ANNUAL REPORT
FOR THE YEAR 2015

OF THE

INTERNATIONAL ENERGY AGENCY IMPLEMENTING AGREEMENT FOR ENERGY CONSERVATION AND EMISSIONS REDUCTION IN COMBUSTION

prepared by the
Executive Committee Secretariat

for
Paul Miles, Agreement Operating Agent
Sandia National Laboratories - California

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INTERNATIONAL ENERGY AGENCY
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IN COMBUSTION IMPLEMENTING AGREEMENT

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Dennis Siebers, Operating Agent
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EXECUTIVE ABSTRACT

The purpose of the IEA Implementing Agreement on Energy Conservation and Emissions Reduction in Combustion program is to improve fundamental and applied combustion technology which is developed to provide predictive design capabilities for internal combustion engines, furnaces, and gas turbines. This document summarizes the progress made in this agreement year.

Since 1978, IEA cooperative research by program participants has focused on developing experimental and computational tools to aid combustion research and on developing advanced laser-optical diagnostic tools that permit time- and space-resolved measurements of combustion phenomena for achieving this end. The Agreement's Annex structure has been planned to improve the modeling and simulation processes as well as the instrumentation required for the supporting experimental activities

The current Annex structure aproved by the Executive Committee is shown below.

Annex 1 Administration and Supportinc Activities

Annex 2 Individual Contributor Tasks

Area 1 Advanced Piston Engine Technology

Area 2 Advanced Furnace Technology

Area 3 Fundamentals

Area 4 Advanced Gas Turbine Technology

Annex 3 Sprays in Combustion

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Annex 5 Advanced Hydrogen Fueled Internal Combustion Engines (No longer active – related work can be found in Annex 9

Annex 6 Alternative Fuels

Annex 7 Nanoparticle Diagnostics

Annex 8 Hydrogen Enriched Lean Premixed Combustion for Ultra-Low emission Gas Turbine Combustors

Annex 9 Gas Engines

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YEAR 2015 ACTIVITIES OF THE EXECUTIVE COMMITTEE

Chair: Prof. Douglas Greeenhalgh, United Kingdom

Vice Chair: Prof. Martti Larmi, Finland

The Executive Committee (ExCo) of the International Energy Agency's (IEA) Program of Research, Development and Demonstration on Energy Conservation and Emissions Reduction in Combustion coordinates the cooperative efforts undertaken by participating institutions. The Committee met twice during the business year. The first meeting took place in April at IEA headquarters in Paris. The second took place following the Agreement's Thirty-seventh Task Leaders Meeting in August in St. Andrews, Scotland

Actions taken by the Executive Committee this year include:

Task Leaders Meeting: The Thirty-sevenh Task Leaders Meeting, sponsored by the Executive Committee was held at St. Andrews University in St. Andrews, In August. Principal Investigators, Executive Committee members, and invited guests gathered to hear papers presented on the Agreement's research. Forty members of the Combustion Research Community attended and thirty eight papers were presented on the Agreement’s ongoing Collaborative Task activities

Executive Committee Meetings: Minutes of the Executive Committee's meetings of April and August have been published and distributed to IEA Headquarters and to ExCo members. The Proceedings of the Thirty-seventh Task Leaders Meeting were published and distributed to IEA Headquarters and Executive Committee members for distribution to participants. The Agreement's Annual Reports and 30 Year Anniversary Report are available on the public web site.

Future Meetings: The Executive Committee scheduled its next meetings for April 2016 at IEA Headquarters, Paris and June 2016 in Finland, The June meeting will be held immediately following the 38th Task Leaders meeting in Finland

Highlights from Recent ExCo Meetings

Paris France --- April 29, 2015

The 2016 Strategy Group Meeting will be held April 23-24 in Normandy, France

Pending confirmation of a meeting room, the Spring 2016 ExCo Meeting will be held at IEA Headquarters, Paris on April 26, 2016.

The 2016 Task Leaders Meeting will be hosted by the United Kingdom in St. Andrews, Scotland in August with Prof. Douglas Greenhalgh as the local host.

The ExCo unanimously voted to request a five year extension to the Agreement which expires February 2017. The written request is due at IEA Headquarters July 2016.

St. Andrews, Scotland --- August 6, 2015

The 2016 Strategy Group Meeting will be held April 23-24 in Normandy, France

Pending confirmation of a meeting room, the Spring 2016 ExCo Meeting will be held at IEA Headquarters, Paris on April 26, 2016.

The 2016 Task Leaders Meeting will be hosted by Finland from June 27 – July 1 with Prof. Martti Larmi as the local host.

Two Page Extended Abstracts will continue to be required for all TLM Presentations

The development of proposals for new Collaborative Tasks focused on Soot Formation and Solid Fuels Combustion was endorsed by the ExCo

The Nanoparticles Diagnostic Task has been completed

The ExCo unanimously elected Prof. Martti Larmi, Finland as the ExCo Chair and Prof. Jacobo Porteiro, Spain as the ExCo Vice Chair for the Agreement Year 2015-2016. Their appointment became effective at the conclusion of the August 6, 2015 ExCo Meeting

Spain was tentatively selected as the location for the 2017 Task Leaders Meeting

SUMMARY OF RESEARCH ACTIVITIES FOR A PROGRAM OF APPLIED RESEARCH, DEVELOPMENT, AND DEMONSTRATION IN ENERGY CONSERVATION AND EMISSIONS REDUCTION IN COMBUSTION

Introduction

The Implementing Agreement for A Program of Applied Research, Development, and Demonstration in Energy Conservation and Emissions Reduction in Combustion requires that the Executive Committee define and adopt detailed specifications for each research task undertaken within the program.

The Agreement is comprised of multiple Annexes with Annex 1 being reserved for Administration and Supporting Activities, Annex 2 being Individual Contributor Tasks, and Annexes 3 and beyond being Multi Nation Collaborative Tasks

Briefly the focus of the individual Annexes is summarized below:

Annex 1 --- Administration and Supporting Activities

The objective of the work in this area is to provide administrative support services and information dissemination as called for by the work in Annexes 2 - 10.

In addition from time to time the Executive Committee may request that a Special Session of invited speakers focused on a Research Area or Policy Matter of current interest be added to the Program for an upcoming Task Leaders Meeting

Annex 2 --- Individual Contributor Tasks

This Annex has been planned to improve fundamental and applied combustion technology which is developed to provide predictive design capabilities for internal combustion engines, furnaces, and gas turbines. The Annex is divided into the following Areas:

Area 1: Advanced Piston Engine Technology
The objective of the cooperative work in this Area is the development of combustion technology, both analytical and experimental, that will provide improved models for advanced internal-combustion piston engines, namely lean homogeneous-charge, stratified-charge, and diesel engines. The research will contribute primarily to technology common to these engine concepts and will provide data bases and descriptive and predictive system codes, in addition to practical demonstrations

Area 2: Advanced Furnace Technology
The objective of the cooperative work in this Area is the development of combustion technology, both analytical and experimental, that will provide models for furnaces and

boilers. The research will provide a data base and descriptive and predictive system codes, as well as practical demonstrations.

Area 3: Fundamentals
The objective of the cooperative work in this Area is to conduct theoretical investigations of the fundamental physical phenomena relevant to the combustion process as is called for in Areas 1, 2 and 4, and to support the development of new diagnostic techniques for application in the future.

Area 4: Advanced Gas Turbine Technology
This Area covers work related to the development of combustor and gas turbine modeling and verification, to the study of emissions formation and control mechanisms, and to practical studies in fuel injection and fuel/air mixing.

Annex 3: Sprays in Combustion

Spray investigations aim at a deeper understanding of the complex interrelated aerodynamic and thermodynamic mechanisms involved in transient & steady spray combustion, which are responsible for the tradeoffs among energy conversion efficiency, nitrogen oxides and soot emissions in advanced engines and combustors. Tasks in the context of spray propagation involve a wide set of investigations on atomization, fuel-air mixing and combustion under high temperature and high pressure, as encountered in advanced diesel engines, gas turbines – and to some extent also boilers

Annex 4: Low Temperature Combustion (formerly HCCI)

The combustion process in the HCCI (Homogeneous Charge Compression Ignition) engine is mainly driven by the chemical kinetics. Thus the chemical properties of the fuel are of outmost importance. Many small molecule fuels like methane and methanol have relatively simple and well controllable combustion process but it has been shown that many fuels experience a two-stage ignition process with a time period between the two stages without significant heat release.

The intent of this Annex is to look into the interaction between HCCI and fuels. It will include activities for both the gasoline and diesel type of fuels and HCCI with fully premixed charge and direct injection.

Annex 5: Advanced Hydrogen Fueled Internal Combustion Engines (No longer active – related work can be found in Annex 9)

Annex 6 Alternative Fuels

The present day engine combustion technology has been fully developed for crude oil based traditional liquid fuels: gasoline and diesel fuel.

The aim of the Annex is develop optimum combustion of future fuels and thereby significantly reduce engine out emissions together with a noticeable increase in engine efficiency. The development of combustion techniques focuses especially on synthetic

and renewable fuels. This Annex concentrates mainly on road transportation. There is a potential of engine out emission reduction by 70% to 90 % or even more**.** Dedicated fuels need new combustion technology to meet optimal emission reduction.

Annex 7 Nanoparticle Diagnostics

This Annex focuses on research concerning the measurement of nanoparticles produced by combustion. The development of diagnostics to characterize the physical or chemical characteristics of the nanoparticles, and demonstration of the application of these diagnostics, are within the scope of this Annex. The development may include experimental, numerical, or both approaches to the research. Demonstration may be in-flame studies of nanoparticle formation and oxidation, or post-flame measurements of nanoparticle emissions.

Annex 8: Hydrogen Enriched Lean Premixed Combustion for Ultra Low Emission Gas Turbine Combustors

In response to national policies gas turbine manufacturers have set the goal to adapt their large gas turbines for CO2-mitigated power generation, whereby up to 90% of the carbon contained in the fired fossil fuel is captured and stored as CO2. In order to mitigate CO2 emissions Zero Emission Power Plant concepts are being explored on a global scale. Gas turbine based configurations are playing a significant role in these scenarios. Following up on the previously conducted collaborative effort on “Hydrogen enriched Lean Premixed Combustion for Ultra-Low Emission Gas Turbine Combustors” it is proposed to widen the future collaborative task activities to gas turbine combustion issues linked to respective Zero Emission Power Plant concepts.

Annex 9: Gas Engines

This task seeks to establish collaborations among IEA membership countries in the field of gas engines.

The following topics were identified as of particular interest/suitable for collaboration:

Ignition systems
- Diesel micro pilot injection
- Extension of lean limit for LPG fuel
- Optimization of injector and spark plug location

Fuels/kinetics
- Self-ignition and knock
- Tailored combustion systems and kinetics for various gaseous fuels with different physical and chemical properties
- Operation to even leaner and/or more dilute mixtures
- Effect of injector configuration and fuel on spray characteristics and mixing process

Novel Concept and Modelling Approaches

LIF experiments of various gas jets
Full scale experiments in optical engines; combustion verification in single-/multi-cylinder Engines

Annex 10: Combustion Chemistry

The aim of this work is to build reaction mechanisms taking into account the formation and the consumption of species detected in combustion processes. Thanks to these models, precious information on the degrees and the rates of reactants conversion, the formation of pollutants, the effects of additives can be obtained. These mechanisms will then be used in the numerical simulation of combustion devices (engines, furnaces, boilers…) to define their best operating conditions.

The Combustion Chemistry (CC) task has to be envisioned as a supporting task to the other IEA tasks (HCCI, Alternative Fuels, Spray...). It will aim at a tighter coordination and enhanced communication between research groups in kinetics. The main focus of this collaborative task is to extend and to improve the understanding of kinetics to reduce pollutants formation. The combustion of hydrocarbons, oxygenated species and surrogate fuels needs to be well understood through more elaborate mechanisms ; such knowledge could be exploited to optimize the combustion processes or devices.

Additional information on any of the work areas of the Agreement may be obtained by contacting:

Dr. Robert J. Gallagher
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How to Join the Agreement

Participation in IEA Combustion is based on mutual benefit to the Implementing Agreement and the interested newcomer.

If there is interest in joining the Implementing Agreement please contact the IEA Combustion ExCo Secretary, Dr. Robert Gallagher (Bobgall@aol.com). The Secretary will provide you with details on the Implementing Agreement and invite you to attend an ExCo Meeting as an Observer. By attending you will become familiar with the Implementing Agreement's current and future research areas. Assuming mutual interest, the next step would be to make a formal presentation to the ExCo at its next regularly scheduled meeting identifying the research areas in which you would propose to contribute. Prior to this ExCo presentation you would also be welcome to attend the next Task Leaders meeting as an Observer and, if you wished to, make a presentation related to a combustion related research topic in which you were currently engaged.

Contracting Parties to IEA Combustion Agreement are usually governments. Therefore, for interested parties it is necessary to seek support from their government to join the Implementing Agreement. The government will later appoint a Delegate and an Alternate to represent the Contracting Party in the ExCo.

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Agreement Year 2015

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Summary of Accomplishments for the 2015 Agreement Year

Each year the Agreement's Executive Committee selects one of the member countries to organize and host a technical meeting known as the Task Leaders Meeting (TLM) for the purpose of disseminating highlights from Agreement research. In 2015 the TLM was hosted by the United Kingdom in St. Andrews, Scotland. Prof. Douglas Greenhalgh from Glasgow Caledonian University was the organizer and local host. A total of thirty eight papers were presented. Proceedings were distributed to all attendees.

Extended Abstracts of selected presentations are included in the pages which follow. If further information on research results are of interest the leaders identified for each of the Tasks or the Executive Committee Member from the country responsible for the Task should be contacted directly.