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# MELCOR code application to VVER440/V213 analyses

**Juraj Jančovič**

**jancovic@vuje.sk**

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- overview of MELCOR models
- core model of VVER440/V213
- AICC pressure calculation
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# MELCOR code usage in VUJE

## MELCOR

- versions 1.8.3 and 1.8.5 have been used in VUJE,
- model development focused exclusively onto VVER440/V213 design,
- the most widely used severe accident code in VUJE.

## Models of VVER440/V213 for MELCOR

**2-loop model for MELCOR 1.8.3**

- *used for research and development projects,*

**2-loop model for MELCOR 1.8.5**

- *used for safety reports, PSA L2 scenario analyses, hydrogen risk assessment,*

**6-loop model of shut-down reactor**

- *used for research projects,*

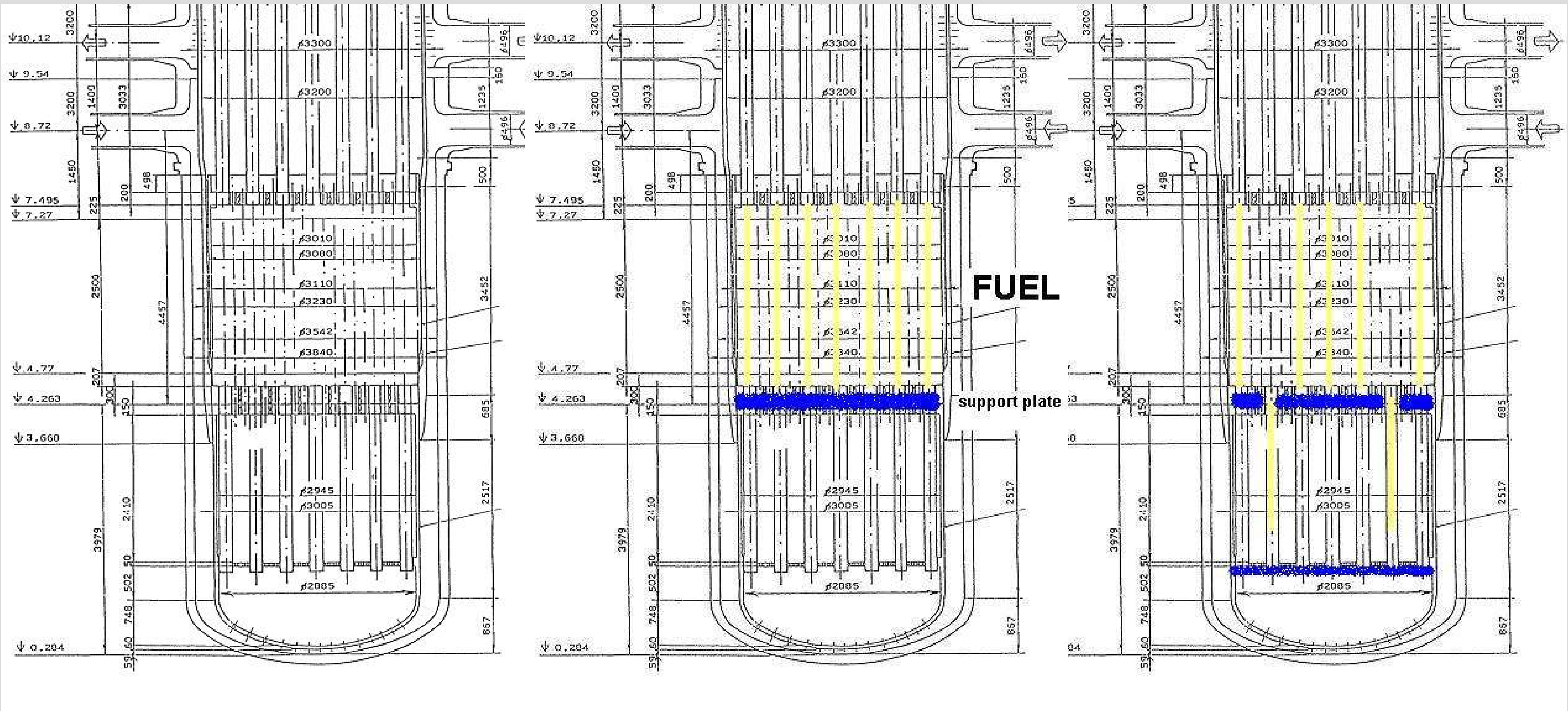
**Detailed containment model**

- *used for safety reports, containment phenomena.*

# Model of the core

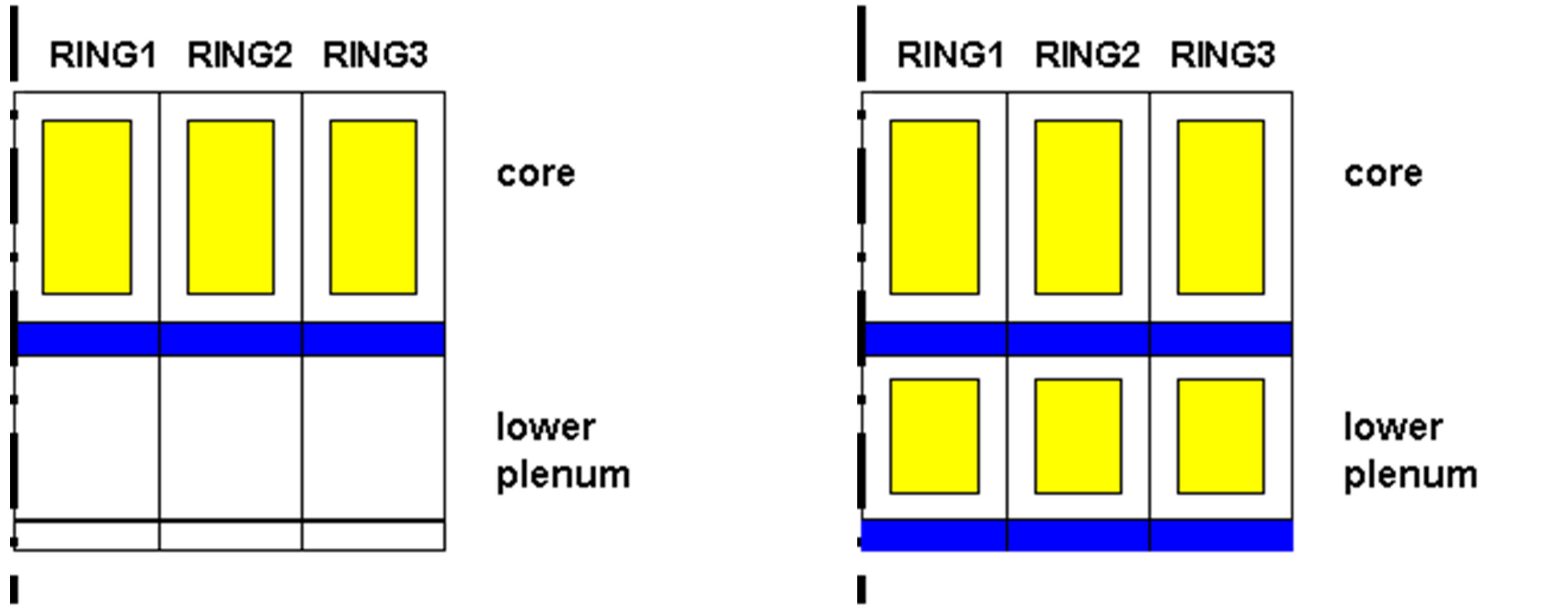
## Model of the core (*the largest challenge – fuel present in the lower plenum)*

**reactor vessel** **during operation** **after reactor trip**



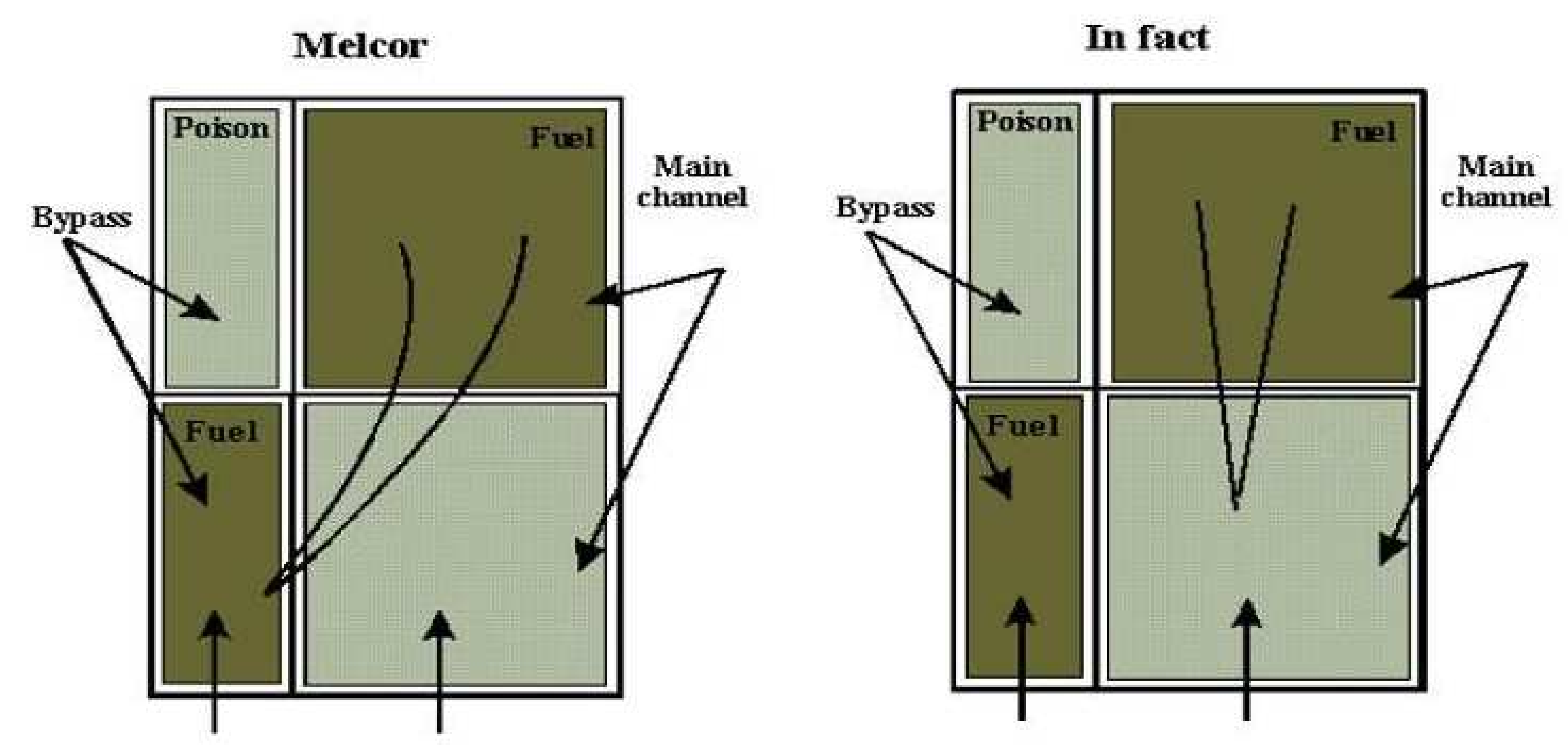
# Model of the core

## Modelling possibilities – already used



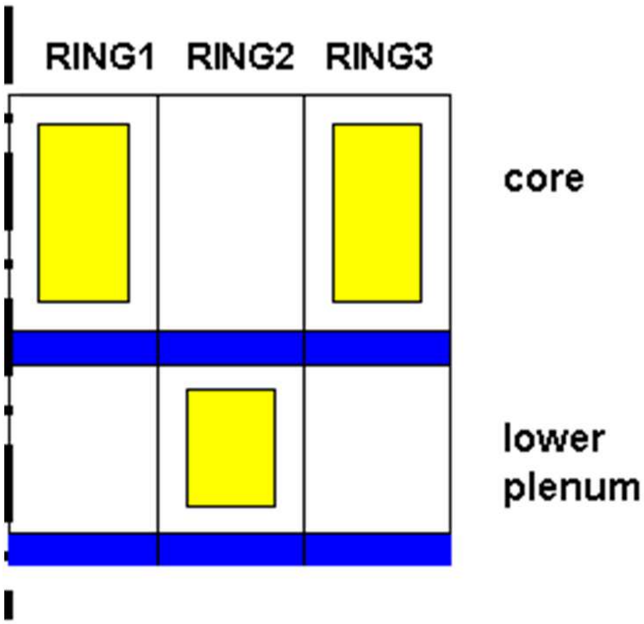
# Model of the core

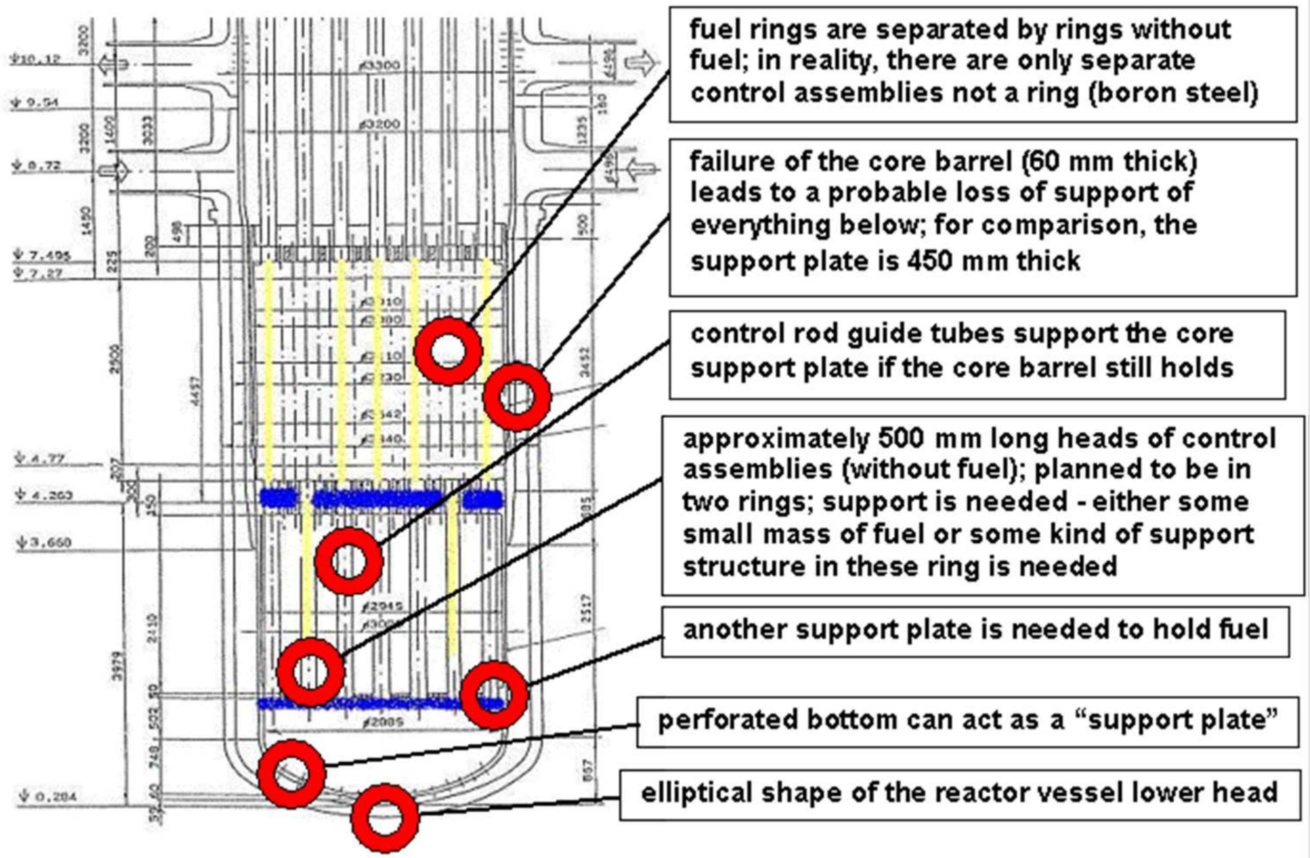
## Relocation; steam flow through channels – hydrogen production



# Model of the core

## Modelling possibility – planned



# AICC pressure calculation

## AICC pressure calculation used for estimation of hydrogen risk

- Evaluation of DDT risk planned for further models

## VVER440/V213 containment features

- “semidetached“ rooms in the containment – large differences in AICC pressures
- airtraps influence amount of noncondensable gases present in the containment
- low containment design pressure – 250 $kPa^{abs}$
- structural analyses show “failure pressure“ cca. 350 $kPa^{abs}$
- AICC pressure below 350 $kPa^{abs}$ and low probability of DDT in the rooms of the containment is the goal of a successful hydrogen risk mitigation strategy.

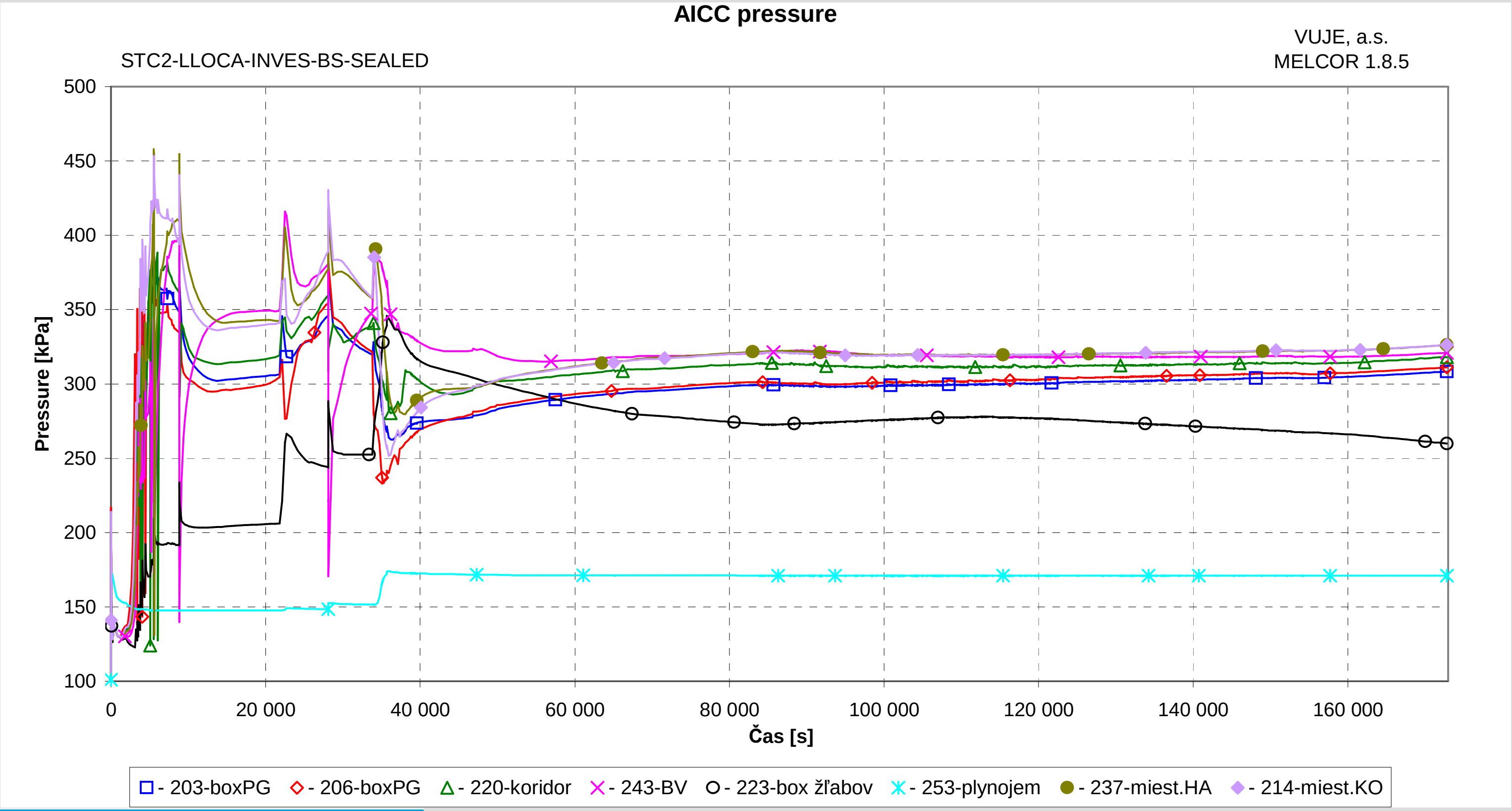
**Assessment of pressure in the containment after hydrogen combustion is of predominant interest.**

# AICC pressure calculation

## External code calculation

**An external code is used for evaluation of AICC pressure peaks in containment volumes.**

**Disadvantage is that the code calculates AICC pressure only from plot file data.**



# AICC pressure calculation

## Internal calculation – AICC module

**An algorithm of AICC calculation was prepared and incorporated into the MELCOR model (input deck). The model tracks AICC pressure in every time step.**

**Hydrogen and carbon monoxide combustion is considered.**

**Disadvantage is that for now only 3 control volumes are calculated simultaneously.**

**Out of memory/variables error encountered.**

**Comprises 6 general TFs, 11 general CFs and 219 CFs per calculated volume.**

**Output for every calculated control volume:**

**- AICC pressure written to plot file,**

**- max. AICC pressure during scenario,**

**- AICC temperature written to plot file.**

# AICC pressure calculation

## Model verification against MELCOR

**Model was verified against MELCOR calculations using BUR package. Closed (isochoric) control volumes without heat structures (adiabatic) with combustion completeness set to 1.0 (complete) were used.**

**Various initial conditions and hydrogen (and CO) concentrations were used.**

Tab. 2.1-2 Comparison of AICC algorithm against MELCOR calculation, $p_p$=101,3 kPa, T = 300 K

| 300 K | p (Pa) | | | | |
|---|---|---|---|---|---|
| $cH_2$ (-) | Initial pressure | AICC | MELCOR | Δp (Pa) | δp (–) |
| 0.02 | 103 061 | 179 300 | 180 010 | 710 | 0.00394 |
| **0.04** | **105 208** | **255 490** | **255 750** | **260** | **0.00102** |
| **0.06** | **107 447** | **329 360** | **329 140** | **-220** | **-0.00067** |
| **0.08** | **109 783** | **401 920** | **401 520** | **-400** | **-0.001** |
| **0.10** | **112 222** | **474 020** | **473 640** | **-380** | **-0.0008** |
| **0.12** | **114 773** | **546 280** | **545 960** | **-320** | **-0.00059** |
| **0.14** | **117 442** | **619 060** | **618 860** | **-200** | **-0.00032** |
| 0.16 | 120 238 | 692 660 | 692 530 | -130 | -0.00019 |
| 0.18 | 123 171 | 767 430 | 767 240 | -190 | -0.00025 |
| 0.20 | 126 250 | 843 560 | 843 230 | -330 | -0.00039 |

# AICC pressure calculation

## Model verification against MELCOR

Tab. 2.1-3 Comparison of AICC algorithm against MELCOR calculation, $p_p$=101,3 kPa, T = 350 K

| 350 K | p (Pa) | | | | |
|---|---|---|---|---|---|
| $cH_2$ (-) | Initial press. | AICC | MELCOR | Δp (Pa) | δp (–) |
| 0.02 | 141 985 | 225 580 | 226 300 | 720 | 0.00318 |
| **0.04** | **144 943** | **309 330** | **310 070** | **740** | **0.00239** |
| **0.06** | **148 026** | **390 490** | **391 390** | **900** | **0.0023** |
| **0.08** | **151 244** | **469 950** | **471 350** | **1 400** | **0.00297** |
| **0.10** | **154 605** | **548 740** | **550 670** | **1 930** | **0.0035** |
| **0.12** | **158 119** | **627 480** | **629 950** | **2 470** | **0.00392** |
| **0.14** | **161 796** | **706 710** | **709 750** | **3 040** | **0.00428** |
| 0.16 | 165 649 | 786 940 | 790 290 | 3 350 | 0.00424 |
| 0.18 | 169 689 | 868 580 | 871 950 | 3 370 | 0.00386 |
| 0.20 | 173 931 | 951 730 | 955 100 | 3 370 | 0.00353 |

Tab. 2.1-5 Comparison of AICC algorithm against MELCOR calculation, $p_p$=101,3 kPa, T = 300 K

| 300 K | p (Pa) | | | | |
|---|---|---|---|---|---|
| cCO (-) | poč. tlak | AICC | MELCOR | Δp (Pa) | δp (–) |
| 0.02 | 101 300 | 188 940 | 189 570 | 630 | 0.003323 |
| **0.04** | **101 300** | **267 960** | **267 860** | **-100** | **-0.00037** |
| **0.06** | **101 300** | **339 220** | **338 470** | **-750** | **-0.00222** |
| **0.08** | **101 300** | **404 740** | **403 540** | **-1 200** | **-0.00297** |
| **0.1** | **101 300** | **465 850** | **464 230** | **-1 620** | **-0.00349** |
| **0.12** | **101 300** | **523 460** | **521 250** | **-2 210** | **-0.00424** |
| **0.14** | **101 300** | **577 990** | **575 080** | **-2 910** | **-0.00506** |
| 0.16 | 101 300 | 629 720 | 626 040 | -3 680 | -0.00588 |
| 0.18 | 101 300 | 679 140 | 674 390 | -4 750 | -0.00704 |
| 0.2 | 101 300 | 726 290 | 720 310 | -5 980 | -0.0083 |

Tab. 2.1-4 Comparison of AICC algorithm against MELCOR calculation, LOCA

| | p (Pa) | | | | |
|---|---|---|---|---|---|
| cH2 (-) | Initial press. | AICC | MELCOR | Δp (Pa) | δp (–) |
| 0.02 | 117 552 | 188 780 | 189 400 | 620 | 0.00327 |
| **0.04** | **120 001** | **260 110** | **260 650** | **540** | **0.00207** |
| **0.06** | **122 554** | **329 200** | **329 810** | **610** | **0.00185** |
| **0.08** | **125 218** | **396 870** | **397 810** | **940** | **0.00236** |
| **0.10** | **128 001** | **463 980** | **465 300** | **1 320** | **0.00284** |
| **0.12** | **130 910** | **531 040** | **532 760** | **1 720** | **0.00323** |
| **0.14** | **133 955** | **598 530** | **600 680** | **2 150** | **0.00358** |
| 0.16 | 137 144 | 666 870 | 669 220 | 2 350 | 0.00351 |
| 0.18 | 140 489 | 736 390 | 738 720 | 2 330 | 0.00315 |
| 0.20 | 144 001 | 807 180 | 809 490 | 2 310 | 0.00285 |

Tab. 2.1-6 Combustion of hydrogen and CO (oxygen starvation conditions)

| | | p (Pa) | | | | |
|---|---|---|---|---|---|---|
| cH2 (-) | cCO (-) | poč. tlak | AICC | MELCOR | Δp (Pa) | δp (–) |
| 0.11 | 0.11 | 101 300 | 748 430 | 744 590 | -3 840 | -0.00516 |
| 0.12 | 0.12 | 101 300 | 791 090 | 786 350 | -4 740 | -0.00603 |
| 0.13 | 0.13 | 101 300 | 832 250 | 826 220 | -6 030 | -0.0073 |
| 0.14 | 0.14 | 101 300 | 872 180 | 864 270 | -7 910 | -0.00915 |
| 0.15 | 0.15 | 101 300 | 874 290 | 866 280 | -8 010 | -0.00925 |
| 0.16 | 0.16 | 101 300 | 858 450 | 851 320 | -7 130 | -0.00838 |
| 0.17 | 0.17 | 101 300 | 842 390 | 836 040 | -6 350 | -0.0076 |
| 0.18 | 0.18 | 101 300 | 825 980 | 820 430 | -5 550 | -0.00676 |
| 0.19 | 0.19 | 101 300 | 809 480 | 804 500 | -4 980 | -0.00619 |
| 0.2 | 0.2 | 101 300 | 792 650 | 788 220 | -4 430 | -0.00562 |

## Model validation against charts based on experimental data

**Model was validated against charts provided along experimental data in “Reactor Safety Course (R-800), USNRC Technical Training Center, Rev 1193“**

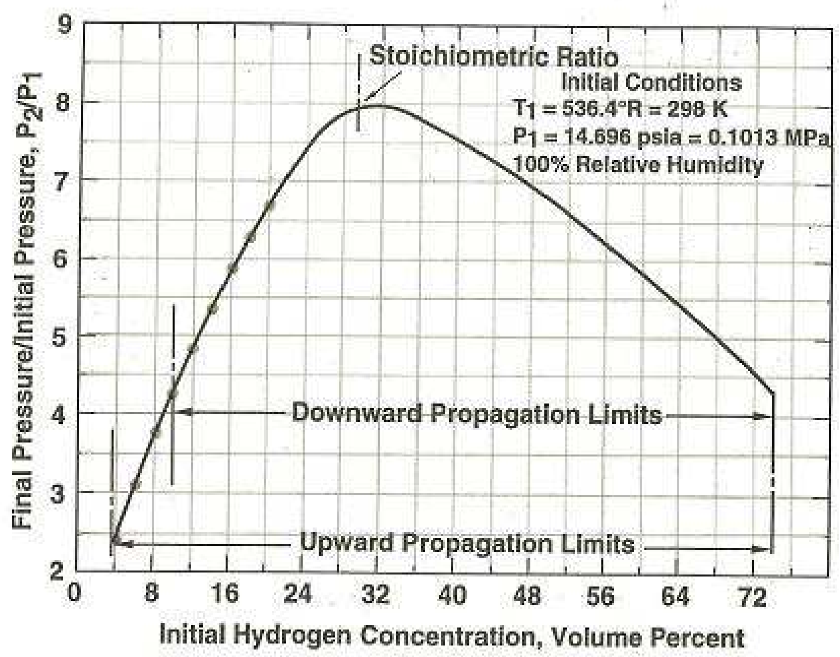



Figure 4A-1 Theoretical adiabatic, constant-volume combustic
pressure for hydrogen : air mixtures

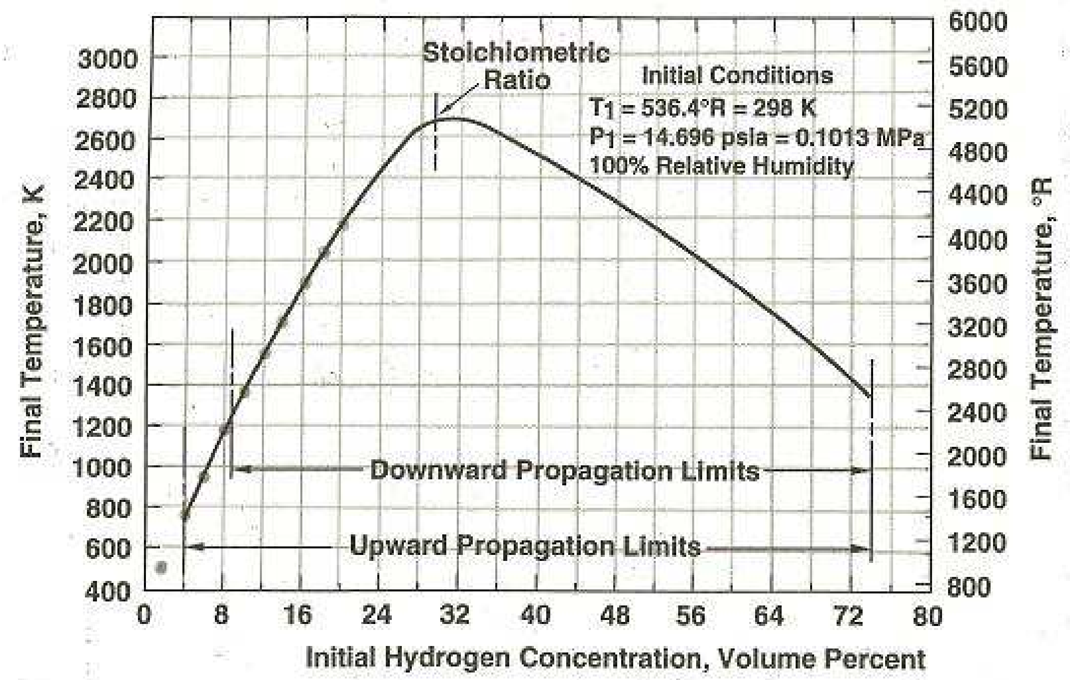



Figure 4A-2 Theoretical adiabatic, constant-volume combustion
temperature for hydrogen : air mixtures

# Conclusions

## Conclusions – core modelling

- fuel/debris support is the main uncertainty in the modelling,
- planned core modelling (core rings without fuel) is being applied for a new model,
- support structures situated below the core support plate can influence core degradation timing and consequently also corium interaction with the reactor pressure vessel

## Conclusions – AICC pressure calculation

Relatively simple model developed. Ready to be used for hydrogen risk related calculations.

Incorporation of such a calculation into the CVH or BUR module would be helpful.

CVH-PAICC.n or BUR-PAICC.n ... maybe?