THERMAL ENERGY STORAGE TECHNOLOGY DEVELOPMENT AT PACIFIC NORTHWEST NATIONAL LABORATORY (PNNL): 1978-1998

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ACTIVITIES

The thermal energy storage (TES) technology development program at PNNL consisted of the following activities during the two decades of its existence:

- **Seasonal thermal energy storage (STES) activities involved storing thermal energy within underground aquifers for future use in heating and cooling buildings.**

- **Utility thermal energy storage (UTES) activities: feasibility assessment studies of integrating TES technologies with power generation technologies to enhance the deliverable plant capacities and improve overall efficiency.**

- **Assessment of various cooling technologies (with and without storage) to incorporate with base-loaded gas turbine plants for capacity enhancements during hot and humid seasons.**

- **Diurnal thermal energy storage technology development using high heat-capacity building materials for passive solar heating of buildings, ammoniated salts for chill storage applications, etc.**

HIGHLIGHTS

The following bullets highlight the accomplishments of the TES program at PNNL:

- **Tests done at the University of Minnesota Field Test Facility clearly demonstrated that high-temperature STES in an aquifer, or an aquifer thermal energy storage (ATES) system is a feasible storage technology and can be successfully interfaced with existing space-conditioning systems in buildings. A similar demonstration of a chilled water storage system at the University of Alabama using an aquifer showed a two-fold increase in the system coefficient of performance for cooling a campus building.**

- **Cogeneration with TES - Natural-gas-fired combustion turbine technologies, including cogeneration and combined-cycle power plants, are becoming the power generating options of choice because of their flexibility, relatively low capital cost, reduced environmental impact, and increasing thermal efficiency. TES for utility-scale applications comprises a range of technologies that can further improve the efficiency, flexibility, and economics of the gas turbine options. The cost of dispatchable power produced by the combined TES/cogeneration system designed to serve a constant process steam load is found to be 60% to 75% of the cost of producing power in a gas turbine plant, and 65% to 86% of the cost of producing power in a combined-cycle plant.**

- **Gas turbine inlet air cooling - The degradation of gas turbine**

generating capacity during periods of high ambient temperature can be a significant problem, especially for industrial plants and summer-peaking utilities. As the ambient air temperature increases, the density of the inlet air, the generating capacity, and the efficiency of the gas turbine all decrease. A review of the data on existing gas turbine installations shows that the summer capacity of a typical gas turbine is between 15 and 25% lower than the winter capacity of the same gas turbine. Traditionally, evaporative cooling has been used to increase the generating capacity of flow-through devices, such as gas turbines, by cooling the incoming air and, thereby, increasing its density. However, it can only reduce the temperature of the inlet air to the prevailing wet-bulb temperature level. Further reductions in inlet air temperature will require additional cooling. The chill storage systems assessed as a part of this study were mainly used to cool the inlet air to 42°F and 0°F (5.6°C and -17.8°C).

- **High heat capacity building materials were developed as a part of this program at the Oak Ridge National Laboratory, which incorporated the use of phase-change materials (PCMs) into conventional building materials to enhance the energy storage capacity through the latent heat of the PCM. The application was in the passive solar heating of a building (hence being able to shift its electrical load), where the PCM wallboard would allow solar energy to supply a larger fraction of building heating than is otherwise practical. The PCM considered was a mixture of paraffins with n-octadecane as the primary ingredient, which has a melting point of 73°F (22.8°C).**

APPLICATIONS OF THE TECHNOLOGY

The following bullets highlight the subsequent applications of the technologies developed as a part of the TES program:

- **As a result of the ATES activity, the aquifer storage and retrieval (ASR) is being evaluated and employed to provide more reliable water supplies in communities where significant variability in water availability exists. Many of the lessons learned in the ATES program will be useful in designing improved ASR systems. Because of the co-location and co-ownership of ASR facilities with major energy consuming elements of the water infrastructure (e.g., waste water treatment facilities), the thermal potential of ASR is likely to be developed also. In addition, as part of the ATES program, the standard geochemical databases (notably carbonate chemistry) were improved. This included a simple analytic tool that can be used to assess the optimal capacity and treatment method required to prevent carbonate scaling in heat exchangers.**

- **Another major offshoot of the ATES program is the CFEST - The Coupled Fluid Energy and Solute Transport computer model developed by PNNL. The code has been included in international code comparison activities and has been applied to many analyses including those related to nuclear waste repository programs and hazardous waste simulations. The code was later modified and commercially sold by Battelle to a Japanese engineering firm to study groundwater problems in Japan. The code has subsequently been further improved and is currently being marketed**

commercially. CFEST is one of the codes being considered as a possible site-wide groundwater model for the Hanford Site.

- **A model developed at PNNL as part of the gas turbine inlet air cooling activity can size, simulate hourly performance, and estimate the cost and economics (including a net present value analysis of the investments) of cooling system components for inlet air cooling applications. This model can also be used to assess the benefits of installing the inlet air cooling systems both in existing and new gas turbine plants. A preliminary screening of the available technologies shows that the 20% increase in gas turbine capacity can be obtained at an average cost of $150/kWe. This represents a 65% reduction in the cost of adding peak capacity by installing new gas turbines at an estimated cost of $380/kWe.**