RELAP5-3D model for the PANDA facility. Application to the simulation of an ISP-42 experiment

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Summary

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- The ISP-42 PANDA experiments
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- Preliminary results
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Introduction

- The UPC TH studies group participated in the ISP-42, based on 6 PANDA tests.
- PANDA is a large-scale test facility (RPV, containment and Passive Safety Systems of an ALWR).
- UPC simulated ISP-42 tests using RELAP5/Mod3.2 and 1D model.
- After the benchmark results, a system code like RELAP5 was considered necessary, but some transients needed a more accurate 3D description.
- UPC has developed a RELAP5-3D model for PANDA and has simulated one PANDA test
- Results are described in the presentation

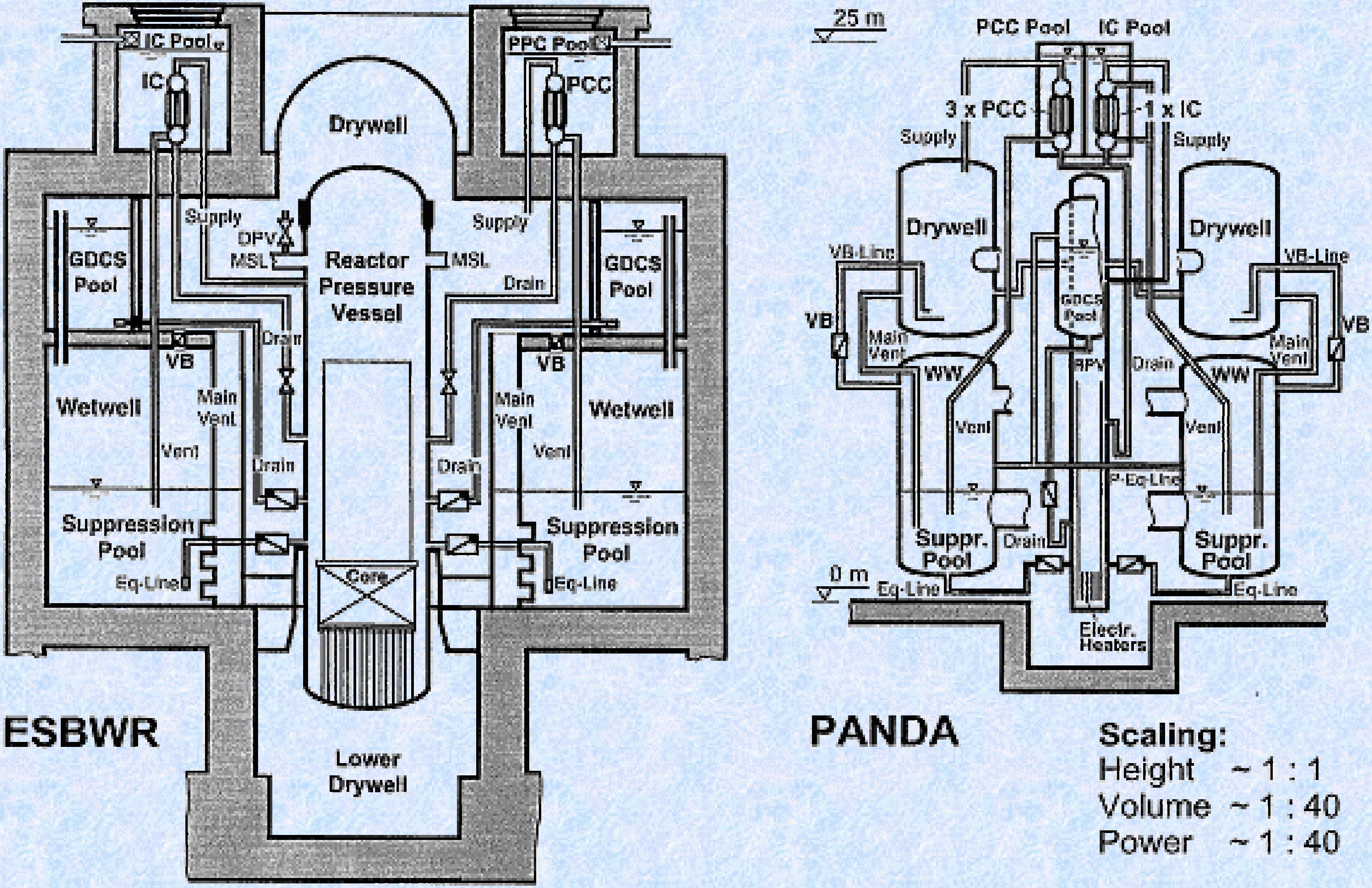
The ISP-42 exercise

- Approved by the OCDE/NEA CSNI on December 1997
- Preparatory meeting to discuss the scenario with some representatives from the OCDE member countries on March 1998
- The series of experiments were carried out in PANDA on April 1998.
- The main interest is code validation in relation to TH issues relevant to ALWR safety

The PANDA facility

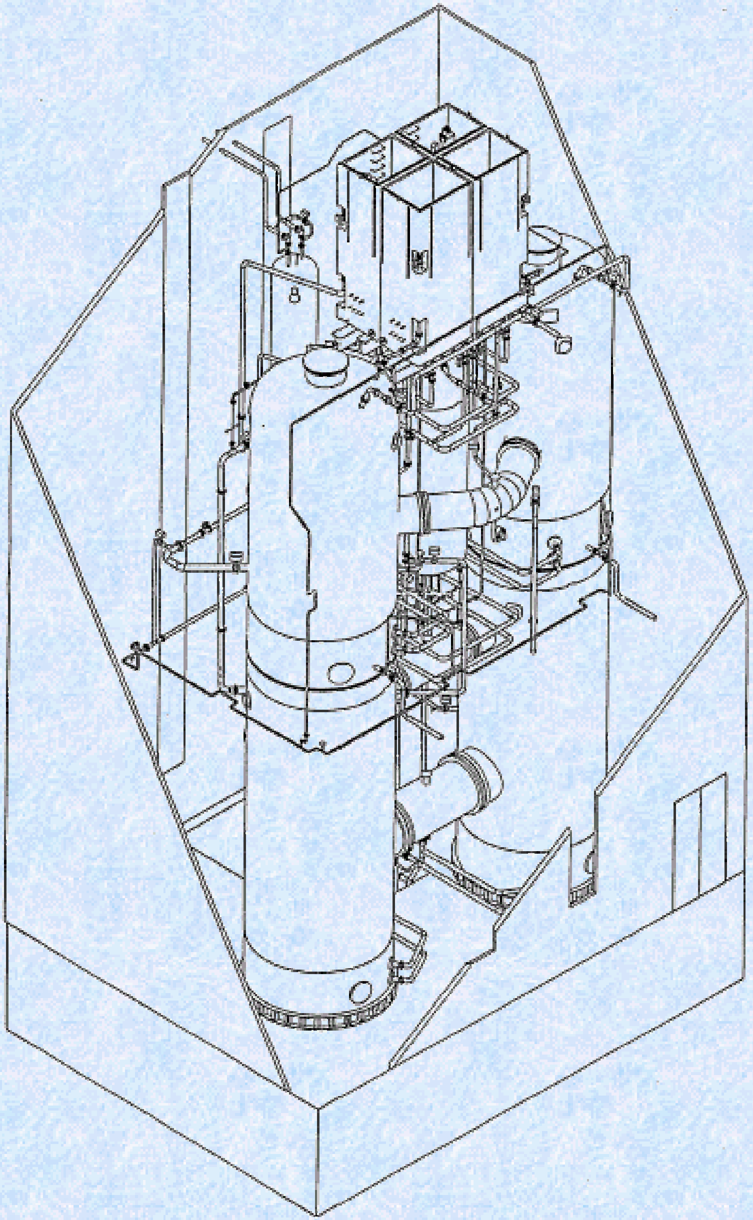
- Large-scale representation of an ESBWR
- 6 large vessels (4 of them $\phi = 4$ m)
- PCCS (condensers have prototypical dimensions)
- Tall vessel simulating RPV is connected with DW vessels to simulate LB LOCAs
- Core simulated by electrical heaters (1.5 MW)
- DW and WW connected via MVL and VB lines
- GDCS pool and drain line also simulated

RELAP5-3D model for the PANDA facility. Application to the simulation of an ISP-42 experiment



Scaling:
Height ~ 1 : 1
Volume ~ 1 : 40
Power ~ 1 : 40

RELAP5-3D model for the PANDA facility. Application to the simulation of an ISP-42 experiment



The PANDA facility

- Walls insulated with rock-wool
- The facility is profusely instrumented:
  - Pressures
  - Temperature profiles in pools, gas spaces and PCC tubes
  - Some air probes in DW and WW
  - Mass flow rates
  - Levels

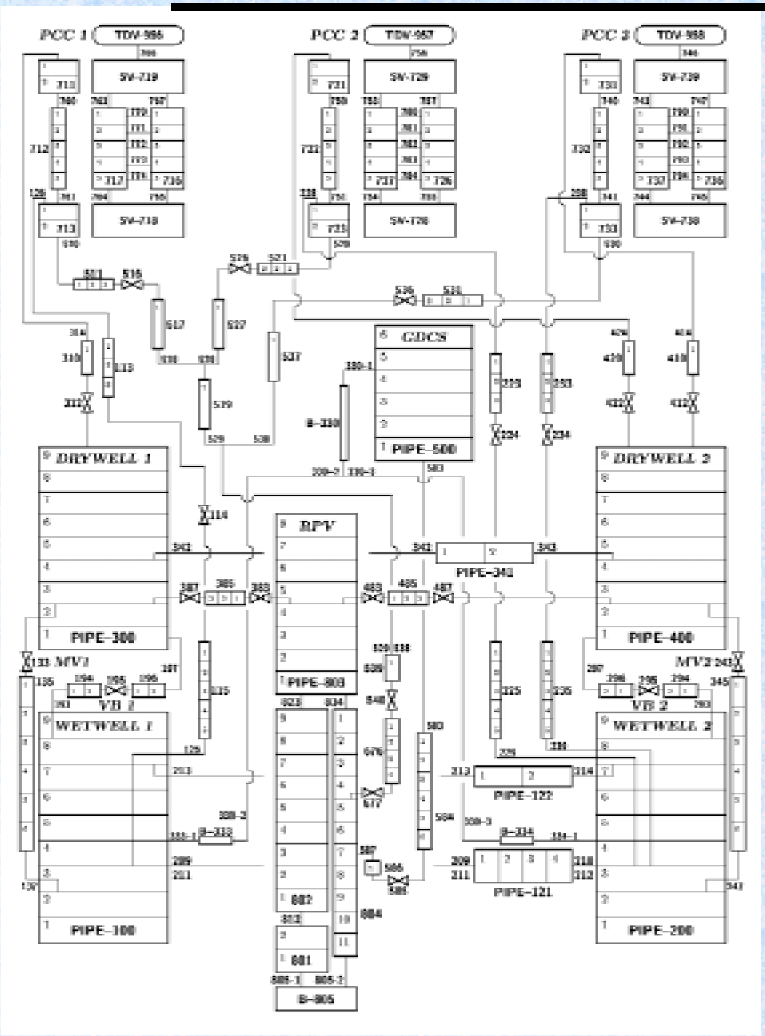
The ISP-42 PANDA experiments

- 6 phases: sequence of a LB LOCA in a ALWR with passive safety systems
- Each phase is a separate experiment, with its own initial and boundary conditions.
- Main issues and phenomena covered:
  - operation of a PCCS
  - coupling of the primary system with the containment,
  - RPV operation at low power and low pressure under natural circulation conditions,
  - GDCS injection
  - venting of a steam/air mixture into the SP
  - steam condensation in tubes in presence of NC gas
  - mixing and stratification of light and heavy NC with steam in large volumes (complex 3D effects)
  - mixing and stratification in large water pools.

The ISP-42 PANDA experiments

- Phase A, PCCS start-up
- Phase B, GDCS discharge
- Phase C, long term passive decay heat removal
- Phase D, overload of the PCCS at pure steam conditions
- Phase E, release of hidden air
- Phase F, severe accident (He injection simulating H_2 release)

The UPC results using RELAP5/Mod3.2



UPC RELAP5/Mod3.2

- 230 volumes
- 258 junctions and valves
- 114 heat slabs
- (635 mesh points)

The UPC results using RELAP5/Mod3.2

Code modified to improve capabilities of handling NC species.

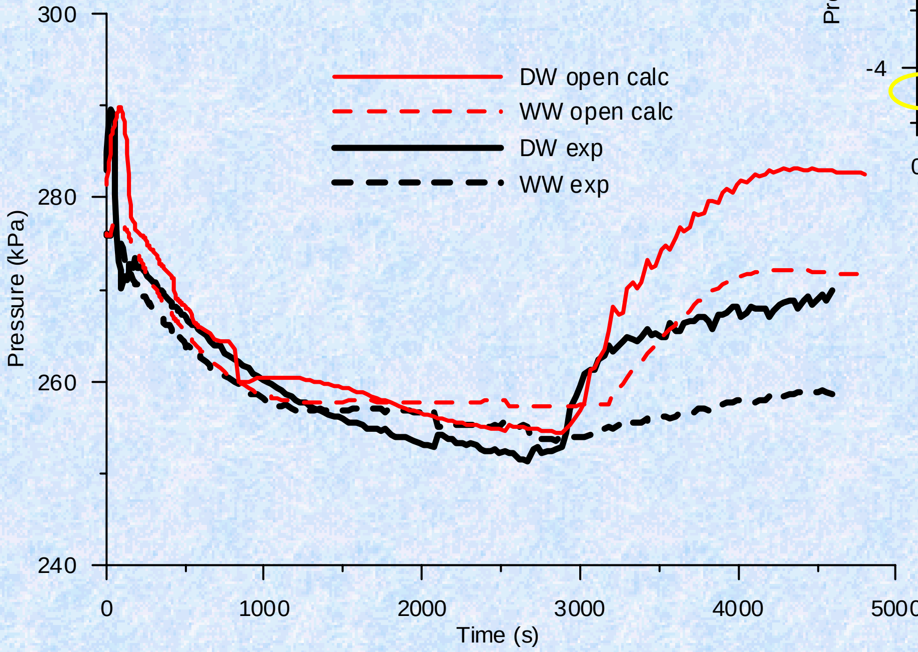
- Especial selection of the wall condensation model:
  - Colburn-Hougen iteration method (default) caused huge distortions when the iteration did not converge, producing unphysical results. It has been de-activated.
  - UCB (Vierow and Shrock) model has been reactivated (/Mod3.1). It is a simpler model that uses a degradation factor depending on mass fraction of NC. Quite robust and does not produce non-physical results.
- For open Phase F calculation, code was modified to allow for two independent gas fields: air and helium.

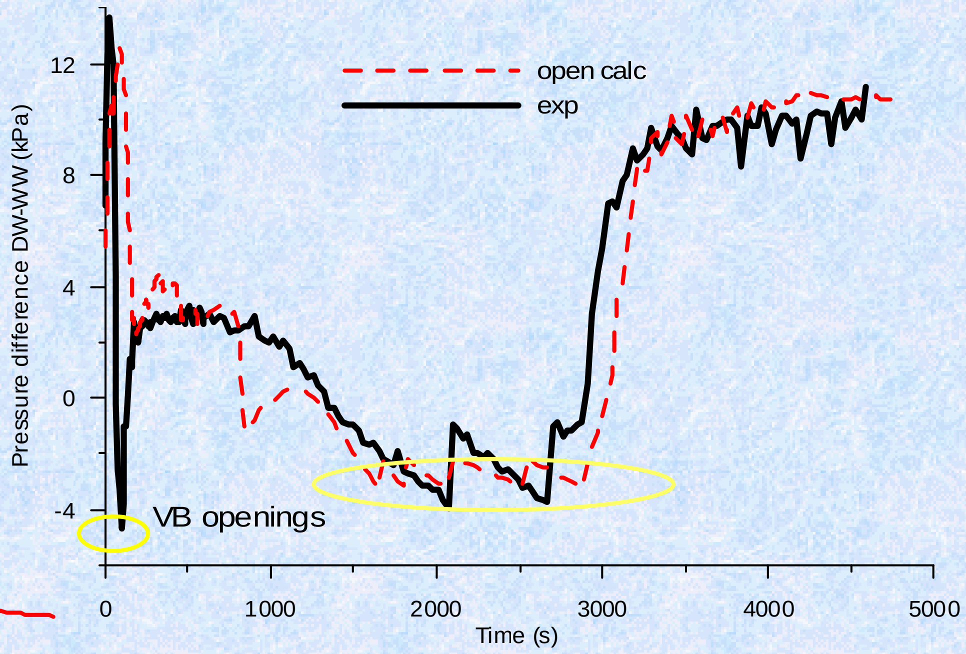
The UPC results using RELAP5/Mod3.2

- RELAP5/Mod3.2 has shown to be a suitable tool, yielding good results from a global point of view with a minimum boundary conditions
- System performance seems to be robust to PCC modeling. Long term heat extraction behavior is well captured by code and model.
- Complex Phase B (involving strong interaction between RPV and containment) has been correctly simulated.
- Transport of NC in the containment is one of the unsolved issues (phases A, E and F) due to 1D modeling
- Also stratification in pools need to be solved (Phase D)

- Phase B results

Pressures DW WW

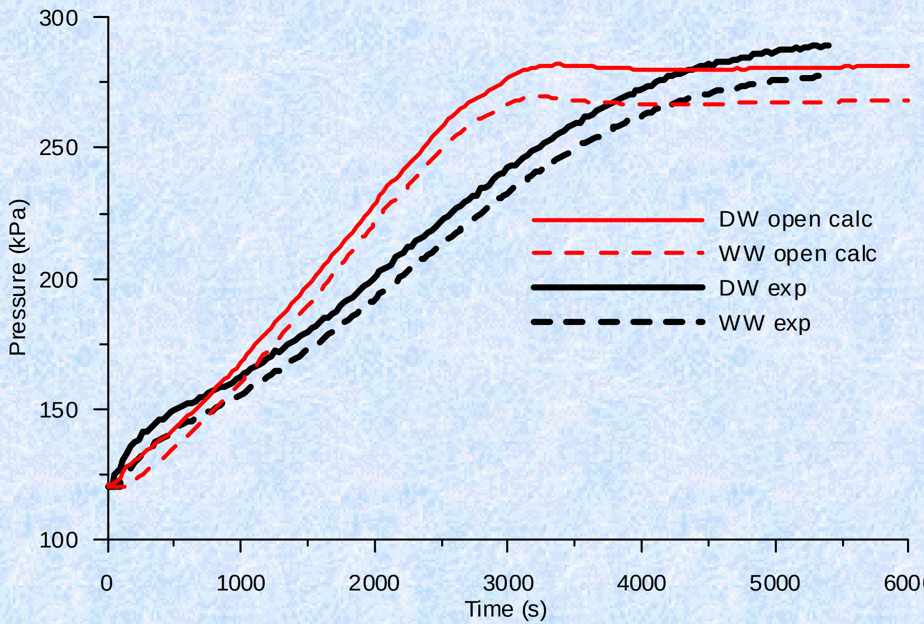


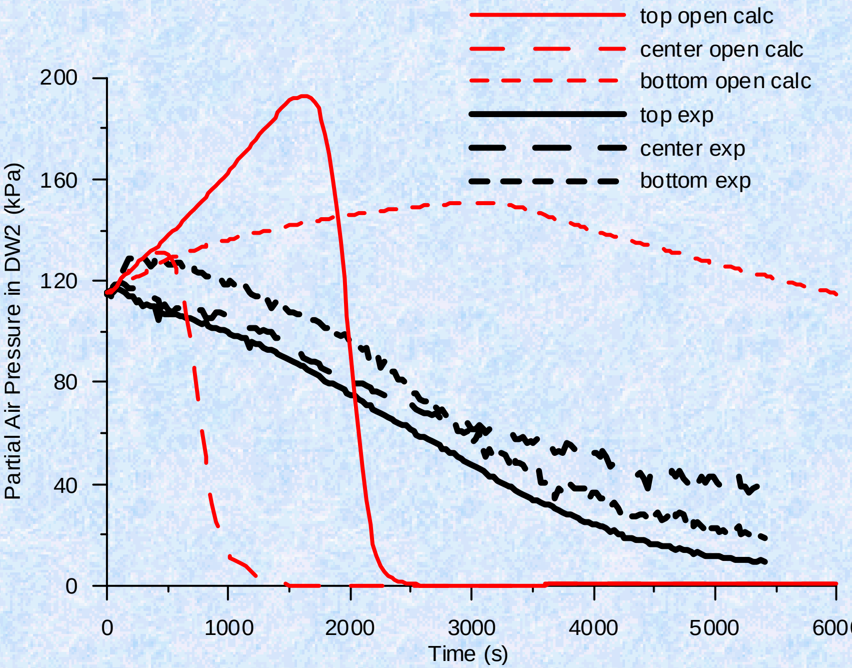


Pressure difference DW-WW

- Phase A results

Pressures DW WW

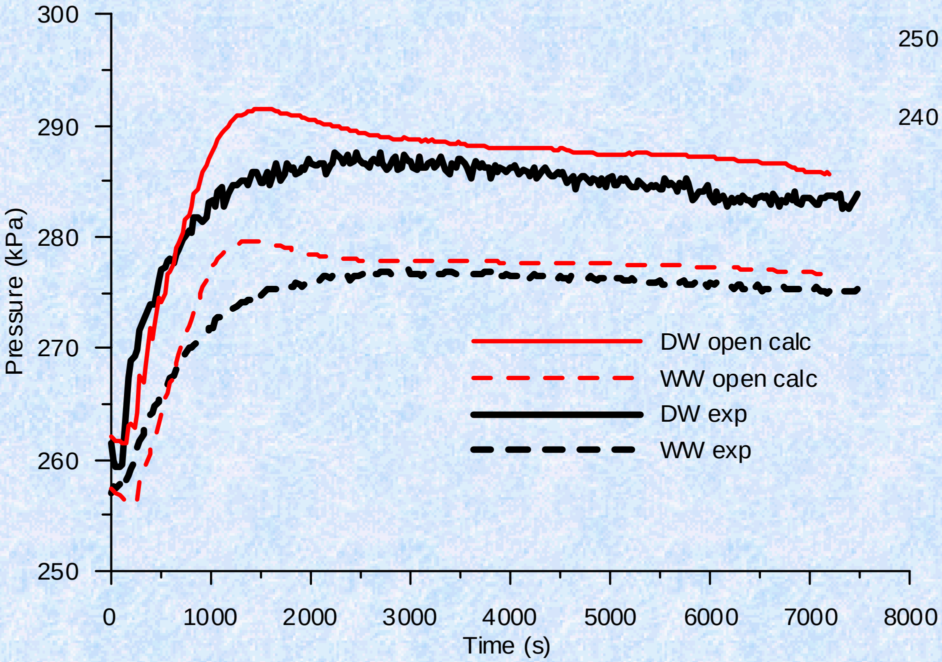


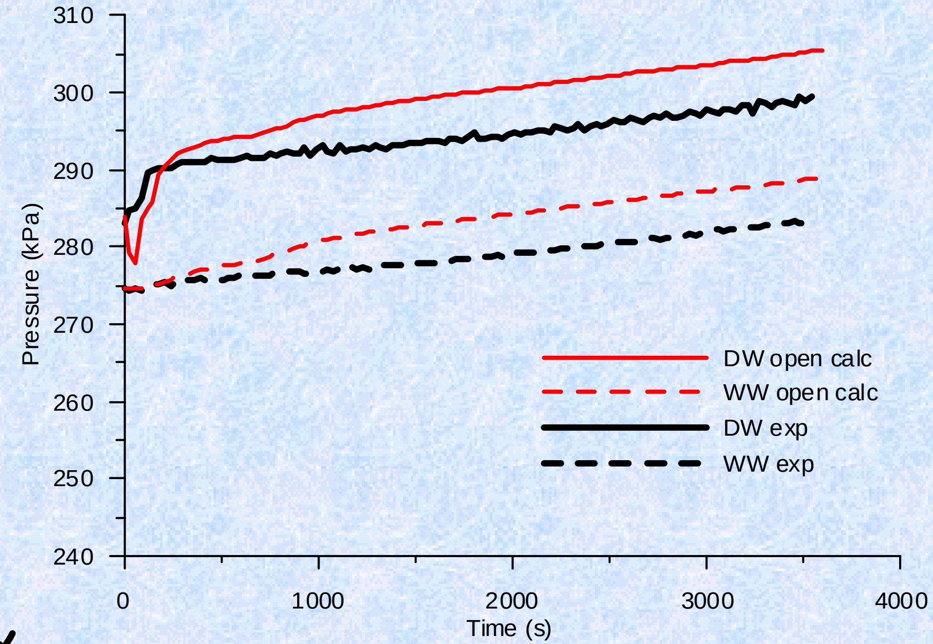


Partial Air Pressure in DW 2

- Phase C

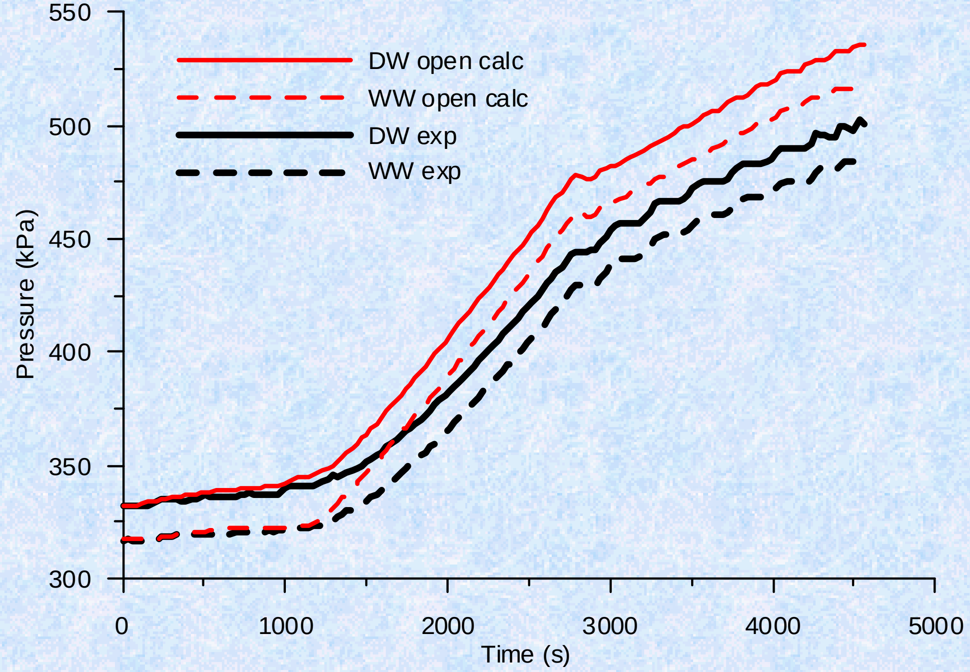
Pressures DW WW





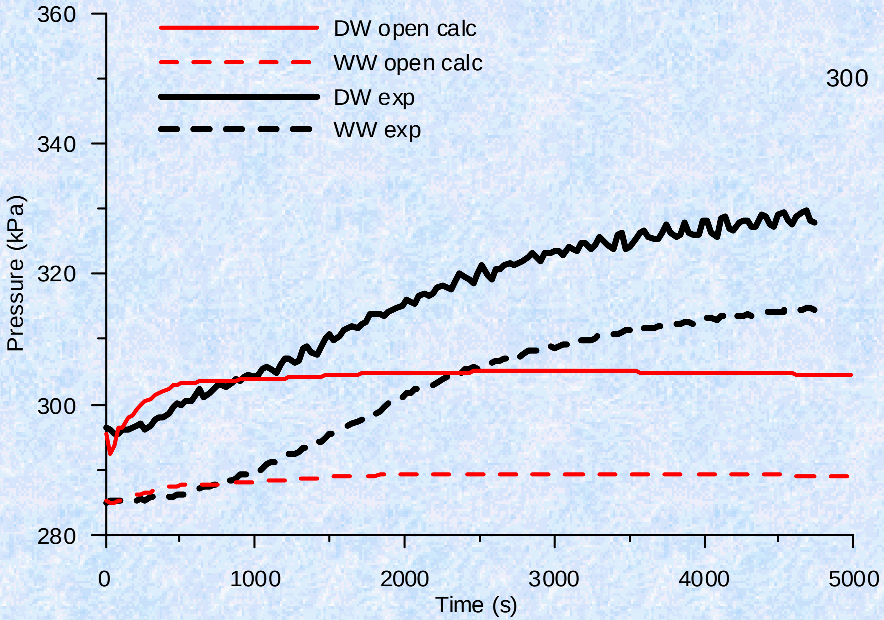
Pressures DW WW

- Phase D



- Phase E

Pressures DW WW



Pressures DW WW

- Phase F

The RELAP5-3D model for PANDA

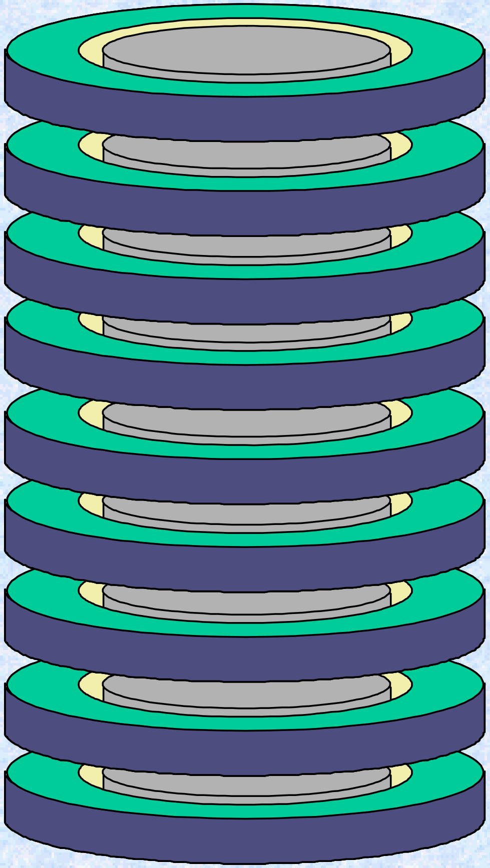
- A system code like RELAP5/Mod3.2 is necessary to simulate ISP-42-like scenarios:
  - It allows the simulation of complex scenarios by imposing only a few boundary conditions.
  - Good results from the global point of view (in most cases it captures the global trend)
  - It is a suitable tool to perform sensitivity analyses as well as to perform LOCA analyses when the interest is in the primary system and not in the containment.
- Nevertheless, the code and the 1D model have important limitations

The RELAP5-3D model for PANDA

- The TH Studies Group of the UPC is developing a 3D model for PANDA, using the RELAP5-3D code.
- The aims of this work are:
  - to go further in the knowledge of the behavior of the models of the passive safety features
  - to contribute to RELAP5-3D validation
- The basis of the 3D model is the 1D UPC model with changes focused in the large containment vessels of PANDA. Multi-D components are used in order to capture with more accuracy the behavior of the mixed flow: liquid, steam and non-condensable gases.

The RELAP5-3D model for PANDA

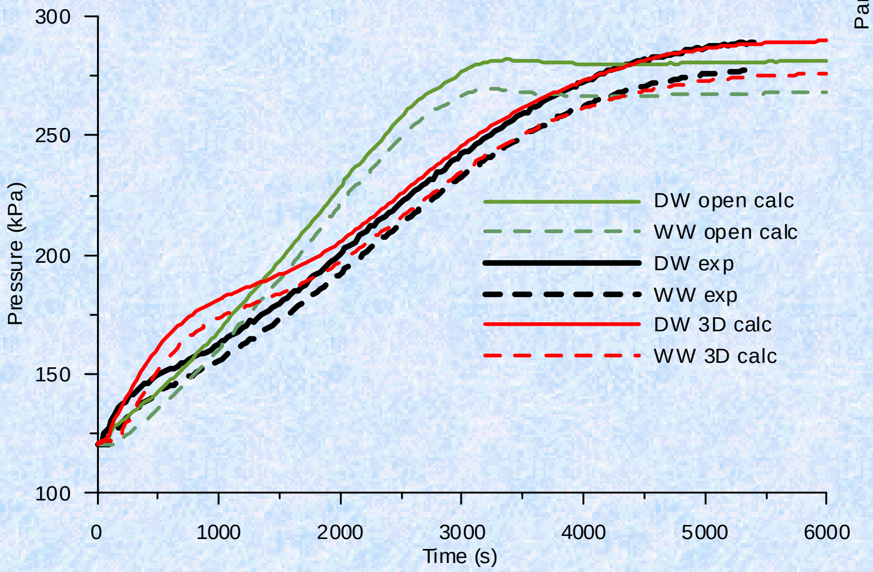
- Several configurations have been tested
- For pragmatic reasons, a 2D nodalization (in DW and WW vessels) has been chosen for the preliminary model: it allows recirculation in the large volumes and is simple enough to permit fast calculations and easy visualization of the results.

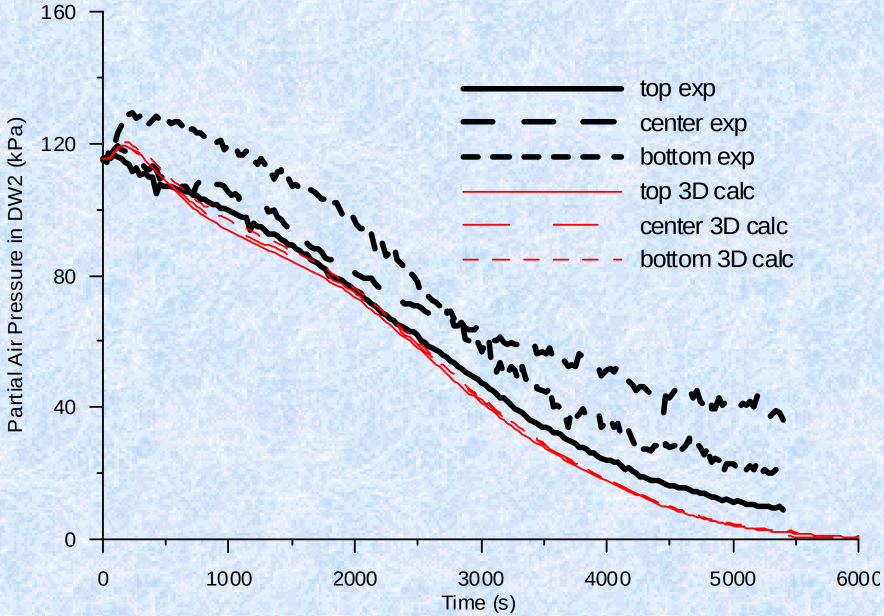


Preliminary results

- Phase A results

Pressures DW WW





Partial Air Pressure in DW 2

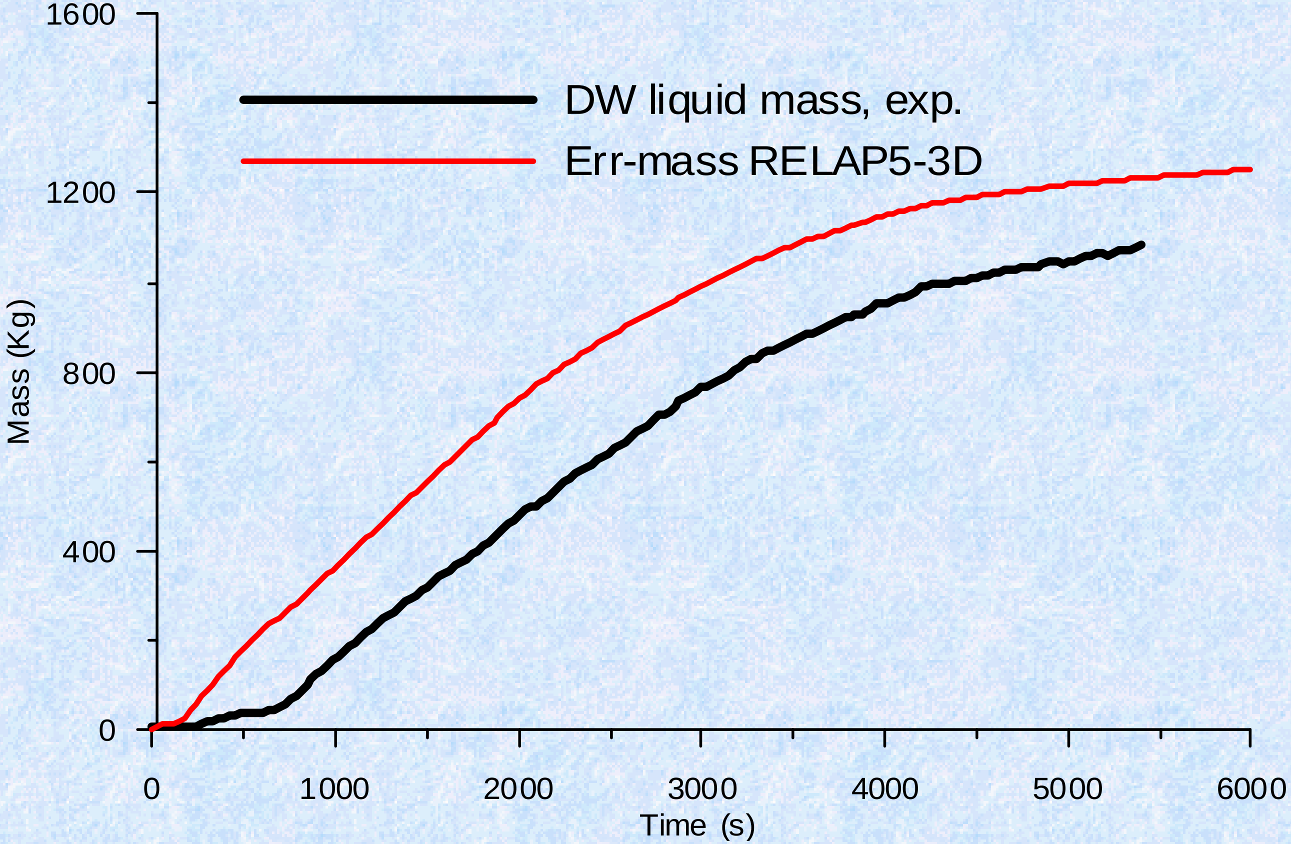
Preliminary results

An important anomaly has been encountered:

- The code shows difficulties to handle the scenario, the most relevant being the wrong performance of the Wall Heat Transfer package.
- A convective boundary condition has been used (only external temperature has been fixed):
  - No condensation takes place in the walls of the DWs but heat transfer rate is calculated more or less accurately.
  - This behavior is related with the mass error given by the code: there is a heat flow from the steam to the wall but, instead of condensing, some steam disappears.
  - Imposing a heat flux condition in the walls (not known a priori) condensate water appears. (RELAP5/Mod3.2 has shown a similar behavior).

Preliminary results

- No condensation observed in DW walls in the simulation
- Energy balance confirm that the condensed steam is “lost”



Conclusions (1)

- The participation in the ISP-42 (OCDE/NEA) has been positive for the TH Studies Group of the UPC:
  - Access to experimental data regarding the behavior of the containment and the passive safety systems of an ALWR
  - Share of knowledge, experiences and points of view with other analysts teams.
  - RELAP5 has been tested in scenarios which, in principle, it was not designed for but that are considered relevant to the safety of future reactor designs.

Conclusions (2)

- UPC used RELAP5/Mod3.2 with a 1D model. Both code and model showed to be a suitable tool for system modelling, although results were not fully satisfactory when complex phenomena involving mixing/stratification of temperatures or NC mass fractions took place in the containment.

- To improve its modelling capabilities, the TH Studies Group of the UPC is developing a 3D model (based on the UPC 1D model) for some suitable components of PANDA, using the RELAP5-3D code. This work is also intended to be useful in the validation of RELAP5-3D.

Conclusions (3)

- In the simulation of Phase A, the use of multidimensional components has allowed to capture with more accuracy the behavior of the system. In order to confirm this tendency, it is considered necessary to extend the study other ISP-42 phases.
- The RELAP5 code has shown a wrong performance of the Wall Heat Transfer package. When using a convective boundary condition no condensate appears in the DW walls although heat transfer rate is quite well calculated. This behavior is related with the mass error (steam does not condense but disappears).