A 5 MWe MOLTEN SALT DEMONSTRATION PLANT

Strategic Step Toward Molten Salt Reactor Deployment

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Molten Salt Fluoride Reactor
5 MWe, LEATO 5

- Homogeneous reactor, Generation IV.
- No melt down, Fluoride Salt + Uranium.
- No fuel rods.
- No cooling pond.
- Reference Plants, ARE (Aircraft Reactor Experiment) 2.5 MW thermal,
- Fuel NaF-ZrF4-UF4, 93 % enriched, peak temperature 880 ^{0}C, 1000 hr, core diameter 46 cm.
- MSRE, Molten Salt Reactor Experiment 7.5 MWth, 1964-69, diameter 55 inch, H 67 inch.
- Fuel Temp 650 ^{0}C, 5 years operation time,first full U-233/Thorium fuel reactor.

DEPLYOMENT SCHEDULE

- Time scenario, Tentative.
- First concept study ORNL report 2011,
- Preliminary design studies, May 2013,
- Basic and detail design 2014,
- Three years construction time,
- Expected criticality in 2019.

Preliminary Main Design Parameters
LEATO 5

Design Parameter	Value	Notes/Limit
Electric power (MWe)	5	
Thermal power (MWth)	To be determined	Thermal efficiency evaluation is undergoing
Fluoride fuel solution	$NaF-BeF_2-UF_4$	One region core
Uranium enriched (w/o)	19.75%	
Refueling schema	Uranium floride pellet	Cont. loading periodically
Average fuel temperature (C)	600	<704C, Hastelloy-N limit
Fluid melting temperature (C)	350 C	High F lower melting temp
Fuel volume (m^3)	0.83	
Power density	18 kW/liter	100 kW/liter limit
Primary coolant	CO_2	AGR as a reference
Secondary coolant	H_2O, steam	
Reactor vessel, estimated T/D/H (mm)	7.9 – 20/1800/1850	
Nuclear island	Underground	Decommissioning, security
Control rod	B4C	
Gas purge system	CO_2	
Hot-cell number (unit)	2	Fluid fuel purification waste
Reactor and auxiliary building (m)	25 x 35	12x35m crane, ARE
Nuclear island site	underground	Decommisioning, security

Schematic Drawing (1st Option)

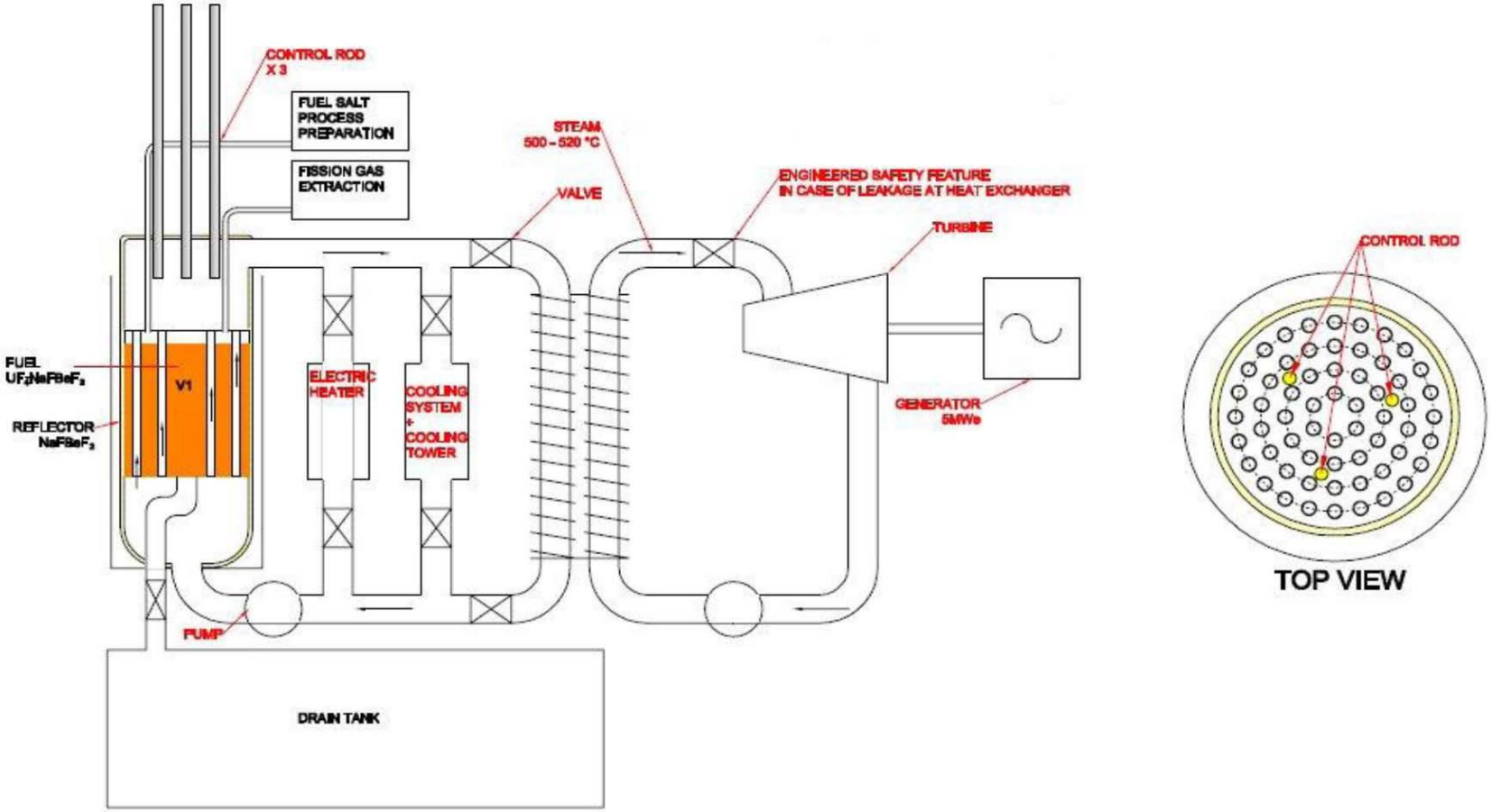


FIGURE 1. Schematic Drawing of LEATO-5 Demonstration Plant

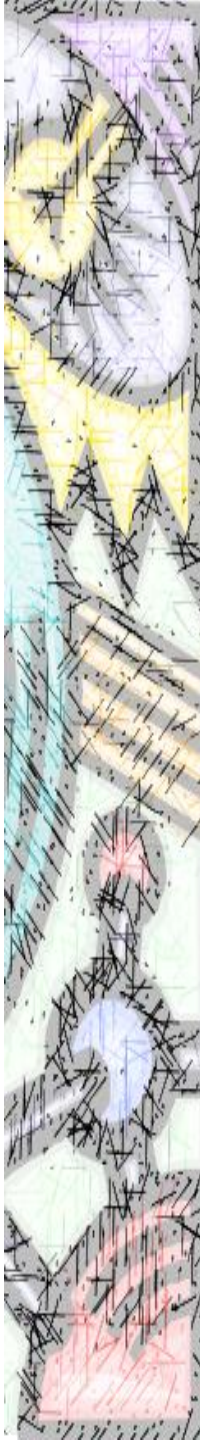
- Nuclear Island Innovative Molten Salt Reactor,
- Balance of Plant reference AGR, Advanced Gas Cooled Reactor.
- Engineered Safety Features.

Design Features and Characteristics

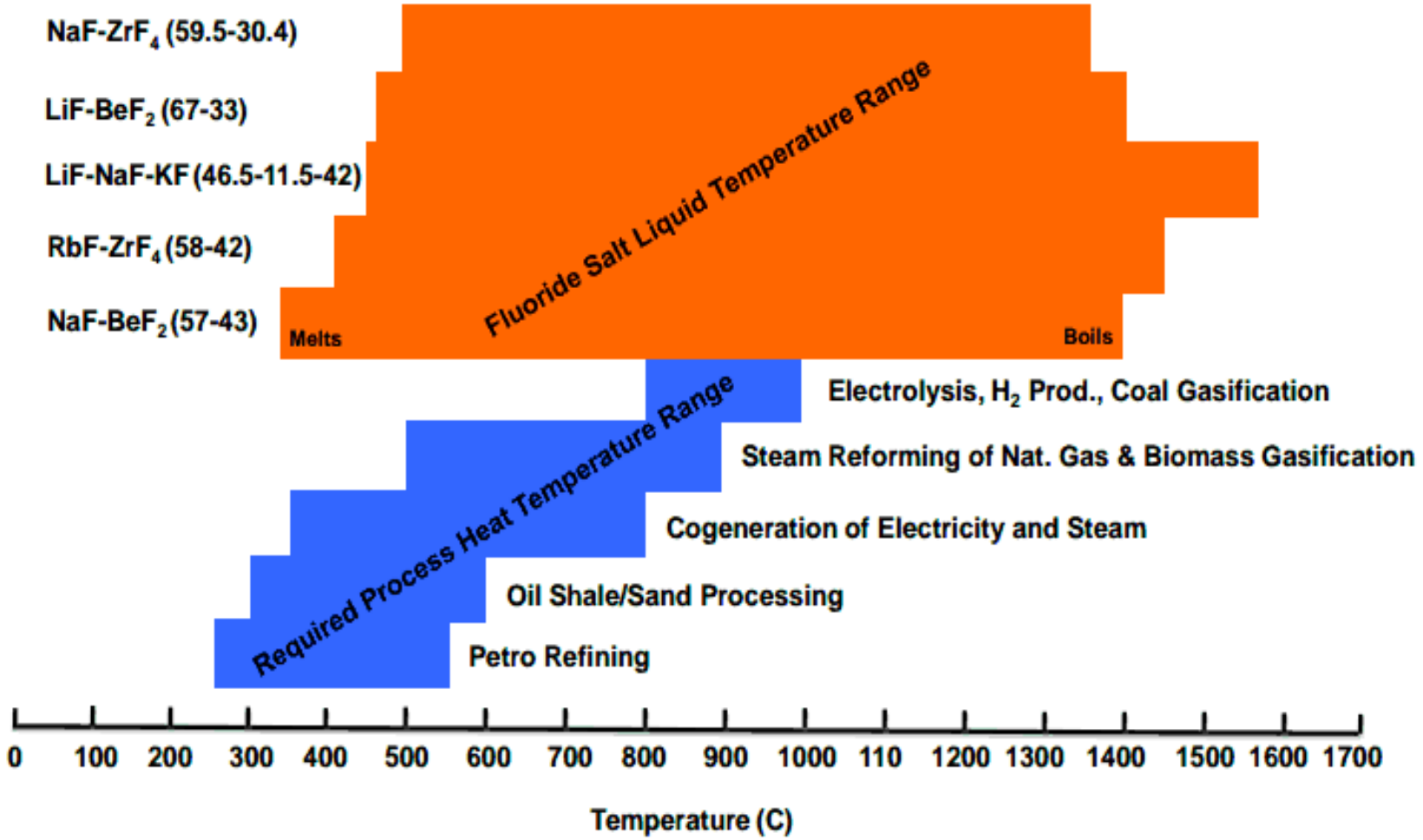
- Lack of radiation damage,
- No expense for fabricating new fuel,
- The possibility of continues gaseous fission products removal,
- Atmospheric pressure at high operating temperature,
- Large negative temperature coefficient,
- The ability to make-up fuel during operation, no excess reactivity,

Design Features and Characteristics….

- Safe for nuclear power excursion,
- Outstanding chemical stability, tested up to 880 ^{0}C,
- Wide variety of Molten Salt Solution, to be utilized for thermal, epithermal and fast neutron spectra.



Fluoride salt temperature characteristic



Design Challenges

- Long term fluoride salt corrosion effect,
- Fuel dynamics for long operation time,
- Licencing Issues
- Material for vessel, heat exchanger, tubing: Hastelloy N,
- ASME code limit the temperature below 704 ^{0}C

Design Requirement

- Optimal geometrical shape to fulfill Neutronics and Thermohydraulic requirement,
- Compatibility of the vessel materials and liquid,
- Good fluid flow patterns and power/temperature distribution, eddies, limit core power density < 100 kW/liter,
- Materials with low neutron poisoning,
- Adequate safety against core shell failure due to mechanical and thermal stress,

Design Requirement….

- Availability, fabricability and costs of materials,
- Vessel 1 and 2 for first and second safety barrier, class 1 components design,
- Transfer of fluid through pipes and tubes will utilize passive features, gravity and pressure differences,
- Cooling needed after shutdown around 13 hours.

The Off-Gas System

- Ability to maintain the concentration of Xenon and Krypton by removing the gases from the fuel system.
- The Removal of FP gases will reduce the effect of poisoning,
- For Power at 15 MWth estimate 4.75 kg FPs will be produced,
- Gas purge using CO_2 , trap and decay.

Manpower, Analytical Tools and Project Package

- Document for Work Break Down, based on ORNL-4541 have been prepared.
- Indonesian Patent Office File P 00201100263 will produce AHR for Radio-isotope production and MSR for power generation.
- Estimated number of scientsts , engineers and technician are around 64 staffs for basic design, and 135 staffs for detail design.
- ARE starting from scratch needed around 300 person including construction.

Manpower, Analytical Tools and Project Package….

- Analytical Tools for neutronics SRAC 2006 Cell Calculation, MVP continues energy Monte Carlo code with JENDL-3.3 based Libraries, DANTSYS and ORIGEN code.
- As for Thermal Hydraulics design and analysis MATLAB and Computational Fluid Dynamics for validation purposes.
- Project Packages foreseen,

1. **Nuclear Island class one components,**
2. **Balance of plant and power conversion unit,**
3. **Civil construction and HVAC,**
4. **Electrical and mechanical plus emergency diesel,**
5. **Licensing PSAR, FSAR, environmental impact report, soil study**

Concluding Remarks

- The World Energy demand is increasing with doubling time of 7 years or less years,
- A Liquid Fluoride-Uranium 233 -Thorium for the next generation,
- The system uses fluoride is one of the most promising one to meet the Generation IV requirement, for electricity and process heat,
- It is expected to have standard unit of 10, 50 MWe and 100 MWe module with overnight cost of $ 4000/kWe.
- A fresh look at government, private sector partnership for RD&D; research, development and demonstration is recommended.


Thank You