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MELCOR-Fusion for the Future: Extending MELCOR 2.X With a Modular Approach

June 2023

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Changing the World's Energy Future

Idaho National Laboratory

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Melcor-Fusion Development

Melcor-Fusion for the Future

Extending Melcor 2.X with a modular approach

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U.S. Department of Energy's Office of Nuclear Energy

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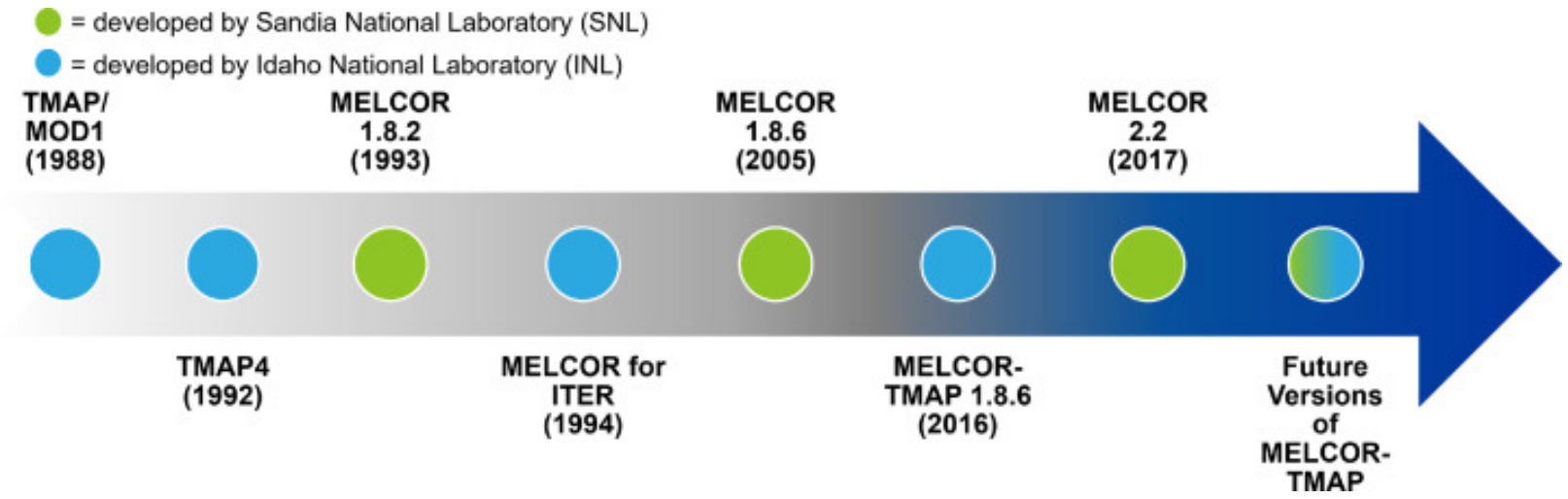
History of MELCOR-Fusion

- Forked from MELCOR 1.8.2 for the development of ITER
- MELCOR-ITER 1.8.2 has been verified and validated for safety licensing
- Additional functionality has been incorporated into more recent MELCOR versions
  - Most recently incorporated with MELCOR 1.8.6



Outstanding Requests to Improve Existing MELCOR-Fusion

- MELCOR-ITER 1.8.2 CR3: Increase maximum number of lines in an input file
- MELCOR-TMAP Pool-atmosphere isotope transfer outstanding bug
- MELCOR-TMAP Implement hydrogen isotope scrubbing to extend internal SPARC-90 code

MELCOR 1.8.6 Fusion-Specific Features

- Support for multiple working fluids (up to four)
- ~~User-specified fluids (no mixing model)~~
- Modified choked flow algorithm, including cross-flow
- ~~Liquid-metal convective heat transfer correlations option~~
- Support for T_2, HD, HT and DT as NCG's
- Dissolved H-isotope transport model
- HTO oxidation and transport
- Simple liquid freezing model (?)
- Thin film frozen condensation model
- Additional aerosol resuspension models – Vahnshtein & Reeks and Hall
- Be, W, ~~graphite~~ oxidation models in air and steam
- Dispersed Flow
- MHD Pressure drop flow-velocity-linear correlation
- Aerosol deposition in gases other than air
- ~~Turbulent deposition~~ (?)
- Resuspension of aerosols entrained in coolants during flash
- Aerosol surface adhesion (Reeks, Reed and Hall)
- Lithium fire model

- Tritium transport from TMAP
  - Adsorption/dissociation
  - Henry's/Sievert's law
  - Transport through composites
  - Interfacial flux balances
  - Surface reactions and boundary conditions
  - Soret Diffusion
  - Trapping
  - H-isotope liquid mass transport

Disclaimer

- This presentation includes forward-looking statements
  - These statements are made based on current views and assumptions
  - As such, they are subject to uncertainty and risk
  - Final outcomes may differ substantially from those outlined here

EMUG 2019 Requirements for MELCOR 2.X

Issue	Urgency	In MELCOR-Fusion 1.8.6?	In 2.2 or under development as of 2023
Introduce additional working fluids with multiphase capabilities	3	Y	D
Implementation of the possibility to use different fluids in different circuits at the same time during the calculation	3	Y	D
extend material physical properties to cryogenic range	3	P	P
Introduce models for chemical reactions in the case of different working fluids	2	Y	N
Model steam oxidation of the plasma-facing component	2	Y	N
model air oxidation of the plasma-facing component	2	Y	N
introduce models for aerosols turbulent and inertial deposition	2	Y	Y
introduce models for aerosols deposition with different carrying gas and mixtures	2	Y	N - ?
introduce aerosol resuspension model	2	Y	Y - ?
introduce models for aerosols transport in multifluid simulation	2	Y - Partial?	D
implementation of specific heat transfer correlations for simulating He as working fluid in the geometry of interest	2	N	N
Introduce dissolved NCG species within working fluids	2	Y - TMAP	N
extend the water properties below triple point temperature	2	Y	N
air condensation onto cryogenic structures	2	Y	N
helium condensation onto cryogenic structures	2	Y	N
allow low temperature operations (>3K) and cryogen working fluids	2	Y	D/Y
enclosure radiant heat transfer	2	Y	Y
extend the deposition and resuspension modelling to take into account remnant magnetization effects	1	N	N
standard scrubber model in FL package for Helium	1	Y - partial V	N
implement magnetic pump modelling for design and features (coast-down, etc.)	1	N	N
include MHD effects on heat transfer correlation and pressure drop evaluation (for design)	1	N	N

Features To Implement in MELCOR 2.X

1. Introduce additional working fluids with multiphase capabilities – Under development by SNL
2. Different fluids in different circuits at the same time during the calculation – Under development by SNL
3. extend material physical properties to cryogenic range – Partially implemented
4. Introduce models for chemical reactions in the case of different working fluids
5. Model steam oxidation of the plasma-facing component
6. model air oxidation of the plasma-facing component
7. introduce models for aerosols deposition with different carrying gas and mixtures
8. introduce models for aerosols transport in multifluid simulation
9. implementation of specific heat transfer correlations for simulating He as working fluid in the geometry of interest
10. Introduce dissolved NCG species within working fluids
11. extend the water properties below triple point temperature
12. air condensation onto cryogenic structures
13. helium condensation onto cryogenic structures
14. allow low temperature operations (>3K) and cryogen working fluids – Partially implemented
15. extend the deposition and resuspension modelling to take into account remnant magnetization effects
16. standard scrubber model in FL package for Helium
17. implement magnetic pump modelling for design and features (coast-down, etc.)
18. include MHD effects on heat transfer correlation and pressure drop evaluation (for design)

Physics Manager

- SNL is developing a new Physics Manager, which allows for modular state calculations
- This will allow “drop in” of new models/physics as they are necessary
  - Expected to speed up development and integration of new models
  - Increases maintainability and modularity of code
  - Ideal for incorporation of alternate aerosol deposition models, extension of physical properties
  - Code affecting physics relevant only to fusion can be kept away from critical fission code

DLL/API Access

- MELCOR 2.X is built on a modular codebase, which allows for easier integration of changes with localized effects
- Functionality not approved for general release will be developed into a separate extension package, which can be loaded into the base executable
- Melcor-Fusion will be a proof-of-concept and test case for extensibility
  - It is expected that those with use-cases which require code additions will be able to extend code functionality using the same API as MELCOR-Fusion
- Functionality which will is of general utility (MSR-relevant models, etc) may be incorporated into the base executable

Public Interface

- Documentation is planned to demonstrate how modifications can be implemented
- API Documentation will be publicly available, using the MELCOR-Fusion extensions as examples
- This is a Long-term work in progress

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