LIST Project Proposal

"Experimental Study on Critical Issues of Nuclear Energy Systems Employing Liquid Salt Fluorides"

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for ISTC CEG meeting, Brussels, EC, January 22-23, 2007

Recent years have demonstrated growing interest in nuclear energy systems employing technology of molten salt fluorides for:

1. Consumption of transuranic elements while extracting their energy (ISTC#1606)
2. Efficient electricity production in Th-U cycle
3. Process heat applications, e.g. hydrogen production
4. Pyrochemical reprocessing of advanced fuels

Development requirements are different for these various missions and MSR's should be viewed as a flexible family of reactor systems, for which technology would be first developed for near term missions (3 or 4) with the option of expanding the missions with further development

Summary LIST Project Proposal Information

Participating Institutions: VNIITF, RRC-KI, IHTE

Project Manager: Alexei Zherebtsov

Project Scientific Leader: Victor Ignatiev

Foreign Collaborators: CEA, CNRS, EDF, FZK, IAEA, KTH, ORNL

Project Duration: 48 months

Status: Under consideration in Rosatom

LIST project proposal

- **Wide set of experimental techniques and facilities** was created as a result of the Task#1606 fulfillment, and these can be used at new ISTC Liquid Salt (LIST) Project
- **The main mission of new LIST project** is to test and select molten salts and metallic structural materials, which will operate successfully under the conditions of promising systems to reflect Gen IV objectives
- **In this project,** focus will be placed on experimental evaluation of the potential of liquid salts for SFR, VHTR, AHTR and MSR (Th-U, U-Pu) designs as well as SNF pyrochemistry partitioning application

LIST general approach

- LIST project plan is based on two primary ground rules. First a project program will be undertaken to resolve the major uncertainties concerning technical feasibility of systems under consideration.
- Main task of the project is to address the key scientific points requiring experimental investigations, in order to assess the actual feasibility and performances of such innovative concepts for deployment.
- Then, assuming favorable resolution of these uncertainties development will proceed in support of liquid salt cooled (SFR, VHTR, AHTR) and Th-U (U-Pu) MSR designs in order to meet principal goals for these concepts in Generation IV.

Useful salt compositions

Alkali fluorides

LiF –PuF3
743°C, *20 mole %*

NaF –PuF3
727°C, *24 mole %*

LiF-KF
(50-50) 492°C

LiF-RbF
(44-56) 470°C

LiF-NaF-KF
(46.5-11.5-42) 454°C

LiF-NaF-RbF
(42-6-52) 435°C

ThF4-based

LiF-ThF4
(71-29) 555°C
3.69 mole %

LiF-BeF2-ThF4
(71-16-13) 499°C
1.41 mole %

LiF-BeF2-ThF4
(64-20-16) 460°C
1.21 mole %

LiF-BeF2-ThF4
(47-51.5-1.5)
360°C

ZrF4-based

LiF-ZrF4
(51-49) 509°C

NaF-ZrF4
(59.5-40.5) 500°C
1.8 mole *%*

LiF-NaF-ZrF4
(42-29-29) 460°C

LiF-NaF-ZrF4
(26-37-37) 436°C

NaF-RbF-ZrF4
(33-24-43) 420°C

RbF-ZrF4
(58-42) 410°C

KF-ZrF4
(58-42) 390°C

NaF-KF-ZrF4
(10-48-42)
385°C

BeF2-based

LiF-NaF-BeF2
(15-58-27) 479°C
1.94 mole %

LiF-BeF2
(66-34) 458°C
0.47 mole %

LiF-BeF2-ZrF4
(64.5-30.5-5) 428°C

NaF-BeF2
(57-43) 340°C
0.26 mole%

LiF-NaF-BeF2
(31-31-38) 315°C
0.43 mole %

Fluoroborate / Others

$LiF-CaF_2$
(80-20) 771oC

$LiF-CaF_2-BaF_2$

$NaF-AlF_3-MgF2$
(47-51.5-1.5) 687°C

KF-KBF4
(25-75) 460°C

RbF-RbBF4
(31-69) 442°C

NaF-NaBF4
(8-92) 384°C

Expected LIST developments

- WP 1: Experimental verification of key physical & chemical properties for selected coolant, solvent and fuel salt compositions, including Th/Ln and An/Ln separation, as well tritium speciation, management and control.
- WP 2: Combined materials compatibility & salt chemistry control in selected molten salt environments at parameters simulating process & design operation.
- WP 3: Evaluation of liquid salt coolants for SFR, VHTR, AHTR concepts and optimization of molten salt breeder design parameters basing on experimental data received within the project.

WP 1

- Experimental studies will be carried out to measure phase behavior and transport property data for selected coolants. Particularly, it should include validation of thermal conductivity, viscosity, expansivity and refinement of heat capacity.
- Fundamental studies of mixtures will include determination of electrochemical properties for both major and minor components of the systems. As for SNF pyrochemistry application, An's deposition on solid cathodes in Li,Ca,Ba/F melts, determination of An's deposition potentials on solid electrodes, electrochemical An/Ln separation, electrolytes recycle, will be experimentally studied.
- As for MSR fuel salt clean up operations, the most uncertain its part concerning rare earths removal from selected Th containing system will be experimentally studied.

WP 1

- For the analysis of molten salt Th containing streams, electroanalitical technique will be developed to determine the redox potential of fuel salt by U^{4+}/U^{3+}.
- Tritium behavior in new MSR as well as liquid cooled salt designs, like SFR, VHTR and AHTR will require a significant effort of project implementation. Significant part of tritium must be trapped in the secondary coolant.
- Measurements of the solubility, diffusivities etc. of tritium in fuel / coolant salt will be made to aid in predicting tritium behavior in the selected salt systems.

WP 2

- Effort will be focused on the compatibility with different liquid salt environments of the metallic structural materials; particularly iron-based alloys - at temperatures range up to 550-600°C as applied to conditions of SFR designs and advanced Ni-based alloys with different complex additions at temperatures > 750°C as applied to conditions of VHTR / AHTR designs and for SNF pyrochemistry application
- An integrated materials design and testing strategy will be required to make the optimal choice of salt based on corrosion metrics. It is recommended that the salt-chemistry, corrosion-chemistry and alloy-selection studies be conducted as a joint effort.

WP 2

- Planning studies indicate that the crucial problem and crucial path item is demonstration of an alloy for the structural material of the selected MSR primary system configuration
- Alloy must have satisfactory resistance to surface cracking when under stress in contact with the selected fuel salts, which parameters (temperatures and composition) differ from MSBR ones, general corrosion resistance in fuel and coolant salts and satisfactory mechanical properties over long term under operating conditions

WP 3

- Main objective of this group will be comparison of selected coolants of main design parameters for liquid salt cooled SFR, AHTR and VHTR concepts in terms of selected and briefly described above coolant criteria, including costs evaluation associated with a given coolant selection.
- New Th-U or U-Pu self breeder concept will be evaluated basing on experimental data received within the project.
- In this task core performance (nuclear data, thermal hydraulics, fuel cycle scenarios, irradiation material damage, tritium production, etc) and core safety related parameters (reactivity feedback coefficients…) are mainly addressed.

Cooperation with partners

ROSATOM Generation 4 Task

Euratom 6th FP ALISIA, 2006-2007
Euratom 7th FP MSR project, 2007-2010

ISTC LIST

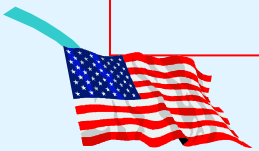
Foreign collaborators:

CEA, CNRS, EDF, FZK, IAEA, KTH, ORNL

IAEA CRPs

2007-2010

FP7 EURATOM PROJECT FOR SNF REPROSECCING AND PARTITIONING
DOMAIN 2: PYROCHEMISTRY



US Liquid Salt GEN 4/ GNEP activity: ORNL