Aquifer Thermal Energy Storage: A Numerical Simulation Of

sole source of energy or as a partial storage; at a temperature useful for direct application or needing upgrade. The sources of energy used for aquifer storage are ambient air, usually cold winter air; waste or by-product energy; and renewable energy such as solar. The present technical, financial and environmental status of ATES is promising. Numerous projects are operating and under development in several countries. These projects are listed and results from Canada and elsewhere are used to illustrate the present status of ATES. Technical obstacles have been addressed and have largely been overcome. Cold storage in aquifers can be seen as a standard design option in the near future as it presently is in some countries. The cost-effectiveness of aquifer thermal energy storage is based on the capital cost avoidance of conventional chilling equipment and energy savings. ATES is one of many developments in energy efficient building technology and its success depends on relating it to important building market and environmental trends. This paper attempts to provide guidance for the future implementation of ATES. Individual chapters have been processed separately for entry onto the Department of Energy databases. The technical feasibility of high-temperature (>100°C; >212°F) aquifer thermal energy storage (ATES) in a deep, confined aquifer was tested in a series of experimental cycles at the University of Minnesota’s St. Paul field test facility (FTF). This report describes the second long-term cycle (LT2), which was conducted from October 1986 through April 1987. Heat recovery; operational experience; and thermal, chemical, hydrologic, and geologic effects are reported. Approximately 61% of the 9.21 GWh of energy added to the 9.38 x 104 m3 of ground water stored during LT2 was recovered. Temperatures of the water stored and recovered averaged 118°C (244°F) and 85°C (185°F), respectively. Results agreed with previous cycles conducted at the FTF. System operation during LT2 was nearly as planned. Operational experience from previous cycles at the FTF was extremely helpful. Ion-exchange softening of the heated and stored aquifer water prevented scaling in the system heat exchangers and the storage well, and changed the major-ion chemistry of the stored water. Sodium bicarbonate replaced magnesium and calcium bicarbonate as primary ions in the softened water. Water recovered form storage was approximately at equilibrium with respect to dissolved ions. Silica, calcium, and magnesium were significantly higher in recovered water than in injected water. Sodium was significantly lower in water recovered than in water stored.Cukurova University, Turkey in collaboration with Ljubljana University, Slovenia and the International Energy Agency Implementing Agreement on Energy Conservation Through Energy Storage (IEA ECES IA) organized a NATO Advanced Study Institute on Thermal Energy Storage for Sustainable Energy Consumption – Fundamentals, Case Studies and Design (NATO ASI TESSEC), in Cesme, Izmir, Turkey in June, 2005. This book contains manuscripts based on the lectures included in the scientific programme of the NATO ASI TESSEC. The concept of thermal energy storage in aquifers was suggested a few years ago. The idea is to store in aquifers large quantities of hot water produced (1) as a by-product of power plants, or (2) from solar energy collectors, and to retrieve the hot water for use when needed. Hence this method will, on the one hand, recover waste heat from power plants that is normally wasted, thus making possible the implementation of large-scale total energy systems. On the other hand, when used in conjunction with solar energy systems, aquifer energy storage provides a buffer between time-varying solar energy inputs and thermal or power demands. It is only recently that sophisticated computer models have been developed to study this storage system using the proper physical conditions and parameters, and to make realistic predictions of the energy storage and retrieval efficiencies. Furthermore, field experiments are currently underway to test this concept. Analytical and numerical studies at the Lawrence Berkeley Laboratory are described. The hydrodynamic and thermal behaviors of the storage system are analyzed and illustrated. The ratio of energy retrieval over energy stored is predicted to be as high as 80%. The technical and economic feasibility of large-scale aquifer thermal energy storage (ATES) was examined. A key to ATESs attractiveness is its simplicity of design and construction. The storage device consists of two ordinary water wells drilled into an aquifer, connected at the surface by piping and a heat exchanger. During the storage cycle water is pumped out of the aquifer, through the heat exchanger to absorb thermal energy, and then back down into the aquifer through the second well. The thermal storage remains in the aquifer storage bubble until required for use, when it is recovered by reversing the storage operation. For many applications the installation can probably be designed and constructed using existing site-specific information and modern well-drilling techniques. The potential for cost-effective implementation of ATES was investigated in the Twin Cities District Heating-Cogeneration Study in Minnesota. In the study, ATES demonstrated a net energy saving of 32% over the nonstorage scenario, with an annual energy cost saving of $31 million. Discounting these savings over the life of the project, the authors found that the break-even capital cost for ATES construction was $76/kW thermal, far above the estimated ATES development cost of $23 to 50/kW thermal. It appears that ATES can be highly cost effective as well as achieve substantial fuel savings. ATES would be environmentally beneficial and could be used in many parts of the USA. The existing body of information on ATES indicates that it is a cost-effective, fuel-conserving technique for providing thermal energy for residential, commercial, and industrial users. The negative aspects are minor and highly site-specific, and do not seem to pose a threat to widespread commercialization. With a suitable institutional framework, ATES promises to supply a substantial portion of the nation’s future energy needs. (LCL). The technical feasibility of high-temperature (>100°C) aquifer thermal energy storage (IOTAS) in a deep, confined aquifer was tested in a series of experimental cycles at the University of Minnesota’s St. Paul field test facility (FTF). This report describes the additions to the FTF for the long-term cycles and the details of the first long-term cycle (LT1) that was conducted from November 1984 through May 1985. Heat recovery; operational experience; and thermal, chemical, hydrologic, and geologic aspects of LT1 are reported. The permits for long-term cycles required the addition of a monitoring well 30.5 m from the storage well for monitoring near the edge of the thermally affected area and allowed the addition of a cation-exchange water softener to enable continuous operation during the injection phase. Approximately 62% of the 9.47 GWh of energy added to the 9.21 x 104 m3 of ground water stored in the aquifer LT1 was recovered. Ion-exchange water softening of the heated and stored ground water prevented scaling in the system heat exchangers and the storage well and changed the major-ion chemistry of the stored water. Temperatures at the storage horizons in site monitoring wells reached as high as 108°C during the injection phase of LT1. Following heat recovery, temperatures wereThermal energy storage (TES) technologies store thermal energy (both heat and cold) for later use as required, rather than at the time of production. They are therefore important counterparts to various intermittent renewable energy generation methods and also provide a way of valorising waste process heat and reducing the energy demand of buildings. This book provides an authoritative overview of this key area. Part one reviews sensible heat storage technologies. Part two covers latent and thermochemical heat storage respectively. The final section addresses applications in heating and energy systems. Reviews sensible heat storage technologies, including the use of water, molten salts, concrete and boreholes Describes latent heat storage systems and thermochemical heat storage Includes information on the monitoring and control of thermal energy storage systems, and considers their applications in residential buildings, power plants and industry. The ability of thermal energy storage (TES) systems to facilitate energy savings, renewable energy use and reduce environmental impact has led to a recent resurgence in their interest. The second edition of this book offers up-to-date coverage of recent energy efficient and sustainable technological methods and solutions, covering analysis, design and performance improvement as well as life-cycle costing and assessment. As well as having significantly revised the book for use as a graduate text, the authors address real-life technical and operational problems, enabling the reader to gain an understanding of the fundamental principles and practical applications of thermal energy storage technology. Beginning with a general summary of thermodynamics, fluid mechanics and heat transfer, this book goes on to discuss practical applications with chapters that include TES systems, environmental impact, energy savings, energy and exergy analyses, numerical modeling and simulation, case studies and new techniques and performance assessment methods.