

## **Status of Development of the Small Secure Transportable Autonomous Reactor (SSTAR) for Worldwide Sustainable Nuclear Energy Supply**

James J. Sienicki, Anton Moiseyev, David C Wade, and Anna Nikiforova<sup>1</sup>  
Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL, 60439, USA  
E-mail: [sienicki@anl.gov](mailto:sienicki@anl.gov)

<sup>1</sup>*Massachusetts Institute of Technology*

Significant progress and improvements have been made on development of a pre-conceptual design of the Secure Transportable Autonomous Reactor (SSTAR) Lead-Cooled Fast Reactor (LFR) concept since it was last reported on at ICAPP '05. SSTAR is a small, 20 MWe (45 MWt), exportable, natural circulation, fast reactor plant concept incorporating proliferation resistance for deployment in non-fuel cycle states and developing nations, fissile self-sufficiency for efficient utilization of uranium resources, autonomous load following making it suitable for small or immature grid applications, and a high degree of passive safety. Customers of SSTAR include: i) clients looking for energy security at small capital outlay; ii) cities in developing nations; and iii) deregulated independent power producers in developed nations. The SSTAR pre-conceptual design integrates three major features: primary coolant natural circulation heat transport; lead (Pb) coolant; and transuranic nitride fuel in a pool vessel configuration. The Pb coolant flows upward through the core which is an open-lattice of large-diameter (2.5 centimeter) fuel pins containing transuranic nitride pellets clad bonded with liquid Pb to silicon-enhanced ferritic/martensitic (F/M) stainless steel arranged on a triangular pitch with spacing maintained by grid spacers; the core does not incorporate removable fuel assemblies as one means of restricting access to the fuel. The whole core is a single removable assembly with a long lifetime (30 years) at which time refueling equipment is brought onsite. Conversion of the core thermal energy to electricity is accomplished using a supercritical carbon dioxide (S-CO<sub>2</sub>) Brayton cycle energy converter providing higher plant efficiencies and lower balance of plant costs than the traditional Rankine steam cycle operating at the same reactor core outlet temperature. A control strategy has been developed for automatic control of the S-CO<sub>2</sub> Brayton cycle in principle enabling autonomous load following over the full power range between nominal and essentially zero power whereby the reactor core power adjusts itself to the heat removal from the reactor system to the power converter through the large reactivity feedback of the fast spectrum core without the need for motion of control rods, while the automatic control of the power converter matches the heat removal from the reactor to the grid load. A safety design approach has been formulated for SSTAR based upon defense-in-depth providing multiple levels of protection against the release of radioactive materials. The inherent safety features of the lead coolant ( $T_{\text{boil}} = 1740\text{ }^{\circ}\text{C}$ , lack of chemical reaction of Pb with the CO<sub>2</sub> working fluid, low absorption of neutrons by Pb, and the heavy Pb), nitride fuel (high thermal conductivity, transuranic nitride decomposition temperature  $\sim 1300\text{ }^{\circ}\text{C}$ , compatibility with cladding, low volumetric swelling and fission gas release), fast neutron spectrum core, pool vessel configuration, natural circulation, and containment enable the requirements for each level of protection to be readily met or exceeded. The interest in higher plant efficiencies has heretofore driven interest in operation of SSTAR at higher Pb temperatures to take advantage of the increase in plant efficiency with temperature of the S-CO<sub>2</sub> Brayton cycle. A peak cladding temperature of 650 °C has been used as a goal; at this temperature, a reactor core outlet temperature of 564 °C is achieved resulting in a Brayton cycle efficiency of 44.2 % and a net plant efficiency of 43.8 %. It has always been recognized that this would require the development of cladding and structural materials for long-term service in Pb coolant up to 650 °C peak cladding temperature with corrosion protection provided by active maintenance and control of the dissolved oxygen potential in the coolant giving rise to the formation of protective oxide layers on the steel cladding and structures. SSTAR development has been supported by the testing in the DELTA loop at Los Alamos National Laboratory of alloy specimens with special treatments or coatings which might enhance corrosion resistance at the temperatures at which SSTAR operates. The focus of LFR development in the U.S. is now shifting towards the development of a near-term deployable LFR test demonstrator and a near-term deployable small exportable LFR. Both reactors would operate at lower temperatures enabling the use of existing materials such as T91 or HT9 F/M stainless steel that is already incorporated into the ASME codes and have been shown to have corrosion resistance to lead-bismuth eutectic with active oxygen control at temperatures below about 550 °C in experiments carried out in the DELTA loop and elsewhere.

