# HOT-WATER AQUIFER STORAGE - A FIELD TEST

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## PROJECT OUTLINE

Project Title: Thermal Energy Storage in Confined Aquifers

Principal Investigator: F. J. Molz and A. D. Parr

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Project Goals: To inject heated water into a confined aquifer, store it for a period of time, and pump it out.

To record water temperatures and hydraulic heads during the injection-storage-recovery cycle.

To determine to the extent possible the feasibility of storing thermal energy in confined aquifers.

Construction of facilities:

- o Drilling of withdrawal and injection wells.
- o Drilling and instrumentation of observation wells.
- o Installation of surface support facilities.

Operation, data collection, and analysis:

- o First cycle
  - Injection
  - Storage
  - Recovery
- o Second cycle
  - Injection
  - Storage
  - Recovery
- o Data analysis and reporting

Project Status: The second cycle has been completed and data are now being analyzed. Final reports and publications are also being prepared. Data have been provided to LBL for simulation modeling analysis.

Contract Number: 7338

Contract Period: July 1977 to December 1979

Funding Level: $387,283

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

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## INTRODUCTION

The storage of hot water in aquifers is considered one of the most promising near-term alternatives for seasonal storage of thermal energy. Excess heat produced during the summer could be stored in groundwater regions and pumped out during the winter months when demand for heat is greatest. The insulating properties of the earth and the vast volumetric capacity of its aquifers make this concept particularly attractive. Auburn University has been involved in a large-scale field study of heat storage in a confined aquifer near Mobile, Alabama. Currently, two injection-storage-recovery cycles have been completed.

The first cycle involved the injection of 54,800 cubic meters of 55$^{\circ}$C water into the confined aquifer. The ambient temperature of the water in the confined aquifer and in the upper semi-confined aquifer from which the supply water is pumped was 20$^{\circ}$C. After a storage period of 51 days, the injection well was pumped until the temperature of the recovered water dropped to 33$^{\circ}$C. At that point 55,300 cubic meters of water had been withdrawn and 66 percent of the injected energy had been recovered.

A volume of 58,000 cubic meters of 55$^{\circ}$C water was injected during the second cycle. The water was stored for 63 days and then recovered. When the recovery temperature equalled the temperature at the end of the recovery period for the first cycle, 33$^{\circ}$C, 66,400 cubic meters had been pumped from the aquifer and 76 percent of the injected energy had been recovered. The recovery period for the second cycle continued until the water temperature was 27.5$^{\circ}$C and 100,100 cubic meters of water was recovered. At the end of the cycle about 90 percent of the energy injected during the cycle had been recovered.

## EXPERIMENTAL SET-UP

The experimental site is located near Mobile, Alabama, at a soil borrow area at the Barry Steam Plant of the Alabama Power Company. The basic injection system is shown in Figure 1. Water was pumped from an upper semi-confined aquifer, passed through a boiler where it was heated to a temperature of about 55$^{\circ}$C, and injected into a medium sand confined aquifer. The injection well has a 6-inch (15-cm) partially-penetrating steel screen. The top of the storage formation is about 40 meters below the surface and the formation thickness is about 21 meters.

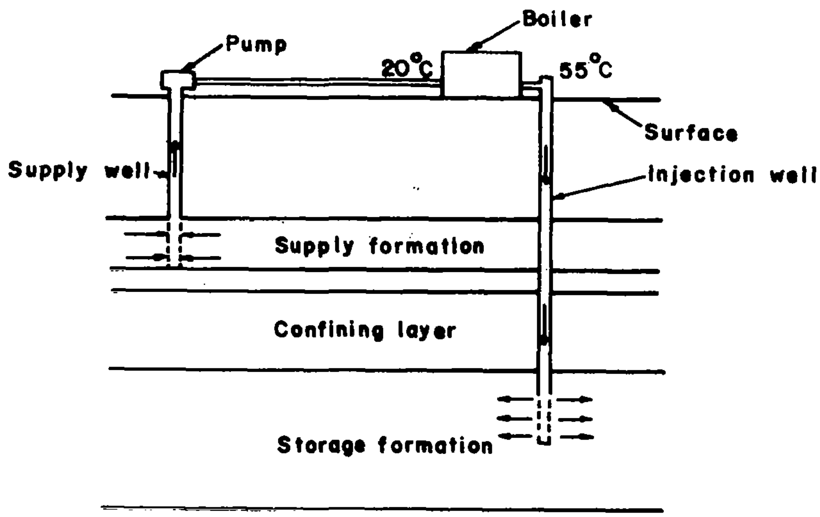


Figure 1. Schematic of Hot-Water Injection System

The relative location of the supply and injection wells and of 14 observations wells is shown in Figure 2. The observation wells were used to monitor temperature and phreatic surface elevations during the experiments. The readings were used primarily to calibrate numerical models describing heat and mass transport in aquifers.

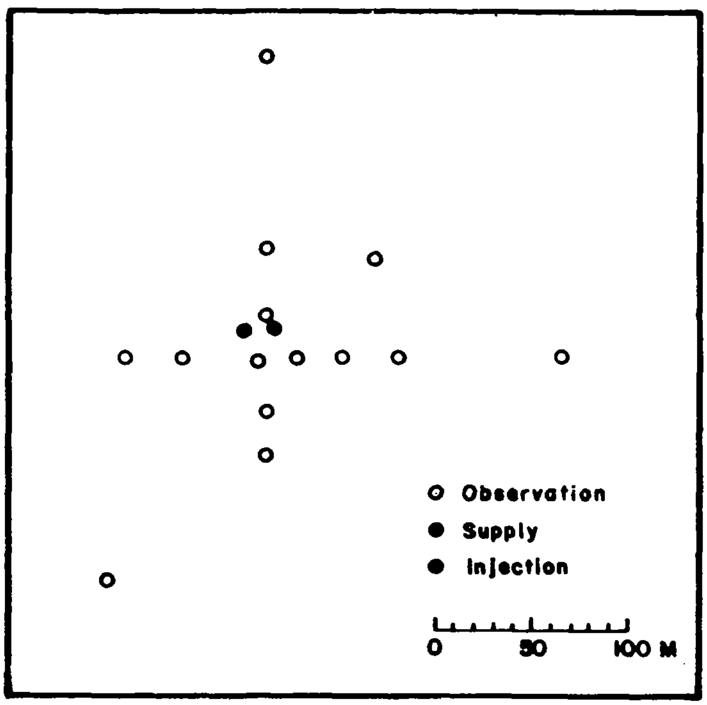


Figure 2. Top View of Well Field at Experimental Site

Figure 3 shows a schematic of a typical observation well in which temperature was measured. The six thermistors were equally spaced over the aquifer thickness. The wells were backfilled with sand in order to preclude extraneous vertical mixing due to convection in the wells.

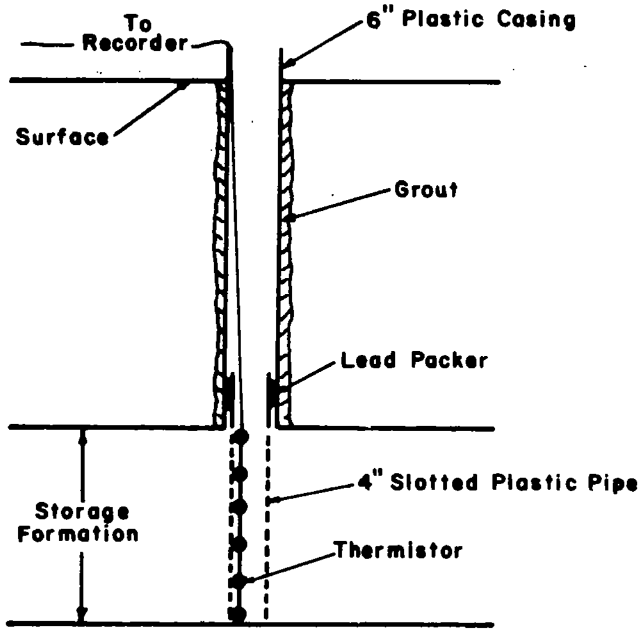


Figure 3. Side View of Typical Observation Well

## EXPERIMENTAL PROCEDURE

Water was injected into the aquifer at rates from 6.3 to 12.6 liters per second during the first cycle. The injection period was 79 days. The variability of the injection rate was due to clogging of the formation around the injection well. Near the end of the first cycle injection period it was realized that backwashing the injection well for a few minutes immediately increased the specific capacity of the well and helped control the clogging problem. After a storage period of 51 days water was recovered from the injection well with a submersible pump at a nearly constant rate of 15.8 liters per second. The recovered water was discharged into a nearby canal.

The injection period for the second cycle lasted 63 days and the discharge rate varied from 9.8 to 13.6 liters per second. The improved discharge rate was attributed to periodic injection well backwashing performed throughout the injection period. After a 63-day storage period, the water was recovered at an average rate of about 14 liters per second.

Hydraulic heads and temperatures were recorded in the observation wells throughout both cycles. The measurements provided a method of observing and analyzing the hydrodynamic and thermodynamic behavior of the injected hot water in the confined aquifer region. Specific presentation and discussion of this data are beyond the scope of this paper.

## EXPERIMENTAL RESULTS

A plot of recovery temperature versus recovery volume is shown in Figure 4 for both cycles. The improvement of the second cycle was due to the residual heat remaining in the aquifer and the surrounding aquitards after completion of the first cycle.

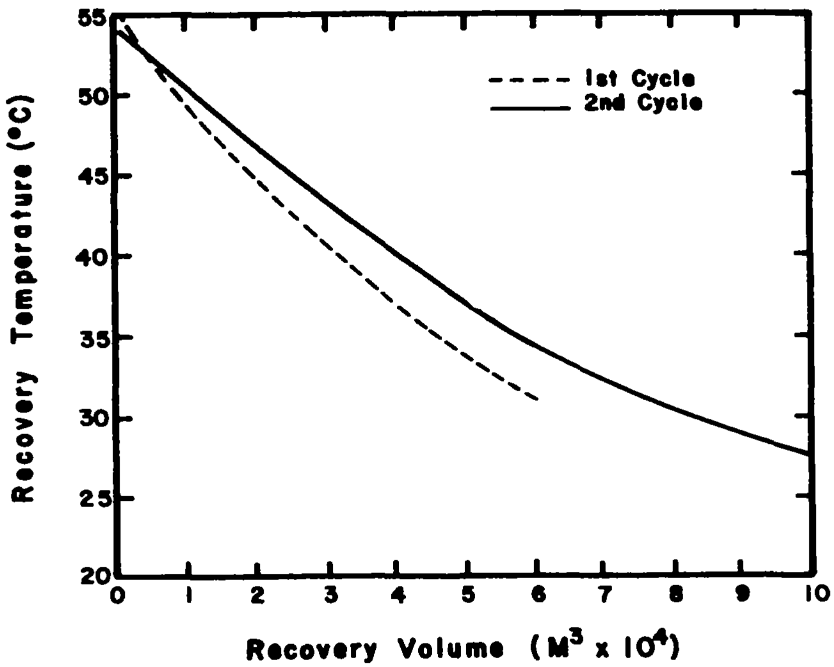


Figure 4. Recovery Temperature versus Recovery Volume

A measure of the effectiveness of a heat storage containment system is the fraction of the energy input of the system that can be recovered at the end of the storage period. This fraction, called the recovery factor, is determined by dividing the energy output, $E_{out}$, by the energy input, $E_{in}$. Figure 5 shows the recovery factor versus recovery temperature for both cycles. The recovery factors for the first and second cycles were 0.66 and 0.76, respectively, for the same recovery temperature of 33°C. The second cycle recovery period was continued until the recovery temperature reached 27.5°C, and the recovery factor was about 0.90. Figure 6 shows recovery factor versus recovery volume.

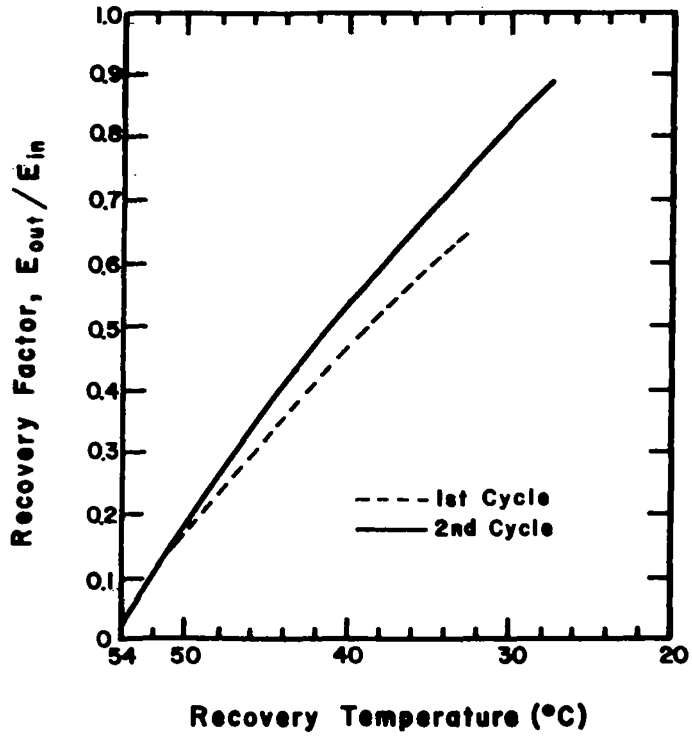


Figure 5. Recovery Factor versus Recovery Temperature

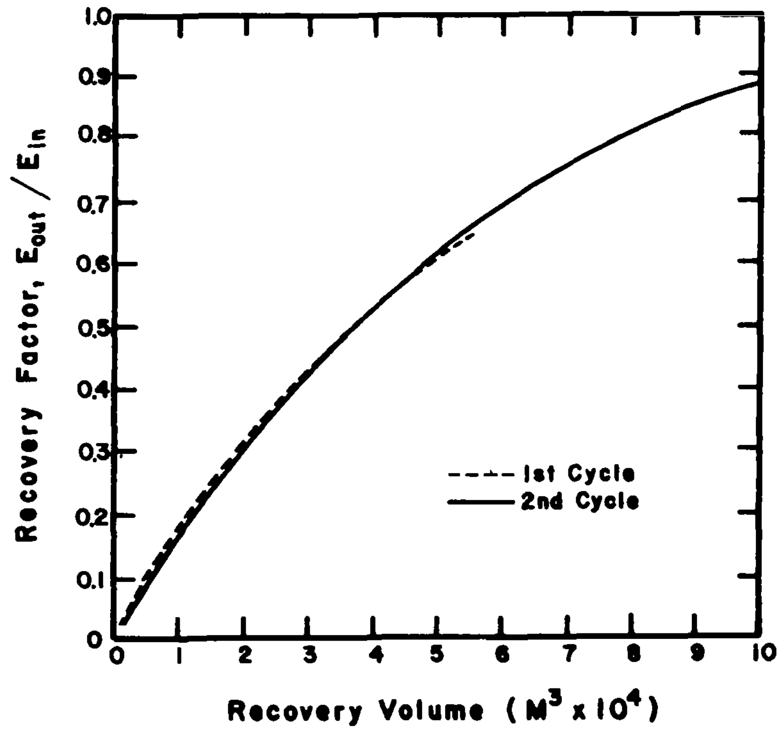


Figure 6. Recovery Factor versus Recovery Volume