Experiences from Application of MELCOR 1.8.6 for Plant Analyses

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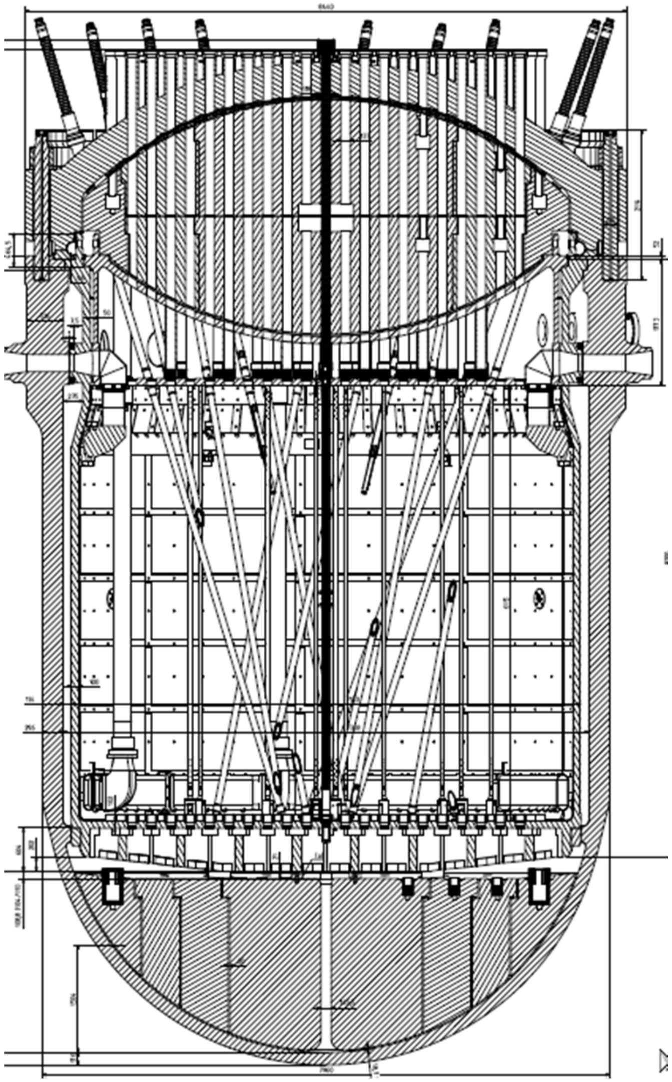
Introduction

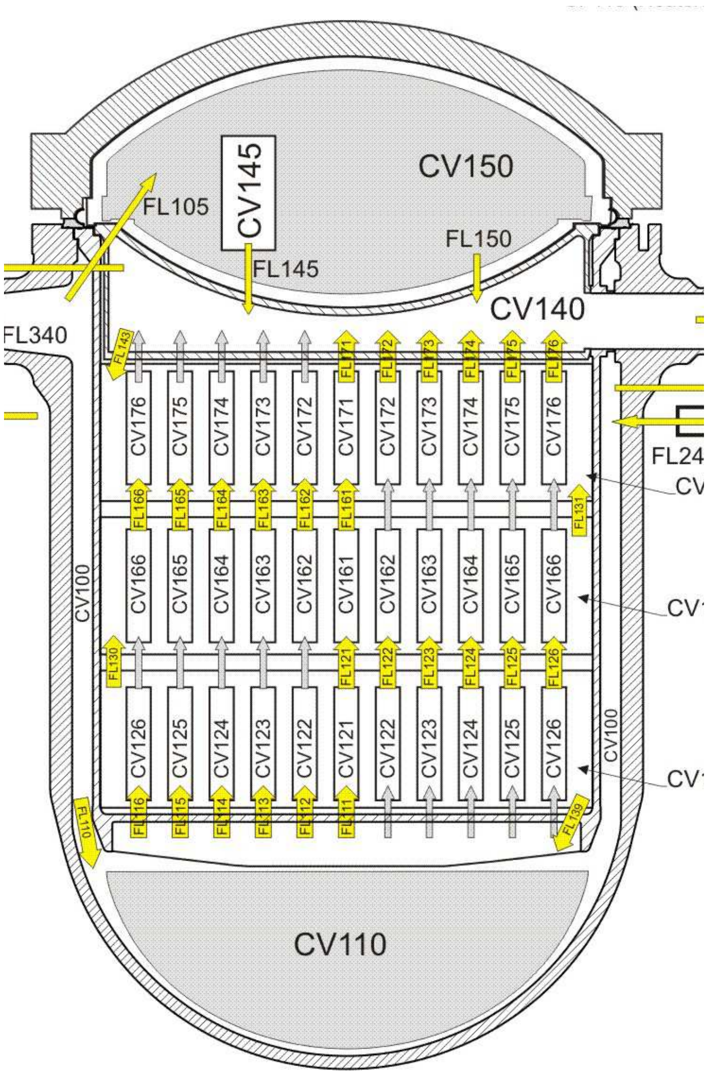
- PSA Level 2 is being performed at GRS for the Argentinian Pressurized Heavy Water Reactor (PHWR) Atucha II
- MELCOR 1.8.6 is used for severe accident and source term analysis
- Atucha II is a 745 MWe second generation Pressurized Heavy Water Reactor (PHWR) with a Siemens/KWU design.
- A detailed input deck has been developed, containing:
  - Primary System: 2 Primary Loops, Pressurizer, Relief Tank, Surge Line, 4 Moderator Loops including coolers
  - Secondary System: 2 Steam generators, Feed Water System, Main Steam Line
  - ECC System: 4 Safety Injection pumps, Flooding Tanks, ACCUs
  - Reactor protection signals
  - Detailed reactor building (containment and annulus, including ventilation systems)
  - Relevant sections of the auxiliary building
  - Predefined release paths from containment into environment
- For this presentation limitation on modeling of the reactor and radionuclides.

Atucha II - Reactor Pressure Vessel (RPV)



- 2 loop pressurized heavy water reactor with 4 moderator loops
- 1 fuel assembly (37 fuel rods) inside a coolant channel
- 451 channels are located inside a big moderator tank
- 94 m^3 coolant volume and 199 m^3 moderator volume filled with heavy water
- Moderator at same pressure as coolant, but at a significant lower temperature
- 18 steel / hafnium control rods
- Lower and upper filling bodies (steel)

MELCOR - RPV Model



RPV thermal hydraulic nodalisation

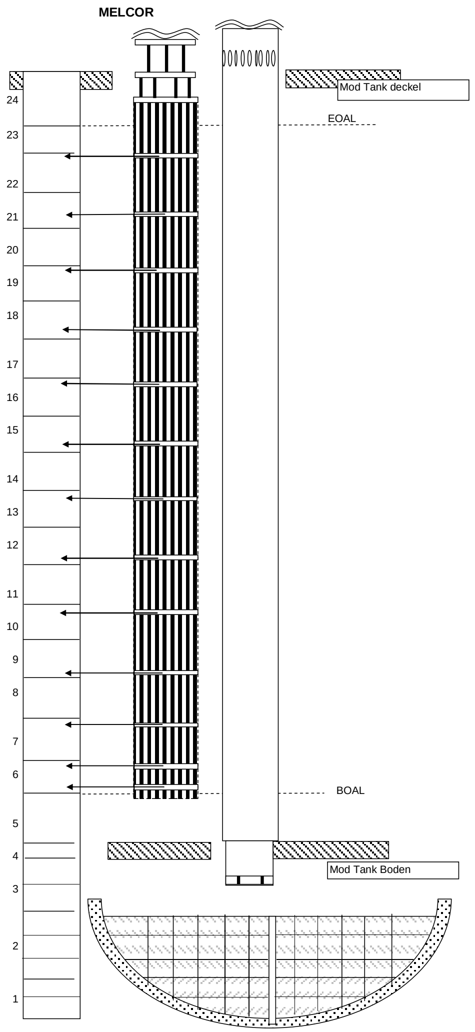
- Moderator tank (3 CV)
- Coolant channels (6x3 CV)
- Cross connections (6x3) from channels to moderator tank in case of channel failure
- Downcomer, lower + upper plenum, upper head (each 1 CV)

Core model uses BWR option

- MELCOR fuel assembly boxes represent zircaloy coolant channel walls
- CN : CB = 50 : 50 as basis assumption and independent of the existence of CR
- **Core:** 6 radial non-uniform rings according to power and mass flow profile

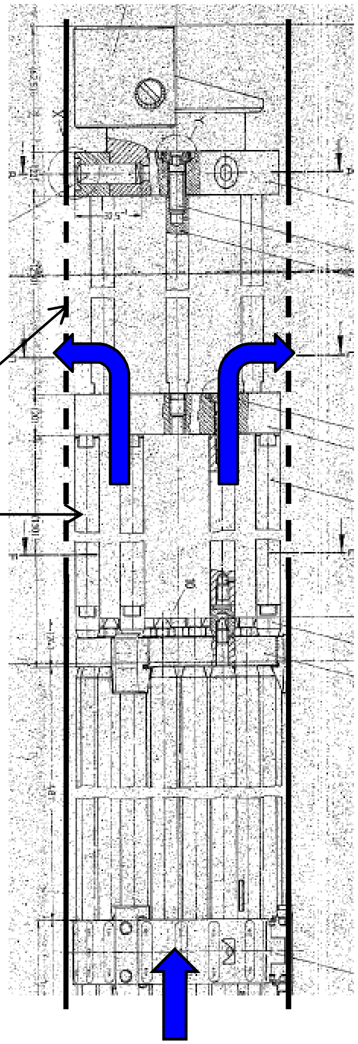
MELCOR - Core Nodalisation

- 28 axial nodes for the core and the lower plenum
- 7 levels for the lower plenum and 1 for the lower core support plate / moderator tank bottom
- 20 levels are inside the core
- 18 levels for active part (16 x 30cm + 2 x 25 cm)
- spacer grid adjusted to individual core levels – no melt retention and modeled as NS
- height of axial levels in lower plenum have been adjusted to MELCOR lower head model needs in combination with the number of radial rings
- Increasing of the axial meshes of the lower plenum in order to describe the heat-up of the filler pieces after melt relocation more precisely

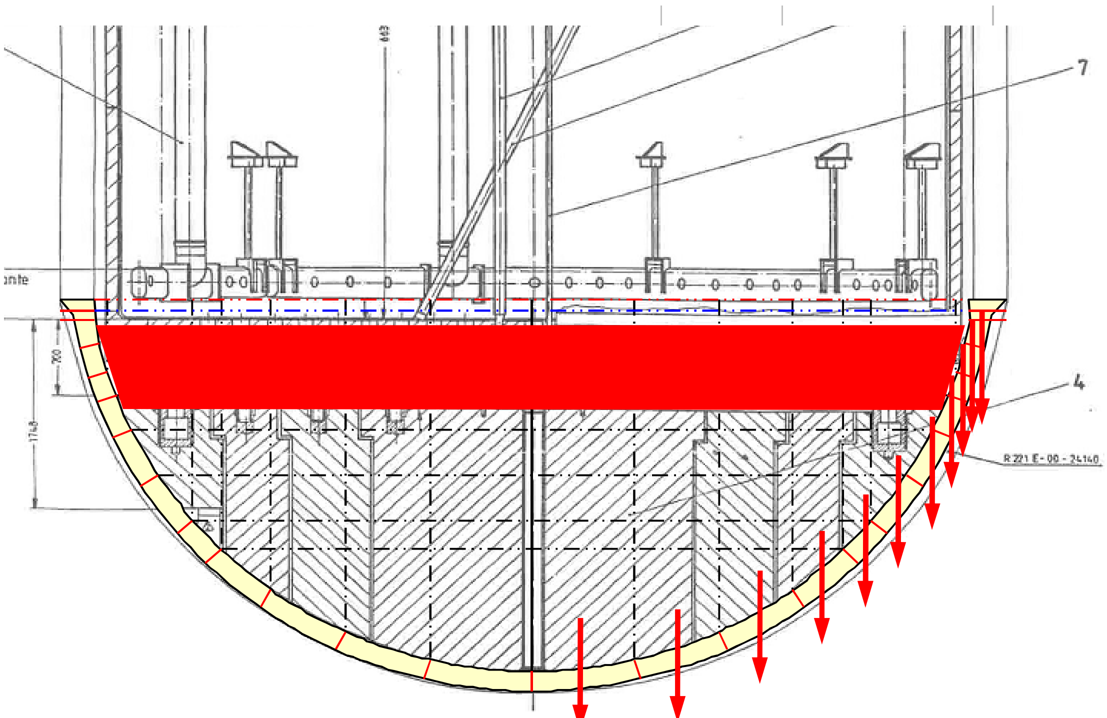


MELCOR - Core Degradation Model

- CR modeled by NS in rings 1 to 3; consisting only of steel; supported from below; failure temperature 1705 K
- coolant channels as fuel assembly canisters of the BWR model
- failure of CN and CB at the same time if 2400 K reached in one of the structures (failure mode modeled by many CF for each ring and level)
- failure of fuel elements at about 2500 K (live time model) reached in each cell **OR** (if the coolant channel failed locally **AND** the support from above is missing); failure of steel structure on FA head; (time delay of 10 sec and 3 axial core levels lumped together)
- no particulate debris allowed in intact fuel channels
- PLATEG model for lower moderator tank bottom
- use of MELCOR 2.0 defaults w/o modifications for HS accuracy



MELCOR - Lower Plenum Nodalisation



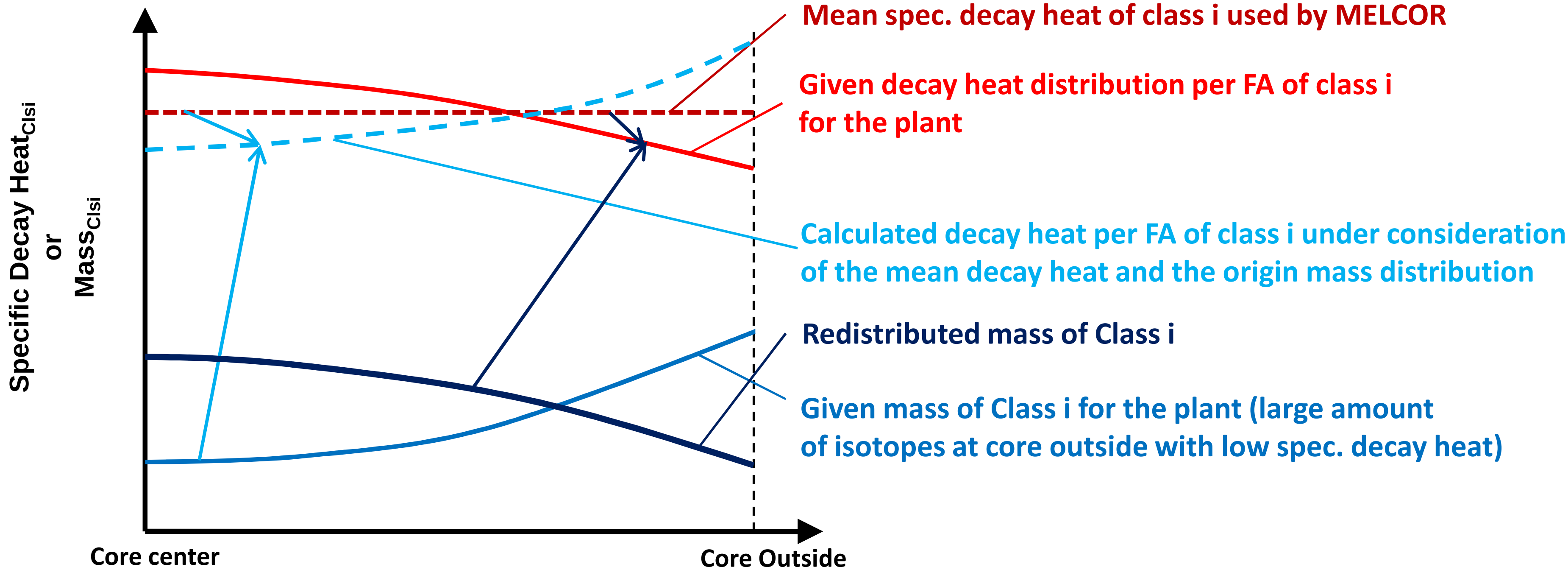
- Filler pieces (ca. 500 t) made of steel in lower plenum modeled as supporting structures (columns) with failure temperature of 1705 K
- 11 segments for RPV wall are used
- Gap above filler pieces is large enough to collect all melt from core
- Collected melt is in contact with RPV wall only in the upper part of the lower plenum, some water my be in cavity

- No entrance of particulate debris into filler pieces region (very small gaps) in order to stabilize the calculation
- No significant pressure drop at the RPV wall has to be expected => Additional failure criterion (outer segment temperature > 1573 K) as conservative assumption => Successive opening of the penetrations (starting with the upper one and 1 s between each penetration)
- Relocation of melt and debris into reactor cavity after lower head failure has been calculated by MELCOR

MELCOR - Input RN Inventory and Decay Heat (1/2)

- Tables with radionuclide inventory and decay heat for 73 elements (for each of 451 fuel elements in 10 axial levels and 75 time steps) were provided by the operator of the Atucha II power plant.
- GRS has used a program in order to group these data into the MELCOR RN classes and to adjust the data for both the radial and axial core input.
- Two alternatives of RN inventory input are possible. Either the decay power profiles are OK or the initial element mass profiles are OK. But never both!
- **Reason:** The specific decay power of a RN element varies within the core location because different isotopes belong to this element. In MELCOR the specific decay power of each RN element is constant. => A well fitting RN mass inventory input leads to a mismatch concerning the power profiles.

MELCOR - Input RN Inventory and Decay Heat (2/2)



- Suggestion for the RN inventory input:
  - Adaptation of the mass profiles in order to get accurate power profiles, because power determine the exact timing of core degradation
  - But the total mass of each element class of the input has to be fit with the plant data!
  - It is difficult to determine the uncertainty due to this redistribution. But it can be accepted because volatile FP are released very fast during early phase and non-volatile FP are gathered inside the lower plenum and are commonly transported into the containment.

MELCOR - Calculation of RN Behavior (1/3)

- RN elements are automatically allocated to the classes; RN normalisation to all classes is necessary; otherwise error in decay heat

  => Check the calculated decay heat variables (DCH-COREPOW.0, DCH-TOTCLSPOW.0, RN1-DHCOR, RN1-DHTOT). Their values should correlate with each other.
- Common decay heat table for each RN class was calculated from individual tables.
- RN distribution to core cells had to be defined by user for the Atucha II deck.
- RN release model from core according to recommendation from SNL: “adjusted ORNL booth” model for low burn-up.
- MELCOR used 16 default classes in the past. The application of 17 classes was recommended on the 9th MELCOR Users’ Workshop, September 2008 as new default in order to consider Cesium Molybdate (Cs2MoO4)

  => 17 classes have been applied for the Atucha II calculations

  => Problem with Release of Class 17 from MCCI

MELCOR - Calculation of RN Behavior (2/3)

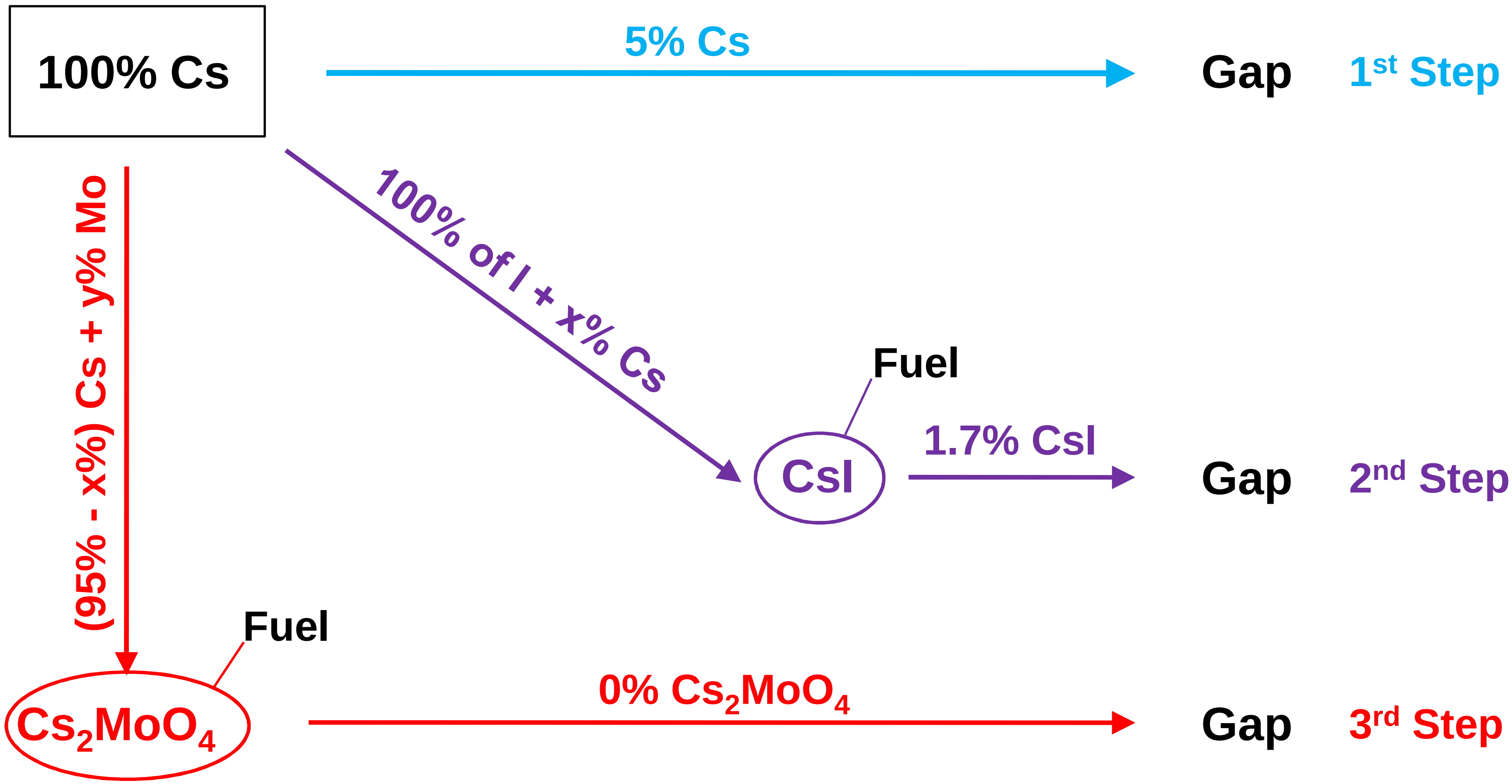
- CsI is defined as class 16
- Cs_2MoO_4 (cesium molybdate) is defined as class 17
- Aerosol Cs_2MoO_4 is formed after release by class combination of classes 2 and 7 similar as for CsI

```
rncls0100 16 * Acceptor Class Number (CsI)
* Donor Class No. Mole Ratio to Acceptor Class
rncls0101   2   1.0 * Cs
rncls0102   4   0.5 * I2
*
rncls0200 17 * Acceptor Class Number (Cs2MoO4)
* Donor Class No. Mole Ratio to Acceptor Class
rncls0201   2   2.0 * Cs
rncls0202   7   1.0 * Mo
**** cavity input
rnclvn02   17   19
rnvncl02   19   17
```

- Big mass balance error for Cs_2MoO_4 during MCCI
- SNL has kindly supported GRS on that issue. Presently, the solution is the application of pre-population for the elements CsOH, CsI and Cs2MoO4.

MELCOR - Calculation of RN Behavior (3/3)

- Pre-population means an initialization of the amounts of CsOH, CsI and Cs2MoO4 and was recommended by SNL. => Class combination has to be neglected!



- Testing of the calculation using 17 classes and pre-population is underway.

Summary

- Recommendations on best user practices:
  - Limitation of the number of one-way flow pathes and avoiding mass injection into small CV => save computational time.
  - For reactor calculations use of plant specific RN mass inventories and redistribute the inventories in order to get the accurate decay heat distribution.
- Recommendations of any modification of default value definition:
  - In cases of small pressure differences at the RPV wall the decrease of the differential-pressure lower limit of creep rupture model of LP (Sensitivity Coefficient 1600 (3)) could be required. Otherwise the model is turned off.
- Suggestions to developers for further code development, modification, or improvement:
  - Inconsistency on the Lower Plenum Output (numbering of segments, message from creep rupture model regarding the location of failure).
  - Automated consideration of Class 17 => no pre-population should be required.