

ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION GRANTS

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SCOPE OF WORK

PIR-14-002, Lawrence Berkeley National Laboratory

I. TASK AND ACRONYM/TERM LISTS

A. Task List

Task #	CPR ¹	Task Name
1		Project Administration
2		Contract Execution
3		Optimize the Configuration of a Reduced-scale Ring Stabilizer Port for Operating at Low Reynolds Number Flows
4	X	Optimize Fuel Venturi for Lean Operation
5		Scaling by Multi-port Clustering for Larger Thermal Outputs
6		Verify NO _x Reduction in Laboratory Experiment
7		Evaluation of Project Benefits
8		Technology/Knowledge Transfer Activities
9		Production Readiness Plan

B. Acronym/Term List

Acronym/Term	Meaning
CAM	Commission Agreement Manager
CAO	Commission Agreement Officer
CPR	Critical Project Review
Energy Commission	California Energy Commission
M&V	Measurement and Verification
NO _x	Nitrogen Oxides
O ₂	Oxygen
ppm	Parts per million

¹ Please see subtask 1.3 in Part III of the Scope of Work (Project Administration) for a description of Critical Project Review (CPR) Meetings.

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Acronym/Term	Meaning
SCAQMD	South Coast Air Quality Management District
TAC	Technical Advisory Committee

II. PURPOSE OF AGREEMENT, PROBLEM/SOLUTION STATEMENT, AND GOALS AND OBJECTIVES

A. Purpose of Agreement

The purpose of this Agreement is to fund research to support the development of a new type of natural-draft burner that can be readily scaled and adapted to reduce emissions of Nitrogen Oxides (NO_x) from commercial and residential cooking appliances such as cook-tops and ovens.

B. Problem/ Solution Statement

Problem

Our project targets residential and commercial appliances because they have been exempt from stringent air emission regulations. These appliances emit about 80 to 90 parts per million (ppm) NO_x (corrected to 3% oxygen (O₂)), while ultra-clean industrial gas equipment emits less than 9 ppm NO_x @ 3 % O₂. This is due to the fact that these consumer-grade devices cannot afford the elaborate active and passive pollutant control technologies developed in the last three decades for the larger commercial and industrial systems.

Solution

The proposed solution is a simple and very cost-effective passive NO_x control technology developed by Lawrence Berkeley National Laboratory for the National Aeronautics and Space Administration's Microgravity Combustion Program called the "ring stabilizer." The Recipient will perform research to adapt the ring stabilizer for natural-draft operation.

C. Goals and Objectives of the Agreement

Agreement Goals

The goal of this Agreement is to develop and characterize a natural draft burner suited to residential and commercial cooking appliances that significantly reduces NO_x emissions,

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moving towards the South Coast Air Quality Management District's (SCAQMD's) 80% NO_x reduction target.

Agreement Objective

The objective of this Agreement is to engineer a class of cost-effective natural-draft ultra-clean burners based on the ring-stabilizer technology for application to residential and commercial cooking appliances. These new burners will:

- Reduce NO_x emissions to levels significantly below current SCAQMD standards;
- Maintain energy efficiency for most applications; and
- Increase energy efficiency for combustion devices that fire into open air (e.g., gas burners for cooking and baking).

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III. TASK 1 PROJECT ADMINISTRATION

PRODUCTS

Subtask 1.1 Products

The goal of this subtask is to establish the requirements for submitting project products (e.g., reports, summaries, plans, and presentation materials). Unless otherwise specified by the Commission Agreement Manager (CAM), the Recipient must deliver products as required below by the dates listed in the **Project Schedule (Part V)**. Products that require a draft version are indicated by marking “**(draft and final)**” after the product name in the “Products” section of the task/subtask. If “(draft and final)” does not appear after the product name, only a final version of the product is required. With respect to due dates within this Scope of Work, “**days**” means working days.

The Recipient shall:

For products that require a draft version

- Submit all draft products to the CAM for review and comment in accordance with the Project Schedule (Part V). The CAM will provide written comments to the Recipient on the draft product within 15 days of receipt, unless otherwise specified in the task/subtask for which the product is required.
- Submit the final product to the CAM once agreement has been reached on the draft. The CAM will provide written approval of the final product within 15 days of receipt, unless otherwise specified in the task/subtask for which the product is required.
- If the CAM determines that the final product does not sufficiently incorporate his/her comments, submit the revised product to the CAM within 10 days of notice by the CAM, unless the CAM specifies a longer time period.

For products that require a final version only

- Submit the product to the CAM for approval.
- If the CAM determines that the product requires revision, submit the revised product to the CAM within 10 days of notice by the CAM, unless the CAM specifies a longer time period.

For all products

- Submit all data and documents required as products in accordance with the following Instructions for Submitting Electronic Files and Developing Software:

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- **Electronic File Format**

Submit all data and documents required as products under this Agreement in an electronic file format that is fully editable and compatible with the Energy Commission's software and Microsoft (MS)-operating computing platforms, or with any other format approved by the CAM. Deliver an electronic copy of the full text of any Agreement data and documents in a format specified by the CAM, such as memory stick or CD-ROM.

The following describes the accepted formats for electronic data and documents provided to the Energy Commission as products under this Agreement, and establishes the software versions that will be required to review and approve all software products:

- Data sets will be in MS Access or MS Excel file format (version 2007 or later), or any other format approved by the CAM.
- Text documents will be in MS Word file format, version 2007 or later.
- Documents intended for public distribution will be in PDF file format. The Recipient must also provide the native Microsoft file format.
- Project management documents will be in Microsoft Project file format, version 2007 or later.

- **Software Application Development**

Use the following standard Application Architecture components in compatible versions for any software application development required by this Agreement (e.g., databases, models, modeling tools), unless the CAM approves other software applications such as open source programs:

- Microsoft ASP.NET framework (version 3.5 and up). Recommend 4.0.
- Microsoft Internet Information Services (IIS), (version 6 and up) Recommend 7.5.
- Visual Studio.NET (version 2008 and up). Recommend 2010.
- C# Programming Language with Presentation (UI), Business Object and Data Layers.
- SQL (Structured Query Language).
- Microsoft SQL Server 2008, Stored Procedures. Recommend 2008 R2.
- Microsoft SQL Reporting Services. Recommend 2008 R2.
- XML (external interfaces).

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Any exceptions to the Electronic File Format requirements above must be approved in writing by the CAM. The CAM will consult with the Energy Commission's Information Technology Services Branch to determine whether the exceptions are allowable.

MEETINGS

Subtask 1.2 Kick-off Meeting

The goal of this subtask is to establish the lines of communication and procedures for implementing this Agreement.

The Recipient shall:

- Attend a "Kick-off" meeting with the CAM, the Commission Agreement Officer (CAO), and any other Energy Commission staff relevant to the Agreement. The Recipient will bring its Project Manager and any other individuals designated by the CAM to this meeting. The administrative and technical aspects of the Agreement will be discussed at the meeting. Prior to the meeting, the CAM will provide an agenda to all potential meeting participants. The meeting may take place in person or by electronic conferencing (e.g., WebEx), with approval of the CAM.

The administrative portion of the meeting will include discussion of the following:

- Terms and conditions of the Agreement;
- Administrative products (subtask 1.1);
- CPR meetings (subtask 1.3);
- Match fund documentation (subtask 1.7);
- Permit documentation (subtask 1.8);
- Subcontracts (subtask 1.9); and
- Any other relevant topics.

The technical portion of the meeting will include discussion of the following:

- The CAM's expectations for accomplishing tasks described in the Scope of Work;
- An updated Project Schedule;
- Technical products (subtask 1.1);
- Progress reports and invoices (subtask 1.5);
- Final Report (subtask 1.6);
- Technical Advisory Committee meetings (subtasks 1.10 and 1.11); and
- Any other relevant topics.

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- Provide an *Updated Project Schedule, List of Match Funds, and List of Permits*, as needed to reflect any changes in the documents.

The CAM shall:

- Designate the date and location of the meeting.
- Send the Recipient a *Kick-off Meeting Agenda*.

Recipient Products:

- Updated Project Schedule (*if applicable*)
- Updated List of Match Funds (*if applicable*)
- Updated List of Permits (*if applicable*)

CAM Product:

- Kick-off Meeting Agenda

Subtask 1.3 Critical Project Review (CPR) Meetings

The goal of this subtask is to determine if the project should continue to receive Energy Commission funding, and if so whether any modifications must be made to the tasks, products, schedule, or budget. CPR meetings provide the opportunity for frank discussions between the Energy Commission and the Recipient. As determined by the CAM, discussions may include project status, challenges, successes, advisory group findings and recommendations, final report preparation, and progress on technical transfer and production readiness activities (if applicable). Participants will include the CAM and the Recipient, and may include the CAO and any other individuals selected by the CAM to provide support to the Energy Commission.

CPR meetings generally take place at key, predetermined points in the Agreement, as determined by the CAM and as shown in the Task List on page 1 of this Exhibit. However, the CAM may schedule additional CPR meetings as necessary. The budget will be reallocated to cover the additional costs borne by the Recipient, but the overall Agreement amount will not increase. CPR meetings generally take place at the Energy Commission, but they may take place at another location, or may be conducted via electronic conferencing (e.g., WebEx) as determined by the CAM.

The Recipient shall:

- Prepare a *CPR Report* for each CPR meeting that: (1) discusses the progress of the Agreement toward achieving its goals and objectives; and (2) includes recommendations and conclusions regarding continued work on the project.

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- Submit the CPR Report along with any other *Task Products* that correspond to the technical task for which the CPR meeting is required (i.e., if a CPR meeting is required for Task 2, submit the Task 2 products along with the CPR Report).
- Attend the CPR meeting.
- Present the CPR Report and any other required information at each CPR meeting.

The CAM shall:

- Determine the location, date, and time of each CPR meeting with the Recipient's input.
- Send the Recipient a *CPR Agenda* and a *List of Expected CPR Participants* in advance of the CPR meeting. If applicable, the agenda will include a discussion of match funding and permits.
- Conduct and make a record of each CPR meeting. Provide the Recipient with a *Schedule for Providing a Progress Determination* on continuation of the project.
- Determine whether to continue the project, and if so whether modifications are needed to the tasks, schedule, products, or budget for the remainder of the Agreement. If the CAM concludes that satisfactory progress is not being made, this conclusion will be referred to the Deputy Director of the Energy Research and Development Division.
- Provide the Recipient with a *Progress Determination* on continuation of the project, in accordance with the schedule. The Progress Determination may include a requirement that the Recipient revise one or more products.

Recipient Products:

- CPR Report(s)
- Task Products (draft and/or final as specified in the task)

CAM Products:

- CPR Agenda
- List of Expected CPR Participants
- Schedule for Providing a Progress Determination
- Progress Determination

Subtask 1.4 Final Meeting

The goal of this subtask is to complete the closeout of this Agreement.

The Recipient shall:

- Meet with Energy Commission staff to present project findings, conclusions, and recommendations. The final meeting must be completed during the closeout of this

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Agreement. This meeting will be attended by the Recipient and CAM, at a minimum. The meeting may occur in person or by electronic conferencing (e.g., WebEx), with approval of the CAM.

The technical and administrative aspects of Agreement closeout will be discussed at the meeting, which may be divided into two separate meetings at the CAM's discretion.

- The technical portion of the meeting will involve the presentation of findings, conclusions, and recommended next steps (if any) for the Agreement. The CAM will determine the appropriate meeting participants.
- The administrative portion of the meeting will involve a discussion with the CAM and the CAO of the following Agreement closeout items:
 - Disposition of any state-owned equipment.
 - Need to file a Uniform Commercial Code Financing Statement (Form UCC-1) regarding the Energy Commission's interest in patented technology.
 - The Energy Commission's request for specific "generated" data (not already provided in Agreement products).
 - Need to document the Recipient's disclosure of "subject inventions" developed under the Agreement.
 - "Surviving" Agreement provisions such as repayment provisions and confidential products.
 - Final invoicing and release of retention.
- Prepare a *Final Meeting Agreement Summary* that documents any agreement made between the Recipient and Commission staff during the meeting.
- Prepare a *Schedule for Completing Agreement Closeout Activities*.
- Provide *All Draft and Final Written Products* on a CD-ROM or USB memory stick, organized by the tasks in the Agreement.

Products:

- Final Meeting Agreement Summary (*if applicable*)
- Schedule for Completing Agreement Closeout Activities
- All Draft and Final Written Products

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REPORTS AND INVOICES

Subtask 1.5 Progress Reports and Invoices

The goals of this subtask are to: (1) periodically verify that satisfactory and continued progress is made towards achieving the research objectives of this Agreement; and (2) ensure that invoices contain all required information and are submitted in the appropriate format.

The Recipient shall:

- Submit a monthly *Progress Report* to the CAM. Each progress report must:
 - Summarize all Agreement activities conducted by the Recipient for the preceding month, including an assessment of the ability to complete the Agreement within the current budget and any anticipated cost overruns. See the Progress Report Format Attachment for the recommended specifications.
 - Provide a synopsis of the project progress, including accomplishments, problems, milestones, products, schedule, fiscal status, and any evidence of progress such as photographs.
- Submit a monthly or quarterly *Invoice* that follows the instructions in the terms and conditions. In addition, each invoice must document and verify:
 - Energy Commission funds received by California-based entities;
 - Energy Commission funds spent in California (*if applicable*); and
 - Match fund expenditures.

Products:

- Progress Reports
- Invoices

Subtask 1.6 Final Report

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The goal of this subtask is to prepare a comprehensive Final Report that describes the original purpose, approach, results, and conclusions of the work performed under this Agreement. The CAM will review and approve the Final Report, which will be due at least **two months** before the Agreement end date. When creating the Final Report Outline and the Final Report, the Recipient must use a Style Manual provided by the CAM.

Subtask 1.6.1 Final Report Outline

The Recipient shall:

- Prepare a *Final Report Outline* in accordance with the *Style Manual* provided by the CAM.
- Submit a draft of the outline to the CAM for review and comment.
- Once agreement has been reached on the draft, submit the final outline to the CAM. The CAM will provide written approval of the final outline within 10 days of receipt.

Recipient Products:

- Final Report Outline (draft and final)

CAM Product:

- Style Manual

Subtask 1.6.2 Final Report

The Recipient shall:

- Prepare a *Final Report* for this Agreement in accordance with the approved Final Report Outline and the Style Manual provided by the CAM.
- Submit a draft of the report to the CAM for review and comment. Once agreement on the draft report has been reached, the CAM will forward the electronic version for Energy Commission internal approval. Once the CAM receives approval, he/she will provide written approval to the Recipient.
- Submit one bound copy of the Final Report to the CAM.

Products:

- Final Report (draft and final)

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MATCH FUNDS, PERMITS, AND SUBCONTRACTS

Subtask 1.7 Match Funds

The goal of this subtask is to ensure that the Recipient obtains any match funds planned for this Agreement and applies them to the Agreement during the Agreement term.

While the costs to obtain and document match funds are not reimbursable under this Agreement, the Recipient may spend match funds for this task. The Recipient may only spend match funds during the Agreement term, either concurrently or prior to the use of Energy Commission funds. Match funds must be identified in writing, and the Recipient must obtain any associated commitments before incurring any costs for which the Recipient will request reimbursement.

The Recipient shall:

- Prepare a *Match Funds Status Letter* that documents the match funds committed to this Agreement. If no match funds were part of the proposal that led to the Energy Commission awarding this Agreement and none have been identified at the time this Agreement starts, then state this in the letter.

If match funds were a part of the proposal that led to the Energy Commission awarding this Agreement, then provide in the letter:

- A list of the match funds that identifies:
 - The amount of cash match funds, their source(s) (including a contact name, address, and telephone number), and the task(s) to which the match funds will be applied.
 - The amount of each in-kind contribution, a description of the contribution type (e.g., property, services), the documented market or book value, the source (including a contact name, address, and telephone number), and the task(s) to which the match funds will be applied. If the in-kind contribution is equipment or other tangible or real property, the Recipient must identify its owner and provide a contact name, address, telephone number, and the address where the property is located.
- A copy of a letter of commitment from an authorized representative of each source of match funding that the funds or contributions have been secured.
- At the Kick-off meeting, discuss match funds and the impact on the project if they are significantly reduced or not obtained as committed. If applicable, match funds will be included as a line item in the progress reports and will be a topic at CPR meetings.
- Provide a *Supplemental Match Funds Notification Letter* to the CAM of receipt of additional match funds.

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- Provide a *Match Funds Reduction Notification Letter* to the CAM if existing match funds are reduced during the course of the Agreement. Reduction of match funds may trigger a CPR meeting.

Products:

- Match Funds Status Letter
- Supplemental Match Funds Notification Letter (*if applicable*)
- Match Funds Reduction Notification Letter (*if applicable*)

Subtask 1.8 Permits

The goal of this subtask is to obtain all permits required for work completed under this Agreement in advance of the date they are needed to keep the Agreement schedule on track. Permits must be identified and obtained before the Recipient may incur any costs related to the use of the permit(s) for which the Recipient will request reimbursement.

The Recipient shall:

- Prepare a *Permit Status Letter* that documents the permits required to conduct this Agreement. If no permits are required at the start of this Agreement, then state this in the letter. If permits will be required during the course of the Agreement, provide in the letter:
 - A list of the permits that identifies: (1) the type of permit; and (2) the name, address, and telephone number of the permitting jurisdictions or lead agencies.
 - The schedule the Recipient will follow in applying for and obtaining the permits.

The list of permits and the schedule for obtaining them will be discussed at the Kick-off meeting (subtask 1.2), and a timetable for submitting the updated list, schedule, and copies of the permits will be developed. The impact on the project if the permits are not obtained in a timely fashion or are denied will also be discussed. If applicable, permits will be included as a line item in progress reports and will be a topic at CPR meetings.

- If during the course of the Agreement additional permits become necessary, then provide the CAM with an *Updated List of Permits* (including the appropriate information on each permit) and an *Updated Schedule for Acquiring Permits*.
- Send the CAM a *Copy of Each Approved Permit*.
- If during the course of the Agreement permits are not obtained on time or are denied, notify the CAM within 5 days. Either of these events may trigger a CPR meeting.

Products:

- Permit Status Letter

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- Updated List of Permits (*if applicable*)
- Updated Schedule for Acquiring Permits (*if applicable*)
- Copy of each Approved Permit (*if applicable*)

Subtask 1.9 Subcontracts

The goals of this subtask are to: (1) procure subcontracts required to carry out the tasks under this Agreement; and (2) ensure that the subcontracts are consistent with the terms and conditions of this Agreement.

The Recipient shall:

- Manage and coordinate subcontractor activities in accordance with the requirements of this Agreement.
- Incorporate this Agreement by reference into each subcontract.
- Include any required Energy Commission flow-down provisions in each subcontract, in addition to a statement that the terms of this Agreement will prevail if they conflict with the subcontract terms.
- If required by the CAM, submit a draft of each *Subcontract* required to conduct the work under this Agreement.
- Submit a final copy of the executed subcontract.
- Notify and receive written approval from the CAM prior to adding any new subcontractors (see the discussion of subcontractor additions in the terms and conditions).

Products:

- Subcontracts (*draft if required by the CAM*)

TECHNICAL ADVISORY COMMITTEE

Subtask 1.10 Technical Advisory Committee (TAC)

The goal of this subtask is to create an advisory committee for this Agreement. The TAC should be composed of diverse professionals. The composition will vary depending on interest, availability, and need. TAC members will serve at the CAM's discretion. The purpose of the TAC is to:

- Provide guidance in research direction. The guidance may include research scope and methodologies, timing, and coordination with other research. The guidance may be based on:
 - Technical area expertise;

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- Knowledge of market applications; or
- Linkages between the agreement work and other past, present, or future research (both public and private sectors) that TAC members are aware of in a particular area.
- Review products and provide recommendations for needed product adjustments, refinements, or enhancements.
- Evaluate the tangible benefits of project research to the state of California, and provide recommendations as needed to enhance the benefits.
- Provide recommendations regarding information dissemination, market pathways, or commercialization strategies relevant to the research products.

The TAC may be composed of qualified professionals spanning the following types of disciplines:

- Researchers knowledgeable about the project subject matter;
- Members of trades that will apply the results of the project (e.g., designers, engineers, architects, contractors, and trade representatives);
- Public interest market transformation implementers;
- Product developers relevant to the project;
- U.S. Department of Energy research managers, or experts from other federal or state agencies relevant to the project;
- Public interest environmental groups;
- Utility representatives;
- Air district staff; and
- Members of relevant technical society committees.

The Recipient shall:

- Prepare a *List of Potential TAC Members* that includes the names, companies, physical and electronic addresses, and phone numbers of potential members. The list will be discussed at the Kick-off meeting, and a schedule for recruiting members and holding the first TAC meeting will be developed.
- Recruit TAC members. Ensure that each individual understands member obligations and the TAC meeting schedule developed in subtask 1.11.
- Prepare a *List of TAC Members* once all TAC members have committed to serving on the TAC.
- Submit *Documentation of TAC Member Commitment* (such as Letters of Acceptance) from each TAC member.

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Products:

- List of Potential TAC Members
- List of TAC Members
- Documentation of TAC Member Commitment

Subtask 1.11 TAC Meetings

The goal of this subtask is for the TAC to provide strategic guidance for the project by participating in regular meetings, which may be held via teleconference.

The Recipient shall:

- Discuss the TAC meeting schedule with the CAM at the Kick-off meeting. Determine the number and location of meetings (in-person and via teleconference) in consultation with the CAM.
- Prepare a *TAC Meeting Schedule* that will be presented to the TAC members during recruiting. Revise the schedule after the first TAC meeting to incorporate meeting comments.
- Prepare a *TAC Meeting Agenda* and *TAC Meeting Back-up Materials* for each TAC meeting.
- Organize and lead TAC meetings in accordance with the TAC Meeting Schedule. Changes to the schedule must be pre-approved in writing by the CAM.
- Prepare *TAC Meeting Summaries* that include any recommended resolutions of major TAC issues.

Products:

- TAC Meeting Schedule (draft and final)
- TAC Meeting Agendas (draft and final)
- TAC Meeting Back-up Materials
- TAC Meeting Summaries

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IV. TECHNICAL TASKS

*Products that require a draft version are indicated by marking “(draft and final)” after the product name in the “Products” section of the task/subtask. If “(draft and final)” does not appear after the product name, only a final version of the product is required. **Subtask 1.1 (Products)** describes the procedure for submitting products to the CAM.*

TASK 2 Contract Execution

The goals of this task are to: (1) confirm the availability of the project demonstration site and a measurement and verification (M&V) contractor; and (2) execute any agreements necessary to secure the demonstration site and M&V contractor.

Subtask 2.1 Execute a Contract with the Selected Demonstration Site

The Recipient shall:

- Reach agreement with the manager(s) of the selected demonstration site regarding the project timeline, space reserved for the project, equipment installation, permit and insurance requirements, indemnity, and the Recipient’s use of any removal or support staff.
- If the selected demonstration site becomes unavailable during the project term, work with the CAM to select a new site.
- Execute a *Contract with the Demonstration Site* that confirms the agreement reached above on the Recipient’s use of the site.

Products:

- Contract with the Demonstration Site

Subtask 2.2 Execute a Contract with the Selected M&V Contractor

The Recipient shall:

- Confirm the selected M&V contractor’s ability to provide required hardware, software, and staff to conduct the required measurements during the project term.
- Confirm that the selected M&V contractor will follow utility M&V protocols, and will prepare a detailed analytical report that verifies energy consumption and engineering calculations for energy and cost savings.

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- If the selected M&V contractor becomes unavailable during the project term, the Recipient shall work with the CAM to select a new M&V contractor.
- Execute a *Contract with the M&V Contractor* that secures the contractor's services during the project term and confirms that the contractor will follow M&V protocol and prepare the detailed analytical report.

Products:

- Contract with the M&V Contractor

TASK 3 Optimize the configuration of a reduced-scale ring stabilizer port for operating at low Reynolds number flows

The goal of this task is to determine the optimal size and ring stabilizer configuration for natural draft operation as well as scaling (via multi-port clustering approach) to the various shapes and sizes of residential and commercial heating appliances. The experiment will involve a parametric study of the ring stabilizer to select two designs that meet the metrics on operation, performance, and ease of manufacturing.

The Recipient shall:

- Determine the operating flow regimes (i.e., Reynolds number, turbulence levels) for a natural draft ring-stabilizer port, to be used as the guideline for sizing the ring stabilizer ports.
- Investigate via laboratory experiments (using a single ring stabilizer port) the effects of varying the parameters of the ring stabilizer (i.e., gap width, and ring width relative to the port diameter) on its performance in terms of flashback, blowoff, emissions, turndown, and flame stability.
- Measure the drag coefficients of various ring stabilizers to determine the correlation between back pressure and performance.
- Select two finalist designs based on the correlation between back pressure and performance trends, and also in terms of ease of manufacturing and durability.
- Characterize the two finalist ring stabilizer port designs in a seven port hexagon cluster configuration in a forced draft setup.
- Prepare a *Report on Forced-Draft Prototype Multi-port Ring-Stabilizer Burner*

Products:

- Report on Forced-Draft Prototype Multi-port Ring-Stabilizer Burner

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TASK 4 Optimize Fuel Venturi for Lean Operation

The goal of this task is to configure the fuel venturi of a natural draft burner to produce a lean fuel/air mixture that will be burned at the ring stabilizer ports. The fuel venturi is an essential component of natural draft burner. It consists of a fuel orifice injecting fuel into a venturi to entrain air and to form a fuel/air mixture for burning at the burner port. Fuel venturis in current natural draft burner produce rich fuel/air mixtures. The research to be performed for this task is to use commercially available fuel orifices and venturi and configure them (i.e., adjust the relative position between the fuel-orifice and venturi as well as the size of the air gap) for producing lean fuel mixtures.

The Recipient shall:

- Re-configure the fuel orifice and venturi assembly of current natural draft burners to produce lean fuel/air mixtures.
- Characterize the mixture stoichiometry and homogeneity produced by different combinations of fuel orifices and venturi designs.
 - Obtain baseline information on the venturi premixer designs that produce fuel/air mixtures at various fuel lean stoichiometries and also at a consistent stoichiometry at over a range of fuel flow rates
- Evaluate the performance of venturi premixer with the seven port ring stabilizer burner
- Prepare a *Fuel Venturi Report* that includes but is not limited to the following a fuel venturi configuration for lean fuel/air mixtures.
- Prepare a *CPR Report* in accordance with subtask 1.3 (CPR Meetings).
- Participate in a CPR meeting.

Product:

- Fuel Venturi Report
- CPR Report

TASK 5 Scaling by Multi-port Clustering for Larger Thermal Outputs

The goal of this task is to investigate port-to-port interactions when the ring stabilizer ports are arranged in various clustering patterns. The objective is to gain the knowledge needed for scaling and adapting the ring-stabilizer burners to the thermal inputs of residential and commercial gas appliances. Natural draft burners are scaled by increasing the number of ports. Issues to be considered when clustering the multi-port ring stabilizers include the distances between the ports and the geometric pattern. The interaction between the flames produced by the ports will affect turndown, ignition, and possibly emissions.

ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION GRANTS

Exhibit A

SCOPE OF WORK

PIR-14-002, Lawrence Berkeley National Laboratory

The Recipient shall:

- Investigate the effects of cluster pattern (e.g., ring, hexagonal, square grid) of the ring stabilizer ports and the distance between ports on burner performances in terms of ignition, turndown, emissions, and thermal stresses.
- Develop a scaling strategy for adapting natural draft multi-port ring stabilizer burners to meet the load demands of heating appliances.
- Prepare a *Report on Scaling Strategy of Natural Draft Ring-Stabilizer Burner*.

Products:

- Report on Scaling Strategy of Natural Draft Ring-Stabilizer Burner

TASK 6 Verify NO_x Reduction in Laboratory Experiment

The goal of this task is to verify the NO_x reduction of natural-draft ring stabilizer burner compared to conventional burner. The approach is to operate a natural draft multi-port ring stabilizer burner and a conventional natural-draft burner of the same thermal output in a controlled laboratory environment that simulates the operating condition of a residential or commercial gas appliances.

The Recipient shall:

- Select, design, and fabricate an experimental station to evaluate a natural-draft, multi-port ring stabilizer burner and a conventional natural-draft burner.
- Characterize and compare the efficiencies and emissions of the ring-stabilizer burner and the conventional burner at various loads.
- Prepare a *Report on Performance of Natural Draft Ring-Stabilizer Burner*.

Products:

- Report on Performance of Natural Draft Ring-Stabilizer Burner

TASK 7 Evaluation of Project Benefits

ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION GRANTS

Exhibit A

SCOPE OF WORK

PIR-14-002, Lawrence Berkeley National Laboratory

The goal of this task is to report the benefits resulting from this project.

The Recipient shall:

- Complete three Project Benefits Questionnaires that correspond to three main intervals in the Agreement: (1) *Kick-off Meeting Benefits Questionnaire*; (2) *Mid-term Benefits Questionnaire*; and (3) *Final Meeting Benefits Questionnaire*.
- Provide all key assumptions used to estimate projected benefits, including targeted market sector (e.g., population and geographic location), projected market penetration, baseline and projected energy use and cost, operating conditions, and emission reduction calculations. Examples of information that may be requested in the questionnaires include:
 - For Product Development Projects and Project Demonstrations:
 - Published documents, including date, title, and periodical name.
 - Estimated or actual energy and cost savings, and estimated statewide energy savings once market potential has been realized. Identify all assumptions used in the estimates.
 - Greenhouse gas and criteria emissions reductions.
 - Other non-energy benefits such as reliability, public safety, lower operational cost, environmental improvement, indoor environmental quality, and societal benefits.
 - Data on potential job creation, market potential, economic development, and increased state revenue as a result of the project.
 - A discussion of research product downloads from websites, and publications in technical journals.
 - A comparison of project expectations and performance. Discuss whether the goals and objectives of the Agreement have been met and what improvements are needed, if any.
 - Additional Information for Product Development Projects:
 - Outcome of product development efforts, such copyrights and license agreements.
 - Units sold or projected to be sold in California and outside of California.
 - Total annual sales or projected annual sales (in dollars) of products developed under the Agreement.
 - Investment dollars/follow-on private funding as a result of Energy Commission funding.
 - Patent numbers and applications, along with dates and brief descriptions.
 - Additional Information for Product Demonstrations:

ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION GRANTS

Exhibit A

SCOPE OF WORK

PIR-14-002, Lawrence Berkeley National Laboratory

- Outcome of demonstrations and status of technology.
 - Number of similar installations.
 - Jobs created/retained as a result of the Agreement.
- For Information/Tools and Other Research Studies:
- Outcome of research.
 - Published documents, including date, title, and periodical name.
 - A discussion of policy development. State if the research has been cited in government policy publications or technical journals, or has been used to inform regulatory bodies.
 - The number of website downloads.
 - An estimate of how the information and research have affected energy use and cost, or have resulted in other non-energy benefits.
 - An estimate of energy and non-energy benefits.
 - Data on potential job creation, market potential, economic development, and increased state revenue as a result of research.
 - A discussion of research product downloads from websites, and publications in technical journals.
 - A comparison of project expectations and performance. Discuss whether the goals and objectives of the Agreement have been met and what improvements are needed, if any.
- Respond to CAM questions regarding responses to the questionnaires.

The Energy Commission may send the Recipient similar questionnaires after the Agreement term ends. Responses to these questionnaires will be voluntary.

Products:

- Kick-off Meeting Benefits Questionnaire
- Mid-term Benefits Questionnaire
- Final Meeting Benefits Questionnaire

TASK 8 Technology/Knowledge Transfer Activities

The goal of this task is to develop a plan to make the knowledge gained, experimental results, and lessons learned available to the public and key decision makers.

ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION GRANTS

Exhibit A

SCOPE OF WORK

PIR-14-002, Lawrence Berkeley National Laboratory

The Recipient shall:

- Prepare an *Initial Fact Sheet* at start of the project that describes the project research. Use the format provided by the CAM.
- Prepare a *Final Project Fact Sheet* at the project's conclusion that discusses research results. Use the format provided by the CAM.
- Prepare a *Technology/Knowledge Transfer Plan* that includes:
 - An explanation of how the knowledge gained from the project will be made available to the public, including the targeted market sector and potential outreach to end users, utilities, regulatory agencies, and others.
 - A description of the intended use(s) for and users of the project results.
 - Published documents, including date, title, and periodical name.
 - Copies of documents, fact sheets, journal articles, press releases, and other documents prepared for public dissemination. These documents must include the Legal Notice required in the terms and conditions. Indicate where and when the documents were disseminated.
 - A discussion of policy development. State if research has been or will be cited in government policy publications, or used to inform regulatory bodies.
 - The number of website downloads or public requests for research results.
 - Additional areas as determined by the CAM.
- Conduct technology transfer activities in accordance with the Technology/Knowledge Transfer Plan. These activities will be reported in the Progress Reports.
- Prepare a *Technology/Knowledge Transfer Report* on technology transfer activities conducted during the project.

Products:

- Initial Fact Sheet (draft and final)
- Final Project Fact Sheet (draft and final)
- Technology/Knowledge Transfer Plan (draft and final)
- Technology/Knowledge Transfer Report (draft and final)

TASK 9 Production Readiness Plan

The goal of this task is to determine the steps that will lead to the manufacturing of technologies developed in this project or to the commercialization of the project's results.

The Recipient shall:

- Prepare a *Production Readiness Plan*. The degree of detail in the plan should be

ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION GRANTS

Exhibit A

SCOPE OF WORK

PIR-14-002, Lawrence Berkeley National Laboratory

proportional to the complexity of producing or commercializing the proposed product, and to its state of development. As appropriate, the plan will discuss the following:

- Critical production processes, equipment, facilities, personnel resources, and support systems needed to produce a commercially viable product.
- Internal manufacturing facilities, supplier technologies, capacity constraints imposed by the design under consideration, design-critical elements, and the use of hazardous or non-recyclable materials. The product manufacturing effort may include “proof of production processes.”
- The estimated cost of production.
- The expected investment threshold needed to launch the commercial product.
- An implementation plan to ramp up to full production.
- The outcome of product development efforts, such as copyrights and license agreements.
- Patent numbers and applications, along with dates and brief descriptions.
- Other areas as determined by the CAM.

Products:

- Production Readiness Plan (draft and final)

V. PROJECT SCHEDULE

Please see the attached Excel spreadsheet.

ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION AGREEMENTS

Exhibit A - Scope of Work

[PIR-14-002, Lawrence Berkeley National Laboratory]

V. PROJECT SCHEDULE

Agreement Term: [11-03-2014 to 11-03-2015]

Within this Scope of Work, "**days**" means working days. Changes to due dates must be approved in writing by the CAM, and do not require a formal amendment if they are within the approved agreement term.

Task/ Subtask #	Task/Subtask Name	Meeting Name	Product(s)	Due Date
1	Administration			
1.1	Products			
1.2	Kick-off Meeting	Kick-off Meeting		12/15/2014
			Updated Project Schedule (<i>if applicable</i>) Updated List of Match Funds (<i>if applicable</i>) Updated List of Permits (<i>if applicable</i>)	7 days after determination of the need to update the documents
			CAM Product	
			Kick-off Meeting Agenda	7 days prior to the kick-off meeting
1.3	CPR Meeting	CPR Meeting #1		6/30/2015
			CPR Report	15 days prior to the CPR meeting
			Task Product(s)	
			CAM Products	
			CPR Agenda	5 days prior to the CPR meeting
			List of Expected CPR Participants	
			Schedule for Providing a Progress Determination	15 days after CPR meeting
		Progress Determination	As indicated in the Schedule for Providing a Progress Determination	
1.4	Final Meeting	Final Meeting		9/30/2015
			Final Meeting Agreement Summary (<i>if applicable</i>)	7 days after the final meeting
			Schedule for Completing Agreement Closeout Activities	
			All Draft and Final Written Products	
1.5	Progress Reports and Invoices		Progress Reports	10 days after the first of each month
			Invoices	10 days after the first of each month or quarter
1.6	Final Report			
1.6.1	Final Report Outline		Draft Final Report Outline	4/30/2015
			Final Report Outline	As determined by the CAM
			CAM Product	
			Style Manual	At least 2 months prior to the final report outline due date
			Comments on Draft Final Report Outline	10 days after receipt of the Draft Final Report Outline
			Approval of Final Report Outline	10 days after receipt of the Final Report Outline

ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION AGREEMENTS

Exhibit A - Scope of Work

[PIR-14-002, Lawrence Berkeley National Laboratory]

V. PROJECT SCHEDULE

Task/ Subtask #	Task/Subtask Name	Meeting Name	Product(s)	Due Date
1.6.2	Final Report		Draft Final Report	6/30/2015
			Final Report	8/31/2015
			CAM Products	
			Comments on Draft Final Report Outline	30 days after receipt of the Draft Final Report
1.7	Match Funds		Match Funds Status Letter	2 days prior to the kick-off meeting
			Supplemental Match Funds Notification Letter <i>(if applicable)</i>	10 days after receipt of additional match funds
			Match Funds Reduction Notification Letter <i>(if applicable)</i>	10 days after any reduction of match funds
1.8	Permits		Permit Status Letter	2 days prior to the kick-off meeting
			Updated List of Permits <i>(if applicable)</i>	10 days after determination of the need for a new permit
			Updated Schedule for Acquiring Permits <i>(if applicable)</i>	
			Copy of Each Approved Permit <i>(if applicable)</i>	7 days after receipt of each permit
1.9	Subcontracts		Draft Subcontracts <i>(if required by the CAM)</i>	As determined by the CAM
			Final Subcontracts	
1.10	Technical Advisory Committee (TAC)		List of Potential TAC Members	2 days prior to the kick-off meeting
			List of TAC Members	7 days after finalization of the TAC
			Documentation of TAC Member Commitment	7 days after receipt of the documentation
1.11	TAC Meetings	TAC Meeting #1		3/30/2015
		TAC Meeting #2		10/1/2015
			Draft TAC Meeting Schedule	20 days after the kickoff meeting
			Final TAC Meeting Schedule	10 days after the first TAC meeting
			Draft TAC Meeting Agendas	20 days prior to each TAC meeting
			TAC Meeting Back-up Materials	
			Final TAC Meeting Agenda	7 days prior to each TAC meeting
			TAC Meeting Summaries	10 days after each TAC meeting

ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION AGREEMENTS

Exhibit A - Scope of Work

[PIR-14-002, Lawrence Berkeley National Laboratory]

V. PROJECT SCHEDULE

Task/ Subtask #	Task/Subtask Name	Meeting Name	Product(s)	Due Date
Technical Tasks				
2	Contract Execution			
2.1	Execute a Contract with the Selected Demonstration Site		Contract with the Demonstration Site	No more than 3 months after the start of the Agreement term
2.2	Execute a Contract with the Selected M&V Contractor		Contract with the M&V Contractor	No more than 3 months after the start of the Agreement term
3	Optimize the configuration of a reduced-scale ring stabilizer port for operating at low Reynolds number flows		Report on Forced-Draft Prototype Multi-port Ring-Stabilizer Burner	3/31/2015
4	Optimize Fuel Venturi for Lean Operation		Fuel Venturi Report	6/30/2015
5	Scaling by Multi-port Clustering for Larger Thermal Outputs		Report on Scaling Strategy of Natural Draft Ring-Stabilizer Burner	8/31/2015
6	Verify NOx Reduction in Laboratory Experiment		Report on Performance of Natural Draft Ring-Stabilizer Burner	10/15/2015
7	Evaluation of Project Benefits		Kick-off Meeting Benefits Questionnaire	no more than 10 days after the kick-off meeting
			Mid-term Benefits Questionnaire	3/30/2015
			Final Meeting Benefits Questionnaire	no more than 10 days after the final meeting
8	Technology/Knowledge Transfer Activities		Draft Initial Fact Sheet	9/23/2015
			Final Initial Fact Sheet	10/23/2015
			Draft Final Project Fact Sheet	9/23/2015
			Final Project Fact Sheet	10/23/2015
			Draft Technology/Knowledge Transfer Plan	9/23/2015
			Final Technology/Knowledge Transfer Plan	10/23/2015
			Draft Technology/Knowledge Transfer Report	9/23/2015
			Final Technology/Knowledge Transfer Report	10/23/2015
9	Product Readiness Plan		Draft Production Readiness Plan	9/23/2015
			Final Production Readiness Plan	10/23/2015

EXHIBIT A, ATTACHMENT A-1 CONTENT AND FORMAT OF PROGRESS REPORTS

PROGRESS REPORT for Project Title, Agreement Number Month, Year

Recipient Project Manager:
Commission Agreement Manager:

What we planned to accomplish this period

[This is taken directly from the section on “What we expect to accomplish during the next period” from the last progress report]

What we actually accomplished this period

[Concise description of major activities and accomplishments.]

How we are doing compared to our plan

[Explain the differences, if any, between the planned and the actual accomplishments. Describe what needs to be done, if anything, to get back on track.]

Significant problems or changes

[Describe any significant technical or fiscal problems. Request approval for significant changes in work scope, revised milestone due dates, changes in key personnel assigned to the project, or reallocation of budget cost categories. If none, include the following statement: “Progress and expenditures will result in project being completed on time and within budget.”]

What we expect to accomplish during the next period

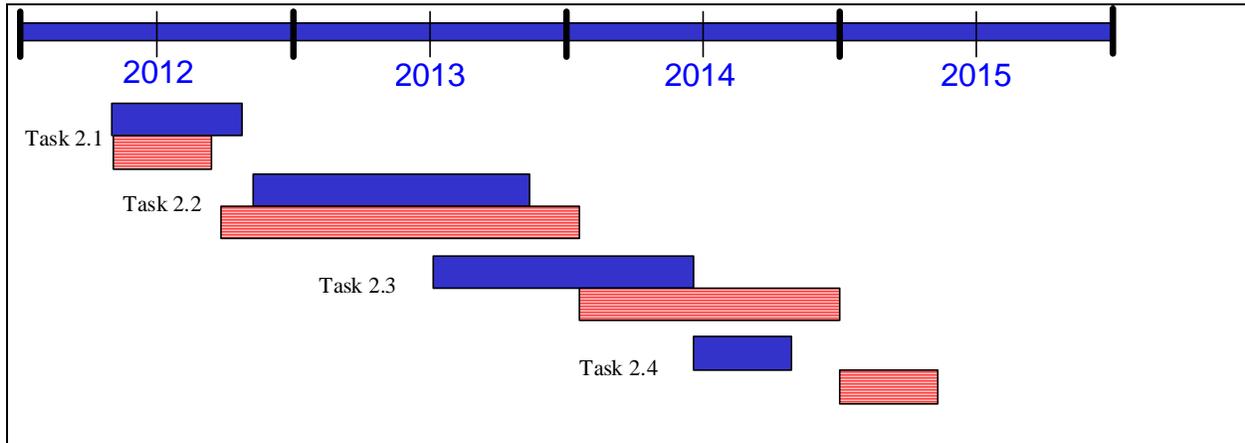
[Concise description of major activities and accomplishments expected. This will be transferred to the next progress report]]

Status of Milestones and Products:

[This should be the complete list as contained in the revised scope of work and Exhibit B. Highlight differences between actual and planned.]

Description	Start Date		Due Date		Status (%)
	Planned	Actual	Planned	Actual	
Identify top 3 assessment candidates	4/15/12	4/15/12	5/1/12	5/1/12	Ontime 100%
Develop test plan	4/20/12	4/10/12	7/7/12	6/10/12	Ahead 100%
Analyze experimental data	5/1/12	6/1/12	1/1/13	2/1/13	Delayed 25%

EXHIBIT A, ATTACHMENT A-1 CONTENT AND FORMAT OF PROGRESS REPORTS



Overall schedule for the _____ project.

[Planned is solid blue, actual is red striped. This work flow diagram needs to correlate with the schedule in Exhibit B. This example has been prepared as a Word Picture, but a comparable Excel diagram or Gantt chart is fine.]

Overview of Fiscal Status: (See invoices for detail.)

[It is useful to track the rate of expenditure of project funds. The most useful way to do this is to compare the actual expenditure rate with the planned expenditure rate. You get the planned rate at the beginning of the project, so it becomes a baseline. If you change course at a critical project review, you should show the original and the modified baseline, and then track against the new one.]

Photographs:

[Include photographs where appropriate to document progress.] The photos shall be shot with color print film or be very high quality digital photos (at least 300 dpi).

Evidence of Progress:

If there is a long time between interim products, then attach evidence of the progress being made (e.g., test data, product mock-ups, field site descriptions, preliminary analyses) to the progress reports to allow the Commission Project Manager to review progress and gauge the quality of research results.

The progress report on each project should be 1-2 pages long (plus photographs) and take about 1 hour to prepare for each reporting period.

EXHIBIT A, ATTACHMENT A-2
RESUMES

PETER LYNN THERKELSEN PH.D.
CURRICULUM VITAE

One Cyclotron Road
Berkeley, CA 94720

(510) 486-5645
ptherkelsen@lbl.gov

EDUCATION

Doctor of Philosophy, Mechanical and Aerospace Engineering **September 2009**

University of California, Irvine

Dissertation: *SI to HCCI Operation of a Small Macro-Scale 4-Stroke Engine*

Masters of Science, Mechanical and Aerospace Engineering **August 2006**

University of California, Irvine

Thesis: *Evaluation of a Low Emission Gas Turbine Operated on Hydrogen*

Bachelor of Science, Mechanical Engineering **June 2003**

University of California, Irvine

PROFESSIONAL EXPERIENCE

Research Scientist

April 2013 – Present

Postdoctoral-Fellow

August 2009 – April 2013

Ernest Orlando Lawrence Berkeley National Laboratory

Berkeley, California

- Develop and analyze fuel flexible, low emission burners for new and retrofitted industrial and commercial combustion systems and gas turbine engines in collaboration with potential tech transfer clients.
- Conduct experimental research focusing on natural gas and hydrogen lean premixed flame stability, dynamics, and acoustics for fuel flexible gas turbine development by utilizing advanced in laser diagnostics.

SELECT PUBLICATIONS

Beerer, D., McDonell, V., Therkelsen, P., and Cheng, R. K. (2014) "Flashback and Turbulent Flame Speed Measurements in Hydrogen/Methane Flames Stabilized by a Low-Swirl Injector at Elevated Pressures and Temperatures," *Journal of Engineering for Gas Turbines and Power*, Vol. 136

Davis, D.W., Therkelsen, P.L., Littlejohn, D. and Cheng, R.K. (2013) "Effects of Hydrogen on the Thermo-Acoustics Coupling Mechanisms of Low-Swirl Flames in a Model Gas Turbine Combustor," *Proceedings of the Combustion Institute*, 34, Issue 2, 3135-3143

Therkelsen, P.L., Portillo, J.E., Littlejohn, D., Martin, S. and Cheng, R.K. (2012) "Self-induced Unstable Behaviors of CH₄ and H₂/CH₄ Flames in a Model Combustor with a Low-Swirl Injector," *Combustion and Flame*, Vol. 160, Issue 2, 307-321.

EXHIBIT A, ATTACHMENT A-2 RESUMES

Robert K. Cheng, Ph. D.

Lawrence Berkeley National Laboratory, One Cyclotron Road, Berkeley, CA 94720

Dr. Robert K. Cheng is a Senior Scientist in the Environmental Energy Technologies Division of Lawrence Berkeley National Laboratory. He is the leader of the Combustion Technologies Group and is the Principal Investigator of research programs supported by the U. S. Department of Energy and other government agencies. He received a B. S. (1972), a M. S. (1974), and a Ph. D. (1977) all from the Mechanical Engineering Department of University of California at Berkeley. He joined LBNL in 1977 and built an experimental research group on combustion fluid mechanics with emphasis on the fundamental processes of lean premixed turbulent flames. He specializes in the design of laboratory experiments and the use of laser diagnostics to investigate flame turbulence interactions and has published over seventy research papers on these subjects. His discoveries of novel flame stabilization methods have generated three patents on ultra-low NO_x emission burners. These technologies are in various stages of development and commercialization for industrial heating and gas turbines for power generation. He is an active member of The Combustion Institute, ASME and the American Institute of Aeronautics and Astronautics. He also serves as a reviewer for numerous federal, agencies and scientific journals.

Patents

Low-swirl burner (US Patent 5,735,681 April 7, 1998)

Guide vane-swirler for weak-swirl burner (U.S. Patent 5,879,148 March 9, 1999. Co-inventor: Derek Yegian)

Stabilizer ring for lean premixed flames (U.S. Patent 5,516,280 May 14, 1996. Co-inventor Larry Kostiuik)

Recent Publications

1. Davis, D., P. L. Therkelsen, D. Littlejohn, and R. K. Cheng, Prog. Comb. Inst. V 34, p. 3135 - 3143 (2013).
2. Therkelsen, P.L., J. E. Portillo, D. Littlejohn, S. M. Martin and R. K. Cheng, Combustion and Flame, v. 106, p. 307-321 (2013)
3. Day, D., S. Tachibana, J. Bell, M. Lijewski, V. Beckner and R. K. Cheng, Combustion and Flame, 159 (1) 275-290 (2012).
4. Littlejohn, D., R.K. Cheng, D.R. Noble, and T. Lieuwen, "Laboratory Investigations of Low-Swirl Injector Operating with Syngases". Journal of Engineering for Gas Turbines and Power, 2010. **132**(1): p. 011502-011510.
5. Cheng, R.K., Turbulent Combustion Properties of Premixed Syngases, in Synthesis Gas Combustion - Fundamentals and Applications, T. Lieuwen, V. Yang, and R. Yetter, Editors. 2009, CRC Press: Boca Raton, London, New York. p. 129-168.
6. Cheng, R.K., D. Littlejohn, P. Strakey, and T. Sidwell, "Laboratory Investigations of Low-Swirl Injectors with H₂ and CH₄ at Gas Turbine Conditions". Proc. Comb. Inst., 2009. **32**: p. 3001-3009.

EXHIBIT A, ATTACHMENT A-2 RESUMES

Vi H. Rapp

Engineering Education

Ph.D. Mechanical Engineering Major: Combustion Minors: Heat Transfer and Chemical Kinetics	University of California at Berkeley, Berkeley, CA	December 2011
M.S. Mechanical Engineering Concentrations: Heat Transfer and Finite Element Analysis	University of Utah, Salt Lake City, Utah	August 2005
B.S. Mechanical Engineering Graduated Cum Laude	University of Utah, Salt Lake City, Utah	December 2003

Relevant Industrial/Academic Experience and Accomplishments

Postdoctoral Fellow
in Residential Building Systems Lawrence Berkeley National Laboratory
Berkeley, CA Jan. 2012 - Present

- Implementing combustion safety diagnostics that mitigating risk when improving energy performance of residential buildings
- Developing low emission, high turndown technologies for residential combustion appliances
- Developing new and retrofit solutions for small engine power applications that reduces particulate and nitrogen oxide emissions by at least 90% compared to diesel
- Designing improved, low emissions biomass cookstoves to reduce the impact of indoor air pollution and improve fuel efficiency in the developing world

Graduate Student Researcher
in Combustion

UC-Berkeley, Berkeley, CA Aug. 2007 – Dec. 2011

- Creating an industry standard index for characterizing fuel performance in advanced combustion engines
- Extending lean limit operation using a microwave assisted spark plug
- Characterized autoignition properties of biofuels and alcohol-fuels in spark-ignited engines
- Developed and validated a high efficiency, zero emissions H₂-O₂-Ar internal combustion engine
- Developed computational models using CHEMKIN, Cantera, and Matlab to investigate flame speed characteristics in H₂-O₂-Ar and H₂-O₂-He internal combustion engines

Thermal & Stress Analysis Engineer MOOG Aircraft Group, SLC, UT Dec. 2005 – Aug. 2007

- Conducted thermal analyses, using Sinda/G, on actuators and electronic flight controls to meet FAA safety standards for commercial and government aircraft
- Performed non-linear and linear stress analyses, using ANSYS, on actuator components and made design modifications to meet structural needs

Selected Refereed Journal Articles

Mack, J.H., Rapp, V.H., Broeckelmann, M., Lee, T.S., Dibble, R.W., "Investigation of biofuels from microorganism metabolism for use as anti-knock additives," *Fuel*, 117(B):939-943, 2014

Rapp, V.H., Perez, A., Singer, B.C., and Wray, C.P., "Predicting Backdrafting and Spillage for Natural-Draft Gas Combustion Appliances: Validating VENT-II," *HVAC & R Research*, 19(3):295-306, 2013

Rapp, V.H., Cannella, W., Chen, J.-Y., Dibble, R.W., "Predicting fuel performance for future HCCI engines," *Combustion Science and Technology*, 185(5):735-748, 2013

Rapp, V.H., DeFilippo, A., Saxena, S., et al., "Extending Lean Operating Limit and Reducing Emissions of Methane Spark-Ignited Engines Using a Microwave-Assisted Spark Plug," *Journal of Combustion*, vol. 2012, Article ID 927081. DOI:10.1155/2012/927081, 2012

DeFilippo, A., Saxena, S., Rapp, V.H., Dibble, R.W., Chen, J-Y, Ikeda, Y., and Nishiyama A., "Extending the lean operation limits of a gasoline engine using a microwave-assisted sparkplug," *Society of Automotive Engineers* 2011-01-0820, 2011

RESOLUTION NO:

STATE OF CALIFORNIA

**STATE ENERGY RESOURCES
CONSERVATION AND DEVELOPMENT COMMISSION**

RESOLUTION - RE: LAWRENCE BERKELEY NATIONAL LABORATORY

RESOLVED, that the State Energy Resources Conservation and Development Commission (Energy Commission) adopts the staff CEQA findings contained in the Agreement Request Form; and

RESOLVED, that the Energy Commission approves Agreement PIR-14-002 with **Lawrence Berkeley National Laboratory** for a \$400,000 grant to fund research to support the development of a new type of natural-draft burner that can be readily scaled and adapted to reduce NOx emissions from commercial and residential cooking appliances such as cook-tops and ovens; and

FURTHER BE IT RESOLVED, that the Executive Director or his/her designee shall execute the same on behalf of the Energy Commission.

CERTIFICATION

The undersigned Secretariat to the Commission does hereby certify that the foregoing is a full, true, and correct copy of a Resolution duly and regularly adopted at a meeting of the California Energy Commission held on September 10, 2014.

AYE: [List of Commissioners]

NAY: [List of Commissioners]

ABSENT: [List of Commissioners]

ABSTAIN: [List of Commissioners]

Harriet Kallemeyn,
Secretariat