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Influence of Corrosion Processes on the Protected Sump Intake after Coolant Loss Accidents

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1. Introduction

In 1996 the USNRC compiled for the OECD the current state of knowledge regarding the phenomenon which could have an adverse effect on the sump intake after a loss of coolant accident (LOCA). An evaluation of this state of knowledge showed that a check of the design assumptions for the sump sieve would make sense and that because of the complexity of the relevant phenomena experimental tests reflecting the situation specific to the facility were necessary. In the following time major efforts were made in Germany and internationally to test the influence factors for the loss of pressure at the sieve.

In recent years the influence of long term effects on the pressure loss were tested internationally. This question is a basically still not completely clarified part of Generic Safety Issue (GSI) 191, " Potential of PWR Sump Blockage Post LOCA".

At the request of the German operators experiments were performed at the Erlangen Tank Test Station to answer this question.

2. Test Facility

Used for the new test program was the Erlangen Tank Test Station which has already proven its suitability for realistic modeling of flow processes in over 50 prior short term tests /1/. Thus one can fall back on considerations formerly investigated for scaling.

In addition to the modeling of transport and sediment processes, the chemical boundary conditions were relevant for the long term considerations. It could be expected that ferritic materials (mostly galvanized) in the device, e.g., grating, air shaft, etc., could be more strongly influenced by the water chemistry after a LOCA than , e.g., austenitic materials or coatings. In previous tests without transport processes (e.g., ring conduit), it was determined that the temperature and pH value have a decisive influence on the corrosion speed of galvanized surfaces. The boundary conditions were chosen accordingly in the tank test station. A boric acid concentration was set corresponding to 2200 ppm of boron as well as a water temperature of 50 deg C.

The known test arrangement was supplemented for the long term tests to the effect, that certain quantities were placed on the test gratings which simulated the previously mentioned galvanized ferritic materials both in the sump water as well as in the leakage stream (See Fig 1).

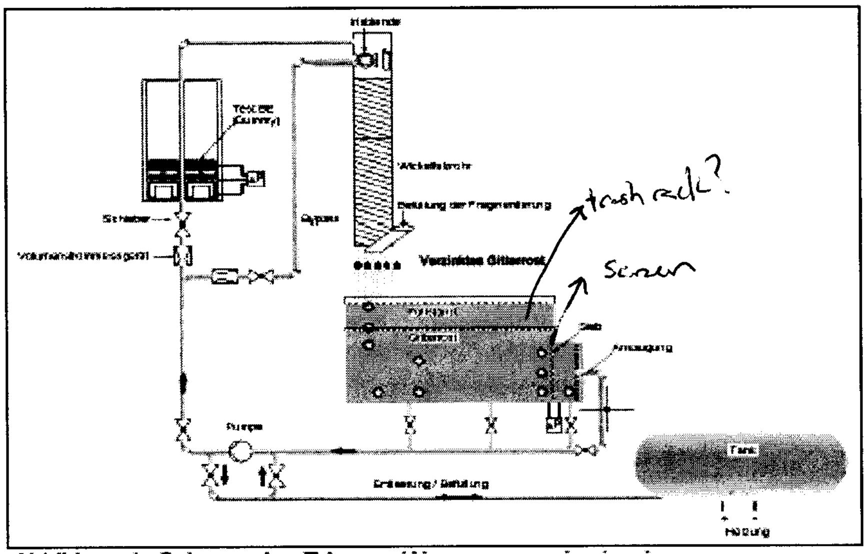

Figure 1: Diagram of the Erlangen Tant Test Station
[Keyed:]
Test BE (Dummy) - Test BE (Dummy)
Schieber - Sieve
Volumenstrommessgerät- Flow volume measuring device
Pumpe - Pump
Bypass - Bypass
Entleerung/Befüllung - Emptying / filling
Irisblende - Instruments
Wickelfalzrohr - Folded spiral pipe
Befüllung der Fragmentierung - Fragmentation filling
Verzinktes Gitterrost- Galvanized grating
Füllstand - Fill level
Gitterrost - Grating → mesh size?
Sleb- Sieve → mesh size ?
Ansaugung- Intake
Tank - Tank
Heizung - Heating

With this test arrangement it was possible in a simple and comprehensive manner to integrally test both the corrosion processes as well as the influence of the corrosion products on the pressure loss across the pump sieve.

3. Results
3.1 Corrosion Processes

There were two basic corrosion mechanisms:

* <u>Galvanized Surfaces in Water</u>
Relatively low flow speeds dominated in the water of the test station. There was no erosion of particles from the zinc-oxide layer that was to be protected. Individual zinc ions were loosened and concentrated in the water, basically as zinc-oxide. The conductance capability was determined by technical measurement as an indicator of the concentration of the zinc ions. It can be easily recognized in Figure 2, that in the corresponding test (in this case a prior test in a ring conduit) the pressure loss at the sieves begins to increase after the attainment of the maximum,

stationary zinc concentration in the water. This pressure loss increase is a definite sign of the accumulation of corrosion products on the mineral wool fibers (See 3.3).

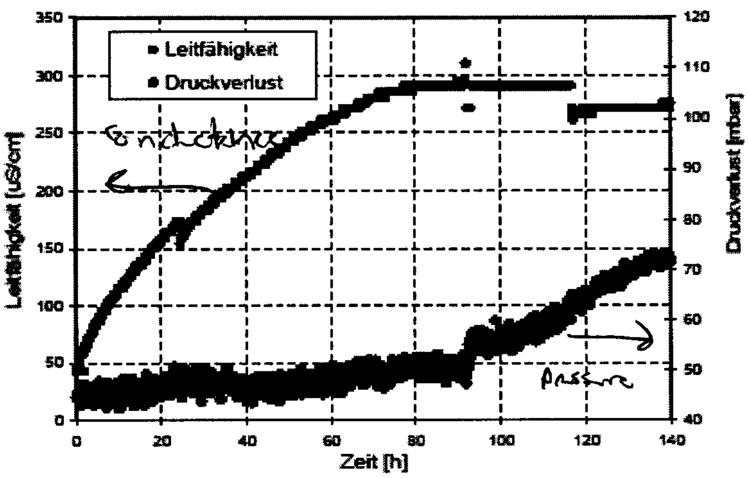

Figure 2 : Pressure Loss and Conductance in Test RD3
[Keyed]
Leitfähigkeit [uS/cm] - Conductance capability (uS/cm)
Leitfähigkeit - Conductance capability
Druckverlust - Pressure loss
Druckverlust [mbar] - Pressure loss (mbar)
Zeit [h]- Time (hours)

* Galvanized Surfaces in Leakage Stream

In the tank tests an increase of the pressure loss was already observed, when the zinc concentration still had not reached a stationary value. The reason is a strong erosion effect of the leakage stream which acts on the test grating from about 8 m and knocks off small particles of zinc corrosion products out of the protective layer. This observation was confirmed by the damage picture of the grating after the tests. It was seen that the zinc layer was removed in particular, where the leakage stream impacted in an especially massive manner (in a test at the edge of the down pipe.

After the loosening of the zinc layer the underlying ferritic material begins to corrode. Iron in water is much less soluble than zinc, so that the first named mechanism plays no role here. The rust particles are immediately rinsed away in large measure with the water and are transported to the sieve.

3.2 Accumulation on the Mineral Wool Fibers

The corrosion products are at least partially transported from the sump water to the sieve and accumulate on the mineral wool fibers because of the different surface tensions.

3.3 Pressure Loss Increase Across the Sump Sieve

The accumulated corrosion particles have a similar effect on the pressure loss when interacting with the mineral wool fibers as do fragments of micro-porous insulants. There only results a slight constriction of the flow paths but the poorer surface roughness results in a significantly higher pressure loss. Overall a total of 20 tests were performed, in order to examine the most important influence factors at the start of the pressure loss increase and the gradients . The most important knowledge gained was:

- The pressure loss increase begins under boundary conditions representative of the Siemens DWR at the earliest after about 10 hours.
- The pressure loss increase is caused by both zinc corrosion and also iron corrosion.
- In the time period of several days that was observed both possible corrosion processes at the sieves themselves and also possible chemical changes to the mineral wool fibers play no role.
- Without appropriate measures the design pressure loss of the sump sieves can be exceeded after several days. In any event, an extremely improbable, conservative scenario is thereby assumed.

3.4 Effectiveness of Measures to Remove Sieve Accumulation

In order to ensure a sump intake even under extremely improbable boundary conditions, the sieve accumulation must be able to be removed, if necessary. It was seen in the tests that an effective removal of the sieve accumulation was achieved by restricting the mass flow through the sump sieves at zero for a few minutes (minimum quantity operation of the re-cooling pumps). Assumed thereby, however, is that the accumulation of the corrosion products has not yet begun, under representative conditions up to at least 10 hours after the start of the interference. The coating so removed sediments on the sump floor and is not dispersed again.

4. Summary

The integral tests have shown that under certain unfavorable conditions the influence of corrosion from materials located in containment on the protected sump intake can not be disregarded. In the process it was proven for the Siemens DWR that even in extremely conservative scenarios the immediate overcoming of an accident is not endangered. It was also shown that simple measures able to be performed in every facility, like the short term restriction of the re-cooling pump to the minimum quantity operation, guarantee the sump intake even in long-term operation. The effectiveness of this measure is valid for at least 10 hours after the start of the accident.

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/1/1 Confirmation of Protected Sump Intake after LOCA for a Siemens DWR by means of Integral Tests Approaching Reality, Ganzmann, Hertlein, Roth, Waas, JTK 2005.