



ThEC
THORIUM ENERGY
CONFERENCE 2011

The City College
of New York

October
10-12, 2011

It's Time To
TALK

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October 10-12, 2011

Place

The City College of New York
Steinman Building
160 Convent Avenue
New York, NY 10031

Time

9:00 Monday, October 10

ThEC11 provides a unique and convenient, cross-disciplinary platform, for people involved in the field of Thorium Energy to be introduced, to speak, and to discover.

Conference Highlights

Tony Favale, AES
Bill Foster, Former U.S. Congressman, Illinois 14th District
Jess Gehin, ORNL
Parker Griffith, Former U.S. Congressman, Alabama 5th District
Stuart Henderson, FNAL
Yacine Kadi, CERN
Kirk Sorenson, Flibe Energy

Contribute

ThEC11 is open for speakers, exhibitors, display of posters, sponsors and partners. Interested should contact us at info@itheo.org

Media

Journalists, reporters and all interested parties are warmly welcome to cover the subject of Thorium Energy by attending ThEC11. You can contact us at info@itheo.org. ThEC11 will be used to spread the awareness about Thorium Energy through broadcasting channels, journals and magazines.

Booking

Final booking can be done by either bank transfer or credit card payment through PayPal (all major credit cards). Add attendee's name and email to the payment, it's your registration name at ThEC11. After payment you will receive an email from IThEO that confirms your booking.

When using bank transfer, use the following beneficiary information:

Name: IThEO
Address: ALDERMANSV. 19-21, 171 48 SOLNA
IBAN: SE5193300000006250575401
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Country: Sweden

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Bank: Nordea Bank
City: Stockholm

To purchase your ThEC11 ticket via PayPal, please go to ThEC11 web page and follow the instructions:
www.itheo.org/thorium-energy-conference-2011

Hotels

We suggest 3 hotels – Park 79, Lucerne, and Belleclaire – based on their proximity to each other, on their Upper West Side location (with many parks, restaurants and museums, et cetera), on their easy access to the conference venues, and on their cost range options. There is no conference rate at any of the hotels.

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Contributors

Bill Foster, Former U.S. Congressman, Illinois 14th District "What Life is Like as a Scientist in Congress"

Bob Cywinski, Uni Huddersfield "The way forward: Science, Technology, or Politics?"

Gary Krellenstein, Ex-JPMorgan "Thorium Economics"

Hywel Owen, Uni Manchester "ADS Demonstrator Issues"

Jess Gehin, ORNL "Liquid Fuel: Molten Salt Reactors"

John Duncan, UK Foreign Office "Towards a World Without Nuclear Weapons"

Kirk Sorensen, Flibe Energy "Introducing Flibe Energy"

Laurence O'Hagan, TWF "The Weinberg Foundation: Continuing His Vision"

Luciano Calabretta, INFN "Developing a High Power Cyclotrons to Drive Subcritical Reactor"

Michael Todosow, BNL "AHWR Non-proliferation Attributes"

Ondrej Beneš, EC Karlsruhe "Physico-chemical Properties of Thorium Fuels"

Oystein Asphjell, Thor Energy "Thorium use in LWRs; the Low-hanging Fruit of Th-utilization"

Parker Griffith, Former U.S. Congressman, Alabama 5th District "Science Doesn't Speak for Itself"

Paul Friley, BNL "Thorium Energy Economics"

Pavel Soucek, EC Karlsruhe "Electrochemistry of Molten Salt"

Peter McIntyre, Texas A&M "ADS Fission in a Molten Salt Core"

Robert Arnold, UK DECC "New Nuclear Technologies in the UK Energy Strategy"

Robert Bari, BNL "Nonproliferation Models"

Robert Hargraves, Dartmouth "Nuclear Ammonia: Thorium's Killer App"

Rol Johnson, Muons Inc "Accelerators for Subcritical Molten Salt Reactors"

Stuart Henderson, FNAL "Report from the DOE ADS Working Group"

Takashi Kamei, Kyoto Uni "The Thorium Energy Bank"

Tony Favale, AES "The U.S. Socio-economic Case for Spent Fuel Treatment"

Yacine Kadi, CERN "Neutronic Analysis and Transmutation Performance of Th-based Molten Salt Fuels"

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Program Schedule Monday

Monday	
08:00 – 09:00	Registration
Session 1	Opening Plenary
09:00	Opening – Andreas Norlin, W.C. Horak, Steve Peggs
09:30	Parker Griffith
10:00 - 10:30	Tea / Coffee Break
Session 2	Strategy Chair: Andreas Norlin
10:30	Paul Friley
11:00	Tony Favale
11:30	Stuart Henderson
12:00 - 13:00	Lunch
Session 3	Liquid Fuel Chair: W.C. Horak
13:00	Jess Gehin
13:30	Kirk Sorensen
14:00	Pavel Soucek
14:30 - 15:00	Tea / Coffee Break
Session 3	Liquid Fuel (continued)
15:00	Ondrej Beneš
15:30	Yacine Kadi
Session 4	External Neutrons Chair: Steve Peggs
16:00	Hywel Owen
16:30	Peter McIntyre

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Program Schedule Tuesday

Tuesday	
Session 4	External Neutrons <i>(continued)</i>
08:30	Luciano Calabretta
09:00	Yacine Kadi
09:30	Rol Johnson
10:00 - 10:30	Tea / Coffee Break
Session 5	Solid Fuels Chair: W.C. Horak
10:30	Oystein Asphjell
11:00	Andy Nelson
11:30	Michael Todosow
12:00 - 13:00	Lunch
Session 6	Economics & Regulatory Issues Chair: Andreas Norlin
13:00	Gary Krellenstein
13:30	Robert Arnold
14:00	Takashi Kamei
14:30 - 15:00	Tea / Coffee Break
Session 7	Environment & Society Chair: Bob Cywinski
15:00	Robert Hargraves
15:30	Laurence O'Hagan
16:00	Bill Foster

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Program Schedule Wednesday

Wednesday	
Session 8	Proliferation Studies Chair: Steve Peggs
08:30	Robert Bari
09:00	Paul Friley
09:30	Jess Gehin
10:00 - 10:30	Tea / Coffee Break
Session 9	Closing Plenary Chair: Steve Peggs
10:30	Roundtable – Bob Cywinski
11:30	Closing – Andreas Norlin, W.C. Horak, Steve Peggs

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Abstracts

Robert Arnold

New nuclear technologies and the UK energy strategy

The UK has set itself challenging CO₂ emission reduction targets to reach by 2050. Current technology trajectory models suggest that nuclear energy may have a significant role to play in meeting these. Whilst early build is likely to centre on Generation III uranium-burning designs, longer term development includes the potential for the thorium fuel cycle to be used. An overview is given of the potential scale and applications for new nuclear build, the regulatory environment for licensing reactors and the opportunity for the use of thorium-based designs.

Oystein Asphjell

An International Consortium to Test, License & Deploy Thorium-based LWR Fuels

Thor Energy is just initiating a large Irradiation Campaign in the OECD Halden Reactor where we will irradiate 90%Th and 10%Pu oxide pellets in a LWR-environment under commercial conditions. We have gathered technical and financial support for this campaign from governments, the fuel industry and European utilities. It is the first fundamental step towards leveraging the benefits of Thorium towards nuclear sustainability – in the present day infrastructure and value chain.

Our presentation will speak of the benefits of Thorium as deployed in LWRs, the various steps and strategy of Thorium introduction and describing the outcomes of the irradiation campaign.

Luciano Calabretta

A Multi Megawatt Ring Cyclotron To Drive Sub Critical Reactor

The study for a Superconducting Ring Cyclotron able to accelerate the H₂⁺ molecules and to deliver proton beam with maximum energy of 800 MeV and a maximum power of 5 MW, will be presented.

This study is an update version of a cyclotron complex accelerator under study for the experiment DAEALUS (Decay At rest Experiment for d_{cp} At Laboratory for Underground Science) proposed by scientist of MIT and Columbia University.

The description of the superconducting magnetic sector simulated by the code TOSCA, the isochronous magnetic field produced and the magnetic forces acting on the coils, will be discussed. Some evaluation on the feasibility of the ring cyclotron, the advantages and problems relates with acceleration of the H₂⁺ molecules, and the main features of a cyclotron injector cyclotron will be also presented.

A proposal to use three cyclotrons modules of this kind to drive an ADS will be presented. The advantages, the reliability and the problems related to this solution will be discussed too.

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John Duncan

Unconventional Alliances

The Nuclear Non-Proliferation Treaty could eventually result in a significant reduction - or even complete elimination - of nuclear weapons. Technologies from the accelerator field, such as transmutation of weapon-grade uranium and plutonium, alternative techniques for nuclear power generation, detection of fissile material and verification, will be very important for this effort. The present trend in modern diplomacy is to form unconventional alliances to make progress on challenging issues. Could an alliance between diplomats and scientists help to achieve the ultimate goal of reducing and eventually eliminating nuclear weapons?

Anthony Favale

Socio-economic case for Accelerator Driven Systems to Treat Spent Nuclear Fuel

This talk presents a review of the Accelerator Driven Systems effect on the US spent nuclear fuel final disposal plans. Social, technical and economic perspectives will be presented and contrasted to arrive at a potential configuration and deployment for the US. The introduction of Thorium into this configurations sub critical assembly will be reviewed. Major R&D requirements derived from the resulting configuration will be presented.

R. Parker Griffith, M.D.

Science Does Not Speak For Itself

The development of Thorium as an energy source has the potential to safely improve living standards worldwide. Not only is the general public unaware of the potential much of the scientific and political community is unaware as well. Solving this problem will require that we engage on political, environmental and financial fronts. How well we communicate will determine if Thorium reaches its potential. The scientific and engineering aspects may be the easier part of our job, convincing the investment, political, and environmental community could be the hardest. Good science is not enough.

Robert Hargraves

Nuclear Ammonia: Thorium's Killer App

Energy cheaper than from coal is not enough. We can use LFTR to phase out coal burning for electric power generation, but we get more energy from oil than coal – and it's mostly imported. We can electrify railroads and small cars, but liquid fuels with high energy density will remain critical to transportation. Carbonaceous fuels can be synthesized with LFTR to dissociate water for hydrogen which is combined with CO₂ from flue gasses (10% abundant) or the atmosphere (0.03% abundant), then burned. Nitrogen-based fuels such as NH₃, ammonia, can be similarly synthesized using atmospheric nitrogen (78% abundant). Ammonia fuel, handled professionally, can replace carbonaceous fuels in most applications, using fuel cells or internal combustion engines. Inexpensive LFTR electric power and new ammonia production techniques such as solid state ammonia synthesis suggest that ammonia fuel may be cheaper than gasoline.

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Steven Henderson

Are Accelerators Ready to Drive Subcritical Reactors? Report from the DOE Accelerator-Driven Systems Working Group

A Working Group was commissioned by the Dept. of Energy to produce a White Paper assessing the readiness of particle accelerator and target technology for application in accelerator-driven subcritical nuclear reactor systems, also known as accelerator driven systems (ADS). Such systems could find application in the transmutation of nuclear waste, generation of electrical power, and in the production of fissile materials for advanced fuel cycles. The Working Group assessed the state-of-the-art in accelerator and spallation target technology and its readiness for meeting the various ADS missions. In this presentation the results of the White Paper working group will be presented, with a focus on the Key Findings of the report.

Rol Johnson

Accelerators For Subcritical Molten Salt Reactors

Reactors built using solid fissile materials sealed in fuel rods are problematic because volatile radioactive materials in the rods are accumulated over years of operation and can be accidentally released in dangerous amounts. Accelerator parameters for subcritical reactors that have been considered in recent studies have primarily been based on using solid nuclear fuel much like the fuel rods that are used in all operating critical reactors. An attractive alternative reactor design that used molten salts was experimentally studied at ORNL in the 1960s, where a critical molten salt reactor was successfully operated using enriched U235 or U233 tetrafluoride fuels. These experiments give confidence that accelerator-driven subcritical molten salt reactors will work as well or better than conventional reactors since they will have better efficiency due to their higher operating temperature, the inherent safety of subcritical operation, and constant purging of volatile radioactive elements to eliminate their accumulation and potential accidental release in dangerous amounts.

Y. Kadi

Thorium- Based Accelerator – Driven Systems

Accelerator driven systems offer the possibility to make nuclear fission energy sustainable and acceptable to society. The Energy Amplifier proposed by Carlo Rubbia at CERN [1] is used to illustrate the potential of TADS (Thorium Accelerator Driven Systems), and the resulting R&D activity wave it triggered in Europe and in the world is briefly discussed. TADS must be part of the strategy to provide clean, safe and abundant energy for a harmonious development of society.

In the past 15 years, a tremendous ADS R&D effort has been made worldwide [2-6]. TADS is a challenging idea with no show-stopper, with the potential for producing acceptable energy for society.

Although TADS have enormous potential and projects are moving ahead to further demonstrate some components of these technologies, there is a need to accelerate progress, pursue whole-of-system technological demonstrations, and move more rapidly to commercial deployment.

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Nuclear fission energy is the only way we have now to produce quasi unlimited amounts of clean energy to sustain harmonious growth on our planet:

- *TADS can change the image of nuclear energy, and make it "acceptable to society";*
- *TADS would be complementary to renewable energies, allowing modulation of electric power production, to follow fluctuations of wind and solar power;*
- *A proof of existence is needed for the accelerator, and a prototype could play an important role, in studying the two main accelerator issues: beam losses and reliability of the early accelerating stage.*

Y. Kadi

Neutronic Analysis and Transmutation Performance of Th-based Molten Salt Fuels

Thorium fuel and thorium fuel cycles are attractive for the long-term nuclear energy production with low radioactive waste. The utilization of thorium in various reactors ranging from thermal to fast neutron energies has been successfully demonstrated, however, substantial R&D is required before commercialization will appear.

The molten-salt reactor systems present the very special feature of a liquid fuel. MSR concepts, which can be used as efficient burners of TRU from spent LWR fuel, have also a breeding capability in any kind of neutron spectrum (from thermal to fast), when using the thorium or fast spectrum U-Pu fuel cycle. In both options, they have a very interesting potential for the minimization of radiotoxic nuclear waste.

Takashi Kamei

Concept Of "The Bank" For Sustainable Implementation Of Thorium Nuclear Power

Sustainable society requires two pillars for satisfying low-carbon emission. One of them is low-carbon energy source and the other is low-carbon transportation. Nuclear power still has an important role after Fukushima accident but this technology also has to satisfy nuclear non-proliferation. Thorium which produces little plutonium corresponds to this requirement. Rare-earth elements are needed to manufacture electric vehicles but the main problem is its byproduct of thorium. Thorium can be utilized as nuclear fuel but it has to be cleared when it is started and how many capacity it will be. If there is a gap between the amounts of supply and demand, the excess amount of production is often thrown into environment without adequate treatment for environmental protection. Thorium has been obtained as byproduct of rare-earth mining since 1940's and it is estimated to be about 100 thousands tonnes in the world. It will increase within these few decades to be about 200 thousands tonnes. On the other hand, thorium utilization by MSR is expected to start at nearest in the middle of 2020's. And its capacity will be about less than 400GWe at 2050 due to limited supply of fissile isotope, plutonium. This capacity requires 76 thousands tonnes of thorium. Therefore, there will be a gap between thorium supply and demand. If thorium does not start within these few years, rare-earth production companies only have to spend cost for protecting radioactive hazard caused by thorium. The proposal indicated here is to store this thorium as byproduct of rare-earth mining by an international organization so as not to put responsibility of taking care of thorium hazard to private companies. It will be

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allowed for the countries who wish to store thorium by themselves. At the same time, we have to remember that the US stored thorium as national resource during 1950's but they stopped national storage because uranium became the only nuclear fuel. This international organization is named "The Bank (Thorium Energy Bank)". Its outline is illustrated in Fig. 1. Detailed design of "The Bank" will be discussed.

Peter McIntyre

Accelerator-Driven Subcritical Fission in a Molten Salt Core

An accelerator-driven subcritical molten salt (ADSMS) fission core is being developed as a basis for generating nuclear power and for destroying minor actinides in spent nuclear fuel (SNF). A scenario is presented for pairing ADSMS units with conventional fission reactors to extract 10x more energy from spent nuclear fuel and also to destroy minor actinides. A similar design using a thorium-based salt provides an ideal basis for destroying existing inventories of minor actinides.

In ADSMS an array of high-power proton beams is used to drive subcritical fission in a molten salt core. The proton beams are produced in a flux-coupled stack of isochronous cyclotrons (IC). The 800 MeV, 3 MW beams are targeted vertically on spallation targets in the molten salt core. The core consists of a molten salt eutectic of either $UCl_3/NaCl$ (the ADSMS-U core) or $ThCl_3/NaCl$ (the ADSMS/

Th core). The choice of chloride salt is motivated by the need for the fastest possible core neutronics to optimize destruction of minor actinides (MA) during operation. It requires prior removal of the n-absorbing stable isotope ^{35}Cl .

The ADSMS-U core can burn spent nuclear fuel (SNF) without reprocessing. Extraction of SNF into molten salt has been developed into practice at INL and is used to prepare the fuel salt eutectic from SNF. The core operates in an isobreeding mode, in which an equilibrium is maintained between breeding ^{239}Pu and fissioning it. The fuel lifetime in each ADSMS-U core is >50 years, and the fertile content is burned to completion.

The ADSMS-Th core operates in closely similar manner and uses thorium-based salt eutectic. The core neutronics maintains an ultra-low equilibrium concentration of minor actinides because breeding them from a thorium fertile fuel is strongly suppressed. The ADSMS-Th can be used as a MA incinerator: batches of MA can be separated from SNF and added to the fuel salt on a regular basis. The MA is consumed with little impact on core neutronics.

Hywel Owen

ADS Demonstrator Issues

Whilst a number of ADS design concepts exist, and tests of key components such as targets have been carried out, there have been remarkably few accelerator-reactor coupling experiments. In addition, there is as yet no demonstrated design of a reliable enough accelerator system to drive a hybrid reactor. This talk will give an overview of the UK work toward demonstrating ADS at significant power, and will relate it to work being carried out worldwide. In particular, I will present recent work looking at how the UK CONSORT reactor may be used for moderate-power experiments; the first successful demonstration of non-scaling FFAG acceleration at EMMA - a technology that may give the accelerator reliability required for ADS. Follow-up design efforts from EMMA will also be presented.

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P. Souček, et al

Electrochemistry of Thorium in Molten Fluoride and Chloride Salts and Electrochemical Methods within the MSR Fuel Cycle

Defining a suitable separation technology for reprocessing of molten salt nuclear fuels is a key point for successful development of the Molten Salt Reactor (MSR), which is one of the very promising advanced reactor systems developed within the Generation IV international forum. The characteristics of MSR make it especially suitable for the thorium fuel cycle, breeding ^{233}U from ^{232}Th . The present paper is dealing with R&D on electrochemical separation methods in molten salts suitable for MSR fuel cycle, with a special emphasis on thorium electrochemical behaviour and thermodynamic properties of thorium dissolved in molten fluoride and chloride salts. A molten salt centre of excellence is being developed in the Institute for Transuranium Elements (ITU), which is operated by the European Commission within the Joint Research Centre directorate (EC-JRC). New experimental equipment closely related to the research on separation techniques for MSR fuel cycle is being installed in ITU. It will facilitate high-temperature electrochemical experiments with actinides in molten fluoride media under purified Ar atmosphere, synthesis and purification of actinide fluoride compounds using gaseous HF at temperatures up to 1200°C and preparation and purification of actinide fluorides molten salts.

Moreover, an apparatus for spectrometric-electrochemical measurement of actinides in molten salts is also being developed, which will couple the electrochemical characterisations and control of the media with UV-VIS, IR, Raman, TRLEFS, LIBS and possibly EXAFS measurements. High-temperature NMR adapted for actinide containing molten salt measurements is also under preparation in ITU.

Up to now, the research on pyrochemical separation methods in ITU was focused mainly on electrochemical techniques using molten chloride salts for reprocessing of metallic nuclear fuels based on An-Zr alloys. An electrorefining process in molten LiCl-KCl eutectic using solid Al cathodes for recovery of An as An-Al alloys was successfully developed and demonstrated in a laboratory scale with non-irradiated fuel containing minor actinides and lanthanides. Within development of the process, the electrochemical properties of all actinides up to Am were investigated in the mentioned media. The study on thorium is detailed in the present paper, showing the evaluation of reduction mechanism of Th(IV) ions, diffusion coefficient, apparent standard red-ox potential and activity coefficient.

A study carried out in Nuclear Research Institute Řež (NRI) on the electrochemical properties of thorium in molten fluoride media will be presented. Reduction mechanism and diffusion coefficient was determined in molten LiF-CaF₂ eutectic, while basic electrochemical behaviour was studied in LiF-NaF-KF eutectic using Ni/NiF₂ based reference electrode. In addition, a flow-sheet for the MSR fuel cycle based on molten salt-liquid metal extraction and electroseparation techniques proposed by NRI is discussed.

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