SAND2015-10828R

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

Project Accomplishment Summary

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia National Laboratories
Operated for the U.S. Department of Energy by
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Nitin Natesan
2389 Lincoln Avenue
Hayward, CA 94545
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Re: CRADA SC14/01825.02.00, titled, "Cryogenic Hydrogen Release Research"

To Whom This May Concern:

Technical work on the above-referenced project was completed. Upon completion of DOE and industry-sponsored CRADAs, DOE requires that we provide a non-proprietary Project Accomplishment Summary (PAS). The PAS is a high-level non-technical overview of the project and the project results which, upon request, may be released to the public. The public release of the information contained in the PAS must be approved by all parties to this CRADA.

Enclosed is an original PAS document prepared by Chris Lafleur and a Public Release Form approved by Sandia. Please sign and return one copy to the address below or send a PDF back to veluce@sandia.gov.

Sandia National Laboratories
Attn: Victoria Newton
CRADA Administrator
MS 0115 - Building 800
1515 Eubank Blvd. SE
Albuquerque, NM 87123
(505) 284-2482

Please note that in the event that we do not receive your reply by 09/16/2015, Sandia will presume your acceptance. Thank you very much for your assistance in this matter. Your return of the signed Public Release Form will conclude Sandia's Administrative work on this CRADA. Feel free to call me at (505) 284-2482, if you have any questions or need additional information.

Sincerely,

Victoria Newton

Victoria Newton
Strategic Relationships Department
Sandia National Laboratories

Sandia National Laboratories
Operated for the U.S. Department of Energy by
Sandia Corporation
Albuquerque, New Mexico

PROJECT ACCOMPLISHMENTS SUMMARY

Cooperative Research and Development Agreement (#1825.02.00)

between **Sandia National Labs** and **Linde LLC**

Note: This Project Accomplishments Summary will serve to meet the requirements for a final abstract and final report as specified in Article XI of the CRADA.

Title: Cryogenic Hydrogen Release Research

Final Abstract:

The objective of this project was to develop a plan for modifying the Turbulent Combustion Laboratory (TCL) with the necessary infrastructure to produce a cold (near liquid temperature) hydrogen jet. The necessary infrastructure has been specified and laboratory modifications are currently underway. Once complete, experiments from this platform will be used to develop and validate models that inform codes and standards which specify protection criteria for unintended releases from liquid hydrogen storage, transport, and delivery infrastructure.

Background:

The Turbulent Combustion Laboratory at Sandia National Laboratories in Livermore, CA, has been used to develop and validate models for high-pressure gaseous releases of hydrogen, utilizing high-fidelity diagnostics with well-controlled laboratory experiments. These models for gaseous releases have been used to generate risk-informed separation distances, which have been implemented in current hydrogen codes and standards. Modifications to the TCL to enable the study of cold hydrogen dispersion and ignition characteristics, using the high-fidelity diagnostics available in the TCL, are needed so that validated models can be used to inform separation distances from cryogenic hydrogen sources. This project directly addressed this need, allowing Linde, experts in working with cryogenic hydrogen, to assist in developing a TCL modification plan to enable these cryogenic hydrogen release experiments at Sandia.

Description:

The objective of the project was to develop a plan for modifying the TCL with the necessary infrastructure to produce a cold (near liquid temperature) hydrogen jet. Sandia was the lead, as the laboratory houses the facility where the experiments will take place once the modification plan is implemented, and Linde provided technical expertise and guidance in working with cryogenic hydrogen. A weekly teleconference, and other communications, allowed all parties to discuss ideas and come up with a safe and effective plan for laboratory modifications. In follow-on work, the modifications will be made to the lab, experiments will be performed, and code revisions will be informed by the scientific-output of these experiments.

Benefits to the Department of Energy:

The Office of Energy Efficiency and Renewable Energy, Fossil Energy, and the Office of Science are working to lower the cost and energy use of the hydrogen delivery infrastructure. Results from the cryogenic hydrogen experiments, from the modified laboratory developed from this CRADA, will inform revisions to codes and standards associated with siting cryogenic hydrogen at fueling stations. This should enable cryogenic hydrogen to be located at more hydrogen refueling sites, leading to lowered costs due to the economic benefits of cryogenic storage over compressed gas storage.

Economic Impact:

The benefit to the DOE listed above of enabling cryogenic hydrogen to be located at more hydrogen refueling sites lowers consumer costs for hydrogen fuel. These codes and standards revisions will also help companies, such as Linde, to build more refueling stations that store hydrogen cryogenically, their preferred and more economical approach. The science-based codes and standards revisions will allow consumers to have a safe and positive experience refueling their hydrogen fuel cell vehicles.

Project Status:

The laboratory modification plan, developed by this project, has been completed. Follow on work will implement these lab modifications; perform experiments using this platform, leading to the code revisions.

ADDITIONAL INFORMATION

Laboratory/Department of Energy Facility Point of Contact for Information on Project

Ethan Hecht
(925) 294-3741
ehecht@sandia.gov

Company Size and Points of Contact

Linde Group LLC
Annual sales €17,047 M
Employees 65,591 (2014 data)

The primary contact for this project is:
Nitin Natesan
Business Development Manager - Hydrogen Fueling
Linde LLC
2389 Lincoln Avenue, Hayward, CA 94545
Office: 510-786-5931, Mobile: 908-720-4754, Fax: 510-786-5988
nitin.natesan@linde.com, www.lindeus.com

The technical lead for this project task is:
Michael Ciotti
Principal Equipment Engineer in H2 Fueling Engineering & CIP
Markets Engineering
Linde LLC
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CRADA Intellectual Property

None

Technology Commercialization

None

Project Examples

The design layout and specifications are provided in the Final Report.

PROJECT ACCOMPLISHMENTS SUMMARY
Cooperative Research and Development Agreement (SC14/01825.02.00)
between **Sandia National Laboratories** and **Linde LLC**

This summary has been approved for public release by Sandia and Linde LLC

Sandia National Laboratories

By _____ 8/6/15
Chris LaFleur
Principal Investigator

Date

Sandia National Laboratories

By _____ 8/6/15
Manager
WFO/CRADA Agreements

Date

Linde LLC

By _____
Title:

Date

In order to expedite the process, if we do not receive your signed reply by 09/16/2015 we will assume your concurrence for the release of this document to the public.