Issues and Challenges of Fast Reactors: Imaginative Breakthrough vs. Business as Usual

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Neutron excess discovered!!

DISCUSSION ON BREEDING

Excerpt from Report N-1729. (Notes on meeting of April 26, 1944).

Present: Fermi, Allison, Szilard, Wigner, Weinberg, Seitz, Morrison, Cooper, Vernon, Tolman, Watson, Ohlinger.

This leads to the equation

\[ \text{Breeding ratio (without losses)} = \frac{\nu_9 + \beta \nu_8 - 1 - \alpha - \beta}{1 + \alpha}. \]

What value of this ratio can we hope to obtain in a "fast" pile (with a core of 9 surrounded by 8)?

The most important term in (1) is \( \nu_9 - \alpha - 1 \). It can be evaluated essentially by a single experiment:

The neutron beam traversing a layer \( l \) cm thick of 9, is decreased by absorption and swelled by fission neutrons. The intensity of the transmitted beam is changed by a factor of

\[ 1 + \sigma_f l (\nu_9 - 1) - \sigma_f \alpha l \]

or

\[ 1 + l [\sigma_f (\nu_9 - \alpha - 1)]. \]

A simple transmission experiment thus permits to evaluate the expression in square brackets. The result of such an experiment, performed at Y is

\[ \nu_9 - \alpha - 1 = 1.85 \]
Whenever an option is considered for sustainability and optimized waste management, the initial Fermi intuition is confirmed and a fast neutron spectrum is consistently required.
A major medium/short term challenge

- At present, there is a convergence on the choice of Na as coolant, with oxide or metal (e.g. for high CR) fuel: how to account for innovation?

- Irradiation capabilities are, and will stay for some time, scarce.

- It seems also sensible to explore/develop a viable back-up option:
  - Lead and Nitride fuel?
  - Gas and Carbide fuel?
  - Other?

Both 1) an innovative Na-cooled Prototype and 2) an Experimental Reactor for a back-up option should/could be joint international initiatives

“The proof is in the pudding”
Medium term challenges

- Availability and reliability (a major utility requirement).
- Reversibility (from burner to breeder and vice versa: prepare for new technologies breakthrough)
- Convergence of safety approaches. Revisit re-criticality
- Fuel and clad performance: beyond 20-30 at% BU and beyond 200 dpa. Transient behaviour of MA-loaded fuel
- Plant simplification (intermediate circuit) and cost
- Conversion ratio higher than 1.5 and non-proliferation concerns
- Reduce uncertainties in all fields (advanced simulation and validation experiments)

Preliminary answers available for each of these challenges.
**Medium term challenges**

- **Availability**: look at the record of BN-600! Also remind the progressive increase of the load factor for LWRs during the last three decades…

- **Reversibility**: an early demonstration successful attempted in the frame of the CAPRA project

- **Recriticality**: the EAGLE experiment and the FAIDUS concept
Medium term challenges

- **Fuel and clad performance**: new ODS and fuel fabrication routes. MA in the fuel: GACID; METAPHIX experiment follow-up; Availability of TREAT?

- **Plant simplification** etc.: JSFR cost evaluation

- **Reduce uncertainties**: advanced simulation and validation experiments, if facilities are upgraded and kept available
Long term challenges

- Need to revisit the standard choice of a solid fuel?
- Simplified fuel cycle and waste management
- Reprocessing? Mostly associated to the choice of a solid fuel...
- Potential for ultra long life cores?
  Traveling-wave reactors?
- Innovative materials (gateway towards higher T and burn-up)
- Advanced simulation and future fuels design

Fast reactors offer a wide range of possible transformational concepts
Prepare for a « hundred years later... » celebration in...2044!
New actors. New agendas

This is an exciting time:

- The Monju restart-up
- new builds…

- new strategic requirements for fast reactor mission
- emergence of regional visions

How will coexist competition and enhanced international cooperation?
Final remarks

- R&D needs will still dominate the scene for the next 10-20 years

- „Business as usual“ is not a guarantee for success. „Imaginative breakthrough“ will be needed to innovate and to cope with the most crucial issues

- International cooperation will be essential:
  - to share experimental facilities
  - To converge on safety approach
  - to provide cutting edge opportunities for education and training

- Hopefully the revival represented by this conference will be confirmed by an expansion of innovative ideas and their realization.
Thank you for your attention