DOE/R4/10601--T1

FINAL TECHNICAL REPORT

VOLUME 1 of 3.

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PROJECT SUMMARY.

DOE Grant DE-FG44-92R410601

**Commercialization
OF
AIR CONDITIONING HEAT PUMP/WATER HEATER**

Submitted by

**WALLACE ENERGY SYSTEMS
WALLACE HEATING & AIR CONDITIONING, INC.
831 Dorsey Street, SW
Gainesville, Georgia 30501
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January 30, 1996

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WALLACE ENERGY SYSTEMS
WALLACE HEATING & AIR CONDITIONING, INC.
831 Dorsey Street, SW
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January 30, 1996

Mr. Robert J. Brown
Contracting Officer
United States Department of Energy
Atlanta Support Office
Suite 876
730 Peachtree Street NE
Atlanta, Georgia 30308

Dear Mr. Brown:

REF: Grant DE-FG44-92R410601 - Commercialization of Air Conditioning
Heat Pump/Water Heater.

Please find enclosed Volumes 1 through 3 of our Final Technical
Report with Appendixes for the above referenced DOE grant. Do not
hesitate to call if you have any questions or require further
information. Please accept my sincere appreciation for all your
assistance.

Sincerely,

Wallace Heating & Air Conditioning, Inc.
d/b/a Wallace Energy Systems

Joe C. Pendergrass
Joe C. Pendergrass
President

Enclosure.

EXECUTIVE SUMMARY

WALLACE ENERGY SYSTEMS

January 30, 1996

FINAL TECHNICAL REPORT for DEPARTMENT OF ENERGY

GRANT DE-FG44-92R410601: Commercialization Of Air Conditioning Heat Pump Water Heater (HPWH).

EXECUTIVE SUMMARY

Wallace Energy Systems received DOE Grant DE-FG44-92R410601 in order to develop and improve an air conditioning heat pump water heating system for commercial and residential systems. The objective of the Project was to produce a saleable system which would be economically competitive with natural gas and cost effective with regard to initial cost versus annual operating costs.

Problems addressed throughout the Project included technical, economic, personnel and marketing considerations. Extensive modification and continuous refinement of commercially available equipment has produced a reliable system which is more cost-efficient than natural gas. However, more work is needed to further reduce both installation costs and annual operating costs. Throughout the Project, we experienced difficulty in finding qualified technical personnel. In addition, we were forced to upgrade systems installed early in the Project in order to retain satisfied customers to support our marketing effort.

The Project progressed in five (5) Phases. During Phase 1, our emphasis was on the study of available data on heat pump water heating systems and the testing of equipment with the objective of reducing manufacturing costs.

Phase 2 was characterized by numerous field installations with extensive systems monitoring in cooperation with utility companies, particularly Georgia Power Company and the Tennessee Valley Authority (TVA). Phase 3 was the proving ground for lessons learned during

Phase 2. During Phase 3, research was performed on the refinement of component parts and improvement of installation techniques. At the close of Phase 3, we were engaged in installation and testing of three (3) separate product lines for different applications: the Independence series, the Conservationist series and the Lexington series.

During Phase 4 of the Project, we began extensive testing of installed systems, notably the Super Wash House in Knoxville, Tennessee in cooperation with TVA. Additional TVA installations provided data regarding the use of single wall heat exchangers for non potable water.

In Phase 5, which continues to date, our efforts extended beyond research and development to include true commercial sales which did not require extensive involvement of Wallace Energy Systems personnel.

The Super Wash House job presents a particularly realistic and well documented illustration of the outstanding performance of our heat pump water heater. TVA played a central role in this installation as an independent testing agency. Using the Synernet system, TVA began an intensive evaluation of the system in April 1995 and is scheduled to continue testing through April 1996 with a comprehensive report by the TVA Engineering Service at the conclusion of the test period.

Results of testing on the Super Wash House revealed consistent Coefficients of Performance (COPs) in the range of 3.88 to 4.68. Significantly, our system performs more efficiently with lower inlet water temperatures since the liquid refrigerant is condensed more efficiently. This fact is of great economic significance since our system may adapt better in northern latitudes of the US where energy demands for hot water are greater due to lower inlet temperatures.

In summary, the heat pump water heater had been a technical success, proving more efficient in water heating than natural gas while producing space cooling at no extra cost. Lessons learned during the Project emphasized the need for qualified technical personnel in the manufacturing and installation process and the requirement for continuing support from the utility companies in order to sell the system on a commercial basis.

During the initial evaluation of our Project in 1986, DOE engineer Joe Dillon stated that "the annual average coefficient of performance (COP) of [the Wallace Energy System's] system must be greater than 2.87 if [it] is to compete with natural gas." As shown by the TVA test data on the Super Wash House job, we have far exceeded this benchmark. In addition, the excellent COPs achieved on the Super Wash House do not include the economic benefits of space cooling at no additional cost. This will be a major factor in the marketing of the system to business owners.

With further development and marketing efforts, in Mr. Dillon's words, our system "has the potential to save 1.14 million barrels of oil equivalent over all-electric water heating systems..." We are confident that we can surpass even this goal for the betterment of the heat pump water heater industry and our national economy as a whole.

PROJECT SUMMARY

WALLACE ENERGY SYSTEMS

January 30, 1996

FINAL TECHNICAL REPORT for DEPARTMENT OF ENERGY

GRANT DE-FG44-92R410601: Commercialization Of Air Conditioning Heat Pump Water Heater (HPWH).

PROJECT SUMMARY

1. **BACKGROUND.** Wallace Energy Systems began the heat pump water heating project with a tremendous advantage over our nearest competitors since the company had extensive experience with conventional heat pump applications extending over a period in excess of 35 years. During the early 1980's, we identified a need for water heating in combination with heating and air conditioning systems in residential and commercial applications. Although several other companies had achieved limited success under laboratory conditions, none had developed a commercially viable product.

At the time of our application for DOE assistance, we had invested considerable time and money in this effort with the following results:

a. A patent was granted relating to control of air flow across the evaporative coil or outdoor coil in the water heating mode. This function enabled us to control compressor suction gas temperatures between 60 and 115 degrees F.

b. We had accumulated considerable experience with heat pump water heaters in earlier research in solar energy applications and had used the heat pump water heaters to augment solar systems.

However, the following problems remained at the time of our grant application:

a. We needed to refine both component parts and systems as a whole, including controls, refrigeration systems, heat exchangers and storage tanks,

b. We needed to install prototype units in a variety of field conditions, both for testing and to gain experience in installing systems on a commercial basis.

The DOE grant was needed for the following reasons:

- a. To fund work required to commercialize the system,
- b. To obtain outside support from the utility companies.

2. PURPOSE AND SCOPE OF GRANT. The purpose of this grant was the development and improvement of an air conditioning heat pump water heating system for both commercial and residential applications. The resulting system should be both economically competitive with non-renewable energy sources, e.g., natural gas, and cost effective with regard to initial investment cost versus annual operating costs. The scope of the project included the following:

a. The modification, refinement and testing of system components, i.e., storage tanks, heat exchangers, fan controls, refrigerant systems and other hardware components, both separately and as a complete system,

b. The development and refinement of refrigerant systems which will allow the air conditioning heat pump water heater to operate effectively over a wider range of outdoor ambient temperatures than conventional heat pump systems,

c. The assembly and development of system components into a marketable package which meets market demands as either a complete system or as a retrofit to existing systems, which will increase their existing efficiency, and

d. The installation, monitoring and testing of systems for the purpose of evaluation under actual field conditions. Testing and evaluation of systems by independent testing agency or authority.

3. **GENERAL CONSIDERATIONS AND PROBLEMS.** The Project was accomplished in five (5) Phases, described below. Problems addressed throughout the Project included the following:

a. Technical considerations. There is no commercially available equipment which will perform both space heating/cooling and water heating. From the outset of the Project, it was obvious that the only realistic solution was to adapt existing commercial equipment to Project requirements. Testing and experimentation was required to determine what available equipment could be adapted and the modifications required to achieve the desired performance.

b. Economic Considerations. Reducing the cost of the initial installation was a major consideration since commercial purchasers of the system, i.e., owners of coin laundries, expect a 2-3 year payback period. Initially, we worked extensively with utility companies such as Georgia Power and the Tennessee Valley Authority (TVA) to use their in-house financing incentives to help sell test-bed systems. This proved advantageous to the Project since much of our test data was obtained through utility testing of installed systems. Data on annual operating costs has been continuously analyzed since the heat pump water heater must be competitive with other energy sources, primarily natural gas, if a mass market for this equipment is to be developed.

c. Personnel Considerations. It has been extremely difficult to find qualified personnel to manufacture, install and maintain our equipment. Of necessity, manufacturing has been done at our facility on a job-shop basis with no attempt at assembly line production to this point. Although we have standardized and streamlined our manufacturing procedures, the highly technical nature of the heat pump water heater manufacturing process requires a qualified technician who is also a craftsman. Under ideal circumstances, the heat pump water heater systems should be easily installed by any local dealer experienced in HVAC products. However, despite our continuing efforts to provide detailed installation instructions, we

continue to experience problems with systems incorrectly installed by third parties. This problem can be partly solved by utility company education of dealers and vocational training of dealer personnel; however, during this developmental period, each of our heat pump systems is a unique product and each system has its own installation and maintenance characteristics. Better system maintenance can also be achieved through dealer education programs, but - as with installation - we must look to the utility companies to provide initial support for this effort.

d. Marketing Considerations. The DOE grant alone was never considered as the sole source of funding for the Project. From the start, the Project had to generate some profit to cover the shortfall in both DOE funding and investment by Wallace Energy Systems. Therefore, during each of the five Project phases, we have sold systems through our own marketing efforts and those of the utility companies. As our technical knowledge and experience increased, it became obvious that our earlier systems would have to be modified to retain satisfied customers as a basis for further market penetration. This has presented both technical and financial obstacles as we attempt to conserve our research dollars to fund further development of the system.

4. **PROJECT PHASE 1.** This initial phase began with study of available data on heat pump water heater development, heat exchangers, hot water storage tanks and production line heat pumps furnished by major manufacturers. Equipment was procured and tested by us in our own facilities. A detailed description of Phase 1 activities is available in Project Status Report 1 (Grant Period 11-6-92 to 1-15-93) and Report 2 (Grant Period 1-15-93 to 3-31-93), enclosed. See Appendix A.

Our Test Plan # 3 was a highlight of this Phase and is described in detail by Mr. Ronald Henderson in the Atlanta Support Office Progress Report for June 1, 1992 (submitted June 2, 1993), enclosed. See Appendix B. The objective of Test Plan # 3 was to reduce manufacturing costs of heat exchangers and storage tanks, while

maintaining space heating comfort levels and economical water heating costs. Recording instrumentation for this test and subsequent on-site evaluations was furnished by Georgia Power Company in the form of a Synernet Monitoring System with an IBM XT computer to read out and record 14 temperature points, plus water flow rates and kilowatt hour usage.

Test results obtained during this Phase showed that a modified 3-ton heat pump could maintain its BTU output over a heating range of outdoor temperatures of 65 degrees F and lower. At this point, testing with various heat exchangers seemed to indicate that the solution for residential applications was a combination of both double walled heat exchangers for domestic water use and single walled for space heating and storage purposes. However, since there was no commercially available product on the market, we continued to experiment with heat exchangers of our own design.

In summary, problems encountered during Phase 1 were:

a. Finding major manufacturers of component parts, i.e., heat pumps and tanks, who were willing to work with us on this project. For example, Wolverine could manufacture a heat exchanger to our specifications, but had no capability to evaluate its performance. In addition, hot water storage tank manufacturers did not want to build specialized products for which there was no immediate mass market. This attitude was shared by heat pump manufacturers, e.g., Amana.

The impact of these problems on the Project included:

a. As a result of the lack of interest by major manufacturers, we had to build our own storage tanks and piece together heat exchangers in order to get some idea of how the total system would function. Major manufacturers did not want to get involved with prototype equipment.

Lessons learned and results achieved during Phase 1 included:

a. Involvement of the utility companies in our Project was absolutely essential. In particular, the support of Mr. Charlie Wall

of Georgia Power Company has been a key element in our success both before and after the DOE grant. Mr. Wall has assisted both with Georgia Power financing and with his personal encouragement and enthusiasm for our work.

5. PROJECT PHASE 2. This Phase was characterized by numerous field installations and extensive systems monitoring. During this Phase, we developed three approaches to the problem of utilizing the same system for space heating/cooling and water heating by marketing and testing our Conservationist series, Lexington series and Independence series of systems. DOE Project Status Reports 3, 4 and 5 describe in detail the results of testing during this Phase. See Appendix A.

The basic investigative approach during this phase was the installation of systems by cost sharing with the owner and Georgia Power and the extensive monitoring of installed systems by the Georgia Power Synernet system. Lessons learned on early installations provided the basis for improvement of later systems.

Jobs installed and tested during Phase 2 included the following:

a. Independence Series.

(1) Village Coin Laundry in Toccoa, Georgia, owned by Roger Craven. Installed one modified Westinghouse 4-ton unit and one modified Amana 4-ton unit,

(2) Mark Gravitt Residence. Installed one 3-ton heat pump system. Georgia Power test data from this site indicated that space heating and domestic water heating for this 1,800 square foot residence with a family of three would cost \$ 210.00 per year,

(3) Hartwell Coin Laundry, Hartwell, Georgia. Installed one modified 4-ton Amana heat pump system. This system was promoted by Mr. Charlie Wall of Georgia Power Company and installed by McGee Heating & Air Conditioning Co. This was a new facility with costs shared as follows: owner paid for equipment; Wallace Energy Systems funded research, service and guaranteed the operation and system performance; and Georgia Power supplied a 120 gallon storage tank with double walled heat exchanger and demand controller,

(4) Mack's Coin Laundry, Franklin, Georgia. This application was a retrofit job using one modified Amana 5-ton unit and is described in detail in the accompanying Wallace Energy System report dated September 20, 1993. See Appendix A. Again, installation costs were shared by the owner, Georgia Power and Wallace Energy Systems. Cost analysis of data collected on this installation indicated that, at current rates, the system is 47 percent more efficient than natural gas.

(5) Jameson Inns (2 sites) in Ozark, Alabama and Brunswick, Georgia. These systems consisted of one 4-ton Amana unit at each site. Test results on the Jameson Inns indicated substandard performance due to our efforts to cut costs in order to sell the job.

(6) Lowndes County School, Valdosta, Georgia. Georgia Power purchased and installed a 5-ton air conditioning system with water heating recovery.

b. Conservationist and Lexington systems were not installed during Phase 2.

Considerable technical progress was made on the Hartwell Coin Laundry, which proved to be the turning point in systems development because we were able to identify problems in the refrigeration system that caused high head pressure to occur during the cooling cycle only.

Due to the exceptional progress on the Hartwell Coin Laundry in terms of test data, systems design and equipment, we were able to apply our Hartwell experience to improve control of refrigerant flows in the reclaim mode and in the cooling-only mode.

In summary, problems encountered during Phase 2 were:

- a. Refrigerant system control,
- b. Fan control reliability,
- c. Proper wiring diagrams,
- d. Misapplication of equipment and heat exchanger size,

e. Determining the refrigerant characteristics within the system when operating through the entire refrigeration cycle.

The impact of these problems made us aware of areas to address and the need to apply the information gained in this Phase to produce a more efficient product.

Lessons learned and results achieved during Phase 2 included:

a. Quality control in our assembly and installation processes was essential,

b. Feedback from coin laundries established that the owners were very pleased with the systems in terms of space comfort, monetary savings and reliability of equipment. With these satisfied customers, we knew that we were on the right track,

c. During the third quarter of 1993, we became concerned about possible patent infringements. Searches were conducted by our patent attorneys and a patent application was made on the refrigerant flow system in January 1995. Please refer to our DOE Project Status Report for the period of 9-30-94 to 12-31-95 and Appendix A for further details.

6. **PROJECT PHASE 3.** During this Phase, we began installation and field testing of the Conservationist and Lexington series in addition to the Independence series. Phase 3 was the proving ground for lessons learned in Phase 2. Research during this period was focused on refinement of component parts including heat exchangers, fan controls and refrigeration systems. In addition, considerable progress was made in techniques for system installation including the installation of outdoor units, fan coils, hot water storage and duct systems. Additional details concerning this Phase can be obtained from DOE Project Status Reports 6, 7, 8 and 9 at Appendix A, together with other attached Appendixes which address specific jobs.

The Conservationist and Lexington series of heat pump water heating systems were introduced because:

- a. A simple design was needed which could be installed by an above-average local heating and air conditioning dealer,
- b. The Independence series was relatively expensive and, for economic reasons, we needed to give owners the choice of a lower initial investment,
- c. Because of simple design and lower cost, the Conservationist and Lexington units helped to introduce heat pump water heaters to the commercial market since they were relatively easy to sell to cost-sensitive business owners.

The Independence series has ultimately proved to be our best design because of its tremendous flexibility in a variety of roles while retaining cost efficiency in installation and operation. As described in the enclosed sales literature, the Independence series can operate in the following modes:

- (a) Water heating only,
- (b) Water heating combined with indoor cooling,
- (c) Standard air conditioning when there is no requirement for water heating,
- (d) Defrost cycle when required during cold weather when the unit is operating in the water heating mode.

See Appendix C for further details.

The Lexington series provides a water heating capacity, but unlike the Independence series, the Lexington must have an inside heat source to operate in a water heating mode. In other words, the Lexington provides heat recovery only in the air conditioning mode and does not operate to heat water when there is no air conditioning load. The Lexington design also functions as a standard air conditioning unit when there is no hot water demand.

The Conservationist series operates in the same basic modes as the Lexington, however, the Conservationist also provides indoor space heating using the heat pump cycle. It will not heat water and indoor air at the same time. Although the Conservationist heats water during the heat pump demand cycle or cooling cycle, it did not work well in

the water heating cycle because the system could not effectively control refrigerant flow. The refrigerant tends to "store out" in the heat exchanger in the storage tank.

Jobs installed and tested during this Phase included the following:

a. Independence series.

(1) Family Life Center, Watkinsville, Georgia. This system was a retrofit application in cooperation with Georgia Power, consisting of one 5-ton Amana unit and one 4-ton Amana unit,

(2) Super Wash House, Knoxville, Tennessee. This job is the most important item in this Final Report. It has produced the most significant results to date and, to our knowledge, is also the most heavily documented case in the history of heat pump water heating development, due to extensive testing by TVA as an independent agency. Therefore, the Super Wash House job, which continues through Phase 5, is described below at Paragraph 9 as a special case,

(3) Hurtsborough Pre-School, Hurtsborough, Alabama. This federally funded project was a remodeling project conducted in cooperation with Alabama Power Company. The installation consisted of one 5-ton Amana unit,

(4) Three (3) Residential units installed by TVA in Townsend, Tennessee; Jasper, Tennessee; and Water Valley, Mississippi. These installations were retrofit projects and consisted of one Amana unit and two Coleman units.

b. Lexington series.

(1) Clarke County Prison, Clarke County, Georgia. Installed in cooperation with Georgia Power Co., consisting of a 3-ton Amana retrofit,

(2) Muscogee County School System, Muscogee County, Georgia. This project consisted of three separate systems with an Amana 5-ton unit in each facility,

(3) Atlanta Ice Forum, Ice Skating Rink in Duluth, Georgia,

(4) Bethune Elementary School, Atlanta, Georgia. Installed in cooperation with Georgia Power, this system used a 5-ton air conditioning unit with a 60 percent heat recovery factor.

c. Conservationist series.

- (1) St. Jude's Catholic Church, Atlanta, Georgia,
- (2) Clarion Motel, Brunswick, Georgia,
- (3) Pierce County School, Pierce County, Georgia.

In summary, problems encountered during Phase 3 were mainly logistical. The installations performed during this period were disbursed over a wide geographic area and Wallace Energy Systems had to perform service and maintenance for many new projects. Even small items like motors or fuses had to be replaced almost immediately by our service personnel.

The impact on these problems on the Project was to lead us to promote the Lexington series since it could be installed relatively easily by the utility companies and a greater sales volume could be achieved.

Lessons learned and results achieved during Phase Three included:

a. Active involvement of TVA management. Although we had worked for years with TVA technicians, we had experienced difficulty in interesting TVA management in our Project. This situation changed in July 1994 when Mr. John Richardson, Director of Technology Management for TVA, authorized the Super Wash House as a TVA demonstration site and committed a substantial amount of TVA funding for purchase of equipment and system testing. See Project Status Report # 7 at Appendix A.

7. PROJECT PHASE 4. This Phase consisted primarily of testing and evaluation of the performance of systems installed during Phase 3. During Phase 4, extremely accurate test data was obtained from the Super Wash House in Tennessee by means of considerable assistance by Bob Schowalter of TVA. In addition, during this Phase, Underwriter's

Laboratory granted approval of equipment used. This approval was necessary if we wished to market the system on a commercial basis to a mass market.

Testing at the Super Wash House continued during this Phase. See Paragraph 9 below for a comprehensive discussion of this job.

Extensive testing by TVA was also conducted on the three TVA residential systems installed in Phase 3.

No new units were installed during this Phase. All units installed in Phases 2 and 3 were operating and the owners of the systems were satisfied.

In summary, we encountered problems with the 3 TVA residential units mentioned above because we used double wall heat exchangers for non-potable water. Although we appropriately used double wall heat exchangers for potable water applications, i.e. domestic use, the single wall heat exchangers were acceptable for non-potable water and the use of double wall heat exchangers for non-potable water increased operating costs to an unacceptable level. Otherwise, these TVA units performed well in both heating and cooling roles.

The impact of these problems on the Project was that we should have used single wall heat exchangers exclusively where only non potable water was required.

Lessons learned and results achieved during Phase 4 included the realization that, at least during this Phase, the heat pump water heater system would not sell without subsidies by the utility companies.

8. **PROJECT PHASE 5.** During Phase 5, lessons learned in previous Phases were used to sell and install systems on a commercial basis. During this Phase, our efforts extended beyond research and equipment development to include a true commercial sales which did not require

extensive involvement of Wallace Energy Systems personnel in installation or service. At the present time, we are still conducting this Phase.

During this Phase, we have concentrated on promoting the sale of the Lexington system as a "bread and butter" item for standard heat recovery requirements. The Independence series was used primarily in special applications where installation and service was performed by local utility companies, particularly Georgia Power. Georgia Power became an active commercial partner during this phase in addition to continuing their support of our research and development efforts. Georgia Power maintains an active sales force through their Energy Planning Department and has well qualified field technicians who can install and service the relatively sophisticated Independence series. Use of highly qualified personnel should eliminate installation problems encountered during the early stages of development of the Independence series. By contrast, The Lexington series can be installed by qualified local heating and air conditioning dealers with a minimum of special training. Our efforts in regard to the Lexington units were focused on increasing sales by making the entire Project more self-supporting.

Jobs installed and tested during this Phase included the following:

a. Independence series.

(1) Jeff Herrin Laundry, Cornelia, Georgia. This system consisted of two 4-ton Amana units and was installed by Wallace Energy Systems with supervision and advice by Georgia Power.

b. Lexington series.

(1) Capital Care Management, Richmond, Virginia. This nursing home application was installed by the property owner.

(2) Maple Street Mansion Restaurant, Carrolton, Georgia. This installation was performed by a local contractor, Wayne Robinson Heating & Air Conditioning through the marketing efforts of Georgia Power.

(3) Middle Georgia Wilderness, near Cochran, Georgia. This State of Georgia Correctional Institution was installed by employees of the State of Georgia with supervision provided by Georgia Power technicians. This system was installed in an existing facility.

(4) Muscogee County Schools Numbers 1, 2, and 3, Columbus, Georgia. This project consisted of separate systems installed in three schools. All three systems were installed by Muscogee County school system personnel with technical assistance and supervision by Georgia Power.

(5) Zachary Seafood Restaurant, Brunswick, Georgia. This system was installed by a local HVAC contractor, with supervision by Georgia Power.

In summary, we have encountered problems during Phase 5 with quality control in the assembly of system packages. At this time, there is not a sufficient sales volume to keep qualified assembly personnel working full-time on the Project. We must significantly increase sales in order to justify the Project economically.

Lessons learned so far in Phase 5 are both technical and economic. The current technical results achieved may be seen in the case study of the Super Wash House below. In the area of sales, Georgia Power now has about eight additional systems sold, and it is probable that warmer weather in the spring will increase the level of sales of the Lexington series.

9. SUPER WASH HOUSE. The Super Wash House job presents a particularly realistic and well documented illustration of the outstanding performance of the heat pump water heater, both as to systems efficiency and reliability. We expect that our system will set the industry standard for heat pump water heater design and applications.

The installation was funded by Wallace Energy Systems, TVA and the owner, Mr. Bob Jessee. Wallace Energy Systems furnished plans for the equipment and air distribution system, along with system start-up and limited service support.

The role of TVA as an independent testing agency cannot be emphasized enough in describing these results. TVA purchased the Synernet system and installed all test equipment at the Super Wash House site; therefore, we believe these results to be completely objective in evaluating performance. TVA personnel included Bob Schowalter, David Dinse and John Richardson.

As the on-site TVA sales engineer, Mr. Bob Schowalter was the point man on this project from the beginning. Mr. Schowalter had been providing us with TVA assistance since 1985, so he was familiar with our company and earlier research. Mr. Schowalter sold the owner on the idea of installing our system in his coin laundry, with the cost of installation shared by Wallace Energy Systems, TVA and the owner. Since this installation was designed to be a true field test, Mr. Schowalter coordinated and arranged for installation of the system using local plumbers, heating and air conditioning contractors and electricians. This installation by contractors who were not experts in heat pump water heaters proved that our system could be sold on a commercial basis and installed effectively by local dealers.

Mr. David Dinse, an engineer with TVA, also has a technical background in the heating and air conditioning field. His role in our project was to assemble test data on a regular basis and prepare a final report for TVA, which will probably be complete within 6 months.

Early in the project, Mr. John Richardson, as the responsible TVA executive, wanted to conduct extensive testing of the system in order to justify TVA's extensive involvement in terms of invested funds and manpower. In addition, our test results would also help determine TVA policy on further research and sales support to be provided to our product.

The owner's role in this job was significant since Mr. Jesse is a professional engineer as well as a business owner. He was therefore

able to understand many of the technical aspects of the job as well as evaluating the entire Wash House project from the standpoint of a property owner making an investment in his business.

The Super Wash House Coin Laundry, as a test site, provided a more realistic test of our system than a restaurant or nursing home because of the levelized load of water heating and because a large amount of space cooling was required. The test data is primarily design to show savings in the water heating mode with little emphasis on the space cooling benefits. These benefits are expressed in ton-hours on the accompanying monthly reports, and the dollar benefits of the cooling must be manually calculated. In the "reclaim" mode of operation, the heat pump water heater uses electrical energy for space cooling and rejects the heat derived through heat exchangers for water heating. Our calculations, based on TVA test results, measure the cost of heating the required hot water using the heat pump versus the cost using natural gas. Since the heat pump is more economically efficient than natural gas for heating the same amount of water, space cooling is provided at no extra cost and should be factored in when considering the total economic benefit provided to the laundry owner.

From an energy savings standpoint, the Coin Laundry had an existing heating and air conditioning system. To show any reduction in KWH usage, the HPWH had to be more efficient than the existing system.

During March, April, May and some of the fall months, mechanical cooling had not been used in the Laundry since exhaust fans were used to exhaust internal heat. This proved sufficient for cooling needs during this period.

Heat pump water heaters are classified as a "low grade" energy source. This term does not refer to either mechanical or economic efficiency, but means simply that water heating is performed to a maximum of 130 degrees F. While natural gas - a high grade energy

source - can produce super-heated steam, normal commercial applications require cost efficient heating of 130 degree water, not super-heated steam. Therefore, even though heat pump water heaters are a low grade energy source, they are the most economical solution for practical commercial uses.

Considering the heat pump water heater as a low grade energy source, it still products BTUs efficiently at outdoor temperatures in the mid-30's F. One of the most interesting observations from the Super Wash House test data is that the COP of the system does not fall at lower ambient outdoor temperatures. This is due to the fact that colder inlet water temperatures condense the liquid refrigerant more efficiently. While we had hope for this result, the actual performance of the system far exceeded our expectations.

For example, as shown the graph at Appendix G, outdoor air temperatures on January 21, 1996 were in the lower 30s and the system produced a COP of 4.68. In contrast, notice that the inlet water temperatures in July were in the mid-70s. This chart shows that, as the inlet water temperature increased during the summer months, the COP began to fall with COPs of 4.02 in July 1995, 3.97 in August, and 3.88 in September. However, as the inlet water temperatures dropped, the COP began to increase with COPs of 4.12 in October 1995, 4.26 in November and 4.31 in December.

Although January 1996 data is not complete at this time, 1995 data indicates that the heat pump water heater may adapt to colder climates, i.e., latitudes in Tennessee and northward, better than we had expected in the past. This is of great economic significance since northern climates have far more required heating degree-days. Therefore, our system can produce BTUs more efficiently in these regions where there is a greater demand and where the cost of fossil fuels is relatively high in terms of unit cost and total amount consumed.

Data provided by Mr. Bob Schowalter by telephone on January 19, 1996 for the Super Wash House confirms this result. It is important to remember that the cost comparisons below do not take in to account that the system provided interior space cooling at no cost. Therefore, actual dollar savings are much greater in real terms. For example, in September 1995, inlet water temperatures were high:

September 23, 1995

Outdoor Air Temp @ 55 degrees F.

Inlet Water Temp @ 77.5 degrees F.

Heat Pump produced 838,531 BTUs

Cost per Million (MM) Electric BTUs at TVA Rates	\$ 3.86
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Cost of Natural Gas per MM BTUs	10.11
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Cost Difference per MM BTUs	6.25
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Daily Savings using Heat Pump

(.838,531 MM BTU x \$ 6.25)	\$ 5.24
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In contrast, inlet water temperatures in January 1995 were low and the dollar savings increased accordingly:

January 16, 1995

Outdoor Air Temp @ 46 degrees F.

Inlet Water Temp @ 46 degrees F.

Heat Pump produced 968,000 BTUs

Cost per MM Electric BTUs	\$ 3.65
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Cost per MM Natural Gas BTUs	9.92
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Cost Difference per MM BTUs	6.27
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Daily Savings using Heat Pump

(.968,000 MM BTU x \$ 6.27)	\$ 6.07
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In this example, the efficiency of the heat pump at lower inlet water temperatures produces an increase in dollar savings of .31/5.24 = 6 percent.

Example of Monetary Savings on The Super Wash House Project: Heat Pump Versus Natural Gas.

To illustrate total dollar savings to the owner, we have selected the month of August 1995. Since water inlet temperatures were high in August and continuous space cooling was required, this illustration presents an extremely conservative picture since the system operates most efficiently when inlet water temperatures are low as shown in the example above. Test data is derived from the period August 1 to August 31, 1995. See Appendix F.

a. Heat Pump used 1573 KWH of electric in the water heating and reclaim mode. Heat pump produced 21,311,734 BTUs and 831 ton-hours of cooling.

b. Energy cost and method of calculation:

- (1) Cost of 1 KWH at TVA Rates = .062 cents.
- (2) Cost of natural gas from TVA test data = \$ 10.00 per Million (MM) BTUs.
- (3) Sensible cooling only was measured.
- (4) No latent heat or condensate was measured.
- (5) During this period, the unit operated solely in the reclaim mode; no operation in the water heating only mode was recorded.
- (6) 12,000 BTUs = One (1) ton of cooling.
- (7) One (1) KWH = 3,412 BTUs.

Total Energy Output for August 1995	21,311,734 BTUs
Less Total Energy Input	5,368,990
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Cooling Output	15,942,738 BTUs
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Tons of Cooling Provided	
(12,000 BTUs/15,942,738 Total BTUs)	1,328 Tons
Normal Cooling Cost per TVA = 1.10 KWH per Ton	
Savings in Cooling Cost	
(1,328 tons x \$ 1.10 per KWH)	1,460 KWH
Natural Gas Cost for Total Energy Output	
(21,311,743 x \$ 10.00 per MM BTUs)	\$ 213.11
Heat Pump Water Heater Cost for Total Energy Output	
(1,573 KWH x .062 cents per TVA KWH)	97.52
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Savings in Water Heating Only Using Heat Pump	115.59
Savings in Cooling Cost Using Heat Pump	
(1460 KWH x .062 cents per TVA KWH)	90.52
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Total Savings Using Heat Pump Water Heater	\$ 206.11
For August 1995	=====

10. PHASE 6 AND BEYOND. At present, Wallace Energy Systems is assembling the Lexington series units on a job shop basis for sale by Georgia Power Company. The Independence series will be assembled only for special applications as required by the utility companies. At this time, we have no plans for expanding our production capabilities and have no reasonable method for anticipating or projecting future sales to support such an expansion.

The future of our heat pump water heater depends on the interest and sales effort of the electric utility industry, with promotion and support by the Electric Power Research Institute (EPRI) and the Department of Energy.