LA-7229-C
Conference Proceedings

UC-38
Issued: April 1978

Heat Pipe Applications Workshop Report

October 20—21, 1977

Los Alamos, New Mexico

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UNITED STATES
DEPARTMENT OF ENERGY
CONTRACT W-7405-ENG. 36

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Microfiche $ 3.00

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HEAT PIPE APPLICATIONS WORKSHOP REPORT

October 20-21, 1977

Los Alamos, New Mexico

by

W. A. Ranken

Sponsored by: Los Alamos Scientific Laboratory

ABSTRACT

The proceedings of the Heat Pipe Applications Workshop, held at the Los Alamos Scientific Laboratory October 20-21, 1977, are reported. This workshop, which brought together representatives of the Department of Energy and of a dozen industrial organizations actively engaged in the development and marketing of heat pipe equipment, was convened for the purpose of defining ways of accelerating the development and application of heat pipe technology. Recommendations from the three study groups formed by the participants are presented. These deal with such subjects as: (1) the problem encountered in obtaining support for the development of broadly applicable technologies, (2) the need for applications studies, (3) the establishment of a heat pipe technology center of excellence, (4) the role the Department of Energy might take with regard to heat pipe development and application, and (5) coordination of heat pipe industry efforts to raise the general level of understanding and acceptance of heat pipe solutions to heat control and transfer problems.

SUMMARY

The Heat Pipe Applications Workshop was held in the National Security and Resources Study Center of the Los Alamos Scientific Laboratory (LASL) on October 20-21, 1977. The objectives of the workshop included developing recommendations on methods of accelerating the development and commercialization of heat pipe technology generally, determining what application areas should be emphasized as well as where emphasis is needed in a technology development program, and exploring the role of the Department of Energy (DOE) in assuring that heat pipe technology fulfills its potential of meeting a wide variety of specific needs in the national energy program.

Roughly half of the participants came from industrial concerns involved in the development and/or marketing of heat pipe equipment. Some of these represented small companies whose business is primarily in heat pipes and others were from large aerospace corporations for whom heat pipe interest was initially stimulated by extraterrestrial applications. An attempt was made to get representation from all the divisions of the DOE that are pursuing programs that could conceivably benefit from heat pipe technology. This endeavor met with limited success, but a reasonably broad representation was obtained, consisting of both DOE people and also DOE and NASA laboratory personnel involved in program management for the DOE. A few representatives from potential user industries and from universities also attended.

The attendees were divided into three study groups. It was through their interaction in these groups that the basic work of the meeting was accomplished.

Among the recommendations of the groups were the following:

- Applications studies done by an objective prime contractor, with consensus input from heat pipe as well as other heat transfer technologies, are needed, particularly in the heat recovery area. These should be comprehensive--and hence well funded--and should be done on a industry-by-industry basis.
- The development of broadly applicable technologies such as heat pipe technology is severely limited by the absence of a single organization within the DOE with the responsibility of supporting such work. Such an organization is needed to bridge the gap between basic research and specific application development.

- Measures that the DOE can take and in some cases has begun to take to aid the commercialization of heat pipe technology include:
  a. providing an energy auditing program to make plant operators aware of heat recovery opportunities,
  b. vigorous promotion of energy recovery through the provision of a strong incentive structure including tax breaks and utility rate reversal,
  c. funding the development of energy recovery systems, particularly ones for high-temperature operation, and
  d. establishment of a program for evaluating alternative approaches for various energy recovery situations.
- The DOE should establish a Heat Pipe Center of Excellence to:
  a. provide heat pipe information for industrial users,
  b. provide heat pipe research and development information for heat pipe manufacturers,
  c. provide program management for heat pipe research and development contracts, and
  d. provide a supporting technology base for applications development work done by private industry.

INTRODUCTION

The Heat Pipe Applications Workshop was conceived at the Los Alamos Scientific Laboratory as a step towards accelerating the development of heat pipe technology and its commercial application in a wide range of energy related areas. It was felt that, although substantial progress has been made in technology development and commercialization, neither the extent nor the rate of this progress has been commensurate with the potential of this technology to make very significant contributions to the task of resolving the national energy dilemma.

Prior to the call of the workshop, a survey was taken of all the companies known by LASL to be either marketing heat pipe equipment or carrying out programs to develop such equipment. The survey results are included in this report as Appendix B. Among other things these results confirmed the interest of the heat pipe industry in having a meeting to discuss marketing and technology development problems and the role the Department of Energy could play in assisting the industry.

The specific objectives of the workshop were to explore the need for application identification and evaluation efforts, determine how to overcome problems in generating new programs in heat pipe technology and application development, decide what areas of heat pipe application deserve more emphasis, and recommend actions by which the DOE can aid the commercialization of heat pipe technology. To accomplish these objectives, representation was sought from all the organizations that are active in heat pipe equipment development and manufacturing and, with mixed success, from most of the energy technology divisions in the DOE.

In the lead-off talk this writer expressed the interest of LASL in furthering heat pipe commercialization and made the point that the combination of the novelty of the heat pipe and the very broad range of potential heat pipe application works to impede the rate of progress. To determine whether the heat pipe approach offers real advantages in a given area of application requires not only a basic comprehension of heat pipe capabilities but also a thorough understanding of the application area. It is rare that both are found in the same individual. This problem could be alleviated by intensive efforts in application identification and evaluation wherein specific application areas are studied in depth, and then heat pipe design concepts are generated and thoroughly analyzed from a viewpoint of technical feasibility and potential cost-effectiveness. This procedure may often involve the complete revision of a given process to take advantage of heat pipe capabilities rather than the replacement of isolated pieces of equipment.

ORGANIZATION

The workshop format was typical in that the participants met in a general session to set the stage for the basic work of the meeting. Subsequently, they separated into three study groups with specific tasks to accomplish and then reassembled the following day in a second general session where the study group chairmen presented the reports of their respective groups and these were discussed at some length.

The initial general session was somewhat unusual in that time slots were allotted for participants to address briefly the entire assembly. Heat pipe industry representatives discussed key aspects of their development and marketing programs and described some of the problems they were encountering. Representatives from the DOE (including DOE and NASA laboratory personnel involved in program management for the DOE) described heat transfer needs in various programmatic areas.

The study groups, designated red, green, and blue, were given the following tasks:

Red Group

Primary Assignment: What is the need for heat pipe applications identification and evaluation efforts? What areas? What size and scope? What means can be developed for carrying these out? Who should do it?

Additional Tasks: Explore possible matchups between DOE thermal systems needs and heat pipe capabilities in:

a. Energy Conservation
b. Nuclear Energy and Waste Management
c. Solar Energy

Green Group

Primary Assignment: What are the problems in generating new programs in heat pipe applications development and heat pipe technology development? What measures could be taken to overcome these problems?

Additional Tasks: What technology development efforts are needed? Why? Explore possible matchups between DOE thermal systems needs and heat pipe capabilities in:

a. Thermal Storage

b. Energy Conservation

c. Energy Conversion

Blue Group

Primary Assignment: What can the DOE do to aid the commercialization of heat pipe technology?

Additional Tasks: Explore possible matchups between DOE thermal systems needs and heat pipe capabilities in:

a. Industrial Energy Conservation

b. Coal Conversion and Utilization

In addition to these tasks, each group was asked to do the following: Examine the desirability, role, and structure of a heat pipe promotional organization to:

a. Speed commercialization.

b. Inform the DOE.

c. Establish Congressional interest.

The body of this report consists of the recommendations that evolved from the study group sessions. The responses to the primary assignments are discussed separately and recommendations concerning application areas, the advisability of a heat pipe organization, and other conclusions are all presented in a combined format.

Primary Assignment: What is the need for heat pipe application and evaluation efforts? What areas? What size and scope? What means can be developed for carrying these out? Who should do it?

In considering the need for heat pipe applications identification and evaluation efforts the group concentrated its thinking primarily in the area of energy conservation. It took note of a study by the Oak Ridge National Laboratory* that estimated the heat rejected by the six largest fuel-consuming industries for various ranges of rejection temperature. The estimates were as follows:

Rejection Temperature:	Below 100°C	100-250°C	250-800°C	800-1800°C
Rejected Heat (10^{15} BTU/yr):	5.6	3.1	2.2	1.0

These numbers are roughly doubled when all industrial usage is taken into account. It is apparent that very large savings of energy could be made by effective heat recuperation and that there is ample incentive to work toward higher recuperator operating temperatures.

The group felt that the importance of applications studies was strongly influenced by the temperature at which heat pipe equipment was required to operate. For temperatures below roughly 200°C (400°F) it was felt that no DOE-sponsored studies were necessary. The markets are well identified and known to the heat pipe industry.

Potential applications for temperatures above 200°C, particularly in the energy conservation field, were considered a different matter. The group was unanimous in the decision that government-sponsored application studies were needed. It was felt that such studies should be carried out by a prime contractor able to evaluate objectively both heat pipe and alternative approaches to a given energy recovery or heat transfer problem rather than by a group whose interests were heavily weighted toward heat pipe solutions. Heat pipe input to

*R. G. Donnelly, V. J. Tennery, D. L. McElroy, T. G. Godfrey, and J. O. Kolb, "Industrial Thermal Insulation - An Assessment," TID-27120, Aug. 1976.

the studies should involve several individuals representing the heat pipe community to insure a consensus. It was deemed important that the prime contractor be able to recognize the imbalance of comparing a fledgling technology that has experienced limited development with 100-yr-old alternative technologies that have had a great deal of development attention over the years. Thus, heat pipes should be evaluated not only for current performance, but for future potential. The differences between current and future potential should be quantified to form the basis of a work statement of a public solicitation to undertake performance improvement investigations. This, of course, applies to situations where potential performance would give a clear advantage to the use of heat pipe systems.

The applications studies should be on an industry-by-industry basis with initial emphasis on the steel and glass industries, with later inclusion of the nonferrous metals, paper, and other industries.

The study group's treatment of the question of size and scope of applications studies was colored by assertions of its DOE members that the funding that might be made available for such efforts would very likely be limited to a figure of approximately $100k. This was felt to be rather meager for the task at hand, since it would allow only minimal studies to be performed rather than a comprehensive and detailed survey of all industrial heat recovery applications.

Primary Assignment: What are the problems in generating new programs in heat pipe application development? What measure should be taken to overcome these problems?

In dealing with its primary assignment the Green Group concentrated primarily on the problem of obtaining adequate funding for heat pipe technology development. It was the feeling of most of the group, particularly the industrial members, that the major difficulty in this area was the nonexistence of a single organization within the DOE that funds technology development per se. The work required lies outside what has heretofore been the range of interest of the Division of Basic Energy Science. At the same time it is difficult to get development funding from project-oriented divisions of the DOE because heat pipes would generally be one of numerous components of a system or sub-system and not apt to attract attention if the job could be done - even inadequately - by more conventional heat transfer methods. It was pointed out that conventional heat exchanger equipment was developed, by and large, without the infusion of government funding. However, the group felt that the pressing nature of the national need for more effective energy conservation - as well as for energy supply alternatives - has created an entirely new situation.

Another difficulty in obtaining funding is that the DOE is not the final customer for much of the work it sponsors. This tends to produce reluctance to look at new technologies on a component level (particularly where these technologies are substitutional in nature) without a high degree of assurance not only of technical feasibility but also of cost-effectiveness. Such assurance is sometimes difficult to give without the technology development type of effort for which funding is largely unavailable.

Other problems were felt to be the lack of a manufacturing technology development program, such as the Air Force one sponsored, and the fact that heat pipe technology is currently too small an area to attract any significant attention within the DOE.

The most obvious solution to the problem of developing technologies that have a broad range of applicability would be the establishment of an office within the DOE with this specific responsibility. Failing this, it was determined that the main recourse would be to turn to divisions such as: Power Systems, Industrial Conservation, Reactor Research and Technology, Advanced Systems and Materials Production, Solar, Fossil Energy Research, MHD, Energy Storage, Geothermal, and Transportation. Other alternatives were to convince the Basic Energy Sciences Division to broaden its charter to include technology development activities and to approach EPRI.

The thought was raised that a single large demonstration project with lots of visibility would be helpful in establishing more support for heat pipe work.

BLUE GROUP REPORT

Primary Assignment: What can the DOE do to aid commercialization of heat pipe technology?

In considering what the DOE could to to aid the commercialization of heat pipe technology, the Blue Group agreed that the most effective action would be the vigorous promotion of energy recovery without regard to specific methods. In general, the group felt that it was more appropriate to think in terms of a heat recovery industry rather than a heat pipe industry. Credence is given to this view by the fact that heat recovery is, and doubtless will remain, the most important application of heat pipe technology.

The first recommendation of the group was that the DOE should develop an incentive structure that would rely heavily on tax breaks for the installation of recovery equipment and also should lead the way in encouraging utilities to reverse their rate structure so that rates increase with usage. There was some sentiment in the group that if incentive measures proved ineffective in bringing about the installation of heat recovery equipment in industrial plants, then sterner measures, such as the establishment of rigid energy-consumption quotas, should be employed.

A second recommendation was that the DOE should encourage and even provide assistance for energy audits in industry. It has been the experience of heat pipe recovery system manufacturers that most industrial operators do not know the flow rates, temperatures, contaminants and corrosive substances that exist in their processes. (This point came up several times during the workshop, the general feeling being that the plant operators knew what went in to and what product came out of a given process, but knew very little about what went on in between.)

It was agreed that funding of research and development of energy recovery systems generally and high-temperature energy recovery systems in particular was a very important role for the DOE to play. It was also felt that the DOE should disseminate technology, should have programs for evaluating alternative approaches for various energy recovery situations and should be a force for enhancing the depth and quality of educational curricula in heat transfer.

In addition to facilitating the deployment of heat recovery equipment, the second major recommendation of the group was that the DOE should establish a Heat Pipe Center of Excellence. It was felt that LASL could be such a center with the following responsibilities:

1. provide heat pipe information for industrial users,
2. provide heat pipe research and development information for heat pipe manufacturers,
3. provide program management for heat pipe research and development contracts, and
4. provide a supporting technology base for applications development work done by private industry.

There was some concern about a psuedo-government organization (i.e., LASL) competing with industry for government research and development funding, but it was generally recognized that the management of research and development contracts would be more effective if associated with an in-house program of technology development - particularly one in which the development of high-temperature (400°C - 1400°C) heat pipes was stressed. An arrangement where industry concentrated primarily on the development of specific applications and the Center of Excellence research program provided technological support for the applications work could result in a strong cooperative program with little threat of competitive interference.

HEAT PIPE TECHNOLOGY DEVELOPMENT

The needs of the heat pipe manufacturers with regard to heat pipe technology development were discussed in all three groups to one extent or another. The major goals of such an effort would be to increase performance, reduce cost, and demonstrate very long lifetime. In general, the amount of effort that is needed becomes greater as the required operating temperature of the heat pipe is increased. However, particular emphasis is needed in the temperature range between 200 and 700°C where the number of currently available working fluids is very limited.

Increased performance holds forth the prospect of reducing the number of heat pipes required for a given job and hence of reducing cost. It was recognized that esoteric methods of achieving higher performance could easily drive the heat pipe costs up faster than the savings that would accrue from decreasing the number required. Hence, sound judgement must be exercised in developing new wick configurations and liquid return systems to avoid the overriding of increased performance by increased cost.

It was felt that, for operating temperature below about 200°C, external heat transfer coefficients (mainly with regard to gas/gas heat exchangers for heat recovery applications) tended to be the limiting factor and hence there would be little pay-off in increasing the internal performance of the heat pipe. Where potential pay-off becomes apparent, company funding or unsolicited proposals to the DOE could be used to do the required development. There was strong dissent to this view by one individual who felt that increased internal performance of the heat pipe would always benefit the system in which it was incorporated and that improvements would come about only if the government set exacting performance standards and solicited bids for work to meet those standards.

There was unanimity among the conferees that a program of technology development for heat pipes operating above 200°C was much needed and would have very high pay-off potential. Such a program should be directed not only at increased performance but also should strongly emphasize materials research to insure the development of low-cost units with long-lifetime capability in whatever environment they are called upon to perform. The need for development of working fluids and compatible container materials in the 300-700°C range and of high-temperature units capable of resisting severely corrosive working environments was particularly stressed. In regard to the first of these, it was felt that mercury, which is an excellent working fluid for the temperature range in question, had been passed over too rapidly because of its toxicity. It was thought that there was a significant degree of overreaction to the toxicity problem - that any potential for accidental escape of this material could be made highly improbable and that such escape, were it to occur, could be safely controlled for many applications.

The Green Group felt that an excellent summary of needed heat pipe technology development appeared in a report by W. H. Thielbahr on general heat exchanger technology needs.* This summary is reproduced here:

"Heat pipes are attractive heat recovery devices in high temperature, hostile environments because they, 1) have no moving parts which improves reliability, 2) can be incorporated into heat exchanger configurations to yield lower thermal stresses (e.g., can have free ends for thermal expansion), 3) can be easily cleaned in some instances, and 4) offer a redundant wall to separate working fluid from heat source. Refractory alloys containing tungsten, niobium, and molybdenum have been successfully used as heat pipe containers for special purposes but these materials are not expected to successfully withstand the rigors of many high temperature, highly corrosive environments for sustained periods of time. Ceramic heat pipe concepts should be developed for high temperature applications. Single units should be fabricated and initially tested in simulated waste heat and coal-fired combustion environments. These results should then be used to design, construct, and test full-scale heat exchanger units under conditions representative of high temperature waste heat and topping cycle applications.

"To minimize the chances of a hazardous working fluid coming in direct contact with the heat source in a bottoming system, promising heat pipe waste heat boiler concepts should be identified and preliminary designs prepared. Following this, the design of a full-scale unit should be prepared for a particular bottoming cycle application. A demonstration of performance and reliability in full-scale should be conducted in a realistic environment.

"In conjunction with the development of ceramic heat pipes and heat pipe waste heat boilers, improved heat pipe working fluids for 500°F (260°C) to 1000°F (538°C) applications should be developed. These materials should be evaluated at realistic conditions to quantify heat transfer characteristics and document long-term thermal stability and compatibility with heat pipe materials

*W. H. Thielbahr, "Heat Exchanger Technology Needs for Conservation Research and Technology, ERDA," NWC Technical Memorandum 2930, Dec. 1976, pp. 34-35.

(wick and container). These results would be used to design recuperators and waste heat boilers for energy recovery or energy transport in environments whose temperatures exceed 700°F (371°C).

"As was pointed out in the survey of heat pipe deficiencies, the theoretical efficiency of heat pipes often exceeds actual performance. A concentrated level of effort needs to be directed at improving the understanding of heat pipe phenomena. Specifically, fluid-vapor interaction phenomena and the effects of gravity need further study and quantification because they so strongly influence heat pipe performance.

"The successful application of gas-to-gas heat pipe exchangers in recovering and transferring energy from sources less than $\sim$ 500°F (260°C) has been accomplished by private industry without the overt support of the federal government. There is one particular deficiency in this application, however, that may require federal assistance if it is desired to maximize the effective use of heat pipes in saving energy and conserving fuel supplies. This is, the apparent lack of a concentrated effort to lower fabrication costs. It is recommended that a study be made of current costs and techniques to fabricate heat pipe components for this particular heat exchanger application (it is understood that much of this information may be proprietary). If cost-benefit analyses indicate substantially more energy can be saved by increasing the utilization of heat pipe heat exchangers, and lower cost fabrication techniques can be identified as a means to increase use, a program to identify lower cost fabrication techniques should be initiated."

HEAT PIPE APPLICATION AREAS

1. Energy Conservation

Energy conservation, primarily heat recovery, was considered by all three groups to be the dominant area of heat pipe application. Most of the recommendations appearing elsewhere in this report were made with this application in mind so that further discussion would be repetitious.

2. Coal Conversion and Utilization

Heat pipe companies oriented primarily toward the manufacture of commercial equipment were not too interested in the area of coal conversion and utilization because it appears that no great market is available, at least in the near time frame. However, companies oriented more towards long-range development feel that this is a very fruitful area for the application of heat pipes. It was recommended that the DOE encourage better communication between coal conversion plant designers and heat pipe technologists. There was a feeling that the former are not too aware of the potential advantage of heat pipe approaches. Conversely, the heat pipe companies have a lot to learn about the specifications and requirements of coal conversion plants. The DOE could provide the thrust required to overcome this communication barrier.

3. Solar Energy

For low-pressure applications, such as building heating and cooling, the advantages of the heat pipe as a largely passive system are pronounced. The main problem is one of cost, which is a problem for all solar items. The development of lower cost fabrication methods is likely to make heat pipe systems competitive. There is some thought that competitive systems could be built now.

In high-temperature concentrating systems heat pipes have the advantage of being able to receive high heat fluxes and transfer the heat to an extended surface area. High performance and high-temperature capability (for operation in air) are needed and both are achievable with a more intensive research and development effort.

4. Space Nuclear Power

Redundancy in reactor core cooling, flexibility for coupling reactor heat to various convertor systems and passive operation have made heat pipe designs the leading contender for space power reactor systems. Research and development are needed to demonstrate the required performance. Present programs address this task, but funding levels are low.

5. Nuclear Waste Management

It appears that current heat pipe technology is adequate for removing heat from a variety of nuclear waste storage systems. An exception might be those systems requiring operating temperature in the vicinity of 300°C. The passive operation characteristic of heat pipes ought to make them the system to beat for this type of application.

HEAT PIPE PROMOTIONAL ORGANIZATION

The advisability of a heat pipe promotional organization was discussed in each of the three groups. The consensus was that the heat pipe group was too limited in numbers and heat pipe applications were too diverse to make a promotional organization a workable construct. Attendees from the larger companies did not anticipate support for the concept from their organizations.

Alternative concepts were discussed, one being a waste heat recovery organization in which all types of heat recovery systems would be promoted. It was felt that heat pipe systems are doing well in competition with other types of heat exchangers (in the temperature range below perhaps 300°C) and that the general concept of heat recovery is what really needs the promotional attention.

The other alternative discussed was the formation of a subgroup under an established technical organization such as ASHRAE, ASME, or AICHE. A significant advantage of this approach would be that it opens the door for participation by government and academic people, in addition to industrial representatives. Functions that such a group could be called upon to perform include:

- Preparation and distribution of a newsletter announcing contract opportunities and awards and giving highlights of new developments.
- Publicizing of heat pipe technology in layman's terms.
- Participation in Congressional hearings.
- Promoting the inclusion of heat pipe technology in engineering college curricula.
- Arranging meetings with users.
- Updating of ASHRAE design procedures.

APPENDIX A

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APPENDIX B

SUMMARY OF RESPONSES TO A SURVEY OF THE HEAT PIPE INDUSTRY RELATIVE TO ITS INTERACTION WITH THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SURVEY OF ERDA/HEAT PIPE INDUSTRY INTERACTIONS

A questionnaire relating to the interaction between ERDA and the newly emerging heat pipe industry has been sent to ten industrial organizations involved in the manufacturing and/or development of heat pipe appliances. Eight of these responded in full and one sent back a limited response. This compilation of the results of the survey lists the questions asked and summarizes the responses after each one.

1. Are you currently marketing heat pipe units designed for energy-related applications?

yes: 8
no: 1

What areas of application?

Air-to-air heat exchangers (HVAC)
Industrial process-to-HVAC heat recovery units
Industrial process-to-process heat recovery units
Arctic soil stabilization units
Electronic component coolers
Spot coolers of various types
Roadway de-icing units
Commercial and domestic cooking appliances
Multi-fuel air heaters.

2. Do you currently have ERDA contracts for heat pipe work in energy-related areas?

yes: 3
no: 6

In what areas?

Solar thermal power:	2	
Energy Conservation:	1	
Thermal Energy Storage:	1	(Through Lewis Research Center,NASA)

3. Have you been generally encouraged in your contacts with ERDA?

yes:	2
no:	4
yes & no:	1
Insufficient contact:	1

Respondent's Comments:

a. One general problem has been the slowness of ERDA's administrative process.
b. ERDA wants assurance that heat pipes will be commercially successful, but is reluctant to carry its programs far enough to supply the information for such a judgment. It is a circular problem.
c. Always interest in the potential, but the expertise needed to make a decision based on technical merit is lacking.
d. Small businesses need a full-time person available for "lobbying" in Washington in order to be able to compete.

4. Do you feel ERDA has given sufficient attention in its overall RD&D program, to potential energy-related applications of heat pipes?

yes:	1
no:	6
Unfamiliar: (with program)	1

Respondent's Comments:

a. ERDA has not defined its objectives well enough to see where heat pipes fit.
b. ERDA fears being accused of direct support of commercial programs yet it wants commercial acceptance of the products of its R&D funding.

c. ERDA sponsors some heat pipe work as part of energy-related programs, but is not directly sponsoring heat pipe technology development, hence is not laying the groundwork for future applications.

5. If not, in what areas of application should ERDA put more emphasis?

Energy recovery
Coal gasification
Coal combustion primary heat exchangers
Constant temperature process control (for endothermic and exothermic reactions).
Solar heating and cooling
Geothermal heat exchangers
Gas turbine recuperators
Space power
Reactor cooling

6. What measures do you feel should be taken to stimulate ERDA participation?

None:	0
Formation of a heat pipe promotional organization	6
Other coordination of individual company efforts (promotional)	2
Obtaining of backing of potential users.	6

7. Were you aware of the PON from the Division of Industry, Energy Conservation Office, ERDA, relative to the demonstration of high-temperature exchangers?

yes: 3
no: 5

8. Are you able to devote adequate manpower to in-depth assessment of potential marketing opportunities and/or proposal preparation?

yes: 0
no: 7

If not, what measures would be helpful?

a. [A revision of the rules of the proposal game.] ERDA has recently tightened its rules for the acceptability of unsolicited proposals. The effect is to increase selling costs, yet such selling costs are disallowed under ERDA contract rules.

b. More resources!

c. ERDA support of in-depth applications identification and evaluation studies.

9. Given the goal of a dramatic extension of heat pipe technology into energy-related areas, what research do you feel needs to be done?

Respondents were given a list and asked to rank five in order of importance. These were weighted on a basis of 10 for first priority, 8 for second, etc., with the following results.

Score	Votes		Research goal
5.3	5	a.	Development of adequate working fluids in the 700-1100 °F range.
4.3	5	b.	Comparative design studies (relative to non-heat-pipe systems).
4.0	6	c.	Development of durable, economical, very high temperature heat pipes (> 2000 °F) for industrial applications.
4.0	6	d.	Development of low-cost fabrication methods.
4.0	5	e.	Applications identification and evaluation program.
2.3	3	f.	Performance maximizing of gravity-assist or gravity-return wicking systems.
2.3	3	g.	Heat pipe systems analysis and design "optimization."
1.3	2	h.	Theory of vertical, low-fill gravity-return systems with trough configurations.
1.0	2	i.	Development of general engineering design code, readily adaptable to various machines.
1.0	1	j.	Theory of high fill gravity-return systems with flow separator.
0.5	1	k.	Working fluid hazards analysis.
0.3	1	l.	General unified heat pipe theory.
0	0	m.	Investigation of start-up dynamics.

10. What do you feel would be a reasonable current level of funding for ERDA for heat pipe applications development work?

zero:	0
1 to 2 million:	2
4 to 5 million:	1
10 million:	4
10 to 50 million:	1

11. What role(s) should LASL take in broadening the base of heat pipe applications?

- 0 None
- 5 Promotional with ERDA
- 3 Promotional with potential users
- 6 General supporting research
- 2 Development of specific applications through prototype stage
- 1 Joint development programs with specific heat pipe companies
- 2 Technical monitoring of ERDA heat pipe development contracts.

12. Would a one-day meeting of representatives of the heat pipe industry at LASL to chart possible cooperative action to promote heat pipe development and utilization be useful?

yes:	7
no:	2

Two additional questions relative to the format, topics to be covered and attendees, drew responses that showed some preference for a well-organized workshop format discussing the topics broached in the questionnaire with ERDA representatives participating. There was also considerable support for a discussion of heat pipe capabilities by heat pipe people, coupled with presentations by ERDA personnel of identified ERDA needs relative to the handling of heat.