

Final Technical Report

Award Number: DE-FC36-02GO12092

Project Title: *University of Michigan Industrial Assessment Center*

Project Period: 9/1/2002 to 11/30/2006

Recipient Organization: *University of Michigan, Ann Arbor, MI*

Partners: *Assistant Director: Prof. Margaret Wooldridge, UofM.*

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Executive Summary

Provide a brief executive summary which includes a discussion of 1) a summary of the center's accomplishments; 2) how the effort contributed to energy savings in the U.S.; and 3) how the project is otherwise of benefit to the public. Note: This section can be cut and pasted into the online DOE Form 241.3 in the Description/Abstract section.

The UM Industrial Assessment Center assisted 119 primary metals, automotive parts, metal casting, chemicals, forest products, agricultural, and glass manufacturers in Michigan, Ohio and Indiana to become more productive and profitable by identifying and recommending specific measures to improve energy efficiency, reduce waste and increase productivity. This directly benefits the environment by saving a total of 309,194 MMBtu of energy resulting in reduction of 0.004 metric tons of carbon emissions. The \$4,618,740 implemented cost savings generated also saves jobs that are evaporating from the manufacturing industries in the US.

Most importantly, the UM Industrial Assessment Center provided extremely valuable energy education to forty one UM graduate and undergraduate students. The practical experience complements their classroom education. This also has a large multiplier effect because the students take the knowledge and training with them.

Task Summary

Summarize the IAC's activities by task for the entire period of funding.

Task 1: Conduct Industrial Assessments, to include a variety of plant types and sizes and well as coverage of the geographic area defined in the Annual Workplan Industrial Assessments: *Provide a summary of the assessments performed over the life of the award. Include overall number of assessments, types of businesses assessed, number of ARs, and any other related info.*

Year	# of Companies	Industries Served	# of Energy AR	Energy Savings Implemented (MMBtu/year)	\$ of savings proposed	\$ of savings Implemented
2006 9/1/05 to 11/30/06	23	Eleven Steel Five Chemical Four Plastic One Aluminum One Food One Forest Product	185	108,499 Only for 14 out of 23 companies	2,931,111	1,217,185 only for 14 out of 23 companies
2005	23	Thirteen Steel Three Forest Products Two Chemical Two Plastic Two Agricultural One Metal Casting	150	60,537	2,342,646	861,076
2004	27	Fourteen Steel Three Plastic Two Chemical Two Forest Product Two Rubber One Aluminum One Agricultural One Clothing One Copper	189	28,604	2,745,020	653,741
2003	22	Seven Steel Five Chemical Four Plastic Two Forest Products One Aluminum One Rubber One Zinc One Food	146	71,373	2,978,972	1,259,861
2002	24	Nine Steel Seven Chemical Three Aluminum Three Forest Products One Metal Casting One Electronics	149	40,181	4,816,815	626,877

Task 2: Promote and increase the adoption of assessment recommendations and employ innovative methods to assist in accomplishing these goals. *Provide a summary of the efforts used to promote the adoption of ARs, including any available overall adoption statistics.*

To accomplish these goals we have done the following:

- (i) Increased the company contact time through additional telephone calls and by involving the company personnel in the report development process by sending them a draft report and asking for comments;
- (ii) We sent the draft-reports to the company as soon as possible after the visit followed by the final report;
- (iii) We increased the number of follow-up calls regarding implementation; and
- (iv) Improve the accessibility of the center, its students and our research through the use of web-based materials and we also provide the company with DOE-OIT software tools and introduce them to the DOE web-based material.

Task 3: Promote the IAC Program and enhance recruitment efforts for new clients and expanded geographic coverage. *Describe efforts to promote the IAC program and expand the reach of the center.*

We promote the IAC program and enhance recruitment efforts of new clients by:

- (i) Expanding our geographic coverage: A variety of manufacturers are located in the UM-IAC service area. Large factions of these manufacturers are located in the major industrial centers of Detroit, Cleveland, Grand Rapids and Toledo. UM-IAC has strived for diversity in geographical location and has served companies in Ohio and Indiana. We have gone as far north as Oscuda and Kalkaska, MI; as far west as St. Joseph, MI and Hicksville, OH and as far east as Jefferson & Akron, OH, which is east of Cleveland. We have also conducted an assessment in Kentucky and several assessments in Indiana.
- (ii) Developing solid IAC-industry relations through UM programs in manufacturing (PIM & TMI).
- (iii) Working with the State of Michigan Energy and Environmental Quality offices and the State representatives of Industries of the Future.
- (iv) Presenting seminars and short courses in collaboration with State offices and NextEnergy.

Task 4: Provide educational opportunities, training, and other related activities for IAC students. *Summarize education, training and other any other activities for the students. Include overall number of students that participated during the course of the award.*

Forty one undergraduate and graduate students participated in the UM-IAC program. The students greatly enjoy and benefit from the IAC company visits because it and the IAC training complement their thermo-fluid-science courses. It provides hands-on technical experience and develops important communication skills and confidence when they discuss their technical ideas with the upper management of the company. For professors, the IAC company visits provide important practical examples for classroom teaching of thermo-fluid-science courses.

The UM-IAC also encourages and engages students in creative thinking. Pre- and post-assessment brainstorming sessions are held to encourage innovative recommendations. Additional motivation is provided by travel to DOE-OIT events and participation in special projects.

The IAC faculty has developed Energy & Environmental courses [Energy and Waste Reduction in Manufacturing Processes, Management for Sustainable Manufacturing, Energy Solutions] to provide IAC and other students with appropriate background.

Task 5: Coordinate and integrate Center activities with other Center and IAC Program activities, DOE's Industrial Technologies programs and other EERE programs. *Summarize the integration activities with other centers, the ITP program, state programs, etc.*

INTERACTION WITH STATE & REGIONAL ENERGY OFFICES: UM-IAC has excellent relationship with regional and State of Michigan Energy offices (Mr. John Sarver). In fact, one of our energy projects was funded by DOE through the Michigan Energy Office. We also have a good relationship with the NIST Manufacturing Extension Program, Michigan Association of Energy Engineers, Michigan Pollution Prevention Program and have participated in their meetings on several occasions. We regularly work with US-DOE Midwest Regional Office.

UM-IAC PROCESS HEATING QUALIFIED SPECIALIST OPERATIONS: UM-IAC is uniquely positioned in that the director and the assistant director, as well as, the graduate students conduct research and teach courses in the area of combustion, thermodynamics and heat and mass transfer. These are areas directly related to process heating. The director is also a process heating qualified specialist. Thus, we have contributed to the IAC program in our area of expertise in the following manner:

- Helping other centers regarding process heating recommendations.
- Giving presentations/short courses to interested industry clients through the State of Michigan.
- Hosting & participating in Process Heating training at University of Michigan.
- Special case studies at DOE request by participating in assessments outside our territory.

Task 6: Other tasks or special projects, as needed, and as determined by DOE to be advantageous to the program and in furtherance of IAC Program goals. *Briefly describe any other special projects or tasks performed for DOE under the award.*

We are actively engaged in developing a new design for industrial furnaces and developing methods for utilizing biomass. A special furnace meeting and demonstration was held in September, 2005 in conjunction with the process heating training. The following students supported partially by center have worked on the following special projects:

1. Mungekar H.P. – Special project on pollutant formation in flames.
2. Hyoseok Lee – Special project on Highly Preheated Furnace Research.
3. Wonchan Park – Special project on Pyrolysis of Biomass for Energy.
4. Seung Jun Shin – Special project on Radiative Homogeneous Combustion.

Following papers have been published:

Journals:

1. Everest, D. and Atreya, A., "Lessons Learned from Industrial Assessments of Metal Casting Facilities", Energy Engineering, v. 99 n5, p. 38-54, 2002.
2. David Everest and Atreya, A. "Simultaneous measurements of drop size and velocity in large-scale sprinkler flows using laser-induced fluorescence and Mie scattering." Journal of Flow Visualization & Image Processing, vol. 10, pp. 163–182, 2003.
3. Mungekar, H.P. and Atreya A., "Effect of Partial Premixing on Sooting structure of Methane

Flames," *Combustion and Flame*, 144 (1-2): 336-348, Jan 2006.

4. Mungekar, H.P. and Atreya, A; "Flame radiation and soot emission from partially premixed methane counterflow flames," *Journal of Heat Transfer-Transactions Of The ASME*, 128 (4): 361-367; APR 2006
5. Mungekar, H. P. and Atreya, A , "NO formation in counterflow partially premixed flames," *Combustion And Flame*, 148 (3): 148-157; 2006.
6. Won Chan Park, Arvind Atreya and Howard R. Baum, "Numerical study of thermal decomposition and pressure generation in charring solids undergoing opposed-flow flame spread," *Proceedings of the Combustion Institute* 31 (2006) 2643–2652.

Conferences:

1. Atreya and D. Everest, "Highly Preheated Combustion Air Furnace with Oxygen Enrichment for Metal Processing to Significantly Improve Energy Efficiency and Reduce Emissions," ACEEE Conference on Energy Efficiency in Industry, 2003.
2. T. Pinder and A. Atreya, "Experimental and Computational Investigation of Dynamic Control Strategies for Nonpremixed Flames," UM-KAIST Workshop, Aug, 2003.
3. Pinder, T. and Atreya, A., "An Experimental Investigation of the Effect of Fuel Concentration Fluctuations on Non-premixed Jet Flames," Work-in-Progress Poster, Presented at the Thirtieth International Symposium on Combustion, July 2004.
4. Pinder, T. and Atreya, A., "An Experimental Investigation of the Effect of Fuel Concentration and Velocity Fluctuations on Non-Premixed Jet Flames," Presented at the Spring Technical Meeting of the Central States Section of the Combustion Institute, May, 2004.
5. H. S. Lee and A. Atreya, "Experiments and Simulations of Mixing of Aligned Multiple Fuel-Air Jets," Technical Meeting of the Central States Section of The Combustion Institute, May, 2004.
6. Pinder, T. and Atreya, A., "Optical Measurements of Radiative Emission to Monitor the Effect of Fuel Concentration Fluctuations on Non-premixed Flames," Proc. of the Fourth Joint Meeting of the U.S. Section of the Combustion Institute, March 2005.
7. Won Chan Park, Arvind Atreya and Howard R. Baum, "Numerical Study of Opposed-Flow Flame Spread over Charring Solids," Proc. of the Joint Meeting of the U.S. Sections of the Combustion Institute, March, 2005.
8. Lee, H., Pinder, T., and Atreya, A., "Radiative Homogenous Combustion for Improved Efficiency and Reduced Emissions" Poster presented at the American Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Industry, July, 2005.
9. Atreya, A. "High Temperature Industrial Furnace Based on Radiative Homogeneous Combustion for Improved Efficiency and Reduced Emissions," TMS 2006 Annual Meeting, 2006.
10. Atreya, A. Cupola Performance Enhancement by Controlled Oxygen Injection, 2003.
11. Atreya, A. Presented a seminar at Rutgers on "Radiative Homogeneous Combustion for Improved Efficiency and Reduced Emissions", 2004.
12. Carlos J. Garciamoreno, Atreya, A, "Heat Transfer in Glass Quenching" in the World Energy Engineering Congress, Atlanta Georgia, Nov. 2003.