International Atomic Energy Agency

BEFAST and SPAR from 1981 to present: Thirty years of spent fuel behaviour, performance and research

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PIE – Inspection Techniques Meeting Series and BEFAST - SPAR Coordinated Research Projects

- **Since 1981 PIE and Inspection Techniques – required for the research and the assessment of the performance of spent fuel – is a technical meeting's series holding its seventh edition this week**

- **Spent fuel integrity and performance during wet and dry storage have been investigated since 1981 in five completed CRPs (BEFAST-I, -II, -III and SPAR-I, -II) and continues with SPAR-III**

- **Need for continuous work:**
  - **Higher burnups being achieved**
  - **Likely longer storage periods being foreseen**
  - **Wet storage incidents and accidents recently happened**

Short Term and Long Term Storage of Spent Fuel

(Draft Specific Safety Guide DS-371 Storage of Spent Fuel)

- **Short term storage (conventional storage) is defined in this Safety Guide as storage that could last up to approximately fifty years**

- **Long term storage is considered in this Safety Guide to be storage beyond approximately fifty years, and with a defined end point. The storage end point is important since it becomes the basis for the design lifetime of the facility, packaging requirements and financial guarantees and the planning basis for subsequent disposal facilities. Long term storage is not expected to last more than approximately one hundred years.**

BEFAST-I (1981-1986)

- Behaviour of spent fuel assemblies during extended storage, IAEA-TECDOC-414, IAEA, 1987
- 11 institutions from 10 countries. Because of delay in commercial reprocessing storage up to 30-50 years or more
- Aim: Provide a significant database on cladding integrity after extended wet and dry storage

BEFAST-I (1981-1986)

Objectives:

1) Survey existing experience worldwide
2) Investigate DT before and after extended storage (Shippingport, wet, 25 years)
3) Investigate cladding degradation mechanisms - theoretical, experimental (laboratory, pilot and full scale)
4) NDT for surveillance (conventional and new)
5) Behaviour of pool equipment (liner, rack, absorber)

BEFAST-I (1981-1986)

Main results:

1) Storage of Water Reactor Fuel in Water Pools, Survey of World Experience, TRS No. 281, IAEA, 1982
2) DT before and after extended storage (Shippingport, wet, 25 years)
3) Wet: all known failure mechanisms can be excluded in in proper conditions. Dry: No problem in inert gas at temperatures limited to 450 ºC
4) Wet: Fuel and environment is monitored (method development work ongoing). Dry: Only environment is mnonitored (fuel retrieved, Kr-85 in demonstratio programmes)

BEFAST-II (1986-1991)

- Extended storage of spent fuel, IAEA-TECDOC-673, IAEA, 1992
- 16 institutions from 13 countries. Though some new reprocessing facilities extended storage prior to reprocessing or disposal
- Three major topics: Long term behaviour, surveillance, and facilities & operation

BEFAST-II (1986-1991)

Reseach subjects:

1) Long term behaviour: Materials, degradation mechanisms and models, validation (experiments or experience)
2) Surveillance: Monitoring wet/dry (environment, components, fuel assemblies, operational doses), fuel conditions (operation, fabrication, failed rod and assembly), different reactor types
3) Facilities & operation: dose rate reduction, system performance, migration wet/dry, capacity enhancement (reracking, doped coolant, rod consolidation)

BEFAST-II (1986-1991)

Main results:

1) Extended wet storage of Zr alloy clad spent fuel is feasible even with through-wall defects for Magnox and AGR close chemical control of pool water is needed
2) Monitoring and surveillance confirmed that is needed to comply with water chemistry and temperature to prevent fuel degradation and preserve pool structural integrity
3) For extended wet storage (over 50 years) certain water pool liner materials (non-stabilized stainless steel require further investigation
4) For extremely long term storage (much longer than 50 years) need for further studies on fuel integrity and performance modeling are needed
5) Additionally to standard pool and hot cell inspection techniques, advanced monitoring techniques such as γ-scanning, neutron interrogation, ultrasonic inspection and electrochemical noise analysis are now being deployed

BEFAST-III (1991-1996)

- Further analysis of extended storage of spent fuel, IAEA-TECDOC-944, IAEA, 1997
- 16 institutions from 13 countries. Though some new reprocessing facilities extended storage prior to reprocessing or disposal
- Three major topics: Long term behaviour, surveillance, and facilities & operation

BEFAST-III (1991-1996)

Reseach subjects:

1) Long term behaviour: Validation (experiments or experience)

2) Surveillance: Monitoring wet/dry (environment, components, fuel assemblies, operational doses), fuel conditions (operation, fabrication, failed rod and assembly), different reactor types

3) Facilities & operation: system performance, migration wet/dry, heavily damaged fuel

BEFAST-III (1991-1996)

Conclusions:

1) PWR and BWR burnup is steadily increasing in the last decade from 40 to 50 GWd/tU resulting in: increase in fuel rod internal pressure, higher Zr alloy corrosion from longer residence time, increase in cladding H concentration from higher Zr allow corrosion
2) After 14 years co-operation the fundamental R&D questions have been answered so that licencing of both wet and dry storage is possible in most countries
3) Efects of extended burnup need to be assessed
4) Extrapolation for very long storage times (> 50 years, exceding the periods covered by the CRP) has yet to be confirmed

SPAR-I (1997-2001)

- Spent fuel performance assessment and research, IAEA-TECDOC-1343, IAEA, 2003
- 11 institutions from 10 countries
- Rapid evolution of dry storage technology, increasing burnups, new fuel materials and designs and extremely long periods of time (more than 50 years)

SPAR-I (1997-2001)

Overall objectives:

1) Perform research work to evaluate the technical basis for storing spent fuel for extended periods of time i.e. more than 50 years

2) Build a comprehensive database for supporting the licensing of present and future storage technologies

3) Assist in defining how storage requeriment are connected with the back-end of the fuel cycle

4) Exchage operating experience

SPAR-I (1997-2007)

Results:

1) An approach of compliance of results and objectives by project was adopted
2) Most project objectives were fulfilled
3) No general conclusion on the overall objectives were synthesized

SPAR-II (2005-2009)

- DRAFT TECDOC sent to the Publication Committee

IAEA Subprogramme 1.2.3 - Management of Spent Fuel from Nuclear Power Reactors (B.3)

B.3 Management of Spent Fuel from Nuclear Power Reactors

Project 1.2.3.1 - <u>Promoting strategies</u> for spent fuel management for established and newcomer nuclear countries (B.3.01)

Project 1.2.3.2 - <u>Providing technical guidance</u> on good practices for long term management of spent fuel (B.3.02)

Project 1.2.3.2 (B.3.02) 2006-2011

Providing technical guidance on good practices for long term management of spent fuel

Objectives: To **improve the capability** of interested Member States **to develop individually, or through international cooperation**, methods for **long term management** of spent fuel.

Outcomes: Use of Agency **guidance and technical information on good practices in long term** spent fuel **management** in interested Member States.

Project 1.2.3.1 (B.3.01) 2008-2011

Promoting strategies for spent fuel management for established and newcomer nuclear countries

Objectives: To **improve the capability** of interested Member States **to plan and implement** improved spent fuel management strategies by **identifying problems and fostering collaboration and using information** provided by the Agency

Outcomes: Increased use in Member States of **information** provided by the Agency **on state of the art technologies in strategies** for spent fuel storage **and overall** spent fuel **management** over longer periods of time **(100 years or more)**

B.3 Subprogramme Project & Activity Chart

B.3 (1.2.3)
Management of Spent Fuel from Nuclear Power Reactors

B.3.01 (1.2.3.1)
Promoting strategies for SFM

- Contribute to develop standards SF storage
- Costs of SFM options
- System integration considerations (potential interface issues)
- Multilateral cooperation in SFM
- SF treatment options and applications including reprocessing and recycling

B.3.02 (1.2.3.2)
Providing technical guidance on good practices for long term SFM

- Burnup credit for SF storage, transport and disposal
- Influence of high burnup and MOX fuels on SFM
- Storage facility operations and lessons learned
- Int. Conf. on Management of SF from NPR
- SF inventories
- **Very long term storage (VLST) of Used Nuclear Fuel**
- **CRP on SF Performance Assessment and Research (SPAR-III)**
- **CRP on SF Performance Demonstration**

Plan 2011 and beyond

- **Continued tasks (2011):**
  - Multilateral approach in SFM in the ASEAN region
  - Burn-up credit applications in SFM
  - Spent fuel treatment options including reprocessing
  - Impact of high burn-up UO_2 and MOX nuclear fuel on SFM
  - Costing of SFM options
  - System integration considerations (potential interface issues) in SFM
  - **Very long term storage (VLTS) of UNF (2010 - 2012)**
  - **CRP on SF Performance Assessment and Research (SPAR–III) (2009 [2010] - 2012 [2013])**
  - **CRP on SF Performance Demonstration (2010 [2011] - 2015)**

- **Some new activity proposals (2012-2013):**
  - Societal acceptance of the nuclear fuel cycle
  - Technology, Safety and Security of Spent Fuel Storage (Joint NE-NS activity)

PIE and Inspection in Wet and Dry Storage of Spent Fuel from Nuclear Power Reactors

- **Very long term storage (VLST) of Used Nuclear Fuel (1st TM April 2011 next TM April 2012)**
- **CRP on SF Performance Assessment and Research (SPAR–III) (1st RCM November 2010)**
- **CRP on SF Performance Demonstration (1st TM December 2011 or February 2012)**

PIE and Inspection in Wet and Dry Storage of Spent Fuel from Nuclear Power Reactors

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Thank you for your attention.

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