EUROPEAN COMMISSION
5th EURATOM FRAMEWORK PROGRAMME 1998-2002
KEY ACTION : NUCLEAR FISSION

HTR-M

European Project for the development of HTR Technology - Materials for the HTR

CONTRACT N°
FIKI-CT-2000-00032

HTR RPV Sensitive Zones

By

A. Buenaventura
EA

Spain

Dissemination level : CO
Document Number: HTR-M-02/02-D-1.1.28

EUROPEAN COMMISSION

Project:
EUROPEAN PROJECT FOR THE DEVELOPMENT OF HTR TECHNOLOGY - MATERIALS FOR THE HTR

Title:
HTR RPV Sensitive Zones

Document No: **092-089-E-M-00004**	Issue: **1**
Purpose of issue: Information and comments	Date: 25/01/02

Prepared: ABP

Reviewed: AOM

Approved: MDB

EMPRESARIOS AGRUPADOS

EMPRESARIOS AGRUPADOS INTERNACIONAL, S.A.

Magallanes, 3 28015 Madrid - España

CLASSIFICATION

Contains information for the design of structures, systems or components: Yes ☐ No ☒

Design verification : Not applicable ☐ Head of OU/Supervisor ☒ Verifier Level 1 ☐ Level 2 ☐

CONTROL OF MODIFICATIONS

Issue	Modifications
1	N.A

PRELIMINARY OR PENDING INFORMATION

Issue	Paragraphs	Subject	Status
1			

DISTRIBUTION

External	Internal	No. copies/Format
	FAZ, ABP, AOM, MDB, AGD	

CONTENTS

List of Abbreviations

BWR	Boiling Water Reactor
HTR	High Temperature Reactor
PCU	Power Conversion Unit
PWR	Pressure Water Reactor
RPV	Reactor Pressure Vessel

1. OBJECTIVE AND SCOPE

The work presented in this document has been carried out within the European Project for the "Development of HTR technology, Materials for the HTR (HTR-M)".

The development of advanced HTR concepts requires material data information and understanding of material behaviour under reactor operating conditions. This will lead to the selection of best candidate materials for HTR components.

In particular, within the study for the HTR RPV material selection, this document aims to contribute to the analysis of the RPV sensitive zones (HTR-M, Work Package 1, Task 1.3).

2. HTR RPV DESIGN

The HTR RPV is expected to be approximately 6 to 7 m in diameter and around 20 m high, and lined inside by a thick layer of graphite that will act as a reflector and passive heat transfer medium. The RPV will enclose the reactor core, some 3.5 m in diameter and 8.5 m high. The internals (weighing about 900 tonnes) will be supported by a structure attached to the bottom of the RPV. The total weight of the RPV (including internals) will come to around 1600 to 1800 tonnes. The design pressure will likely be from 7 to 8 MPa, with vessel thicknesses ranging from 120 to 250 mm.

Some zones of the RPV will probably be manufactured by forming and others by forging. The use of forged rings would reduce the number of welds required and facilitate the in service inspection tasks.

3. RPV SENSITIVE ZONES

For the HTR environment working conditions, the RPV material could potentially be subjected to the following damage mechanisms:

- Embrittlement
- Fatigue
- Creep
- Ratchetting
- Thermal ageing

The effect of these material damage mechanisms depends on temperature, radiation and stress levels and time. Some local zones of the RPV will have higher stress levels, or be subjected to higher operating temperatures than others. As a result, the damage mechanisms will probably affect the material of these sensitive zones sooner. These sensitive zones should be analysed in detail, since they will limit the lifetime of the RPV.

A preliminary list of RPV sensitive zones follows:

- Welds, especially those in front of the reactor core. Neutron irradiation is known to cause material embrittlement. Therefore, special attention will have to be paid to the selection of the additional welding (filler) material, avoiding those that may contain Cu, P and any other component that could be affected by irradiation embrittlement. Furthermore, pre- and post-welding heat treatments will be required in order to avoid residual stresses due to welding procedure likely leading to fatigue
- Hot spots, that is, zones of the RPV wall where temperatures are higher. These zones may correspond to areas close to the heat source or zones where the heat flux coming in is larger than the heat being dissipated. These zones may be sensitive to creep and thermal ageing. Therefore, detailed thermal analyses will have to be carried out to obtain the temperature field of the RPV wall for normal operating and transient conditions and detect any possible hot spots. In this case, some redesign considerations should be made in order to reduce the thermal gradients
- Nozzles and openings, since they are geometrical discontinuities that may lead to stress concentrations that could potentially produce fatigue. The design and

material selection of the cooling inlet and outlet nozzles require especial attention since they are transition pieces between the RPV and the PCU.

- The internals support will likely be sensitive to fatigue and ratchetting because of the large mechanical loads due to the dead weight of the internals (about 900 tonnes). Moreover, since the internals support is close to the reactor core, the zone may suffer from irradiation embrittlement. In addition, temperatures will be high, therefore making the zone sensitive to creep and thermal ageing. Consequently, the internals support requires careful design and material selection

- The hemispherical bottom and lid are sensitive to fatigue, since they are full of openings and, consequently, geometrical discontinuities, which lead to stress concentrations

- The RPV support to foundation base. The total dead-weight of the RPV (including internals) will likely be on the order of 1600 to 1800 tonnes. The design of the RPV support must avoid large stresses or stress concentrations so as to prevent possible fatigue. Moreover, stresses due to thermal expansion of the support should also be avoided in the design. In PWRs, vessel support is typically through the main nozzles; for BWRs, it is by way of a cylindrical support plate. For the HTR, the support system will probably be based on a supporting ring welded to the RPV, which will distribute stresses from dead loads along the complete vessel circumference and allow thermal expansion.

Moreover, the design of the RPV support to foundation should be compatible with the support of the PCU, that is, ensuring homogeneous thermal displacements. This will avoid large loads through the gas inlet and outlet nozzles to the RPV.

4. CONCLUSIONS

A preliminary analysis of sensitive zones of the HTR RPV has been carried out. Several of the possible material damage mechanisms that could potentially affect the vessel material during operation have been considered in the analysis. More detailed description of the material damage mechanisms is foreseen within the HTR-M project.

A list of RPV sensitive zones is proposed and will contribute to the selection of best candidate materials for the HTR RPV. Detailed mechanical and thermal analyses for normal operating and transient conditions are required for design and material selection of the RPV.

In this sense, all information obtained from other HTR projects being developed in other countries will be essential. This may be achieved through collaboration agreements between HTR-TN and those HTR projects.

The RPV stress and radiation levels and temperature fields will define the locations of most of the sensitive zones, and will be directly responsible for the level of material damage during HTR operation, and determine the maximum safely-acceptable RPV lifetime.

A design lifetime of 60 years is foreseen [1] and therefore the RPV design, considering the HTR environment conditions, should fulfil this requirement. Moreover, in order to monitor the material damage level during HTR operation, test specimens should be placed inside the RPV and nearby the identified sensitive zones. During programmed maintenance of the reactor, these test specimens will be analysed to evaluate material damage and quantify the real safety-acceptable lifetime of the RPV (life extension programme)

5. REFERENCES

1. A. Buenaventura et al, Material selection for HTR Reactor Pressure Vessel. HTR-M 01/10 D.1.0.17, October 2001