Fifth International Conference on WWER Fuel Performance, Modelling and Experimental Support

D. Elenkov
Nuclear Regulatory Agency, Bulgaria

TWGFPT Meeting
Vienna, IAEA, 11-12 May 2004

Short history

The conference is organised by:

- The Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Science;
- The International Atomic Energy Agency, Vienna.

The first conference took place in 1994, at the Black Sea Resort “St. Konstantin”, the House of the Scientists


Bulgarian Sea Resorts

The second conference was held in 1997, in the town of Sandanski, the foot of the Pirin mountains

The third conference was held in the resort place "Pamporovo", high in the Rodopes mountains

The Forth and the Fifth conferences took place at the sea resort “Albena”

- WWER fuel operation and performance, advanced fuel cycles, fuel failures
- Improvement of the WWER fuel design and operation
- Licensing and QA of WWER fuel and computer codes
- WWER fuel PIE, experimental support and data bases
- WWER fuel performance and improvement of the operation, safety and fuel cycle efficiency
- WWER fuel modelling and computer code applications
- Panel discussions on all topics above

Plenary Reports (invited speakers)

- J. Kileen – IAEA, Vienna
- W. Wiesenack – HRP
- V. Molchanov – TVEL, Russia
- R. Terasvirta - Fortum Nucl. Serv. Ltd., Finland
- I. Vasilchenko - FSUE OKB Gidropress, Russia
- H. Weidinger – Germany
- J. Beelac – NRI, Rez, Czech
- A. Smirnov - FSUE “SSCR RIAR”, Russia
- P. Chantoin – France
- V. Likhanskij - SRC RF “TRINITI” - Russia


Coordinated Research Projects
FUMEX-II
A new CRP on the 'Improvement of Models used for Fuel Behaviour Simulation' to assist Member States in improving the predictive capabilities of computer codes used in modelling fuel behaviour for extended burn-up started at its 1st RCM, Vienna, December 2002.

Programme B
Nuclear Fuel Cycle

Objectives

:

- Solutions to key fuel performance issues
- Harmonisation of Eastern and Western approaches in fuel technology, performance and utilization
- Transfer of technical knowledge

Programme B: Nuclear Fuel Cycle

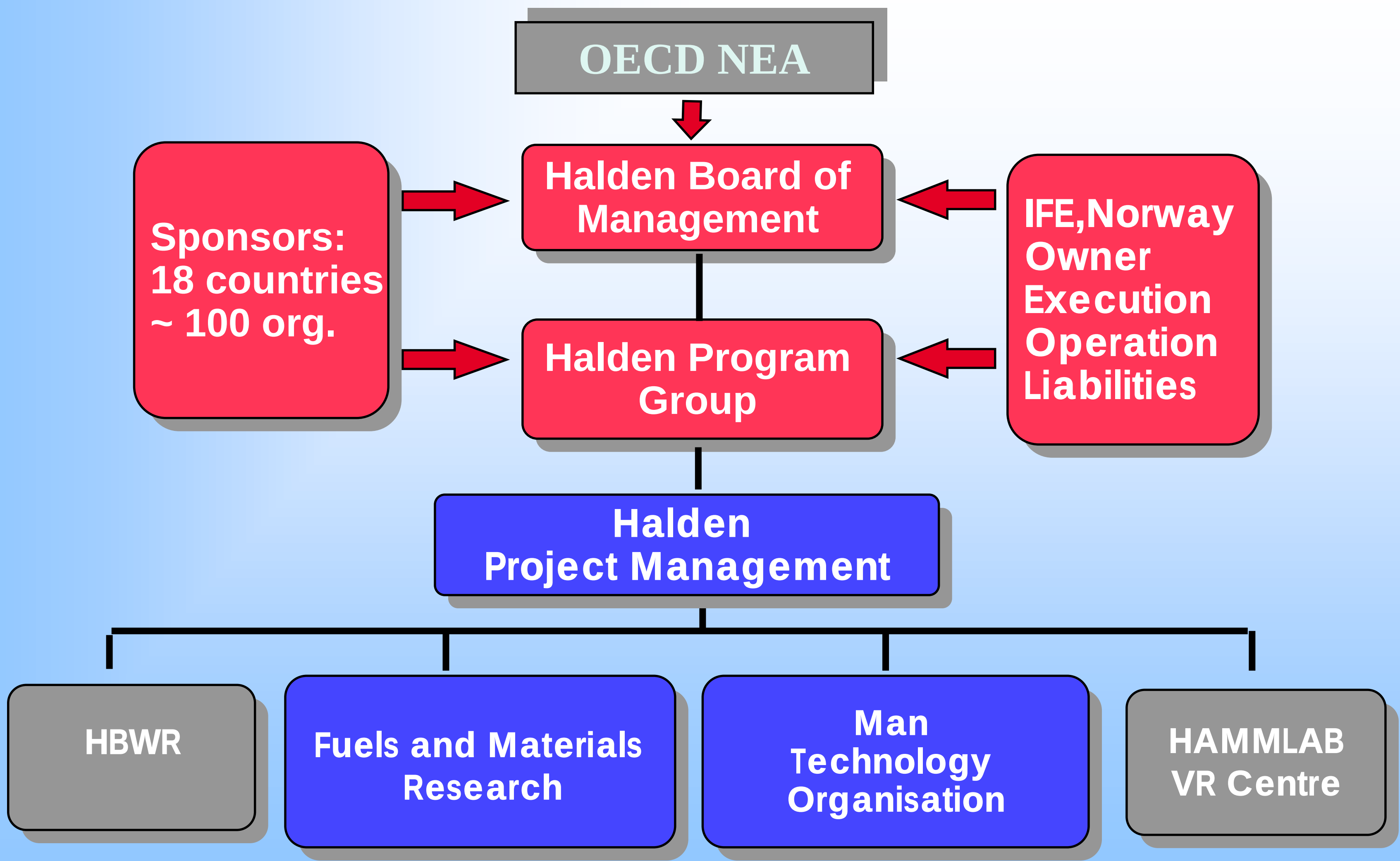
- **Programme B**
  Nuclear Fuel Cycle
  - **Sub-programme B.1**
    Uranium Production Cycle and Environment
  - **Sub-programme B.2**
    Nuclear Fuel Performance and Technology
  - **Sub-programme B.3**
    Spent Fuel Management
  - **Sub-programme B.4**
    Nuclear Fuel Cycle Issues and Information Systems

- Technical Working Groups
  1. TWG on Nuclear Fuel Cycle Options
  2. TWG on Water Reactor Fuel Performance and Technology
- Main Outputs of Sub-programme B
- C R Projects – FUMEX-II
- Collaborations –
  1. IFPE Data base - within FUMEX-II CRP, histories for more than 300 WWER-1000 high burn-up fuel rods prepared and added to the IFPE Database –PIE data from RIAR, Russia and calculated power histories from VNNINM, Russia
  2. Conferences supported – France, India, Canada, Bulgaria
  3. Meetings – TCM's in Slovakia, Czech Republic and Belgium
  4. Technical Co-operation projects - (ARG 4/087), ROM 4/025, BUL 4/006) (BRA 4/052)
  5. **Sub-program B.2 – trends for 2004-2005**
  6. **Detailed description of the FUMEX-II**
  7. **Other activities, incl. publications**

Halden Reactor Project Activities, Achievements and International Collaboration

W. Wiesenack
OECD HRP,Norway

HRP Organisation



- **Deliverables**
  - Computerised Test fuel data since 1972
  - Software products, e.g. Picasso, COAST, PEANO
  - Research Work reports (ca. 120 per 3 year period)
- **Secondee arrangement**
- **International network**
  - Specialist Workshops
  - International Summer School
  - Halden Program Group- and Halden Board meetings
- **Enlarged Halden Programme Group Meeting**
  - Next one at Sandefjord May 2004, 200 external participants

V. Molchanov
JSC TVEL

Perspective decisions of WWER nuclear fuel. Implementation at Russian NPPs

I.N. Vasilchenko
FSUE OKB "Gidropress"

New requirements for the WWER fuel and their consideration in designing the fuel assemblies

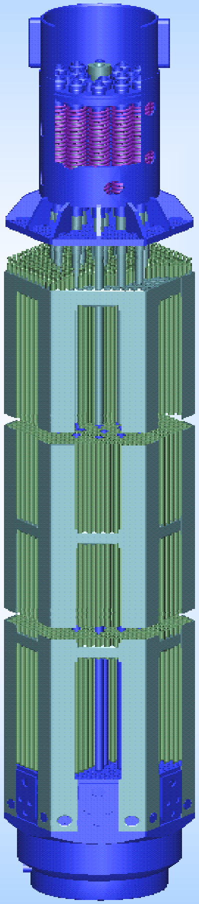
The two papers describe the improvements being made to WWER fuel, particularly with changes being made to the mechanical stability of the assembly for significant decrease of the bowing. The papers addressed the potential for higher burn-up and more efficient fuel cycles and described advanced fuel designs

Goal: increase of FA resistance to bow, core "straightening", extension of operation resource

Implemented at WWER-1000:

Operation of TVSA started in 1998 at Kalinin NPP, Units 1,2

Skeleton formed by 6 angle pieces and 15 spacer grids welded to them



There is significant progress in design improvement of WWER FAs. Very fruitful approach for problems solutions was demonstrated by JSC TVEL, which includes scientific and design teams from different Russian Institutes for solution the problems.

- This approach was applied to improve FA design and for justification these design solutions.

- Different teams were involved in fuel codes development for improvement of the reliability results of the code predictions.

Smirnov A. (FSUE SSC FR RIAR)

«Results of post-irradiation examination of WWER-1000 uranium fuel rods and uranium-gadolinium fuel rods to validate 4 and 5-Year fuel cycles»

«Results of post-irradiation examination of WWER-1000 uranium fuel rods and uranium-gadolinium fuel rods to validate 4 and 5-Year fuel cycles»

Smirnov A., Markov D., Smirnov V., Polenok V.

Perepelkin S., Ivashchenko A.

(FSUE SSC FR RIAR)

Justification

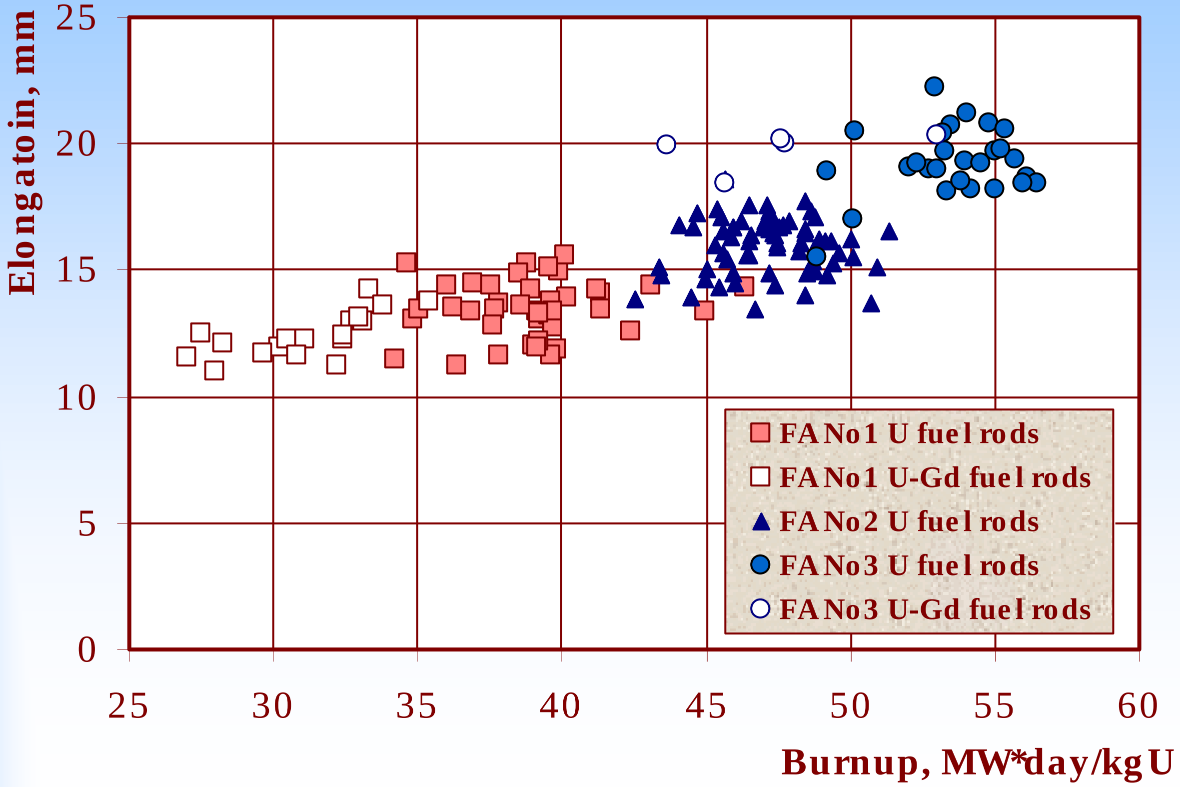
The economic progress of NPPs can be achieved by the decrease of fuel cost. Due to this fact, new fuel cycles are implemented with the increased burn-up and operation period.

⇨

It is necessary to carry out further examination of serviceability of FA and fuel rods.

- *change in the geometry of the claddings (elongation, change in the diameter);*
- *fuel swelling (elongation of fuel column);*
- *decrease in fuel-cladding gap*
- *fuel-cladding interaction;*
- *increase in oxide film thickness on the fuel rod surface;*
- *fission gas release from the fuel.*

Variation in length of U fuel rods and U-Gd fuel rods

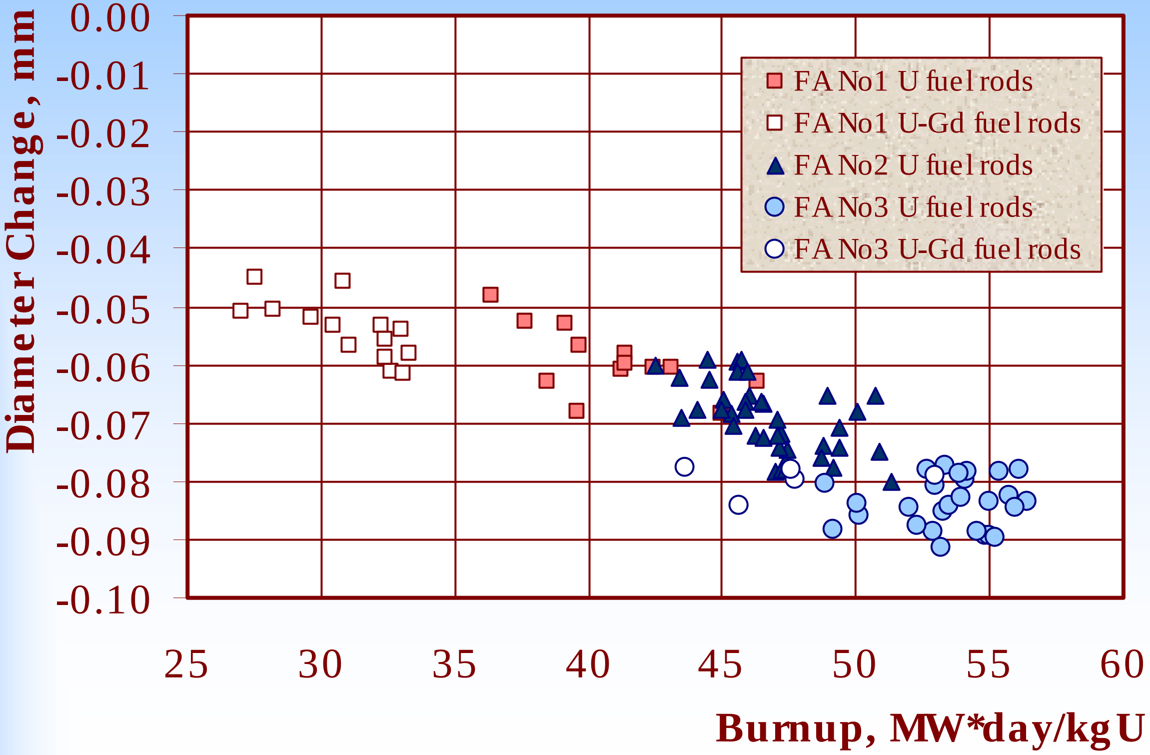


Dependence of elongation of U fuel rods and U-Gd fuel rods on fuel burnup

- *no significant changes in dependence of cladding elongation on burnup*
- *in U-Gd fuel rods elongation values are reached at lower burnup as compared with U fuel rods*

Absence or insignificant axial deformation due to fuel-cladding interaction

Change in cladding diameter of U fuel rods and U-Gd fuel rods

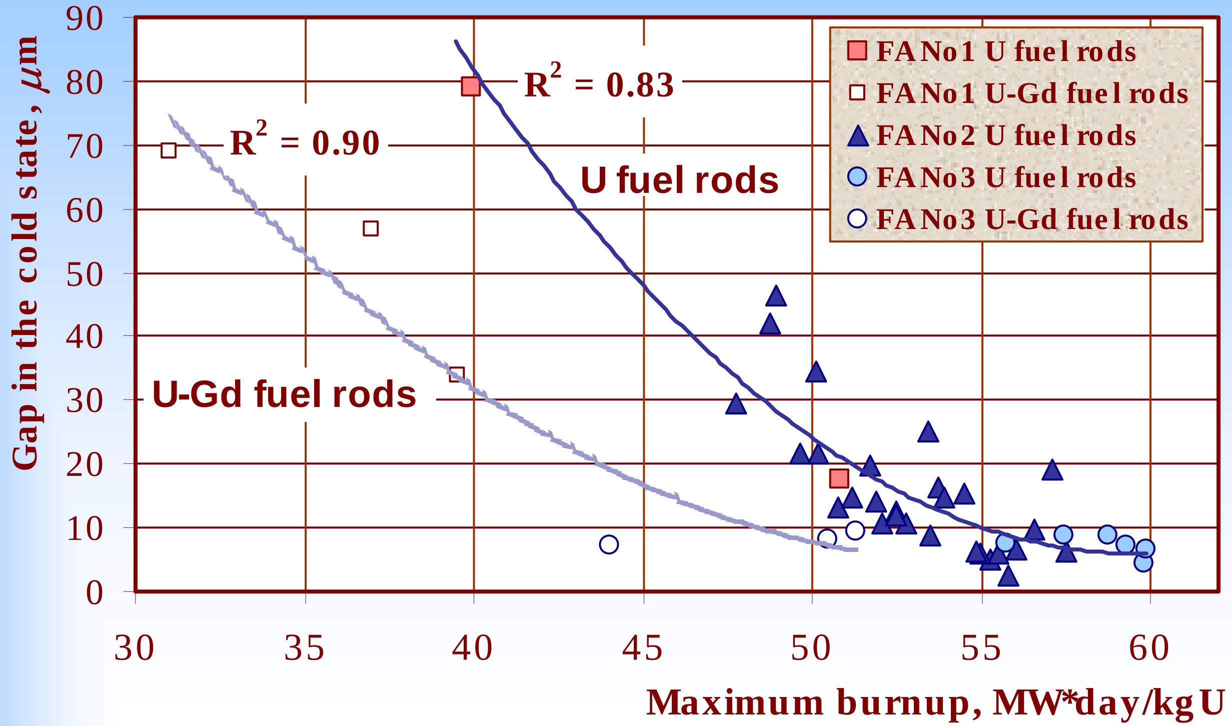


Dependence of cladding diameter change on burnup

- *U fuel rod diameter in the range of 50-57 MW*day/kgU doesn't significantly change*
- *Reverse deformation in the examined burnup range isn't observed*
- *in U-Gd fuel rods the same decreased values of diameter are reached at lower burnup as compared with U fuel rods*

The cladding diameter stops reducing at the burnup of ~ 50-52 MW*day/kgU for U fuel rods and at ~ 44-47 MW*day/kgU for U-Gd fuel rods.

Fuel-cladding gap

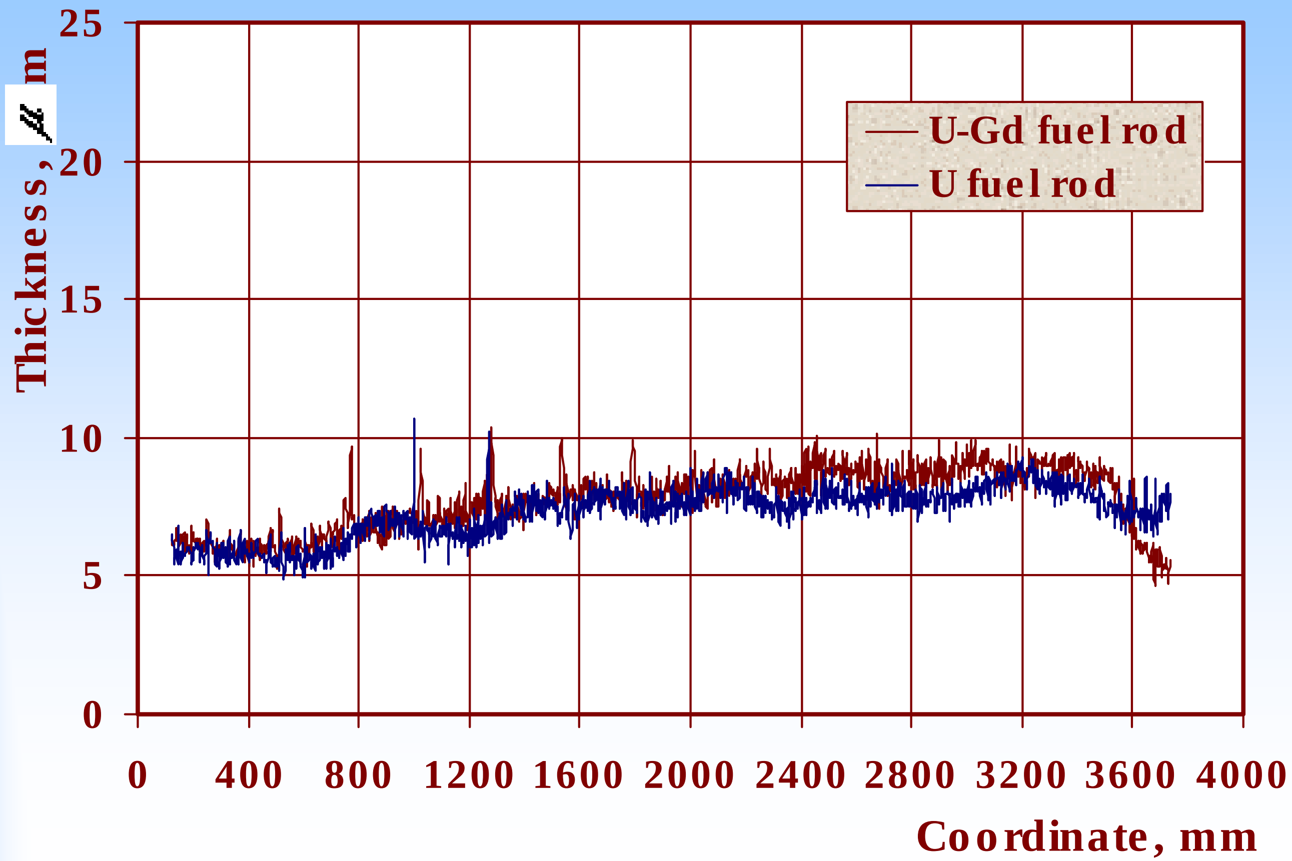


Dependence of fuel-cladding gap in the area of the core on burnup

- *in u fuel rods up to about 50 MW*day/kgU the dependence is linear, above 55 MWd/kgU it reaches saturation;*
- *at the similar burnups fuel-cladding gap in U-Gd fuel rod has lower value than in U fuel rod*

Fuel and cladding are in contact at about 50-55 MW*day/kgU for U fuel rods and at about 43-47 MW*day/kgU for U-Gd fuel rods.

Oxide film thickness

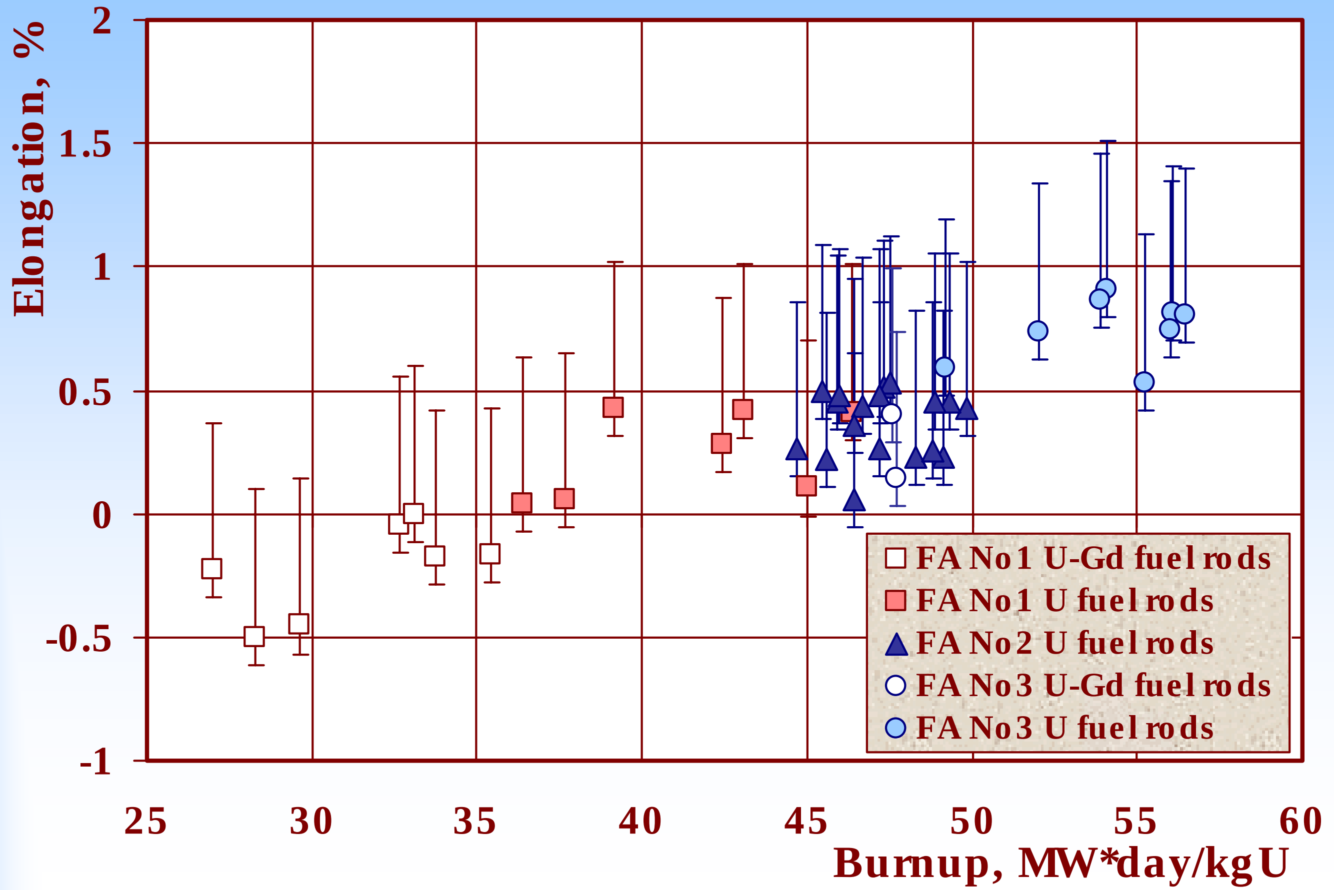


Distribution of oxide film along the length of
U fuel rod and u-Gd fuel rod

- *distribution of oxide film along fuel rods is typical for WWER FA*
- *there are no differences in the cladding oxidation either in U fuel rods or in U-Gd fuel rods*

The average value of oxide film thickness in U fuel rods and U-Gd fuel rods with maximum burnup doesn't exceed 10 μm.

Elongation of fuel column

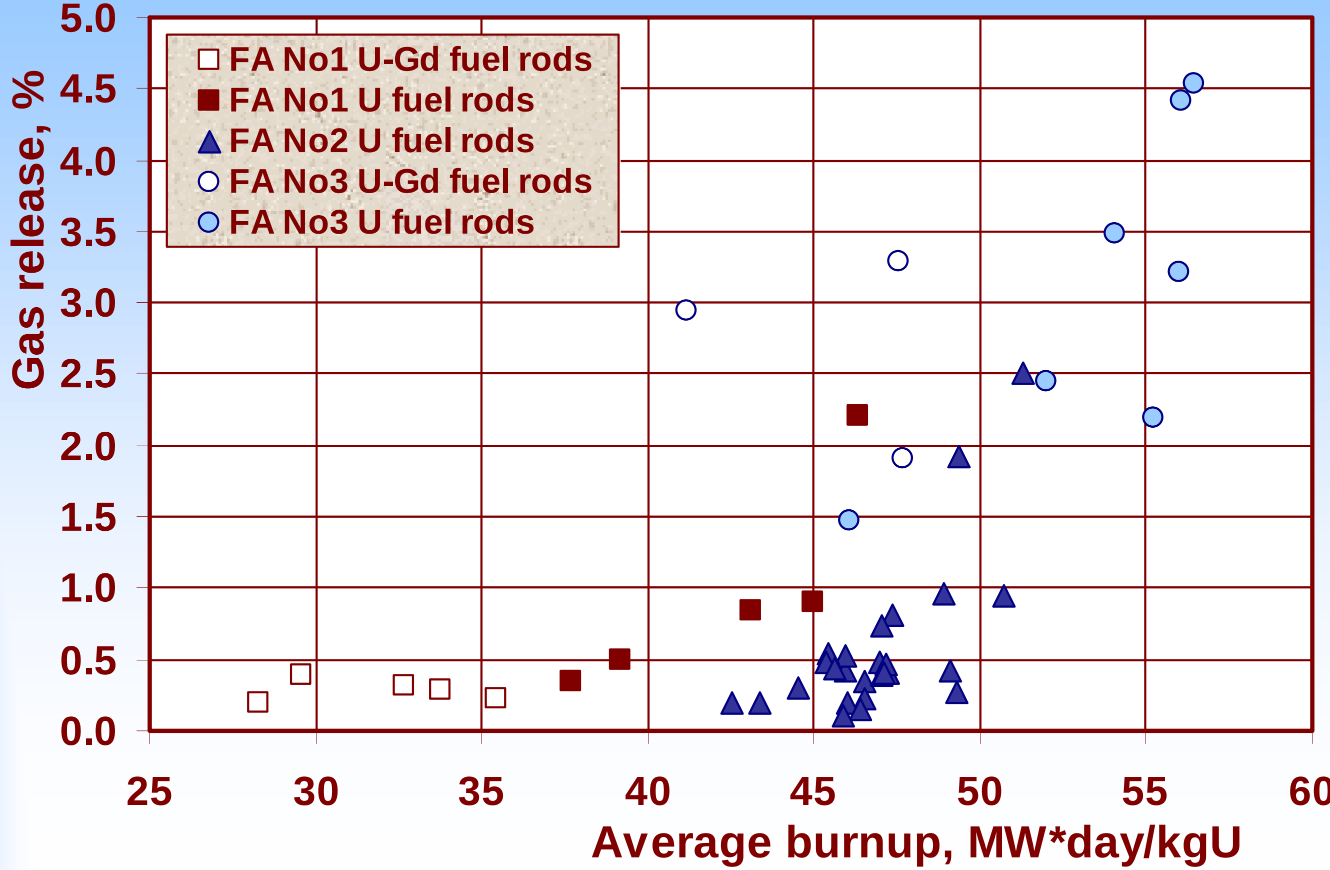


Dependence of fuel column elongation on burnup

- *elongation of fuel column has linear dependence on burnup in the examined range*
- *differences in swelling of U-Gd and U fuel were not detected*

Gd2O3 component didn't resulted in increase of fuel swelling under steady-state operation conditions.

Fission gas release from fuel



Dependence of fission gas release in U fuel rods and U-Gd fuel rods on fuel burnup

- *fission gas release becomes more intensive at burnup of ~45-50 MW*day/kgU*
- *in U fuel rods with a burnup of 57 MW*day/kgU fission gas release doesn't exceed 4.3%*
- *in U-Gd fuel rods at burnup of 48 MW*day/kgU fission gas release doesn't exceed 3.2%*

In the range of the examined burnup fission gas release doesn't result in strain in the claddings under conditions of the core.

Conclusions

- absence or insignificance of axial deformation due to fuel-cladding
- interaction (up to about 57 MW*day/kgU);
- achievement by U-Gd fuel rod claddings the same dimension variation at
- lower burnup as compared with U-Gd fuel rod;
- fuel-cladding contact at the burnup of ~50-55 MW*day/kgU for U fuel rods
- and ~45-50 MW*day/kgU for U-Gd fuel rods;

- appearance of local deformations of the claddings at the contact points of
- the pellets at the absence of the cladding diameter increase;
- gadolinium component doesn’t result in the fuel swelling increase;
- oxide film thickness doesn’t exceed 10 μm;
- fission gas release doesn’t result in appearance of strain in the claddings.

The PIE results of U and U-G fuel rods of the WWER-100 fuel assembly operated within 4 fuel cycles under steady-state operation conditions showed that their period is not exhausted.

None of the parameters and factors influencing the fuel service life (dimensional stability, cladding corrosion, swelling and gaseous product release from fuel) reaches critical values up to the maximum burnup of 64MW*day/kgU.

Likhanskii V.
TRINITI, Troitsk, Russia

Physical models and codes for prediction of activity release from defective fuel rods


Physical models and
for prediction of activity
release from defective
fuel rods
Likhanskii V., Evdokimov I., Khoruzhii O.,
Sorokin A. (TRINITI, Troitsk, Russia)
Novikov V. (VNIINM, Moscow, Russia)
Fifth International Conference on WWER Fuel Performance,
Modelling and Experimental Support, Albena, Bulgaria,
29 September - 03 October 2003
HOTEL
Albena

Outline

- **Introduction –brief review of existing Russian fuel codes**
  - **Fuel performance codes**
  - **Codes for design accidents analysis**
  - **Codes for management of fuel assemblies in NPP**
- **Physical processes in defective fuel rods controlling activity in primary coolant**
- **Ways to improve fuel management during operation in NPPs**

Russian Fuel Performance Codes

- **START-3 (VNIINM) – thermal, mechanical and FGR analysis of fuel rods under normal and transient conditions. The code includes options for high burnups. START-3 is official fuel performance code of JSC ”TVEL”.**
- **RTOP-2 (TRINITI) – thermal, mechanical and FGR analysis under normal transient conditions. The code includes options for high burnups. Detailed physical models for FGR and high burnups.**

Russian Fuel Performance Codes

- **PULSAR-2 ("Kurchatov Institute") – thermal, mechanical and FGR analysis of fuel rods under normal and transient conditions, includes detailed models for analysis of cladding mechanics.**
- **SPAN ("Kurchatov Institute") – thermal, mechanical and FGR analysis. High burnup and MOX fuel options are under development.**
- **TOPRA-1-2 ("Kurchatov Institute") – thermal, mechanical analysis up to high burnups.**

  TOPRA-s is used for simplified engineering calculations of fuel temperature (included in KASKAD neutron code)

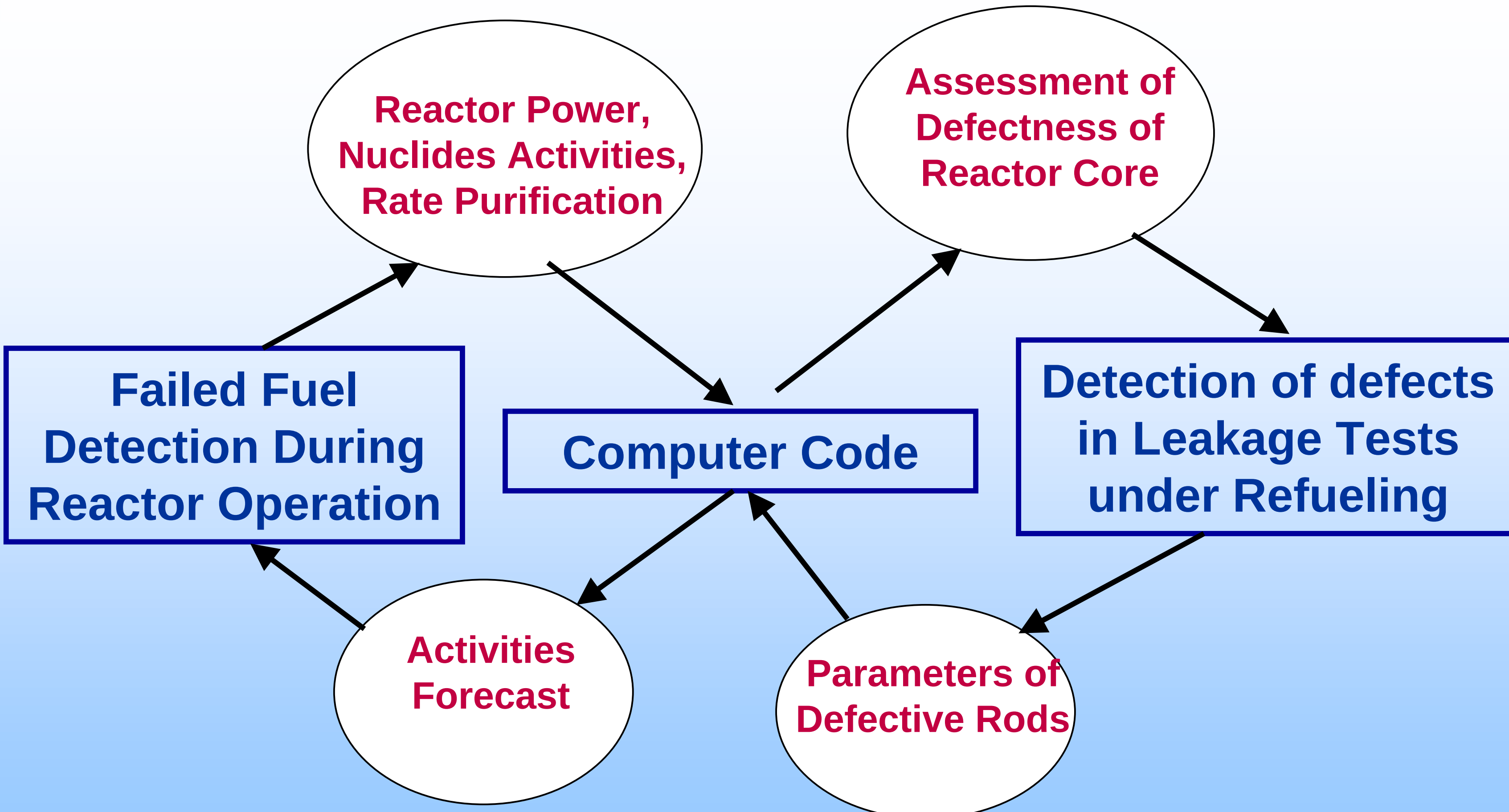
Russian codes for design accidents analysis

- RAPTA (VNIINM) – for design accidents analysis. The code is official code of JSC ”TVEL”.
- PULSAR+ (“Kurchatov Institute”) – for design accidents analysis.
- RTOP-R (TRINITI) RIA analysis.
- MFPR (IBRAE RAN & IRSN) – module for description of FG behaviour and chemically active elements at high temperature conditions.

Russian codes for management of WWER fuel in NPP

- **RELWWER-2.0 (“Kurchatov Institute”) – assessment of number of failed fuel rods and defect characteristics on the base of iodine activities measuring in primary coolant.**
- **RTOP-CA (TRINITI) – mechanistic models for assessment of number of failed fuel rods and defect characteristics on the base of FP activities measuring.**
- **RTOP-LT (TRINITI) – modelling of activity release in leakage tests under refueling.**

Integrated Approach to Defective Fuel Detection Problem



Conclusions

Development of codes and physical models for defective fuel analysis of reactor core is important for economy, safety and competitive ability of nuclear energy production

Recommendations to the following conference

- The conference participants recognised the usefulness of the present conference and recommended that another conference be organised in 2005, and that the hosts should again be INRNE in cooperation with the IAEA.
- High burn-up remains an issue and should be a feature of the next conference.
- Storage of WWER fuel is vulnerable to fission gas release and this should be a topic for the next conference.

Recommendations to the following conference

- FUMEX-II for fuel modelling should be supported.
- Provision of data to help modellers to understand the high burn-up and rim effect issues should be supported where possible.
- It will be possible to discuss existing similar problems in the fuels and exchange opinions on ways of their solution.
- The use IAEA-OECD-NEA PIE database for fuel modelling is supported.

Some statistics

- 60 scientific presentations
- more than 120 participants from more than 20 countries and 30 industrial, operational and scientific organisations