumped parameter representations of the components and processes that can play the most significant role for the containment response

When is Containment Modeling Needed?

Consider three ways that the primary coolant system may interact with containment during a loss of coolant accident:

Overpressure valves may open releasing liquid or steam into containment

When valves open due to over pressurization, the flow out the valve is choked, and containment backpressure is irrelevant

A pipe break may release primary system coolant into containment

For LOCAs, at first the break flow is choked so containment backpressure is initially irrelevant. However, as the primary system depressurizes, the break flow may unchoke. Containment backpressure may increase enough to significantly reduce the break flow rate or to reverse the break flow

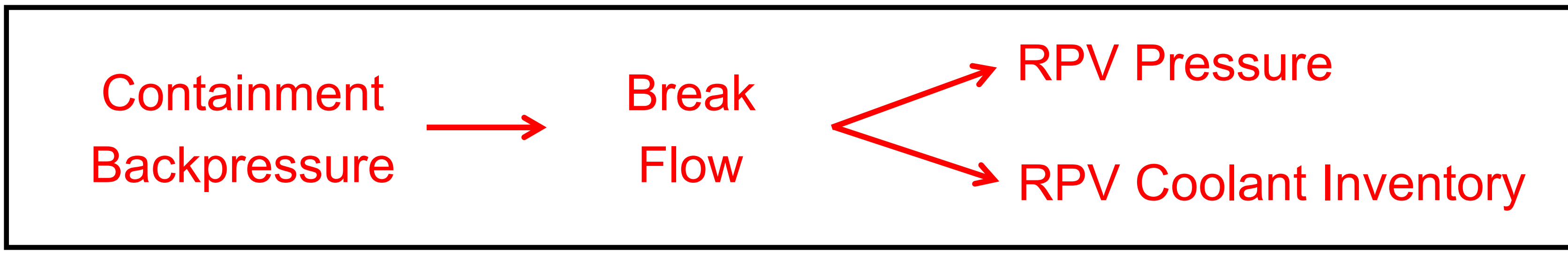
When is Containment Modeling Needed?

Liquid from the containment region may be injected into the primary coolant system to replenish its inventory

If pools in containment are used to condense steam, then pool temperatures may be impacted in the long term. Generally, the portions of accident scenarios evaluated using TRACE are too short for this effect to be significant.

When is Containment Modeling Needed?

Break flow is a key parameter for LOCA scenarios. It directly impacts the reactor vessel coolant inventory and pressure



Reactor vessel pressure impacts timing of safety system startup and injection flow rates

Reactor vessel coolant inventory determines the timing of fuel rod uncovery and the start of fuel rod heat-up

When is Containment Modeling Needed?

For best estimate LOCA analysis methods, a containment model may be included to gain margin by providing accurate predictions for the break flow and containment pressure

For conservative evaluation LOCA analysis methods, a low containment pressure (such as a fixed initial pressure) is often assumed in lieu of modeling the containment

For Small Break LOCAs, a low containment pressure assumption is of little consequence because the reactor system pressure remains elevated far above the containment pressure and the break flow never unchokes

When is Containment Modeling Needed?

For Large Break LOCAs, a low containment pressure assumption is conservative:

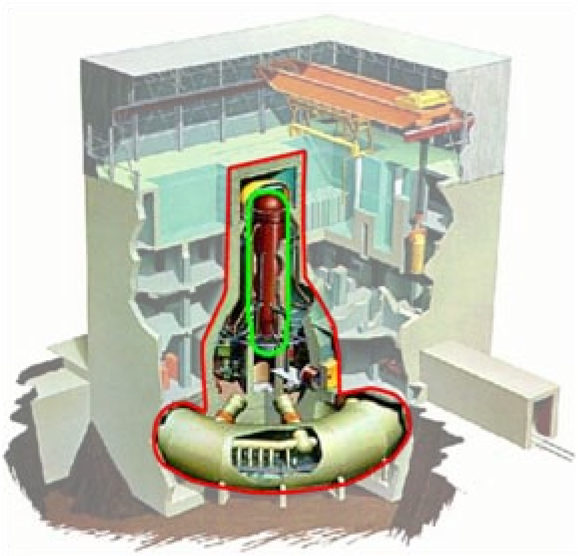
After the break unchokes, low containment pressure leads to a high break flow rate, which accelerates loss of reactor coolant system inventory

Because of an extreme influence of pressure on steam density, low containment pressure also results in low reactor coolant system pressure, which slows the reflood process:

- The incoming liquid quenches the core fuel, which produces steam
- When vaporized, each pound of liquid produces almost twice the steam volume at 20 psia than it does at 40 psia
- A higher steam volumetric production rate keeps the reactor vessel pressure elevated, which produces a greater resistance for refilling the core, lowers safety system injection rates, extends the fuel rod heat up time and increases the peak cladding temperature, thereby leading to a conservative result

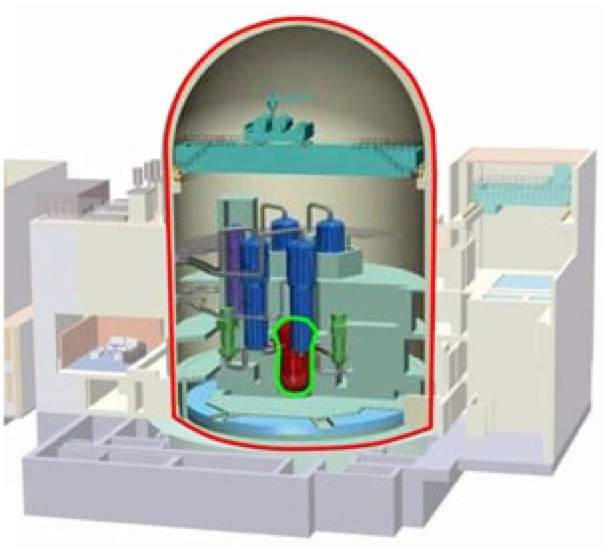
When is Containment Modeling Needed?

Typical BWRs have a much smaller relative containment volume than PWRs. Therefore containment pressure and break flow tend to have a larger impact on one another in BWRs and it is more common to include containment models when analyzing BWR loss of coolant accident scenarios.



BWR

Note the Vessel Size vs. the Containment Volume for BWRs vs. PWRs which characterizes the impact that break flow can have on pressure.



Typical PWR

CONTAN Subcomponents

The CONTAN component employs the following subcomponents for modeling containments:

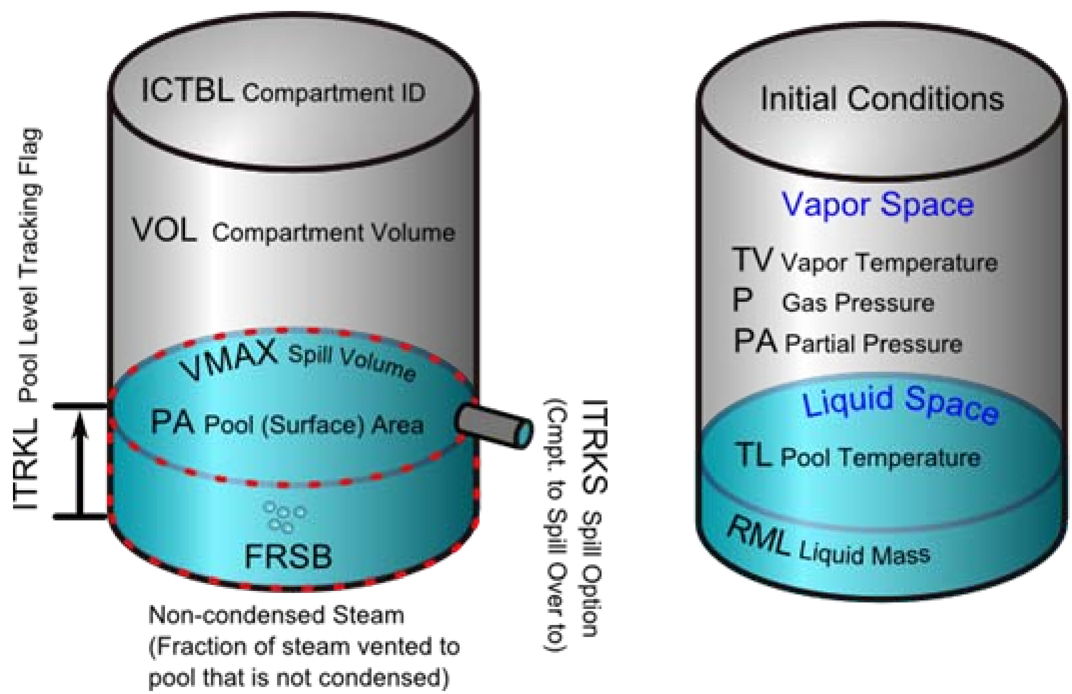
1. Compartment	Drywell, Wetwell, etc.
2. Passive Flow Junction	Pipe between compartments
3. Forced Flow Junction	Pump/Spray between compartments
4. Heat Structure	Compartment walls or solid structures
5. Cooler	Direct heat removal (HR)
6. Fan Cooler	HR using finned tube fan cooler
7. Source/Sink Junction	Flow Boundary Conditions

In addition, the BREAK component is an honorary CONTAN subcomponent that is used to couple a CONTAN model of a containment with TRACE components representing the reactor coolant system.

1. Compartment

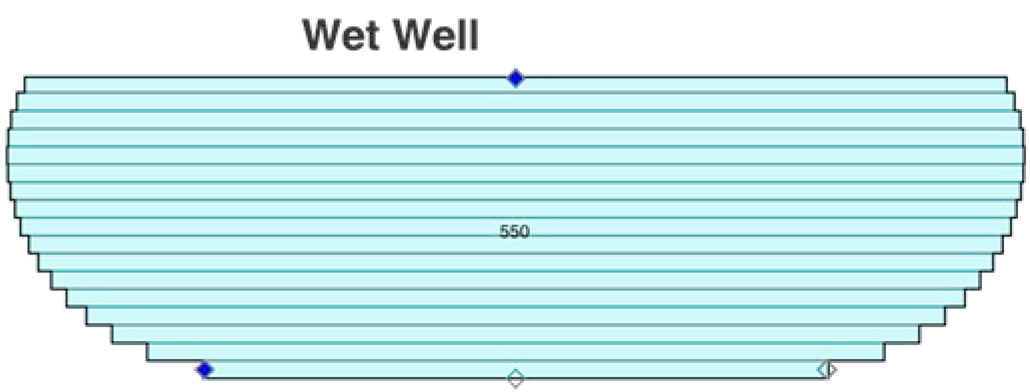
A CONTAN compartment is divided into a **liquid space** and **vapor space**. Several of the compartment inputs are depicted below:

Component Name	Drywell
Compartment ID	562
Description	<none>
Pool Level Tracking	Off
Spilling Option	Compartment 550 ...
Volume	3600.0 (m³)
Spill Volume	35.0 (m³)
Terminate At Saturation	○ True ◉ False
Non-condensed Steam	0.0 (-)
Heat Transfer Fraction	1.0 (-)
Condensation Multiplier	1.0 (-)
Estimated Pressure Change Rate	0.0 (-)
Pool Area	75.0 (m²)
Depth Vs Volume Table	Rows: 0 []
▼ Initial Conditions	
Liquid Mass	0.0 (kg)
Gas Pressure	1.0E5 (Pa)
Pool Temperature	310.0 (K)
Vapor Temperature	310.0 (K)
Partial Pressure	1.0E5 (Pa)



1. Compartment

A depth vs. volume table (DEPTH) can be specified for a compartment, which allows TRACE to calculate the liquid level as the volume fills. Note that conditions for only a single volume are calculated, although SNAP represents it with multiple segments as seen below.



Editing Depth Vs Volume Table

Volume m^3	Depth m
0.0	0.0
96.0	0.4
266.0	0.8
480.0	1.2
724.0	1.6
992.0	2.0
1272.0	2.4
1568.0	2.8
1864.0	3.2
2168.0	3.6
2464.0	4.0
2760.0	4.4
3040.0	4.8
3304.0	5.2
3544.0	5.6
3752.0	6.0
3912.0	6.4
3992.0	6.7

Add Remove

OK Cancel

2. Passive Flow Junction

The CONTAN passive flow junction represents one of the following connection types, as specified by the input ITYPP:

1. A pipe connecting two compartment vapor spaces. Flow rate is based on the differential pressure between compartments.

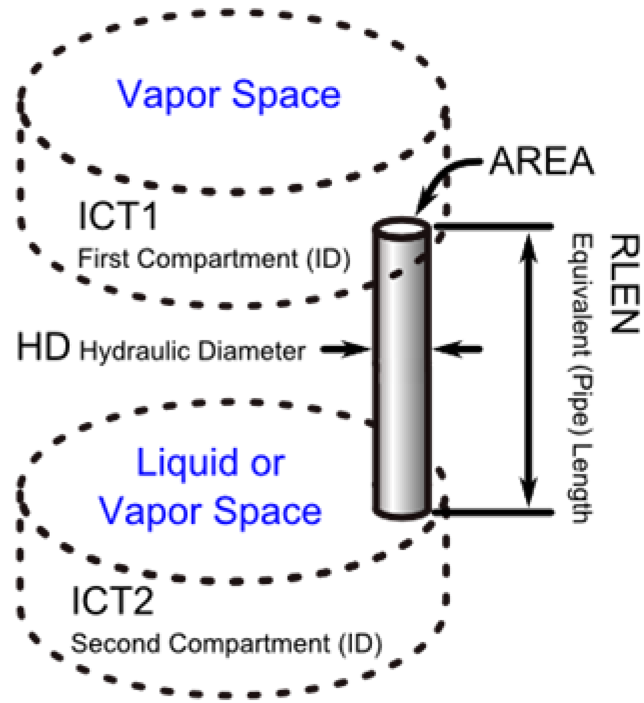
2. A check valve connecting two compartment vapor spaces. A pressure difference (DPCR) required to start flow may be specified.

3. A check valve connecting a compartment vapor space to a compartment liquid space. A pressure difference (DPCR) represents the vapor pressure required to start flow (for a pipe outlet submerged below the pool surface).

2. Passive Flow Junction

A friction factor (FR) can be specified. The friction factor is controllable. Additional input include the following:

Component Name	Vent Header Downcomer
Junction Number	551
First Compartment	Compartment 562 (Drywell)
Second Compartment	Compartment 550 (Wetwell)
Description	<none>
Junction Type	[3] Vapor to Liquid w/ Check
Hydraulic Diameter	0.4 (m)
Area	24.0 (m^2)
Equivalent Length	8.0 (m)
Friction Factor	0.035 (-)
Minimum Pressure	1.0E4 (Pa)



3. Forced Flow Junction

The CONTAN forced flow junction can be used to model behavior of pumped flow between two compartments or a containment spray with flow rates specified. The forced flow junction type (IFTYP) provides for the following options:

Controlled velocity or flow rate from vapor space to vapor space.

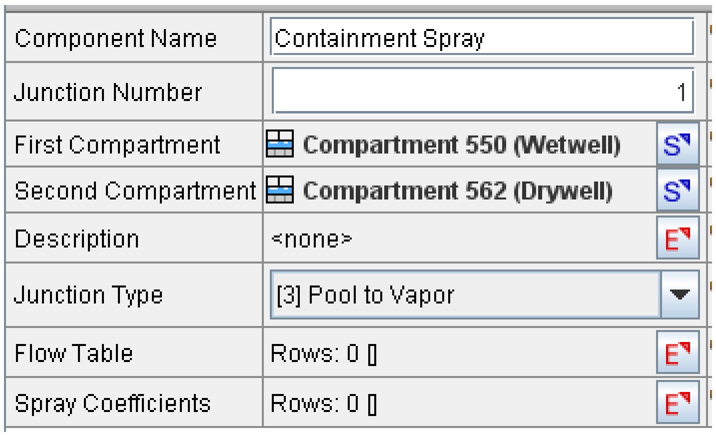
Controlled velocity or flow rate from liquid space to liquid space.

Controlled velocity or flow rate from liquid space to vapor space (can be used to simulate containment spray).

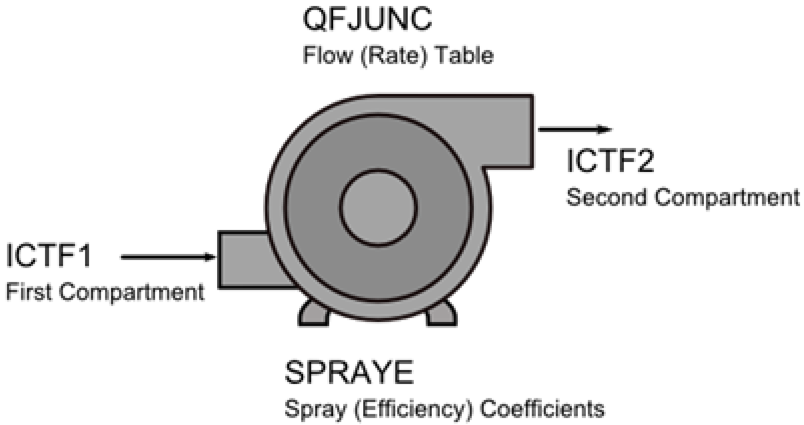
3. Forced Flow Junction

For the containment spray options, the spray efficiency (SPRAYE) can be controlled.

The spray efficiency is a value between 0 and 1 indicating the fraction of the spray flow subcooling that is available for condensing steam and cooling the containment.



Component Name	Containment Spray
Junction Number	1
First Compartment	Compartment 550 (Wetwell)
Second Compartment	Compartment 562 (Drywell)
Description	<none>
Junction Type	[3] Pool to Vapor
Flow Table	Rows: 0 []
Spray Coefficients	Rows: 0 []



4. CONTAN Heat Structures

The CONTAN heat structures (HS) capture wall condensation. The wall heat transfer coefficient can either be specified directly as a boundary condition, or can be calculated from built-in correlations. (Note that wall condensation effects may be small relative to the direct condensation of steam which is blown into the wetwell pool).

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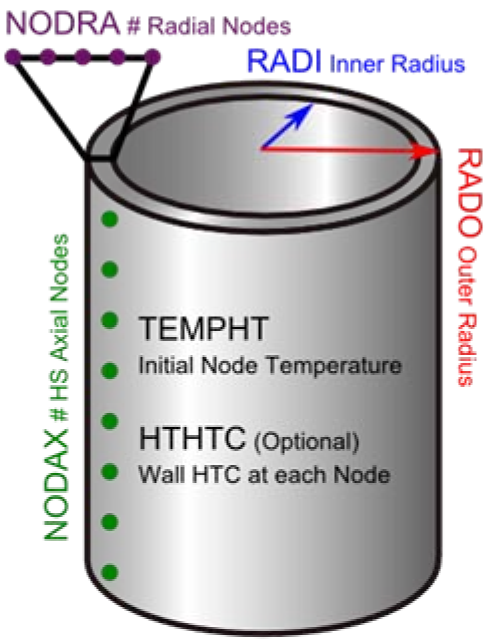
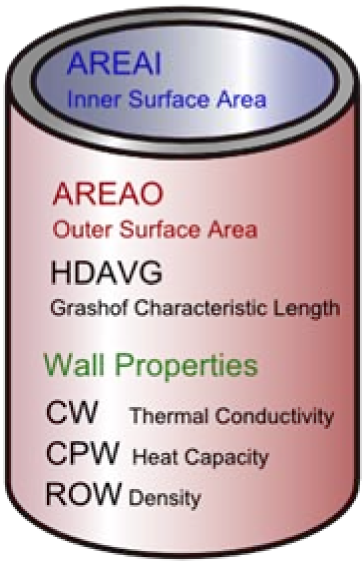


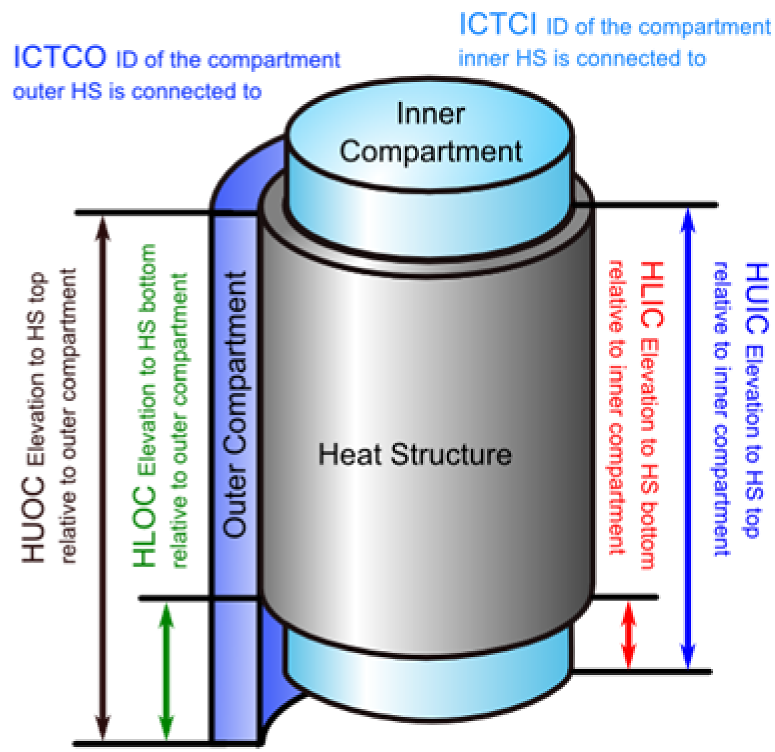


4. CONTAN Heat Structures

The HS inner and outer surfaces are each connected to compartments. A **level tracking flag** can be enabled to cause the HS to check which nodes are in the liquid and vapor spaces for calculating condensation and heat transfer.

Heat structure nodalization and the elevation relative to the compartment are *only used if level tracking is enabled*.

Note that although the HS component uses cylindrical slab terminology, any HS geometry characterized by thickness and inner and outer surface area can be modeled.



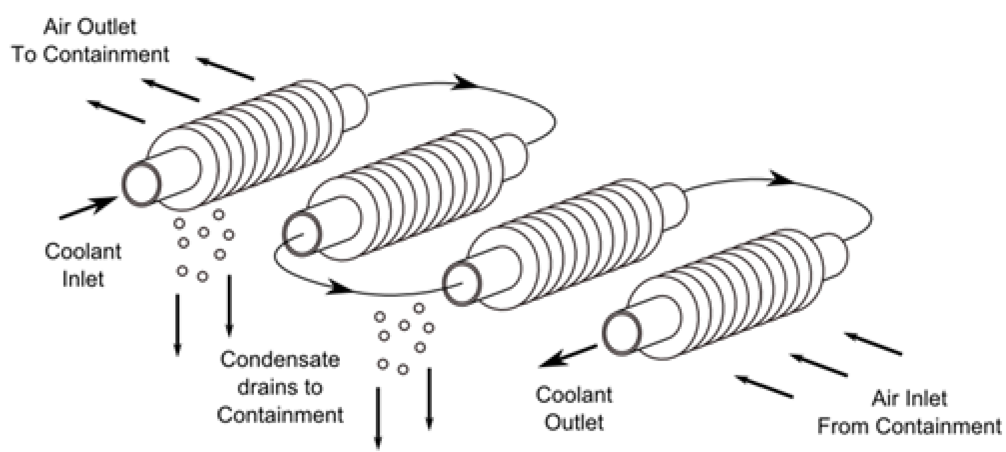
5. Cooler

The CONTAN cooler models either direct heat transfer to/from a compartment, or heat transfer via a combination of heat transfer coefficient (HTC) and wall temperature (Twall). The cooler be used to model a specified wall boundary condition or a simple cooling system. Inputs include:

- The compartment and region (liquid or vapor) to which the cooler is connected
- The cooler type (HTC + wall temperature OR direct heat flux Q)
- Trip signal that enables the cooler, control block ID to specify T or Q, and a control table to specify value based on a control block
- HTC value (only used if the cooler type is HTC + temperature)

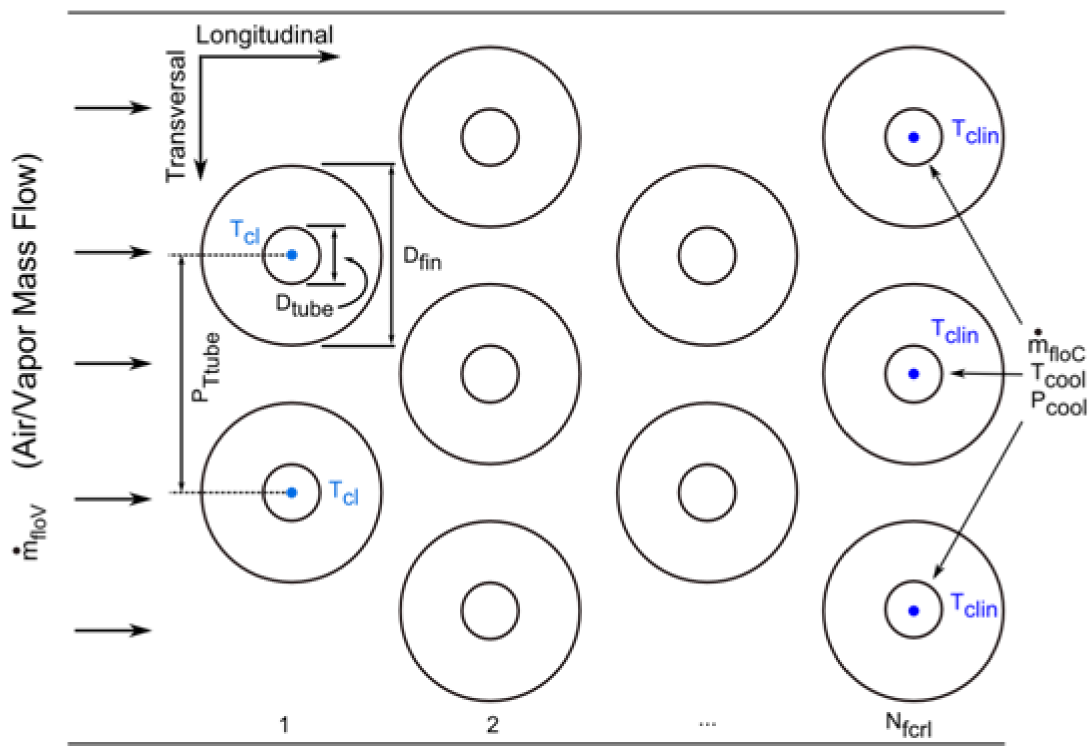
6. Fan Cooler

The CONTAN fan cooler subcomponent models heat transfer for a finned tube fan cooler such as the simplified one depicted below. Unlike the cooler, the fan cooler calculates condensation rates thus capturing the transfer of vapor to liquid inside the fan cooler. Specific knowledge of the fan cooler geometry is required to develop the input needed for this model.



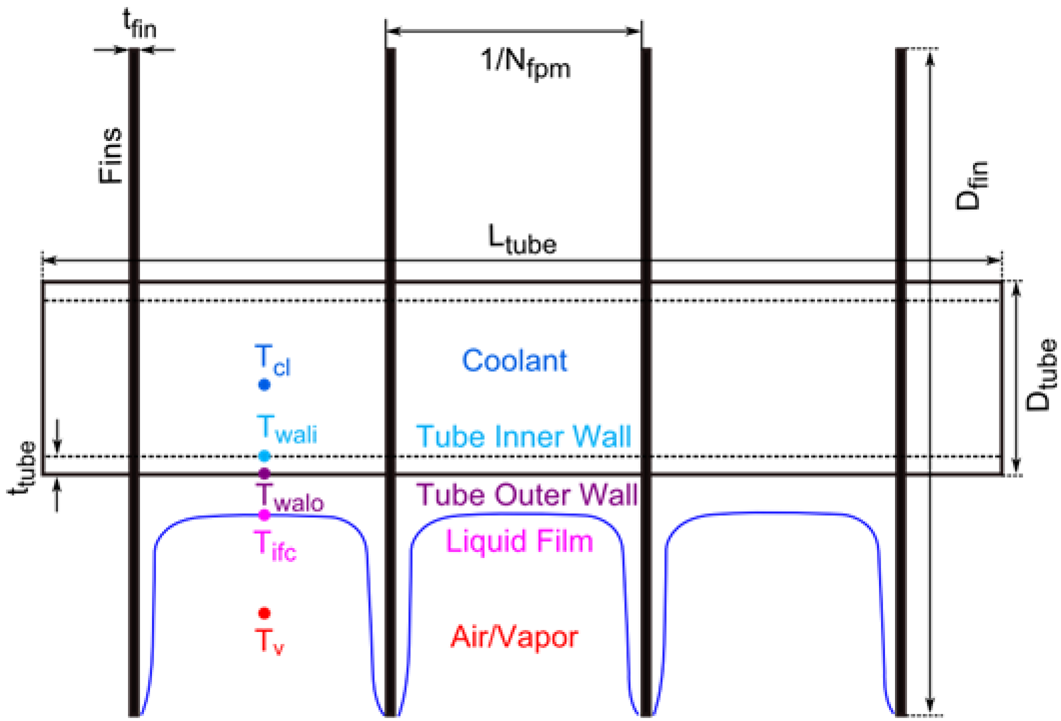
6. Fan Cooler

Basic inputs for the fan cooler model are shown below in black (calculated parameters that may be plotted are shown in color)



6. Fan Cooler

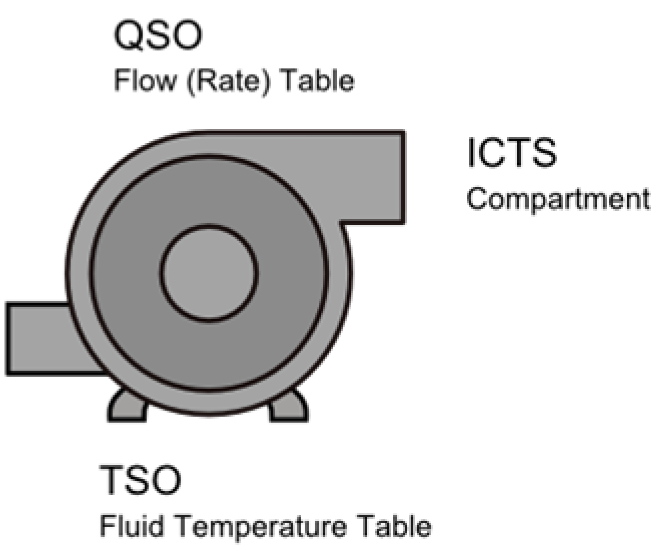
Required inputs also include thermal conductivity of the tubes and fins and the items shown below in black text. The fan cooler model can be enabled/disabled via a trip, and the temperature, pressure, and flow rates can all be controlled via control systems.



7. Source/Sink Junction

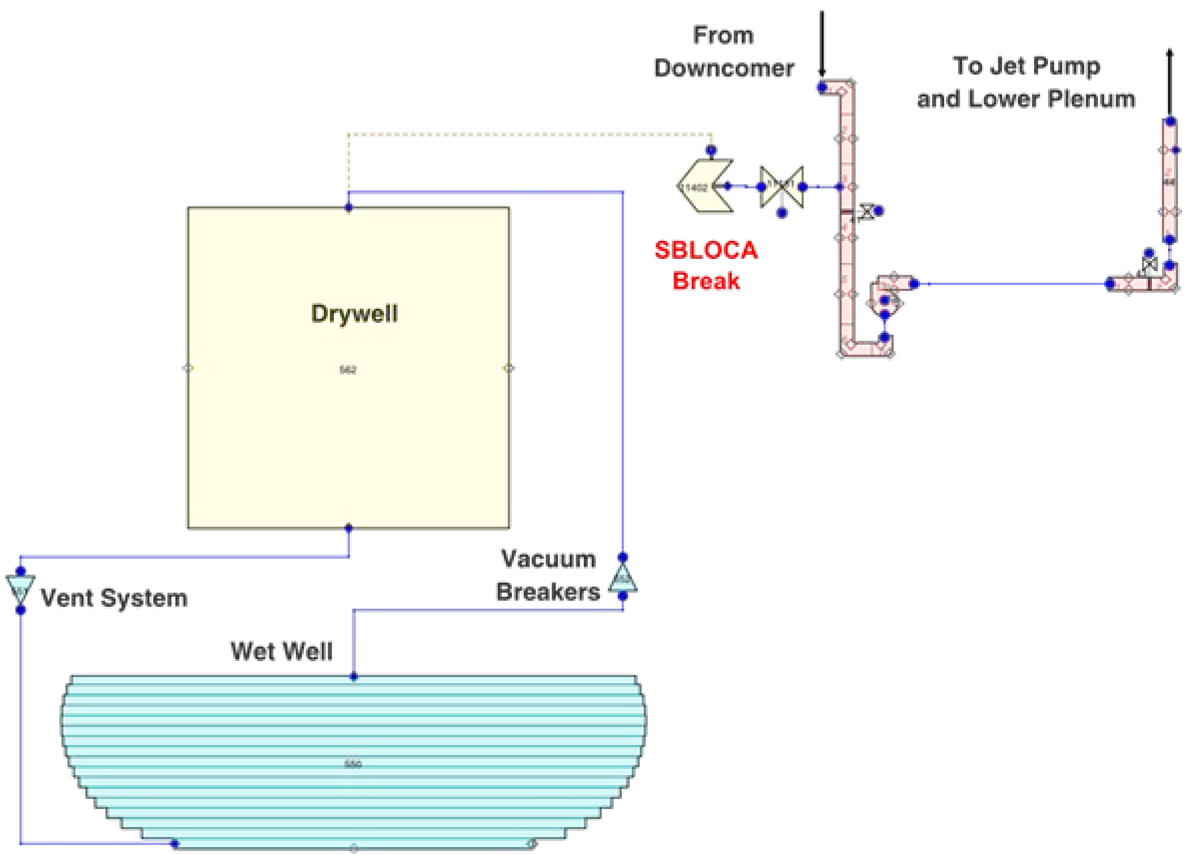
CONTAN source/sink junctions specify a flow boundary condition for a compartment. The source/sink junction type (ISTYP) can be one of the following:

1. A Liquid Source
2. A Liquid Sink
3. A Saturated Steam Source
4. A Steam Sink



Example CONTAN Containment Model

- An example BWR LOCA CONTAN containment model for a recirculation pump inlet line break is shown here



Questions?

Any questions before moving on to the workshop exercise?