HIGH TEMPERATURE REACTOR DEVELOPMENT IN THE NETHERLANDS

A.I. VAN HEEK
Netherlands Energy Research Foundation ECN,
Petten, Netherlands

Abstract

This year, some clear design choices have been made in the WHITE Reactor development programme. The activities will be concentrated at the development of a small size pebble bed HTR for combined heat and power production with a closed cycle gas turbine. Objective of the development is threefold: 1. restoring social support, 2. commercial viability after market introduction, and 3. to make the market introduction itself feasible, i.e. limited development and first-of-a-kind costs. This design is based on the peu-à-peu design of KFA Jülich and will be optimized. The computer codes necessary for this are being prepared for this work. The dynamic neutronics code PANTHER is being coupled to the thermal hydraulics code THERMIX-DIREKT. For this reactor type, fuel temperatures are maximal in the scenario of depressurization with recriticality. Even for this scenario, fuel temperatures of the 20MWth PAP-GT do not exceed 1300°C, so there should be room for upscaling for economic reasons. On the other hand, it would be convenient to fuel the reactor batchwise instead of continuously, and the use of thorium could be required. These two features may lead to a larger temperature margin. The optimal design must unite these features in the best acceptable way.
To gain expertise in calculations on gas cooled graphite moderated reactors, benchmark calculations are being performed in parallel with international partners.
Parallel to this, special expertise is being built up on HTR fuel and HTR reactor vessels.

1. Introduction

R&D activities dedicated to the helium cooled graphite moderated high temperature reactor (HTR) started in 1993. In 1994 the name WHITE Reactor was given to the programme, standing for Widely applicable HIgh TEmperature Reactor. The programme is mainly executed by ECN, although three partners contribute in the framework of the Programme to Intensify the Nuclear Competence (PINK) of the Dutch Ministry of Economic Affairs. These are the Interfaculty Reactor Institute of Delft, the engineering company Stork NUCON and the utility research institute and engineering company KEMA. Parallel to this, an HTR Technology Assessment Study is being performed by ECN and the University of Utrecht. This study mainly investigates societal aspects of the technology.
In 1994, ECN hosted an IAEA Technical Committee Meeting on Development Status of Modular High Temperature Reactors and their Future Role, and the Dutch activities on HTR were presented on a Workshop organized on the occasion of the TCM [1].

2. Design requirements and basis

The objective of the WHITE Reactor programme is to contribute to HTR development for safe, environmentally friendly and economical energy supply. Three requirements are to be met for the HTR design:

1. restoring social support,
2. commercial viability after market introduction, and
3. to make the market introduction itself feasible, i.e. limited development and first-of-a-kind costs.

To comply with these requirements, some clear design choices have been made in the WHITE Reactor development programme this year. Design efforts are focused on simplicity. To restore public support for nuclear power, designs will have to be very transparant. No emergency core cooling systems, backup shutdown systems or containments should be needed. This limits the per level per unit, so modularization will be needed to comply with larger power level demands. More important, the low power level even has a positive effect on plant economics, because components can be omitted and the safety grade of certain components could be lower than usual for nuclear power plants. A small plant size will also benefit market introduction, because building a small unit can be an "adventure" of limited size. The activities will therefore be concentrated at the development of a small size pebble bed HTR for combined heat and power production with a closed cycle gas turbine. The power level will be no more than 100 MWth, to keep the design as simple as possible and to minimize development and prototype cost. Pebble bed fuel is chosen for two reasons: 1. the possibility of continuous fuelling, and therefore assure a limited overreactivity, and 2. less development work remains to be done on the pebble fuel type than on the prismatic fuel type. The combined heat-and-power application has been chosen because it fits the chosen power range and to cover a market segment additional to large scale base load electricity generation for the nuclear industry.
The design is based on the GHR-20 design by BBC/HRB [2] and on the peu-à-peu design of KFA Jülich [3]. This is an extremely simple pebble bed HTR design. The reactor is being fuelled on-line continuously or in small batches. After a period of several years, the reactor is unloaded off-line. Like all modular HTRs, the reactor employs no emergency core cooling system, since even after the worst core heatup accident (depressurization) the reactor is shut down by it's negative temperature coefficient and the fuel does not attain unacceptably high temperatures, offering ample time for an active shutdown by insertion of rods. But the shut-down by negative temperature coefficient is only temporary, because of cooling of the fuel and decay of xenon. To decrease the safety function of the shutdown system, the reactor is also required to cope with recriticality after core heatup. Calculations performed at KFA Jülich show this is possible with wide margins for 20 and 40 MWth peu-à-peu designs. It is intended to uprate the power level and to optimize the design.

3. Computer codes for core design

Although the pebble bed neutronics/thermal hydraulics code VSOP of KFA Jülich is available through the NEA Databank now, ECN decided to develop it's own code system. The dynamic neutronics code PANTHER has been acquired from AEA, UK. This code is being coupled to the thermal hydraulics code THERMIX-DIREKT, kindly delivered to ECN by KFA Jülich in a cooperation framework.
Much attention is being paid to the generation of nuclear data. For the PANTHER-THERMIX system, neutron cross sections are generated by WIMS-E and SCALE-4 codes. The Monte-Carlo code MCNP is used for this as well, and to check certain reactor calculations.

To gain expertise in calculations on gas cooled graphite moderated reactors, benchmark calculations are being performed with these codes in parallel with international partners on similar systems: the PROTEUS experiment at PSI Villigen, and the 450MWth MHTGR of General Atomics.

4. Fuel and pressure vessel

Parallel to this, special expertise is being built up on HTR fuel and HTR reactor vessels. Experiments are being performed on oxidation and interaction with fission products of SiC as well as the stability of UO_2/UC_2 mixtures. The pressure vessel stress assessment code ISAAC is being equipped with a fracture mechanics and creep assessment feature for high temperatures, to be able to design a licensable HTR pressure vessel in the near future.

5. Future plans

In 1996, static and dynamic calculations are being performed on the 20MWth PAP-GT of KFA Jülich and compared to their calculations with different codes. For this reactor type, fuel temperatures are maximal in the scenario of depressurization with recriticality. Even for this scenario, fuel temperatures do not exceed 1300°C, so there should be room for upscaling for economic reasons. On the other hand, it would be convenient to fuel the reactor batchwise instead of continuously, and the use of thorium could be required. These two features may lead to a larger temperature margin. The optimal design must unite these features in the best acceptable way.
An economic evaluation of the optimized design will be made. Attention will be paid to the possibility of omitting components and decreasing of the safety grade of components.

5. Conclusion

After a familiarization phase, the Dutch HTR program is well under way. First decisions have been made on design features for the HTR conceptual design in The Netherlands. The activities will be concentrated at the development of a small size pebble bed HTR for combined heat and power production with a closed cycle gas turbine. An independent neutronics and thermal hydraulics code system is being developed. An optimized design based on the GHR-20 and the PAP-GT is planned for 1996.

REFERENCES

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