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Gas Pressure Test of THTR Steam Generators

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Summary

The pressure and leak tightness test of the THTR steam generators was performed from December 2 to 4, 1983. The steam generator tests also covered the connection piping to the headers and the steam/feedwater circuit up to the first or second shut-off valve.

In accordance with the Cerman Boiler and Vessel Code TRD normally hydrostatic tests are envisaged on the occasion of the in-process inspection. Conventional dumping of the steam generators is impossible. Since it was intended to perform the pressure test at an earlier date for optimizing the assembly sequence of the power plant, and since at that time an optimum conservation was not ensured, a gas pressure test using nitrogen was proposed instead of the hydrostatic test originally envisaged.

Because of the change to a gas pressure test, it was necessary - in accordance with § 8 Section 3 Atomic Energy Act - to obtain a permission from the Northrhine Westphalian Minister for Labour, Health and Social Welfare to deviate from § 15, Section 2 No. 2, Steam Boiler Ordinance for the initial pressure test of the steam boiler plant. The licensing authority agreed to accept the gas pressure test as a fully valid substitute for the hydrostatic test.

The successful performance of the pressure and leak-tightness test showed that this procedure can be applied also for complicated plants and that it is technologically favourable and, in the present conditions, more economic.

Thus e.g. all the efforts and risks combined with drying of the system or wet conservation were avoided.

Technical Codes and Regulations

In addition to the commercial regulations for the protection of environment and personnel, the following regulations were relevant for the design:

- Ordinance on Steam Boiler Plants (Dampf KV)
- Boiler and Vessel Code TRD 500, Section 2.1.2 (2)
- Boiler and Vessel Code TRD 503, Section 5

Substitution of Hydrostatic Test by Gas Pressure Test

The gas pressure test was envisaged for the following reasons:

- Each steam generator unit consists of the section integrated in the prestressed concrete reactor vessel and the connection piping and headers arranged in the steam generator ring room. Due to this structural configuration, the steam generators and reheaters cannot be dumped through a drain at the lowest point of the piping.
- After a pressure test with water, drying of the steam generators with subsequent safe dry conservation by heating of the primary system would not have been possible.
- The alternative of wet conservation would only have been possible for a limited period (maximum 8 months). In addition, dry conservation is a better way of conserving steam generators than wet conservation.
- Postponing the test to a later date in order to reduce the period of wet conservation to about 6 to 8 months was not possible because of assembly interdependences. The early start of the hot trial operation required the preceding termination of the insulation works.

In planning the gas pressure test, it had to be taken into consideration that subsequent to the pressure test verification of the system tightness was to be performed by a pressure proof test at a lower pressure level. For ruling out a hazard from brittle fracture, the pressure had to be reduced slowly in a way to avoid that in the ferritic materials the temperature falls below 20 °C.

Thus, not only the impact of temperature fluctuations in the system had to be taken into consideration with regard to the measuring procedure, but also the temperature reduction resulting from pressure reduction had to be kept in admissible limits by processing boundary conditions (relaxation velocity).

Quality Assurance Measures

The pressure test in accordance with the Ordinance on Steam Boiler Plants (Dampf kV) (regulations on steam boiler plants) has the objective to verify the integrity and tightness of the component supplementing the computational strength verification and the inspections during manufacture.

For the THTR the following in-progress tests were performed prior to the system pressure test:

- In excess of compliance with the technical codes and regulations TRD, (technical regulations on steam boilers), a stress and service life analysis was performed for all the important component parts of the steam generators. This permitted a detailed knowledge on the utilization factor of strength.

- The component was subjected to a hydrostatic test at the manufacturer's works (1.3 times the operating pressure at a minimum) with the exception of the assembly seam welds. The share of the assembly seam welds was about 20 % of the total number of seam welds (approx. 4.200).
- In addition, the steam generators were subjected to helium tightness tests on the construction site after their transport.
- In the total scope of inspection non-destructive tests were conducted on 100 % of the seam welds.
- All valves were subjected to a first pressure test in the manufacturer's works.
- Manufacture and assembly of the component and its connecting elements were accompanied by a comprehensive quality control by HRB and an accompanying inspection by the Technical Supervisary Association (TÜV).
- Pressure test and leak rate test of the steam generator vessel closures (double closures) had already been performed on the occasion of the proof pressure test of the prestressed concrete reactor vessel.

Plant Conditions and Scope of Tests

During the test period the prestressed concrete reactor vessel was filled with air at a pressure of 1 bar.
Already several weeks before the start of the tests sufficient ventilation and continuous winter-time heating of the reactor hall was arranged. All the engineered safety devices preventing an excess of the permitted pressure had been subjected to functional tests before.

Corresponding to the high-pressure and low-pressure sections of these 6 steam-generators, the test covered two times six pressure loops up to the first or second shutoff valve, each including

- one steam generator unit
- the external connection piping with the headers and
- the connection piping of the steam/feedwater circuit.

Performance of the Test

Comprehensive protective measures for the personnel were taken during the test (e.g. indication of limited access areas; monitoring of pressure and temperature by TV cameras and recording devices; acoustic monitoring of platforms using directional microphones).

As can be seen in the load diagram (Fig. 1), the test was started by an initial low pressure level intended to detect major leaks. This test was performed at a pressure level of 10 bar. The nitrogen was filled into the steam generator units from N_2-bottles. During the test visual inspection was possible using ultrasonic detectors.

For the pressure test at 295 bar in the high-pressure section and 76 bar in the low-pressure section liquid nitrogen was supplied from tank trucks.

The pressure was applied using a mobile pressurization device. The test gas was pumped into the piping system through pumps and evaporators. All the six pressure loops were pressurized at the same time. Visual inspection using ultrasonic equipment was performed up to a pressure level of 15 bar. From that level upwards the pressure was continuously increased up to the full test overpressure. After reaching the test pressure, it was maintained during 30 minutes and then the compressor was shut off. Following this peak level, depressurization was performed to a test level of 80 bar in the high-pressure section/69 bar low pressure in order to permit an in-situ inspection.

Subsequently the sufficient tightness of the system had to be verified by the leak-tightness test. After exceeding the test overpressure, the tightness of the system was verified in a longterm pressure test, after the temperature influence had stabilized. Since leakages in the system are detected by a time-dependent reduction of the gas pressure, and this pressure reduction is influenced also by temperature changes, gas pressure as well as gas temperature were recorded over the test period.
The leak-tightness test was performed at a pressure level of 80 bar high pressure section and 69.2 bar low pressure section.
The maximum permissible overall leakage of one steam generator pressure loop is specified on the basis of the activity containment concept of the power plant to be 1000 mbar x 1 x s^{-1} helium at 260 °C and 40 bar. This corresponds to a maximum permissible pressure reduction of 0.6 bar/h in the high pressure section and 0.45 bar/h in the low pressure section under test conditions.

In this test all the 6 pressure loops were pressurized at the same time (HP sections and LP sections separately). In case of exceeding the 1000 mbar x 1 x s^{-1}, it would have been possible to separate the jointly tested 6 pressure loops in order to detect the permissible tightness of each individual pressure loop.

The overall scope of the test scope covered approx. 700 shutoff valves of different type of DN 15-250. The valves used in the pressure ranges had to ensure a tightness of 10^{-1} torr x 1 x s^{-1} regarding the activity confinement and were monitored by ultrasonic measuring instruments. Initially tests with necal and balloon envelopes were performed in limited areas at lower pressure levels (up to 2 bar). This was to ensure that possible individual leakages above 10^{-1} torr x 1 x s^{-1} could be detected and repaired independently of the result of system tightness.
Since each steam generator contained assembly seam welds which had not yet been subjected to pressure tests in addition to visual testing of the external system piping, also the assembly seam welds of the piping integrated in the prestressed concrete reactor vessel had to be inspected. On this occasion the interior of the vessel was subjected to a visual inspection and measurements

were performed by ultrasonic detectors and electronically amplified stethoskopes.

Result and Evaluation

The pressure and leak-tightness test was performed according to schedule and without any problems.

Parallel to the performance of the test, absolute pressures, differential pressures and temperatures were evaluated and compared with the expectancy values determined by calculation. The measured and the calculated values were in good agreement.

Thus the following verification was furnished:

The steam generators with their connection piping and headers as well as the steam/feedwater pressure loop up to the first or second shutoff valve ensure safe containment of the energy content at 295 and 76 bar, respectively. The long-term pressure test showed a leak rate which was below the specified permitted values:

	specified (per pressure loops)	measured (for 6 connected loops)
- High pressure section (bar/h)	0.6	0.54
- Low pressure section (bar/h)	0.45	0.12

A separate verification of the individual volumes (separation of the pressure loops) did not become necessary. The overall leak rate of all the six pressure loops which had been tested jointly was even lower than the permitted boundary value for the tightness of one pressure loop.

Valves of the steam-feedwater circuit on which leakages had been detected were repaired immediately after the initial low-pressure test. The individual leaks detected in the overall test were caused by valves only and had no essential influence on the overall system. The leakages mainly resulted from stuffing boxes and valve seats, and were eliminated by ajustment or exchange of the packings and ajustment, blowing or refacing. Leakages on the assembly weld seams were not detected.

During the test the temperature never fell below the temperature permitted for the materials integrated in the pressure loop.

The gas pressure test revealed the following technical advantages:

- Simple and economic detection of major leaks already during the initial low-pressure test.
- This procedure of using gas at an initial low-pressure level is of advantage also for a main hydrostatic test of complicated systems at a later date.
- Higher accuracy of the test results
- Clean test conditions without water leakages in the test area
- Higher plant safety because of elimination of subsequent corrosion
- Higher flexibility of timing within the assembly and commissioning schedule of the nuclear power plant.