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Low-Temperature Thermal Energy Storage Program Annual Operating Plan FY 1979

D. M. Eissenberg
H. W. Hoffman

OAK RIDGE NATIONAL LABORATORY
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Engineering Technology Division

LOW-TEMPERATURE THERMAL ENERGY STORAGE PROGRAM
ANNUAL OPERATING PLAN
FY 1979

D. M. Eissenberg H. W. Hoffman

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PREFACE

The Low-Temperature Thermal Energy Storage (LTTES) Program Annual Operating Plan (AOP) described herein is based on Department of Energy-Division of Energy Storage Systems (DOE/STOR) program guidance received at the beginning of FY 1979. During the second quarter of the fiscal year, DOE/STOR implemented a major change in the responsibilities for the organizations carrying out its several programs in thermal energy storage. As a result, many of the tasks in this AOP — particularly those in the areas of seasonal storage and industrial waste heat reuse — are no longer within the purview of the LTTES Program. Therefore, this AOP is being issued, not as a description of the present commitments and directions of the LTTES Program, but as documentation of the national effort in these areas in its FY 1979 form.

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ABSTRACT

The Low-Temperature Thermal Energy Storage (LTTES) Program operating plans for FY 1979 are described in terms of general program objectives and the technical activities being implemented to achieve these objectives. The program structure provides emphasis on several principal thrusts; namely, seasonal thermal storage, daily/short-term thermal storage, and recovery and reuse of waste heat. Fiscal data are summarized according to thrust area, individual efforts, and funding source.

1. INTRODUCTION

This Annual Operating Plan (AOP) describes activities to be carried out by the Low-Temperature Thermal Energy Storage (LTTES) Program during FY 1979. The effort is managed by the Oak Ridge National Laboratory (ORNL) in support of the Department of Energy (DOE) program on thermal energy storage as implemented through the DOE-Division of Energy Storage Systems (STOR). Responsibility for managing the LTTES Program was delegated to ORNL in FY 1976; the work is carried out in consultation with and with the concurrence of DOE/STOR.

The LTTES Program objectives and plans are detailed in the succeeding chapters of this document. Overall (long-range) objectives and schedules are described in Chapters II and III, respectively; these are organized in accordance with the thrusts (principal emphases) established in FY 1978. Chapter IV outlines each specific work element in progress or proposed in the next year to fulfill the stated objectives and achieve the desired milestones. Budget (Chapter V) and management plans (Chapter VI) complete the presentation.

The AOP amplifies the information provided in the Budget Proposal Activity C8 03 02 01 0, 189 No. 00001, for FY 1979.

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2. PROGRAM OBJECTIVES AND GOALS

The overall objectives of the LTTES Program are (1) to carry out research and development on new technologies for storing thermal energy as low-temperature sensible or latent heat, and (2) to develop, test, and demonstrate cost-effective systems for collecting, storing, and discharging low-temperature thermal energy, which will have significant national impact on energy conservation in the near- and mid-term.

Technologies will be proven in the LTTES program up through the prototype system development stage. Both the economic and technical feasibilities of the concepts under development will be established sufficiently to recommend their viability for demonstration and ultimate commercialization. These technologies will be considered in the context of both new and retrofit applications for centralized systems or decentralized systems.

The objectives of the LTTES program are consistent with those of the National TES Program and are to be accomplished within the framework of the DOE National Plan. Specific National Thermal Energy Storage (TES) Goals supported by the LTTES program are indicated in Table 2.1. This

Table 2.1. National TES program goals supported by the LTTES program

Application area	TES program goals	LTTES primary support
Household and commercial	1) Improve energy management	Yes
	2) Improve economics of solar systems	Yes
	3) Utilize waste heat from industry and utilities	Yes
Utilities	4) Utilize base load generating system for peak load following	No
	5) Improve economics of solar electric power generation	No
Industrial and agriculture	6) Improve process efficiency and waste heat utilization	Yes
	7) Improve economics of solar generated	Yes
	8) Improve energy management	Yes
Transportation	9) Utilize vehicle heat storage for propulsion system	No

table, organized into four general application sectors, relates the National TES Program Goals to specific application areas. As shown, the LTTES program provides support to the TES program in two of these application sectors: (1) household and commercial [H/C], and (2) industrial and agricultural [I/A].

3. PROGRAM IMPLEMENTATION PLAN

3.1 Program Scope

3.1.1 Technology thrusts

The LTTE Program is directed toward the development of TES technologies and systems that are applicable to near-term (by 1985) and mid-term (1985-2000) use. Refinements of existing systems are excluded. The program is divided into three technological areas:

1. Geological storage: seasonal sensible heat or cold storage in natural aquifers (underground water-bearing strata), surface ponds, and subsurface earth.
2. PCM storage: decentralized daily/short-term latent heat or cold storage devices incorporating phase-change materials (PCMs) for use with utility load management or solar applications.
3. Waste energy reuse: industrial heat reuse for district heating applications involving use of either seasonal or short term storage.

Of these three areas, seasonal storage in aquifers has been identified by DOE as being of sufficient near-term national economic/conservation potential to warrant designation as a principal thrust. Thus, a major expansion of work in geological storage is planned in FY 1980; this proposed expansion is reflected in the long-range implementation plan.

3.1.2 Application areas

Low-temperature TES application areas include residential and commercial space conditioning (heating and cooling) and industrial, commercial, and agricultural process heat. Space conditioning applications include dispersed systems (individual buildings) and central systems (district heating). Process heat applications include within-plant cascading and transfer of cascaded process heat between plants.

3.1.3 Energy sources

Heat sources to be exploited include (1) waste heat discharged to the environment from industrial or utility operations, (2) heat cogenerated

in conjunction with electric power production, (3) solar heat, and (4) heat generated during utility off-peak periods, either by heat pumps or directly by resistance heaters.

Sources of cold include (1) those generated by mechanical or absorption air conditioners operating on either solar heat or off-peak electricity, (2) environmental cold, collected by exchange with the ambient atmosphere during the winter, and (3) possibly reject cold from low-temperature industrial operations as in food processing or from heat pump operation in the wintertime.

The matching of sources with storage mode depends on the intended application of the stored energy.

3.2 Implementation Plan

The implementation plan provides a description of the logic for present and future directions in the LTTEs Program. It reflects the program scope (including the technology thrust areas, applications, and energy sources) and describes for each thrust area and work element an appropriate sequence of tasks over the next five years.

3.2.1 Geological storage

Storage of hot or cold water underground in natural geological formations (e.g., aquifers) can bridge the seasonal gap between a heat or cold surplus period and a later heat or cold demand period. The attractiveness of the concept lies in utilizing geological formations for storage without the need for significant alterations other than providing suitable input and output devices.

A major demonstration program aimed at construction and operation of up to six systems for heat recovery storage and use is being initiated in FY 1980 by DOE/STOR. As a result, the focus of the LTTEs program in geological storage is to provide the technology base necessary to support the planned aquifer demonstrations.

Subsurface artificial and natural cavities containing hot and cold waters as well as the earth itself appear to have potential for seasonal storage of heat or cold. An investigation of pond storage under way in

Europe under the sponsorship of the International Energy Agency, with funding assistance from DOE/STOR, will be monitored as a part of this program. Previous work on earth storage will be reviewed; further studies will be initiated, if justified.

In order to guide development of the technology for aquifer storage to the stage where one demonstration system can be designed and built, a comprehensive, multi-element, long-range, aquifer R&D program is planned. This program will be aimed at uncovering and resolving critical technical, economic, and institutional issues in a timely manner. Seven work elements are included in this aquifer R&D program:

1. Techno-economic studies: application surveys to identify and locate suitable seasonal storage applications both nationally and, in more detail, regionally; analysis of the value of seasonal storage for specific applications; feasibility studies of proposed aquifer storage projects; parametric studies to determine sensitivity of the cost of aquifer storage to the principal cost components; development of a national plan for implementation of aquifer storage technology.

2. Experimental field test: development and operation of pilot-size aquifer storage well systems to demonstrate overall technical feasibility, to develop good operating methods, to uncover and resolve operational problems, to test novel components, and to acquire a data base against which to develop and test mathematical models for predicting performance of new systems.

3. Mathematical modeling: development of mathematical models for predicting aquifer storage characteristics, including thermal recovery efficiency, hydraulic behavior, geochemical behavior, and structural integrity over multiple-storage cycles.

4. Support R&D: experimental small-scale studies aimed at increased understanding of specific areas of aquifer behavior during storage cycles, including geochemical research, structural mechanical research, and physical modeling of complex well systems.

5. Technology development: development and testing of aquifer storage system components not already commercially available or where optimization for the aquifer storage system is indicated, including systems

for capturing winter cold and transferring it to aquifer water, down-well pumps, well casings, heat exchangers, systems for unplugging wells, systems for monitoring well performance, etc.

6. Environmental and institutional analysis: generic analysis of possible impacts on the environment of aquifer storage systems and experiments; site-specific analyses of planned systems, where appropriate; analysis of the legal implications of aquifer storage, ownership of stored water, usage restrictions, etc.

7. Prototype system well doublet: aquifer selection, preliminary site analysis, test-well drilling and hydrological testing, well system design and cost estimate, well construction, preliminary testing, performance testing with heated or cooled water over one or more seasonal cycles, incorporation into application system.

Table 3.1 details the long-range schedule (through FY 1985) for each work element for the geological storage R&D program; milestones currently identified with these program elements through FY 1980 are also indicated.

3.2.2 Daily short-term latent heat storage for building heating and cooling

The efficient use of off-peak electricity and of solar energy for space heating and cooling of residential and commercial buildings will require storage of either heat or cold to supply thermal loads during time intervals when energy is either unavailable or more expensive. These periods can range from several hours to several days. Storage elements for such applications could be in the form of central modular units, with forced convection charging or discharging, or they could be incorporated as part of building structures, as, for example, applications to passive solar systems in which natural convection and radiation supplement or replace forced convection for either charging or discharging. The storage in each case could be as sensible heat, as latent heat, or a combination of the two. At the present time, it is possible to store thermal energy (either heat or cold) using commercially available heat storage systems with water or solids as the storage medium in either modular or structural storage units. However, these systems presently have limited application because of the large storage volumes required, the

Table 3.1. Geological storage

Program element	Fiscal year				
	1979	1980	1981	1982	1983
<u>Aquifer storage</u>					
Techno-economic studies	1 2	4 3 5 6			
Experimental fields tests	7	8			
Mathematical modeling					
Support R&D		9 10			
Technology development		11			
Environmental/Institutional analyses	12 13				
Prototype doublet tests		14 15			
<u>Pond storage</u>					
Techno-economic studies		16			
Experimental field tests					
<u>Earth storage</u>					
Techno-economic studies		17			

Milestones:

- (1) Complete JFK feasibility study
- (2) Complete JFK preliminary design and cost estimate
- (3) Complete aquifer application survey in TVA region
- (4) Complete value analysis for Twin Cities District Heating system
- (5) Complete national aquifer application survey
- (6) Complete sensitivity study of aquifer storage systems
- (7) Complete heat storage cycle (Auburn)
- (8) Complete cold storage cycle (Texas A&M)
- (9) Initiate geochemistry research program
- (10) Construct and operate aquifer system model
- (11) Develop and test cold capture systems
- (12) Complete generic environmental impact analysis of aquifer storage
- (13) Complete environmental impact analysis of first prototype doublet well (Bellingham)
- (14) Complete prototype well doublet construction
- (15) Complete first cycle of prototype system
- (16) Establish liaison with the International Energy Agency pond storage program
- (17) Issue request for proposal (RFP) for new earth storage work

high initial cost, and the inherent thermodynamic inefficiency associated with sensible heat storage.

The LTTES Program focuses primarily on identification, development, and demonstration of cost-effective systems that can store low-temperature thermal energy as latent heat. Applications will be for individual building space conditioning, with the transformation temperatures for systems of interest in the range of 5°C to 250°C. Both modular systems and systems involving incorporation of the phase-change materials in building structures will be developed. The emphasis in each case will be on developing reliable, safe, commercially available systems that are cost-effective in terms of the value of the stored energy and that are capable of national application.

The approach to be followed in achieving this goal is to explore alternate system concepts for each application and to select from these the one or more that appear on the basis of available information to have significant economic and conservation potential. New concepts will be identified by maintaining current awareness of technical developments and needs, issuing RFPs aimed at specific applications, and, in some cases, accepting unsolicited proposals. Concepts selected for development will be periodically reevaluated to insure continuing promise compared with alternate systems.

The summary schedule for daily/short-term storage, given in Table 3.2, reflects the continuing, parallel, system-oriented approach. Work elements currently funded or planned for funding are indicated.

3.2.3 Waste energy reuse

Energy conservation through the recovery, storage, and later reuse of large quantities of low-temperature heat for district heating applications is the third thrust of the LTTES Program. This thrust differs from the first two in that its emphasis is not on the development of new thermal storage technology but on the demonstration of thermal storage (using new or conventional storage technology) to improve energy conservation. The approach is to uncover instances where the application of thermal energy storage will allow the economic recovery and use of the waste heat. As examples are found, suitable demonstration projects will

Table 3.2. Daily and short term storage

Storage system/element	Fiscal year				
	1979	1980	1981	1982	1983
<u>Modular PCM systems</u>					
Heating systems	1	2	3		4
Cooling systems (hotside storage)	5	6	7		
Cooling systems (coldside storage)		8	9		
<u>Building material PCM systems</u>					
Concrete based systems		10			
Ceramic based systems		10			
Other materials			11		
Techno-economics			12		

Milestones:

- (1) Complete performance test of pilot-scale immiscible fluid system
- (2) Complete design of prototype rotating drum system
- (3) Complete performance test of prototype immiscible fluid system
- (4) Complete performance test of rotating drum system
- (5) Decision on further look for new PCMs
- (6) Complete development of form-stable polyethylene based on E-beam crosslinking
- (7) Complete performance test of form-stable polyethylene
- (8) Complete materials development of Glauber's salt chub system
- (9) Complete performance test of Glauber's salt chub system
- (10) Issue RFP for concrete and ceramic PCM building materials systems
- (11) Issue RFP for novel building materials systems incorporating PCMs
- (12) Prepare a value analysis of daily and short-term storage

be developed and installed to test feasibility and to publicize both that specific application and applications similar to the one demonstrated.

The sources of energy include industrial waste heat, cogenerated heat from electric utilities, and winter cold (captured in water by heat exchange with the environment). Applications include reuse as process heat, and use in district heating or cooling systems. Projects that utilize new thermal storage technologies being developed in the other thrusts of this program will be coordinated to insure timely development and demonstration.

The summary schedule for waste energy recovery and reuse projects is given in Table 3.3.

Table 3.3. Waste energy reuse

Source/application	Fiscal year				
	1979	1980	1981	1982	1983
Industrial waste heat/space conditioning

Milestones:

- (1) Complete engineering and institutional analysis of the Bellingham project

4. PROGRAM TECHNICAL ELEMENTS

4.1 Introduction

This chapter describes the FY 1979 LTTE Program in terms of the specific projects comprising it. Included are those projects that were active in FY 1978 and continue into FY 1979, those currently planned to begin in FY 1979, and those planned if additional 1979 funds are made available. The projects are organized into the three thrust areas.

The selection of projects to be funded in FY 1979 reflects both the expected funding level during FY 1979 and the guidance provided the program by DOE for future priorities and funding. Specifically, the division of FY 1979 dollars among the thrust areas reflects DOE information that the aquifer storage thrust will receive a major funding increase in the period FY 1980-1983. To accommodate that escalation within the existing FY 1979 funding level, it was necessary to postpone or reduce in scope projects not directly related to aquifer technology prototype demonstration.

4.2 Seasonal Storage

Seasonal storage involves projects in both aquifer storage and pond storage. Emphasis will be on aquifer storage projects for FY 1979, with the effort in pond storage limited to maintaining awareness of work ongoing in Europe.

Aquifer storage projects currently planned for funding in FY 1979 cover five of the program elements described in Chapter III: technoeconomic studies, experimental field tests, mathematical modeling, environmental and institutional analyses, and prototype aquifer projects.

Title: Experimental Study of the Storage of Thermal Energy in Confined Aquifers

Contractor: Auburn University, Water Resources Research Institute

Principal Investigator: F. J. Molz, J. C. Warman

Contract Amount: \$387,000

Contract Term: July 1, 1977 through October 31, 1979

Objective: Determine the technical feasibility for storing warm water in a confined aquifer for extended periods. Obtain thermal, hydraulic, and structural performance data for verifying existing analytical descriptions of aquifer behavior.

Project Description: In a series of cycles, warm water will be injected into a confined aquifer, stored for some time, and then withdrawn. Appropriate instrumentation in observation wells disposed around the injection well will provide data on water temperature and water level throughout the cycle. Injection water will be taken from an overlying aquifer and heated in a portable boiler to the desired injection temperature of 120°F; the withdrawn water will be discarded. Surface subsidence and rebound will be measured. The experiment will determine recovery thermal efficiency and identify physical or chemical problems.

Prior Accomplishments: During FY 1978 one cycle was carried out in which approximately 14.5 million gallons of 120°F water were charged into the aquifer over a 79-day period, stored for 51 days, and withdrawn successfully over a 41-day period. Initial analysis has indicated Btu recovery of 65% (minimum discharge temperature of 92°F). Equipment was also installed during FY 1978 to monitor subsidence effects during future cycles.

FY 1979 Program: A second and third cycle will be carried out to essentially repeat the conditions of the first successful cycle. Measurements will include surface subsidence and rebound as well as temperature profiles and thermal recovery efficiencies. The results of all three cycles will be analyzed and compared with theoretical estimates.

Beyond FY 1979: Future work will depend on results of the FY 1979 program. Experiments related to well plugging and unplugging may be undertaken.

Schedule:

Auburn University	Fiscal year (thousands of dollars)		
	1978	1979	1980
1st storage cycle
2nd storage cycle
3rd storage cycle
Well plugging
Funding	217	150	100

Title: Storage of Cold Water in Groundwater Aquifers for Cooling

Purposes

Contractor: Texas A&M University

Principal Investigator: D. L. Reddell

Contract Amount: \$360,450

Contract Term: September 1, 1977 through September 30, 1981

Objective: Determine the technical feasibility of capturing winter-chill water by means of a spray pond and of storing the cold water in an unconfined aquifer. Obtain thermal-hydraulic and subsidence data for verifying analytic descriptions of aquifer behavior.

Project Description: A doublet well pair will be drilled into an unconfined aquifer, and monitoring wells will be drilled and instrumented in the region surrounding the doublet. The wells will be connected to a spray pond built for the experiment. During the winter, aquifer water will be pumped to the pond, cooled by spraying into the ambient air, and pumped back into the aquifer. After storage for several months, the cool water will be withdrawn and the thermal efficiency of storage calculated. If successful, a second cycle, either a cold water or hot water storage experiment, will be carried out. During the first cycle, the effects of aquifer hydraulic gradient, the performance of the spray pond, subsidence effects, and the effect of pumping spray-aerated water back into the aquifer will be determined.

Prior Accomplishments: The well doublet pair and observation wells were drilled, and initial pumping tests were completed in FY 1978. The cooling pond was built and connected to the wells.

FY 1979 Program: The first cycle of capture, storage, and withdrawal of cold water will be carried out during the winter of 1978-1979. The results will be compared with analytical descriptions of aquifer performance. The system will be modified as necessary for subsequent cycles.

Beyond FY 1979: Depending on the results obtained in FY 1979, a second cold water cycle will be carried out during the winter of 1979-1980. Alternately, modifications in the system may be made to convert to a hot water storage experiment, if it appears to be suitable.

Schedule:

Texas A&M University	Fiscal year (thousands of dollars)		
	1978	1979	1980
System construction
1st storage cycle
2nd storage cycle
Funding	80	90	115

Title: Mathematical Modeling of TES in Aquifers

Contractor: Lawrence Berkeley Laboratory

Principal Investigator: C. F. Tsang

Contract Amount: \$210,000 (\$60,000 in FY 1979)

Contract Term: Fiscal Year

Objective: Apply computer model to predict the behavior (thermal-hydraulic) of aquifers storing hot and cold waters; develop injection/withdrawal strategies; determine preferred locations of wells for field tests and prototype demonstrations.

Project Description: LBL will modify the convection-conduction-compaction (CCC) computer model (developed in support of geothermal studies) to study heat and mass flow in a 3-D aquifer used for thermal storage and to estimate the vertical deformation (subsidence/elevation) associated with the water injection and withdrawal. Sensitivity studies will estimate recovery efficiencies and subsidence rates as a function of aquifer characteristics, well characteristics, and operating modes. The model results will also be compared to data obtained from field tests and will be used to predict the performance of future field tests and prototype demonstrations.

Prior Accomplishments: Calculations have been performed which parametrically analyzed the effect on recovery efficiency of such parameters as well penetration, storage temperature, clay lenses, inhomogeneities, regional flow, compaction, and multiple wells. LBL also contributed to the aquifer program by hosting a workshop on aquifer storage organized as a part of the LTTEs Program and by beginning a bimonthly newsletter.

FY 1979 Program: A simulation study will be made of the current field experiments performed by Auburn University. This will validate the numerical model, increase the understanding of the heat and mass flow associated with hot storage, and focus on problems and precautions in future field tests. In addition, modeling of other typical situations will be carried out including calculation of daily cycle storage. This will involve estimating the effect of heat loss along the well bore. LBL will also continue responsibility of publishing a bimonthly aquifer thermal energy storage newsletter.

Beyond FY 1979: Continued modeling efforts will depend on results obtained this year.

Schedule:

Lawrence Berkeley Laboratory	Fiscal year (thousands of dollars)		
	1978	1979	1980
Analytical modeling
Analysis of aquifer tests
Analysis of short-term storage
Funding	120	60	100

Title: Test-well Drilling Project for Preliminary Definition of
Aquifer Parameters at JFK Airport

Contractor: New York State Energy Research and Development Authority
(NYSERDA)

Principal Investigator: M. E. Singer

Contract Amount: \$65,000

Contract Term: August 15, 1978 through January 15, 1979

Objective: Determine the thicknesses, lateral extent, depths, hydraulic characteristics of the aquifers underlying the J. F. Kennedy Airport, Long Island, New York.

Project Description: The stratigraphy and preliminary hydrology of the Jameco aquifer under the J. F. Kennedy Airport will be investigated by drilling, sampling, logging, and casing four small-diameter boreholes of about 500-ft length. The work provides information needed for the engineering analysis of the Kennedy Aquifer Thermal Storage Prototype. This project is being cofunded by NYSERDA.

Prior Accomplishments: New effort in FY 1978; no significant results.

FY 1979 Program: The program as described will be completed by the middle of FY 1979.

Beyond FY 1979: Additional test wells will be drilled if required to characterize other sites in the same aquifer.

Schedule:

NYSERDA	Fiscal year (thousands of dollars)		
	1978	1979	1980
JFK aquifer characterization			
Funding	65	0	0

Title: Cyclical Storage and Withdrawal of Chilled Water in Aquifers

Beneath JFK International Airport, New York, NY

Contractor: U.S. Geological Survey, Syosset, New York

Principal Investigator: J. H. Kantrowitz

Contract Amount: \$45,000

Contract Term: Fiscal Year

Objective: Provide consultation and review services to the LTES Program Manager relative to the geological and hydrological characteristics of the Long Island, New York, region.

Project Description: USGS will interpret the geological and hydrological features of the Long Island, New York, area aquifer structures and will provide the LTES Program Manager with critical comment on the hydrology aspects of the Kennedy Aquifer Thermal Storage Prototype. USGS will monitor test drillings to assure proper execution and will perform the interpretative evaluation of the data obtained.

Prior Accomplishments: Effort initiated in late FY 1978.

FY 1979 Program: Assist in the acquisition, analysis, and interpretation of data obtained as part of the test-well drilling project. Assist in a review of alternate sites as requested.

Beyond FY 1979: Provide continued support as requested by LTES Program.

Schedule:

USGS — Syosset	Fiscal year (thousands of dollars)		
	1978	1979	1980
Consulting services	-----		
Aquifer characterization	-----		
Funding	25	20	0

Title: Subsurface Heat Storage Project

Contractor: U.S. Geological Survey

Principal Investigator: C. Collier

Contract Amount: \$37,000

Contract Term: Fiscal Year

Objective: Provide consultation and review services to the LTTEs Program relative to the geological and hydrological characteristics of the Bellingham, Washington, region.

Project Description: USGS will interpret geological and hydrological features of the Bellingham, Washington, area aquifer structures and provide critical comment on the aquifer storage aspect of the proposed Bellingham district heating system. USGS will also monitor any test drillings to assure proper execution and will carry out the interpretative evaluations of the data obtained.

Prior Accomplishments: Effort to be initiated in FY 1979.

FY 1979 Program: Provide assistance to LTTEs Program Manager in evaluating potential sites for the Bellingham Aquifer Thermal Storage Project. Assist in interpretation of initial test well results.

Beyond FY 1979: Provide assistance as requested throughout the lifetime of the Bellingham Aquifer Thermal Storage Project.

Schedule:

USGS — Tacoma	Fiscal year (thousands of dollars)		
	1978	1979	1980
Consulting services		-----	
Aquifer characterization		-----	
Funding		10	27

Title: Evaluation of Thermal Energy Storage for the Proposed Twin
Cities District Heating System

Contractor: General Electric Company-Center for Advanced Studies
(TEMPO)

Principal Investigator: C. F. Meyer

Contract Amount: \$131,000

Contract Period: August 1978 through September 1979

Objective: Determine the value of seasonal aquifer thermal energy storage in the proposed Minneapolis-St. Paul district heating system.

Project Description: The U.S. Department of Energy, Minnesota Energy Agency, Northern States Power Company, and other organizations are cooperatively performing an in-depth study to determine the feasibility of district heating in the Minneapolis-St. Paul area using cogenerated hot water from power plants. GE-TEMPO will examine the value of incorporating seasonal storage of hot water to this concept. Specifically, a comparison will be made between a mature district heating system based on no seasonal storage and one based on seasonal storage. The storage elements will be considered as "black boxes," and the value of the black box at breakeven will be calculated.

Prior Accomplishments: New project in FY 1978.

FY 1979 Program: This contract will be completed as described in FY 1979. Recommendations for future work will be developed as appropriate.

Beyond FY 1979: Further activity will depend on results of this value analysis.

Schedule:

GE — TEMPO	Fiscal year (thousands of dollars)		
	1978	1979	1980
Storage value study			
Funding	16	115	0

Title: Application of Low Temperature Thermal Energy Storage in the TVA Region

Contractor: Tennessee Valley Authority (Knoxville)

Principal Investigator: A. Manaker

Contract Amount: \$90,000

Contract Term: Fiscal Year

Objective: Assess the potential for aquifer seasonal thermal energy storage systems in the TVA region.

Project Description: This project will develop the general criteria for suitability of aquifers for thermal energy storage, including an analysis of the parameters of importance (storativity, permeability, depth, thickness, water composition, etc.). The criteria will be applied to the known aquifers in the TVA area. These aquifers will be examined as to suitability for future thermal energy storage demonstrations.

Prior Accomplishments: New program

FY 1979 Program: This project will be completed in FY 1979.

Beyond FY 1979: If a suitable site is found, a feasibility study for a demonstration aquifer storage system at that site may be carried out.

Schedule:

Tennessee Valley Authority	Fiscal year (thousands of dollars)		
	1978	1979	1980
Aquifer criteria		—	
Application analysis		—	
Funding	0	90	

Title: Aquifer Thermal Energy Storage Applications Analysis

Contractor: RFP

Principal Investigator:

Contract Amount: \$200,000 (estimated)

Contract Term: 6 months

FY 1979 Funding: 0

Objective: Assess the range of opportunities for applying aquifer seasonal thermal energy storage systems in the United States.

Project Description: The project will identify, characterize, and rank sites in the United States where there are:

- large sources of thermal energy suitable for seasonal storage, including industrial waste heat, utility cogenerated heat, winter chill, and solar heat
- potential applications of stored thermal energy, including district heating and cooling systems, agricultural heat, and industrial process heat
- suitable aquifers in the immediate vicinity of the heat source and/or application system

Prior Accomplishments: New program

FY 1979 Program: No funding is planned for FY 1979

Beyond FY 1979: Program will be funded in FY 1980

Schedule:

RFP	Fical year (thousands of dollars)		
	1978	1979	1980
Applications analysis			—
Funding		0	200

Title: Mathematical Modeling of Geochemistry of Aquifer TES

Contractor: Pacific Northwest Laboratory

Principal Investigator: J. Stottlemire

Contract Amount: \$10,000

Contract Term: Fiscal Year

Objective: Determine the applicability of an existing computer model for use in predicting the effects of temperature on chemical equilibria between the aqueous and solid phases in natural aquifers

Project Description: In this brief scouting experiment, an existing chemical equilibrium computer program, developed as part of a geothermal energy project, will be utilized to predict the effect of temperature on the equilibrium concentrations of dissolved species in natural underground waters. Samples of cores from experimental aquifer storage wells along with aquifer water samples will be used to define the baseline conditions from which the effect of temperature will be obtained. The results will be used to determine the applicability of the computer program to predicting geochemical behavior in aquifer thermal energy storage systems.

Prior Accomplishments: New program

FY 1979 Program: The program as described will be completed in FY 1979.

Beyond FY 1979: Continuing work will depend on results obtained this year.

Schedule:

Battelle Pacific Northwest Laboratories	Fiscal year (thousands of dollars)		
	1978	1979	1980
Computer simulation			
Funding		10	60

Title: Aquifer Thermal Energy Storage Generic Environmental Impact
Assessment

Contractor: Oak Ridge National Laboratory — Energy Division

Principal Investigator: E. K. Triegel, W. Stockdale

Contract Amount: \$75,000

Contract Term: Fiscal Year

Objective: Prepare an Environmental Impact Assessment (EIA) of the use of aquifers for seasonal storage of hot or cold.

Project Description: Aquifer thermal energy storage systems may find widespread application in the United States as a means of conserving energy by utilizing otherwise wasted thermal energy. This study will examine the environmental impacts of the use of such systems in accordance with Federal law. This will include a description of the proposed system, description of the affected environment, an assessment of the potential impacts, a determination of institutional problems, and a list of reasonable alternatives to the proposed actions.

Prior Accomplishments: New Program

FY 1979 Program: Complete a draft EIA.

Beyond FY 1979: No work planned at this time.

Schedule:

ORNL — Energy Division	Fiscal year (thousands of dollars)		
	1978	1979	1980
Generic EIA			
Funding	0	75	0

Title: Kennedy Aquifer Thermal Storage Demonstration Engineering
Analysis

Contractor: Oak Ridge National Laboratory — Engineering Technology
Division

Principal Investigator: E. C. Fox

Contract Amount: \$75,000

Contract Term: Fiscal Year

Objective: Carry out an engineering and cost analysis of the proposed Kennedy Aquifer Thermal Storage Demonstration, to provide information for a decision to proceed with engineering design.

Project Description: The engineering analysis will revise work carried out under an earlier program "Aquifer Storage of Winter Cold for Summer Air Conditioning" to take into account the results of the project "Test Well Drilling Project for Preliminary Definition of Aquifer Parameters at JFK Airport." In addition, the analysis will review methods for capturing winter cold and will determine the effect of adding heat exchangers between the well and the air-conditioning system. System costs and a cost sensitivity analysis will be developed.

Prior Accomplishments: New program

Fiscal 1979 Program: Program will be completed.

Beyond FY 1979: The direction of any further effort with the Kennedy Airport Aquifer Thermal Storage Prototype will depend on the results of this analysis plus the policy decisions and expected level of cooperation of the Port Authority of New York and New Jersey and NYSERDA. Alternate sites utilizing the same aquifer for different purposes will be investigated with NYSERDA if this project is unable to proceed.

Schedule:

ORNL — Engineering Technology Division	Fiscal year (thousands of dollars)		
	1978	1979	1980
Engineering analysis of aquifer storage at JFK			
Funding	0	75	

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4.3 Diurnal and Short-Term Storage Projects

Projects described in this section include those funded by DOE/ Conservation and Solar Applications (DOE/CS) but managed by the LTTEs Program, as well as projects funded by DOE/STOR.

A total of seven projects, embracing three different approaches to improved heat transfer at low cost, are planned in the area of modular storage.

No projects are planned this year in the area of building materials. It is expected that an RFP will be issued to develop new concepts, and two proposals (one each for ceramic and cement-based materials) will be selected for funding in FY 1980.

Two projects dealing with the behavior of PCMs under thermal transient conditions are to be funded — one developing the mathematics and one obtaining data in well-defined geometries.

Title: Development and Scale-up of TES in Crosslinked Polymer Pellets
for Absorption Air-Conditioning Applications

Contractor: University of Dayton

Principal Investigator: Ival Salyer

Contract Amount: \$54,585

Contract Term: (One Year)

Objective: Develop a method for electron-beam crosslinking polyethylene to produce a form-stable PCM.

Project Description: Form-stable polyethylene, a partially crosslinked polyethylene PCM, which in the melt form is an elastic rather than a viscous material, has been developed and tested for use in modular PCM thermal energy systems. The method of manufacture has involved chemical crosslinking, which itself adds significantly to the product cost. This project aims at demonstrating that an equivalent form-stable polyethylene PCM can be produced by electron-beam crosslinking at a much lower cost.

Prior Accomplishments: The original development of form-stable polyethylene was carried out by the same principal investigator while employed by Monsanto Research Corporation.

FY 1979 Program: During FY 1979, only Task I, which defines the optimum electron beam irradiation conditions, will be carried out.

Beyond FY 1979: If the above work is successful, Task II, preparation of a 250-lb batch of the material and testing in a small test unit, will be carried out.

Schedule:

University of Dayton	Fiscal year (thousands of dollars)		
	1978	1979	1980
Define the optimum electron beam irradiation conditions		┌───┐	
Preparation 250-lb batch and test performance			┌───┐
Funding	0	25	30

Title: Immiscible Fluid — Heat of Fusion Heat Storage System

Contractor: Clemson University

Principal Investigator: D. D. Edie

Contract Amount: \$139,000

Contract Term: June 1, 1976 through November 30, 1978

Objective: Evaluate the feasibility of a direct contact heat exchanger to overcome problems of heat transfer lag and phase separation in a PCM storage system. The work is divided into four major areas: (1) selection of salt solutions, (2) selection of immiscible fluids, (3) crystal growth velocity study on selected salts, and (4) studies of heat transfer and system geometry.

Prior Accomplishments: Four salts were found to be acceptable for use as storage materials: di-sodium hydrogen phosphate ($T_t = 34\text{ C}$), calcium chloride (27 C), sodium sulfate (32 C), and sodium thiosulfate (47 C). A list of 12 satisfactory immiscible fluids were also selected for further testings; these fluids cost in the range of \$0.50/gal (butyl oleate) to \$5.30 (silicone oil).

Tests were carried out to measure crystal growth velocity as a function of undercooling in order to provide data useful in modeling the performance of PCM systems.

A modular storage tank has been constructed to study heat transfer and system geometry effects. The effects of diffuser geometry, column height, and choice of PCM were studied.

FY 1979 Program: The heat transfer and system geometry effects study will be completed. A 55-gal prototype will be operated by cycling over a prolonged period to yield long-term performance data using a selected PCM-immiscible fluid system.

Beyond FY 1979: Further work is not currently planned until the final report is reviewed. If justified, a cost analysis of a full-scale system for one or more applications will be carried out.

Schedule:

Clemson University	Fiscal year (thousands of years)		
	1978	1979	1980
Materials selector	┌────────┐		
Crystal growth studies	┌────────┐		
Heat transfer and geometry		┌────────┐	┌────────┐
Funding	40	0	

Title: Life and Stability Testing of Packaged Low Cost Energy Storage Materials

Contractor: University of Delaware — Institute of Energy Conversion (IEC)

Principal Investigator: G. R. Frysinger

Contract Amount: \$146,255

Contract Term: September 1, 1978 through September 30, 1979

Objective: Demonstrate that the PCM chub packaging concept has the reliability, life expectancy, and physical and chemical stability to satisfy the requirements of the marketplace.

Project Description: IEC, working with duPont, has developed a film packaging concept for use with Glauber's salt clay gel that is claimed to be technically and economically competitive for use as a modular cool storage unit. This study will subject the proposed cylindrical film packaged TES units (chubs) to freeze/melt cycling to verify film physical integrity and moisture permeability and obtain data on life and stability of the Glauber's salt-clay gel. Cycles will consist of 10-hr freezing followed by 14-hr thawing over 100 cycles (equals approximately 100 days of a cooling season); accelerated cycles will consist of 4- to 6-hr freeze-thaw periods over about one year. Chub failures encountered during the life and stability testing program will be analyzed; the exposed packaging film will be examined at the test conclusion to detect incipient failures.

Prior Accomplishments: Previous work involved development of the Glauber's salt-clay gel to overcome phase separation problems and identification of appropriate containment materials and configurations.

FY 1979 Program: Assemble chubs using the most promising films, carry out preliminary package integrity tests and perform multiple-freeze thaw cycle tests at 55°F.

Beyond FY 1979: If successful, this work will result in installation of TES systems in demonstration buildings.

Schedule

	Fiscal year (thousands of dollars)		
	1978	1979	1980
Materials qualification		┌───┐	
Packaging integrity		┌───┐	
Thermal cycling tests		┌───┐	
Funding	11	135	

Title: Development of Intermediate Temperature TES Units Using Phase-Change Materials

Contractor: University of Delaware — Mechanical Engineering Department

Principal Investigator: J. R. Moszynski

*Contract Amount: \$286,500

Contract Term: April 1978 through March 1981

Objective: Develop phase-change TES systems in the temperature range appropriate to utilizing solar energy for absorption air conditioning.

Project Description: This project will identify and evaluate PCMs melting in the temperature range of 90°F to 180°F and containment materials compatible with these PCMs. Physical properties are to be determined as necessary to the design and performance testing of a system model. A full-scale system will be designed on the basis of this information and judged as to economic viability.

Prior Accomplishments: The principal candidate PCM, ferrous sulfate, was tested initially. It was found to undergo irreversible chemical reaction during freeze/thaw cycling, losing phase-change capability. Alternate PCMs are being investigated. The result of a short study of storage of vapor was that it was not considered economical.

*Funding from DOE/CS.

FY 1979 Program: The search for new PCM candidates will continue. The program will be evaluated during FY 1979 to determine whether continued funding is justified.

Beyond FY 1979: Program will continue as determined in FY 1979.

Schedule:

University of Delaware -- Mechanical Engineering Department	Fiscal year (thousands of dollars)		
	1978	1979	1980
PCMs selection	-----		
Funding	70	90	

Title: Thermal Energy Storage Subsystems for Solar Heating and Cooling Applications

Contractor: General Electric Company — Corporate Research and Development

Principal Investigator: Roy Thornton

*Contract Amount: \$345,938

Contract Term: July 31, 1978 through July 31, 1980

Objective: Develop the rotating drum concept for utilizing hydrated salts as thermal energy storage media.

Project Description: The rotating drum system is proposed as a means for avoiding solids buildup on heat exchange surface, phase separation, and supercooling in modular TES units using PCMs. This is accomplished by containing the PCM in a horizontal cylinder that is slowly rotated. The flow pattern thus created in the fluid provides sufficient mixing to prevent phase separation and promote heat transfer.

Prior Accomplishments: GE has carried out exploratory bench-scale experiments that have shown:

- continued full recovery of latent heat of phase change for Glauber's salt ($\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$) after 200 melt/freeze cycles,
- reliable nucleation using a proprietary nucleation device, and
- no solids buildup on the heat transfer surface.

*Funding from DOE/CS.

FY 1979 Program: The program will undertake laboratory studies and analyses aimed at understanding the behavior of the proposed rotating drum PCM storage system, including internal and external thermal analyses, thermal testing, corrosion evaluation, and model synthesis. Based on these results, a preliminary conceptual design of a prototype system will be prepared.

Beyond FY 1979: The prototype rotating drum will be built and preliminary testing carried out using water or other test material. Follow-on work will include operations with PCM.

Schedule:

General Electric Company, Schenectady	Fiscal year (thousands of dollars)		
	1978	1979	1980
Thermal analysis and testing		┌──────────┐	
Corrosion evaluation		┌───┐	
Model synthesis		┌───┐	
Design prototype and test equipment		┌──────────┐	
Construct prototype			┌──────────┐
Funding	0	150	196

Title: Thermal Transport in PCM Systems: Mathematical Modeling

Contractor: Oak Ridge National Laboratory — Computer Sciences

Division

Principal Investigator: A. D. Solomon

Contract Amount: \$75,000

Contract Term: Fiscal Year

Objective: Develop mathematical models of the thermal transport behavior of PCMs during freeze-melt cycling.

Project Description: A computer model of the moving boundary problem incorporating latent heat has been adapted for use in exploring the behavior of PCMs during freeze-melt cycling. The model will be applied to different geometries, different combinations of PCMs and container materials, and different boundary conditions and operating procedures. Results will be useful in predicting performance, in designing optimum geometry systems, and in diagnosing and correlating performance test results.

Prior Accomplishments: The computer model has been developed based on one-dimensional conduction heat transfer, and solutions have been obtained for several geometries and different boundary conditions.

FY 1979 Program: The program will be modified to include one-dimensional natural convection along with thermal conduction and solutions obtained for differing geometries, PCM, and boundary conditions. The effect of conduction enhancement techniques within the PCM will be studied. A report describing the model will be prepared. Close-form approximations for a variety of the systems studies will be developed for use in validating the models and for application in the field.

Beyond FY 1979: The program will continue as new problems are defined.

Schedule:

ORNL — Computer Sciences	Fiscal year (thousands of dollars)		
	1978	1979	1980
Computer modeling of PCM behavior	-----		
Funding	50	25	

Title: Thermal Transport in PCM Systems: Physical Modeling

Contractor: Oak Ridge National Laboratory — Engineering Technology
Division

Principal Investigator: R. M. Deal

Contract Amount: \$30,000

Contract Term: Fiscal Year

Objective: Study experimentally the thermal transport behavior in PCMs actively storing and releasing heat.

Program Description: PCMs used either in modular units or building materials are both heat sinks (and sources) and heat transfer media. The storage capacity of such systems is limited by the complex interrelationships between the rates of phase change, heat conduction, and convection within the PCM. This program will study the performance of sample PCM systems undergoing phase change by heat addition or removal in terms of their thermal transport properties. The systems to be studied will utilize a small loop circulating heated or cooled water past the walls of the cells containing the PCM. Photographic and temperature measurements of the phase change front will be obtained under a variety of operating conditions. The results will be analyzed and compared with those obtained from mathematical models.

Prior Accomplishments: In FY 1978, the experiment was designed and most of the equipment assembled.

FY 1979 Program: The system will be completed and tested. Experiments on thermal conduction will be carried out and the results analyzed. Experiments involving natural convection will be initiated.

Beyond FY 1979: Experiments will be continued in the area of combined natural convection and conduction. Other experiments such as those involving conduction enhancement will be carried out.

Schedule:

Oak Ridge National Laboratory - Engineering Technology Division	Fiscal year (thousands of dollars)		
	1978	1979	1980
System construction
Thermal conduction experiment
Conduction/convection experiments
Funding	30		

Title: Thermal Energy Storage Thermal Cycle Facility
Contractor: Oak Ridge National Laboratory — Engineering Technology
Division
Principal Investigator: R. J. Kedl
Contract Amount: \$25,000
Contract Term: Fiscal Year

Project Description: PCM and other thermal energy storage modular systems must perform effectively over a wide range of external operating conditions, including both the total quantity of energy stored or removed and the rates of addition or removal. As new systems are developed to the prototype stage, it is important that their performances be measured in a consistent, reproducible manner so that effective cross comparisons are possible.

A versatile thermal cycle facility will be constructed at ORNL to test prototype TES systems under the wide range of operating conditions simulating actual performance requirements. Two separate loops will be built, sharing common controls and heat sources and sinks. The thermal transport fluid in one loop will be liquid, and the other will utilize air. The loop will be capable of testing systems with storage capacities in the range 50,000 to 500,000 Btu.

Prior Accomplishments: The design of the liquid loop has been initiated.

FY 1979 Program: The design of the liquid loop will be completed and the loop fabricated. Design of the air loop will be completed and construction initiated.

Beyond FY 1979: Tests involving TES systems will be carried out as required.

Schedule:

Oak Ridge National Laboratory — Engineering Technology Division	Fiscal year (thousands of dollars)		
	1978	1979	1980
Liquid loop		-----	
Air loop		-----	
Funding		25	100

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4.4 Waste Heat Reuse Demonstration Projects

One project is currently planned for funding during FY 1979: the Bellingham Industrial Waste Heat Reuse Demonstration. This project involves the recovery of industrial waste heat for district heating use, with storage of hot water either for the short term, utilizing steel tanks, or seasonal, utilizing aquifers. The work in FY 1979 will focus on the technical and institutional issues associated with that project.

Title: Bellingham Industrial Waste Heat Reuse Demonstration —
Techno-economic Analysis

Contractor: Rocket Research Company

Principal Investigator: D. D. Huxtable

Contract Amount: \$1,000,000

Contract Term: 1 1/2 years

Objective: Prepare an in-depth analysis of the major technical economic and institutional issues associated with implementing a proposed industrial waste heat/thermal storage/district heating system at Bellingham, Washington.

Project Description: A district heating system has been proposed for Bellingham, Washington, based on utilizing waste heat generated by the Intalco Aluminum Company smelter in nearby Ferndale and other available low-temperature waste heat sources. The system may utilize thermal storage either on a seasonal or a short-term basis.

This study will provide an in-depth analysis of critical issues which must be addressed prior to a decision to proceed with a complete system design. These include a market survey to determine the size and nature of the district heating system customer network; a technology review to insure availability of system components and to identify areas of needed R&D; a review of potential energy sources, including characterization and availability; an analysis of institutional issues, including funding options and regulatory requirements; and a system cost analysis to provide a firm basis for obtaining cost information, to identify cost impacts of technological risk areas, and to identify critical components.

Prior Accomplishments: This work supplements the feasibility study carried out by Rocket Research Company under an earlier contract. In that study, the national conservation potential for waste heat recovery from aluminum smelters was calculated, and the broad design features for the Bellingham district heating system were described.

FY 1979 Program: During FY 1979 the market survey will be completed. In addition, work will be in progress with regard to the technology review, additional energy sources, and institutional issues.

Beyond FY 1979: All work will be completed on this project in FY 1980. A decision as to whether to proceed with the design and subsequent construction of the Bellingham district heating system will be made late in FY 1980.

Schedule:

Rocket Research Company	Fiscal year (thousands of dollars)		
	1978	1979	1980
Market analysis		┌───┐	
Technology review		┌─┐	┌───┐
Additional sources		┌─┐	┌─┐
Institutional considerations		┌───┐	
Design analysis			┌───┐
Funding		300	700

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5. BUDGETS

The fiscal resource requirements by thrust area are summarized in Table 5.1.

Table 5.1. LTTES Program FY 1979 budget summary

	FY 1979 budget (thousands of dollars)
<u>Seasonal storage</u>	
Aquifer heated water field test (Auburn University)	150
Aquifer chilled water field test (Texas A&M)	90
Evaluation of aquifer TES in Twin Cities (GE-TEMPO)	130
Analytical modeling (LBL)	60
Kennedy feasibility study	
Exploratory well tests support (USGS-Syosset)	20
Technical and economic analysis (ORNL/ETD)	75
Bellingham prototype doublet	
Experimental program/exploratory well (FUGRO)	200
Exploratory well test support (USGS-Tacoma)	10
Aquifer characterization (TVA)	90
Aquifer geochemistry analysis (BPNL)	10
<u>Daily/short-term storage</u>	
Encapsulation of PCM in concrete (BNL)	30
Form-stable polyethylene development (Univ. of Dayton)	25
Chub storage packaging and stability (Univ. of Del.-IEA)	135
Analyses of heat pump storage options (RTI)	60
Mathematical modeling of PCM dynamic behavior (ORNL-CSD)	25
Physical modeling of PCM dynamic behavior (ORNL-ETD)	30
Thermal Energy Storage Thermal Cycle Facility (ORNL-ETD)	25
<u>Industrial waste heat reuse</u>	
Aluminum plant/district heating	300
<u>Management</u>	
Staff	300
Meetings	60
Reserve	90

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6. MANAGEMENT PLAN

6.1 Introduction

Responsibility for the LTTES program is delegated to the Oak Ridge National Laboratory (ORNL) by the Department of Energy-Division of Energy Storage Systems (DOE/STOR). Under the general coordination of the DOE/STOR Test Program Manager, the LTTES Program manager at ORNL has the authority to execute, manage, and plan all LTTES activities subject to the restrictions that: (1) approval is required for Program Plans, (2) approval is required for Annual Operating Plans, and (3) concurrence is required for in-house and subcontract procurements. The LTTES Program Manager will develop and implement plans, review and evaluate technical efforts, monitor and control costs, schedules, and other resources, disseminate to the technical and general public results of investigations, and report to both ORNL and DOE/STOR managers all matters of programmatic significance (technical and administrative). In carrying out program functions, the LTTES Program Manager will report through the Head of the Heat Transfer-Fluid Dynamics Section and the Director of the Engineering Technology Division to the Associate Laboratory Director for Nuclear and Engineering Technologies. Close coordination is maintained with the Associate Laboratory Director for Advanced Energy Systems, who has been assigned ORNL responsibility for all energy conservation programs. Reporting to the LTTES Program Manager are staff responsible for implementing and controlling technical efforts in the several principal thrust areas. Procurement actions will be supported by the Union Carbide Corporation-Nuclear Division (UCC-ND) Contracts Office, with review and concurrence by the DOE-Oak Ridge Operations Office (ORO).

6.2 Subcontractor Procurements

All contractual arrangements will be made in accord with existing UCC-ND policy, regulations, and procedures, except where specific statutory requirements of DOE prevail.

Negotiated procurements will be conducted under competitive procedures to the extent practicable. Noncompetitive procurements will require formal and complete justification for selection. The ORNL/UCC-ND procurement system provides definite guidelines for contract preparation, the extent and clarity of request-for-proposal (RFP) instructions, and source evaluation and selection processes.

The LTTES Program Manager will be responsible for initiating all procurements, assuring appropriate procedures are followed, and obtaining necessary concurrences from the DOE/STOR TES Program Manager. All unsolicited proposals submitted to DOE/STOR but falling within the LTTES program purview will be referred to the LTTES Program Manager for action.

6.3 Planning, Controlling, and Reporting

Annual Operating Plans (supporting 189 budget requests) and updated Program Implementation Plans will be submitted regularly to DOE/STOR by ORNL. These plans, on approval by DOE/STOR, will provide the basic control for both subcontractor and in-house technical efforts. The LTTES Program Manager will be responsible for achieving the technical goals within the fiscal guidelines described by these Program Plans; these responsibilities will be carried out subject to the following general understandings:

1. DOE/STOR will provide sufficient funding, within their limitations, to execute all approved technical and management activities.
2. DOE/STOR will designate sufficient funding within the total funding to supporting a viable in-house technical program directed to LTTES objectives; this funding should be over and above that required for program management.
3. All technical studies (subcontract and in-house) will be subject to concurrence by the DOE/STOR TES Program Manager.
4. ORNL will assign appropriate staff to manage the LTTES effort and will periodically review and evaluate the performance of this staff.
5. DOE/STOR will review the LTTES program status and the performance of the ORNL management team regularly.

6. Uncommitted funds may be recalled by the DOE/STOR TES Program Manager as directed by overall program changes.

The preparation and submission of work plans, technical progress narratives, financial reports, topical reports, and final reports on all subcontract activities will be in accordance with ORNL contract management control procedures. Distribution of contract status reports will be limited to ORNL and, on request, to the DOE/STOR TES Program Manager; contractor topical and final reports will receive public distribution in accord with ORNL procedures subject to the concurrence of DOE/STOR.

The LTTES Program Manager will submit status reports to DOE/STOR that cover both in-house and subcontract technical results and program schedule and fiscal activity; this reporting will be normally constrained to monthly and annual frequencies but may be varied through mutual agreement.

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