Comparison of CONTAIN - Results with Experimental PHDR Data

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1. INTRODUCTION

The German BMFT sponsors the verification and further development of the CONTAIN-Code in the GRS to enable appropriate analysis of severe accident consequences in an LMFBR containment. GRS received CONTAIN /1/ from the code developer SNL (Sandia National Laboratories) with agreement of the USNRC for this specific use. In CONTAIN the main groups of containment phenomena including their interaction are respected as thermodynamics and chemistry of the atmospheres, coolant and core melt on the floor of a room, aerosol behaviour and the behaviour and decay of radioactive materials. In /2, 3/ first verification results have been published by GRS.

In /3/ natural convection flow already has been respected, but the validation was restricted to a parallel calculation with another code. No experimental proof was available, as no LMFBR-type severe accident oriented containment experiments have been realized.

As CONTAIN has been designed to evaluate both LWR- and LMFBR-accident sequences in the containment by having the choice for the coolant, LWR-oriented experiments can help in the verification of phenomena which are important for both reactor types.

The physical equations for natural circulation flow as well as for condensation are very similar for Na-vapour and steam.

So a steam-oriented verification of the mentioned physics can cover the same phenomena for an LMFBR.

At the HDR-facility a remarkable number of LWR-containment experiments have been performed /4/.

The experiment T31.6 /5/ shows an LMFBR-near behaviour with small long term leakage and subsequent natural circulation phase, but including condensation. So this experiment had been chosen for the mentioned CONTAIN-verification.

2. THE HDR-CONTAINMENT AND THE EXPERIMENT T31.6

The HDR-contaiment consists of a steel shell with a height of 60 m and a diameter of 20 m. The steel shell encloses a concrete structure consisting of 71 volumes below the semi-sphere shaped dome (fig. 1). The volumes are connected by about 230 openings.

Remarkable groups of rooms are assembled around the two staircases. Together with the dome they have dominant influence on the flow behaviour within the containment, especially after the blowdown phase.

The blowdown from a small leak takes place in compartment 1805 in the second floor below the dome.

The mass flow as well as the energy addition is given in figure 2. After 5 hours a valve is being closed to stop the leakage. Then buoyancy forces, heat transfer and condensation mainly determine the flow, the steam concentration and the temperature behaviour in the containment.

The starting conditions were not uniform due to an earlier experiment with energy release to the containment. A not too detailed temperature distribution was given.

The temperature behaviour in different compartments and at selected structures have been registered as well as the gas flow behaviour between different containment regions.

3. MODELING THE HDR-CONTAINMENT

The physical model consists of 39 volumes which represent the whole HDR-containment. Neighbouring compartments connected with large openings are assembled to one cell in the model. Special attention was payed to regions where - due to buoyancy flow - more or less strong temperature gradients or transients had to be expected.

For example, the compartment 1805 - where the leakage was injected - had to be modeled very carefully as one had to expect that due to natural circulation flow a part of this room does not adequately participate at the leak induced temperature rise.

The two staircase regions needed special attention because they represent the major vertical flow paths. In the dome complicated flows had to be expected. In a first step five different subcells have been created to represent this region.

The chosen 39 cells of the model are connected by about 100 openings. A lot of them represent several openings with different behaviour. The VAR-AREA-option in CONTAIN enabled the correct integral behaviour of these "representative" openings.

The various materials, shapes and measures of the structures of the HDR-containment were similarly condensed to groups per cell. About 150 different structures have been respected within the model.

4. RESULTS

In the following only those results will be discussed, which can be compared with experimental data:
Figure 3 shows the comparison of the calculated and measured containment pressure. The calculated results are only a bit lower, the tendency has been met satisfactorily.

In figure 4 the temperatures in the room above the break room are presented and in figure 5 the calculated and measured temperatures of the steel shell inner surface in the dome can be compared. The agreement ist quite good.

Figure 6 shows the measured and calculated temperature distribution via the big staircase after 150 minutes and figure 7 that via the spiral straicase on the opposite side after 200 minutes.

We got very good agreement for the experimental and calculated flow velocity at the entrance from the big staircase to the dome, this can be obtained from figure 8, wheras figure 9 presents the poorest agreement of flow velocity for the flow from the dome to the spiral staircase.

We think that the lack of sufficient vertical discretication as well as a poor knowledge about starting temperatures for this region will have caused this. Here already very small temperature differences of 1 to 4 K will result in remarkable changes of mass flow as it is rather far away from the location of the disturbance.

5. CONCLUSION

The comparison of CONTAIN-results from a 39-cell-model calculation simulating the HDR-experiment T31.6 with experimental results shows, that

- The CONTAIN-code is capable to perform containment calculations with strong influence of natural circulation and condensation.
- The measured flow velocities and room atmosphere temperature behaviour mostly could be reproduced by the calculation with acceptable accuracy.
- A few stronger discrepancies can be explained and could mostly be avoided by improvement of the model (greater number of cells, dropout of condensed water in the atmosphere) and by more detailed information on starting conditions.
- CONTAIN is able to predict and to calculate flow behaviour between the connected cells of a containment up to natural circulation including condensation processes with about the same precision as the most material properties and physical correlations are known.
- As the CONTAIN calculations using the physical correlations for flow phenomena including natural circulation as well as for condensation and for heat transfer have a general form, the verification - performed for water and steam - is valid too, if sodium properties are uses.
- This verification assures the applicability of CONTAIN for severe accident analyses in LMFBR-containments, where sodium vaporization and condensation and flow by natural circulation can dominate the important processes.

REFERENCES

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/3/ Langhans, J.: Verification of CONTAIN by comparison with results obtained by CACECO
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/4/ Kanzleitner, T.F.: Containment atmosphere stratification during severe accidents, results of HDR and DEMONA experiments
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/5/ Schall et al: Blowdown - Untersuchungen in einem Reaktor Containment, Langzeitverhalten
report: PHDR 72-87, KFK, September 1987

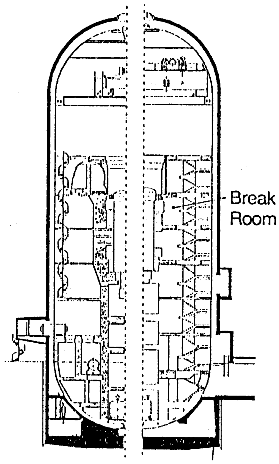

Figure 1: HDR-Containment

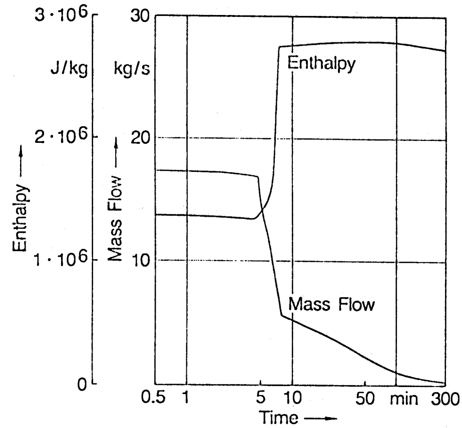

Figure 2: Mass Flow and Enthalpy

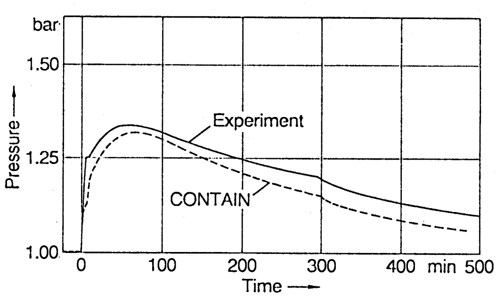

Figure 3: Containment Pressure

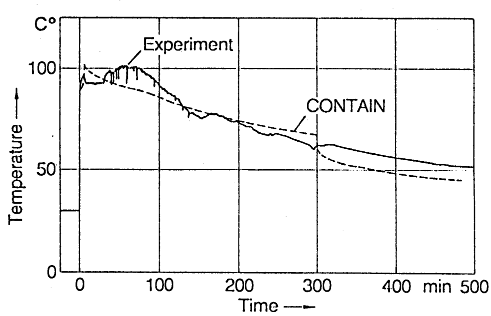

Figure 4: Temperature in the Break Room

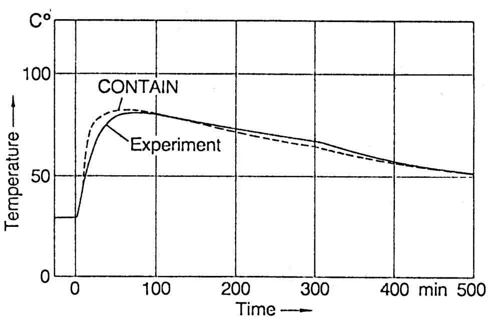

Figure 5: Surface Temperature of the Steel Shell in the Dome

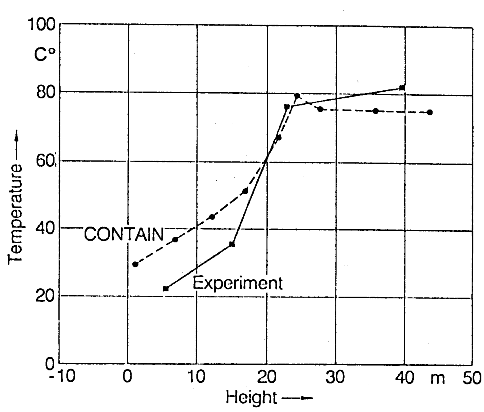

Figure 6: Temperature Profile Along the Big Staircase at t = 150 min

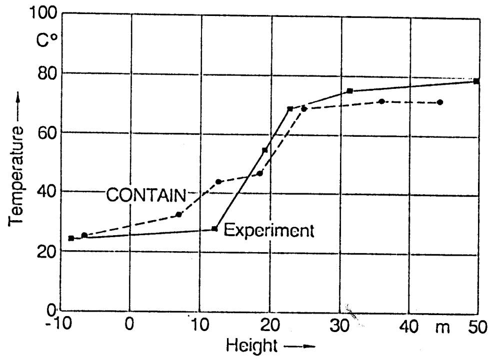

Figure 7: Temperature Profile Along the Spiral Staircase at t = 200 min

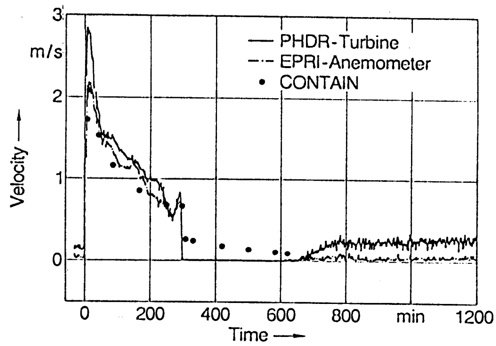

Figure 8: Flow Velocity Between Big Staircase and Dome

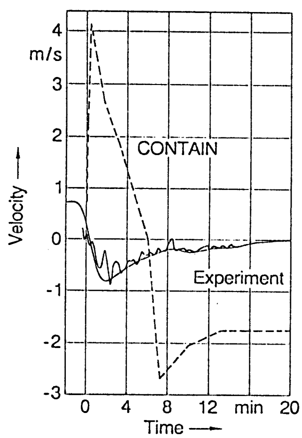

Figure 9: Flow Velocity Between Spiral Staircase and Dome