PB88-217070

GRI-88/0109

ADVANCED HEAT-PIPE HEAT EXCHANGER AND MICROPROCESSOR-BASED MODULATING BURNER CONTROLS DEVELOPMENT

FINAL REPORT

January 1985 - December 1987

Gas Research Institute
8600 West Bryn Mawr Avenue
Chicago, Illinois 60631

GRI DISCLAIMER

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. GRI-88/0109	2.	3. Recipient's Accession No. PB88 217070/AS

4. Title and Subtitle
Advanced Heat-Pipe Heat Exchanger and Microprocessor-Based Modulating Burner Controls Development

5. Report Date: February 1988

6.

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8. Performing Organization Rept. No. TE4367-36-88

9. Performing Organization Name and Address
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10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C) 5084-241-1069
(G)

12. Sponsoring Organization Name and Address
Gas Research Institute
8600 West Bryn Mawr Avenue
Chicago, Ill. 60631

13. Type of Report & Period Covered
Final
Jan. 1985 - Dec. 1987

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

The work presented in this report includes: 1) the development of a heat-pipe condensing heat exchanger, 2) the development of a nominal 100,000-Btu/hr modulating air/gas valve, 3) the experimental performance studies of water/copper thermosyphons, 4) the field operation of a six-zone warm-air heating system, 5) the adaptation of a conventional venturi-type burner to modulation, and 6) the results of a one-day workshop for manufacturers of HVAC equipment on heat-pipe heat exchangers. Several of the accomplishments of the project included:

- A unique air/gas valve was adapted to furnaces with heat-pipe and drum-type heat exchangers, providing these furnaces with over a 5-to-1 turndown capability.
- A six-zone warm-air heating system was tested for two winters with the modulating furnaces previously described. The systems performed well, maintaining zones at their setpoints and providing almost continuous furnace operation at outdoor temperatures below 35°F.
- A data base for the application of copper/water thermosyphons was started. Very high heat transport capacities were demonstrated for a thermosyphon with a unique internal artery.
- A ten-tube heat-pipe heat exchanger was incorporated into a conventional clam-shell furnace as its second-stage condensing heat exchanger with only a small increase in the furnace's dimensions. With the heat-pipe heat exchanger, the furnace reached a 92-percent steady-state efficiency.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) Unclassified	21. No. of Pages 206
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

Report No. TE4367-36-88

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January 1985 - December 1987

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Contract Number: 5084-241-1069

RESEARCH SUMMARY

TITLE	Advanced Heat-Pipe Heat Exchanger and Microprocessor-Based Modulating Burner Controls Development
CONTRACTOR	Tecogen Inc. GRI Contract Number: 5084-241-1069
PRINCIPAL INVESTIGATORS	A. Lowenstein, B. Cohen, S. Feldman, J. Marsala, E. Smith, M. Spatz and J. Tandler
TIME SPAN	January 1985 through December 1987
OBJECTIVES	Improve the competitiveness of gas-fired, residential, HVAC equipment by developing advanced designs that exploit heat-pipe heat exchangers and modulating burners. Perform basic studies both to improve the function of heat-pipe heat exchangers and modulating burners, and to characterize their performance so that they can more readily be incorporated into HVAC equipment. Finally, develop and test prototypes of equipment that use these novel components.
TECHNICAL PERSPECTIVE	Both heat pipes and modulating burners can greatly enhance the function of thermal equipment. Heat pipes, which provide an extremely high thermal conductivity path for heat to be transferred between two fluid streams, can produce very compact and lightweight heat exchangers in comparison to conventional clamshell designs. They also have the unique ability to act as a thermal diode, reducing standby losses in some applications by preventing heat from leaving the system via the path it entered. Modulating burners can improve the operation of many thermal systems that have a variable heating load. For example, a residential. warm-air furnace that is designed to meet a house's design load is greatly oversized for much of the heating season. If a modulating burner is incorporated into the furnace, its efficiency can be improved by operating it continuously at lower firing rates and blower speeds rather than cycling it at maximum firing

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rate and blower speed. Operating nearly continuously, the warm-air furnace also becomes less intrusive to the homeowner.

RESULTS

Task 1 - Condensing Heat-Pipe Heat Exchanger: A ten-tube manifolded heat-pipe heat exchanger that would convert a conventional clamshell furnace into a high-efficiency condensing unit was developed. The heat exchanger was incorporated into the cabinet of the clamshell furnace with only a small increase in its dimensions. With the condensing heat exchanger, the furnace exceeded a 92-percent steady-state efficiency. However, almost all furnace manufacturers have now developed their own condensing furnaces. Because the original incentive for this task no longer exists, it has been discontinued.

Task 2 - Modulating Burner and Controls Development: A thorough investigation of the parameters that affect the performance of a variable orifice modulating air/gas valve was completed. Based on this work, a valve was designed that maintained a nearly constant air-to-fuel ratio over a 7-to-1 turndown range. A means of varying the air-to-fuel ratio on a predetermined schedule that ensures that the burner operates stably in a particular application is described.

Task 3 - Heat-Pipe Technology: The performance of a single-tube copper/water thermosyphon was characterized as a function of fluid inventory and inclination angle. As part of this work, the maximum heat-transport capacity of the thermosyphon was measured. The effect of antifreeze, oil and noncondensible gas on the performance of the thermosyphon was also determined. An internal artery was developed for the thermosyphon that increased its heat transport capacity 300 percent.

Task 4 - Desiccant Technology - Residential Applications and Development: The potential of several thermally regenerable desiccants to be applied in total air treatment systems was explored. Under subcontract to Tecogen, Arthur D. Little, Inc., prepared a report on consumer attitudes towards indoor comfort and air quality.

Task 7 - Field Evaluation of a Zoned Heating System: A six-zone warm-air residential heating system using the modulating valve developed in Task 2 was tested during the 1985-86 heating season. The system was operated by a controller developed by Johnson Controls. The system ran for over 2000 hours with almost no problems, while it effectively maintained zone temperatures at their setpoints.

Task 9 - Field Evaluation of a Modulating Furnace: A Yukon condensing furnace retrofit with the air/gas valve developed in Task 2 was operated as part of a zoned heating system. The zoned heating system, which was first operated in Task 7, was modified to: (1) achieve longer periods of continuous operation, and (2) allow the homeowner to adjust temperature setpoints remotely from the zones. The system operated satisfactorily throughout the three-month test. Essentially, continuous furnace operation was achieved below 35°F outdoor temperature, with damper cycling rates three to ten times lower at these temperatures than they had been in the earlier test.

Task 11 - The Development of a Modulated Venturi-Type Burner: A venturi burner made by Wayne Home Equipment was modified to increase the range of firing rates over which it could be modulated. By installing a baffle to maintain a more constant primary-to-secondary air ration and an extension to the gas orifice so that gas could be introduced at the lowest pressure location in the venturi, the modulating range was increased from 1.8 to 6.6. Further work on modulating burners will focus on induced-draft residential furnaces in a parallel GRI project.

Task 13 - Heat-Pipe Technology Development: The effect of manifolding on the heat transport capacity of a heat-pipe heat exchanger was studied. Manifolded heat-pipe heat exchangers of 7, 10, and 18 tubes were operated in a gas-fired test rig, as was a single-tube device. While all manifolded heat exchangers could transport much higher heat fluxes per-tube than the single-tube device before failure occurred, per-tube capacities decreased as the number of manifolded tubes increased. Furthermore, manifolded systems had higher heat transport capacities in a veritical position than when tilted 45 degrees. Explanations for the preceding observations are given in this report.

Task 14 - Heat-Pipe Workshop: A heat-pipe technology workshop, sponsored by GRI and hosted by Tecogen, was held on May 22, 1987 for manufacturers of gas-fired appliances and heating equipment. The objectives of the workshop were to: (1) gauge industry's interest in heat-pipe heat exchangers, (2) identify the barriers to their wider implementation, and (3) determine whether GRI can help overcome these barriers. A summary of the workshop is included in the report.

TECHNICAL APPROACH

The research in this project on both modulating burners and heat-pipe heat exchangers has proceeded as follows: (1) determine the most promising applications for the new technologies through activities such as the workshops, studies of users' needs and discussions with manufacturers, (2) develop a better understanding of each device's performance characteristics through controlled operation in the laboratory, and (3) test novel designs of thermal equipment using either device under conditions that simulate field operation.

PROJECT IMPLICATIONS

The Advanced Heat Pipe Heat Exchanger and Microprocessor-Based Modulating Burner Controls Development Project has served the GRI Residential Space Conditioning Program in a number of ways, including:

1. Developed a modulating burner capable of precisely controlling the air-to-fuel ratio and capable of stable operation over a wide range of outptus, for use in future modulating furnaces or any other appliance needing a gas-powered modulatable heat input
2. Provided extensive basic information about the operation of heat pipes and the improvement of the heat transfer rate of such pipes
3. Provided GRI with two patent filings on heat pipe technology

This background technology will be essential in the future applications of heat pipes and may be critical in future GRI developments in modulating furnaces and zoned systems. All information from this project, as well as the modulating furnace concept itself, is being transferred to Building Systems, Area 4.1.8.

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