Proceedings of

International Conference on
Seasonal Thermal Energy Storage and Compressed Air Energy Storage

October 19-21, 1981
Seattle, Washington

Vol. I

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

PNL-SA--10347 Vol. 1
DE82 012419

Pacific Northwest Laboratory
Richland, Washington 99352

Universitätsbibliothek und
Technische Informationsbibliothek
Welfengarten 1 B
3000 Hannover 1
# TABLE OF CONTENTS: VOLUMES I & II

## VOLUME I

### PLENARY SESSION

John J. Brogan (U.S. Department of Energy) ............................................ 3

**OVERVIEW OF SEASONAL THERMAL ENERGY STORAGE IN THE UNITED STATES**
James E. Minor (Pacific Northwest Laboratory) ........................................... 5

**COMPRESSIBLE AIR ENERGY STORAGE IN THE UNITED STATES**
Lars H. Kannberg (Pacific Northwest Laboratory) ........................................ 15

**ENVIRONMENTAL AND INSTITUTIONAL CONSIDERATIONS FOR AQUIFER ENERGY STORAGE PROJECTS - STES AND IACS**
Brian J. Gallagher (University of Wisconsin-Milwaukee) ............................ 31

**CENTRAL SOLAR HEATING PLANTS WITH SEASONAL STORAGE - REVIEW OF TASK VII OF THE IEA SOLAR HEATING AND COOLING PROGRAMME**
Arne Boymen (Rengt Nideck Gösta Danielson Arkitektkontor AB) ..................... 46

### SEASONAL THERMAL ENERGY STORAGE

**STES OVERVIEW**

**HEAT FROM EARTH, ROCK, AND WATER**
B. Svedinger, et al. (VIK) ................................................................. 54

**STATUS OF R & D FOR LONG TERM THERMAL ENERGY STORAGE IN GERMANY**
P. J. Friedrich and V. Loitner (Kernforschungszentrale Jülich) ..................... 58

**ALTERNATIVE ENERGY STORAGE FOR THE SWEDISH IEA NATIONAL DESIGN CASE**
Torbjörn Lindh (Swedish State Power Board)
Thomas Bruce (Södertälje Energy Supply Authority) .................................. 67

**PRELIMINARY ASSESSMENT OF PROMISING NONAQUIFER STES**
Donald E. Blahnik (Pacific Northwest Laboratory) ..................................... 70

**LARGE SCALE THERMAL STORAGE SYSTEMS APPLICATION IN COGENERATION DISTRICT HEATING**
R. Jank (Planung-Energie-Konsult) ...................................................... 81

### SYSTEMS I - STES PROJECTS

**SEASONAL HEAT STORAGE IN GREENHOUSE SOIL**
A. Nir, A. Amiel, and Basot Neir (The Weizmann Institute of Science) ............ 95
AQUIFER STORAGE USING THE DOUBLET WELL CONFIGURATION
Joel G. Melville, Fred J. Wolf, A. David Parr, David A. King, and Mike T. Hopf
(Auburn University) ........................................ 103

REALIZATION OF RECOVERABLE ZONE FROM THE STAND OF STREAM LIMES
H. Uemiyama and T. Yokoyama (Yamagata University)
K. Katayama (Tokyo Institute of Technology)
K. Katsuragi (Nippon Chikusui Kihateu Co. Ltd.) .................. 114

SEASONAL THERMAL STORAGE FOR HEAT PUMP
Douglas M. Jardine and David W. Jones (Kaman Sciences Corporation) ....... 124

THE AQUIFER THERMAL ENERGY STORAGE (ATES) PROGRAM - UNIVERSITY OF MINNESOTA
Matt S. Walton (Minnesota Geological Survey) ................................ 132

THE DEVELOPMENT AND APPLICATION OF AQUIFER STORAGE IN CHINA
Qi-Sen Yan (Tsinghua University) ........................................ 141

SYSTEMS I - STES PROJECTS

AQUIFER BASED COOLING - A DEMONSTRATION
C. C. Angus and G. T. Williams (Hooper and Angus Associates Ltd.) ........... 153

TWO CONCRETE PROJECTS OF SPACE HEATING WITH SOLAR ENERGY AND AQUIFER THERMAL USE
P. Iris (Ecole Nationale Superieure des Mines de Paris) ........................ 162

SUNCLAY PROJECT - FIRST YEAR OPERATION WITH A SEASONAL STORAGE OF 80,000 m³ CLAY
Goran Hultmark (Bengt Dahlgren AB) .................................................. 171

SUNSTORE - THE COMPLETE SOLAR ENERGY SYSTEM FOR HEATING
G. B. PlateH, Thomas Nilsson, and P. Morgen (Sunstore KB) ...................... 177

THE AVESTA TEST PLANT FOR STORAGE OF HOT WATER IN AN UNLINED ROCK CAVERN
Juri Martna (Swedish State Power Board) ............................................. 186

EXPERIMENTAL RESULTS OF AN EARTH-STORAGE SYSTEM OF 350 m³
P. Chuard, D. Chuard, C. Mercier, and J. C. Hadorn (Soroae SA) ............... 193

FIELD EXPERIMENTATION OF THE "SOIL THERM" INTERSEASONAL STORAGE SYSTEM OF SOLAR ENERGY IN THE SUBSOIL
Georges Vachaud and Jean-Pierre Person (Institut de Mecanique de Grenoble)
Alain de la Gaminiere (Groupe Solarte, C.R.T.B.P.-C.N.R.S.) .................. 203

SYSTEMS II - STES METHODOLOGY

CHARACTERIZATION AND MODELING OF AN UNCONSOLIDATED AQUIFER FOR 40,000 MWH
OF CHILL STORAGE AT STONY BROOK
Donald J. Supkow and William V. Skinner (Dames & Moore) ..................... 217

SEALING AND INSULATION OF LONG-TIME HEAT STORAGES IN WOLFSBURG
Werner Breuer and Johannes Strickrodt (Forschungsgesellschaft Wolfzburg) ...... 245

HEAT STORAGE IN ROCK - MULTIPLE WELL SYSTEM
Soren Anderson and Anders Eriksson (AIB Consulting Engineers)
Bo Nordell (University of Lulea) ....................................................... 253

A NEW LABORATORY TEST FACILITY FOR AQUIFER MATERIALS
S. C. Blair and J. A. Stottlemyre (Pacific Northwest Laboratory) ................. 263

CHEMICAL HEATPUMP WITH SEASONAL ENERGY STORAGE
E. G. Clark (Rocket Research Co.) .................................................... 270
VOLUME II

COMPRESSED AIR ENERGY STORAGE

CAES OVERVIEW

A REVIEW OF THE STATUS AND POTENTIAL OF COMPRESSED AIR ENERGY STORAGE
Charles L. Driggs (Acres American Incorporated) ........................................... 443

AIR STORAG£ SYSTEMS
T. J. Doherty (Pacific Northwest Laboratory) ..................................................... 454

R&D PERSPECTIVES ON COMPRESSED AIR ENERGY STORAGE (CAES) FROM THE UTILITY PERSPECTIVE
Robert B. Schairer (Electric Power Research Institute) ...................................... 469

ANALYSIS OF JOINTLY OWNED LARGE-SCALE UTILITY STORAGE PROJECTS
Jonathan W. Hurwitch (Battelle Columbus Laboratories) ..................................... 476

ENVIRONMENTAL AND REGULATORY ASPECTS OF COMPRESSED AIR ENERGY STORAGE
Mike A. Beckvith (Pacific Northwest Laboratory) .............................................. 493

RESERVOIR TECHNOLOGY

FACTORS INFLUENCING THE DESIGN OF CAES FACILITIES IN HARD ROCK
D. C. Willett and R. H. Curtis (Acres American, Inc.) ....................................... 501

THE FORMATION OF UNDERGROUND ENERGY-CONVERSION CAVERNS USING HYDRAULIC BOREHOLE
MINING METHODS
William R. Archibald and G. Stuart Knoke (Flow Technology Company) ............... 511

CAES SITING IN SEDIMENTARY ROCKS
Sher Bahadur (Acres American Incorporated) ..................................................... 519

EXPERIMENTAL AND ANALYTICAL STUDY OF THE CHAMPAGNE EFFECT IN CAES
P. A. Thompson, H. J. Sneck, and B. Meyer (Rensselaer Polytechnic Institute) ........ 527

RESOLUTION OF THE CHAMPAGNE EFFECT FOR HYDRAULICALLY COMPENSATED CAES
Jean Pellin (Société Électrique de l'Our) ......................................................... 531

ANALYTICAL MODELING OF THE CHAMPAGNE EFFECT IN HYDRAULICALLY COMPENSATED CAES
RESERVOIRS
D. S. Rowe and C. A. McMonagle (Rowe & Associates) ..................................... 538

FIELD CALIBRATION OF THE REM COMPUTER METHOD USED FOR CAES CAVERN DESIGN
James P. McNamara, Frank Tsai, and Shosel Serata (Serata Geomechanics, Inc.) ....... 545

IN SITU CAES TESTS FOR SALT RESERVOIRS
R. L. Thoms and R. M. Gehle (Louisiana State University) .................................. 553

THE HUNTOF PLANT: OVER 3 YEARS OPERATING EXPERIENCE WITH COMPRESSED AIR CAVERNS
Peter Quast (Kavernen Bau- und Betriebs) ....................................................... 562

BASIS FOR COMPRESSED AIR ENERGY STORAGE (CAES) FIELD TEST AT PITTSFIELD, ILLINOIS
R. D. Allen (Pacific Northwest Laboratory) ....................................................... 573
COMPRKSSED AIR ENERGY STORAGE AQUIFER FIELD TEST CONCEPTUAL DESIGN, CONSTRUCTION AND OPERATION
John A. Istvan (PB-KBB Inc.) .......... 584

PREDICTION OF THE THERMODYNAMIC PERFORMANCE OF POROUS MEDIA RESERVOIRS FOR COMPRSKED AIR ENERGY STORAGE
L. E. Wiles and R. A. McCann (Pacific Northwest Laboratory) .......... 595

PROBLEMS IN RESERVOIR-ROTATING EQUIPMENT MATCHING IN AQUIFER CAES
David L. Ayers (Westinghouse Electric Corporation - Indiana)
Paul A. Berman (Westinghouse Electric Corporation - Pennsylvania) .......... 604

IMPLEMENTATION OF CAES

THE CAES POWER PLANT - A TOOL IN THE LOAD DISPATCHER'S HANDS IN AN ELECTRIC UTILITY SYSTEM
Hans-Christoph Herbst .......... 615

MEETING LOAD GROWTH WITH A COMPRSKED AIR ENERGY STORAGE SYSTEM
B. R. Clausen (Alabama Electric Cooperative Inc.)
A. J. Karalls and E. J. Sosnowicz (United Engineers & Constructors Inc.) .......... 626

ADVANTAGES AND PLANS FOR CAES IN THE SOYLAND POWER COOPERATIVE SYSTEM
Royal B. Newman (Soyland Power Cooperative) .......... 632

SITING COMPRESSED AIR ENERGY STORAGE (CAES) FACILITIES
(Environemtal Science and Engineering, Inc.) .......... 641

PRELIMINARY EVALUATION OF CAES IN ISRAEL
Avraham Melamed (Tushia Consulting Engineers) .......... 656

CONCEPTUAL DESIGN OF ADIBATCIC CAES IN HARD ROCK
M. J. Hobson, S. Behedur, C. L. Driggs, and D. J. James
(Acres American Incorporated) .......... 662

SECOND-GENERATION TECHNOLOGY

THERMAL ENERGY STORAGE MATERIALS SCREENING TEST
G. L. Marksberry and D. C. DeCoursin (Fluidyne Engineering Corporation) .......... 675

THERMAL ENERGY STORAGE FOR ADIBATIC CAES
P. E. Chew (Marchwood Engineering Laboratories)
D. C. James (Acres American Incorporated) .......... 685

TURBOMACHINERY CYCLE OPTIMIZATION FOR CAES APPLICATIONS
John R. Stange, Louis F. Giannuzzi, and Michael Nakhshkin (Gibbs & Hill, Inc.) .......... 700

COAL-FIRED AIX STORACE POWER PLANTS FOR LOAD LEVELING APPLICATIONS
A. J. Giroumeti and R. D. Lessard (United Technologies Research Center) .......... 708

COAL GAS-FIRED CAES FOR MID-RANGE GENERATION
J. L. Haydock and M. J. Hobson (Acres American Incorporated) .......... 716
BANQUET ADDRESS

SOME LIKE IT HOT, SOME LIKE IT COLD
John L. Yellott (Arizona State University) 733

POSTER PAPERS

A SOLAR ENERGY ROCK BED STORAGE SYSTEM
Robert M. Jusko (Energy Research and Development) 741

A VACUUM INSULATED HYBRID HEAT STORAGE SYSTEM (HWS)
Lothar Schill (ERNO Raumfahrttechnik) 748

VACUUM SUPER INSULATION
Lothar Schill (ERNO Raumfahrttechnik) 758

SOLAR HEATING OF GREENHOUSES WITH HUMIDITY CONTROL AND SEASONAL HEAT STORAGE
Avraham Melamed (Tushia Consulting Engineers) 769

ANALYTIC MODELING APPROXIMATIONS OF ATE'S THERMOCLINE BEHAVIOR
Walter Hausz (General Electric Co., TEMPO) 775

AGENDA - SEASONAL THERMAL ENERGY STORAGE 781
AGENDA - COMPRESSED AIR ENERGY STORAGE 787
LIST OF ATTENDEES 791