Static Fuel Molten Salt Reactors - Simpler, Cheaper and Safer

Ian Scott

The many conceptual designs for Molten Salt Reactors (MSR's) today are all evolutions from the prototype MSR that went critical at Oak Ridge 50 years ago. Critically, they are based on pumping the molten fuel salt from a reaction chamber where the fuel achieves critical mass through a heat exchanger where the resulting heat is transferred to another working fluid. This basic concept was not the first idea that the Oak Ridge scientists considered. Their initial preference was to put the molten salt fuel into tubes, just like solid fuel pellets in their cladding, and circulate a coolant past the tubes. They concluded however that the low thermal conductivity of the salt meant that the tubes could be no wider than 2mm which would be entirely impractical. In this analysis they ignored the contribution of convection to heat transfer in fluids, probably because they were designing an aircraft engine where varying g forces would make convection unreliable. Moltex Energy has re-examined this decision using the modern tools of computational fluid dynamics to simulate convective flow in the molten salt and discovered that in fact tubes of similar diameter to those used for solid fuels are entirely practical. Power densities of 250kW/litre of fuel salt are readily attainable providing a higher overall power density than a PWR reactor. This discovery permits MSR's to be built without any of the complex pumping, passively safe drain systems, on line degassing, filtration and chemical processing needed in pumped MSR's. Their design is very simple and they have many intrinsic safety factors including low pressure operation, chemically unreactive fluids and strongly negative fuel thermal and coolant voiding reactivity coefficients. Most importantly, the highly radioactive fission products are retained in non-volatile form within the fuel tubes in the reactor core. Radioactive fuel salt never leaves the reactor vessel except in an immobile frozen form during refuelling. These reactors are relatively straightforward simplifications of conventional solid fuelled reactors. The fuel assemblies are similar both in design and in construction materials. Replacement of water as coolant with a (fissile free) molten salt removes explosion risks from the reactor containment. There are many possible designs of reactors utilising this form of fuel. One design, a fast spectrum actinide burning reactor called the Stable Salt Reactor has been developed to the stage where realistic capital cost estimates can be made. This was done independently of Moltex Energy by Atkins Ltd. The capital cost (UK prices) for a $1GW_e$ nuclear island was estimated (rough order of magnitude, reflecting the early stage of the design) as £718 per kW, a small fraction of the cost for any conventional nuclear island. Of particular interest to this conference may be the potential for a thorium breeding version of the reactor. Simply replacing the coolant salt with one based on ThF_4 turns the reactor into an efficient ^{233}U breeder. The basic principles of this version will be described during the talk.

Dr. Ian Scott

Ian won an Open Scholarship to Cambridge University to study nuclear physics, but was seduced during his first year by the excitement of the biological sciences and made his career in that field. He became Chief Scientist for Unilever plc before leaving to start an entrepreneurial drug discovery company. In 2012 he became bemused by how nuclear energy had gone from being "too cheap to meter" to too expensive to afford and determined to try to remedy that flaw. The result was his invention of the Stable Salt Reactor and the creation of Moltex Energy.