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Implementation of alternative ISLOCA modelling on generic PWR

12-16 April 2021

EMUG Virtual Meeting

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Presentation topics

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1 – Previous ISLOCA modelling

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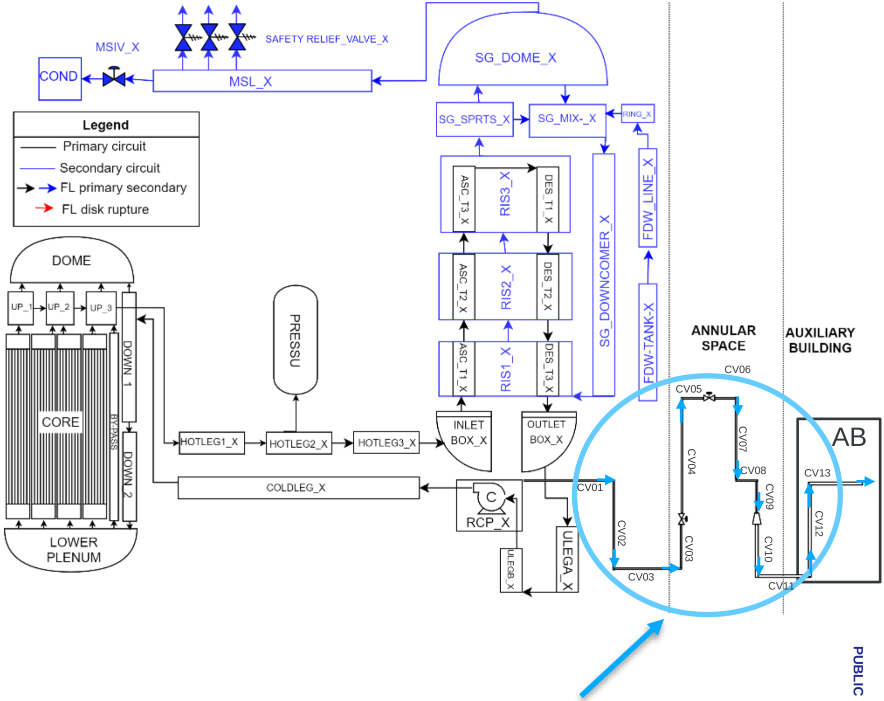
Detailed piping model

- Detailed piping model for the ISLOCA path
  - Desired for best estimate turbulent deposition
  - Many bends and pipes with various diameters
  - Using MELCOR 1.8.6 on generic PWR
- Example : ISLOCA on thermal barrier
  - Break creates a path from Reactor Coolant Pump (RCP) to the Auxiliary Building (AB)
  - Several CVs and FLs for ISLOCA modelling, following Component Cooling (CC) piping
  - Number of CVs defined in order to have 1 CV for each pipe diameter and for each building it goes through



ISLOCA detailed flow path to the AB

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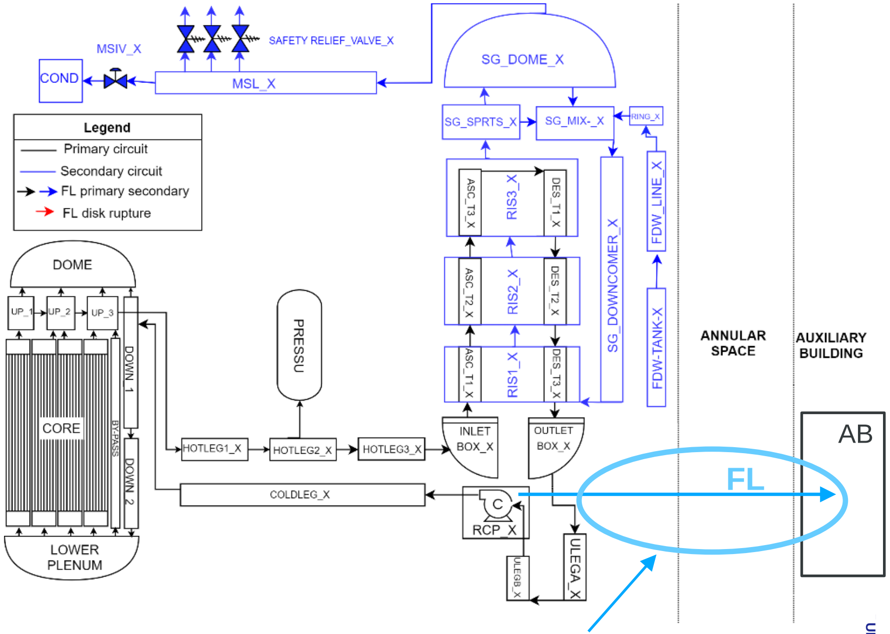
1 – Previous ISLOCA modelling

Detailed piping model

- Issues with the approach
  - Very long runtime for the model (> 1 month) for MELCOR 1.8.6 calculations
  - If modelling error found, a complete rerun is required
  - Courant limit – prevents that all the material in a CV flows out of the CV in a single time step
    - For small CV modelling the ISLOCA path the calculation runtime is affected by the courant limit : time step decreases so that material does not flow out of CV in a single time step

➔ Goal of alternative modelling : get the best of a detailed model but with the runtime of a single flowpath model for the ISLOCA



ISLOCA 1 flow path to the AB

2 – Alternative ISLOCA modelling

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Description of the approach

- Three steps approach :

1. Run MELCOR calculation with single flowpath model of ISLOCA path and full plant model
2. Run a detailed standalone MELCOR model of the ISLOCA path to determine the Decontamination Factors (DFs) in the ISLOCA path
3. Run full plant model with 1 FL for the ISLOCA path and integral class DFs from step 2

- Runtime for steps 1 and 3 : 1 week to reach Basemat Melt Through (BMMT)
- Runtime for step 2 : 1 day

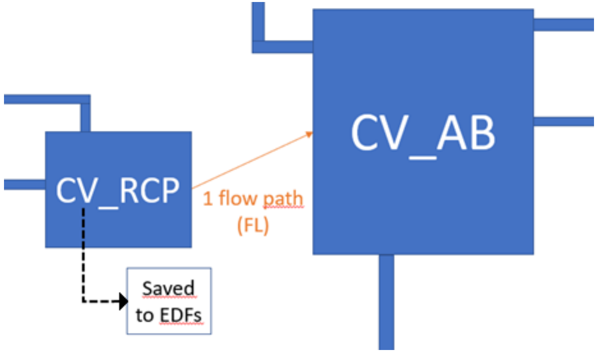
→ Major gain in terms of runtime but much more labour required

- Similar to approach presented by Sandia National Laboratories during EMUG 2018

2 – Alternative ISLOCA modelling

Step 1 Implementation

- Full plant model with 1 FL for the ISLOCA path between the RCP and the AB
- Single flowpath has to reproduce the same head losses and mass flow rate of the ISLOCA path piping network in order to have the same kinetics of the RCS depressurization
- All necessary properties to replicate the RCP control volumes are stored in an External Data File (EDF)
  ➔ EDFs define the thermalhydraulics and radionuclides evolution of the RCP control volume as a function of time
- This model does not consider turbulent deposition along the ISLOCA leak path



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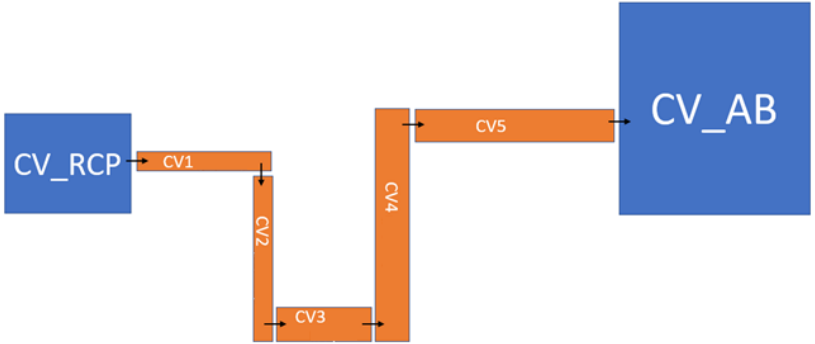
2 – Alternative ISLOCA modelling

Step 2 Implementation

- Standalone model :
  - From the full plant model only remain the CV of the RCP and of the AB
  - Detailed model for the ISLOCA path is implemented
  - Relies on EDF from step 1 for the property-specified CV of the RCP
- Considers turbulent deposition in each CV of the ISLOCA path



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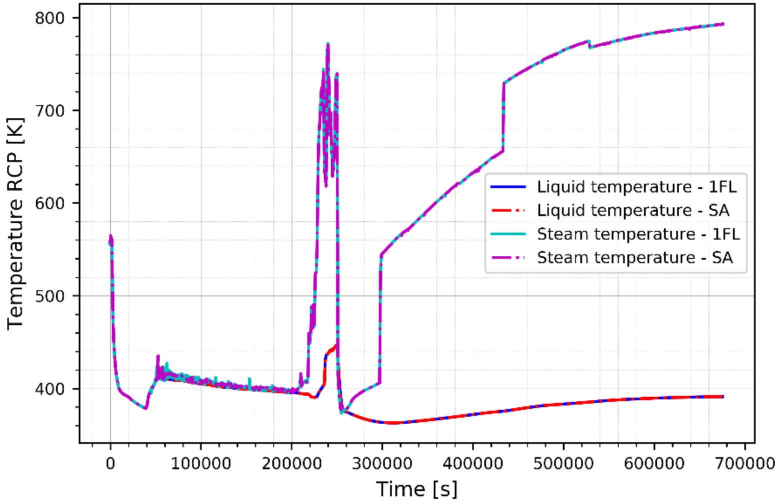
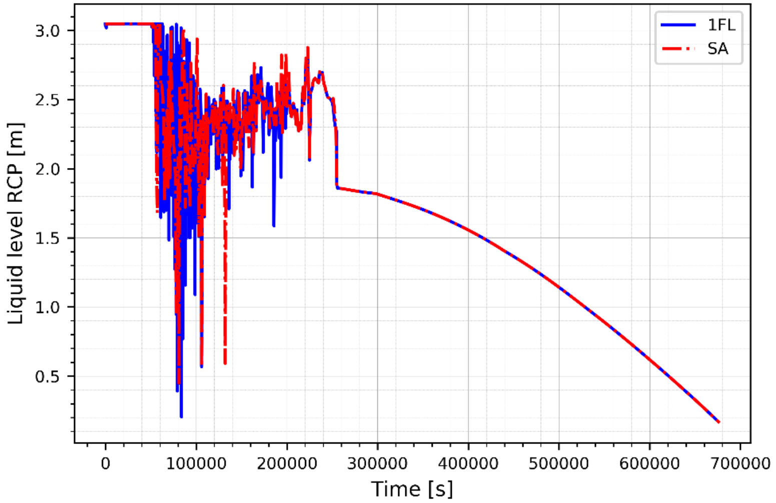
2 – Alternative ISLOCA modelling

Comparison between step 1 and step 2

Fixing pool parameters (temperature, elevation and volume) and the atmposphere temperature in RCP volume allows for faithful reproduction of results from the full model by the standalone





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2 – Alternative ISLOCA modelling
Comparison between step 1 and step 2

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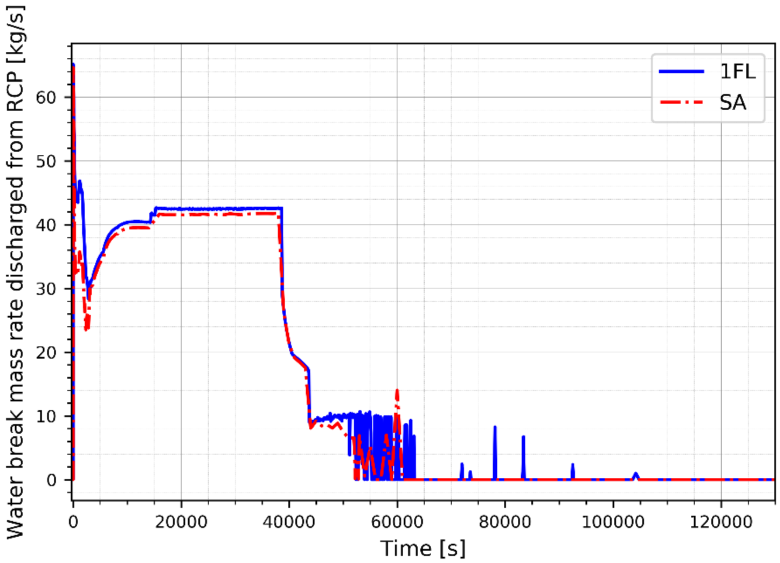
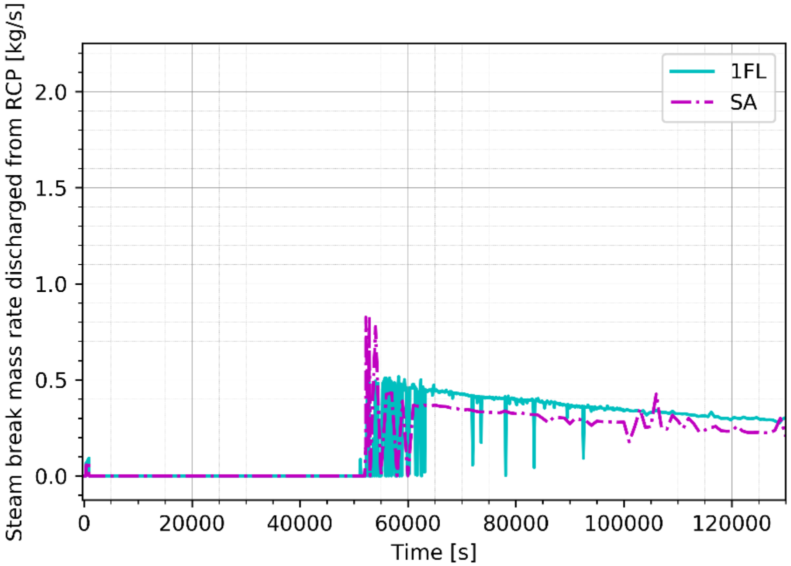
Faithful reproduction of liquid and steam mass flowing out of the break for the standalone model





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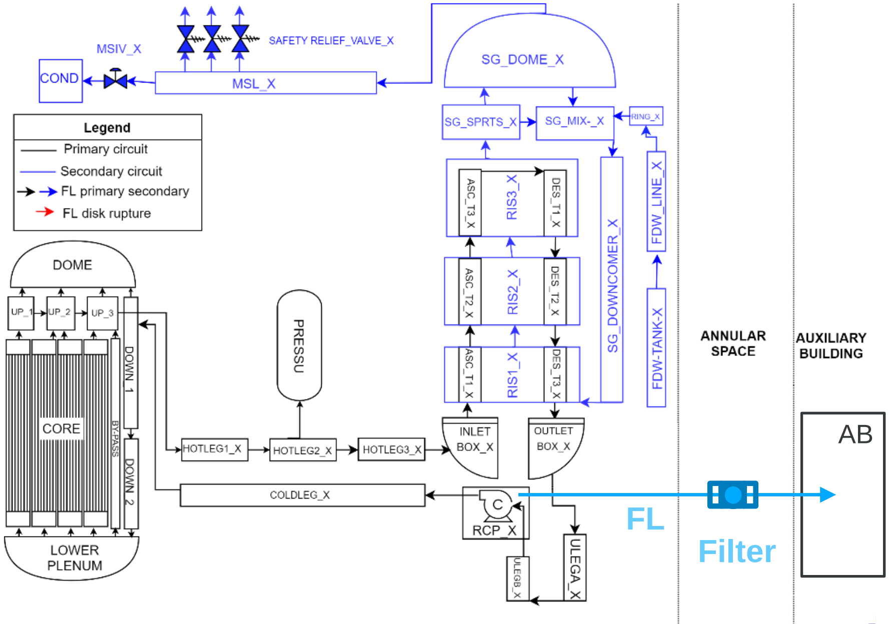
2 – Alternative ISLOCA modelling

Step 3 Implementation

- Full plant model with 1 FL for the ISLOCA path between the RCP and the AB – same as step 1
- The DFs determined in step 2 for each class are used as filters (RN2_FLT and RN2_CLS inputs)
- To be started soon as step 2 is currently being implemented



3 – Implementation issues

3 – Implementation issues

Issues with step 2 and solutions proposed

Problems encountered with step 2 and solutions proposed

- If only fixing Zpol, Tpol and Pvol in CV RCP, the atmosphere if present will consist of saturated water vapor at PVOL. However, if ever atmosphere of CV RCP is superheated or contains noncondensable gases, TATM (atmosphere temperature) must be specified
  - Practically, how to know in advance that TATM will need to be specified ?
  - At first, saturated water only was assumed to be present and TATM was not imposed
  - But comparing the model of step 1 and step 2 shows that TATM does not coincide, and the standalone is not conservative ➔ TATM will thus be specified
  - Mole fraction of noncondensable gases, record MLFR.n, must be specified if TATM is specified. However, when no atmosphere present, issue as the sum is not 1.0 for MLFR records
    ➔ Problem solved by redefining the EDF of MLFR for H2 in order for the sum to be 1.0 using a Python tool (could be done with CF on MELCOR)

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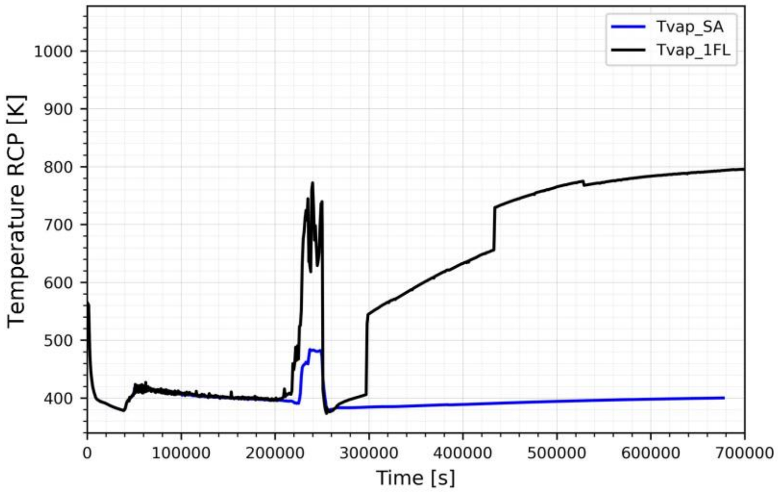
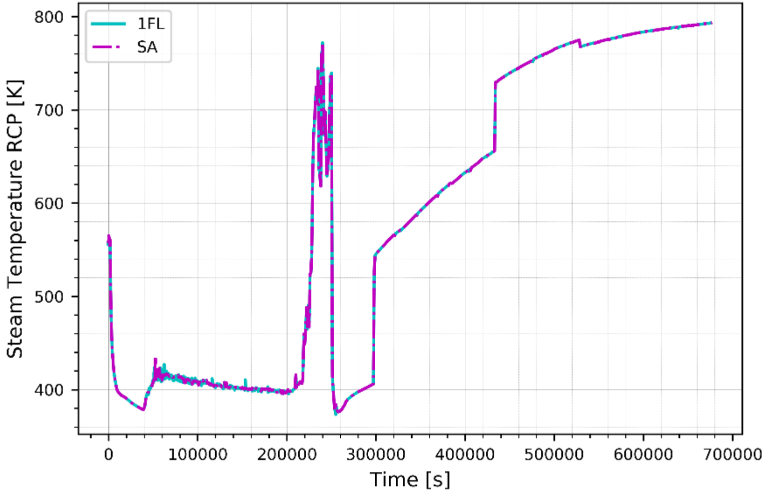
3 – Implementation issues
Issues with step 2 and solutions proposed

Left figure : before specifying TATM

Right figure : after modifications to specify TATM and atmosphere compostion





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3 – Implementation issues

Issues with step 2 and solutions proposed

Problems encountered with step 2 and solutions proposed

- RN Aerosol Source (RNAS) input in MELCOR standalone can only refer to a CF or TF and not to an EDF
  - However, a CF requires a function (interpolation of data, not possible as nonlinear) and a TF is limited in number of data pairs (TFnnn10 to TFnnn99 so 90 entries possible)

  ➔ Circumvented by defining RN sources of a same class number that will refer each time to a different TF that handles another time interval

  ➔ **Although referring to an EDF would be much simpler and more precise**

- The RN extracted with the EDF is a mass in kg of aerosol in liquid or gas phase, whereas the RN sources defined in the standalone (RNAS) need a mass rate in kg/s as input
  ➔ Circumvented by deriving data using a Python post treatment tool

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4 – Conclusion

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- Alternative ISLOCA modelling proposed based on SNL methodology
  - Drastically decreases runtime of calculation…
  - … But much more labour is required from the analyst
- 3 steps for implementation
  - Step 1 : Full plant model with simplified ISLOCA model (1FL) ➔ Completed
  - Step 2 : Standalone model with detailed ISLOCA path : gives DFs
    ➔ Extracting RNAS data using EDF would be simpler and more precise than multiple TF
    ➔ Extracting mass flow rate instead of mass of RN using EDF
    ➔ Possibility to use EDFs in .dat files (for now exclusively in .txt files)
    ➔ Not imposing the sum of MLFR.n to 1.0 when no atmosphere
    ➔ Debugging ongoing
  - Step 3 : Full plant model with simplified ISLOCA model (1FL) and DFs from step 2
    ➔ To be started once step 2 is completed – debugging foreseen

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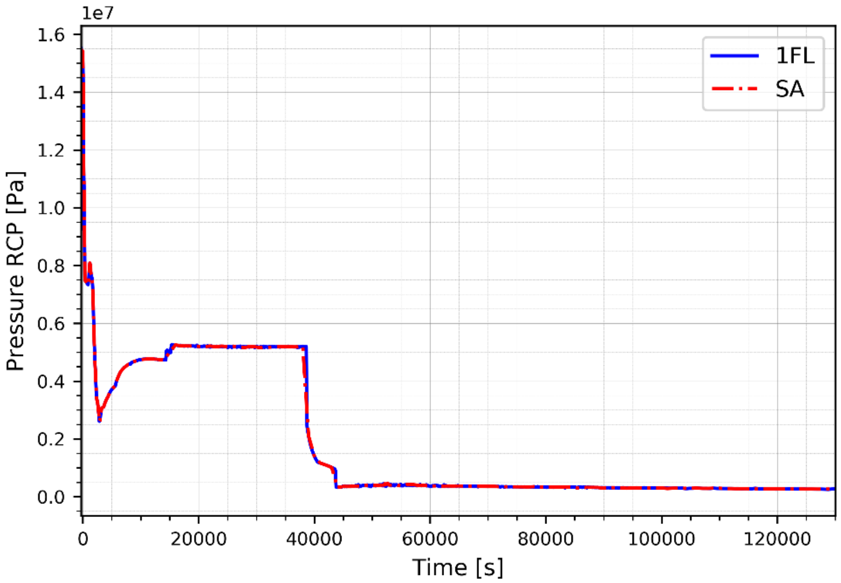
Thank you for your attention ! Any questions ?

Contact information

mathieu.barbion@tractebel.engie.com

Additional information

Comparison of primary pressure between the full plant model and standalone calculation



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Additional information

- Application for MELCOR 2.2 :
  - Alternative methodology still relevant as the runtime of a detailed ISLOCA calculation is also long in MELCOR 2.2
  - The same 3 steps for the alternative ISLOCA modelling are followed
  - Issue of limited TF entries avoided : almost unlimited entries for a TF in MELCOR 2.2.
  - Same issue for extracting mass flow rate of RN ➔ Mass is provided and data must be derived

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