

framatome

Current MELCOR-related Activities of Framatome

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Content

- 1 AMHYCO Project
- 2 MELCOR Issues during Secondary Cool-Down
- 3 PSA Level 2 for the NPP Gösgen
- 4 Framatome R&D Roadmap (for MELCOR)

General information

- Improve knowledge about late phase containment atmospheres containing Hydrogen (**H₂**) and Carbon monoxide (**CO**)
- 12 Partners (EU & Canada) ^[1]
- EU funding period 2021-2024
- **Work ongoing,**
only preliminary results shown here

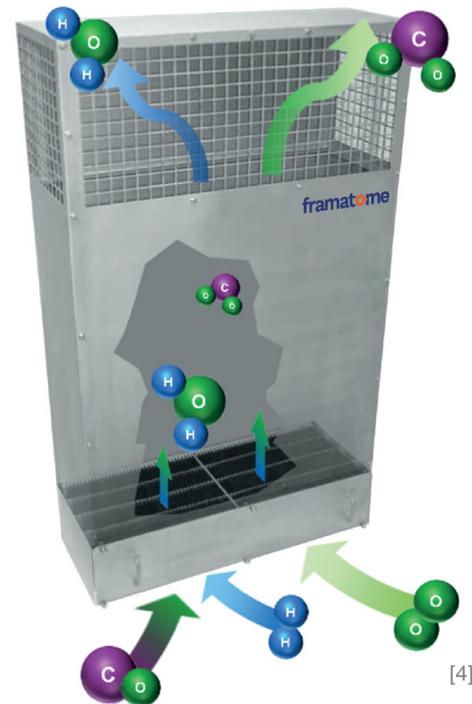
The following is not a full program overview, but only the parts likely most interesting for the broader MELCOR community

[1] <https://amhyco.eu/>



Work Package 3: Improvement of the PAR engineering correlation

- In Lumped Parameter codes, PAR are modeled as mass/energy source/sinks
 - Fast-running engineering correlation describes PAR recombination rate depending on CV-parameters
 - Engineering correlations always have validation limits
 - MELCOR PAR model is based on NIS-PAR and only recombine hydrogen^[2]
- Original AREVA PAR engineering correlation
 - Well validated in a wide range of parameters e.g. in the THAI facility^[3]
 - Used extensively in safety demonstrations (PAR back-fitting / new builds)
 - Describes H₂-recombination and CO-recombination (**and their interaction**)
 - **Not publicly available**
 - Newer experiments (THAI-3 & THEMIS) show deviations at O₂ < 3vol% in presence of CO - **CO-Poisoning**
 - Not very safety-relevant (low O₂ → no combustion, and Framatome PAR restart when O₂ con. rises again), but still an avoidable uncertainty



[4]

[2] MELCOR Reference Manual Version 2.2.18019

[3] Gupta et al. Summary of THAI Experimental Research on PAR Behavior and related Model Development, CSARP 2013

[4] Framatome Passive Autocatalytic Recombiner

Work Package 3: Improvement of the PAR engineering correlation

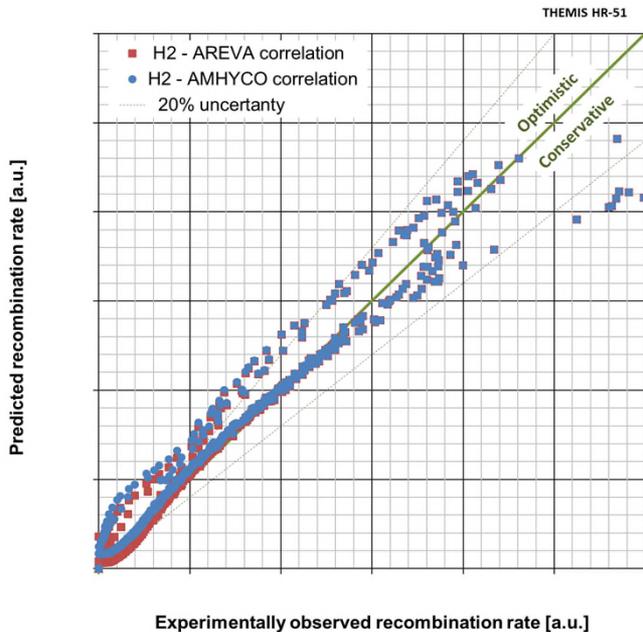
- Scale experiments in the REKO-facility (FZ Jülich)^[5], complementary to THAI experiments
 - Reduction of uncertainties
 - Evaluation of the CO poisoning phenomena
- Development of AMHYCO PAR correlation which shall
 - have an extended validity for the CO + low O₂ regime
 - be publicly available
- Current status:
 - Basic AMHYOC-correlation defined
 - In the limit of high O₂ concentration, the AMHYCO-correlation goes over into the AREVA-correlation
 - Numerical implementation tested (MELCOR, ASTEC, GOTHIC, SPECTRA)
 - Validation at the vast PAR validation history **ongoing**

[5] [Severe accident related activities of the research center Jülich/Germany](#)

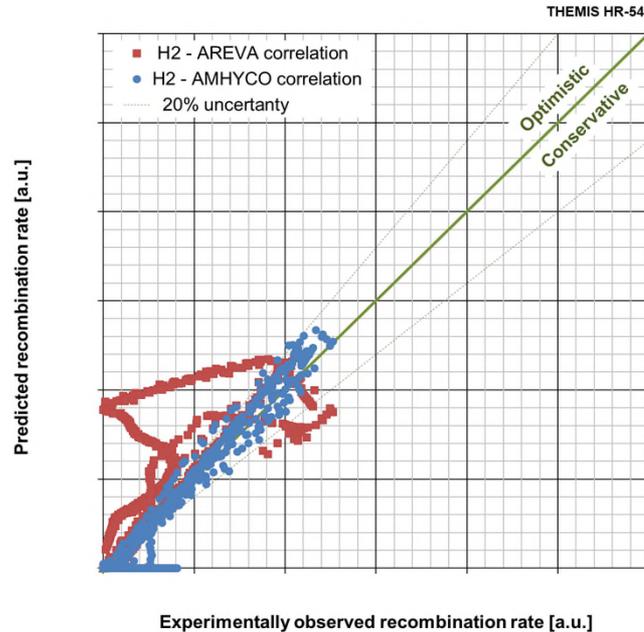


Work Package 3: Improvement of the PAR engineering correlation

O₂ ~ 15 vol%



O₂ ~ 3 vol%

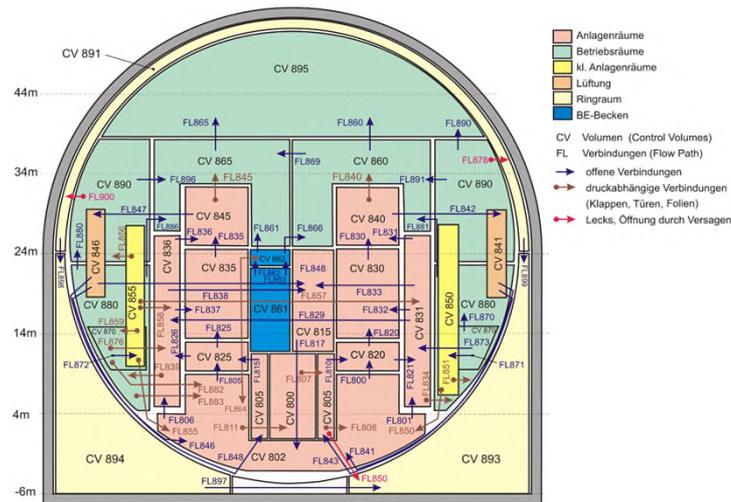


Work Package 4: Comparison of Containment Simulations

- Lumped parameter codes (ASTEC, MELCOR, GOTHIC)
- CFD-Simulation tools
- Generic containment types for PWR-W, PWR-KWU, WWER
 - not necessarily the most physically accurate models
 - generic to be publishable
 - minimization of user approach influences

Goal:

- Identification of main influence aspects
- Modelling best practices
- Systematic tendencies of the different codes (LP overestimates convective mixing)

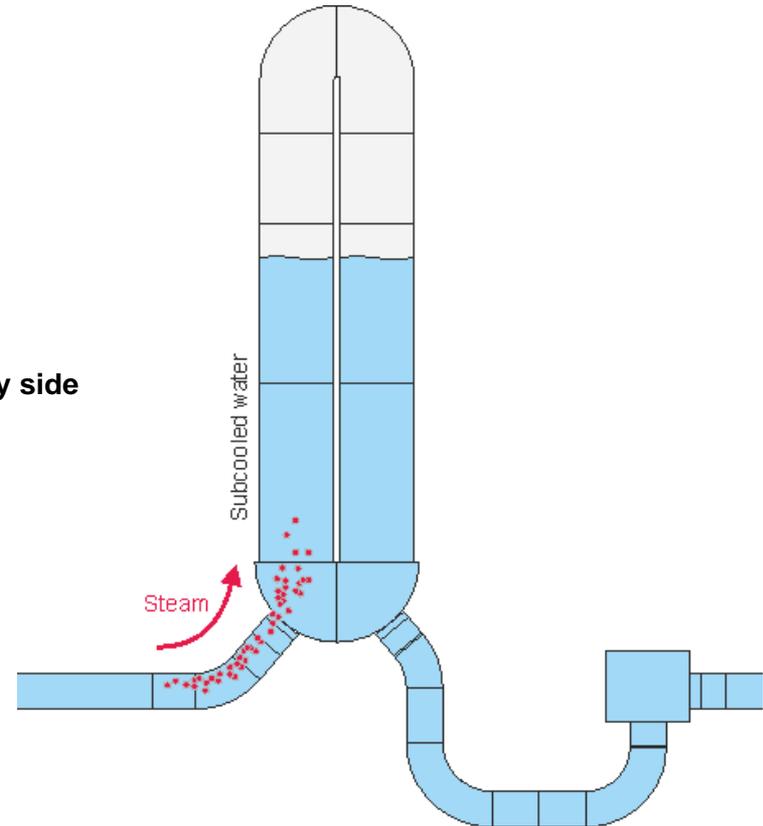


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2) MELCOR Issues during Secondary Cool-Down

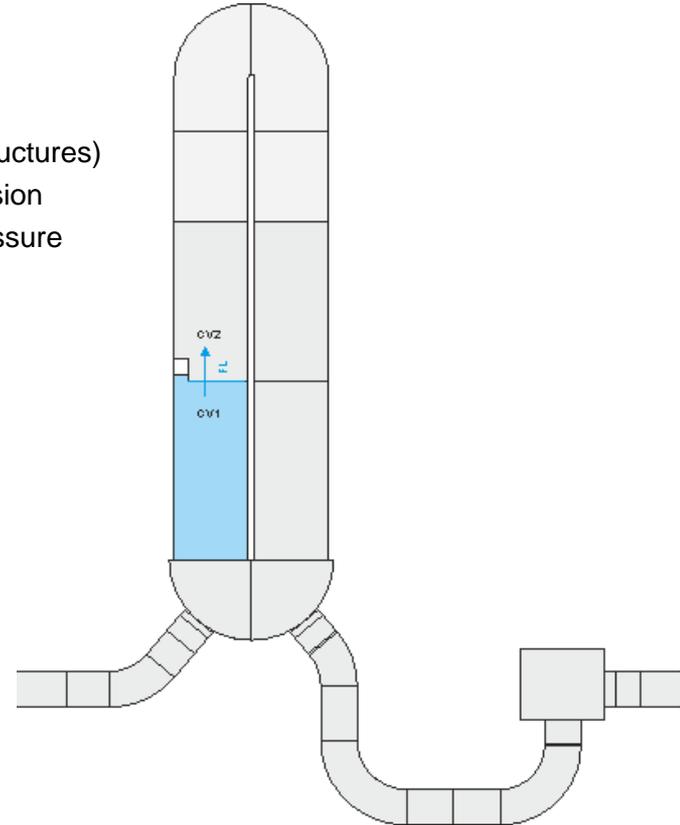
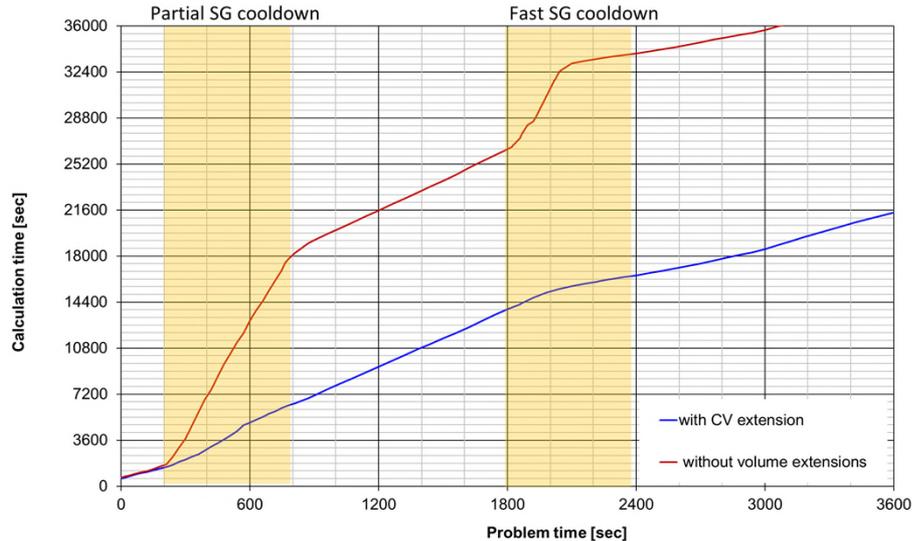
- **EPR Steam generator cool-down in case of emergency**
 - Normal plant operation ~78 bar
 - After SCRAM $p_{\text{set}}=95$ bar-a (via roof) and 90 bar (via condenser)
 - In case of LOCA → partial cool-down to 60 bar (pressure lower than the HP ECCS pumps)
 - As manual measure, fast cool-down to near atmospheric pressure
- **Issue: Reflux-condenser mode with very cold water in the SG secondary side**
 - Secondary cool-down sub-cools the water in the HX tubes CV
 - Steam enters from below into solid CV
 - Strong condensation of the steam
 - Water is incompressible → CVH-package has hard time to converge
→ **MELCOR starts limiting time steps**
 - The worse the more detailed the SG is modelled (more CV → smaller CV → higher pressure fluctuations)



2) MELCOR Issues during Secondary Cool-Down

■ Solution / Fix

- Reduce the number of CV in the SG tubes as far as reasonable possible (what is reasonable depends what the scope of the model is)
- Add small volume extension on top of SG HX volumes (above the HX heat structures)
- Set FL_JLF / FL_JLT heights so that no fluid is drawn from that volume extension
→ a small stream bubble can remain in that small volume, stabilizing the CV pressure

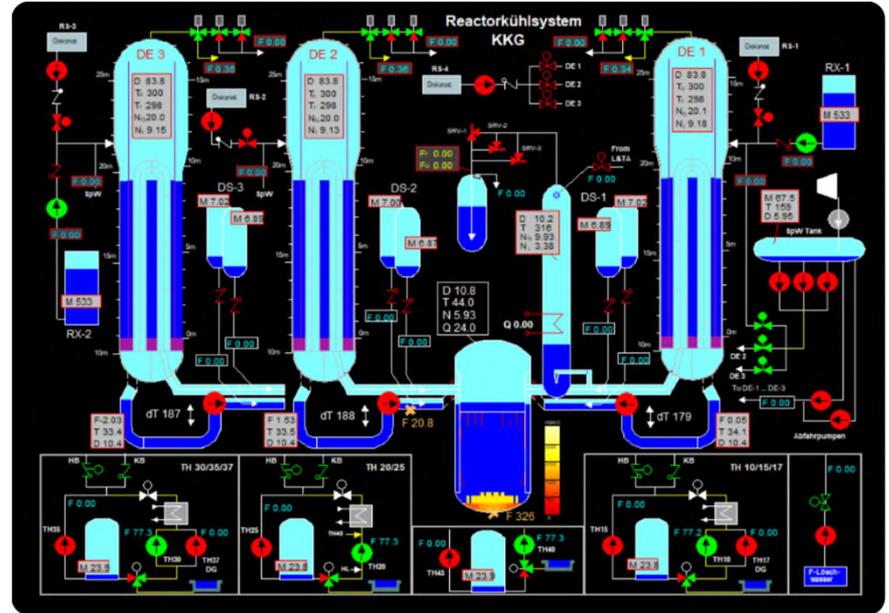


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3) PSA Level 2 for the NPP Gösgen

- **Series of MELCOR simulations to support the probabilistic risk assessment Level 2**
 - Initiating events: TLAP, SB-LOCA, LB-LOCA, SGTR, Interface-LOCA, ...
 - Emergency actions: primary depressurization, secondary cool-down, filtered venting, ...
 - FP release via early or late containment failure modes
 - Combinations lead to large number of simulations
- **MELSIM model / software by RMA [6]**
 - Based on MELCOR
 - Graphical simulation representation (very beneficial for quality assurance)
 - Interactivity (less relevant for the PSA L2, but great for training)
 - Clear definition of accident sequence



[6] https://www.psi.ch/sites/default/files/2019-04/EMUG_2019_11.pdf

3) PSA Level 2 for the NPP Gösgen

General consideration: Where to define the scenario input?

- In the MELGEN-input **is highly discouraged**
- In the MELCOR-input (as CF-re-definition) **is feasible**
 - Error-prone due to large list of parameters
 - Cumbersome by CF limitations (only multiplier and additive constant changeable)
- In MELSIM handled within the GUI
 - Pushed internally onto CF during simulation
 - Changeable during the simulation (good for bug-fixing)
 - Documentation / Archiving in log file
 - Flexible (time-dependence or condition depending on other parameter)
 - Additional software layer

MELSIM scenario definition interface

Sequence Control - [S1a-L005c.noHP_CI_2023-02-16.SEQ]

MaFunction Sequence | Time Control

Add Change Delete New Load Save Print

Sequence Information:

Identifier: S1a-L005c.noHP_CI
Description: Small Break LOCA without HP injection
Comment: Event: Small Break LOCA 5cm2 at cold leg
- All high-pressure safety injection pumps fail
- Loss of Offsite power after reactor trip (after 30s) -> SG blow-down via roof
- No H2 burning in containment

Chart Mode: Manual Automatic Auto Decision
Associated Code Input File: MELIN_21_RES

System	MF Parameter	Time Range/Para...	Description
PRZ-SLJen	PARAM = 1e-005	0.s - 100.d	FLLEN for PRZ Surge Line FLs (<0=input, 0=default.
HL-VxFLJen	PARAM = 1e-005	0.s - 100.d	FLLEN for HL vertical x-FLs (<0=input, 0=default.
BUR-flg.CONT	PARAM = 85	0.s - 100.d	H2 burning in Containment CVs (0=enabled, 85=disab
TAB1D001	PMP: F/RUN	CF-VALU(ICF_581)	Emergency Boron Injection pump TAB1D001
TAS2D001	PMP: F/RUN	CF-VALU(ICF_592)	Emergency Boron Injection pump TAS2D001
HL1-Creep Rupt	PARAM = 0	0.s - 100.d	HL-1 Creep Rupture size [%] (0=disabled)
HL2-Creep Rupt	PARAM = 0	0.s - 100.d	HL-2 Creep Rupture size [%] (0=disabled)
HL3-Creep Rupt	PARAM = 0	0.s - 100.d	HL-3 Creep Rupture size [%] (0=disabled)
SRGL-Creep Rupt	PARAM = 0	0.s - 100.d	PRZ Surge Line Creep Rupture size [%] (0=disabled)
TL42S003	VLV: SET 0%	CF-VALU(ICF_3968)	TL42 line isolation valve
BUS-BA, BD	EL. P. LOSS	30.s - 100.d	Loss of power on buses BA, BB, BC, BD
TH15D001	PMP: F/RUN	0.s - 100.d	HP injection pump TH15
TH25D001	PMP: F/RUN	0.s - 100.d	HP injection pump TH25
TH35D001	PMP: F/RUN	0.s - 100.d	HP injection pump TH35
TH45D001	PMP: F/RUN	0.s - 100.d	HP injection pump TH45
CL-2-SBRK	BREAK : 5	0.s - 100.d	Small break in CL-2 (max 100 cm**2)
CFV-RD-open.P	PARAM = 720	0.s - 100.d	CFV RD isolation valve opening pressure [0.01-bar]
MCP-KLOSS.add	PARAM = 16.65	0.s - 100.d	MCP additional pressure loss coefficient (use 16.6

OK Abbrechen Übernehmen

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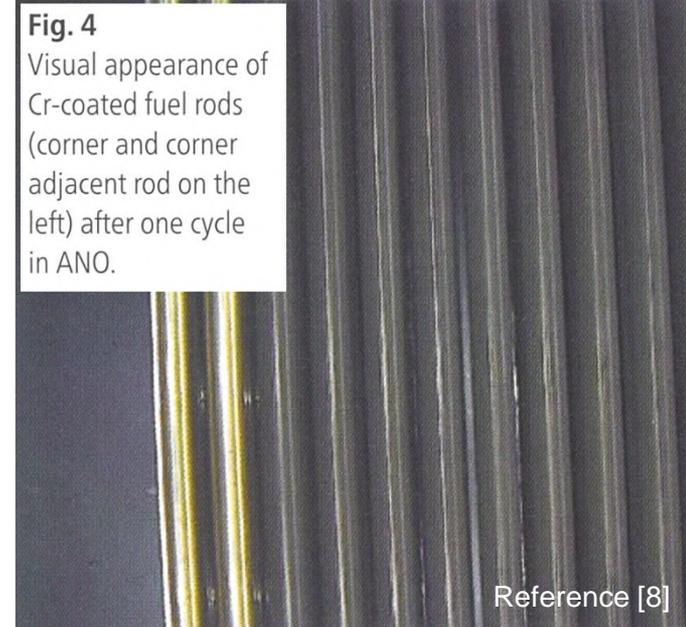
4) Framatome R&D Roadmap

Accident Tolerant Fuel

- **Framatome PROtect**
 - Cr-coated fuel rods [7]
 - Test rods & full assembly tests in KKGö, Vogtle, ANO, Calvert Cliffs... [8]
- **OECD-NEA QUENCH-ATF joint project [9]**
- **Impact on Numerical Simulations (MELCOR)**
 - Change in onset of fast oxidation → Entry into SAMG
 - Change of oxidation characteristics → PAR system design basis
 - Change of core degradation → Core melt stabilization

Fig. 4

Visual appearance of Cr-coated fuel rods (corner and corner adjacent rod on the left) after one cycle in ANO.



Reference [8]

Expectation is that ATF is conservatively enveloped by normal fuel simulations, but its nuclear, thus, it has to be evaluated ...

[7] <https://www.euronuclear.org/archiv/topfuel2018/fullpapers/TopFuel2018-A0152-fullpaper.pdf>

[8] Current Trends in Fuel Assembly Development from a Materials Perspective, ATW 2-2023

[9] https://www.oecd-nea.org/jcms/pl_36597/quench-atf-project

4) Framatome R&D Roadmap

Code-to-Code Comparisons

MELCOR

- Installed base plants
- Support for SA-back-fittings

MAAP

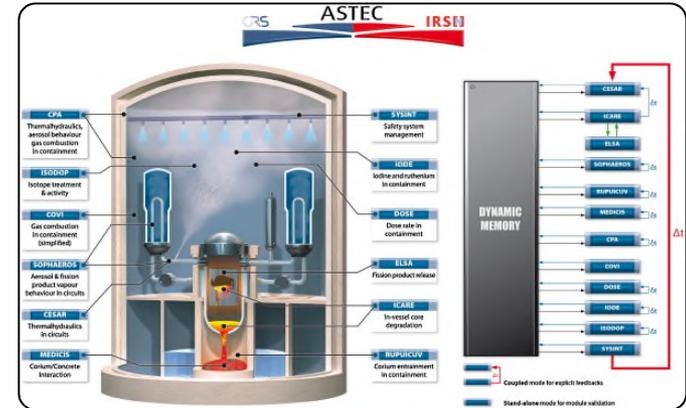
- New builds (EPR / EPR2) - Design
- New builds (EPR / EPR2) - Licensing

ASTEC

- French development - Export control / licensing restrictions
- Long-term availability

Agreement between the codes is in part improvable [10]

- Different model assumptions
- Difference of users
- Best-estimate or conservative philosophy



[10] Di Giulì et al. MELCOR 2.2-ASTEC V2.2 crosswalk study

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