COMMERCIAL/INDUSTRIAL ELECTRIC THERMAL STORAGE

Bart Chezar, New York Power Authority, and
Laurence I. Moss, Demand Shift Technologies, Inc.

An electric thermal storage (ETS) system has been developed[1] which provides a low cost load management option for electrically heated commercial and industrial buildings. Four units are being installed in buildings in upstate New York. These systems will be operated during the 1990/91 heating season to determine their operating characteristics and economic viability.

Reducing the growth in peak electric demand is an important objective of electric utilities. In New York State electric demand exceeds 90% of the peak demand only 100 to 200 hours per year. In northern New York the electric peak demand occurs in the winter and is temperature dependent. The space heating of commercial and industrial customers represents a large portion of their on-peak electric demand. Using thermal storage to shift this space heating to off-peak hours can improve utility load factors and increase reserve margins.

The ETS system consists of an insulated steel shell filled with crushed basaltic rocks. During off-peak hours electric heating elements housed in cylindrical or planar modules within this shell heat the rocks. This design offers advantages compared with the conventional way of heating a rock bed, which is to heat air outside and then move it through the rock bed.[2]

The heating of the rocks is terminated when the stored energy is equal to the estimated on-peak building energy requirement for the next day.

During on-peak periods the heating elements are turned off. When the building demands heat during this period, air is circulated through both the rock bed and a parallel bypass duct. The heated air and the bypass air are mixed and air at a constant temperature is either distributed through the building's duct system, or, in the case of a building with a hydronic system, moved through an air-to-water heat exchanger to supply heat to the hydronic loop. The units have a programmable controller which is able to evaluate sensor inputs and to modulate the operating functions of the unit.

---

1 *By Demand Shift Technologies, Inc., Estes Park, Colorado 80517.*

2 *Most solar-heated rock beds, as well as the rock bed ETS unit developed by Fluidyne/Calidyne with the support of the Electric Power Research Institute (EPRI), function in the conventional manner.*

INTRODUCTION

A program to demonstrate the technical and economic feasibility of Electric Thermal Storage (ETS) for commercial and industrial buildings is being sponsored by the New York Power Authority (NYPA), Empire State Electric Energy Research Corporation (ESEERCO), and New York State Energy Research and Development Authority (NYSERDA).

Crushed rock was selected as the storage medium because of its low cost and high volumetric heat storage capacity. Demand Shift Technologies, Inc. (DST) was selected as the contractor to perform feasibility studies and then to manufacture and install the units. The DST technology includes some unique features to be described below. A variety of building types (two municipal garages, an office building, and a school) are included in the program.

DESIGN OF UNITS

ETS units for commercial and industrial buildings typically require higher storage capacities than those for residences. For example, the storage capacity of the unit for the school building in the demonstration project is 2400 kwh, compared with about 30 kwh for unit heaters and 190 kwh for central furnaces for single family homes. Such large storage capacities favor the use of inexpensive storage media (such as crushed rock or water) over relatively expensive media (such as ceramic/refractory brick).

A bed of crushed rock heated to 1200°F has a higher volumetric heat capacity than water heated to 280°F, which, because of the cost of pressurized containment, is a practical upper limit for water. The ratio of volumetric heat capacity of rock[3] to water depends in part on the temperature swing, i.e., the difference between the maximum and minimum temperatures of each medium. The lower limit temperatures are determined by the type of heat distribution system in the building. The normalized storage capacities for typical installations are given in Table 1.

Table 1. Effective kwh Stored in One Cubic Foot of Water and Crushed Rock

	Type of Heat Distribution System	
Storage Medium	Air	Water
Water	2.0	1.3
Crushed rock	5.6	4.7

Note: Supply air temperature 130°F, supply water temperature 190°F.

Space is often at a premium in such buildings, so the use of crushed rock is favored.

The conventional way of heating a rock bed is to heat air outside the bed and move the hot air through the rocks. Typically the air flows downward through the bed at this stage, so the rocks at the top are heated first, and to a higher temperature than the lower rocks. Later, when the building demands heat, the air flow is reversed so that rock bed exit air is at the maximum possible temperature. The external heaters and the need for flow reversal add to the overall size of the unit, increase complexity, and contribute to uncontrolled heat loss.

Heating elements can be inserted directly into ceramic/refractory brick ETS units because the bricks can be manufactured with grooves and other spaces to provide the necessary clearances. This is not true for a bed of crushed rock. Heating elements buried in the bed would quickly fail because of the hostile environment. The rocks shift position as they expand and contract, and sharp edges and abrasive surfaces destroy all but the strongest components located in the bed.

The DST approach is to use heating element arrays protected from but in close proximity to the rocks. A schematic diagram of one of the designs is shown in Figure 1. Heat is transferred, primarily by radiative heat transfer, to the barrier protecting the heating elements and then to the rocks. Forced convection is not used. Avoiding the need for fan operation during this mode is not in itself a major factor, but, with this approach, there is no need for flow reversal with its added complexity, the unit can be made more compact, and standby heat losses can

[3] *Rock bed density of 95 lb/ft^3 and heat capacity of 0.20 Btu/lb-°F.*

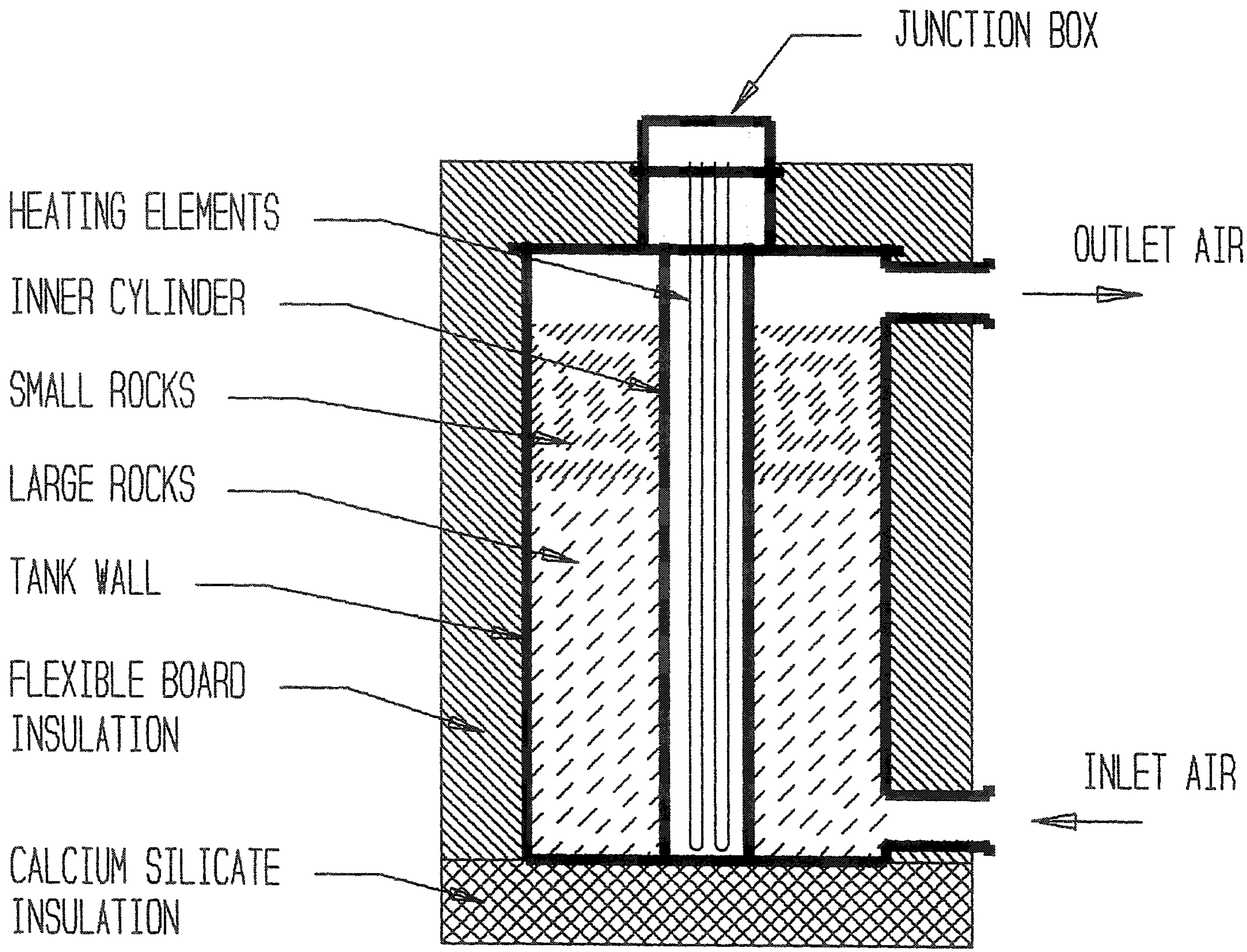

Figure 1. Schematic of One of the DST Designs

be minimized because the rock bed is heated from the inside out. Rocks near the vessel wall and its insulation are at relatively low temperatures for much of the heating cycle.

One objective of the demonstration program was to determine whether the rate of heat transfer from the heating elements, through the protective barrier, to the rocks, and then throughout the rock bed would be sufficient to achieve a practical design. Analysis showed that this would indeed be the case, but experimental verification was needed to assure prospective users that the concept was sound.

DEMONSTRATION PROGRAM BUILDINGS

Characteristics of the buildings in the demonstration program are listed in Table 2.

ETS units were designed to supply heating loads with stored heat during all on-peak hours. This involved an analysis of each utility's load profiles for the six highest-demand days of the year to define on- and off-peak hours; an evaluation of the expected heating load for each building; and the sizing of both storage and heating element capacity to match the requirements of the building and the utility. Thermal storage capacities range from 280 to 2400 kwh. Electric duct heaters were provided to supply off-peak building heat for CHG, POB, and SHG. In the case of PVS, operation with an electric boiler for off-peak building heat was not feasible initially because of limited feeder-line capacity. The feeder line is scheduled to be upgraded, so an electric boiler may be installed at some future time. In the interim, the existing oil-fired boilers will serve to provide off-peak heating. Since off-peak electricity in this area is less costly than is heating oil, the ETS unit is programmed to provide as much off-peak building heating as possible without sacrificing its ability to provide all on-peak heating. The ability to do this demonstrates the flexibility of the microprocessor controls being used.

At CHG, POB, and PVS, on-peak hours are defined by time of day. At SHG, where the utility has a radio-controlled load management system in place, a signal is provided which identifies the on-peak hours. As the other utilities install similar systems, the units will be converted to allow utility control.

RESULTS

The units at CHG and SHG have been installed and initial operation begun. The testing program is in its early stages, but already the validity of the unique design concept described above has been demonstrated. Also, thermal storage capacities are equal to or greater than specified. Standby heat losses appear to be low.

The units at PVS and POB will be installed in the summer and fall of 1990. Performance testing of the units will be conducted, followed by monitoring of operation in the 1990-91 heating season.

ACKNOWLEDGMENTS

In addition to the sponsors mentioned above, the authors wish to acknowledge the cooperation of the following municipal and cooperative utilities participating in the demonstration program: Arcade, Churchville, Plattsburgh, Sherrill, and Steuben.

Table 2. Characteristics of Buildings in the Demonstration Program

Location	Function	Heat Distribution	Original Heat Source	Identifier
Churchville	municipal garage	air	electric	CHG
Plattsburgh	office building	air	electric	POB
Sherrill	municipal garage	air	natural gas	SHG
S. Dayton	school	hydronic	heating oil	PVS