

Molten Salt Reactor Standards Review

Nicholas Smith

Chair, Molten Salt Reactor Technology Working Group (MSR TWG)

Molten Salt Reactor Technology Working Group (MSR TWG)



- *Molten salt reactors represent the future of nuclear energy on the basis of being clean, safe and cost-effective means of meeting increased energy demands on a sustainable basis.*
- *The six member companies of the MSR TWG collaborate to influence policy makers and work on common R&D scope.*
- *Active projects include:*
 - *Engagement with international partners through Nuclear Energy Agency (NEA)*
 - *The International Experimental Thermal-Hydraulic Systems Database (TIETHYS)*
 - *Participation in NEAMS Executive Advanced Reactor Industry Council (NEARIC)*
 - *Review of consensus standards and guidelines related to MSR licensing*



Terra Power

Fast
Breeder
Liquid Fuel
Salt Cooled
Uranium
(Could use Th)

Thorcon

Thermal
Burner
Liquid Fuel
Salt Cooled
Thorium

**Terrestrial
Energy**

Thermal
Burner
Liquid Fuel
Salt Cooled
Uranium
(Could use Th)

Flibe Energy

Thermal
Breeder
Liquid Fuel
Salt Cooled
Thorium

**Transatomic
Power**

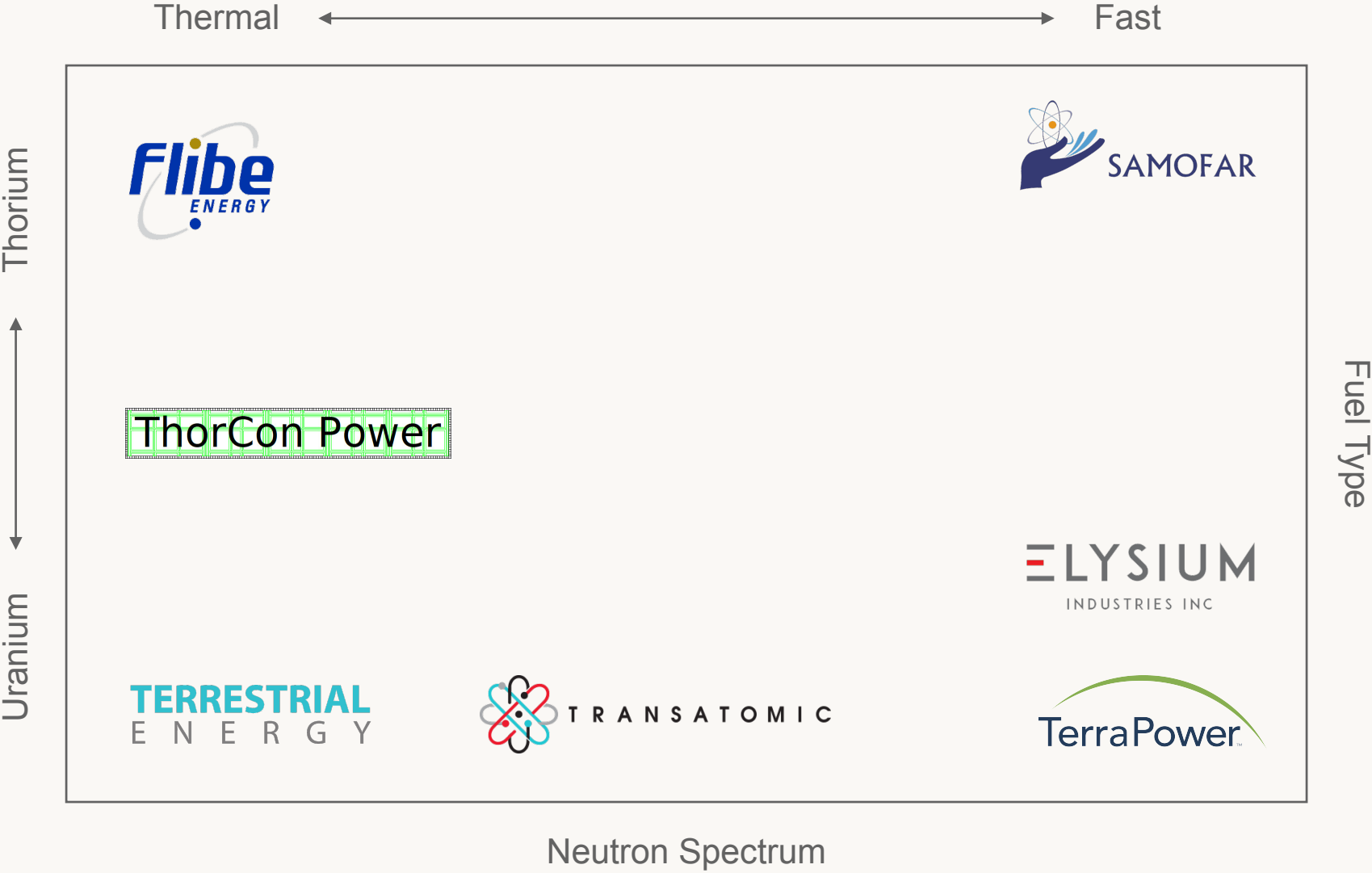
Hybrid
Burner
Liquid Fuel
Salt Cooled
Uranium

**Elysium
Industries**

Fast
Breeder
Liquid Fuel
Salt Cooled
Uranium



MSR Design Space



Introduction



- *Most Nuclear power plant consensus standards were developed for LWRs*
- *MSRs differ from LWRs in many ways – notably liquid fuel*
- *Different standards desired to license MSRs*
- *This list is not comprehensive*

American Nuclear Society (ANS)

ANS 3.2 – Managerial, Administrative, and Quality Assurance Controls for the Operational Phase of Nuclear Power Plants



- *BWR/PWR specific standard*
- *Modify for typical procedures used by MSRs*
- *Referenced by RG 1.33*

ANS 3.5 – Nuclear Power Plant Simulators for Use in Operator Training and Examination



- *LWR centric standard*
- *Modify so it applies to MSR designs*
- *Referenced by RG 1.149*

ANSI/ANS-5.1-2014, Decay Heat Power in Light Water Reactors



- *Clearly an LWR centric standard*
- *Comparable standard desired for MSR*s
- *Referenced by RG 1.157*

ANS 6.4 Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants



- *MSRs would utilize an update to this standard*
- *New temperature requirements, different spectrum*
- *Changes calculation of both dose and concrete thickness*
- *Referenced by RG 1.69*

ANS 15 Series Standards for the Operation of Research Reactors



- *Need to be re-examined for applicability to MSR*s
- *Referenced by NUREG-1537*
 - *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors*

ANS 15 Series Standards for the Operation of Research Reactors



- *15.1: The Development of Technical Specifications for Research Reactors*
- *15.4 : Selection and Training of Personnel for Research Reactors*
- *15.7 : Research Reactor Site Evaluation*
- *15.8 : Quality Assurance Program Requirements for Research Reactors*
- *15.10 : Decommissioning of Research Reactors*
- *15.11 : Radiation Protection at Research Reactor Facilities*
- *15.12 : Design Objectives for and Monitoring of Systems Controlling Research Reactor Effluents*
- *15.15 : Criteria for the Reactor Safety Systems of Research Reactors*
- *15.16 : Emergency Planning for Research Reactors*
- *15.17 : Fire Protection Program Criteria for Research Reactors*
- *15.19 : Shipment and Receipt of Special Nuclear Material (SNM) by Research Reactor Facilities*
- *15.20 : Criteria for the Reactor Control and Safety Systems of Research Reactors*
- *15.21 : Format and Content for Safety Analysis Reports for Research Reactors*

ANS 20.2 Nuclear Safety Design Criteria and Functional Performance Requirements for Liquid-Fuel Molten-Salt Reactor Nuclear Power Plants



- *Request that NRC endorse this standard*
- *Alternative to Appendix A of 10 CFR Part 50*
- *Equivalent of standards referenced in DG-1330 for HTGRs and SFRs*

ASME/ANS RA-S-1.4-2013: Probabilistic Risk Assessment Standard for Advanced Non-LWR Nuclear Power Plants



- *Does not need to be revised*
- *Equivalent of LWR PRA Standard*
- *Has not been formally endorsed by NRC yet*

American Society of Testing and Materials (ASTM)

There are a lot of ASTM Standards.



- *Over 12,000 ASTM standards total*
- *223 ASTM standards referenced in NRC Regulatory Guides*

ASTM Standards Relevant to MSR:



- *Standards related to material coatings*
- *Standards related to determining physical and chemical properties of molten salts*
 - *A few exist but at wrong temperature range*
- *Standards related to measuring volatiles specific to MSRs (off-gas system)*

American Society of Mechanical Engineers (ASME)

Nuclear Quality Assurance (NQA-1)



- *Technology inclusive as is*
- *MSRs plan to utilize this standard*
- *Referenced by RG 1.28*

ASME BPV Code Section III: Rules for Construction of Nuclear Facility Components



- *Division 1: Metallic Components*
- *Division 2: Concrete Containments*
- *Division 3: Transportation and Storage of SNF and High Level Radioactive Material and Waste*
- *Division 5: Construction of High Temperature Reactors*

Institute of Electrical and Electronics Engineers (IEEE)

IEEE I&C Standards Relevant to MSRs



- *Instrumentation standards in MSR core systems*
 - *Existing controls standards should be generally applicable*
- *I&C standards for fuel salt ex-core*
 - *i.e. Off-Gas System, Fuel Filtration*

Other IEEE Standards Relevant to MSRs



- *Current standards for “cave-man” battery technology*
- *MSRs likely to take advantage of Li-ion or better*
- *Robotics standards and remote maintenance*

American Concrete Institute (ACI)

ACI Standards Relevant to MSRs



- *Likely applicable to MSRs but may require research and testing*
- *Higher temperatures*
- *Additionally, fast flux and lack of water shielding could change requirements*

American Society of Civil Engineers (ASCE)

ASCE Standards Relevant to MSRs



- *Seismic standards are likely generally applicable*
- *MSRs would utilize an endorsed standard on seismic isolators*
- *Japanese standard JEAG 4614 could be translated and implemented as ASCE standard*

National Fire Protection Association (NFPA)

NFPA 805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants



- *Focus on LWRs*
- *MSRs would utilize an appropriate Fire Protection standard*
- *Referenced by RG 1.189*

International Atomic Energy Agency (IAEA)

IAEA Standards Relevant to MSR



- *Current solid fuel safeguards practices cannot be directly applied to liquid fueled systems*
- *No longer counting fuel rods*
- *Safeguards-by-Design for MSRs*

Key Takeaways



- *There is a lot of work ahead of the MSR community related to standards.*
- *Materials and I&C standards are likely the biggest risk to MSR licensing as they will be challenging to come to a consensus on in a timely manner.*
- *DOE has previously funded a standards gap analysis for SFRs; however, this work was not funded for MSRs in FY'18.*
- *The MSR TWG would like DOE to fund a formal standards gap analysis for MSRs and support the closure of these gaps.*
- *Active participation by NRC SMEs in development and revision of key MSR standards is beneficial to NRC and designers; Such participation should be encouraged by NRC management.*

