LFW-SG ACCIDENT SEQUENCE IN A PWR 900: CONSIDERATIONS CONCERNING RECENT MELCOR 1.8.5 / 1.8.6 CALCULATIONS

F. DE ROSA
ENEA FIS NUC - Bologna

1st EUROPEAN MELCOR USERS' GROUP
Villigen, Switzerland
15-16 December 2008

REFERENCE PLANT:

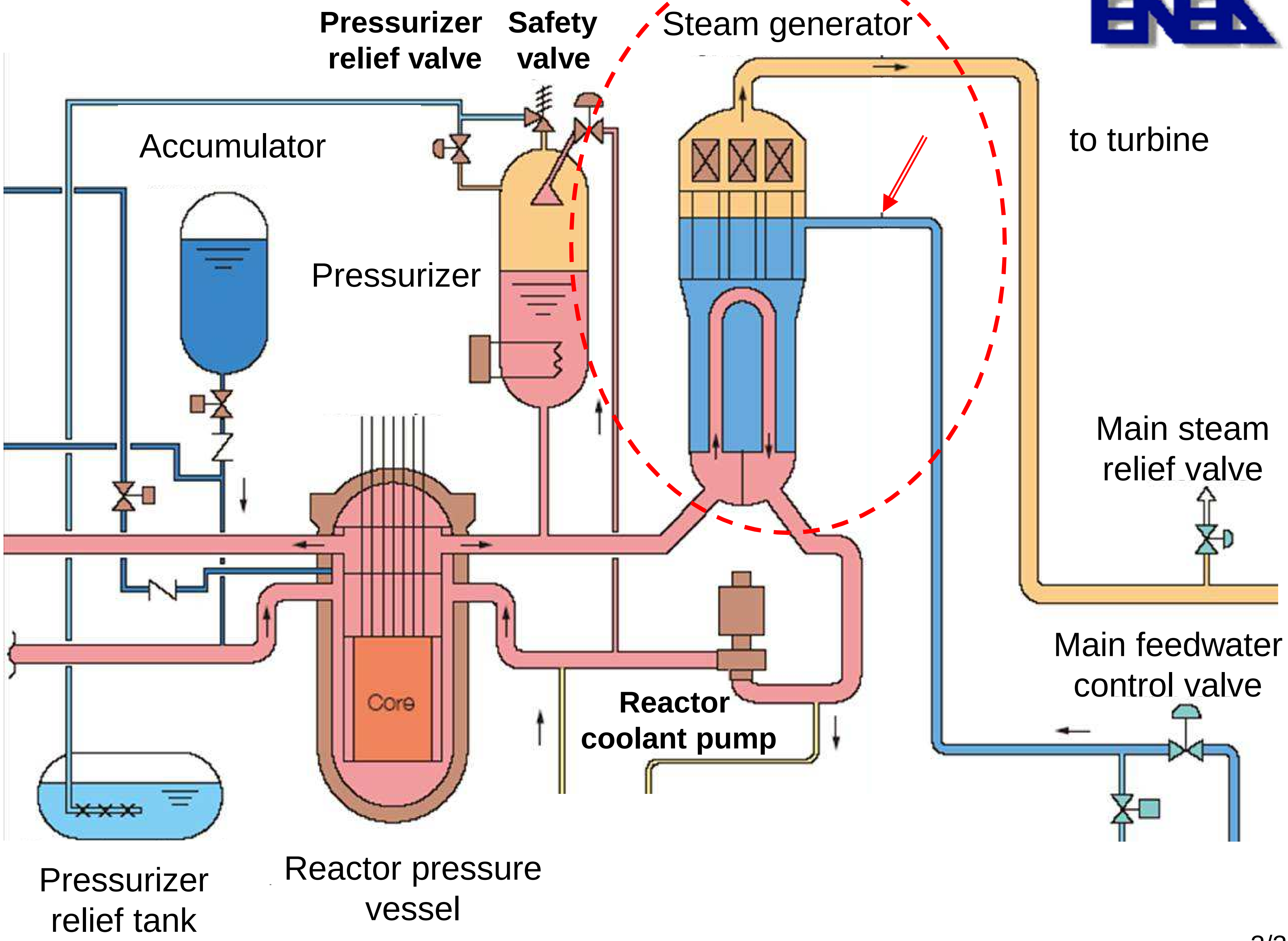
PWR 900 MWe

ACCIDENT SEQUENCE:

LFW – SG (H2)

INITIATOR:

LOSS OF NORMAL (AND AUXILIARY) SG FEEDWATER


Pressurizer relief valve
Safety valve
Steam generator
to turbine
Accumulator
Pressurizer
Main steam relief valve
Core
Reactor coolant pump
Main feedwater control valve
Pressurizer relief tank
Reactor pressure vessel

WHY A CODE-TO-CODE COMPARISON IS IMPORTANT

DURING OPEN CALCULATIONS, WE HAVE THE OPPORTUNITY TO COMPARE OUR RESULTS WITH AVAILABLE EXPERIMENTAL DATA.

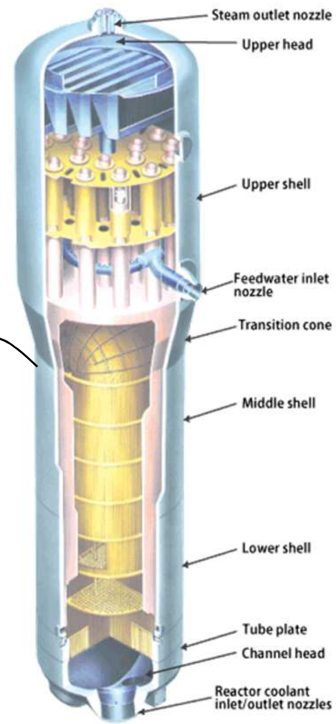
DEALING WITH PLANT CALCULATIONS THERE IS NOT AN EXPLICIT REFERENCE: A PLANT CALCULATION IS PRACTICALLY A BLIND CALCULATION.

**WP4 (SARNET 1 NoE)
GAVE A GOOD OPPORTUNITY
TO PERFORM A CODE-TO-CODE
COMPARISON USING ASTEC, MAAP
AND MELCOR.**

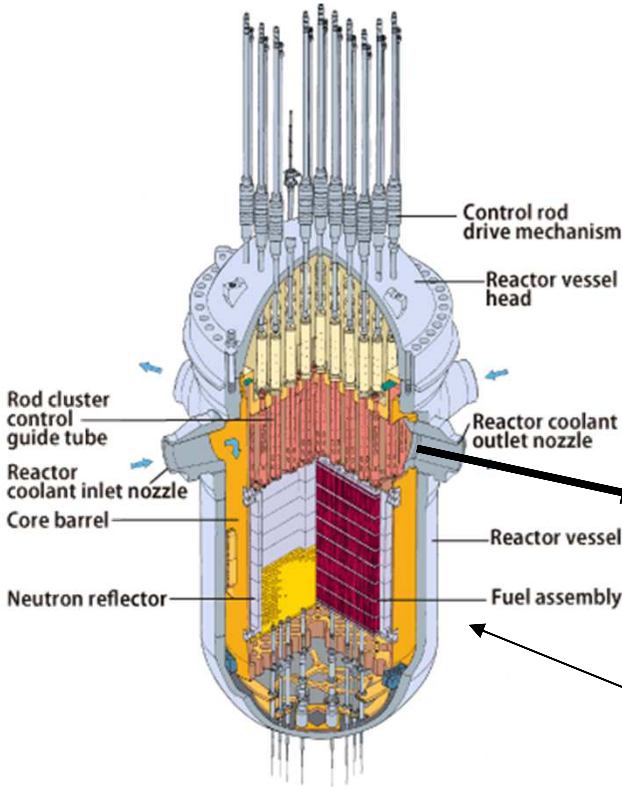
ACCIDENT DESCRIPTION

DETAILS: ACCIDENT EVOLUTION

Steam Generator

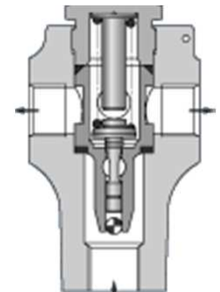


RPV and Core details



cooling fluid outlet

Relief valve



1

- THE LEVEL OF WATER IN SG GOES DOWN

└→ **REACTOR SCRAM**

2

- THE TEMPERATURE OF FLUID COMING OUT FROM THE CORE (T_{RIC}) GOES UP

3

- WHEN TRIC > 603 K (330 C)

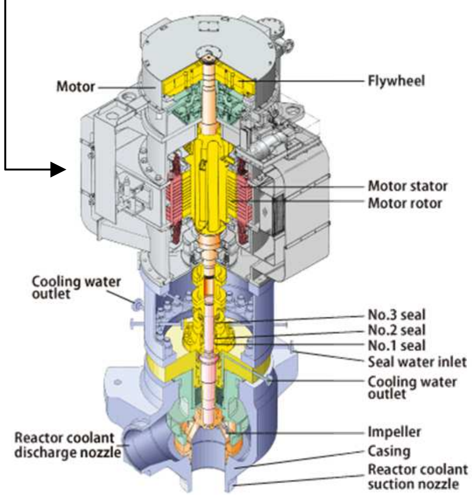
└→ **TOTAL OPENING OF RELIEF VALVES**

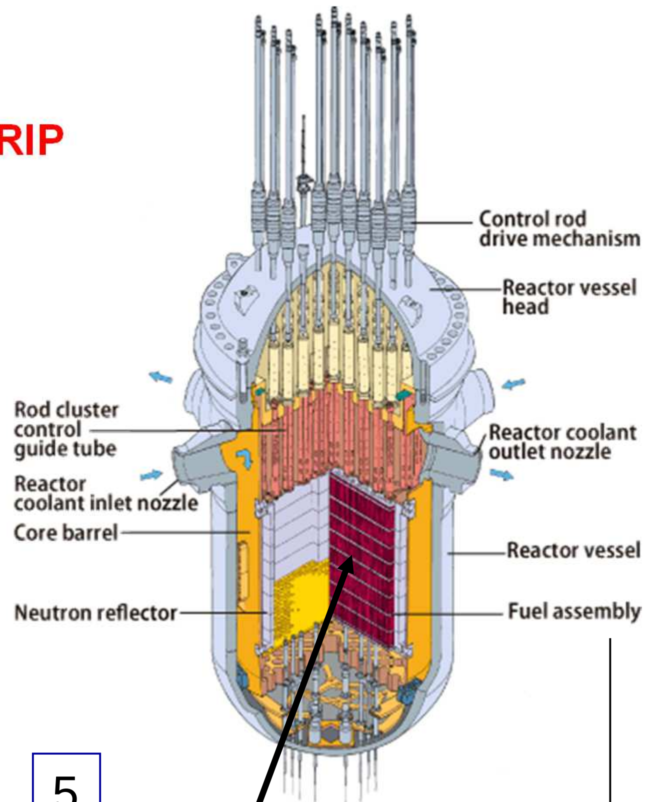
DETAILS: ACCIDENT EVOLUTION

4

- WHEN ΔT_{sat} < 283 K (10 C)

→ **MAIN COOLANT PUMPS TRIP**

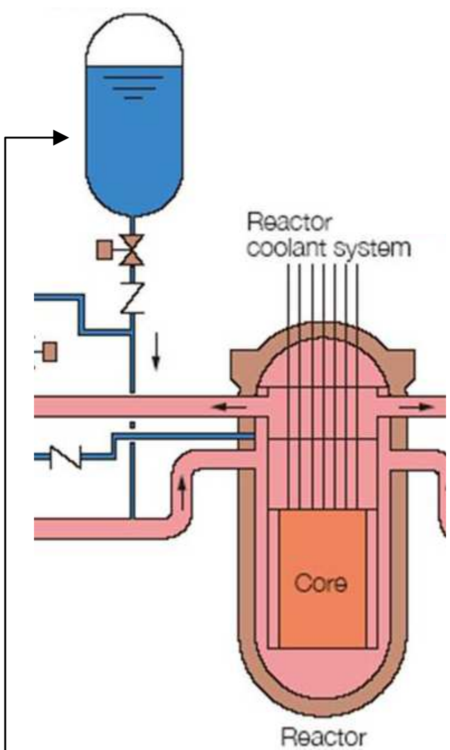




5

- FIRST CORE UNCOVERY

ACCUMULATOR



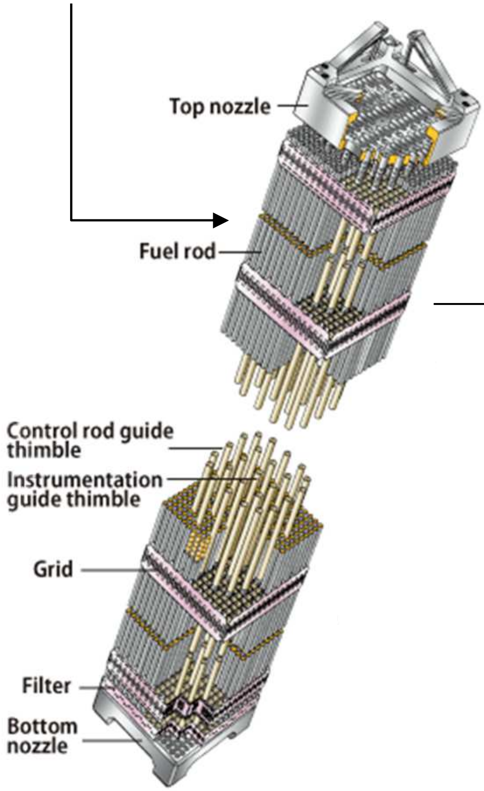
6

- ACCUMULATORS INJECTION

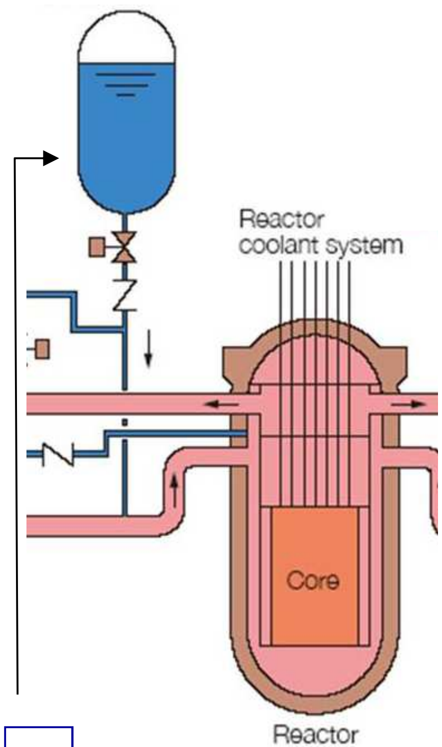
DETAILS: ACCIDENT EVOLUTION

7

- FIRST FUEL CLADDING RUPTURE AND FISSION PRODUCT RELEASE



ACCUMULATOR



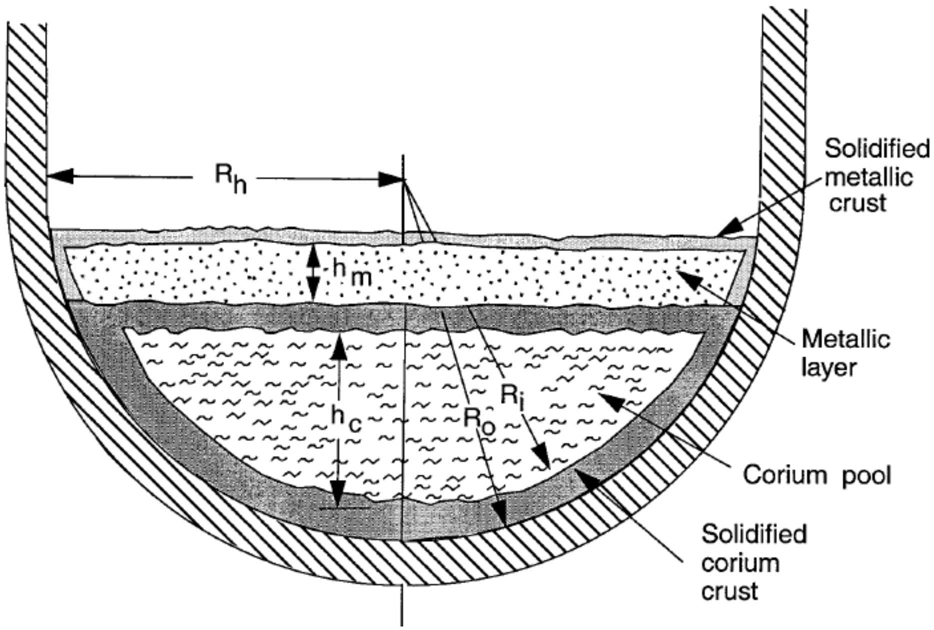
8

- ACCUMULATOR ISOLATION

DETAILS: ACCIDENT EVOLUTION

9

- FIRST MATERIAL SLUMP IN LOWER HEAD



Corium and metal pools in lower head of reactor pressure vessel

10

- **Corium slump from lower head to cavity**

COMPUTING DETAILS

COMPUTING DETAILS

COMPUTER (the same for MELCOR and ASTEC)

PC - PENTIUM 4 - CPU 2400 MHz - 1024 MB of RAM - WINDOWS XP Pro

TRANSIENT LENGHT (CALCULATION TIME) (the same for MELCOR and ASTEC)

First Phase: 17 h (61200 s)

Now : 24 h (86400 s)

Reason: To check CODE stability and capability to perform long calculations without computer hangs.

CPU TIME

First Phase: 15 h (54000 s) for ASTEC V1.1p2
2 h (7200 s) for MELCOR 1.8.5 p3

Now : 13 h 25m (48300 s) for ASTEC V1.2 rev.1
2 h 50 m (10200 s) for MELCOR 1.8.6

good news

CALC RATIO (calc time / cpu time)

First Phase $\begin{cases} \xi astec = 1.133 \\ \xi melcor = 8.500 \end{cases}$ Now $\begin{cases} \xi astec = 1.788 \\ \xi melcor = 8.471 \end{cases}$

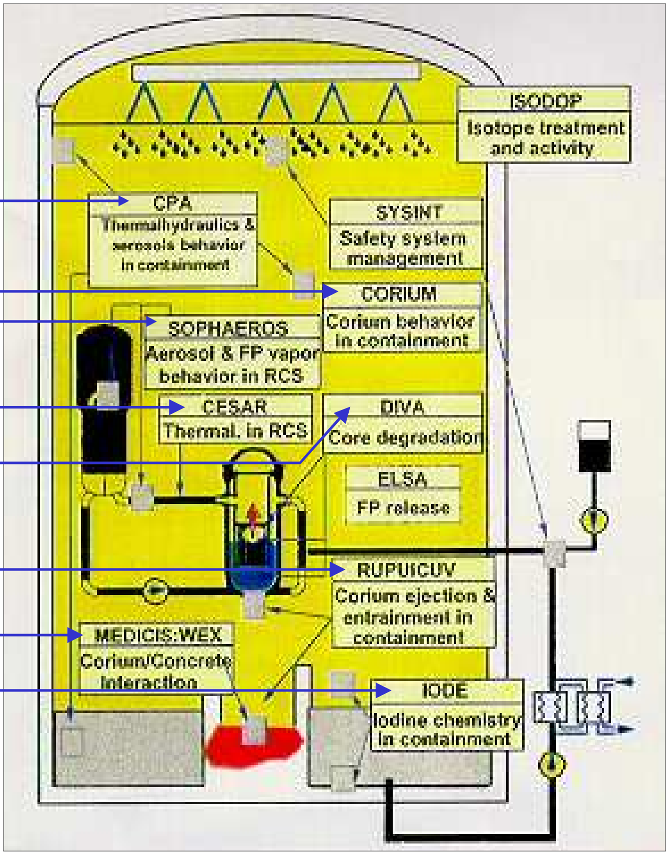
PLANT MODELLING

ASTEC

INPUT DECK
PROVIDED BY IRSN

ASTEC MODULES INVOLVED IN THE CALCULATION:

- CPA
- CORIUM
- SOPHAEROS
- CESAR
- DIVA
- RUPUICUV
- MEDICIS
- IODE

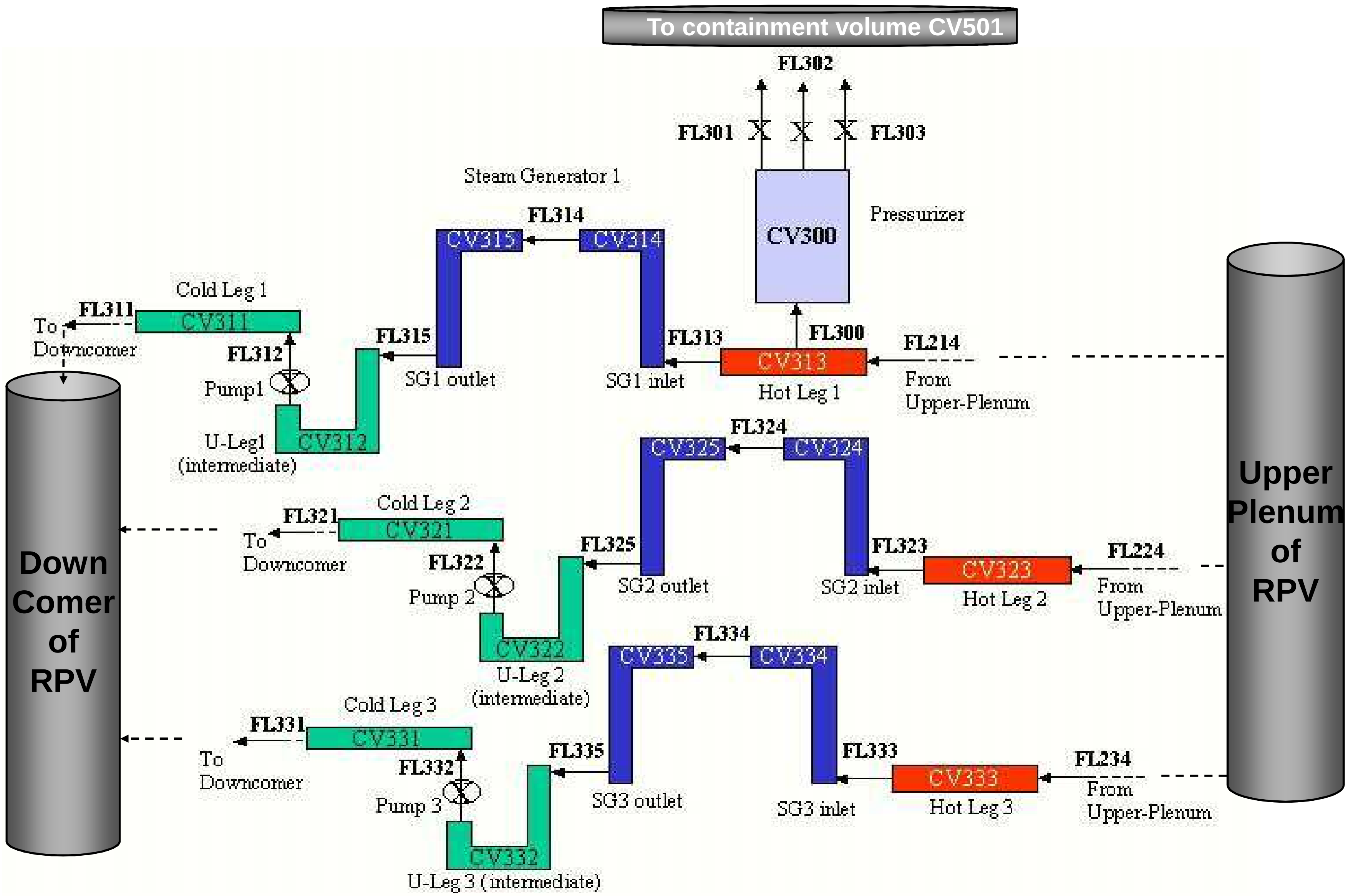


DIFFERENT INPUT APPROACH

IN **MELCOR** SOME DATA AND CONDITIONS MUST BE PROVIDED BY MEANS OF CONTROL (CFs) AND TABULAR FUNCTIONS (TFs), ESPECIALLY IN THE CASE UNDER EXAMINATION, IN WHICH THE MODELLING OF SEVERAL PHENOMENA AND COMPLICATED SYSTEMS IS REQUIRED.

IT MEANS THAT, IN GENERAL, **ASTEC AND MELCOR** INPUT DECKS ARE NOT EASILY COMPARABLE.

PRIMARY CIRCUIT MODELLING (1)



PRIMARY CIRCUIT MODELLING (2)

VOLUMES

CV300 : pressurizer
CV311, 321 and 331: cold leg plus pump 1, 2 and 3
CV312, 322 and 332: intermediate leg 1, 2 and 3
CV313, 323 and 333: hot leg 1, 2 and 3
CV314, 324 and 334: ascending part of steam generator 1, 2 and 3 (SG inlet)
CV315, 325 and 335: descending part of steam generator 1, 2 and 3 (SG outlet)

JUNCTIONS

FL214, 224 and 234: from upper-plenum of reactor vessel to hot leg 1, 2 and 3
FL300 : from hot leg1 to pressurizer
FL301, 302 and 303: from valve 1, 2 and 3 of pressurizer to containment
FL311, 321 and 331: from cold leg 1, 2 and 3 to downcomer of reactor vessel
FL312, 322 and 332: from u-leg 1, 2 and 3 to pump/cold leg 1, 2 and 3
FL313, 323 and 333: from hot leg 1, 2 and 3 to SG1, 2 and 3 inlet
FL314, 324 and 334: from SG1, 2 and 3 inlet to SG1, 2 and 3 outlet
FL315, 325 and 335: from SG1, 2 and 3 outlet to u-leg1, 2 and 3

PRIMARY CIRCUIT MODELLING (3)

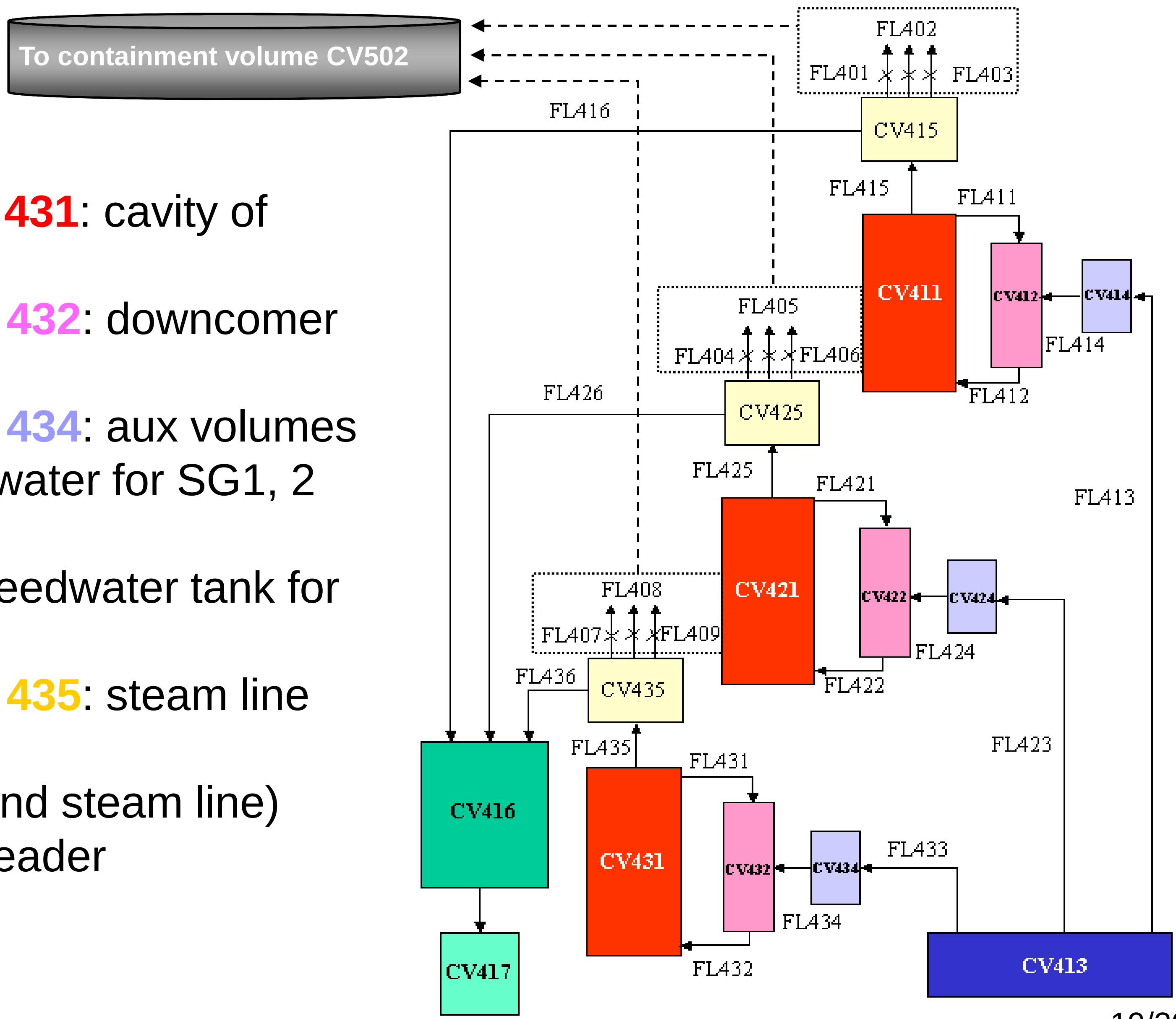
HEAT STRUCTURES

HS30001	: pressurizer
HS30002	: expansion line of pressurizer
HS31100, 32100 AND 33100	: cold leg plus pump 1, 2 and 3
HS31200, 32200 AND 33200	: intermediate leg 1, 2 and 3
HS31201, 32201 AND 33201	: pump1, 2 and 3
HS31300, 32300 AND 33300	: hot leg 1, 2 and 3
HS31400, 32400 AND 33400	: ascending part of SG 1, 2 and 3
HS31500, 32500 AND 33500	: descending part of SG 1,2 and 3

SECONDARY CIRCUIT MODELLING (1)

VOLUMES

- **CV411**, **421** and **431**: cavity of SG1, 2 and 3
- **CV412**, **422** and **432**: downcomer of SG1, 2 and 3
- **CV414**, **424** and **434**: aux volumes to describe feedwater for SG1, 2 and 3
- **CV413**: normal feedwater tank for SGs
- **CV415**, **425** and **435**: steam line for SG1, 2 and 3
- **CV416**: barrel (end steam line)
- **CV417**: steam header



SECONDARY CIRCUIT MODELLING (2)

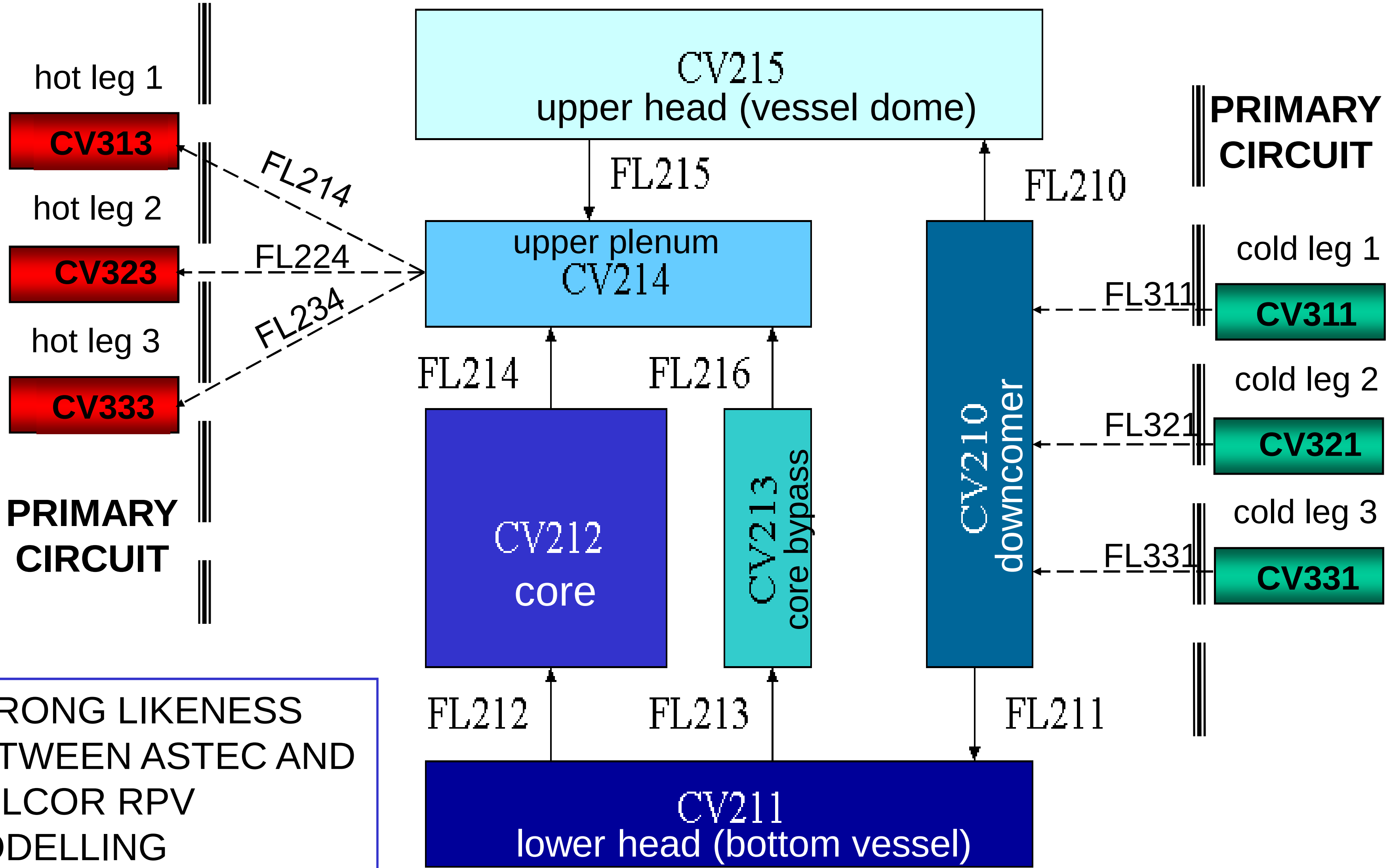
JUNCTIONS

- FL401, 404 and 407: from the first group of safety valves to environment
- FL402, 405 and 408: from the second group of safety valves to environment
- FL403, 406 and 409: from the third group of safety valves to environment
- FL411, 421 and 431: from cavity 1, 2 and 3 to downcomer of SG1, 2 and 3
- FL412, 422 and 432: from downcomer 1, 2 and 3 to cavity of SG1, 2 and 3
- FL413, 423 and 433: from normal feedwater tank to aux volume 1, 2 and 3
- FL414, 424 and 434: from aux volume 1, 2 and 3 to downcomer of SG1, 2, 3
- FL415, 425 and 435: from cavity 1, 2 and 3 to steam line 1, 2 and 3
- FL416, 426 and 436: from steam line 1, 2 and 3 to barrel
- FL417: from barrel to steam header

HEAT STRUCTURES

- HS41100, 42100 and 43100: bottom internal of cavity side of SG 1, 2 and 3
- HS41101, 42101 and 43101: top 1 internal of cavity side of SG 1, 2 and 3
- HS41102, 42102 and 43102: top envelop of SG 1, 2 and 3
- HS41103, 42103 and 43103: top 2 internal of cavity side of SG 1, 2 and 3
- HS41200, 42200 and 43200: bottom envelop of downcomer side of SG 1, 2, 3
- HS41201, 42201 and 43201: envelop of tube bundle of SG 1, 2 and 3

VESSEL (1)

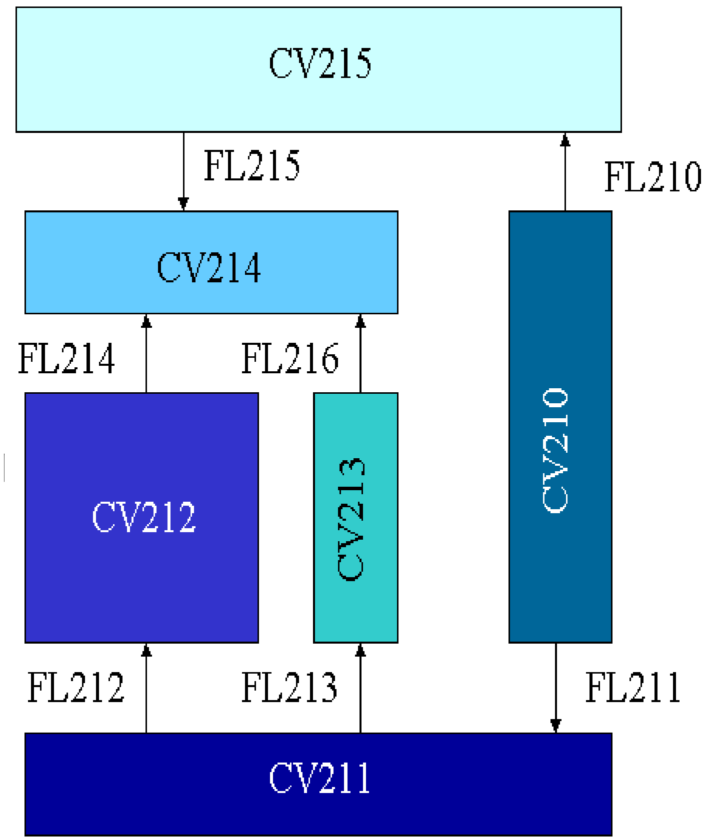


STRONG LIKENESS BETWEEN ASTEC AND MELCOR RPV MODELLING

VESSEL (2)

JUNCTIONS

FL210: from downcomer to dome
FL211: from downcomer to bottom
FL212: from bottom to core
FL213: from bottom to core bypass
FL214: from core to upper plenum
FL216: from core bypass to upper plenu
FL215: from dome to upper plenum



VESSEL (3)

HEAT STRUCTURES

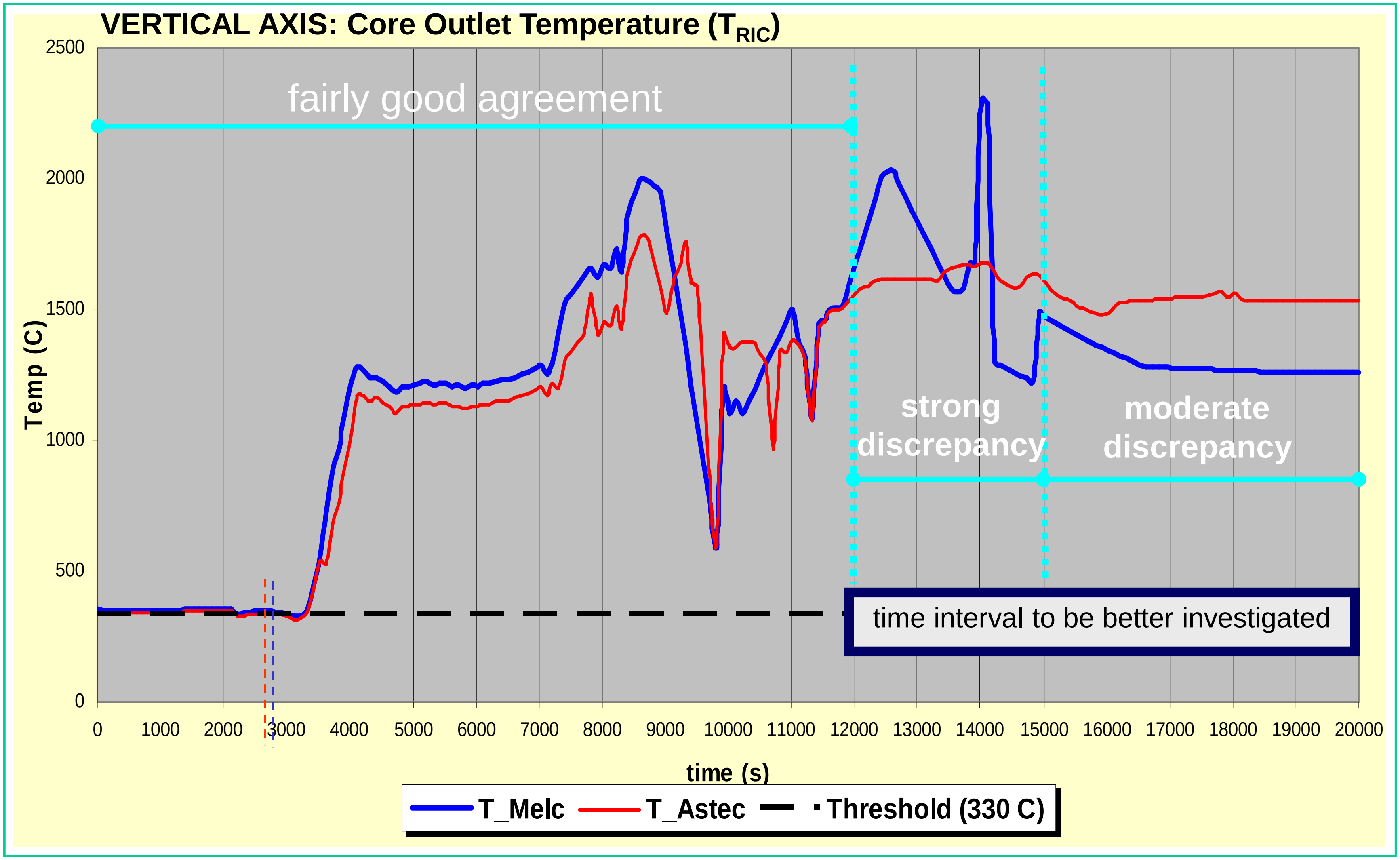
HS21001: downcomer, rectangular part
HS21002: downcomer, lateral, bottom side
HS21003: downcomer, lateral, upper side
HS21100: bottom, hemispherical shape
HS21101: bottom, cylindrical side 1
HS21102: bottom, cylindrical side 2
HS21103: bottom, cylindrical side 3
HS21201: core, partition plate 1, rectangular, vertical (located at level 1)
HS21202: core, partition plate 2, rectangular, vertical (located at level 2)
HS21203: core, partition plate 3, rectangular, vertical (located at level 2)
HS21301: core bypass, cylindrical shape
HS21302: core bypass, partition plate, rectangular, horizontal
HS21401: upper plenum, downcomer side, cylindrical shape
HS21402: upper plenum, support wall of guide tubes
HS21403: upper plenum, horizontal core support plate, rectangular shape
HS21404: upper plenum, vertical guide for tubes, rectangular shape
HS21405: upper plenum, vertical structure, rectangular shape
HS21501: dome, lid, hemispherical side
HS21502: dome, lid, cylindrical side
HS21503: dome, internal structures, rectangular shape

RESULTS

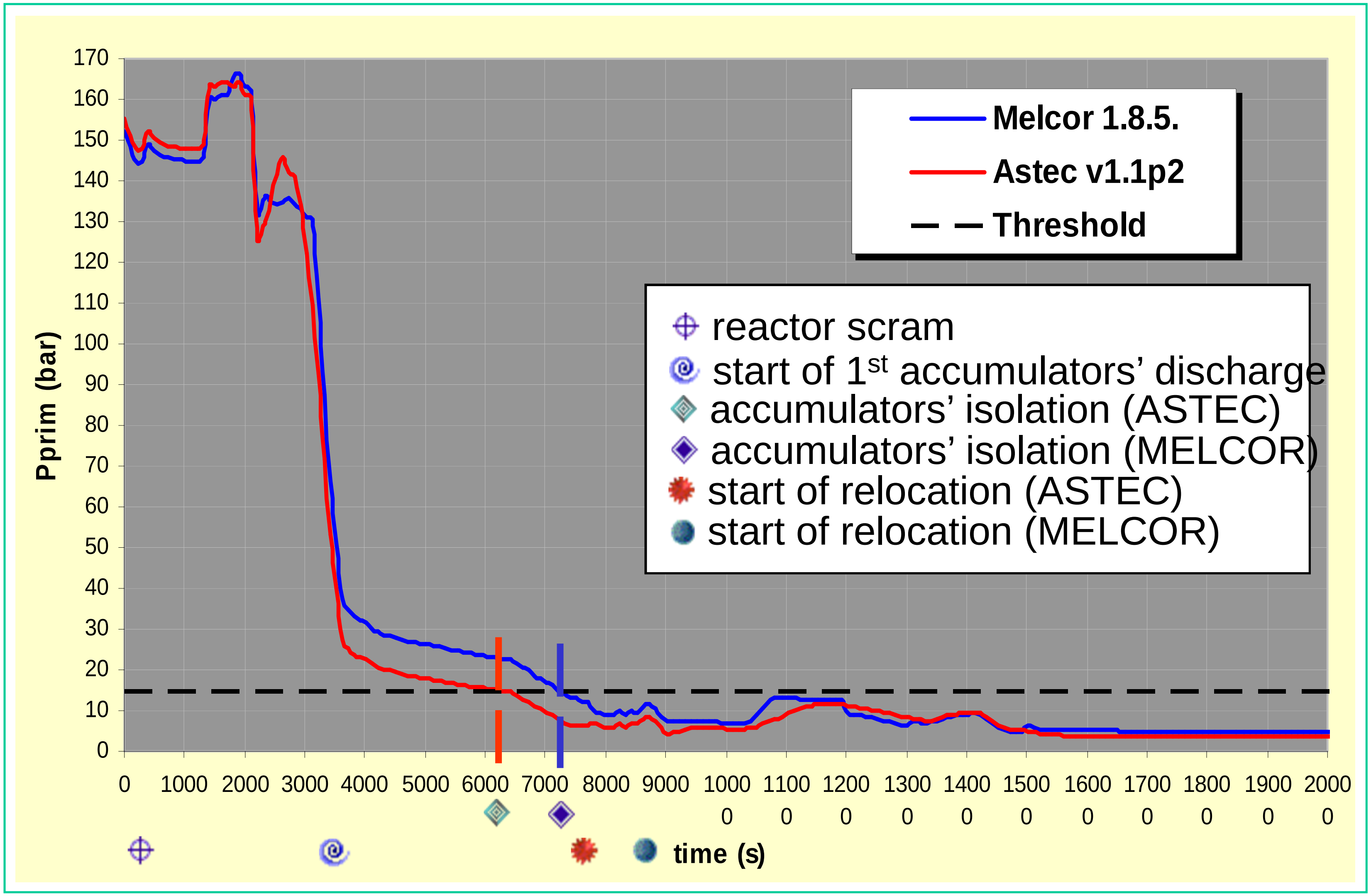
ASTEC - MELCOR (Timing Comparison)

EVENT	ASTEC v1.1 patch 2	MELCOR 1.8.5 patch3
Loss of SG Feedwater (initiator)	0 s	0 s
Scram	28 s	28 s
Total Opening of Relief Valves (T_{ric}> 330 C)	2209 s	2259 s
Main Coolant Pumps trip (ΔT_{sat}< 10 C)	2214 s	2266 s
Accum injection (start of first accum discharge)	3524 s	3603 s
Accum isolation (accum off)	6189 s	7184 s
Start of relocation to Lower Plenum (first corium slump)	7487 s	8700 s
Vessel failure (Lower Head Vessel failure)	18254 s	18474 s

TOTAL OPENING OF THE RELIEF VALVES

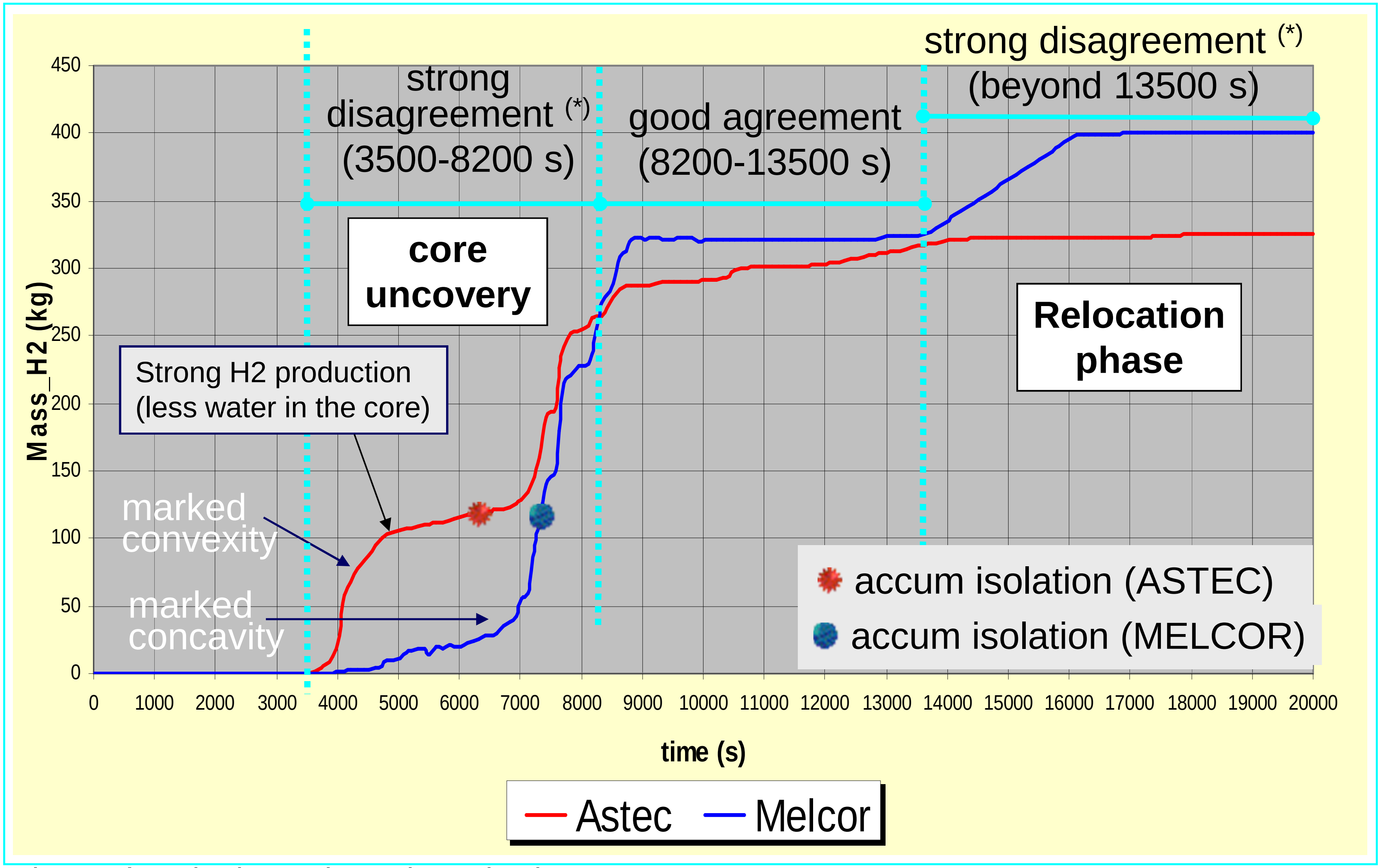


Accumulators isolation



Accum isolation when P_{prim} < 15 bar (1.5 MPa)

HYDROGEN PRODUCED DURING THE IN-VESSEL PHASE



(*) time intervals to be better investigated using
latest ASTEC and MELCOR versions

CONCLUSIONS (1)

- **ASTEC AND MELCOR are able to calculate a whole LFW-SG (H_2) sequence for a French PWR 900 MWe.**
- **A new comparison made using MELCOR 1.8.6 and the latest version of ASTEC evidenced a general tendency of results to become closer for both codes, but...**

EVEN IF THERE IS A FAIRLY GOOD CONSISTENCY BETWEEN ASTEC AND MELCOR, MAINLY IN THE "FRONT - END" PART OF THE LFW-SG SEQUENCE (PRIMARY SYSTEM BEHAVIOUR, CORE HEAT-UP PHASE UNTIL STRONG OXIDATION), IN THE SECOND PART OF THE ACCIDENT EVOLUTION, WHEN SIGNIFICANT MATERIAL RELOCATION OCCURS, SOME DISCREPANCIES STILL APPEAR.

CONCLUSIONS (2)

IT IS VERY IMPORTANT TO CONTINUE A COMPARISON WORK TAKING INTO ACCOUNT ALSO THE SOURCE TERM.