Status of the TMSR-SF1 Licensing Efforts

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TMSR Test Reactors

✓ TMSR-SF1: 10 MWth molten salt-cooled test reactor

- TRISO fuel particle, pebble fuel element;
- FLiBe primary coolant, FLiNaK secondary coolant;
- Graphite reflector;
- Nickel-based alloy structure material;
- Option for thorium fuel elements tests.

✓ TMSR-LF1: 2 MWth molten salt test reactor

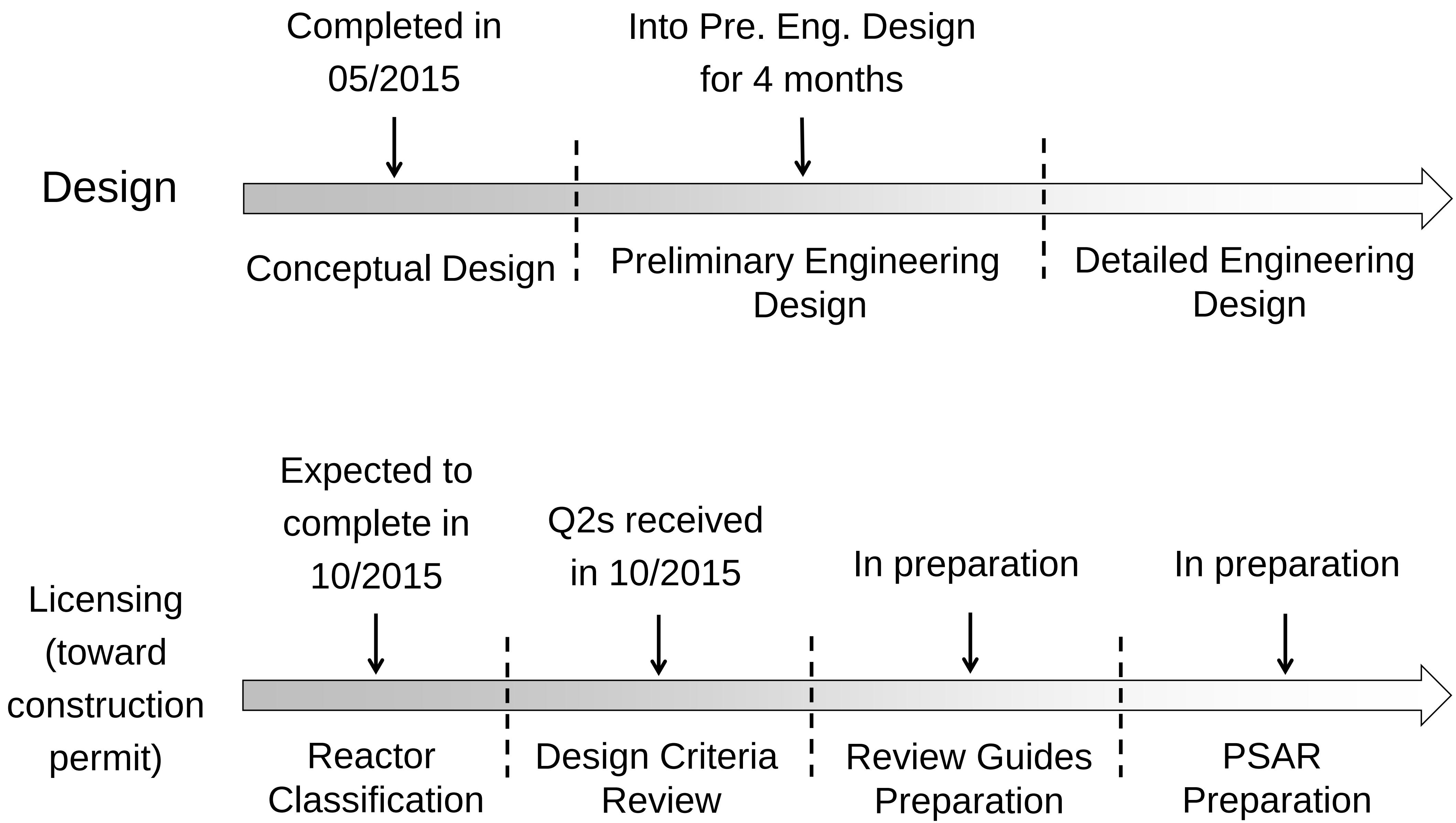
- Liquid fuel containing uranium and thorium;
- FLiBe primary coolant;
- Graphite moderator and reflector;
- Nickel-based alloy structure material.

Two-Step Licensing Process for Research Reactors

Stage	Supporting Documents	Minimal Lead Time	Permit
Siting	SAR and EIA for siting	6 Months*	Site Permit
Construction	PSAR, EIA, QAP, DC, etc.	12 months*	Construction Permit
Test-Operation	FSAR, EIA, QAP, etc.	12 months*	Initial Fuel Loading Permit
Operation	FSAR (updated), EIA, QAP, etc.	Not defined	Operation Permit

*For class II and III research reactors.

Progress of the TMSR-SF1 Design and Licensing



Challenges for Licensing of the TMSR-SF1

- ✓ Insufficient codes or guidance for advance reactors, especially for fluoride salt-cooled high-temperature reactors (FHRs) and molten salt reactors (MSRs).

- ✓ Most designers and reviewers have a strong PWR power plants mindset
  - People tend to apply PWR power plants rules directly to FHR and MSR test reactors.

- ✓ FHRs or MSRs are either first-of-the-kind reactors or haven't been operated for decades
  - Unlike other advance reactors built in China.

Classification of the Research Reactors

- ✓ The National Nuclear Safety Administration (NNSA) of China classifies all research reactors into three classes
  - Class I: criticality experiments, zero-power reactors;
  - Class II: medium-power research reactors that do not necessarily follow nuclear power plants rules;
  - Class III: high-power research reactors that follow nuclear power plants rules.

- ✓ Criteria for classification
  - Potential source terms - power level: 500 KW and 10 MW thresholds;
  - Safety features;
  - Consequence of radiological release.

Consequence of the Radiological Release

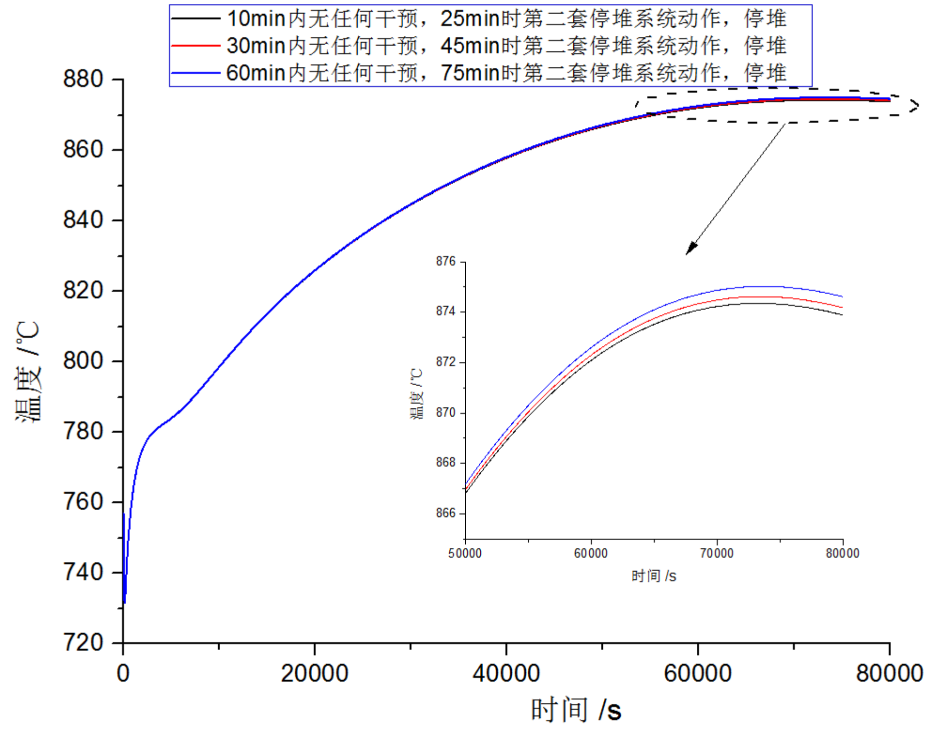
✓ We adopted action levels (dose limits) that defined in the emergency preparedness requirements as the quantitative criteria for evaluating the consequence of the radiological release.

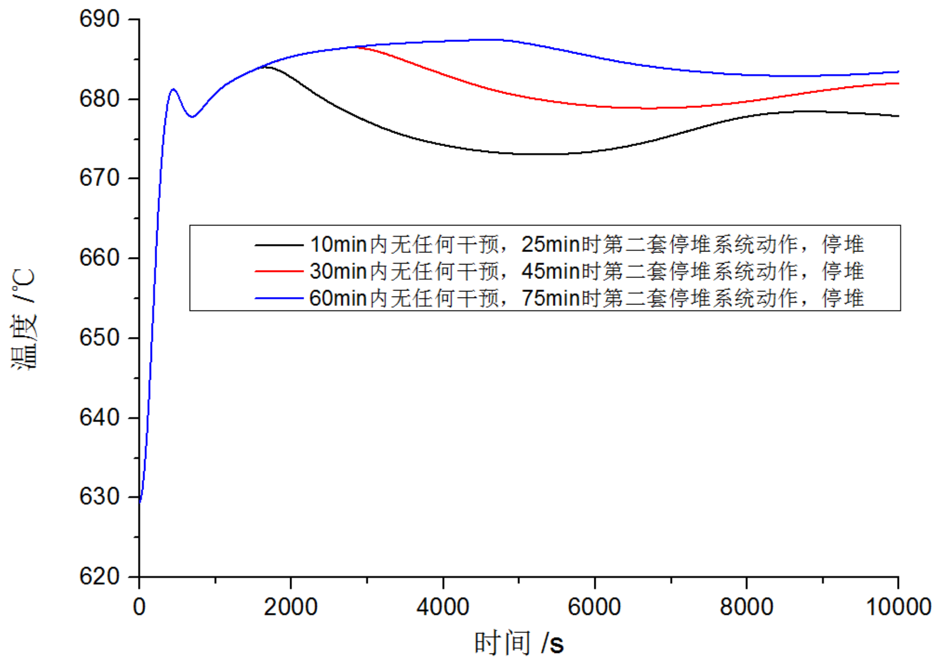
Emergency Class	**Action Level**
Alert	0.15 mSv, whole body accumulated effective dose equivalent in 24 hours at exclusive area boundary.
Plant Emergency	0.75 mSv, whole body accumulated effective dose equivalent in 24 hours at exclusive area boundary.
Site Area Emergency	3.75 mSv, whole body accumulated effective dose equivalent in 24 hours at exclusive area boundary.
General Emergency	10 mSv, whole body accumulated effective dose equivalent caused by radioactive plume at exclusive area boundary.

Values from the research reactor emergency planning and preparedness (HAD002/06) table 1.

Determine the Bounding Event

- ✓ Analyzed typical AOOs, DBEs and BDBEs
  - Inadvertent removal of one control rod under full power operation;
  - Trip of primary loop pump caused by locked rotor;
  - Inadvertent increase of intermediate loop flow rate;
  - Minor break in primary loop;
  - Release of the primary cover gas;
  - Station blackout caused by flooding;
  - Station blackout without scram (results shown on the right).
- ✓ PRA methods were used to support the analyses.
- ✓ Conclusion: The total release of the primary cover gas is the bounding event in terms of the radiological consequence.





Transport of Isotopes

- ✓ Fission products from TRISO fuel
  - Uranium contamination introduced in fuel manufacturing;
  - Fuel damage caused by irradiation;
  - Diffusion of nuclides from the fuel kennel;
  - Kr, Xe, I, Cs, Sr, Rb-88 and Ag-110m.
- ✓ Activation products from coolant, graphite and structure material
  - Tritium, C-14, N-16, O-19, F-20, Co, Ni, Mn, and Fe.
- ✓ Transport of isotopes from coolant to cover gas
  - Kr, Xe, and part of I, C-14 and tritium in cover gas;
  - Others stay in the coolant.
- ✓ Radioactive isotopes in the cover gas are the major sources that may cause radiological consequence.

Calculations of the Dose

- ✓ SCALE and other codes developed by ORNL used to calculate the inventory in the fuel and activation products in the primary loop.
- ✓ FRESCO-II and data from HTR-10 used to calculate the radioactive isotopes release rates of the TRISO fuel.
- ✓ Data from MSRE used to estimate the share of the radioactive isotopes in the primary coolant and in the cover gas.
- ✓ No credit taken from the reactor building when calculating the release.
- ✓ Method defined in NRC Regulatory Guide 1.145 used to calculate the dose.

Current Status and Path Forward

- ✓ In the final stage to demonstrate that the TMSR-SF1 is a Class II research reactor
  - Provide an alternative to following PWR power plant rules;
  - Significantly simplify design, construction, maintenance, etc.

- ✓ Set the total release of the primary cover gas as the bounding event
  - Set up a basis in site evaluation, environmental impact assessment, emergency planning, safety analysis, etc.

- ✓ To complete the design criteria, review guides and PSAR of the TMSR-SF1 based on the Class II reactor work.