Verification of CONTAIN by comparison with results obtained by CACECO

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1 INTRODUCTION

In the GRS the consequences of hypothetical LMFBR accidents are being analyzed to obtain information on the risk resulting from LMFBRs.

Accidents with resulting failure of the primary system will cause pressure and temperature rise and the release of coolant and radioactive materials within the containment.

With agreement of the USNRC the CONTAIN-code /1/ from Sandia National Laboratories (SNL), New Mexico, USA, is in use for the calculation of these consequences.

The necessary code-verification first leads to the confirmation or correction of models for single effects - as it has been demonstrated in the previous paper of this session.

In a second step the cooperation of the different models of single phenomena coupled in a code has to be proven.

Therefore containment case seven of the risk oriented analysis on the SNR-300 /2/ has been chosen as the published results have been evaluated with the containment code CACECO /3/.

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2 RISK-ORIENTED ANALYSIS ON THE SNR-300 /2/

This risk oriented analysis has been performed for the Federal Minister for Research and Technology by the GRS as contractor together with a number of additional institutions.

It is the purpose of risk analyses for nuclear reactors to determine possible consequences of releases of radioactive material beyond releases in controlled accidents, and to estimate their expected frequencies of occurence.

Within this spectrum of accidents one HCDA with failure of the primary system is represented in /2/ as containment case seven where a total loss of power is one of the main assumptions. A more detailed specification of the situation is given in chapter 5.

3 CONTAIN-CACECO

CONTAIN has been developed by SANDIA National Laboratories (SNL), USA, and is determined for the application to LMR- and LWR-accident analy-

ses. Figure 1 shows the coupling of the four different groups of containment phenomena and their interaction:

- thermohydraulics and chemistry of the atmosphere,
- coolant leakage and core melt on the concrete floor of a room,
- aerosol behaviour and
- behaviour of fission products and other radioactive materials.

For our calculations release 1.05 of CONTAIN has been used.

CACECO /3/ is a US-containment code programmed by Hanford Engineering and Development Laboratories (HEDL), USA. As the modeling is restricted to thermodynamics of the containment no aerosol behaviour and decay or transport of radioacitve materials can be taken into account directly in one single calculation as it is possible in CONTAIN.

On the other hand this restriction enables the programmer to allow more detailed modeling of the thermodynamic processes.

In addition to the thermodynamic capabilities of CONTAIN CACECO allows to respect

- two condensable gases: water/steam and sodium, instead of one,
- radiation heat transfer not only between the floor region of a compartment and the other structures of this room but between the other structures, too, and
- release of water from heated concrete.

In hypothetic accident situations of LMFBRs these additional capabilities can influence the results of a calculation and should be respected when results obtained with both codes are being compared.

4 MODELING OF THE SNR-300-CONTAINMENT

Figure 2 shows a simplified view of the SNR-300 containment system with the reactor cavity, the inner containment enclosing the primary system with nitrogen atmosphere, the inerted region of the outer containment containing the auxiliary sodium systems and the remaining outer containment filled with air, mainly represented by the reactor-components hall. These containment regions are enclosed within concrete walls of minimum 1.4 m thickness.

The concrete building is surrounded by a steel shell. The gap between the concrete and the steel shell is called the "reventing gap".

During accidents with radioacitve release the containment is closed and all leakages flow into the reventing gap as its pressure is kept lower than that in the containment and lower as the atmospheric pressure, too. Blowers pump the leakage from the reventing gap back into the containment. So a rather long time of zero release can be realized before a controlled release via the chimney.

The CACECO-calculations contained a model of four rooms:

1. the inner reactor cavity inside the biological shield
2. the rest of the inner containment
3. the inerted region of the outer containment
4. the air filled region of the outer containment including the reventing gap.

The CONTAIN-calculations allowed to split the fourth compartment into two cells:

4.1 the air filled outer containment and

4.2 the reventing gap.

Leakages between the regions base on measurements of volumetric flows and on opening pressures of valves or structures. For CONTAIN they have been approximated by variable flow areas dependent on the actual pressure difference.

5 DESCRIPTION OF THE ACCIDENTAL SCENARIO

During an HCDA sodium is spilled into the containment and initiates sodium spray fires for a few seconds. All energy supply fails, the containment is closed automatically. The reventing system as well as the heat removal systems do not work.

The reactor vessel and the guard vessel loose their integrity so that core melt, liquid steel and sodium can fall into the external core catcher. The volatile fission products release their decay heat in the atmospheres of the four major compartments.

Figure 3 shows the simplified model of the reactor cavity, where the decay heat is released in the fuel zone and the Na-24-decay heat is released in the Na-pool. This heat release causes a gas and energy transportation into the rest of the inner containment by natural convection flow from the reactor cavity via the primary cells to the relief room, from where the cooler nitrogen gas returns to the reactor cavity via separated channels.

This natural circulation has not been modeled but has been represented by a heat flux from the reactor cavities' atmosphere to that of the inner containment.

After 10 hours the steel lining fails in the floor region of the reactor cavity. The steam release from the concrete enters the atmosphere and reacts at the sodium surface with resulting energy release to the Na-pool and to the atmosphere as well as hydrogen release.

Two hours later the core catcher cavity fails and the sodium closes the channels in the lower part of the biological shield. The natural circulation stops together with the heat transfer from the reactor cavity to the inner containment.

The steam release now enters and reacts within the sodium pool. 15 hours from the initiation the core-catcher is assumed to collapse and a strong Na-concrete interaction with heat release to the structures on the cavity floor takes place.

In two regions of the containment the remaining sodium in the systems releases Na-24-decay heat and water or steam is released from the heated concrete of walls, ceilings etc. into the outer containment.

6 COMPARISON AND INTERPRETATION OF THE RESULTS

In figure 4 the gas temperatures in the different compartments and the pool temperature are plotted. The CONTAIN-results for cells 2, 3 and 4 are very close to those of CACECO, the heat transfer into the structures seems to be more effective in CONTAIN, so that the gas temperatures remain lower.

The gas temperature in the reactor cavity (1) obtained by CONTAIN differs in detail from the CACECO-results. While the temperature from CACECO increases very uniformly that from CONTAIN falls slightly after the first increase. After 12 hours both temperatures rise parallel.

The deviations depend on the simpler model for radiative heat transfer of CONTAIN.

The cooler structures as the biological shield (1) and the core catcher cavity (2) don't receive heat from the hotter structures as the reactor roof (3) and the core remainder on the grid plate (4) + (5). So structures (1) and (2) release less heat to or even receive heat from the atmosphere due to their smaller being heated by radiation. Together with the increasing heat flux from the reactor cavity to the rest of the inner containment (cell 2) by natural circulation - which has separately been evaluated and is given in the input - a negativ

heat balance for the atmosphere resulted. In reality a reduction of the gas temperature would cause a decrease in natural circulation and in the connected heat transfer to cell 2 so that temperature decrease couldn't appear.
The parallel rise after 12 hours can be explained by the same reason - the lack of radiative heat transfer between the structures. From that time most structures are colder than the atmosphere. The core remainder on the grid plate (5) can only transfer energy to the other structures by convection. This is only possible by a higher gas temperature as structure (5) is cooled down less effective without radiative heat transfer.

Figure 5 shows the pressures in the compartments. Due to the lower gas temperatures in cells 3 and 4 - as mentioned above - the pressures remain lower while the pressures in cells 1 and 2 depend nearly only on that what happens in the reactor cavity. The strong temperature rise after 10 hours in the CONTAIN-results is the the reason for the pressure increase as well as the hydrogen generation from that time on, due to sodium-water-reactions with direct energy release to the atmosphere.

After 12 hours this energy is released only to the Na-pool. This causes the drop of pressure at this time. Later the CONTAIN pressure rises parallel to that of CACECO as the temperature does.

The sodium pool temperature shows for both results the same temperature behaviour due to its big heat capacity and its boundary conditions.

7 CONCLUSION

The CACECO- and the CONTAIN-results for a detailed thermodynamic problem show the same tendencies and most results meet acceptable.

A direct modeling of natural circulation in the inner containment would reduce the differencies even when the CONTAIN modeling for heat transfer by radiation is not as extended as for CACECO.

REFERENCES

/1/ Bergeron, K.D., et al. User's manual for CONTAIN 1.0. Report: NUREG/CR-4085, SAND 84-1204. May 1970.
/2/ Gesellschaft für Reaktorsicherheit. Risikoorientierte Analyse zum SNR-300. Report: GRS-51.
/3/ Peak, R.D. Users Guide to CACECO Containment Analysis Code. Report: HEDL-TC-859. June 1977.

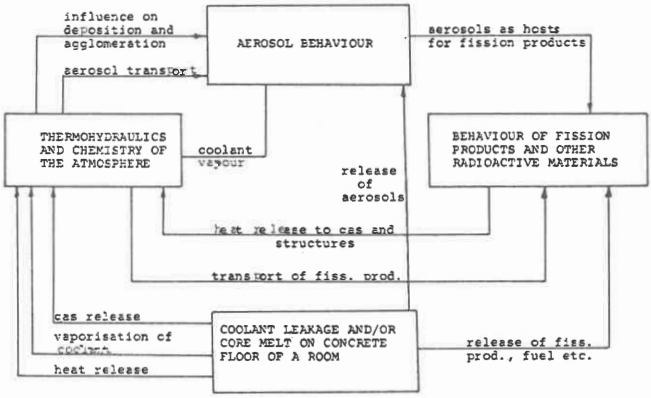

Figure 1.
Coupled phenomena in CONTAIN.

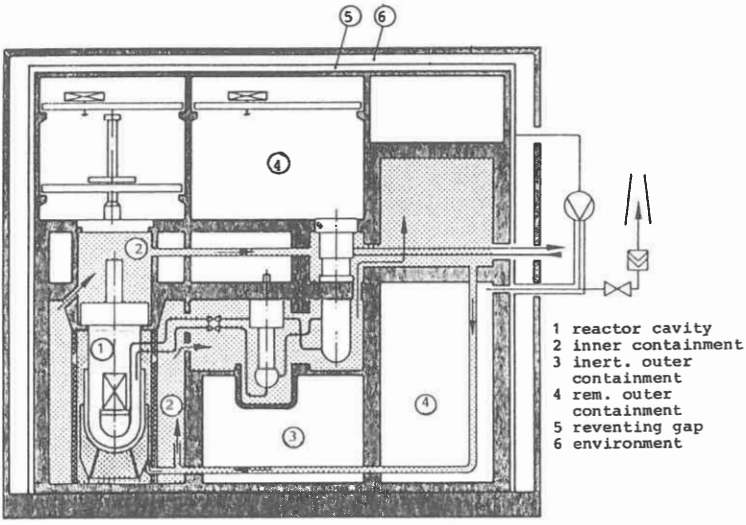

Figure 2. Schematic view of the SNR-300 containment

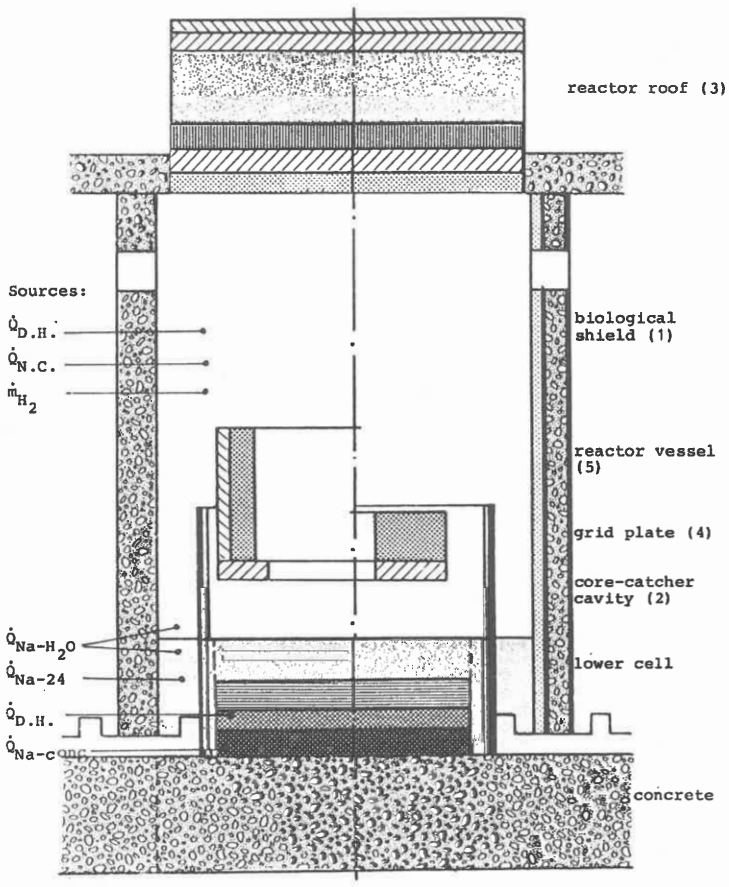

Figure 3. Simplified model of the reactor cavity.

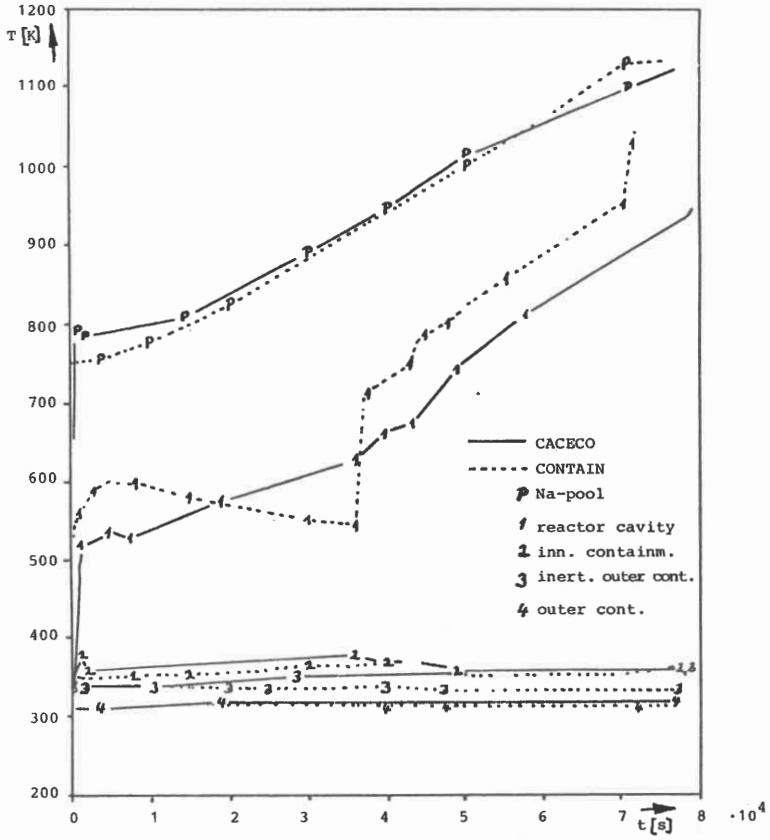

Figure 4. Temperatures in the different cells.

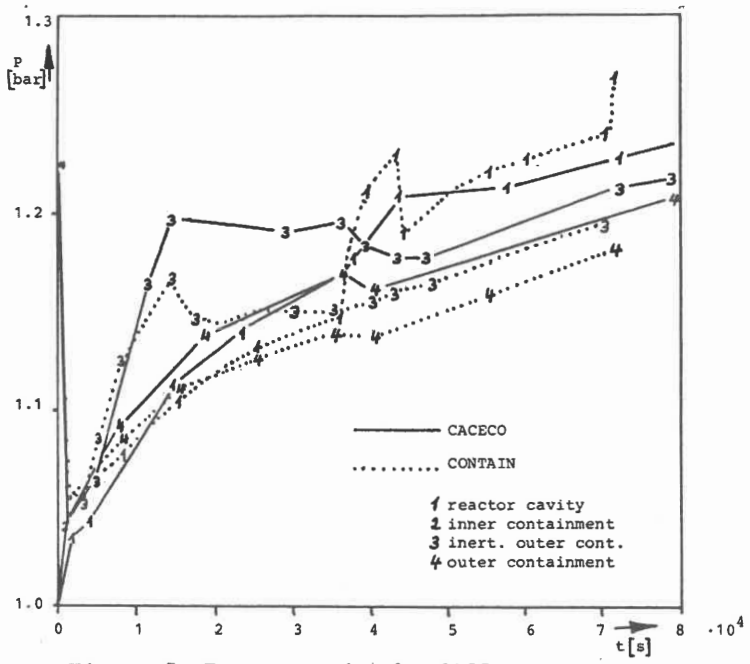

Figure 5. Pressures in the different cells.