Proliferation Resistance of Nuclear Technologies

# *Molten Salt Reactors*

## *Minimizing the Inventory of Weapons-Usable Materials*

**Joint United States–Russian Study on Enhancing Proliferation Resistance of Nuclear Technologies**

**C. W. Forsberg**

**First Joint Study Workshop**

**Moscow**

**June 27–29, 2000**

## *An Assessment was Conducted to Determine What Type of Power Reactor Would be Most Proliferation Resistant Using the Primary Criterion of Proliferation Resistance: Minimization of the Chemically Separable, Weapons-Usable Fissile Inventory*

- **There were two secondary criteria**
  - **Significant work must have been done on the reactor concept**
  - **Weapons-usable fissile materials in core are to be of poor quality**
- **The evaluation determined the reactor characteristics that could best meet the previous criteria**
  - **Thorium-$^{233}$U fuel cycle**
    - **Sufficient $^{238}$U is added such as to make $^{233}$U nonweapons usable**
    - **Is self-sufficient in $^{233}$U production and utilization**
  - **Highly moderated thermal neutron spectrum**
    - **Suppresses plutonium inventory relative to $^{233}$U**
    - **Minimizes total fissile inventory and, thus, weapons-usable fissile inventory**
    - **Maximizes $^{242}$Pu production in the minimized Pu inventory**

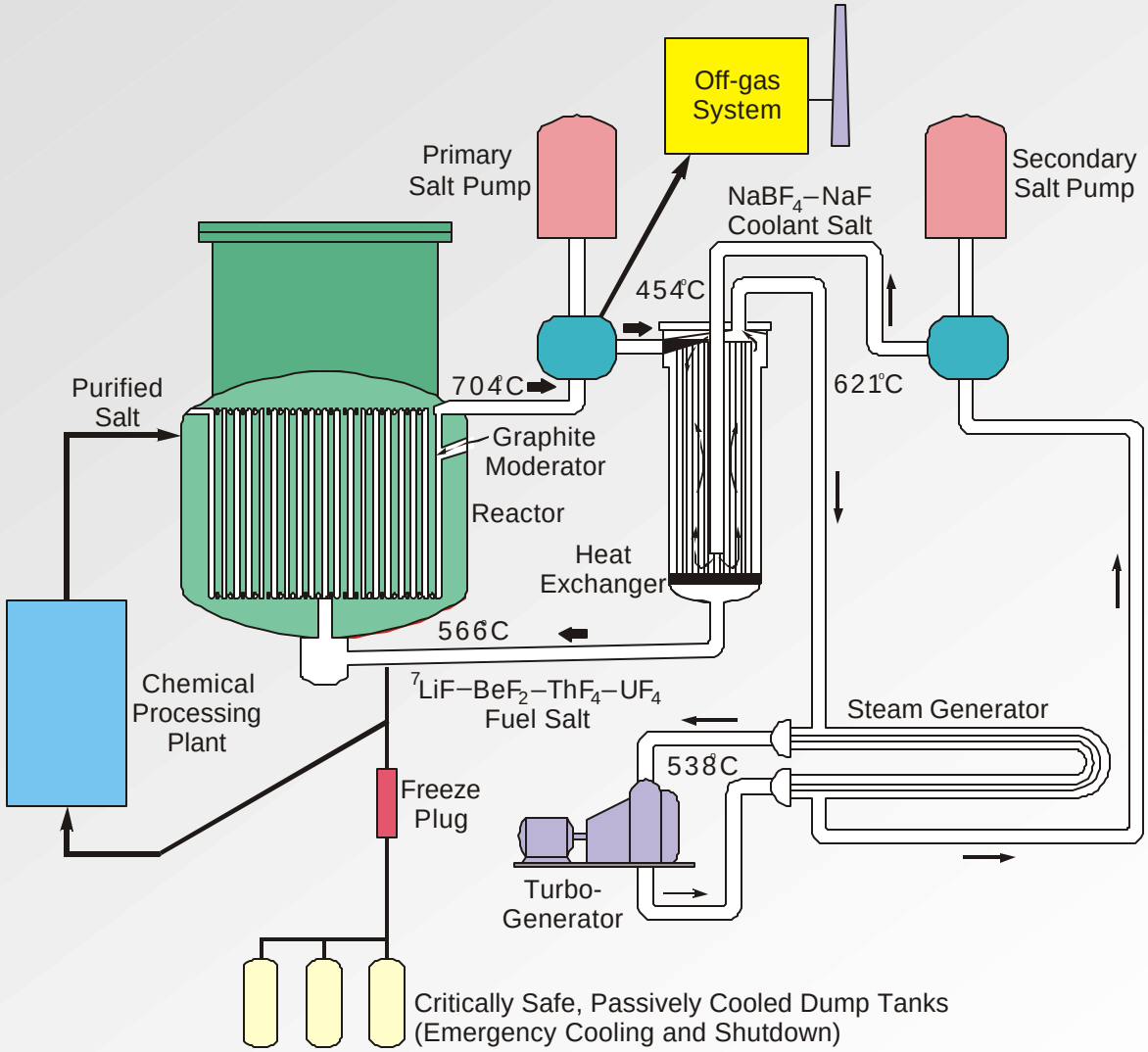
# *The Assessment Indicated That a Modified Molten Salt Reactor is the Preferred Reactor*

- **General characteristics for a 1000-MW(e) reactor**
  - **The chemically separable, weapons-usable inventory is very low**
  - **Plutonium-242 is the primary plutonium isotope**
  - **No spent nuclear fuel (SNF) is produced (except in final core residuals)**
    - **Fissile and fertile materials are never removed from reactor**
    - **Only fission products are removed from the molten salt**
- **Fuel cycle options**
  - **Stand-alone option**
    - **Reactor is started up on low-enriched uranium**
    - **Long-term feed is thorium and $^{238}U$**
  - **Weapons-usable, fissile-material converter (SNF converter)**
    - **Chemically convert light-water reactor (LWR) SNF to fluoride form [uranium/transuranic (TRU)/fission products]**
    - **Reactor converts fissile SNF fluorides to non-weapons-usable mixtures of $^{233}U$ in $^{238}U$**

# *Proliferation-Resistant Molten Salt Reactor—Status*

- **The United States had a large molten salt breeder reactor (MSBR) program in the 1960s and early 1970s. Consequently, a large base of technology exists**
  - **The MSBR was the backup for the fast breeder reactor program**
  - **The priority at the time was breeding $^{233}U$**
  - **A successful small prototype reactor was built and operated [8 MW(t)]**
- **Very limited studies were conducted on more proliferation-resistant MSBRs in the late 1970s**
  - **Conversion of $^{233}U$ to non-weapons-usable $^{233}U$ by adding $^{238}U$ was investigated**
  - **Concept for non-weapons-usable $^{233}U$ MSBR is viable**
  - **Reducing the small plutonium inventory was not investigated**
  - **The reactor analysis indicated that the small plutonium inventory could be reduced if design modifications were made**

# Proliferation-Resistant Molten Salt Reactor



# *Proliferation-Resistant Molten Salt Reactor—Proposed Areas of Research*

- **Research objectives**
  - **Quantify the potential proliferation resistance of a modified molten salt reactor**
  - **Assess long-term economic and environmental acceptability**
- **Research needs to meet objectives (priorities)**
  - **Develop a detailed reactor physics model to investigate weapons-usable fissile inventories as a function of design**
  - **Establish an acceptable measure of relative intrinsic weapons usability of different plutonium isotopes ($^{239-242}$Pu)**
  - **Develop updated fission-product removal system flow sheet, which is compatible with all goals**
  - **Evaluate LWR–molten salt reactor global fuel cycle with the objective of minimization of the global, chemically separable, weapons-usable fissile inventories**
  - **Identify and quantify potential installation vulnerabilities for bypassing safeguards**