

TerraPower
partnered with
Los Alamos National Laboratory

NE-21-25117, Density Measurements of Plutonium Bearing Salts via Neutron Beam Dilatometry

YEAR AWARDED: 2021

TOTAL PROJECT VALUE: \$525k (DOE: \$400k, TerraPower: \$125k)

STATUS: Completed

PRINCIPAL LAB INVESTIGATORS: J. Matt Jackson (LANL), Perry Motsegood (TerraPower)

DESCRIPTION: TerraPower is developing the Molten Chloride Fast Reactor and the Molten Chloride Reactor Experiment test reactor. The work performed under this GAIN voucher was to produce density data for some compositions of plutonium-bearing salts. Archived data needed to be vetted because referenced values don't always agree or do not allow for measurement uncertainty. System performance relies on measurement uncertainty to fully develop design margins and boundary conditions. The density of the chloride fuel salt ultimately determines fissile mass for criticality and active core size. With aid from Los Alamos National Laboratory (LANL), TerraPower seeks to confirm existing assumptions and leverage fundamental scientific principles to advance reactor design.

BENEFIT: With the first-of-its-kind neutron radiography technique, Los Alamos National Laboratory has the necessary expertise to determine the density of actinide molten salt solutions using neutron dilatometry. The visualization of molten salt samples yields extremely accurate data resulting in significantly reduced design costs — a critical component of advanced reactor commercialization.

IMPACT: Four samples of sodium chloride (NaCl)/magnesium chloride ($MgCl_2$)/plutonium chloride ($PuCl_3$) and four samples of NaCl/uranium chloride (UCl_3)/ $PuCl_3$ were prepared, shipped to the Los Alamos Neutron Science Center (LANSCE) and radiographed with the density via neutron radiography (DvNR) apparatus. Given the ability to produce composite images of the entire sample height, aberrant features were identified and accounted for in the analysis of the data. Density data in the form of meniscus heights were recorded as a function of temperature. The data from duplicate sample sets demonstrate a high degree of experimental precision. From the measured density correlations, a correlation for the density of $PuCl_3$ was derived. A method for the generalization of this data to extend to arbitrary mixtures was offered and shown in the case of $PuCl_3$ additions in (NaCl- $MgCl_2$) eutectic and (NaCl- UCl_3) eutectic mixtures.

SIGNIFICANT CONCLUSIONS: The results show a linear dependence of density with temperature and a third order polynomial dependence of density with composition as a function of mol % $PuCl_3$ addition in the corresponding halide salt mixture. Additions of $PuCl_3$ result in a significant increase in density of the salt mixture and a slight reduction in the coefficient of volumetric expansion.

NEXT STEPS: This work builds on previous studies of the density of liquid chloride salts and forms the basis of future work measuring other intensive properties. These results most likely represent a first measurement of the density of plutonium chloride salt mixtures and, in combination with additional measurements, may lead to a generalized description of the density of such salt systems for arbitrary compositions and temperatures.