PROBLEMS WITH CORE BYPASS ATMOSPHERE FREEZING OF THE VVER-1000 AND SIMILAR TYPES OF REACTORS: RELATED HINTS

Preparing an input deck for the RPV of the VVER-1000 type of reactor – specific problems, related solutions, hints and tips

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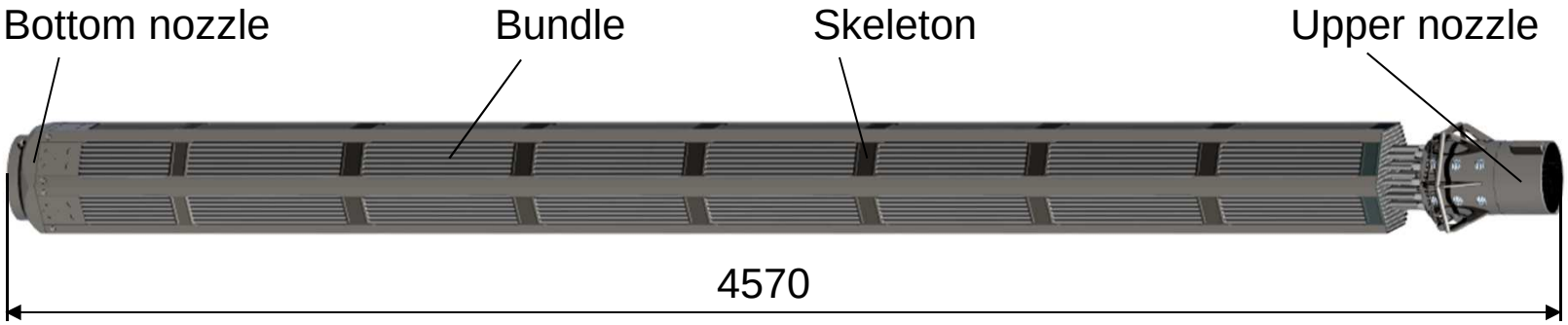
Keynote overview

- TVEL “TVSA-T” fuel assembly
- Core bypass modelling
- Core support plate modelling
- Lower head top elevation modification

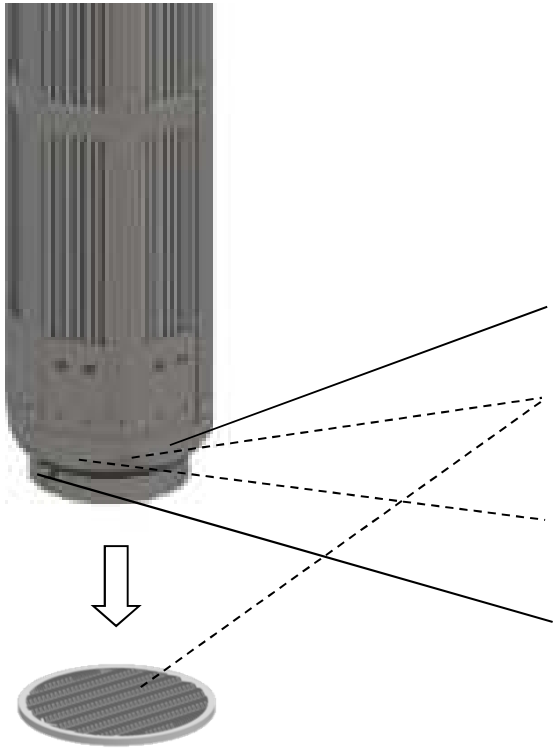
TVSA-T fuel assemblies

- **Temelin NPP: 2x VVER-1000/320, 3000 MWt**
- **Westinghouse “VVANTAGE6” => TVEL “TVSA-T”**
- **hexahedral geometry**
- **163 fuel assemblies (FA) in the core**
- **312 fuel rods in each FA**
- **61 control rod (CR) clusters (18 CRs in each cluster into 18 guide tubes (GT) in a FA)**



Sources of TVSA-T images: **V. Molchanov**, *Nuclear fuel for VVER reactors. Actual state and trends*, 9th International Conference on VVER Fuel Performance, Modeling and Experimental Support, 17-24 September 2011, Helena Resort, Bulgaria

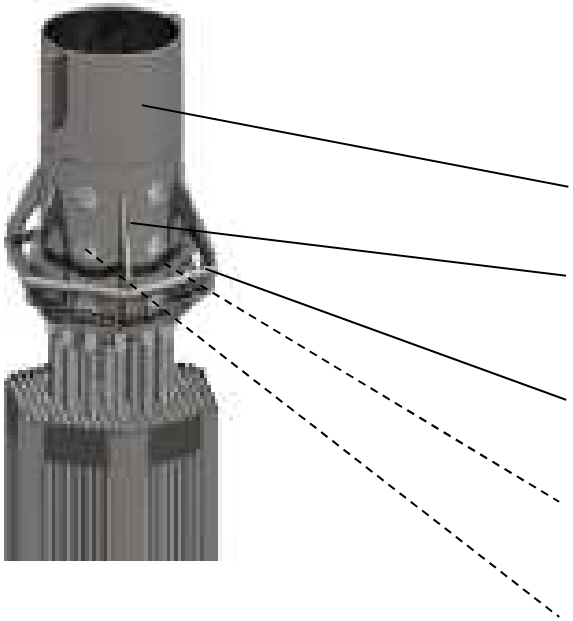
Bottom nozzle - parts, materials & COR components



TVSA-T part	Real material (MELCOR mat.)	COR component
Casing	08Ch18N10T (SS)	SS
Anti-debris filter	08Ch18N10T (SS)	
Ribs	08Ch18N10T (SS)	
Fixing element	08Ch18N10T (SS)	

… MELCOR material colors legend

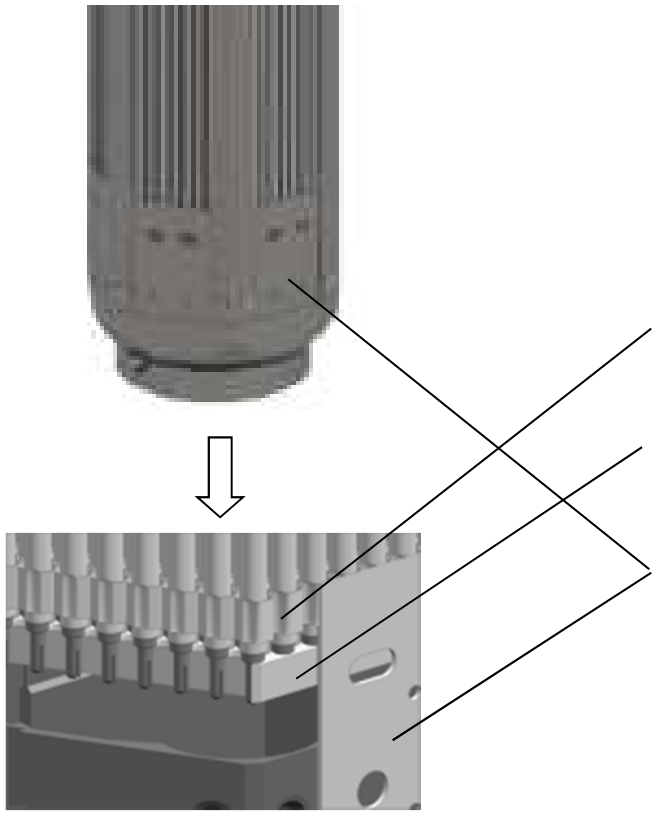
Upper nozzle - parts, materials & COR components



TVSA-T part	Real material (MELCOR mat.)	COR component
Upper shell	08Ch18N10T (SS)	SS
Cylinder	08Ch18N10T (SS)	
Spacing skeleton	08Ch18N10T (SS)	
Connecting pieces	08Ch18N10T (SS)	
19x spring	ChN77TJuR (SS)	

UO SS SX ZR CP … MELCOR material colors legend

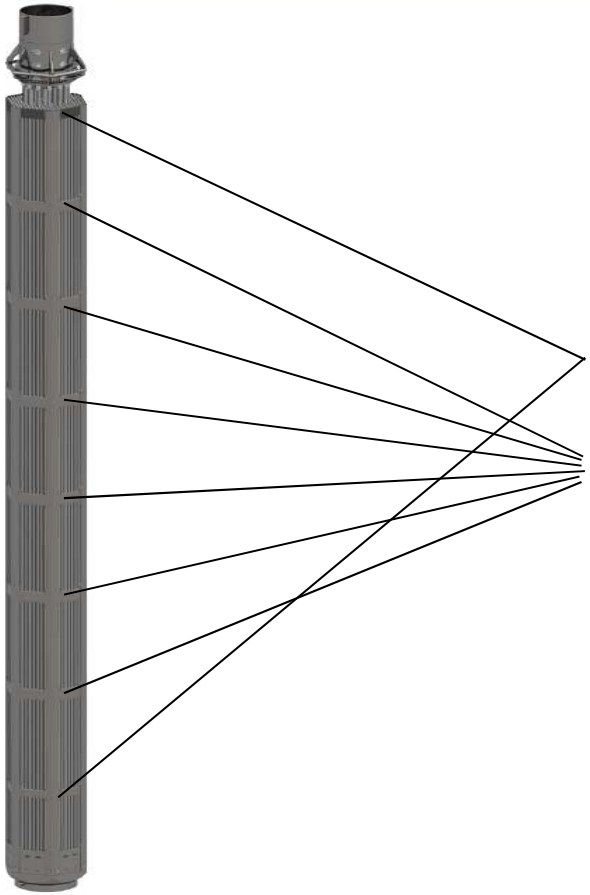
Skeleton (bottom support assembly) - parts, materials & COR components



TVSA-T part	Real material (MELCOR mat.)	COR component
Anti-vibration grid	08Ch18N10T (SS)	SS
Core support plate	08Ch18N10T (SS)	
6x strap	08Ch18N10T (SS)	

UO SS SX ZR CP … MELCOR material colors legend

Skeleton (spacer grids) - parts, materials & COR components



TVSA-T part	Material (MELCOR mat.)	COR component
2x simple grid	E110 (ZR)	CL
6x mixing grid	E110 (ZR)	

… MELCOR material colors legend

Skeleton (spacer grids) – supporting properties

CORijjDX – Particulate Debris Exclusion Parameters in a Single Cell

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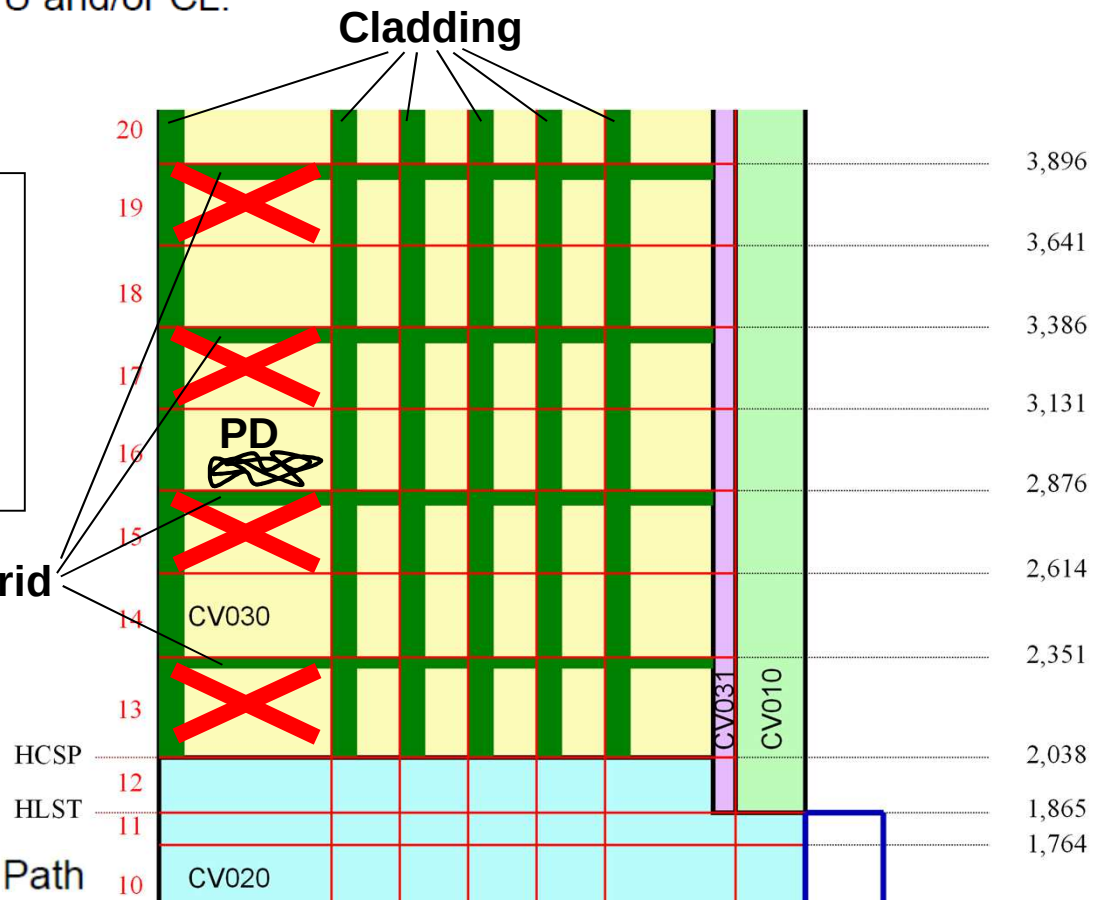
(1) FCHXRD - Fraction of channel volume denied to particulate debris by presence of fuel rods, FU and/or CL.

```
...
COR111DX   0.9   0.0   0.0   0.0   0.05   0.9   0.0
COR112DX   0.9   0.0   0.0   0.0   0.05   0.0   0.0
COR113DX   1.0   0.0   0.0   0.0   0.05   0.0   0.0
COR114DX   0.9   0.0   0.0   0.0   0.05   0.0   0.0
COR115DX   1.0   0.0   0.0   0.0   0.05   0.0   0.0
COR116DX   0.9   0.0   0.0   0.0   0.05   0.0   0.0
COR117DX   1.0   0.0   0.0   0.0   0.05   0.0   0.0
COR118DX   0.9   0.0   0.0   0.0   0.05   0.0   0.0
COR119DX   1.0   0.0   0.0   0.0   0.05   0.0   0.0
...
```



• to ensure proper heat conduction between PD and CL ([COR-RM-45]):

CORHTRxx – Added COR Heat Transfer Path

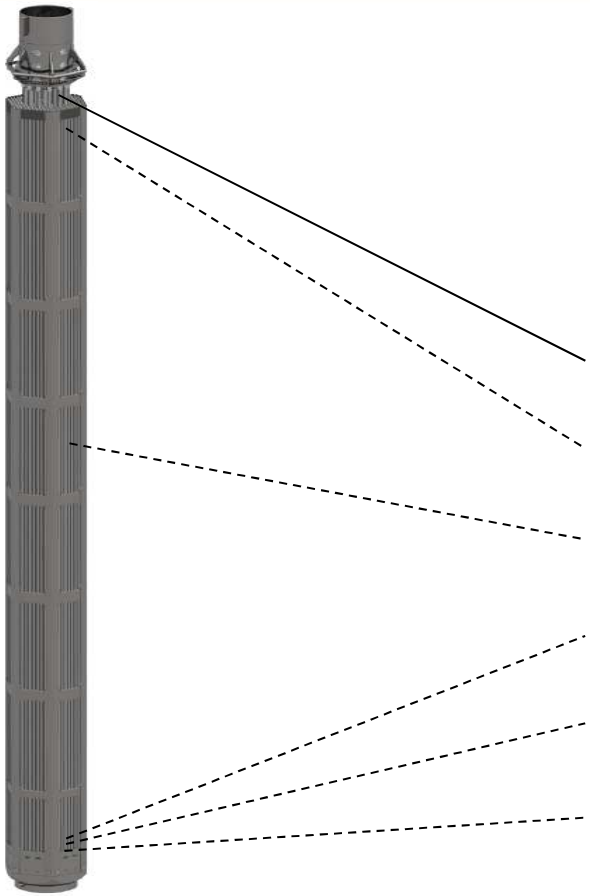
Skeleton (angle pieces) - parts, materials & COR components

TVSA-T part	Material (MELCOR mat.)	COR component
6x angle piece	E635 (ZR)	CL

… MELCOR material colors legend

Skeleton (guide tubes*) - parts, materials & COR components

** Guide tubes = 18x guide tube + 1x central tube*



TVSA-T part	Material (MELCOR mat.)	COR component
19x sleeve	12Ch18N10T (SS)	SS/NS
19x spiral	06Ch18N10T (SS)	
19x tube	E635 (ZR)	
19x screw	E110 (ZR)	
19x bush	E635 (ZR)	
19x rod	08Ch18N10T (SS)	

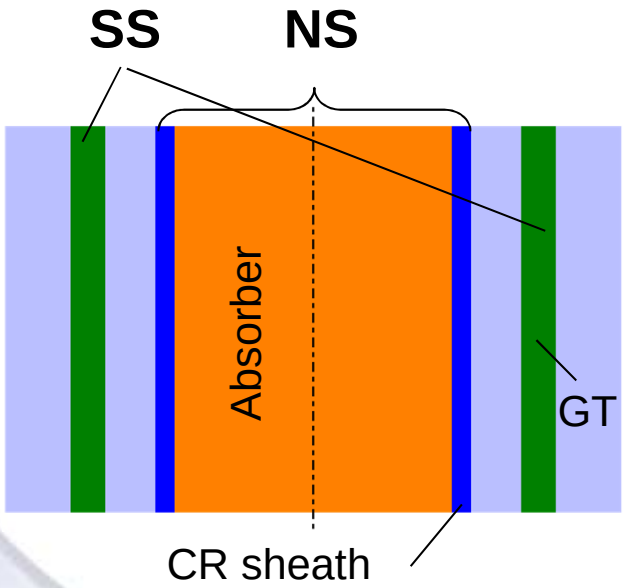
… MELCOR material colors legend

Skeleton (guide tubes) – which COR component, SS or NS???

COR000SS – Global Loading and Failure Rule for SS
Optional

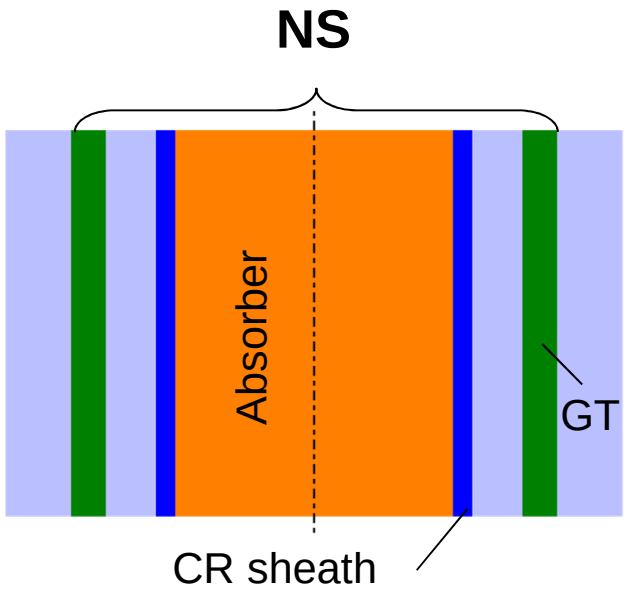
The primary use of the SS component in modeling a commercial reactor is to represent supporting structures such as core plates and control rod guide tubes. This record defines the global rule for loading and failure of SS. The options are described briefly in Section 1.1.44(3) of this report, and in more detail in the COR Package Reference Manual.

#1 – GTs as SS:



- heat convection – 2 vs. 1 component (Dh definition)
- supporting definitions

#2 – GTs together with CRs as NS:



Skeleton (guide tubes) – heat convection: Dh definition

Convection → **forced** $Re = v.Dh/\nu$ $Pr = \nu/\kappa$ => $Nu = f(Re, Pr)$

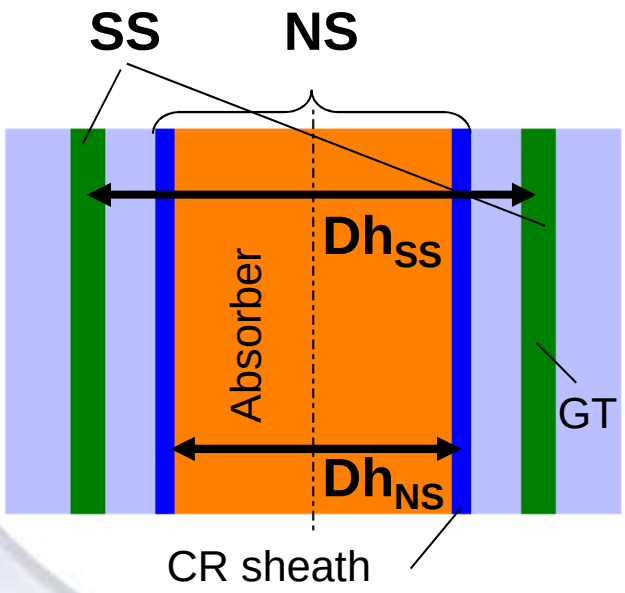
Convection → **free** $Ra = Gr.Pr = \beta.g.\Delta T.Dh^3/\nu.\kappa$ => $Nu = f(Ra)$

Convection → **laminar**

Convection → **turbulent**

$Nu=h.Dh/k$

#1 – GTs as SS:

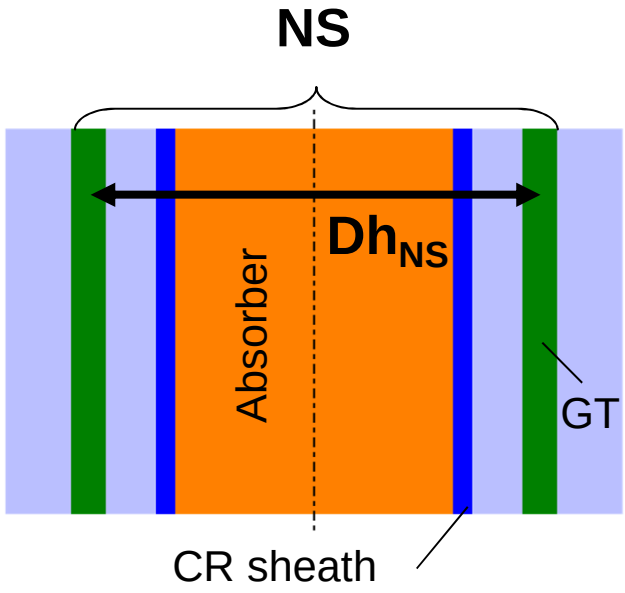


flow cross-section

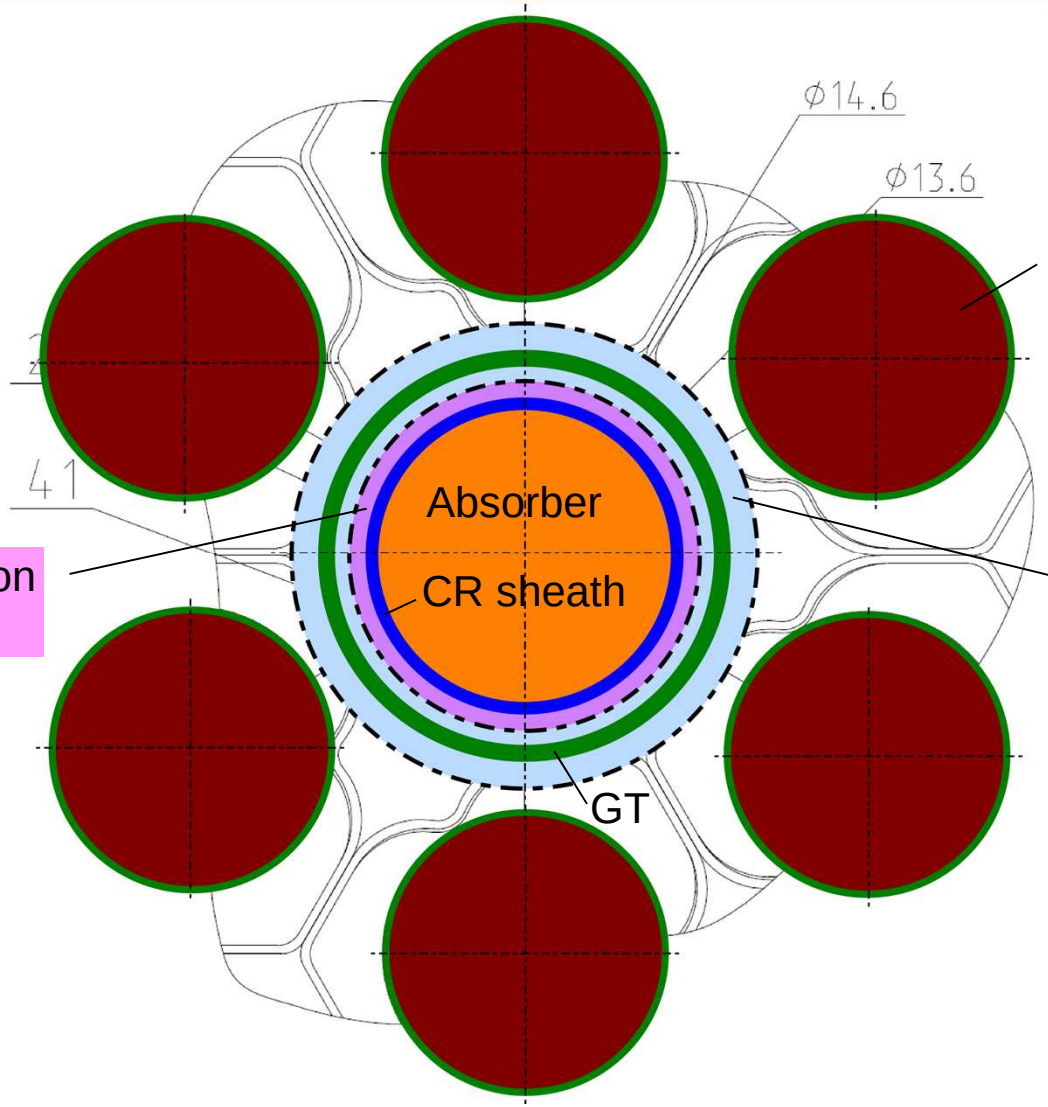
$Dh = 4.A/p$

wetted perimeter

#2 – GTs together with CRs as NS:



Skeleton (guide tubes) – heat convection: Dh calculation

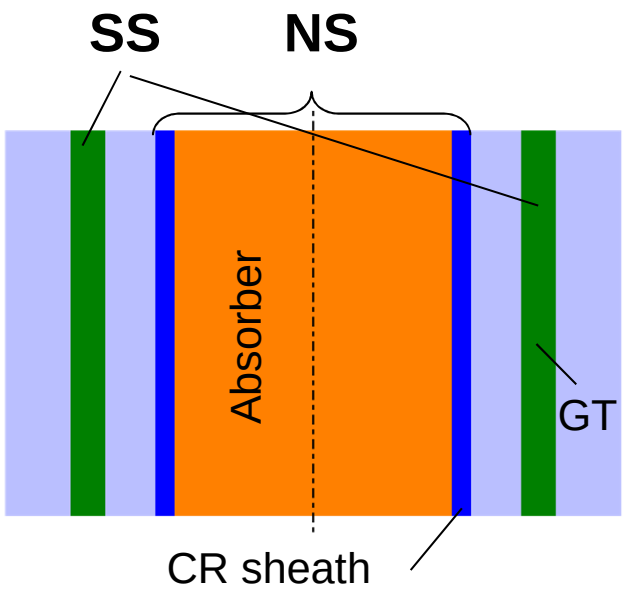


Flow cross-section for CR

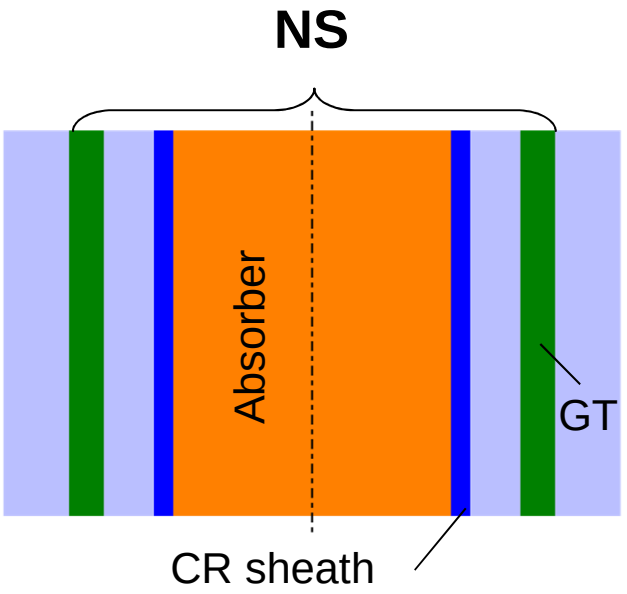
Flow cross-section for GT

Skeleton (guide tubes) – supporting definitions

#1 – GTs as SS:



#2 – GTs together with CRs as NS:




```
CORZjjSS  'SSIN'  'TSFAIL'  1500.0
```

<= CORZjjSS =>

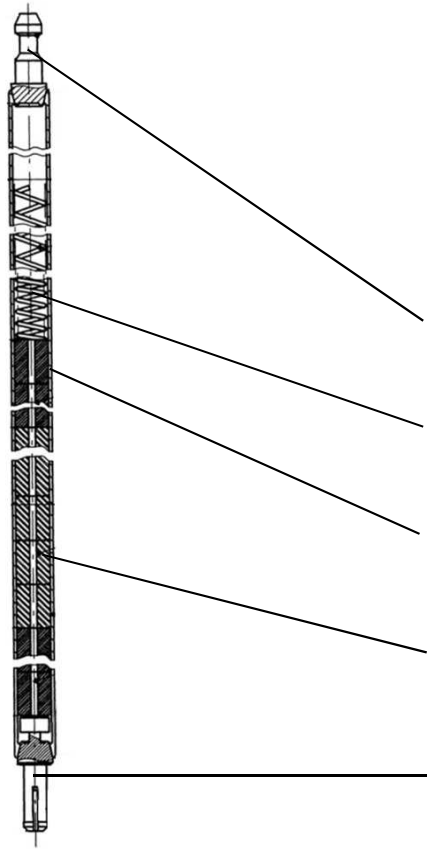
```
*No SS in the core
```

```
CORZjjNS  'FIXED'  STEEL'  1420.0  0.0001
```

<= CORZjjNS =>

```
CORZjjNS  'FIXED'  'ZIRC'  1420.0  0.0001
```

Bundle – parts, materials & COR components



TVSA-T part	Material (MELCOR mat.)	COR component
312x upper plug	E110 (ZR)	CL
312x spring	12Ch18N10T (SS)	FU
312x cladding	E110 (ZR)	CL
312x fuel pellets	UO_2,UO_2+Gd_2O_3 (UO2-INT)	FU
312x bottom plug	E110 (ZR)	CL

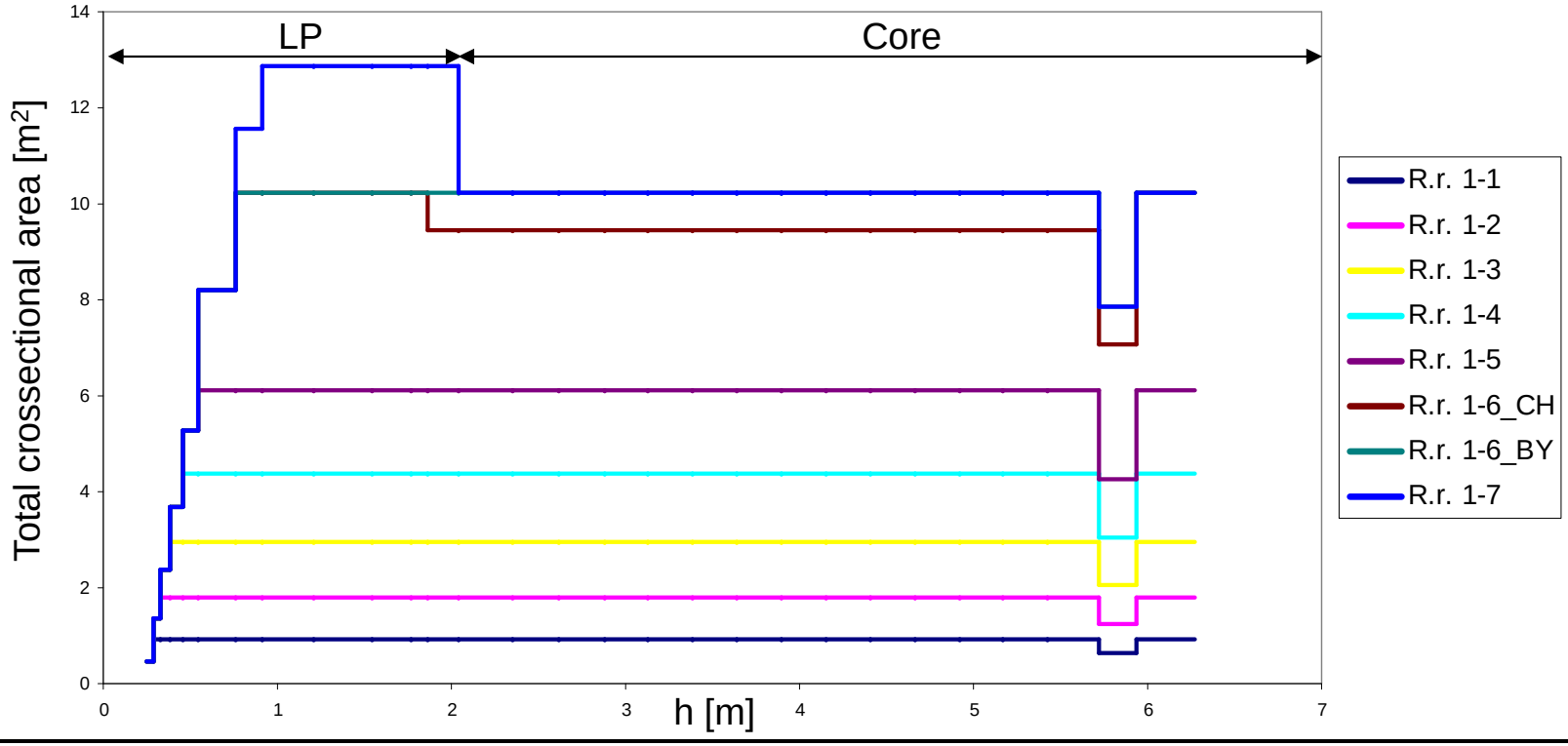
… MELCOR material colors legend

Bundle – MELCOR does not consider voids

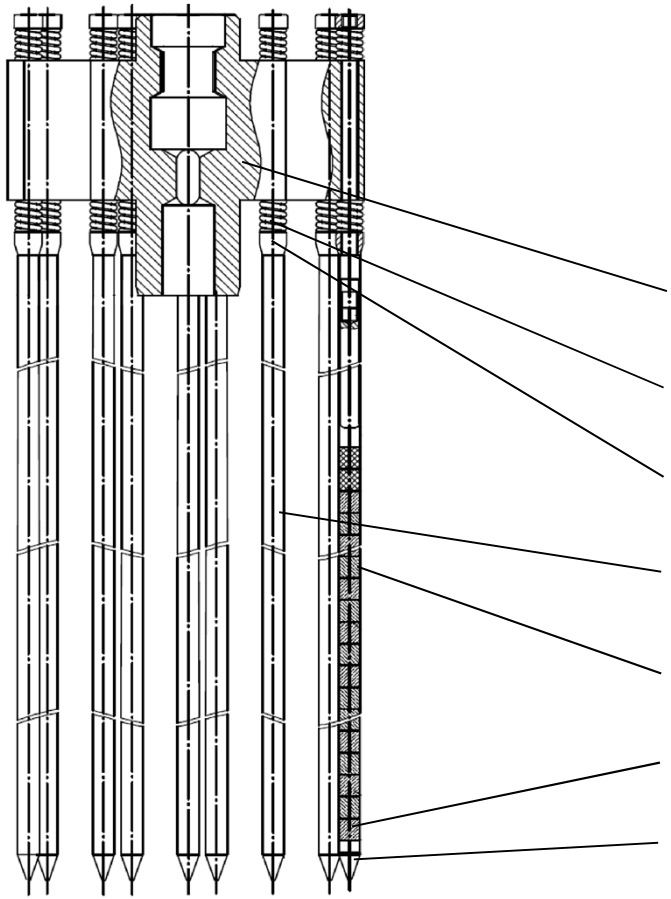
CORijj05 – Cell Boundary and Flow Areas Record

MEGOUT:

```
EDIT OF CELL CROSSSECTIONAL AREAS (M**2)

IA **** IR =        1         2         3         4         5         6         7

28  TOTAL AREA  9.1645E-1 8.6821E-1 1.1576E+0 1.4470E+0 1.7364E+0 4.1097E+0 0.0000E+0

27  TOTAL AREA  9.1645E-1 8.6821E-1 1.1576E+0 1.4470E+0 1.7364E+0 4.1097E+0 0.0000E+0
 :     CHANNEL                                                    3.3312E+0
 :     BYPASS                                                     7.7849E-1
```



CR cluster – parts, materials & COR components

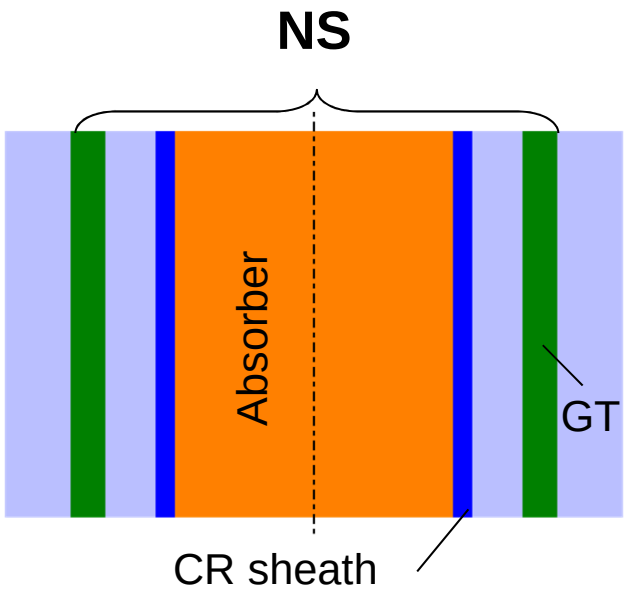


```
CORZ15NS   'FIXED'   'ZIRC'   1420.0   0.0001
CORZ14NS   'FIXED'   'ZIRC'   1500.0   0.0001
CORZ13NS   'FIXED'   'ZIRC'   1500.0   0.0001
```

Cluster part	Material (MELCOR mat.)	COR component
Head	42ChNM (SS)	NS
36x spring	ChN77TJuR (SS)	
18x stud	42ChNM (SS)	
18x sheath	42ChNM (SS)	
18x B_4C	B_4C (B4C-INT)	
18x Dy_2TiO_5	Dy_2TiO_5 (SX)	
18x bottom plug	42ChNM (SS)	

… MELCOR material colors legend

Cluster – surface area distribution



CORijj06 – Surface Area Record

⋮

(6) ASNS - Nonsupporting structure surface area. (type = real, default = –1.1, units = m^2)

How is the surface area for NS distributed among 3 different materials?

⋮

```
*           XMNSSS          XMNSCP          XMNSZR          XMNSSX          XMNSZX
COR315KNS   3.143123886     1.957108276     27.78903008     0.0             0.0
  ⋮
*           ASFU            ASCL            ASOS            ASCN            ASSS            ASNS
COR31506    46.84147822     94.89169041     0.0              0.0            0.0             9.053497826
```

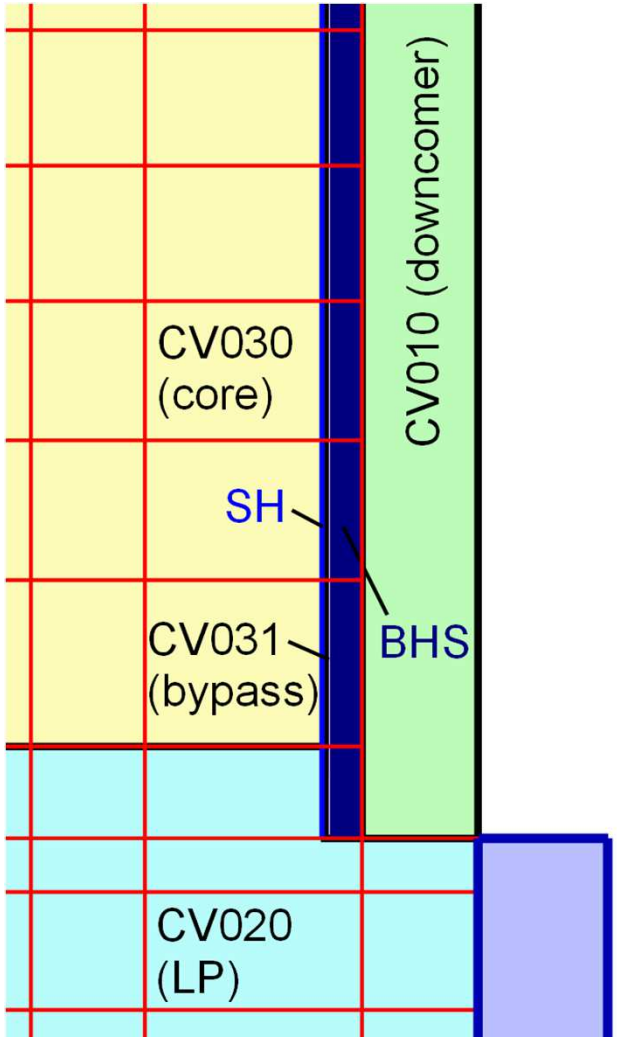
⋮

Core bypass – using the SH component

- 1,8 % of coolant bypasses the core through the region between core shroud and core support barrel during operation
- during a SA, almost stagnant flow can be expected in the bypass region
- total volume of the bypass region is only 0,445 m^3

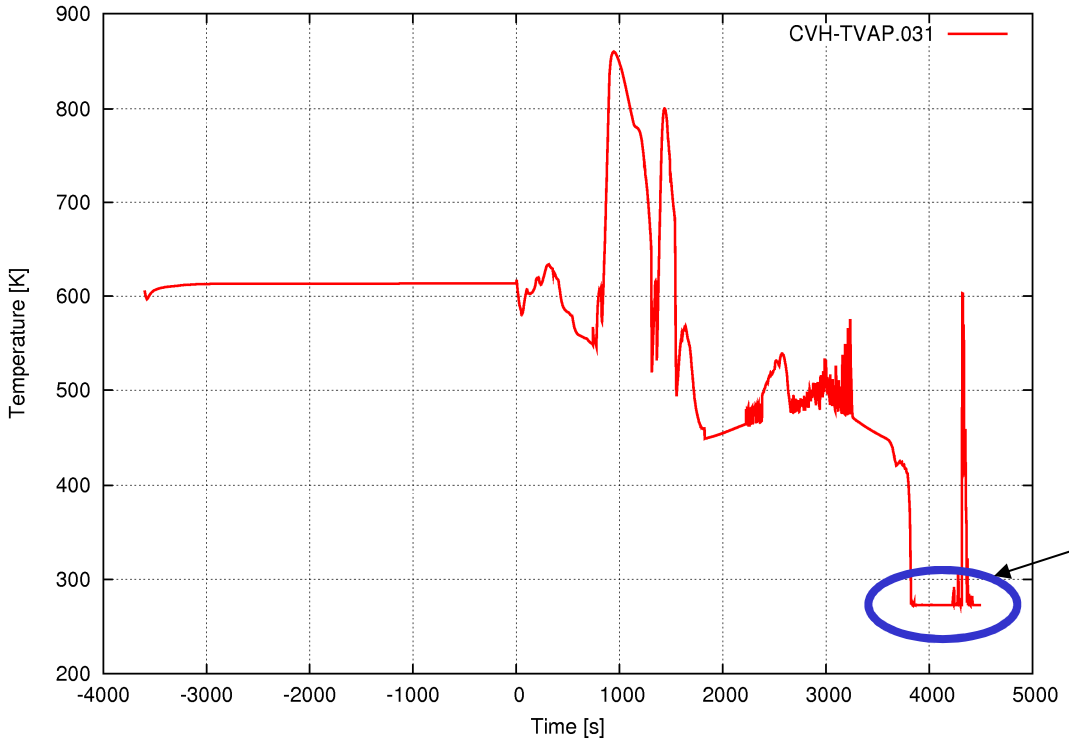
Is it really meaningful to model the core bypass?

=> at least to separate core shroud (SH) and core support barrel (boundary heat structure - BHS)



Core bypass – atmosphere “freezing”

- **Scenario: SGTR**



- **Melzilla: Bug #818**
- **Solution: C1030(4): 10.0 => 1.0 s … characteristic time for coupling between dT/dz-calculated and CVH temperatures**

Core support plate modelling – tricky ‘PLATEG’

The PLATEG model represents a plate that is supported by an underlying array or grid of beams, which may be formed as an integral part of the plate. In general, the beams have sufficient strength that their failure is not an issue, and the interest is in failure of the web between them. PLATEG is not dependent on support from SS in any other core cell. After failure, the plate element will remain in place until it melts.

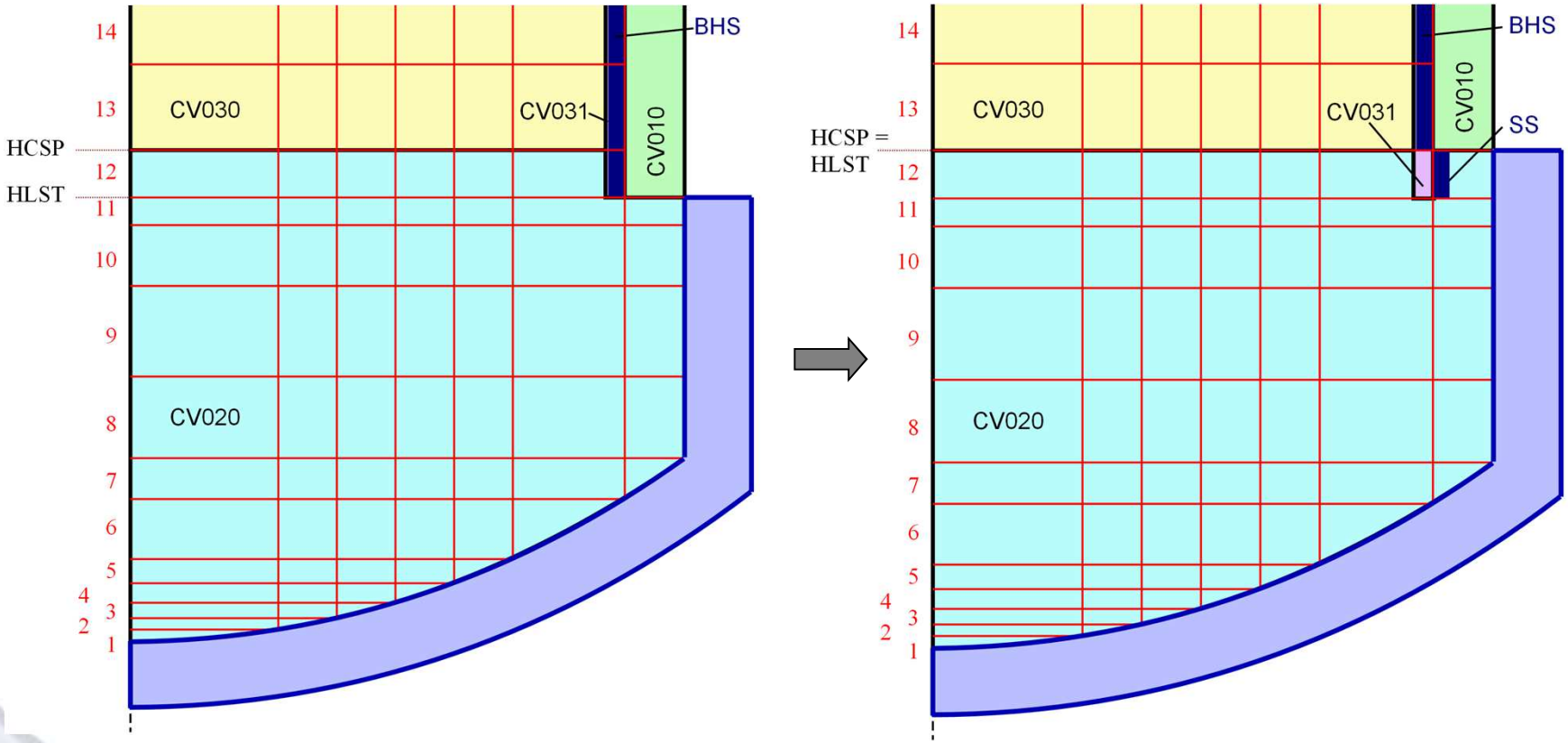
- **Danger: if a molten ZR candles on a supporting structure (SS) modelled as a PLATEG and it freezes (=> conglomerate debris), the whole SS remains at place until reaching the melting temperature of ZR (or even ZRO2, if the ZR oxidizes) – because PLATEG remains self-supporting after failure!**

- **Solution: user defined SS which is NOT self-supporting after its failure**

```
CORi11SS  'SSINDB'  'LOG-CF'  1041113
```

Lower head top elevation increase

- **If the lower plenum fills with molten corium, the uppermost metallic layer can reach above the lower head representation => no failure due to focussing effect**



Thank you for your attention!