

Lawrence Berkeley National Laboratory

LBL Publications

Title

STES Newsletter Vol 8 No 4

Permalink

<https://escholarship.org/uc/item/1j28x3bn>

Author

Lawrence Berkeley National Laboratory

Publication Date

1986-09-01

Copyright Information

This work is made available under the terms of a Creative Commons Attribution License, available at <https://creativecommons.org/licenses/by/4.0/>

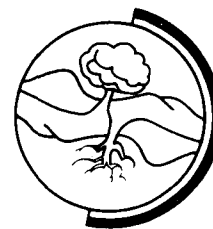
DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

PUB-428

STES NEWSLETTER

A Quarterly Review of Seasonal Thermal Energy Storage



RECEIVED

JAN 9 1987
 PUB FILE
 L.B.L. LIBRARY

Sponsored by the Pacific Northwest Laboratory
 Operated by Battelle Memorial Institute for the U.S. Department of Energy

EARTH SCIENCES DIVISION/LAWRENCE BERKELEY LABORATORY
 UNIVERSITY OF CALIFORNIA

Vol. VIII, No. 4

September 1986

** A SPECIAL NOTE ** FROM THE EDITOR

This issue marks eight years of continuous publication for the STES Newsletter. Every three months the Newsletter has sought to bring readers in 28 countries the latest information on a variety of field, laboratory and theoretical work in energy storage. The Newsletter has been sponsored by the U.S. Department of Energy, through Oak Ridge National Laboratory (1978-79), and Battelle Pacific Northwest Laboratory (1979-present).

With the establishment of the International Council for Thermal Energy Storage in 1985 during the ENERSTOCK Conference in Toronto, it seems appropriate to transfer the sponsorship of the Newsletter to the International Council, under the guidance of the Council President. After discussions with current President Dr. E. L. Morofsky of Public Works Canada, and with the U.S. Department of Energy, it has been decided to make the transition effective with the next issue (Vol. IX, No. 1; December 1986).

Publication of the Newsletter will become a function of the Council Presidency, a position that will change at every International Conference on Thermal Energy Storage. The conferences have been meeting every 2-3 years, and the next one is scheduled to take place in 1988. I have been asked by Ed Morofsky to remain as editor during this period of transition to Council sponsorship, and I have agreed to continue for a period of one year, until September 1987.

Thus, not only will the STES Newsletter remain as a major means of communication among scientists and engineers in our field worldwide, but it will become an official publication of the International

Council for Thermal Energy Storage. We continue to encourage all readers to support the Newsletter with news of current investigations, recent results and future plans, and to inform us of new readers and address changes.

On a separate note, I would like to draw attention to the two articles from China appearing in this issue. The articles offer a very good overview of the many aquifer thermal energy projects underway in China. These are practical projects that appear to have significant positive economic impact on the communities in which they are carried out.



The STES Newsletter is a compilation of written contributions from researchers working in the field of seasonal thermal energy storage. Articles and reviews of current research, recent results and future plans are welcome. Contributions for upcoming issues, as well as suggestions and changes of address should reach us at the address below by **December 5, 1986.**

Dr. Chin-Fu Tsang
 Editor, STES Newsletter
 Earth Sciences Division
 Lawrence Berkeley Laboratory
 Berkeley, California 94720 USA

Telephone: (415) 486-5782
 Telex: (910) 366-2037

PUB - 428

AQUIFER ENERGY STORAGE APPLICATIONS IN CHINA

Contact: Sun Yongfu, The Geological Center of Shanghai Economic Area, No. 17 Guang Dong Road, Shanghai, PRC; Ju Huiyang, Shanghai Railway Institute, 1 Zhen Nan Road, Shanghai, PRC; and Yao Bangchi

Aquifer energy storage is used in many applications in China. It has become widely adopted in textile, chemical, pharmaceutical, fermentation, and food processing industries, as well as in theaters, hotels and airport buildings to provide heating, cooling and humidification.

In the early 1960s, in order to control land subsidence and recharge groundwater, experiments involving artificial recharge of groundwater were carried out in Shanghai. By the end of 1965, the technique of summer recharge and winter extraction of hot water, and winter recharge and summer extraction of cool water had been developed throughout the entire city. Since 1967, studies on the technique of aquifer energy storage have also been carried out in Beijing, Xi'an and Tianjing.

There are many types of water-bearing structures in our country which can be used for aquifer energy storage, such as the crevice karst aquifers of hard rock and the porous aquifers of soft soil. In crevice karst aquifers in Shanghai and Hangzhou, cold water storage in limestone aquifers is quite successful, and efficiencies (amount of energy extracted relative to the amount stored) of 55 - 56% have been achieved. In porous aquifers, the results of energy storage become quite different as the hydrogeologic conditions change. Good results are usually found in aquifers of fine-grained material, large thickness and low regional groundwater velocity, where efficiencies can be 70 - 75%. In aquifers of coarse-grained material, small thickness and high regional groundwater velocity, energy storage is not as successful, and efficiencies are only 25 - 35%.

Energy storage techniques differ from city to city depending on the types of resources available and the particular energy storage needs of the city. In Tianjing, Beijing, Shijiazhuang and other cities, water is first air-cooled by spraying, and then injected into an aquifer for winter storage. In Shanghai, cyclical storage using one or more aquifers is carried out, with winter recharge and summer extraction, and summer recharge and winter extraction. In Hangzhou and other cities, some of the processes used also include the use of waste heat to provide hot water for summer storage and winter extraction, the recharge and extraction of salt and fresh water to improve water quality, and the recovery of waste water from air conditioners for heat storage.

In cities in Northern China, where surface water is scarce, groundwater is used for energy storage. In southern cities, on the other hand, surface water, groundwater and industrial waste water can all be used for energy storage. Thus, one must be careful to consider protection of the water quality when a water source is selected.

The textile industry consumes a huge amount of energy for heating, cooling and humidification. In Shanghai, for example, where there are 32 textile factories, $9.8 \times 10^6 \text{ m}^3$ of cool water is extracted every summer at an average temperature of 11°C , which is 13°C below ambient conditions. This amounts to a cooling capacity of 1.274×10^{11} kilocalories, or 60% of the total summer cooling load. Compared with an ammonia or steam-injection refrigerator, aquifer storage saves the equivalent of 80,949 tons of coal. In winter, $3.5 \times 10^6 \text{ m}^3$ of high-temperature water is extracted from the aquifer, at temperatures averaging 15°C above ambient conditions. This yields 5.25×10^{10} kilocalories of thermal energy, which is equivalent to 10,714 tons of coal.

In Shanghai, at least ten cinemas use cold water storage for summer air-conditioning. A volume of $12 \times 10^5 \text{ m}^3$ of cool water is extracted, with an average temperature of 10°C below ambient conditions. This yields 1.2×10^{10} kilocalories of cooling capacity and requires a power consumption of $4.56 \times 10^5 \text{ kW}$. If an ammonia refrigerator were used instead (for the same water temperature difference of 10°C), the power consumption would be $3.99 \times 10^6 \text{ kW}$.

The use of cold water storage for summer air-conditioning of the Shanghai Hongqiao airport lounge is a typical illustration of the application of energy storage for cooling. The airport uses two wells for cold water storage, thus replacing a lithium bromide refrigerator having a cooling capacity of 1×10^6 kilocalories per hour. The savings in initial investment is 350,000 yuan. Moreover, the energy storage system saves $4.32 \times 10^4 \text{ kW}$ in electric power consumption, 360 tons of coal and 14,688 yuan in operating costs every year.

Many of the industries in China consume large quantities of low-temperature ($<16^\circ \text{C}$) water in summer and high-temperature ($>28^\circ \text{C}$) water in winter for a variety of industrial purposes. However, there is a serious mismatch between supply and demand. Therefore, many cities have applied aquifer energy storage techniques to meet their industrial needs. One example is the Dongnan Chemical Fertilizer Plant in Hangzhou. Since the cool water ($12 - 16^\circ \text{C}$) extracted from a deep karst well has been used as cooling water in summer, the total production of chemical fertilizer has increased by 10%. Another example is the No. 1 Yiming Factory in Shanghai, which produces tomato ketchup. The low-

temperature water extracted from the wells enables the steamed tomato ketchup to cool and thicken quickly. Therefore, not only can the tomatoes retain their original taste and color, but the utilization rate of the equipment is improved by 15%.

During the dry season in China, sea water flows inland from the coastal areas, making river water too saline for factory use. Since 1970, when aquifer energy storage techniques were first applied, the use of aquifer water has replaced the use of river water during the dry season, thus ensuring the normal water supply to the factories year-round.

In conclusion, it has been shown that aquifer energy storage has many advantages over artificial mechanical refrigeration and conventional heating systems. These include lower initial investment, lower consumption of electric power and coal, lower operating costs, easy management, and high economic return. The use of aquifer energy storage has not only solved the problem of matching energy supply and demand, but has also increased the recharge of groundwater, raised the groundwater table, controlled land subsidence, improved groundwater quality, and reduced energy costs. For example, in Shanghai and Tianjing, aquifer energy storage is an aid in controlling land subsidence, and in the cities of Xi'an, Nanchang and Zhengzhou, aquifer energy storage is combined with the recharge of groundwater and raising of the groundwater table. In the industrial parts of Beijing and Shanghai, aquifer storage techniques are used solely for providing energy.

In order to improve techniques, we have studied aquifer energy storage on a large scale, based on previous small-scale results. In the future, we hope to strengthen scientific exchange with foreign engineers and scientists, and learn from each other how to best utilize our energy resources for the people.



AQUIFER STORAGE IN SHANGHAI CARPET PLANT

Contact: Sun Yongfu, The Geological Center of Shanghai Economic Area, No. 17 Guang Dong Road, Shanghai, PRC; Ju Huiyang, Shanghai Railway Institute, 1 Zhen Nan Road, Shanghai, PRC; and Yao Bangchi.

As a means to conserve energy and water resources, decrease the need for waste water disposal, and increase energy storage efficiency, a study was begun in 1972 that considered a combination of heat and cool storage using two different aquifers.

Although the heat-storage well and cool-storage well can be drilled in the same aquifer, there are several benefits to using separate aquifers for the storage of the hot and cold fluids, including the elimination of interference between the hot and cold water, reduction of the work site area, and reduction of equipment costs. In this article we describe an experiment conducted from 1972 to 1979 in the Shanghai carpet plant.

The workshops in the carpet plant need energy sources both to provide summer air conditioning and winter heating and humidification. In the past, a steam jet machine was used to provide air conditioning, and coal was burned to supply heat. In 1972 it was decided to test the concept of using one aquifer for winter injection for summer cooling, and another aquifer for summer injection for winter heating and humidification. The heat-storage well and cool-storage well were located 4 m apart. The wells were equipped with heater, cooler, filter, etc.

During summer, cool water (8 - 12 °C) stored around the cool-storage well was withdrawn and used to air-condition the workshops (humidity: 60 - 65%; temperature: 26 - 28 °C). The waste water (22 °C) was retrieved and heated by solar energy on the roof of the building to 30 - 40 °C, and then purified in a pressure filtering pool. Finally, it was reinjected into the aquifer through the heat-storage well.

During winter, the hot water (28 - 35 °C) stored around the heat-storage well was withdrawn and used to heat and humidify the workshops (humidity: 65 - 70%; temperature: 22 - 25 °C). The waste water (20 °C) was retrieved, cooled by spraying it through a chill-tower to 4 - 8 °C, purified in the pressure-filter pool, and then reinjected into the cool-storage well.

At the end of the seven-year experiment, it was concluded that this was a viable means to meet the heating, cooling, and humidification needs of the workshops. During this period, the technique saved $8.15 \times 10^5 \text{ m}^3$ of water, 1.108×10^6 units of electricity, and 600 tons of coal. As a result of this success, the technique of heat and cool storage in aquifers is widely used in Shanghai today.



**** REMINDER ****

All contributions and address changes for the next issue of the STES Newsletter should reach us by December 5, 1986.

INTERNATIONAL PROGRESS IN SOLAR PONDS

The Electrical Research Institute of Mexico is sponsoring the conference International Progress in Solar Ponds, to be held March 28 - April 3, 1987, in Cuernavaca, Mexico. The conference will address the technical status and issues of solar pond technology in depth.

The main purpose of the conference is to bring together solar pond specialists and enthusiasts from all over the world, providing a relaxed environment for the friendly discussion of ideas, in order to assess the progress made in the development of solar pond technology, identifying at the same time the important issues and further research needs. The conference program will include technical presentations and round table discussions on selected topics.

The conference will be preceded by a one-week long seminar on The Science and Technology of Solar Ponds. The goal of the seminar will be to disseminate, in the Latin American region, the current knowledge on solar ponds.

Anyone interested in attending the conference, or in obtaining further information should send correspondence to:

Dr. Jorge M. Huacuz V.
Instituto de Investigaciones Eléctricas
Apartado 475
Cuernavaca, Mor., 62000 México



THE HELIOGEOTHERMAL DOUBLET AT AULNAY-SOUS-BOIS, FRANCE

Contact: P. Iris, Ecole Nationale Supérieure des Mines de Paris, 35 Rue Saint Honore, 77305 Fontainebleau, France

The demonstration plant at Aulnay-sous-Bois, near Paris, France, has been described in detail in Vol. VII, No. 4 of this Newsletter. Basically, the experiment involves the use of aquifer energy storage coupled with heat pumps to heat 224 collective apartments. Groundwater is pumped from the sandy, confined Ypresian aquifer, which underlies the northern part of the Parisian Basin at a depth of about 80 m. The aquifer is reached by two wells for pumpage and injection. There are three heat pumps for space heating and domestic hot water (total of 650 thermal KW). Climatic collectors are used for summer thermal recharge of the aquifer in order to lessen the extent of the cooled zone in the aquifer.

The demonstration plant was first put into operation in 1983, and its progress has been monitored for the past three years. The long-term objective of the project was to test the heliogeothermal concept, which is designed to maximize the use of aquifer heat pumps in dense urban areas. The short term objective of the project was to analyze the behavior of a pilot plant using heat pumps with an aquifer, a technique first developed in France.

Table 1 gives the primary results of plant operation to date. In the table, the coefficient of performance (COP) includes the electricity used by the different pumps. These results are close to the expected ones.

During the first years of the project, several problems were encountered. The domestic hot water heat pump, which operated under severe conditions (high condensing temperature (65 °C) and discontinuous operation) had one of its two compressors fail. During some periods, this heat pump worked at only 50% of its nominal power. On the other hand, the space heating heat pumps worked without incident during this period.

Special attention was given to potential problems associated with injection. The wells were developed at a flow rate much higher than the nominal operating injection flow rate (100 m³/hr vs 50 m³/hr). Several steps were taken to prevent the accidental injection of air into the aquifer. The injection system was designed to prevent air injection, the injection wells were backwashed weekly, and the specific injection flow rate was monitored weekly. The flow rate remained constant until November 1984, when an accidental air injection occurred, clogging the injection well in less than one month. This phenomenon was caused by precipitation of iron hydroxide near the injection well screen. Treatment with a local injection of hydrochloric acid permitted flow rate recovery. No other problems of a chemical or bacteriological nature were encountered.

The most recent major incident to occur was the breakdown of a steel pipe supporting a submerged pump. This was caused by poor installation and corrosion, and the metal pipes have since been replaced.

Table 1. Results from demonstration plant.

Year (winter)	Total Needs (MWh)	Heat Pumps (%)	Global COP
1983/84	2110	89	3.4
1984/85	2584	78	3.3
1985/86	2352	80	3.2

At this point in time, we can make several observations regarding the performance of the system. Overall, this demonstration plant has yielded positive results. However, it does not seem that the injection problem has yet been solved. It would be of great interest to gather the results of different experiments to define basic guidelines for the completion of the wells, their maintenance and eventual water treatment. It is extremely valuable to have performance data without lengthy delays. Otherwise, minor incidents can compound to have major consequences on the overall performance of the system. A well organized management system is a very important factor in this regard. Finally, special care must be taken to couple the underground and surface installations, each of which has its own operational constraints. A good understanding between hydrogeologists and mechanical engineers is necessary for successful operation.

Economically, such a system is well adapted to large-scale buildings that need both cooling and heating. The economical feasibility depends on comparable energy prices and on the ratio of thermal needs to the cost of the access to the aquifer; that is, the size of the building and the depth of the aquifer.



SECOND LONG-TERM TEST CYCLE AT THE UNIVERSITY OF MINNESOTA

Contact: L. Kannberg, Underground Energy Storage Program, Battelle Pacific Northwest Laboratory, Box 999, Richland, Washington 99352 USA, or M. Walton, Minnesota Geological Survey, 2642 University Avenue, Minneapolis, Minnesota 55114 USA

The following is an update of the report appearing in the previous issue of this Newsletter (Vol. VIII, No. 3) on the seasonal thermal energy storage project underway at the University of Minnesota Saint Paul campus.

The University of Minnesota initiates its second long-term test cycle on October 2, 1986. The long-term cycle will involve injection of softened, heated (up to 150°C) groundwater for a period of 60 days. During this period, it is planned that 9×10^7 liters of water will be injected. The injection period will be followed by a 60-day storage period, and then a recovery period (nominally 60 days), during which a volume equal to the volume injected will be withdrawn from the aquifer. The testing is being performed using a doublet well system at the St. Paul Field Test Facility. Energy for heating the groundwater is supplied from the campus steam heating plant.

After completion of the second cycle, the recovered groundwater will be pumped from the aquifer. Additional pumping will be conducted to restore the aquifer to conditions approaching those existing prior to testing. A lengthy period of environmental monitoring will be conducted after the pumping has been completed.

This project is supported by the U.S. Department of Energy through its Pacific Northwest Laboratory (operated by Battelle Memorial Institute). For further information, please contact Dr. Matt Walton at the above address.

Editor's note: Please note two minor corrections in the article on this subject appearing in the previous issue. In Table 1, column 3 (Cycle 3), the number 2.5 should read 20.5. Also, the list of "other project members" should include the name R. Kanivetsky.



22ND INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE

The 22nd Intersociety Energy Conversion Engineering Conference, on the subject of Advanced Energy Storage Technologies for Terrestrial Energy Storage, will be held in Philadelphia, Pennsylvania, August 10-14, 1987. This topical symposium will include papers on bulk energy storage for electric utility applications, thermal energy storage for both solar and non-solar applications, and automotive energy storage. In particular, papers on utility-scale battery energy storage, compressed air energy storage, magnetic energy storage, flywheels and other rotating devices are sought. Papers on systems analysis and applications will be included, as well as papers addressing the design and testing of components.

All interested authors are encouraged to submit 4 copies of a 500-word abstract by December 15 to:

Dr. Susan Schoenung
Bechtel National, Inc.
50 Beal Street
MS-50/15/D15
San Francisco, California 94105
(Telephone: (415) 768-2582).

Abstracts should include an introductory statement indicating the purpose and significance of the work. The author should discuss the results of the effort and how it differs from or extends beyond previously reported work. Authors will be notified of acceptance and given further instructions by March 1, 1987. Final manuscript deadline is May 15, 1987.

For Reference

Not to be taken from this room



PUB-428 9/86/625 Lawrence Berkeley Laboratory is
an Equal Opportunity Employer.

This work was supported by the U.S. Department of
Energy under Contract No. DE-AC03-76SF00098.