

RECENT CAMP ACTIVITIES IN SLOVENIA

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October 31st – November 1st, 2002**



Outline

Part 1:

Update of MOD3.3 assessment calculations against two real transients at Krško NPP, caused by MSIV 1 and MSIV 2 inadvertent closure

Part 2:

Assessment of RELAP5/MOD3.3 for fast transients (water hammer)



Part 1

NPP Krško MSIV closure event simulations

Two transients caused by inadvertent MSIV closure at Krško NPP, before SG replacement, both from steady-state full power operation:

- September 25th 1995 at 10:22:06
 - malfunction in MSIV SG1 regulation
 - plugging level: SG1: 18.87 %, SG2: 17.27 %
- January 1st 1997 at 08:33:30
 - MSIV SG2 stem breach (**slightly faster transient**)
 - plugging level: SG1: 16.27 %, SG2: 10.05 % , reduced after extensive U-tube sleeving during the 1996 outage

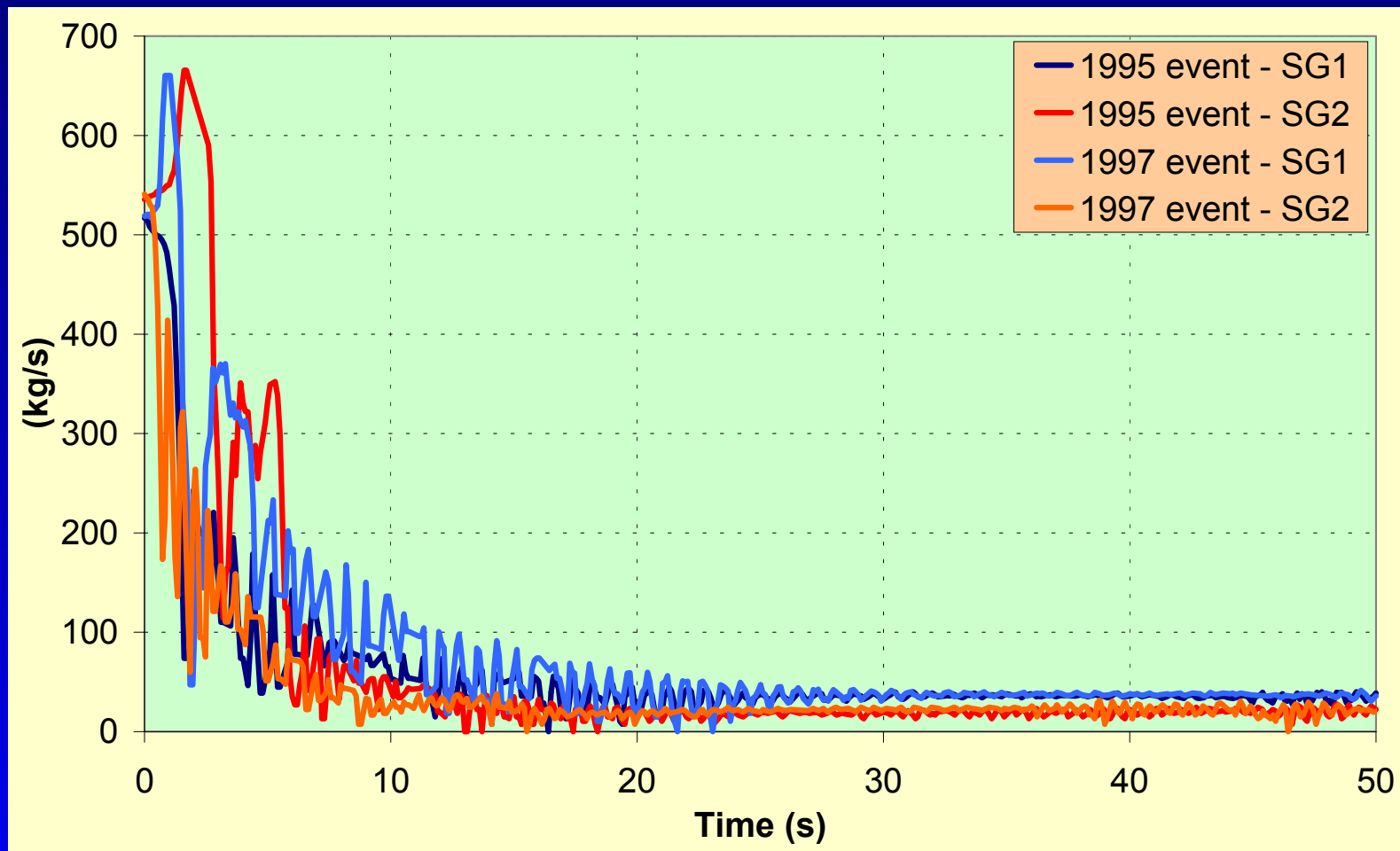


Initial Conditions

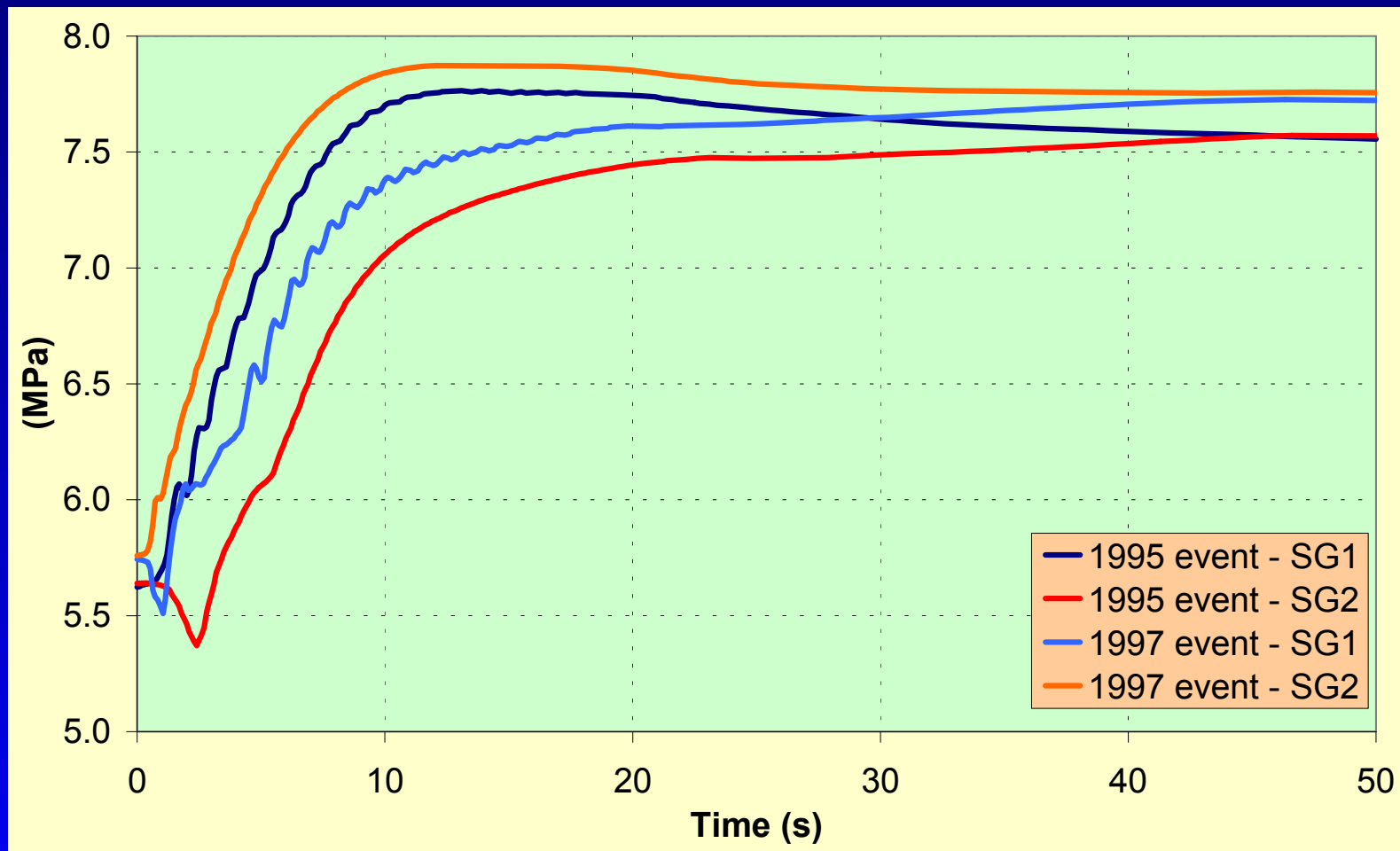
parameter	1995 transient	1997 transient
core power	1876 MWt	1876 MWt
PRZ pressure	15.47 MPa	15.47 MPa
PRZ level	62.3 %	62.8 %
T_{average}	578.5 K	578.8 K
T_{hot} HL1 / HL2	596.2 / 596.8 K	596.4 / 596.4 K
T_{cold} CL1 / CL2	560.6 / 560.5 K	561.4 / 560.9 K
SG1/SG2 pressure	5.19 / 5.24 MPa	5.32 / 5.35 MPa
SG1/SG2 WR level	64.3 / 64.3 %	63.1 / 63.1 %
SG1/SG2 NR level	60.1 / 60.3 %	60.6 / 60.8 %



Comparison of plant data steam flow



Comparison of plant data SG pressure



RELAP5 Model

Full two-loop plant model has been developed

- 183 volumes
- 200 junctions
- 203 heat structures (705 mesh points)
- 109 trips
- 180 control variables

18 % SG tube plugging was assumed in both RELAP5 simulations (before SG replacement)



Modeling features

- Model parameters initialized close to plant initial conditions for each simulation separately
- MSIV closure time shortened to match plant data (5 to 1 s – 1995 event or even to 0.1 s – 1997 event)
- MSIV valve characteristic changed (faster area reduction versus stem position)
- charging and letdown flow: plant data used
- AFW flow: plant data used
- **MSIV #1 and #2 leakage modeled in each simulation to match SG pressure development**



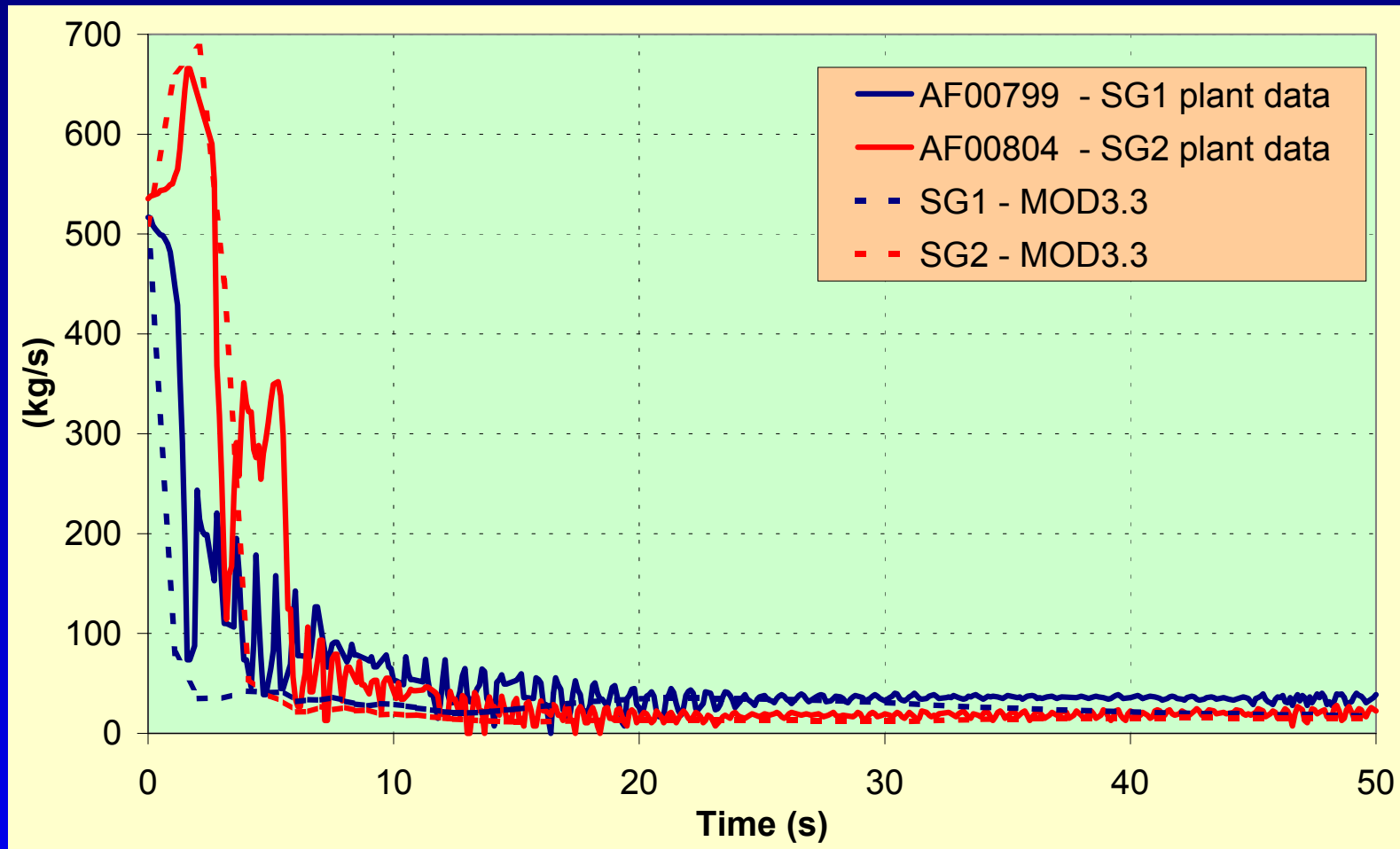
Sequence of events in MOD3.3 simulation

event	1995 transient	1997 transient
initial event	0 sec	0 sec
intact MSIV closure	2.9 s	1.7 s
SI signal	2.9 s	1.7 s
turbine trip	3.0 s	1.7 s
scram	4.0 s	2.7 s
MFW closure	5.2 s	3.8 s
RCP trip	not occurred	not occurred
CVCS behavior	plant data	plant data
AFW flow	plant data	plant data



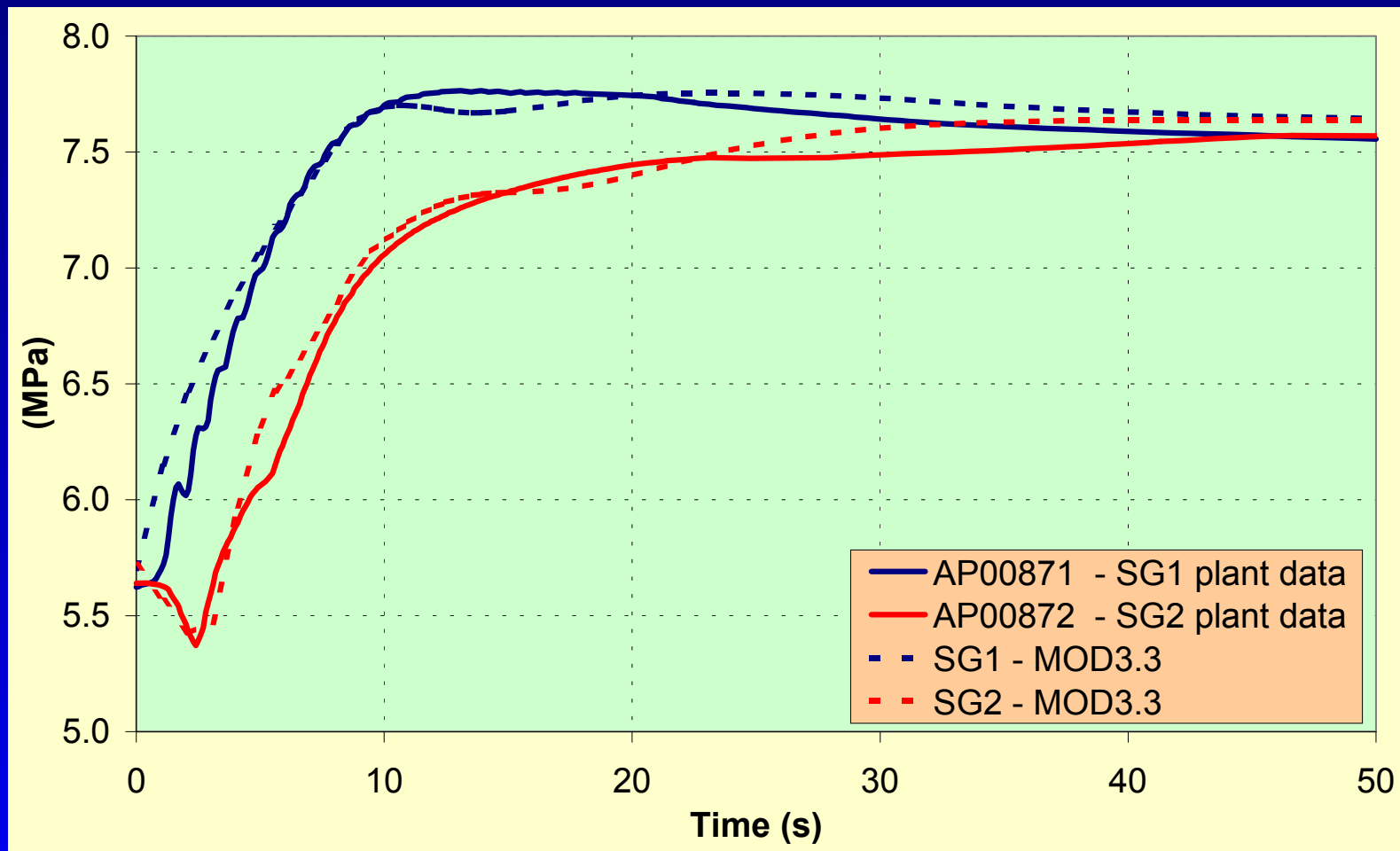
1995 event - MSIV #1 closure

Results: steam flow



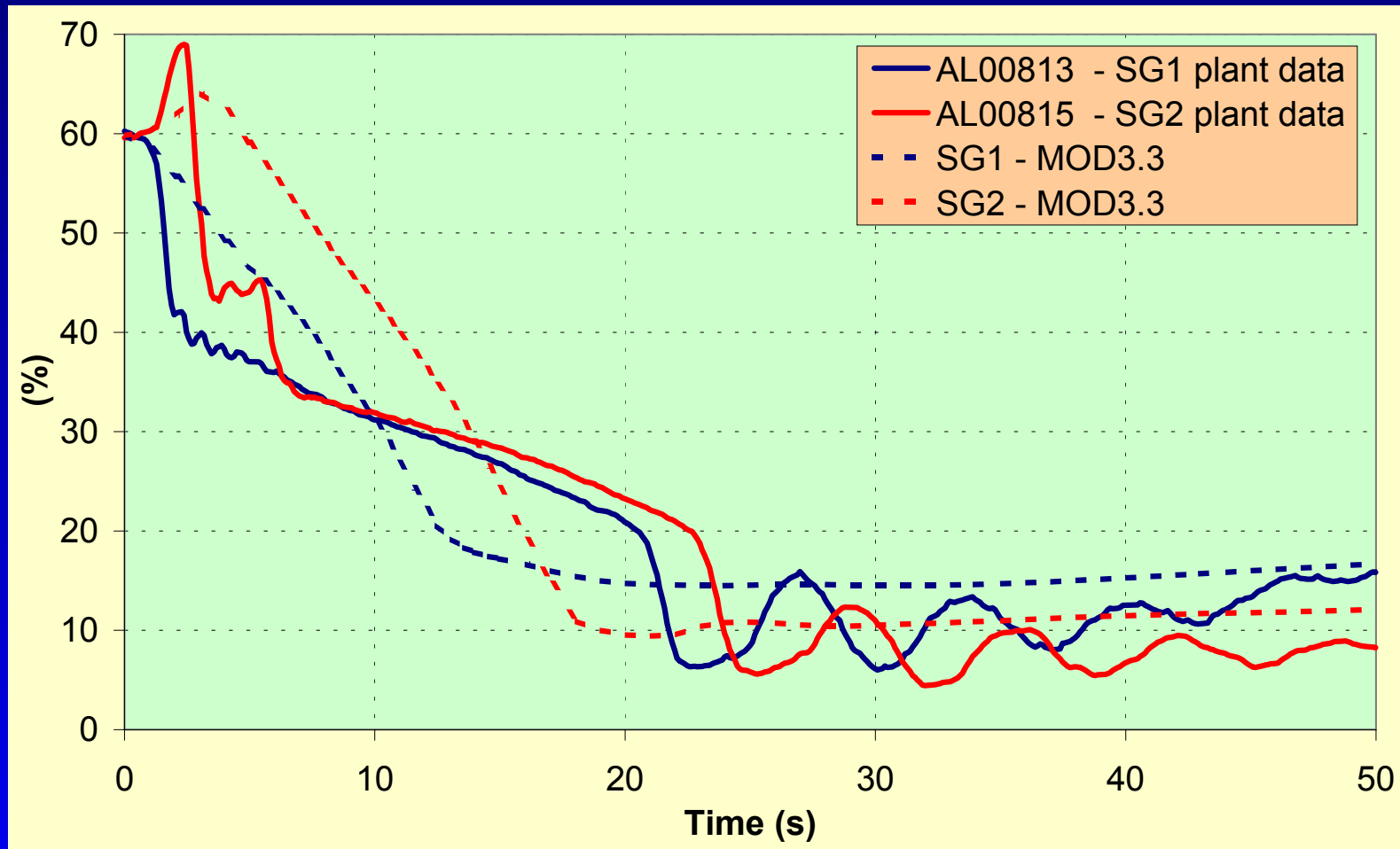
1995 event - MSIV #1 closure

Results: SG pressure



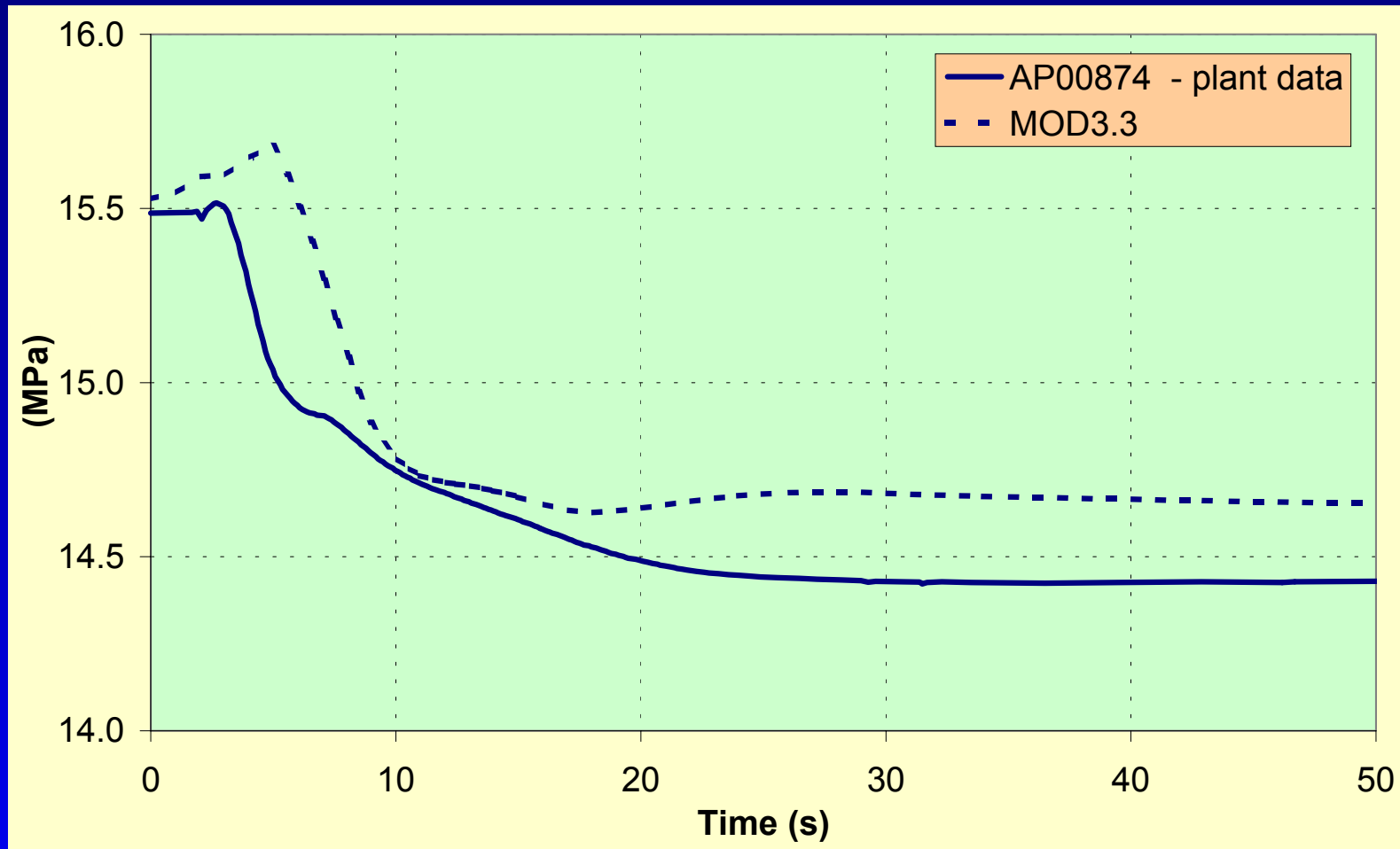
1995 event - MSIV #1 closure

Results: SG Narrow Range level



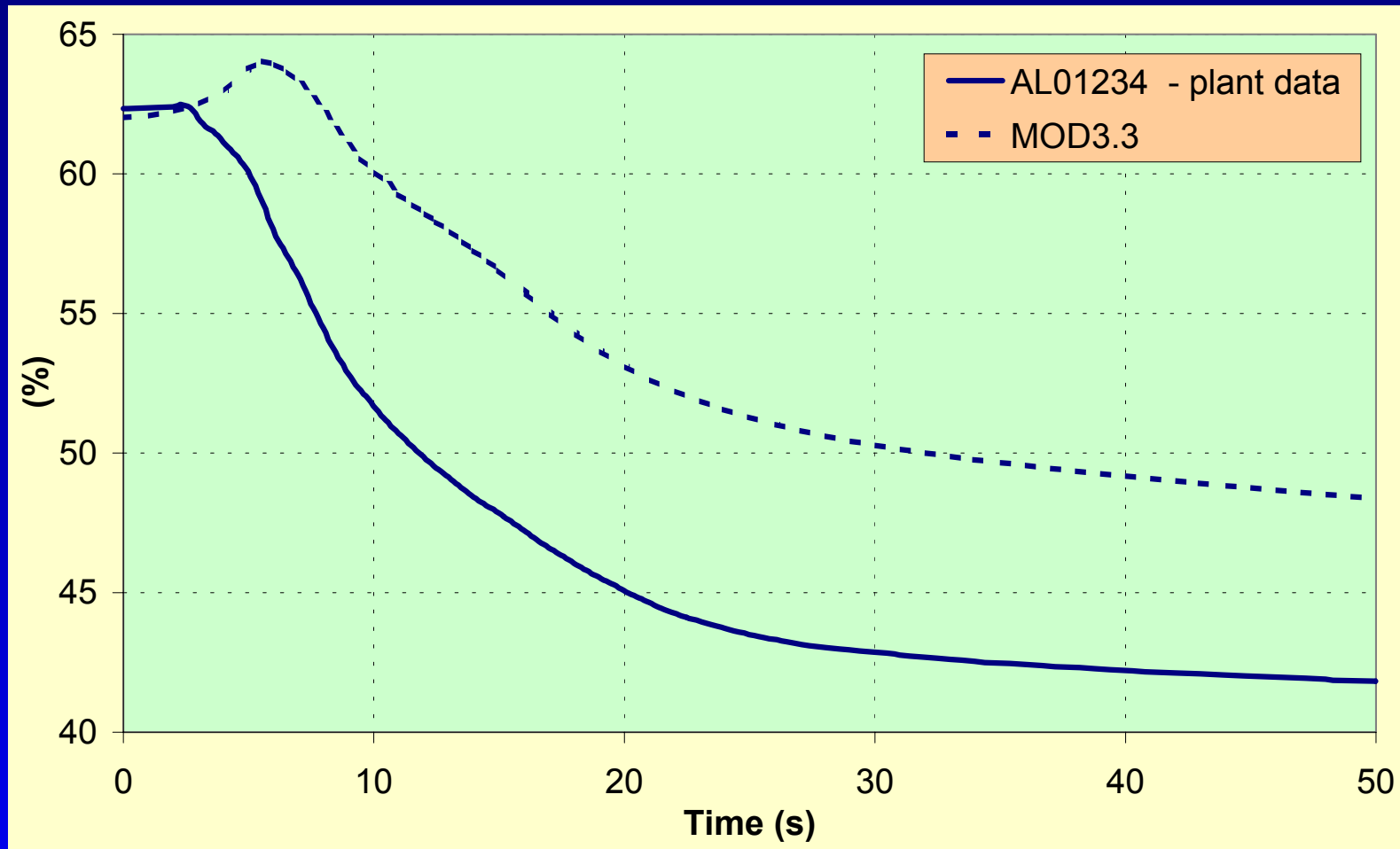
1995 event - MSIV #1 closure

Results: PRZ pressure



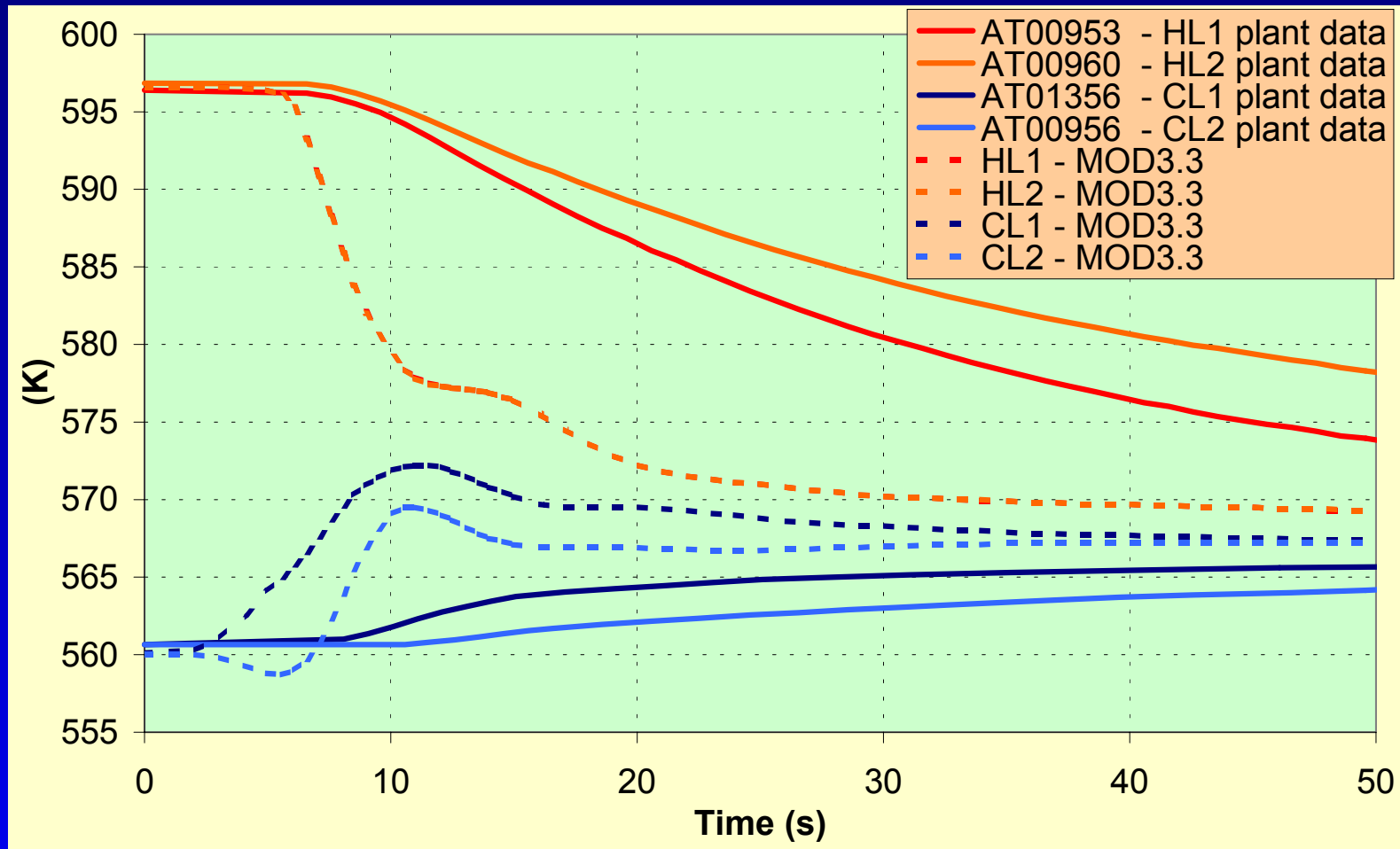
1995 event - MSIV #1 closure

Results: PRZ level



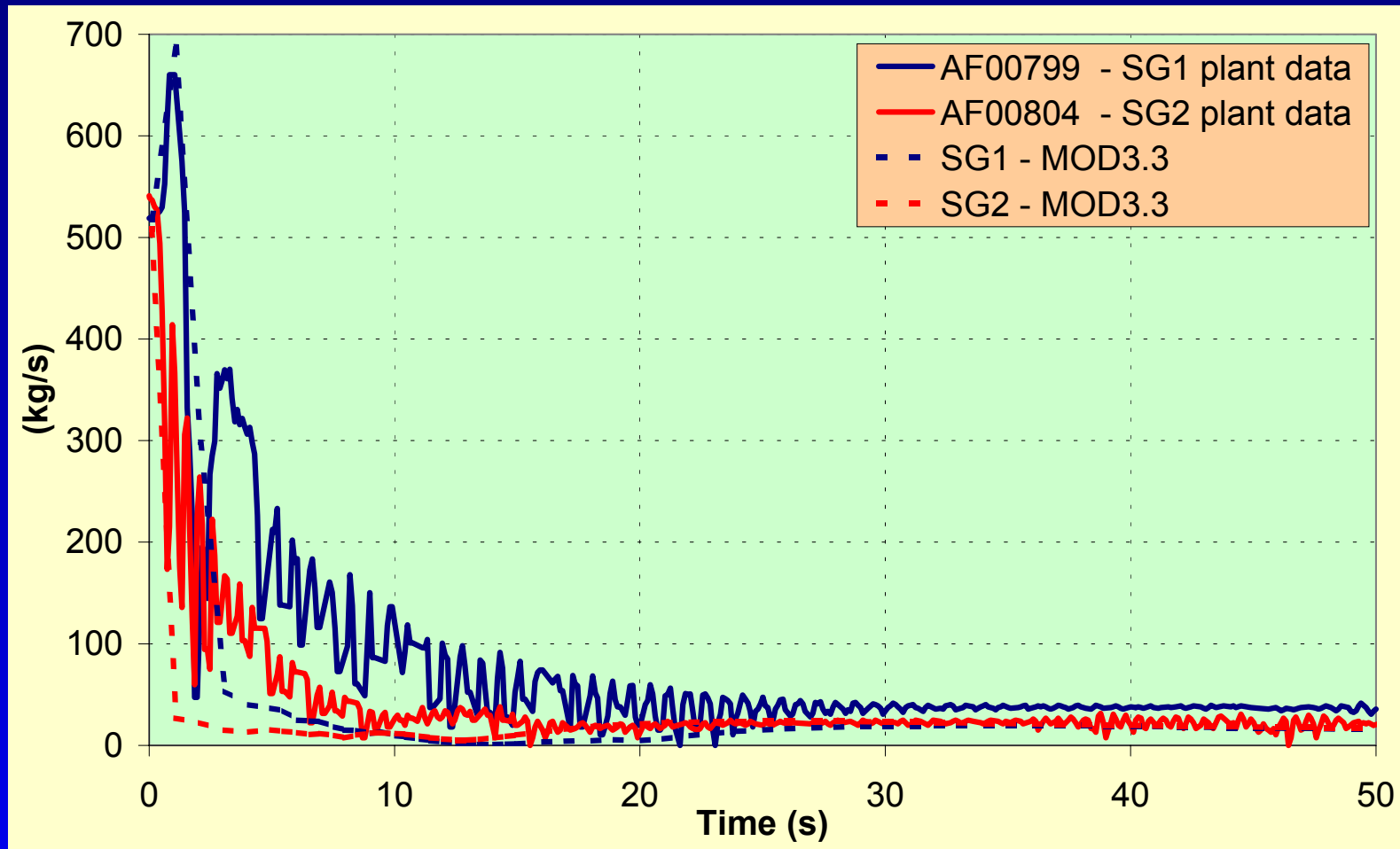
1995 event - MSIV #1 closure

Results: loop temperatures



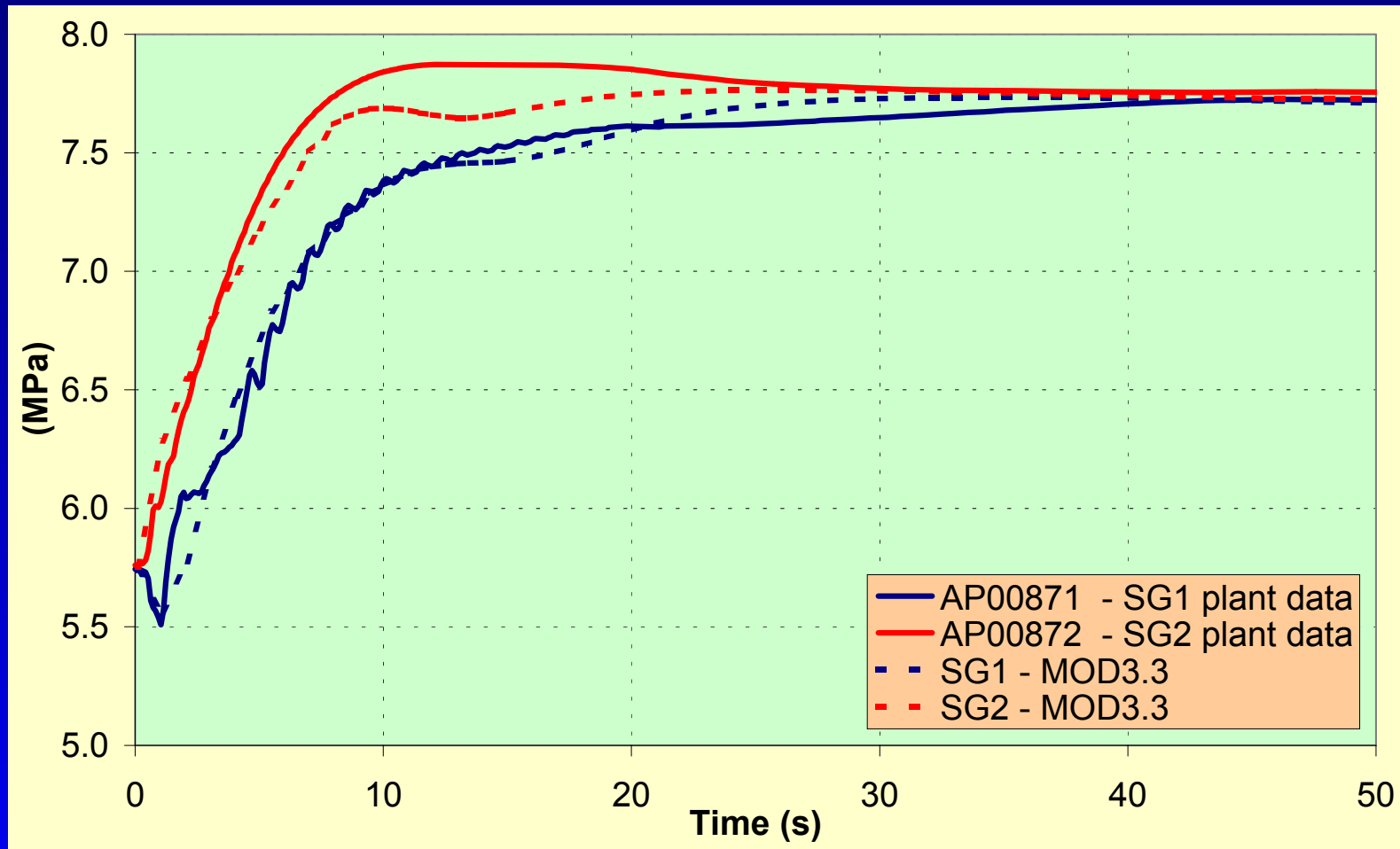
1997 event - MSIV #2 closure

Results: steam flow



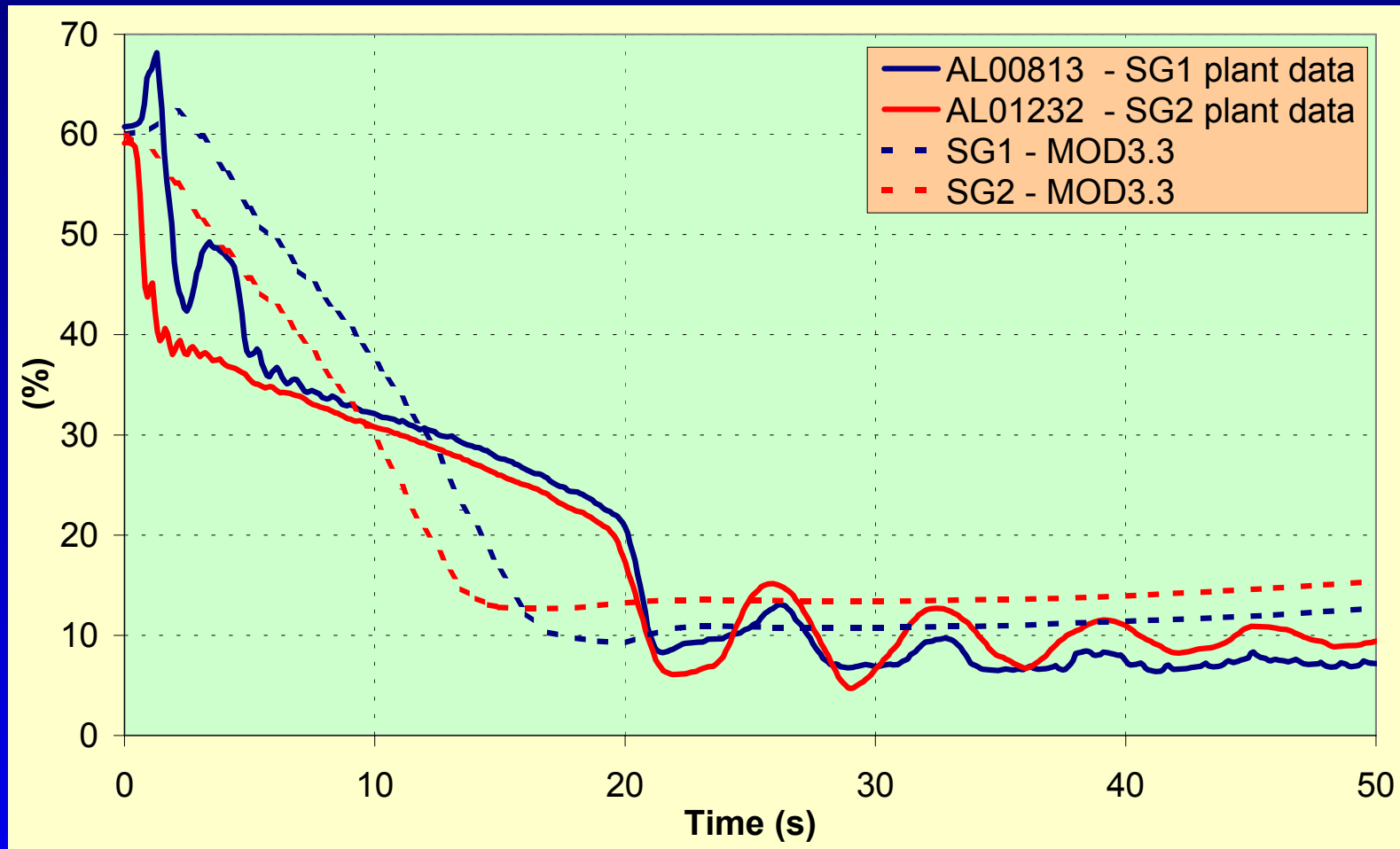
1997 event - MSIV #2 closure

Results: SG pressure



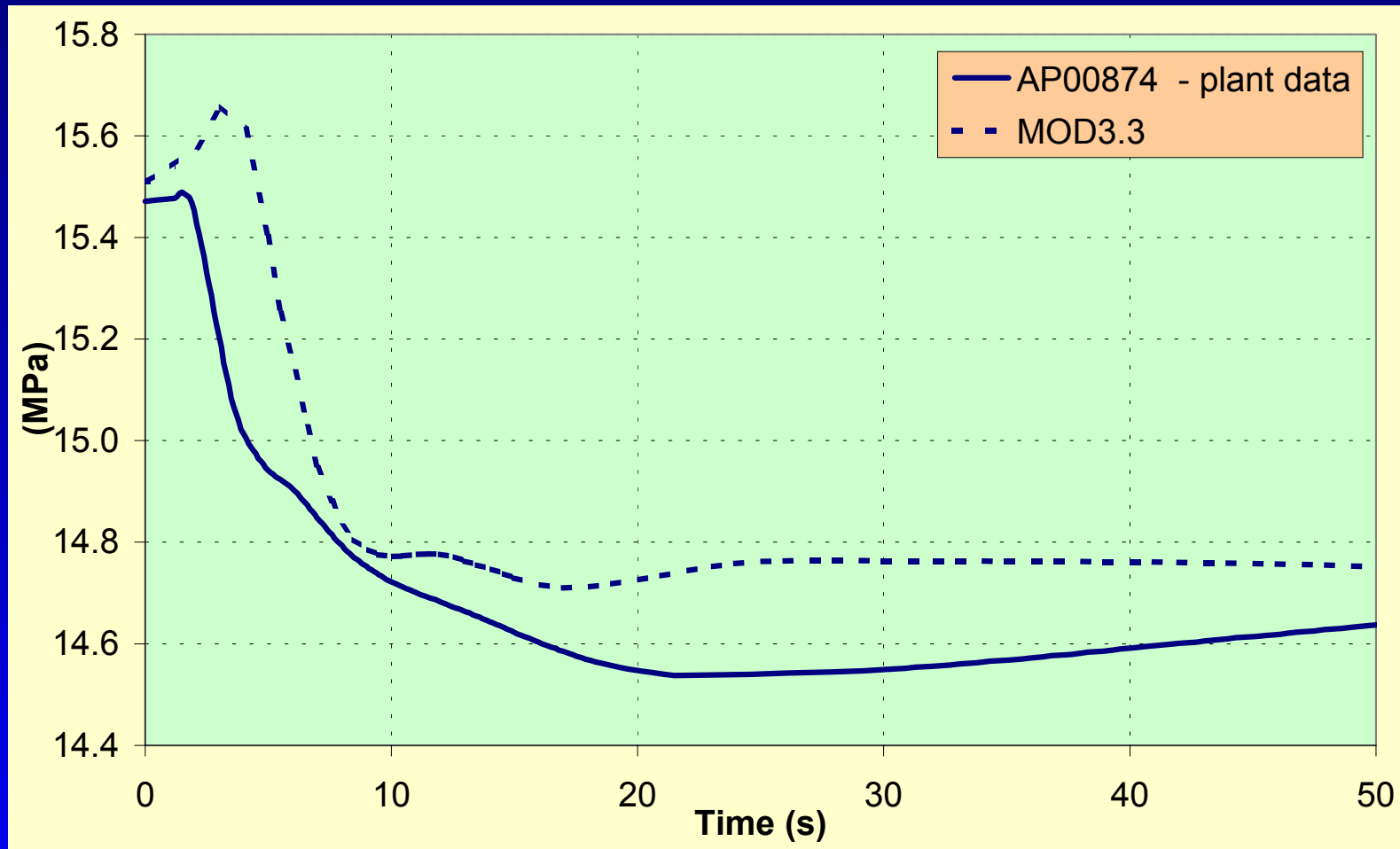
1997 event - MSIV #2 closure

Results: SG Narrow Range level



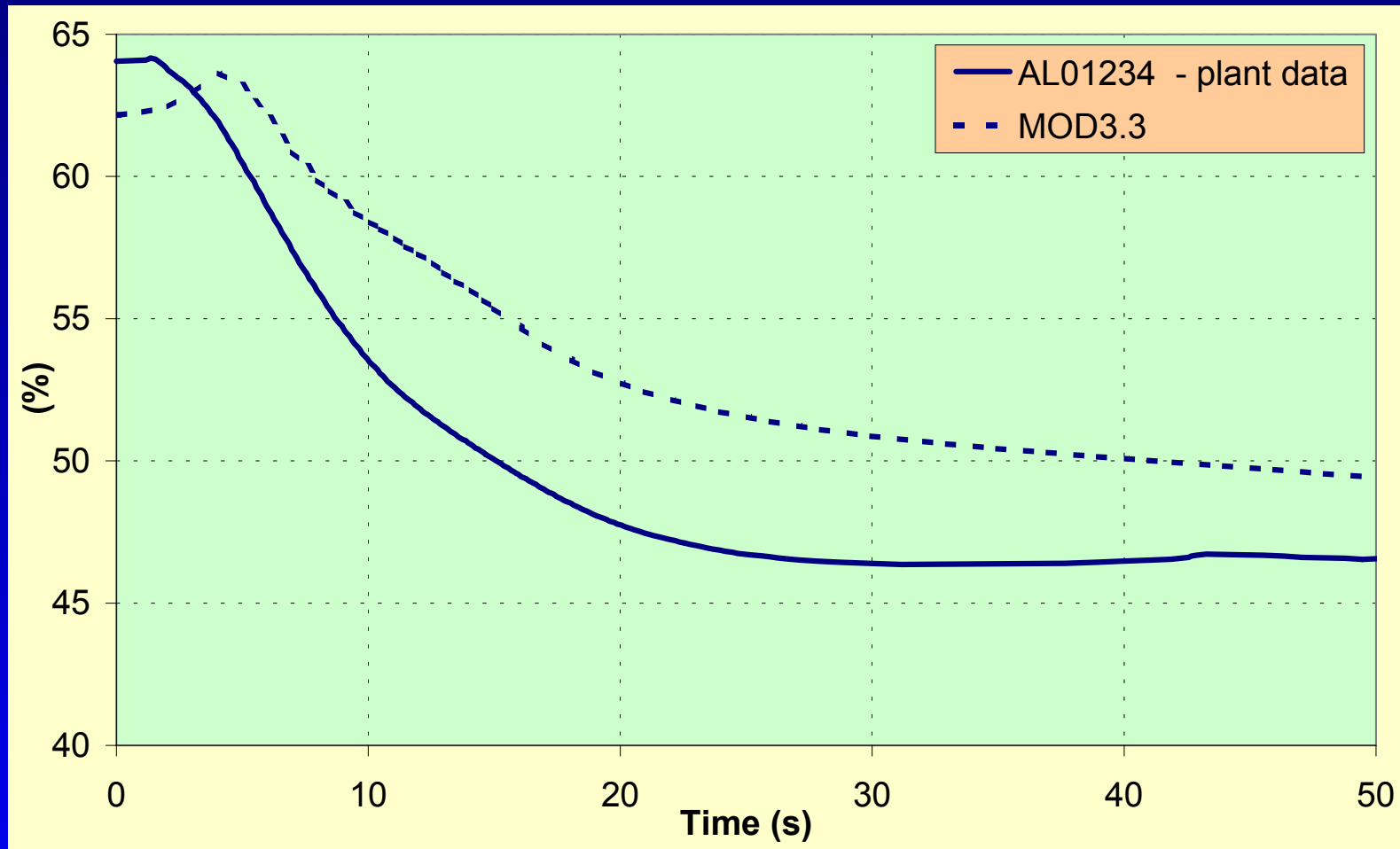
1997 event - MSIV #2 closure

Results: PRZ pressure



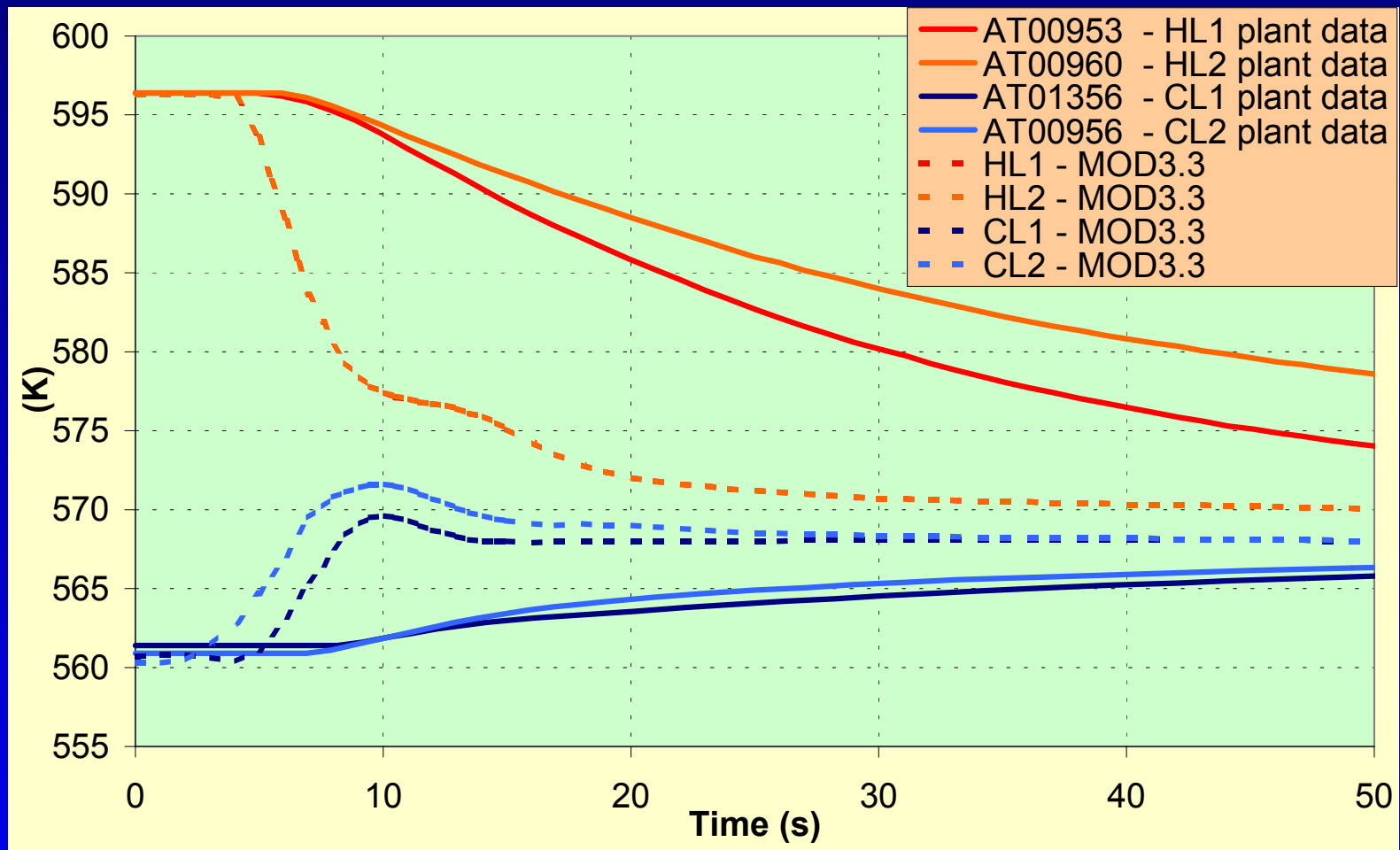
1997 event - MSIV #2 closure

Results: PRZ level



1997 event - MSIV #2 closure

Results: loop temperatures



Conclusions

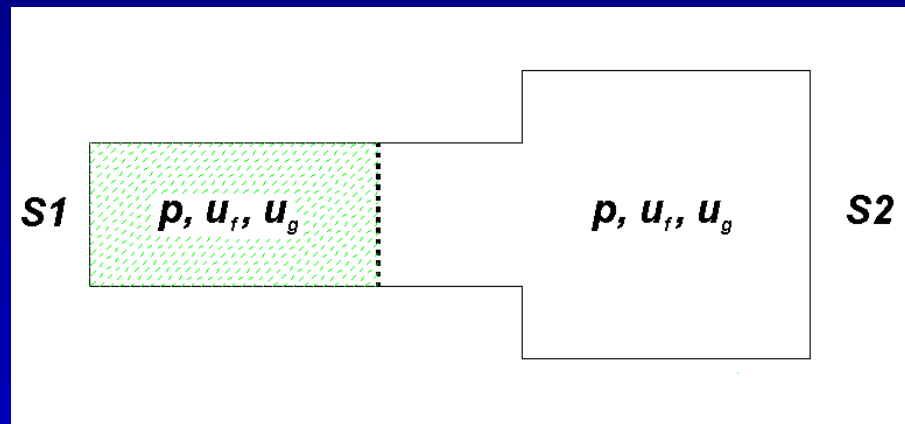
- Plant data were reproduced very well by RELAP5/MOD3.3
 - secondary parameters matched better because of the MSIV leakage tuning
 - turbine flow unknown (possible turbine runback)
 - intact SG initial flow and pressure matched better after appropriately shortening the affected MSIV closure time
- Exact event sequence not recorded, but seems to be captured closely by MOD3.3
- intact MSIV closure initially predicted too slow in 1997 event simulation, improved after the affected MSIV closure time further shortening (down to 0.1 sec)



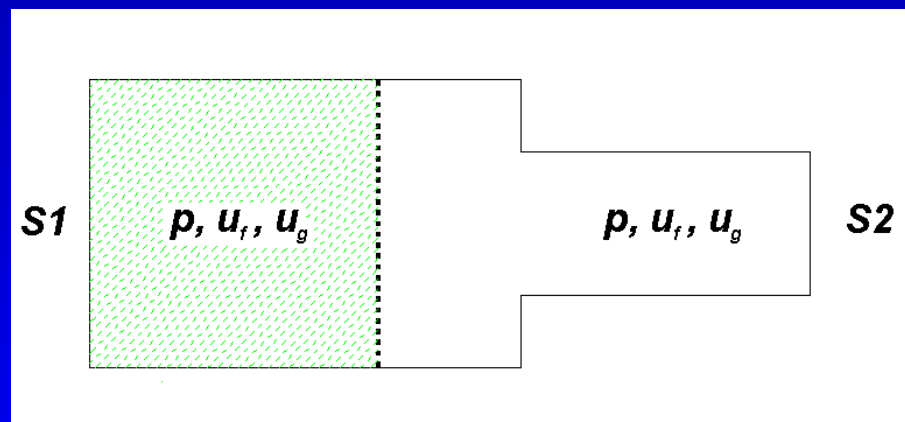
Part 2

RELAP5/MOD3.3 assessment for fast transients

- Abrupt-area expansion



- Abrupt-area contraction



RELAP5/MOD3.3 assessment for fast transients

Nodalization and initial conditions

- Instantaneous breach of the membrane
- Identical nodalization for RELAP5 and WAHA
 - 5 m long pipe ($S1/S2 = 1/5$ or $5/1$), 125 nodes (0.04 m)
 - leftmost 75 nodes: $S=S1$, rightmost 50 nodes: $S=S2$
 - leftmost 50 nodes: $p=15$ MPa, rightmost 75 nodes: $p=10$ MPa
 - leftmost 50 nodes: $a=0.5$, rightmost 75 nodes: $a=0.9$
- Two-phase flow cases shown here only (contraction and expansion in pipe)



RELAP5/MOD3.3 assessment for fast transients

Test cases for comparison (R5 vs. WAHA)

- Test of single-phase flow (water) through an expansion
- Test of single-phase flow (water) through a contraction
- Test of single-phase flow (steam) through an expansion
- Test of single-phase flow (steam) through a contraction
- **Test of two-phase flow through an expansion**
- **Test of two-phase flow through a contraction**



RELAP5/MOD3.3 assessment for fast transients

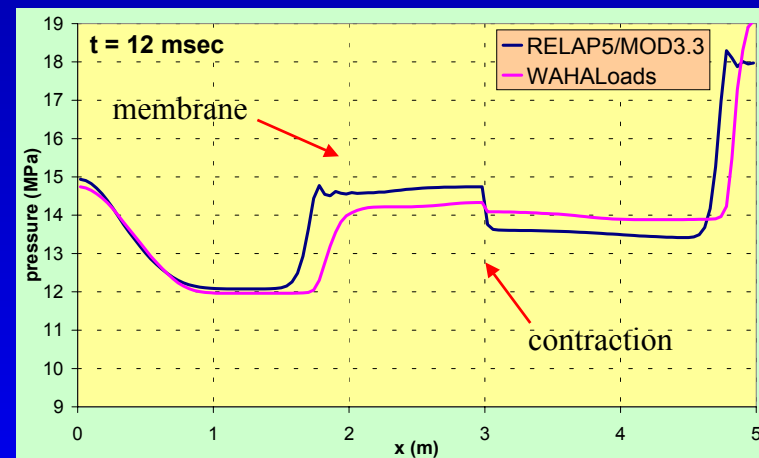
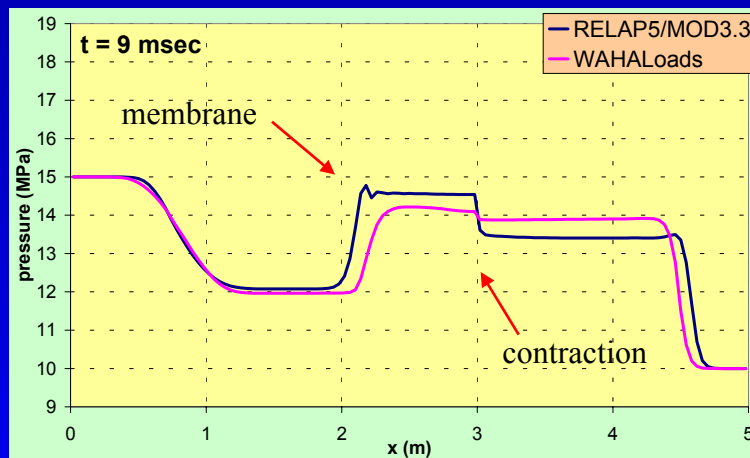
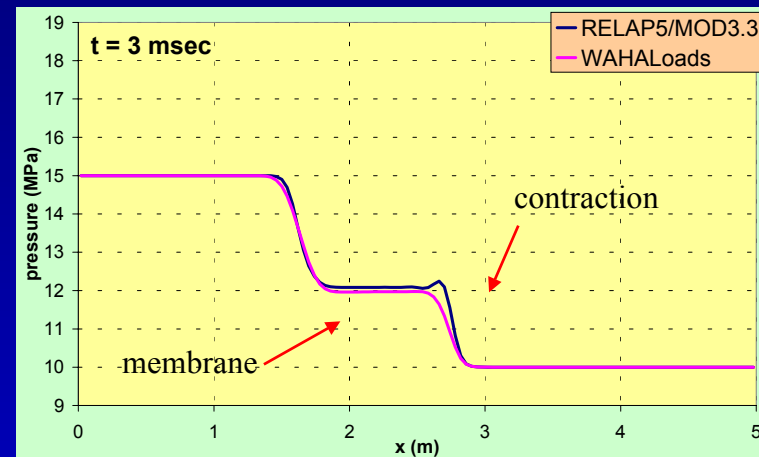
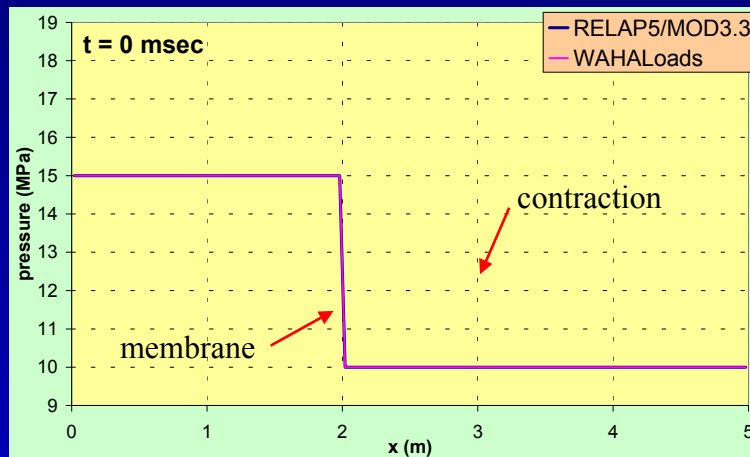
WAHA code characteristics

- 6 – equations (two-phase)
- No sources and sinks (mass, momentum or energy)
- Homogeneous, equilibrium model (HEM)
- Second order high resolution numerical scheme
 - mixing of 1st and 2nd order according to identifier (more 1st order close to shock; super-bee limiter)
 - upwind differencing in the direction of characteristics
- Friction calculated (can be switched off)
- Abrupt area change model present



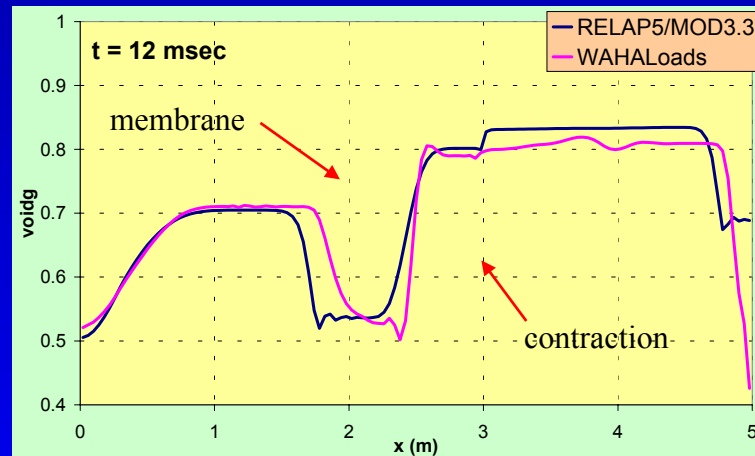
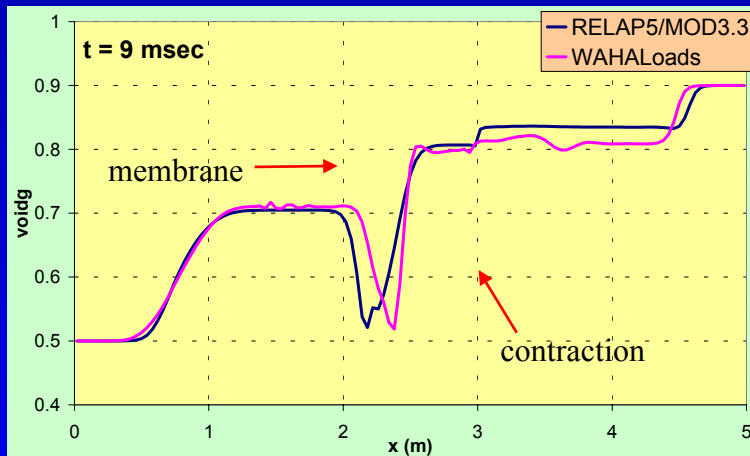
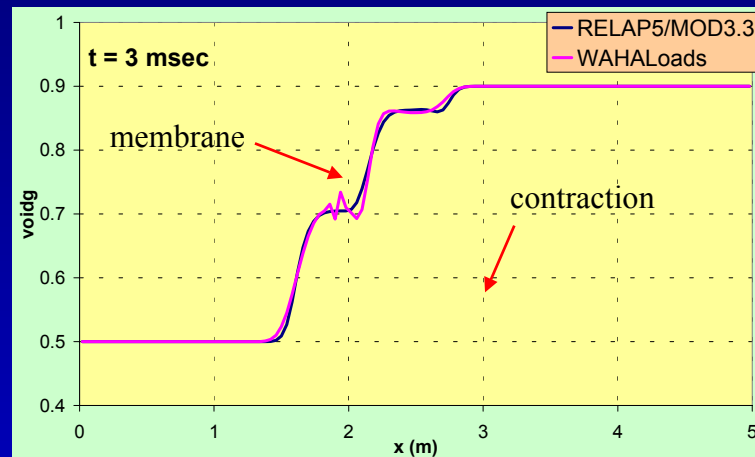
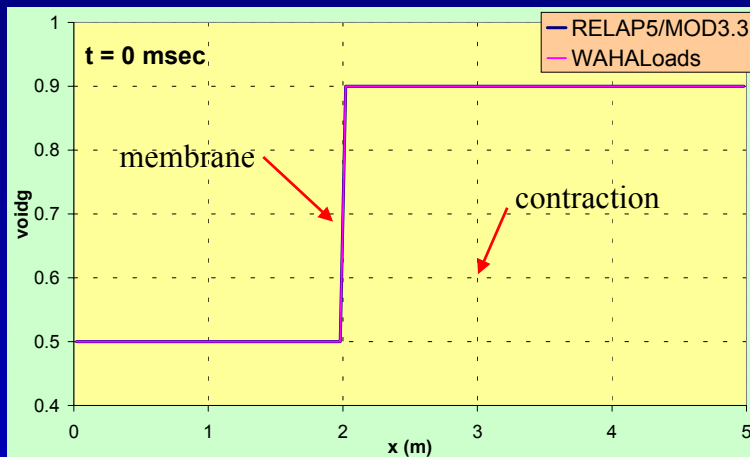
RELAP5/MOD3.3 assessment for fast transients

Results: contraction in pipe - pressure



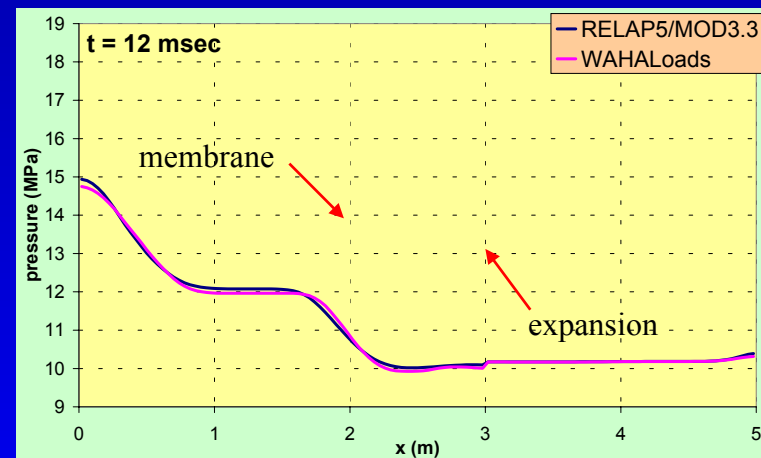
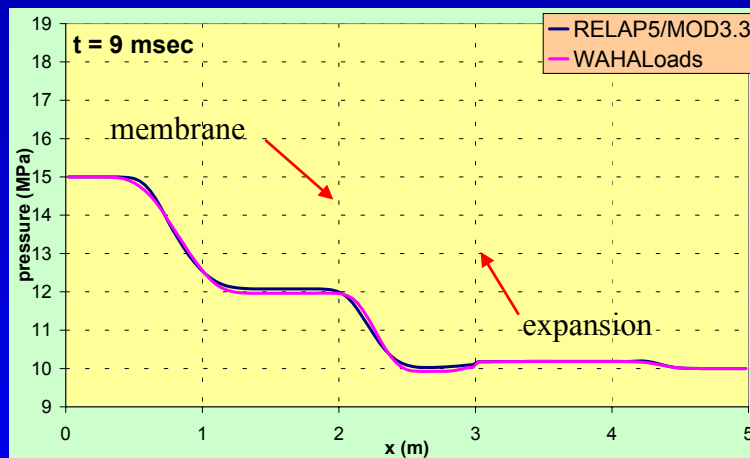
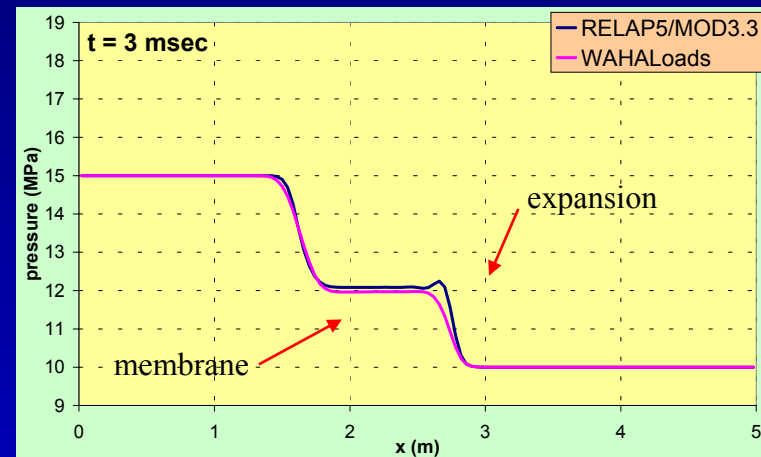
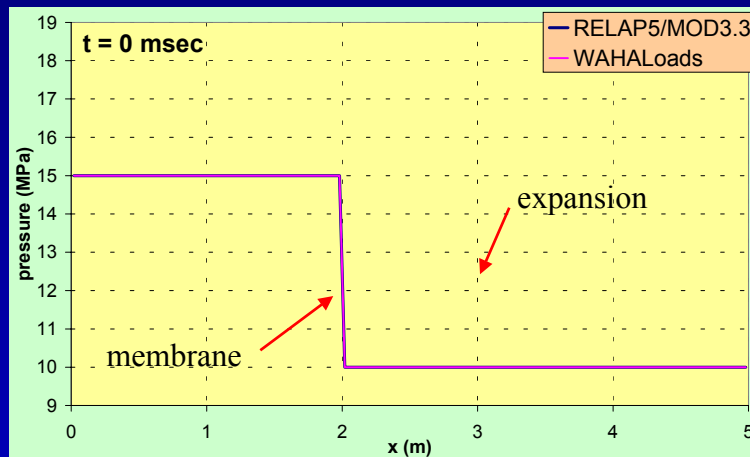
RELAP5/MOD3.3 assessment for fast transients

Results: contraction in pipe – vapor void fraction



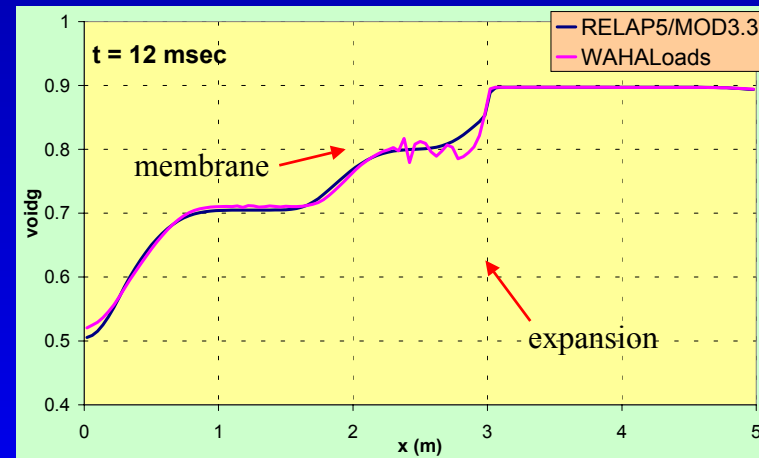
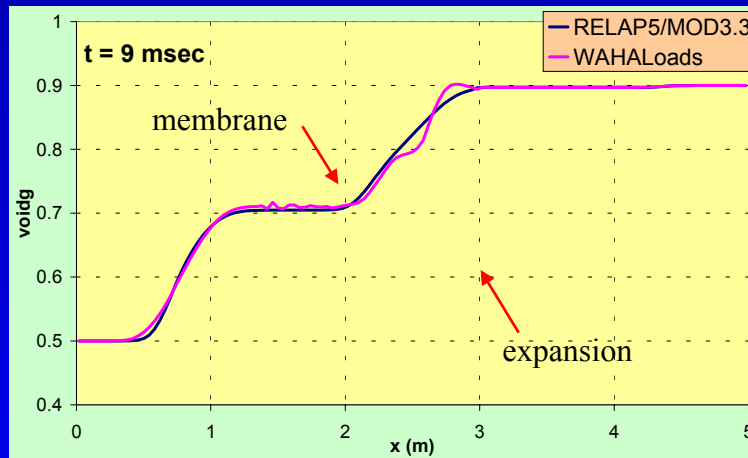
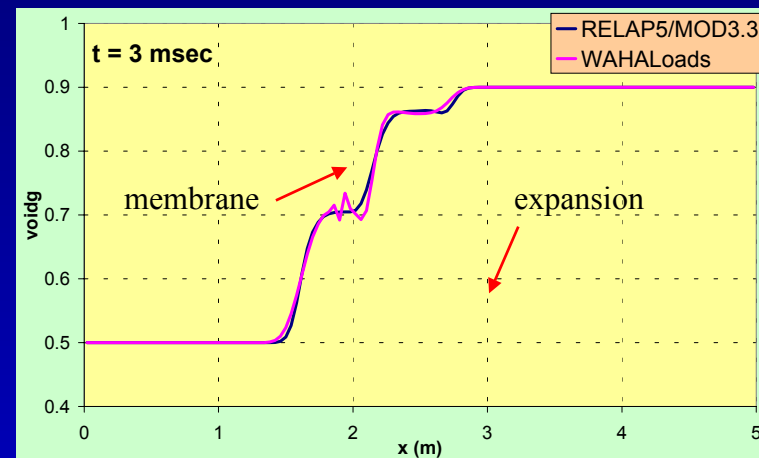
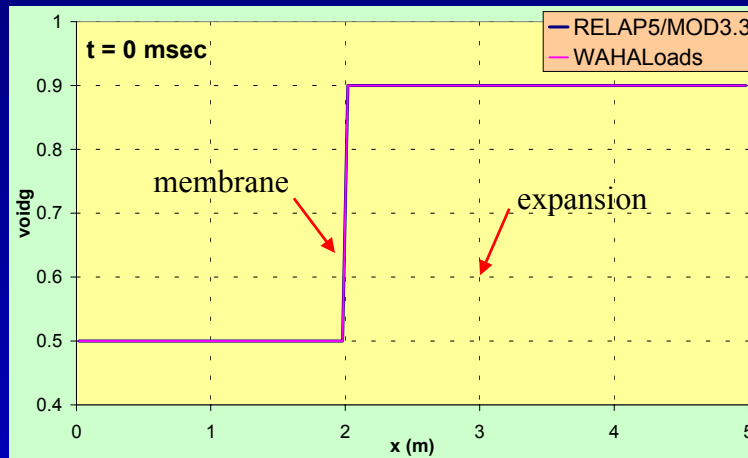
RELAP5/MOD3.3 assessment for fast transients

Results: expansion in pipe - pressure



RELAP5/MOD3.3 assessment for fast transients

Results: expansion in pipe – vapor void fraction



RELAP5/MOD3.3 assessment for fast transients

Conclusions

- The conducted tests for (single- and) two-phase flows show reasonable agreement between RELAP5 and WAHA code results
- Due to decoupled nature of the balance relations in WAHA code, there are some stability restrictions ($p1/p2$, $S1/S2$ and τ) for the abrupt-area change model
- RELAP5/MOD3.3 performs at least as well as the specialized WAHA code in the presented cases
- Future work: After certain improvements in the WAHA code more assessment of RELAP5 for fast transients will be performed

