GLOBAL ENERGY TECHNOLOGY R&D

Edward Stevens
U.S. Department of Energy
Chair, Executive Committee
Environmental, Safety and Economic Aspects of Fusion Power Implementing Agreement (ESEFP IA)

iea Energy Technology Network

Summary on End-of-Term Report for the
IEA Implementing Agreement on a

Co-operative Programme on Environmental, Safety and Economic Aspects of Fusion Power (ESEFP)

FPCC Meeting

22-23 January, 2013

IEA Headquarters

Paris, FRANCE

Presented by
Edward Stevens, ESEFP ExCo Chairman

Background on ESEFP IA-

Mission/Policy Statement

Fusion energy has the potential to be a very safe, environmentally attractive and inexhaustible source of power. To achieve this status, a significant amount of research must still be accomplished including developing and demonstrating the safety aspects of various fusion systems to both the regulator and the public as well as determining the cost of future fusion power plants.

Background on ESEFP IA, cont -

Overarching Objectives

- Establish pedigreed analysis tools for safety characterization of fusion applications

  Developing the tools requires not only fundamental understanding of relevant physical phenomena but also providing suitable simulation methods, and utilizing data and simulation results to validate the tools.

- Develop analysis methodologies for consistent assessment of various concepts with respect to environmental, safety, and economic aspects of fusion applications

  Mutually understood methodologies allow fair comparison among concepts, for example, to the benefit of various bodies developing energy policies.

Background on ESEFP, cont -

Implementation

Coordinated activities in several R&D tasks:

Task 1 – In-vessel Tritium Source Terms
Task 2 – Transient Thermofluid Modeling and Validation Tests (presently on hold)
Task 3 – Activation Products Source Terms
Task 5 – Failure Rate Data Base
Task 6 – Radioactive Waste Study
Task 7 – Socio-Economic Aspects of Fusion Power
Task 8 – Magnet Safety
Task 9 – Fusion Power Plant Studies

**Task 4* – Safety System Study Methodology was terminated in July 2002

Participation

Contracting Parties: Governments of Canada, China, European Union, Japan, Russian Federation and the United States of America

Executive Committee Members and Participants:

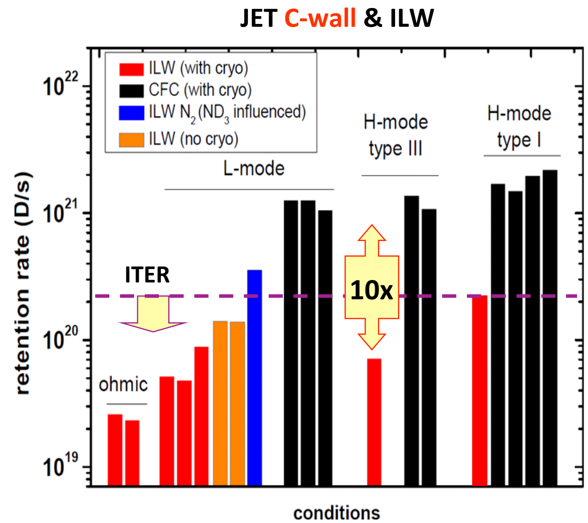
Canada:	D. Jackson, McMaster University
China	Y. Wu, INEST (2011-2013)
European Union:	D. Maisonnier, EFDA
Japan:	K. Tobita, JAEA
Russia:	A. Kalashnikov, RF-FAAE
	B. Kolbasov, Russia (Alternate)
USA:	E. Stevens, DOE, *Chair 2012-2013*

Participation, cont.

Task	Participating Party (Coordinators in Red)				
	China	Europe	Japan	Russia	United States
1 – In-vessel Tritium Source Terms	Y. Song	V. Philipps	H. Nakamura	A. V. Markin	M. Shimada
2 – Transient Thermo-fluid Modeling and Validation Tests (Task on Hold K. Takase, Japan)					
3 – Activation Prod. Source Terms	K. Feng	C. Grisolia	N. Asakura	Y. Martynenko	P. Humrickhouse
5 – Failure Rate Data Base	Y. Li	T. Pinna	T. Yamanishi	D. Kurbatov	L. Cadwallader
6 – Radioactive Waste Study	Z. Chang	M. Zucchetti	K. Tobita	V. Kapyshev	L. El-Guebaly
7 – Socio-Economic Aspects of Fusion Power	J. Jiang	D. Ward	S. Konishi	M. Subbotin	L. Waganer
8 – Magnet Safety	Y. Song	V. Pasler	H. Chikaraishi	I. Rodin	B. Merrill
9 – Fusion Power Plant Studies	Y. Wu	G. Federici	K. Tobita	A. Borisov	F. Najmabadi

* Task 4 – Safety System Study Methodology – Terminated July 2002

Term Highlights- *Task 1* *In-vessel Tritium Source Terms*



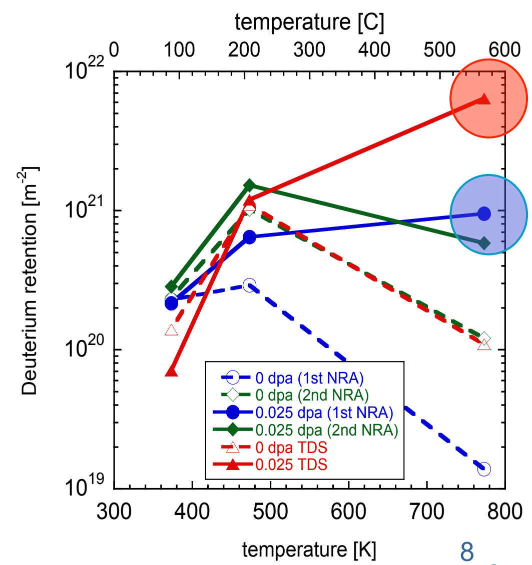
Objective: Understand and learn to control tritium source term inventories and uncertainties in experimental and future fusion energy systems.

Key Issue: Accurately estimate tritium retention in a fusion nuclear environment.

Principal Results:

- Reduction of deuterium (D) retention from ITER like wall (ILW) (i.e. beryllium or tungsten wall) campaigns in JET.
- x10 reduction compared with carbon wall
- High D retention and deep D migration in neutron-irradiated tungsten in TPE experiment (INL).

D retention in neutron-irradiated W



Term Highlights- Task 3

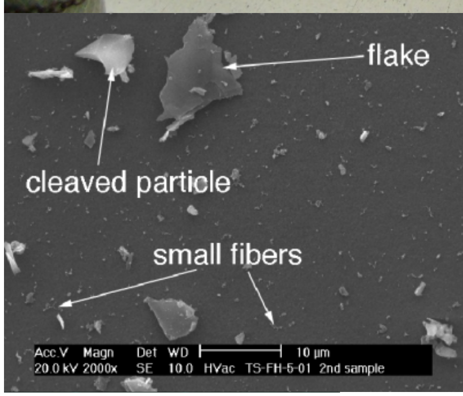
Activation Products Source Terms

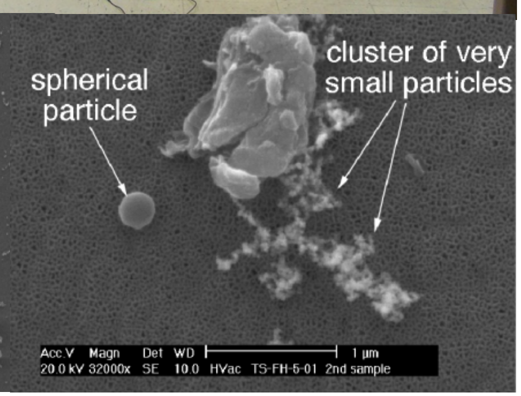
Key Issue: Generation and behavior of dust. Safety issues:

- Radiological and/or toxic hazard
- Chemically reactive (explosive)
- Impacts reactor operation

Dust characterization

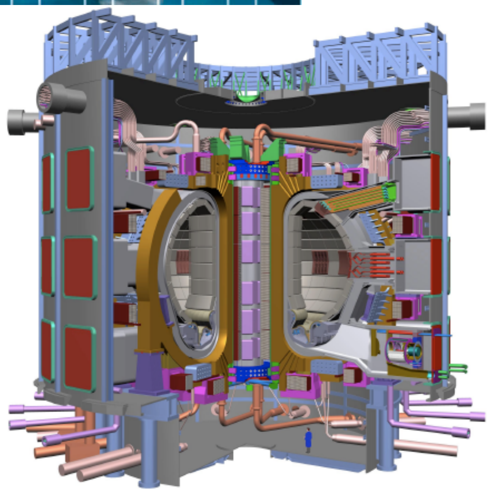
- Particle Size Distribution,
- Specific Surface Area
- Surface Mass Density
- Composition, Shape and Tritium Content





Machine	CMD (µm) ± GSD		
	Lower Regions	Middle Regions	Upper Regions
DIII-D	0.66 ± 2.82	0.60 ± 2.35	0.89 ± 2.92
TFTR	0.88 ± 2.63	1.60 ± 2.33	-
Alcator-Cmod	1.58 ± 2.80	1.53 ± 2.80	1.22 ± 2.03
JET	27 ± (-)	-	-
TEXTOR	5-20 ± (-)	-	-
Tore Supra	2.68 ± 2.89	2.98 ± 2.94	3.32 ± 2.94
ASDEX-Upgrade	2.21 ± 2.93	3.69 ± 2.81	3.59 ± 3.08
LHD	8.59 ± 2.67	6.31 ± 2.39	8.73 ± 2.09
NOVA	1.12 ± 1.90	0.76 ± 2.03	0.90 ± 1.93

Term Highlights- Task 5



Task 5 Failure Rate Data Base being used by ITER

Records Number: 5
Component data ⦿ Failure data ○

☐	Component Class	Short Desc.	Function	Failure Mode	Cause	Mean Failure Rate	FR Dist.	Reference Document
☐	Fusion specific device - Liquid Metal-cooling Systems - LiPb cooling system for blanket - -	17Li83Pb cooling system	Cooling	Leakage - Rupture		3.30E-01 /y		[INEL EGG-FSP-8709]
☐	Fusion specific device - Liquid Metal-cooling Systems - LiPb cooling system for blanket - -	17Li83Pb cooling system	Cooling	Leakage - Rupture		3.80E-05 /h		[INEL EGG-FSP-8709]
☐	Fusion specific device - Liquid Metal-cooling Systems - Cold trap - -	Cold trap		Leakage		1.00E-07 /h	LogNormal (EF)	[INEL EGG-FSP-8709]
☐	Fusion specific device - Liquid Metal-cooling Systems - Water reflector system - -	Water reflector system		Leakage - Rupture		6.70E-02 /y		[INEL EGG-FSP-8709]
☐	Fusion specific device - Liquid Metal-cooling Systems - Water	Water reflector system		Leakage - Rupture		7.60E-06 /h		[INEL EGG-FSP-8709]

New Component | Export

Back

Objective: Coordinate the collection and development of fusion operating experience data for use in probabilistic safety assessment, traditional safety analysis, RAMI and other analyses.

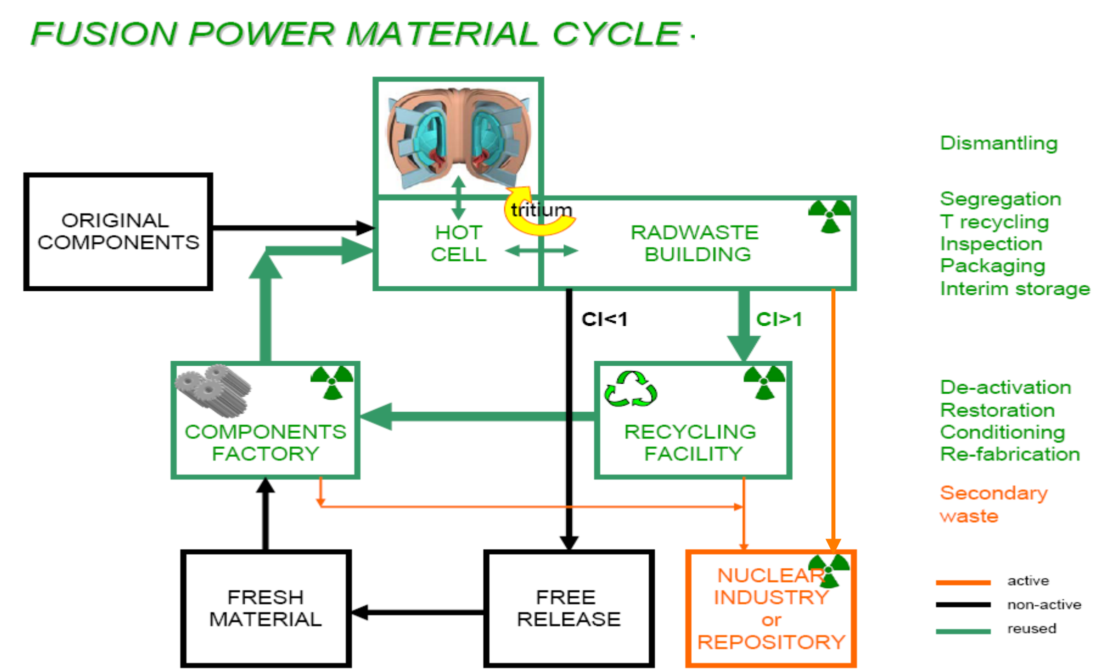
Key Issue: Valid assessment requires integration of systems at mixed levels of development or concept maturity.

Principal Results: The database is being transferred to ITER for use in design support, RAMI and safety.

Activities have a direct project impact on ITER, and important to assess options on the fusion development roadmap.

Term Highlights- Task 6

Radioactive Waste Study



Principal Results: Recent power plant studies show encouraging results for recycling and clearance: waste can be minimized, optimizing the materials cycle.

Objective: Pursue a common waste management strategy suitable for environmental and resource stewardship.

Key Issues:

- Achieving an international consensus on clearance levels
- Defining of hands-on and remote recycling levels and procedures
- Assessment of the low hazard of fusion permanent waste compared to fission
- Address impact of detritiation

Term Highlights- Task 7

Socio-Economic Aspects of Fusion Power

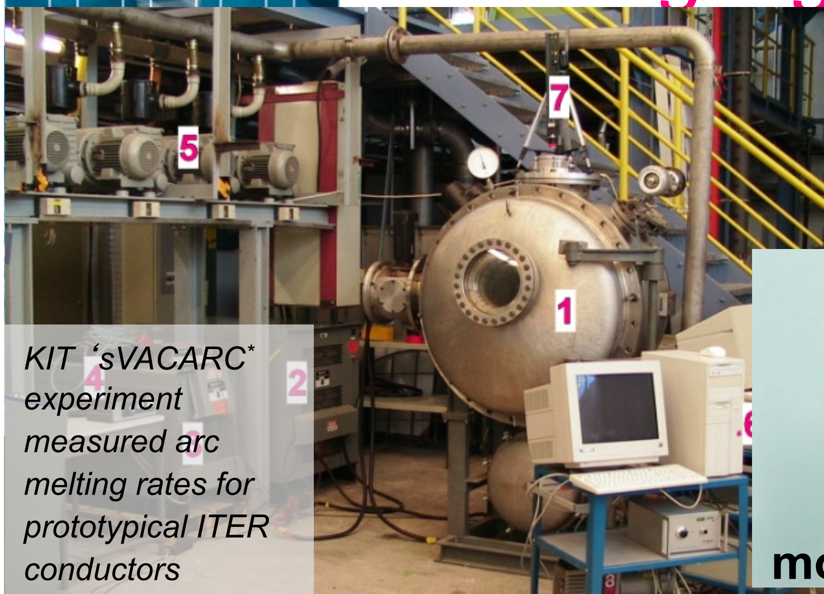
Objective: Co-operative activities to develop better understanding of the issues and improved models and assessment, in the areas of system codes, externalities, economic valuation, social acceptance, comparison of fusion with other energy sources.

Key Issues: What role can fusion play in timely addressing cost-effective global energy needs and climate change?

Principal Result: Technical work performed focused on updating costing models applied to technology development needs for conceptual reactor components, and included technology-based technical readiness level assessments. The models were incorporated into systems codes for evaluating cost-of-electricity for several envisioned plants.

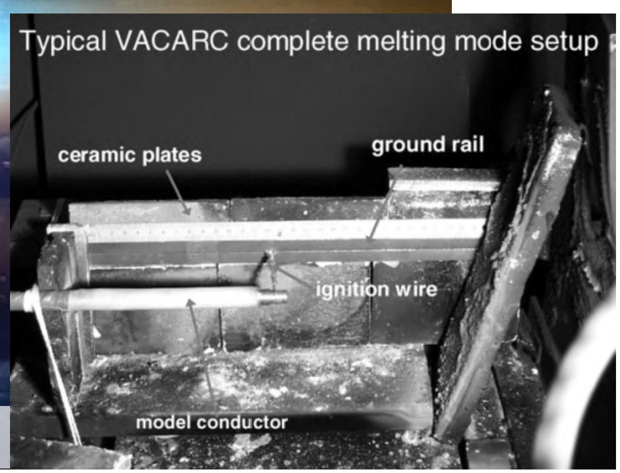
Term Highlights- Task 8

Magnet Safety



KIT 'sVACARC experiment measured arc melting rates for prototypical ITER conductors*

**Vacuum Arc Experiment*



Objective: Coordination of development and validation of superconducting magnet arcing computer codes.

Key Issues: The failure modes being modeled to help improve the design and safety of ITER are: magnet melt, molten material jets and current arcs to the vacuum vessel, cryostat, or busbar guard tube.

Principal Results:
Experiments verified computer models of the experiments. Task continues in evaluation of magnet failure in ITER.

Term Highlights- Task 9

Fusion Power Plant Studies

Objective: Inter-comparison of conceptual fusion power plant design studies under way in JA (compact tokamak), EU (tokamaks) and US (tokamak and compact stellarator).

Key Issues: Define and evaluate pathways to fusion power. Outline requirements for DEMO and beyond.

Principal Results:
Completion of various conceptual designs unique to participating countries. Cross-comparisons were used to help define DEMO. Computer codes for design optimization are continually evolving to give improved assessments of fusion power plant physics and technical issues, guiding R&D.

Term Summary

Meetings, workshops, publications:

Information dissemination (across terms):

	Year						
Scientific Publications	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Total**
Task 1 - In-vessel Source Terms	0	2	1	1	13	1	18
Task 3 - Activation Products Source Term	1	1	0	4	2	9	17
Task 5 - Failure Rate Database	2	2	4	4	6	2	20
Task 6 - Radioactive Waste Studies	1	2	2	1	2	6	14
Task 7 - Socio-economic Aspects	1	1	0	0	1	0	3
Task 8 - Magnet Safety	0	1	1	1	0	1	4
Task 9 - Fusion Power Plant Studies	1	2	7	5	9	2	26

- The Executive Committee (ExCo) met annually throughout the term of the IA, primarily during international conferences when most, if not all, of the committee members could be in attendance
- All tasks reported progress to the ExCo annually and updated their five year plans on an annual or biennial basis. All tasks held coordination meetings (some several times)
- IA produced a total of 102 publications that included 94 journal articles and 8 books and/or book chapters being published in open literature

Term Summary (cont.)

Contribution to technology evolution / progress:

- Tasks 1, 3, 5, and 8 have produced information that has supported ITER licensing, in particular ITER's Preliminary Safety Report (Rapport Préliminaire de Sûreté, RPrS) and reliability-availability-maintainability-inspectability (RAMI) activities.
- Tasks 6, 7, and 9 provided guidance regarding the economic, environmental, and public perception of fusion power
- Spin-offs to other energy technology areas have occurred in Tasks 7 and 9 with studies of fusion-fission hybrid reactors as one possible reactor concept on the path to realizing fusion power. The failure rate database developed under Task 5 has been used to support particle accelerator operations planning

Contribution to environmental protection:

- Task 6 made significant progress in coordinating international activities that reduce the environmental impact of fusion waste by developing an international consensus on waste clearance for public reuse and waste recycling

Term Summary (cont.)

Outreach to IEA Member and non-Member countries:

- The People's Republic of China was added to the IA during this term. They join Russia as the second non-Member country participating in this IA
- The Democratic People's Republic of Korea is in the process of joining the IA (ExCo affirmative vote in Sept. 2012, letter of invitation Jan 2013).

Added value:

- The participants in this IA recognize that when the research work is shared that no one participating country has to perform all of the research thus reducing the costs in each country.
- As examples:
  - Under Task 2 data from the Japanese ICE and the French EVITA experiments were used to validate thermal hydraulic safety codes now used in ITER licensing
  - Under Task 8 data from KIT's VACARC experiment has been used to develop magnet arcing codes in the EU and US
  - Under Task 5 failure rate data has been shared. No single country working alone could achieve such a high level of data verification

Future Directions

Motivation for ESEFP Continuance

Mankind's development of fusion power continues with the commitment of several parties to construct and operate ITER. The anticipated success of ITER in controlling burning plasmas is a critical first step, and research and development in the upcoming years must focus on the outstanding challenges faced in going to the next step beyond ITER.

Many of these challenges center on technology development for fusion reactors, and thorough assessment is prudent for understanding the environmental, safety, and economic aspects of the maturing technologies.

Extension of the IEA ESEFP Implementing Agreement can ensure rational, effective, and coordinated efforts for such assessments, and provide the necessary pedigree and defensibility of information used during decision-making for the future of fusion power and energy policy.

Future Directions, cont.

Strategy

Aspects of the strategy include:

- The direction of this IA supports the mission of the Fusion Power Coordinating Committee (FPCC) by tailoring the R&D performed by this IA to addressing fusion science and engineering issues, particularly with regard to environmental, safety and economic issues of fusion power
- Using the experience of the four previous terms of the IA on ESEFP, continue to apply the successful coordination and management structure while retiring outdated tasks and adding new ones
- Understand, coordinate, and respond to parties developing pathways of fusion development, including IFMIF, FNSF, DEMO, etc.
- Encourage new partners entering the IA so that all ITER Parties are represented in the IA, in particular Korea and India.

Future Directions, cont.

Strategy (cont.)

Strategic Focus (cont.):

- A high priority for our IA will continue to be supporting safety and regulatory requirements and activities in preparation for licensing of the ITER reactor being built in Cadarache, France. This IA will build on the expertise pool in the ESEFP to ensure the success of ITER as it moves through the licensing process.
- In November, 2012, the French nuclear regulator (ASN) granted the ITER Organization a nuclear operator's license and the ITER device qualified as a nuclear installation. This is the first time in the world a fusion nuclear operator has successfully gone through the rigorous process, as established by a national nuclear regulator, of documenting the design and operational conditions required for receiving a license to construct a nuclear fusion facility. This IA played an important role in this effort.
- This is not the final regulatory approval. The French nuclear regulator will need to issue an operating license based on additional data before operations commence.

See (*http://www.world-nuclear-news.org/NN-State_blessing_for_ITER_construction-2011127.html).

Future Directions, cont.

Strategy (cont.) Strategic Focus (cont.):

Energy & Environment | New Nuclear | Regulation & Safety | Nuclear Policies | Corporate | Exploration

State blessing for ITER construction

20 November 2012

The French state has authorised full construction of the world's largest tokamak nuclear fusion reactor with a formal decree to allow creation of a 'basic nuclear installation'.

ITER today: the seismic pads that will support the Tokamak Complex(Image: ITER Organisation)

Related Stories

- EU to raise nuclear research spending
- Contracts for Iter components awarded
- Superconductor work progresses for Iter
- Iter financing package secured

WNA Links

- Nuclear Fusion Power

See (*http://www.world-nuclear-news.org/NN-State_blessing_for_ITER_construction-2011127.html).

Future Directions, cont.

Some Areas for Coordinated Activities:

- Testing and validation of modeling tools for advanced blanket cooling systems in an integrated environment
- Apply failure rate data to ITER not only for safety analysis but also operations performance, maintenance practices and scheduling, etc. to reduce occupational hazards
- Study fuel retention and permeation in DEMO-relevant blanket and plasma facing component configurations
- Determine requirements for component detritiation that allows recycling and clearance of waste

Many more ESEFP challenges exist, and several are expected to materialize as humankind continues pursuing fusion power.

Summary

- The ESEFP Executive Committee requests that the FPCC recommend that the CERT approve the term extension from 1 July 2013 to 30 June 2018.
  - The next term will be critical as parties pursue fast track fusion development.
  - Several task workshops are planned during 2013 to decide work plans for continued success in the next term.