EXPERIMENTAL EVALUATION OF THERMAL ENERGY STORAGE

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PROJECT OUTLINE

Project Title: Demonstration of Storage Heater Systems for Residential Applications

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Project Goals: Demonstrate the thermal performance, utility impact, and customer acceptance of residential TES systems using off-peak electricity. Identify and define after-the-meter TES R&D needs.

Two separate demonstrations are included. The University of Vermont and Central Vermont Public Service Company are collecting and analyzing data over two heating seasons for 17 ceramic TES systems, 6 hydronic TES systems, and 19 control systems. The University of Maine and Central Maine Power Company are collecting and analyzing data from 10 ceramic TES systems and 8 control systems.

Project Status: Data were collected from the first winter season. A survey of customer attitudes was completed.

Contract Number: ANL 189 #49897

Contract Period: FY 79 continuing

Funding Level: $590,000

Funding Source: U.S. Department of Energy
Division of Energy Storage Systems

PROJECT SUMMARY

Project Title: Experimental Evaluation of Thermal Energy Storage

Principal Investigators: J.G. Asbury and H.N. Hersh

Organization: Special Projects Group, Energy and Environmental Systems Division
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Argonne, IL 60439

Project Goals:

- Experimentally validate the technical performance of commercially available TES residential heating units under severe U.S. weather conditions.
- Assess the benefits and costs of TES to the customer, the utility and society.
- Determine user acceptance of TES.
- Identify and define TES issues, R&D needs and barriers to commercialization.
- Establish uniform TES testing standards.

Project Status:

- Installations have been completed in 45 test and 30 control sites and data collected; based on results for one heating season, and comparison with electric baseboard systems, the technical performance of TES ceramic and hydronic systems is good.
- A preliminary assessment of the benefits and costs of customer-owned TES for residential and commercial applications indicates that the net returns to society of such investments exceed their costs by a substantial margin.
- A user survey by an independent organization indicates a high degree of customer acceptance.
- Issues of proper rate design and correct sizing of TES capacity by vendors and contractors have emerged and are currently being examined.
- A calorimeter chamber has been built and standardized procedures for testing TES modular units are being developed as an aid to commercialization.

Contract Period - FY80
Contract Funding - $150K

EXPERIMENTAL EVALUATION OF THERMAL ENERGY STORAGE: AN INTERIM REPORT

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1. BACKGROUND

Early results from the ANL assessment of energy storage technologies indicated that customer-owned TES units of the type used in Europe could provide a cost-effective means for utility load management in the U.S. (1). It was necessary, therefore, that the technical and economic viability of this technology be examined under U.S. conditions. These conditions now include a changing regulatory atmosphere encouraging rate reform and, of course, climatic conditions more extreme than in Europe. The region selected for this field study was New England, with its strong dependence on oil and scarcity of natural gas. Electric baseboard heating is a major heating alternative in this area. In Vermont, utilities had already begun to investigate thermal energy storage and off-peak rates as one form of load management and had instituted programs to reduce loads by direct utility control of storage hot water heaters.

2. SCOPE AND OBJECTIVES

We report here some results of the first year's tests involving a collaborative effort among ANL, Purdue University, the Universities of Maine and of Vermont, and several local cooperating electric utility companies (Central Maine Power Co., Central Vermont Public Service Co., Green Mountain Power Co. and Vermont Electric Cooperative).

The principal objectives of the study are to:

- Validate the technical performance of commercially available TES units under severe U.S. weather conditions.
- Assess the benefits and costs of TES.
- Determine potential customer and utility acceptance of customer-owned TES.
- Identify and define TES issues, R&D needs and barriers to commercialization.
- Establish uniform TES testing standards.

The method adopted for achieving each objective is described below.

3. FINDINGS

Since work is still in progress the findings reported here must be regarded as tentative.

3.1 Technical Performance

Field tests in Vermont and Maine are being carried out to evaluate the performance of TES systems. TES systems are operating in 45 test homes, and monitoring equipment records the electric heating demand and the inside and outside temperatures every 15 minutes in these test homes and in 30 control homes. All of the participating homes have been energy-audited by an electric utility. Most of the TES units in the test homes are room-type ceramic storage heaters, but six hydronic storage heaters and one central ceramic storage furnace are also being tested. The control sites are heated with conventional resistance baseboard units. All units were sized by the vendor to meet the full design-day heating load and were commercially installed.

During the first heating season, data were collected from 34 test and 26 control sites, with some loss of data and uncertainties due to malfunctions in monitoring equipment and problems in magnetic tape handling. Functional performance of the TES systems has generally been good, and it has been concluded that TES units, if properly sized for the home, perform well. This preliminary conclusion applies equally to dispersed and central ceramic units and to hydronic central units.

The major criterion for this assessment was the maintenance of essentially identical inside temperatures in thermally matched test and control homes throughout the heating season, e.g., on typical wintry January days, on October days (which have more volatile temperature fluctuations), and on the coldest day of the year. In Vermont the lowest temperature recorded at the sites was -28^{o}F on February 12, 1979; in Maine 70 degree-days were accumulated on February 14, providing opportunities to observe heating-system performance under "design" conditions and to evaluate shortcomings in sizing formulas. Graphical records of daily electrical demand and inside temperatures of test homes clearly distinguish adequately sized storage heating systems that use only off-peak electricity from those that additionally require the use of electricity generated during high-use times.

3.2 Social Benefits and Costs

Studies of the economics of TES in Maine and Vermont using a social welfare approach indicate that there are net social benefits and that benefits can accrue to both user and utility (2,3). This conclusion is based upon a comparison of the estimated costs and consequent savings. Factors taken into account include:

(1) additional customer costs, compared to direct baseboard systems, of installed TES systems (room units and central furnaces) in homes having a wide range of heat loss;

(2) utility costs of special controls, meters and transformers;

(3) utility returns due to estimated future savings in foregone generation, transmission and distribution needs (discounted to present value.

In Vermont, benefit-cost ratios are estimated to be greater than 3.4 for room units and greater than 5.6 for central units (3). The higher ratio for central units is due to their lower capital cost per kilowatt of heat loss. In Maine, the total savings are estimated to be about $344 per kilowatt of heat loss, and the additional capital cost with respect to electric baseboard heaters is about $225 per kilowatt of heat loss. (The cost of electric baseboard heaters is about $150/kW.)

3.3 Potential Customer and Utility Acceptance

A survey of users by an independent research organization revealed equal satisfaction with storage heaters and with instant heaters (baseboard). The survey was based on 156 households, of which 131 are heated via thermal storage and 25 by direct electric heating (4). Over 95% of the owners of homes with TES units would recommend TES to a friend (the same as for users of baseboard heaters). The improvements most frequently suggested were decreasing the physical size of the room units and improving their appearance.

Many utilities that have had exposure to, or interest in, TES as a load management tool feel it can have a positive impact. However, public concern about the environmental degradation due to the use of nuclear and coal baseload fuels negatively affects utility planning and initiative, creating uncertainties in the size and stability of the cost differential of baseload and non-baseload electricity.

3.4 Issues

Many issues must be identified and resolved before there can be any extensive adoption of TES. Among them are capital cost of TES equipment, correct sizing of the TES systems and proper rate structure.

- Electricity Pricing - The problem of increasing the use of TES is that of transferring some of the anticipated utility savings to the customer so that TES will be an attractive investment. The problem is complex. At this time, based on an on-going comparative analysis, a load management agreement between customer and utility seems better than either a time-of-use rate format or a time-of-use plus demand-charge rate. Load management agreements insure more control of utility capacity growth and less customer risk of rate instability.

- How Much Storage? - The adoption of TES will be very sensitive to calculating and installing the proper amount of storage heating capacity. Preliminary energy-use studies of TES in Maine indicate that the sizing method for an 8-hour charge period is marginal for extreme weather conditions. Simulation studies have underscored the potential problem of developing a shoulder peak of demand of supplemental heat which is required toward the end of the on-peak period. The problem of supplying a building with optimal thermal storage capacity is one of skirting the Charybdis of inadequate storage capacity (which may neither cut oil demand nor sufficiently decrease the need for investments in new generating capacity) and the Scylla of too much installed storage capacity (which may be so expensive that the customer will not buy the TES system). This sizing problem has several interrelated elements:

(1) the incentive of the vendor to make a sale by lowering the capital cost (i.e., recommending smaller capacity than may be required),

(2) the goal of the customer or real estate developer who wants TES but wants to minimize initial cost (thereby impacting the utility on its peak demand days),

(3) different sizing methods used by different vendors, and

(4) the intrinsic uncertainty in the heating capacity margin required by different users and types of use.

- Capital Costs of TES and Control Equipment - Sensible heat storage devices and control units are essentially simple products. Reducing the capital costs of TES systems by cheaper manufacturing methods and more vendor competition can ameliorate, to some extent, some of the above problems and provide customer incentive to buy TES equipment.

3.5 Testing

TES units of different manufacture can have different characteristics and storage capacities. Depending on details of design, units having the same nominal rating and total storage capacity may have different rates of spontaneous radiative emission, rates of forced discharge, hot air temperatures, storage medium temperatures, etc. Since the units are modular, it will be possible to measure and compare their thermal performance by appropriate calorimetric techniques. Simple electric-input thermal-output ratings can then be used by customers in making buying decisions and total performance characteristics can be used by architects and others for heating-system design; such available information should accelerate the rate of commercialization. For this reason, developing and promulgating standard calorimetric procedures that can be duplicated in other laboratories is a component of the ANL program. At Purdue University a calorimeter has been built following the German standard as described in DIN 44572. Initial attempts to calibrate and use this calorimeter indicated the necessity for a redesign. Several design modifications were made and investigated experimentally. The present design has greatly improved uniformity in the cross-sectional temperature distribution of the outlet duct where the temperature of the exiting air is measured. A 2-kW room-size TES unit is soon to be installed in the calorimeter chamber for testing. At the same time a 30-kW central unit is being readied for installation and initial calorimetric measurements in a large, environmentally controlled room.

4. COMMENTS

The findings so far support the expectation of earlier studies: TES is technically and economically viable in winter-peaking electric service areas of the U.S. that rely on electricity for space heating, where the underutilized baseload energy is supplied by coal or other cheaper baseload fuels. It is probably not too early for industry and the government to start those studies and activities necessary to accelerate the introduction of sensible-heat thermal energy storage where it is deemed possible and desirable. While further studies are necessary for solid documentation, there is presently a need for TES handbooks, seminary for potential suppliers, installers and contractors, and the dissemination of technical and financial information to public utilities, regulatory commissions, consumer groups, financial institutions, etc.

REFERENCES

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3. Nelson, S., "Assessment of Cost-Effectiveness of Thermal Energy Storage From Electricity in New England", Unpublished ANL Report (September 1979).

4. Elrick and Lavidge, Inc., "Storage Heating Study Report", for Argonne National Laboratories (July 1979).