Achievements and Prospects for Advanced Reactor Design and Fuel Cycles

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Consist of evolutionary designs and design requiring substantial development effort. It can range from moderate modifications of existing design to entirely new design concepts.

Advance design achieving improvements over existing designs through small or moderate modifications (strong emphasis on maintaining proven design features to minimize technological risks)

Advanced design that incorporates radical conceptual changes in design approaches or system configuration in comparison with existing practice

Cost of Development

- Engineering + Confirmatory Testing

Substantial R&D + Engineering + Confirmatory testing + prototype / demonstration plant
ACHIEVEMENTS

Let’s them believe...

Evolutionary designs or third-generation reactors have:

- A standardized design for each type to expedite licensing, reduce capital cost and reduce construction time,
- A simpler and more rugged design, making them easier to operate and less vulnerable to operational upsets,
- Higher availability and longer operating life - typically 60 years,
- Reduced possibility of core melt accidents,
- Minimal effect on the environment,
- Higher burn-up reduce fuel use and the amount of waste,
- Burnable absorbers ("poisons") to extend fuel life.

**Light and Heavy Water Reactors**

- **Commercial Operation**
  - WWER-1000 (RUSIA)
  - ABWR (JAPAN-USA)
  - KSNP (KOREA)

**Improved Safety**
- Low cost electricity
- High fuel efficiency
- 60 years plant life, 48 m construction
- Less waste

**Design Completed**
- EPR
- FRANCE-GERMANY
- NRC Certified


Light and Heavy Water Reactors

AP600
NRC CERTIFIED
September 2004
USA

ACR-700
CANADA

AP1000
USA

Improved Safety
Low cost electricity
High fuel efficiency
60 years plant life, 48 m construction
Less waste

AHWR
INDIA


Gas Cool Reactors

- GT-MHR
- PBMR
- HTTR

Modular Plants
- Low cost
- Direct cycle gas turbine
- High fuel efficiency
- Passive safety features


Also: Russia - Japan - India - Canada

- Modular Plants
- Passive features
- Non-electrical application
- 36 m construction
- 1000 $/KW install

Fast reactors

JAPAN

RUSIA

CHINA

CEFR

INDIA

@ Recycling Pu
@ Actinide burning
@ Desalination
@ Th Cycle

FRANCE

USA-FRANCE Agreement

SUPERPHENIX

Key research areas of NRC’s Advanced Reactor Research Program

1. Accident Analysis - risk assessment techniques, human factor tools, models to address advancements in instrumentation and control (I&C).

2. Reactor Systems Analysis - thermal-fluid dynamics, nuclear analysis, and severe accident codes and models.

3. Fuels Analysis - methods to assess coated fuel particle performance and higher burnup fuels.

4. Materials Analysis - codes and standards to address metallic and graphite components under high temperature operating and accident conditions.

5. Structural Analysis - methods to assess aging, degradation and impact of external events.

6. Consequence Analysis - tool enhancements to address differences in the mix of radionuclides and chemical forms.
Safety goals for future NPP from IAEA’s Safety Standards and INSAG documents:

1. A reduction in core damage frequency (CDF) relative to current plants;
2. Consideration of selected severe accidents in the design of the plants;
3. Ensuring that the releases to the environment in the event of a severe accident are kept as low as practicable with the aim of providing a technical basis for simplification of emergency planning.
4. Reduction of the operator burden during an accident by an improved man-machine interface.
5. The adoption of digital instrumentation and control.
6. The introduction of passive components and systems.

Advanced technologies in the Front end of the NFC

Fuel Assembly Design...

- Fuel assembly structure with internal water channel enables optimum moderation and thus best fuel utilization
- ULTRAFLOW™ spacer for excellent dryout performance
- Part length fuel rods for optimum axial fuel distribution and favorable stability performance
- High efficiency FUELGUARD™ debris filter

> Spacer grids with optimized swirl vanes provide enhanced thermal-hydraulic performance
> HTP spacer grids featuring line contact provide improved fretting resistance
> Reinforced structure provides high margins with respect to assembly bow (MONOBLOC™ guide tubes)
> High efficiency bottom nozzles (FUELGUARD™, TRAPPER™) effectively retain debris thus preventing fretting damage to the fuel rods
> Advanced cladding material IM5™ provides outstanding margins with respect to corrosion, hydriding as well as creep and growth


Advanced technologies in the Front end of the NFC

Fuel Assembly Design...

“I Contribution of Advanced Fuel Technologies to Improved Nuclear Power Plant Operation

Ralf Güldner & Friedrich Burtak – Siemens

DUPIC cycle anticipated benefits:

- Save of Unat for CANDU due to the reuse of PWR spent fuel.
- Removal of PWR spent fuel
- Reduction of CANDU spent fuel due to the increase of burnup
- Environmental benefit due to the transmutation effect of burning again PWR spent fuel.

DUPIC can be apply in countries with LWR and HWR at the proportion of 4 by 1.

Gaze Into The Crystal Ball...
Generation IV nuclear energy systems will:

- Provide sustainable energy generation that meets clean air objectives and promote long-term availability of systems and effective fuel utilization for worldwide energy production.
- Minimize and manage their nuclear waste and notably reduce the long-term stewardship burden in the future, thereby improving protection for the public health and the environment.
- Increase the assurance that they a very unattractive and least desirable route for diversion or theft of weapon-usable materials.
- Excel in safety and reliability.
- Have a very low likelihood and degree of reactor core damage.
- Eliminate the need of offsite emergency response.
- Have a clear life-cycle cost advantage over other energy sources.
- Have a level of financial risk comparable to other energy projects.
Comparative advantages include: reduced capital cost, enhanced nuclear safety, minimal generation of nuclear waste, and further reduction of the risk of weapons materials proliferation. The purpose of Gen IV is to develop nuclear energy systems that would be available for worldwide deployment by 2030 or earlier.

**Gen IV Fast Reactor Concepts**

The GFR’s and SFR’s fast spectrum also makes it possible to use available fissile and fertile materials (including depleted uranium) considerably more efficiently than thermal spectrum reactors with once-through fuel cycles.

The LFR battery is a small factory-built turnkey plant operating on a closed fuel cycle with very long refueling intervals (15 to 20 years) cassette core or replaceable reactor module.

...is a fast-spectrum lead or lead-bismuth eutectic liquid metal-cooled reactor and a closed fuel cycle for efficient conversion of fertile uranium and management of actinides.

The GFR’s and SFR’s fast spectrum also makes it possible to use available fissile and fertile materials (including depleted uranium) considerably more efficiently than thermal spectrum reactors with once-through fuel cycles.

...is a fast-neutron-spectrum, helium-cooled reactor and closed fuel cycle.

...is a fast-spectrum, sodium-cooled reactor and a closed fuel cycle for efficient management of actinides and conversion of fertile uranium.
Advanced technologies in the Front end of the NFC

New enrichment technologies currently being developed
- atomic vapor laser isotope separation (AVLIS)
- molecular laser isotope separation (MLIS).
- Each laser-based enrichment process can achieve higher initial enrichment (isotope separation) factors than the diffusion or centrifuge processes can achieve. Both AVLIS and MLIS would be capable of operating at high material throughput rates.

- In 1985 the US Government backed it as the new technology to replace its gaseous diffusion plants. After some US$ 2 billion in R&D, it was abandoned in USA in favor of SILEX, a molecular process.
- Development of AVLIS, and the French SILVA began in the 1970s.
- French work on SILVA has now ceased but continuo the MLIS technology evaluation.

New approach of reprocessing are needed for:
- P & T or P & C
- NFC for FR
- ADS

Pyrometallurgical processes:
- Molten salt bath (LiCl+KCl or LiF+CaF₂)
- Fuse Metals (Cd, Bi, Al)
- Electrochemical separation

UREX +

Pyro-processing

Technology Description
INPRO (INternational PROyect on Innovative Nuclear Reactors and Fuel Cycle) objectives are:

- Help to ensure that nuclear energy is available to contribute in fulfilling energy needs in the 21st century in a sustainable manner, and to
- Bring together both technology holders and technology users to consider jointly the international and national actions required to achieve desired innovations in nuclear reactors and fuel cycles.
INPRO
(INternational PROyect on Innovative Nuclear Reactors and Fuel Cycle)

Development of a Methodology for the Assessment of suitable INS for future deployment (Basic Principles User Requirements and Criteria on Economics, Sustainability and Environment, Safety, Waste Management, Proliferation Resistance and Infrastructure)

INPRO PHASE II

DEFINITION OF REGIONAL SCENARIOS AND METHODOLOGIES

INPRO METHODOLOGY APPLICATION TO REGIONS AND COUNTRIES UPON REQUEST

WORLDWIDE INVENTORY OF ONGOING R & D IN “INS” AND RELATED TECHNOLOGIES

COORDINATION OF R & D IN NON-COVERED AREAS AND/OR IN NON-GEN IV COUNTRIES

FINAL REPORT

AVAILABLES “INS”

• Burnup Increase increasing the enrichment. Only improved the Zry use.
• High Reactor efficiency with the results of higher cost of the NFC/Reactor system.
• Waste Storage is better at 700 m deep in isolate areas than in protected areas. Urge the decision of transport the spent fuel.
Second Approach

Disruptive technologies!

...upon C.M. Christensen definition

...is a technology that enters the market providing a product which has lower performance than the incumbent, but exceeds the requirements of certain segments thereby gaining a foothold in the market.
¡Disruptive technologies in INS!

Disruptive Concept
Gas Cool Reactor

500 U$S/KW

Disruptive Concept
Gaseous Diffusion
Enrichment Plant

50 U$S/SWU
Proliferation resistant-
Modular Plant

Disruptive Concept
Spent Fuel Dry Storage

Three time less expensive than metal casks
“Those who believe in progress run the risk of being born too early”

Oscar Wilde

Thank you very much... ...for your attention.