Thorium-Based Siloxanes and Silicones

A Technical Assessment of Feasibility as a Non-Corrosive Alternative to Molten Salt Reactors (MSRs)

Executive Summary

While **thorium metallosiloxanes** (compounds containing Th-O-Si linkages) successfully exist in advanced inorganic research, they are entirely unsuitable as liquid fuel carriers or structural replacements for conventional molten salts in a nuclear reactor environment. Molten Salt Reactors (MSRs) use ionic salts (such as LiF-BeF■-ThF■) because ionic bonds tolerate extreme radiation and heat. In contrast, organosilicon compounds rely on covalent bonds that suffer catastrophic degradation under reactor conditions.

1. Chemical Synthesis & Structural Reality

Thorium can be complexed with siloxanes, but through distinct pathways that differ dramatically from commercial silicone plastics:

- **Thorium Siloxide Complexes:** Synthetic chemists react thorium halides (e.g., ThCl■) with bulky alkali metal silanolates to build molecular structures dominated by Th-O-Si bonds.
- **Tripodal Frameworks:** These systems use heavy, highly branched organic ligands to trap and stabilize a central thorium atom, primarily for catalytic study.
- **Absence of Polymers:** Long, flexible silicone-like fluids containing thorium do not naturally form because the massive thorium atoms heavily distort polymer geometries, favoring discrete molecules or rigid crystalline matrices over flexible chains.

2. Feasibility Assessment as an MSR Fluid Alternative

The primary appeal of standard siloxanes is their non-corrosive, inert nature at room temperature. However, this property breaks down completely when subjected to the interior environment of a fission reactor core. The table below details why a thorium-siloxane framework cannot substitute for ionic molten salts:

Property / Hazard	Ionic Molten Salts (MSR Standard)	Organosilicon / Siloxane Alternatives
Bond Type	**Ionic Bonds:** Atoms are electrostatically attracted. When broken by radiation, they immediately recombine.	**Covalent Bonds:** Sharring electrons. Radiolytic cleaving causes irreversible decomposition.
Radiation Stability	**Exceptional:** Immune to permanent structural radiation damage (radiolysis).	**Catastrophic:** High neutron and gamma flux breaks Si-C and Si-O bonds, causing severe cross-linking and gas release.
Thermal Limits	**Extremely High:** Thermally stable up to and beyond 1400°C without vaporizing or decomposing.	**Very Low:** Organic side chains burn off above 300°C-400°C. Backbones rearrange into brittle silica.
Fuel Density	**High:** Actively carries massive concentrations of dissolved fissile/fertile heavy metal isotopes.	**Extremely Low:** Thorium siloxides require huge organic shells, diluting the actinide density below criticality thresholds.

3. Fatal Engineering Failure Modes in a Reactor Core

If a thorium-siloxane fluid were pumped into a nuclear reactor core, three cascading failures would occur instantly:

1. **Radiolytic Gas Evolution:** Radiation would immediately clip methyl/organic groups off the silicon atoms. This generates massive volumes of flammable hydrogen and hydrocarbon gases, resulting in rapid system overpressurization.
2. **Solidification & Clogging:** Stripped of their organic groups, the remaining silicon and thorium atoms will rapidly cross-link. The liquid will solidify into a brittle, glass-like thorium-silicate grit, permanently clogging pumps, heat exchangers, and plumbing.
3. **Loss of Heat Transfer:** Solidified or highly volatile degraded fluids lose all ability to safely transfer heat away from the core, triggering a rapid thermal excursion and structural meltdown.

4. How the Industry Actually Solves MSR Corrosion

Because changing the fluid from a salt to a covalent compound is chemically impossible, nuclear engineers solve the corrosion dilemma through targeted materials engineering rather than fluid substitution:

- **Advanced Nickel Alloys:** Utilizing specialized alloys like *Hastelloy-N*, which are engineered to resist leaching from molten fluoride salts.
- **Redox Potential Control:** Chemically monitoring and neutralizing the salt chemistry (e.g., adding sacrificial beryllium or controlling U(III)/U(IV) ratios) to stop corrosive fluorine reactions at the container wall.
- **Alternative Salts:** Shifting from highly corrosive chloride salts to cleaner fluoride configurations, or utilizing purified isotopes to suppress aggressive cross-reactions.