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„New Reactor Concepts“

An assessment

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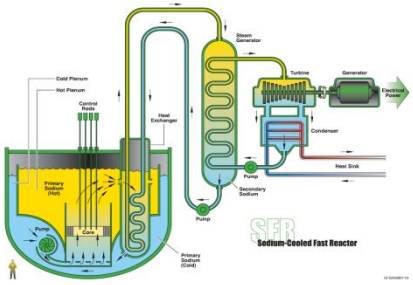
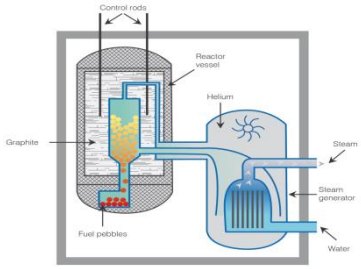
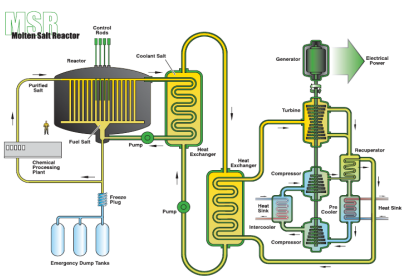
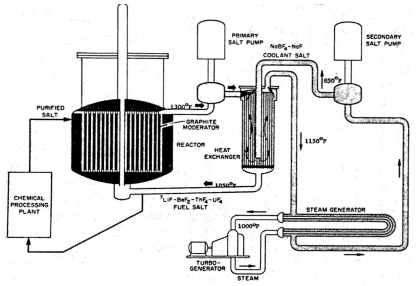








Agenda

1 Introduction

2 Selected Systems and Evaluation Criteria

3 Cross Cutting Topics

4 Systems Details

5 Conclusions

1

Introduction

Public Promises of „New Reactor Concepts“

In the Swiss press, promises with respect to new reactors have been made:

- 10.000 times less wastes
- Wastes remain dangerous for less than 1.000 years
- Electricity will be so cheap, even emerging countries can afford it
- Reactors are inherently safe, no severe accidents are possible
- Beause of Thorium as fuel, there will be no proliferation problem
- Reactors will be available on the market within 15 to 20 years

Short Study on New Reactor Concepts

- On behalf of the Swiss Energy Foundation (SES)
- Performed March/April 2017
- Literature analysis on selected „new reactor concepts“
  - Systems description
  - Historic and current experiences
  - Assessment with respect to evaluation criteria
- Some cross-cutting issues
  - Thorium as alternative ressource
  - Partitioning and Transmutation as waste management strategy
- 124 pages study download here: https://www.oeko.de/fileadmin/oekodoc/Neue-Reaktorkonzepte.pdf

2

Selected Systems and Evaluation Criteria

Selected „New Reactor Concepts“

- Fast Breeder Reactors, FBR
  - Only concept claimed to be commercially available
- High Temperature Reactors – HTR
  - Currently under development espescially in China
- Molten Salt Reactors, MSR
  - Only reactor concept with liquide fuel
- Small Modular Reactors, SMR
  - No specific reactor concept, but different approach to safety and economic issues

Evaluation Criteria

- Safety
  - Safety concept, inherent safety characteristics?
- Resources
  - Better use of resources, needed infrastructure?
- Waste
  - Reduction of new waste production, other waste characteristics?
- Economics
  - Favorable economics, low risks for investments?
- Proliferation
  - Less proliferation potential from cradle to grave?

3

Cross Cutting Topics

Thorium as alternative resource - Conlusions

- No need for thorium as alternative resource due to sufficient uranium supply
- In the very long term, possible need to breed fissile material: no significant difference between uranium-plutonium or thorium-uranium with respect to resources
- No existing infrastructure for thorium fuels world-wide
- No clear advantages for thorium fuels with respect to safety, wastes or economics
- With respect to proliferation, strong dependance on technical details of chosen fuel supply

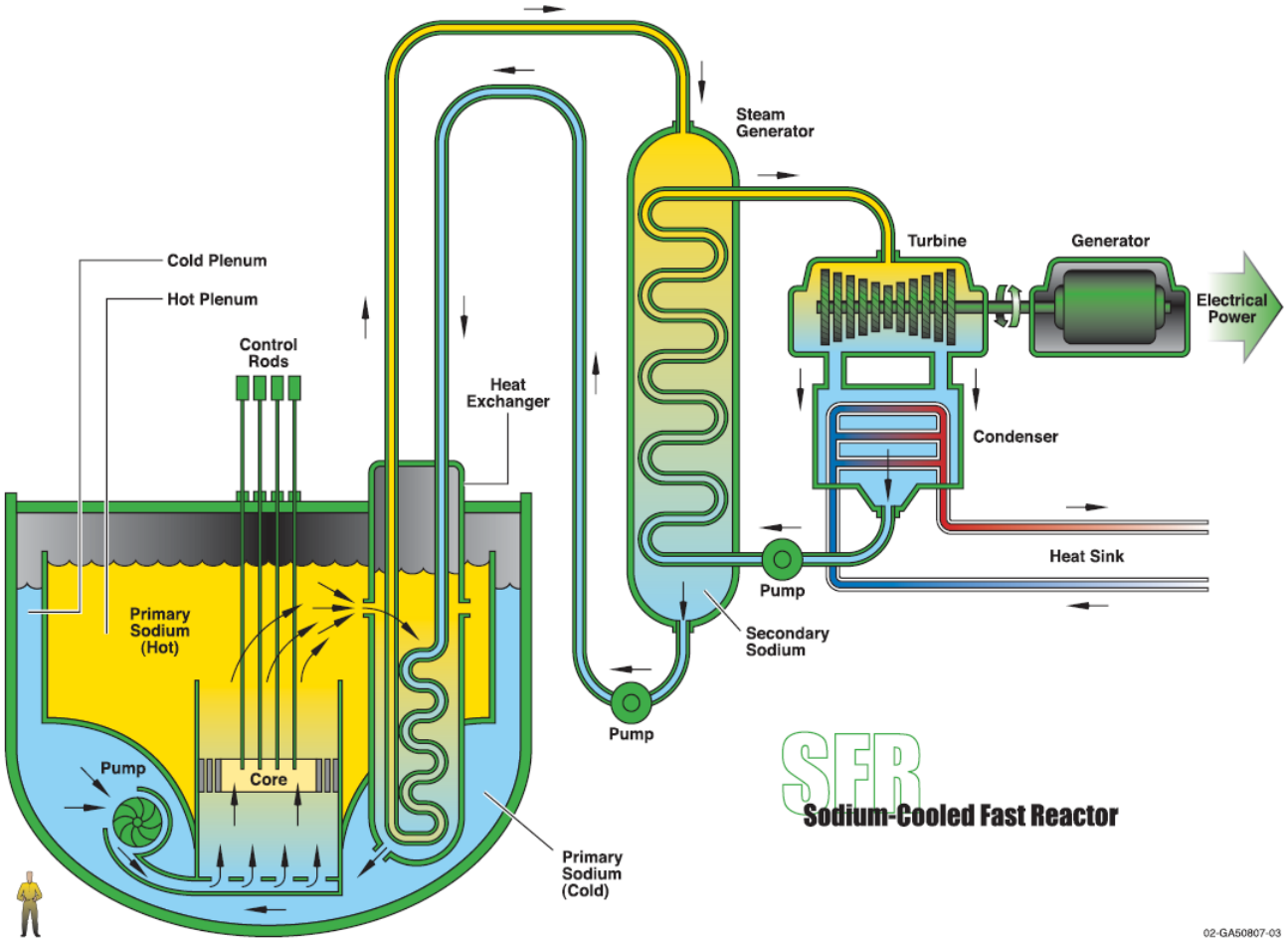
Partitioning and Transmutation - Conlusions

- Only P&T for transuranics in discussion today
- No significant reduction of required timescale for isolation of wastes from the biosphere achievable
- Required volume in geologic repository mainly determined by heat output of wastes, without additional treatment of fission products no relevant reduction of heat output achievable
- Significant amounts of low- and medium-level wastes to be expected
- While fissile material amounts in final repository might be reduced, significant proliferation potential during P&T realisation (decades to centuries)

4

Systems Details

Fast Breeder Reactors, FBR

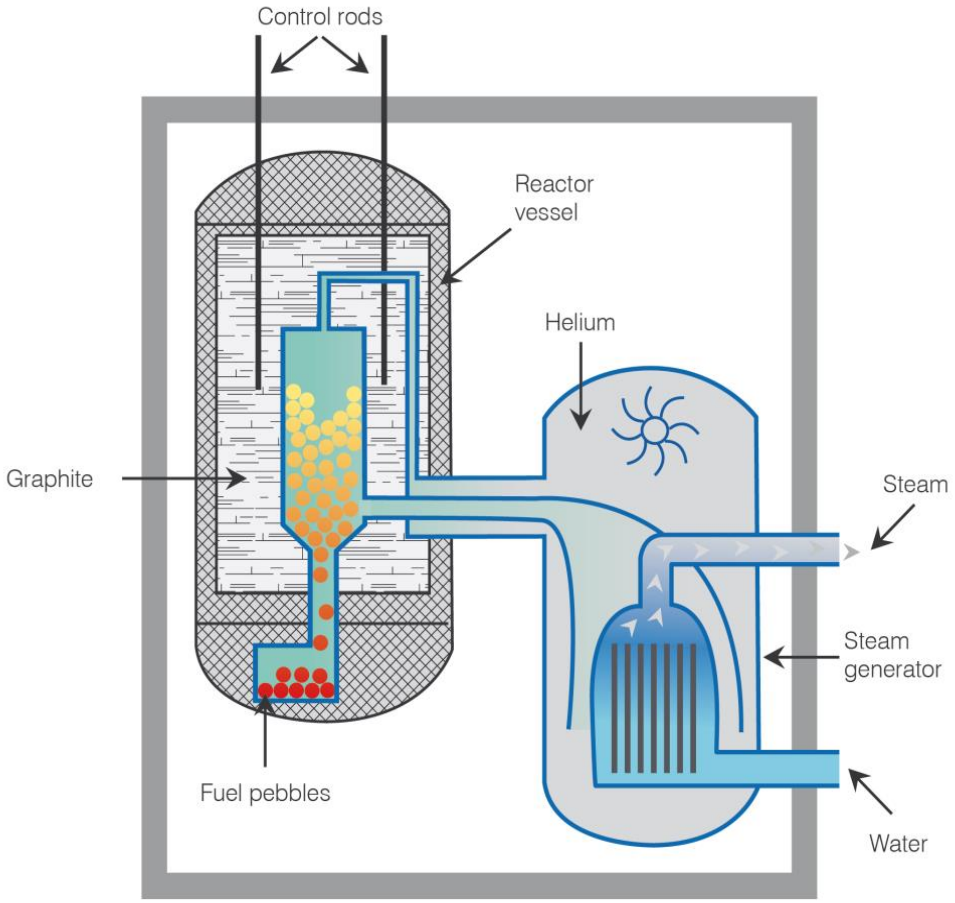


Quelle: GIF 2002

FBR - Conclusions

- More than 20 prototype reactors and 400 years of operational experience since 60 years of R&D, still no commercially viable system
- Fundamental aspect of breeding new fissile material not needed in the forseeable future
- Specific safety advantages and disadvantages, but safety record is bad up to now
- Significant disadvantage with respect to proliferation, as very high quality of fissile materials can be produced, but strongly depending on actual technical layout

High Temperature Reactors – HTR

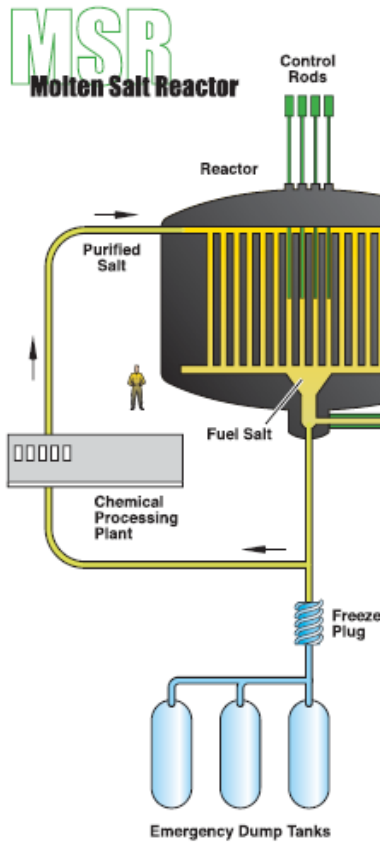


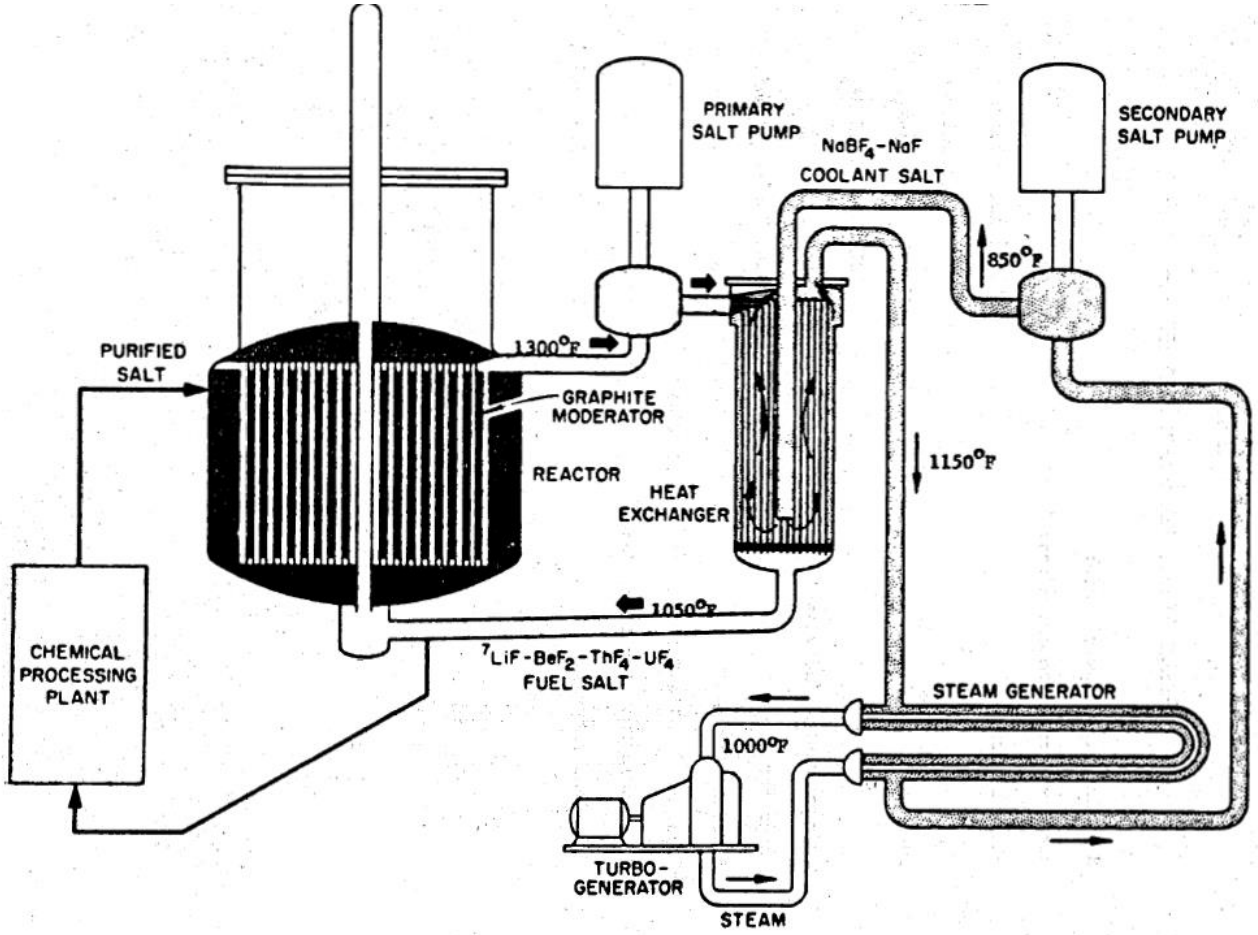
Quelle: WNA 2016c

HTR - Conclusions

- 60 years of development, several ambitious R&D programs (U.S., Germany, South Africa) have failed
- Possible specific safety advantages with respect to loss of cooling and fuel melt, but
- Other accident scenarios have to be considered in detail (air and water ingress, graphite fires etc.), thus no general conclusion
- Comparable waste problem, but different wastes characteristics (graphite) to be considered

Molten Salt Reactors, MSR



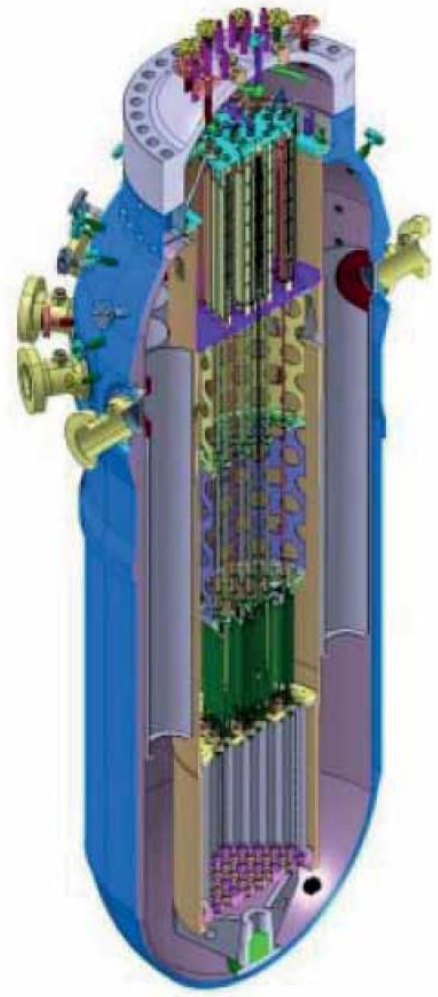


Quelle: GIF 2002, AEC 1972

MSR - Conclusions

- Considerable efforts on MSRs between 1940s and 1970s, revival after 2000
- Commercially viable system not to be expected before 2060
- Some safety advantages possible, but
  - Significant technological development needed (materials, instrumentation)
  - Severe radiation protection problems even during normal operation to be solved
- Different waste streams and other relevant nuclides (T, Cl-36, C-14)
- Breeding possible in principle, actual fuel concepts not decided yet
- Specific proliferation issues due to necessary on-line fuel reprocessing, conceptual description changes depending on focus (with/without breeding of pure fissile material)

Small Modular Reaktors, SMR



Quelle: IAEA 2012c

SMR - Conclusions

- Concept of modularity under discussion since 1960s, revival every now and then, mostly for „specific applications“ (like remote areas)
- All current and historical protoypes much more expensive than common LWRs: only hight number of standardised production may change economics
- Practically all reactor concepts are also discussed as SMRs, study focused on LWR-concepts
- Fundamental safety concept comparable to large LWRs, but in case of lower power and power density possible safety advantages
- Questions remain with respect to „passive“ safety features
- No clear differences with respect to fuel, wastes or proliferation, depending on actual type of SMR

5

Conclusions

Conclusions I

- “New Reactor Concepts” are old
- No major breakthroughs (game changers) identified
- No commercially available system at the horizon (some SMRs?)
- For some reactor concepts potential advantages with respect to single evaluation criteria are possible
- No concept will provide substantial advantages in all of the evaluation criteria simultaneously
- The different evaluation criteria compete with each other, advantages with respect to one criteria may lead to disadvantages with respect to another
- A new reactor concept, providing advantages only with respect to one or a view criteria will not lead to a higher public acceptance

Conclusions II

An academic reactor or reactor plant almost always has the following basic characteristics:

1. It is simple.
2. It is small.
3. It is cheap.
4. It is light.
5. It can be built very quickly.
6. It is very flexible in purpose ("omnibus reactor").
7. Very little development is required. It will use mostly "off-the·shelf“ components.
8. The reactor is in the study phase. It is not being built now.

On the other hand, a practical reactor plant can be distinguished by the following characteristics:

1. It is being built now.
2. It is behind schedule.
3. It is requiring an immense amount of development on apparently trivial items. Corrosion, in particular, is a problem.
4. It is very expensive.
5. It takes a long time to build because of the engineering-development problems.
6. It is large.
7. It is heavy.
8. It is complicated.

Quelle: Hyman Rickover, Journal of Reactor Science and Technology Vol III, No. 3 , June 1953

Vielen Dank für Ihre Aufmerksamkeit!
Thank you for your attention!

Haben Sie noch Fragen?
Do you have any questions?