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RESIDUAL ENERGY APPLICATIONS PROGRAM
TEST & OPERATIONS REPORT

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MASTER

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ABSTRACT

The Test and Operations Report contains policy, objective, and guideline suggestions for utilizing the proposed EAST Facility and for managing EAST operations, preliminary design information regarding the physical plant and facility test support equipment, plus estimates of initial construction costs and staffing requirements for a two bay, three shift operation. Suggested policies address management responsibilities of test project participants and program managers, facility flexibility, test project sponsorship, test article ownership, test article damage and liability, safety environmental protection, ranges of test conditions, facility growth, types of tests, test planning, priorities and schedules, test article readiness, test control, quality assurance, test result reporting, and other topics. Preliminary design information is based on prototype test equipment sizes and capacities described in the Systems Analysis Report, submitted under this contract, and addresses effluent flow and temperature control, auxiliary equipment, instrumentation and data acquisition, and more. The cost estimate for constructing the core facility is approximately \$9.6 million. No estimate is made for facility expansion. The staffing estimate for a two test bay, three shifts per day operation is 61 persons, including professional, technical, and clerical personnel but not including financial and legal staff support.

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Mechanical Technology Incorporated, Research and Development Division - Policy, objective, and guideline concepts for utilizing and managing the EAST Facility. Contributors included D. S. Gabriel, W. H. Woodward, W. S. Scheib, R. G. Sohmer, and B. R. Hao.

United Technologies Research Center - Engineering support for the EAST Facility conceptual design. Contributors included F. R. Biancardi, E. Schulman, R. W. Bass, H. E. Khalifa, M. Krosney, and A. I. Chalfant.

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I. Introduction

A. Statement of Content

This report consists of policy, objective, and guideline suggestions for utilizing the proposed Energy Applied Systems Test (EAST) Facility and managing EAST operations; preliminary design information regarding facility support equipment and the physical plant; plus estimates of initial construction costs and staffing requirements for a two bay, three shift operation. It contains preliminary conclusions, based on recent studies and analyses, and generic information which are intended to be used as a foundation for current and future EAST planning.

B. Participants in Report Preparation

1. Prime Contractor: South Carolina Energy Research Institute (ERI), under the U.S. Department of Energy contract, Systems Test and Evaluation For REAP, DE-AC09-77ET-12866, October 1, 1979, through September 30, 1980.

2. Subcontractor: Mechanical Technology Incorporated, under ERI purchase order EC-77-C-09-1021-Sub-18/P.O., March 13, 1980, through May 12, 1980.

3. Subcontractor: United Technologies Research Center under ERI subcontract DE-AC09-77ET-12866-Sub-15, April 7, 1980, through September 30, 1980.

C. Background Information

1. Reference Documents:

- a. Residual Energy Applications Program (REAP) Plan, dated July 28, 1980, prepared by the Office of Coal Utilization, U.S. Department of Energy. Content: Guidelines for REAP-related activities.

- b. EAST Facility Scope and Capabilities Document, dated July 11, 1980, prepared by the South Carolina Energy Research Institute (ERI) for the U.S. Department of Energy (DOE). Content: Early background and planning information for the likely designer/builder of the EAST Facility (E.I. duPont de Nemours Company) and for DOE (Oak Ridge Operations Office).
- c. Systems Analysis Report, dated October, 1980, prepared by ERI for DOE. Contents: Technical issues that were considered in the process of selecting appropriate sizes and output capacities of candidate heat recovery equipment for testing at the EAST Facility; summaries of key test parameters and test requirements associated with this equipment.
- d. Low Level Waste Heat Utilization Project Savannah River Plant, dated November, 1978, prepared in three volumes by ERI for DOE. Content: Results of a feasibility study of capturing energy rejected in hot water at the Savannah River Plant.

2. Objectives of the Residual Energy Applications Program (REAP):

- a. Conduct realistic feasibility experiments to recover waste heat at U.S. gaseous diffusion plants by 1984.
- b. Effectively utilize large quantities of heat now wasted in the United States.
- c. Conduct technology and systems research and development programs that contribute to maximum utilization of heat currently wasted in gaseous diffusion plants, utilities, and industry and to cost effectiveness of components, subsystems and systems.

- d. Conduct joint activities with utilities and industry to facilitate commercialization of residual heat recovery.
- e. Identify and eliminate jurisdictional, institutional, and regulatory barriers to the commercialization of residual heat recovery.

3. Objectives of the Energy Applied Systems Test (EAST) Facility:

- a. Perform research and development tests on heat energy recovery and conversion equipment as required.
- b. Encourage commercialization by establishing high confidence in system performance, system availability, and system operating, maintenance, and material costs.
- c. Provide a national competence in technologies required for the installation and operation of heat recovery systems.

4. Current Work:

The South Carolina Energy Research Institute (ERI) is currently formulating the EAST Facility Requirements Document, an extensive report that will define the operational requirements to be used as a basis for designing and constructing the facility. The Requirements Document will contain summary information on surveys of low level residual heat resources and applications; the potential market for residual heat recovery equipment; sizes and capacities of candidate heat recovery systems, including heat pump systems and electrical power generation systems; test methods and test requirements associated with these systems; and requirements for the physical structure, the facility test

support systems, and utility services. ERI is performing this work under the U.S. Department of Energy contract identified in paragraph IB1 above and with subcontractors identified in paragraphs IB2 and IB3 above.

5. EAST Facility Schedule:

January 15, 1981 Basic EAST Facility Requirements Document.

March 16, 1981 Amendments to the EAST Facility Requirements Document.

2nd Qtr., FY 82 Core Facility Final Design Complete.

1st Qtr., FY 84 Core Facility Construction Complete.

3rd Qtr., FY 84 Commencement of Testing in EAST Facility.

4th Qtr., FY 84 EAST Facility Expansion Requirements Document.

2nd Qtr., FY 85 Facility Expansion Design Complete.

3rd Qtr., FY 86 Facility Expansion Construction Complete.

D. Objectives of This Report

Two objectives guided the preparation of this report. First, ERI wanted to discuss its views for utilizing the EAST Facility and managing EAST operations for the benefit of the project team, particularly the Department of Energy, the program integration contractor, and the facility design and construction contractor. These matters are highly relevant to the design of the facility. Accordingly, Section II, "Policies, Objectives, and Guidelines", addresses such issues as:

1. Identification of EAST Facility users and test project sponsors.
2. Simultaneous testing of equipment from more than one supplier.
3. Test article damage liability.
4. Protection of proprietary materials, processes, and data.
5. Sizes of candidate test articles.
6. Ranges of test conditions and types of tests to be performed.
7. Facility growth.
8. Safety; environmental protection.
9. Physical and organizational interfaces.

In addition, Appendix III elaborates on the pro's and con's of some key policy questions. Appendix I contains definitions of terms, phrases, and acronyms used in this report. Appendix II provides a convenient policy index.

Section III presents a conceptual design for the EAST Facility, with a caveat to indicate that this reflects only one of several potential approaches to facility design. This design was selected as a result of test support needs discussed in Section III which, in turn, are based on conclusions presented in the Systems Analysis Report regarding potential test articles. Included in the discussions are requirements for effluent and cooling water flow rates, temperatures, and controls; requirements for major facility support systems and equipment; requirements for instrumentation and data acquisition; requirements for facility staffing; and cost estimates for facility construction. This information is preliminary as the requirements for designing and building the EAST Facility are still being formulated. Nevertheless, it represents the best information available for this early effort and will provide grounds for budgetary projections which are needed now.

ERI's second objective was to provide a framework for early discussions with equipment manufacturers and potential users of heat energy recovery equipment. Such discussions are essential for ensuring that the final Requirements Document will adequately address the needs of both suppliers and users. Accordingly, the policy-related material in Section II goes beyond the immediate needs for facility design and addresses issues of interest to the supplier/user community, including:

1. Test planning,
2. Test article readiness; facility readiness,
3. Test article and facility quality assurance, including configuration management,
4. Acquisition, reduction, analysis, and dissemination of test data, and
5. Confidence testing.

Additionally, Appendices IV and V elaborate upon confidence testing and accelerated life testing as these activities are currently perceived for EAST.

The material contained in this report represents the current iteration in the overall planning process for EAST. It will be refined during the maturation of EAST Facility requirements. The final version will be reported in the EAST Facility Requirements Document, which will supersede this report.

In addition to these objectives, it is hoped that this Test and Operations Report will serve as a vehicle for discussions among DOE, ERI, and duPont personnel to determine the optimum allocation of EAST resources.

II. Policies, Objectives, and Guidelines

A. Scope

REAP is in its early program execution phase. Therefore, policies and guidance established now should be sufficient to permit the design of the EAST Facility but flexible enough so that future choices of technologies or applications will not be arbitrarily excluded by premature selections of detail. The initial policies should be selected to enhance this flexibility and to provide program guidance while avoiding detailed direction.

The material in this section suggests policies for EAST operations. It is intended to help guide the design of the EAST Facility and provide a requirements framework for staffing skills, size, and composition, organization and management, contractual planning, financial planning, and many other matters.

B. Participants in EAST Operations

1. Department of Energy:

- a. Office of Coal Utilization, Washington DC (REAP Headquarters Management, N. Gerstein).
- b. Oak Ridge Operations Office (REAP Field Office Management, D. Howard).
- c. Savannah River Operations Office (EAST Project Management, J. Bilyeu).

2. E.I. duPont de Nemours Company (EAST Facility design, construction, and test operations).

3. South Carolina Energy Research Institute (EAST Facility test support and integration).

4. Government organizations, contractors, and manufacturers (test requestors and/or test article suppliers).

5. Federal facilities, utilities, and companies (test article users).

C. Management Responsibilities

1. In conjunction with its management of REAP, DOE will own the EAST Facility and possess complete technical and managerial authority for the EAST program, with responsibilities for:

- a. Technical direction,
- b. Systems development,
- c. Test article selection,
- d. Facility modification,
- e. Fiscal control,
- f. Contractual compliance and change, and
- g. Arbitration of disputes.

DOE will delegate some of these responsibilities in accordance with established practice.

2. Personnel under contract to DOE and under DOE direction will manage and direct the start up and operation of the EAST Facility and the EAST program. Specific responsibilities will include:

- a. Program technical, managerial, and fiscal control within the contract scope,

- b. Organization and administration of the EAST Facility personnel,
- c. Personnel training and security,
- d. Internal and external safety, disaster preparedness, and environmental protection in congruence with established procedures at SRP,
- e. Monitoring and reporting of changes and trends associated with EAST Facility operations effects upon the integrity of SRP nuclear reactor effluents and cooling systems,
- f. Facility operations, maintenance, and repair,
- g. Facility quality assurance, including configuration management,
- h. Facility design and modification requirements,
- i. Test planning,
- j. Test article installation, instrumentation, and operation,
- k. Test article maintenance and repair (as negotiated with supplier),
- l. Test article quality assurance, including configuration management, for tests defined as confidence tests,
- m. Test data recording and reduction,
- n. Test data analysis and reporting,

- o. Failure analysis, corrective action, and deficiency reporting,
- p. Progress and financial reporting, and
- q. Logistics (supplies, equipment spare parts, shipping/receiving, local transportation, special services, office furniture, minor maintenance).

3. Test requestors, who will also be test article suppliers in some cases, will:

- a. Provide complete information about test articles, including detailed description, test parameters, precursor data, equipment schematics, operational/safety/logistical requirements, etc.,
- b. Provide a complete statement of test objectives,
- c. Participate in test project planning, and
- d. Commit test article supplier to provide technical assistance in test project planning, EAST Facility personnel training, test article installation/instrumentation/operation, data acquisition/interpretation, test article maintenance/repair, test article operational safety/environmental impact, and test article failure analysis/corrective action/deficiency reporting as directed by the EAST Facility test manager.

4. Test article users will:

- a. Participate in planning test projects, and
- b. Provide feedback data to EAST Facility test

personnel on equipment performance/ degradation/
failure.

D. Test Project Modes

1. General. The EAST Facility may be utilized in three major modes:

- a. Government owned test articles, Government funded tests,
- b. Privately owned test articles, Government funded tests, and
- c. Privately owned test articles, privately funded tests,

Variations of these modes will be considered individually and may include jointly funded tests, partial Government ownership, ownership by a department other than DOE, EAST initiated tests, and others.

2. Government owned test articles, Government funded tests. Under this mode, Government will fund all aspects of testing, including the test article, and will have unilateral rights to test definition and test conduct. Test data dissemination will be broad within statutory limits.

3. Privately owned test articles, Government funded tests. Government will fund all aspects of testing but will not have title to the test articles. Liability for test article damage will be determined by agreement for each test article. Government will have rights to test definition and test conduct, subject to reasonable concurrence of the equipment supplier, based on technical and safety considerations. Government will have rights to data dissemination in accordance with statutory limitations.

4. Privately owned test articles, privately funded tests.

The test requestor will arrange for provision of the test articles to the EAST facility. The test article supplier will retain title to this equipment and all liability for its damage during testing or in transit. Government will assess the test article supplier's test-operations costs. The test article supplier will have rights to test definition and test conduct, subject to concurrence of the facility test manager. Government will have rights to dissemination of data within statutory limits.

E. Safety and Environmental Protection

Safety and environmental protection will take precedence over other aspects of test operations. The responsibility for these matters will be incumbent upon each test manager. Facility management will establish safety and environmental protection organizational entities separate from the operating organization to support each test manager by recommending system start-up, shutdown, hold, or other actions to ensure safety and environmental protection. Furthermore, facility management will establish and maintain modern safety and environmental protection programs consistent with programs now in effect at SRP.

F. Types of Residual Energy and Recovery Cycles

The sources of residual energy may be concentrated or dispersed, have high, medium, or low temperature, and be liquid and/or gaseous. The facility will be designed to provide actual or supplemental energy sources of practical types between 100°F and 1000°F and be capable of testing appropriate types of energy recovery equipment in conformance with the REAP Plan. Current interests focus on liquids and gases, both clean and contaminated, over wide ranges of flow rate and heat content. Operational cycles of heat recovery devices are diverse. Therefore, it is anticipated that the need to test combinations

of interest will require substantial facility flexibility with multiple test positions having access to several energy sources.

G. Ranges of Test Conditions

The facility will be capable of testing heat recovery equipments across the spectrum of conditions discussed above and within guidelines established in the REAP Plan. As a part of this policy the facility will provide a test capability of both continuous and intermittent sources and be capable of steady-state and transient operations under normal and stressed operating environments. During periods of SRP reactor shutdown when no effluent is available, EAST Facility Test operations may depend upon supplemental heat sources for low and/or high temperature applications. During periods of intermittent reactor operations, the continuity of test operations will be ensured by these supplementations. Thus, the facility will be designed so that test operations are flexible, continuous, and representative of a wide range of commercial applications and practices.

H. Facility Growth

The facility capacity will eventually be sufficient for testing residual heat recovery equipment ranging from prototype components to full-scale commercial systems. An exception will be the very large systems needed for recovery of diffusion plant residual heat if such systems are not modularized. The initial facility capability will be a two or three bay operation involving both high and low temperature applications with simultaneous testing of prototype units. First generation test articles are expected to have power outputs between 0.5MW and 1.0MW, in accordance with the REAP Plan. The facility will increase in capacity to accept the anticipated growth of test articles (1.0MW to 5.0MW equipment, and larger if warranted). To meet these needs, the facility growth plan should be sufficiently ahead of the rate of equipment advances so that progress will not be limited or delayed.

I. Types of Tests

Most equipment tests fall in four categories: exploratory, development, application, and confidence tests (see Appendix I, "Definition of Terms, Phrases and Acronyms"). These categories correspond to successive stages in the research, development, and commercialization of a new system.

The EAST Facility will be designed and operated to accommodate these kinds of tests so as to provide data acquisition support for all phases of systems development. This policy will require multiple test positions in the facility and procedures for test scheduling and priority establishment.

J. Test Planning

1. General. EAST Facility personnel will be responsible for test planning. They will prepare documented procedures for each test project, from the initial test request through the final test report. They will ensure that the test requestor is informed of facility capabilities and that the test article supplier and the test requestor (who may be the same party) participate in the planning process by formulating test objectives and by completely describing test articles and operating/ logistical/other requirements. A facility test engineer will formulate a test plan to include the test project schedule and requirements for facility support personnel and systems. The test requestor will be provided a statement of facility capability aimed at satisfying the test objectives, the proposed method of test, and a cost estimate for the test project. Negotiations will be followed by written agreements among test requestor, test article supplier, Government, and facility personnel; funds will be provided by the test requestor to cover test project expenses.

2. Precursor Requirements. EAST Facility personnel will establish the precursor requirements (see Appendix I) for each

test, with the principal guiding factors being the natures of the test objectives, safety, and environmental protection. Substantial precursor data will be required to develop the test plan and test procedures, conduct test operations, and assess confidence in equipment performance. For exploratory and development tests the principal precursor constraints are safety and environmental protection. It is not the intention of this policy that facility personnel will judge the merits of precursor requirements for privately owned and funded test articles.

K. Priorities and Schedules

A committee will be formed of facility and DOE personnel to establish policy for test project priorities and schedules, approve recommendations for priorities/schedules subject to Government review, and resolve conflicts.

L. Test Readiness and Control

1. General. Test readiness reviews will be conducted by facility personnel prior to each test program and at appropriate intervals during the test program. Readiness will involve safety, compliance with the test plan, and the prospects for success. Such reviews will apply to all test articles and to the facility test support personnel and systems. Readiness findings will be subject to Government review.

A facility test engineer will be in overall control of each test. Facility personnel will operate the facility support systems required by the tests and will operate the test articles with technical assistance provided by the test article supplier as needed. The facility test engineer may effect a test shutdown for safety, environmental, or programmatic reasons. Equipment supplier representatives may participate in the operation of the test articles with the concurrence of the facility test manager and under the direct supervision of the facility test engineer.

These representatives may require a test article shutdown for safety, environmental, or programmatic reasons.

2. Departures and Exceptions. In tests other than confidence tests, strict adherence to a predetermined test plan will not be required. Aside from safety and environmental considerations, freedom to explore is intended. For confidence testing, departures from the test plan will require adherence to formal change procedures as a matter of policy.

M. Logistics and Services

All necessary logistics and services to support test article receipt, installation, instrumentation, operation, maintenance, supply, removal and storage, and shipment will be provided by or through facility personnel as a matter of policy. Exceptions may be specified in the test plan. Test article modifications will be performed by test article suppliers (see next section).

N. Facility and Test Article Quality Assurance and Certification

1. General. Quality assurance activities, including configuration management, will be performed by facility personnel for the facility and all test articles. Quality assurance will extend beyond facility capability and operability to safety and environmental protection as needed. Quality assurance for the test article will vary, depending on its stage of development, but will apply to test article operability, configuration, data validity, and safety. Records will be kept to ensure the traceability of test article components. Test article modifications will be explicitly documented. Facility personnel will ensure that facility and test article configuration management will incorporate the physical interfaces, including mechanical and thermal connections, materials and supplies introduced, instrumentations and calibrations, and control systems.

2. Confidence Tests. In addition to the requirements stated above, facility engineers will be required to certify the validity of facility and test article configurations during all tests and the validity of collected test data.

O. Elements of Test Evaluation

The EAST Facility will be designed to accommodate a full range of tests and evaluations of heat recovery systems, including the following elements:

1. Test article performance and performance deterioration,
2. Test article degradation and failure mechanisms,
3. Failure rates, degradation rates, and variances thereof,
4. Operating, maintenance, and material costs,
5. Technology reporting,
6. Training and certification of personnel,
7. Test data reporting,
8. Deficiency reporting, and
9. Identification of technology needs.

P. Acquisition, Reduction, Analysis and Dissemination of Data

1. General. Facility personnel will be responsible for the collection, reduction, analysis, reporting, and other dissemination of data. Others may assist in various phases of data handling but only one central organizational entity, the EAST facility test manager, will retain full authority and responsibility for test data. Inherent in this responsibility is

the required protection of any classified, proprietary, and otherwise sensitive information. Data may be disseminated in raw form, reduced form, or prepared technical reports, as stipulated in the test plan.

2. Proprietary Interests. Proprietary matters associated with a test article are to be identified during test project preliminary planning. In general, proprietary interests will include such matters as design, fabrication, special features, and unique concepts. As a part of test project final planning, procedures will be developed for the protection of these interests in accordance with statutory requirements. The protection procedures will apply to the handling, processing, and presentation of test data.

Q. Failure Analysis, Corrective Action, and Changes

1. Exploratory and Development Tests. The test article supplier will have final authority for test article failure analysis and corrective actions and will be responsible for comprehensive documentation of his actions. The facility test manager will review these actions for safety, environmental impact, and facility compatibility.

2. Confidence Tests. For confidence testing the initial technical determinations of causes of test article failure will be made by the test article supplier with final authority provided by the facility test manager for corrective actions involving safety, environmental impact, or test article configuration changes that may have potential for invalidating the test results.

3. Other Changes. The policy for other test project changes will be the same as in paragraphs Q-1 and Q-2. Included might be a change in a material supplied, a change of sensor or instrument, or a change in a maintenance or repair procedure.

R. Test Project Documentation

During the test planning stages for each test project a comprehensive documentation plan will be developed and implemented. Thereafter, documentation will include information pertinent to every facet of the project, from preliminary planning through final material dispositions. Development of the plan will be the responsibility of the facility planner, assisted by the test requestor as necessary.

S. Test Reports

The EAST Facility test manager will establish standards of format and technical content for all facility test reports and will form editorial and technical review boards and management review procedures to ensure production of high quality test products.

T. Interfaces

1. General. While communications and information will be provided freely to all participants, direction will be strictly confined to the line organization. Facility personnel, with the approval of the Government, will develop and distribute technical, financial, and other documents and procedures which aid in explaining the roles, capabilities, costs, purposes, procedures, and other facets of the EAST Facility of interest to potential users. The facility will encourage communications with the private sector and all government agencies. The facility will conduct such training and information exchanges as required to ensure the currency and skills of its staff.

2. EAST Facility and Government. Information will be exchanged freely between the facility and many government offices; however, direction to facility management will be from the responsible government office. The operating interface will be determined by contract.

3. EAST Facility and Savannah River Plant. Day-to-day technical and administrative interfaces will exist between the EAST Facility and the Savannah River Plant. These interfaces will involve operational safety, environmental protection, specialist (shops) support, computer support, plant security, communications, and other matters. The facility operator, with the approval of the Government, will negotiate, develop, and publish an interface operations plan and/or a host-tenant agreement, if appropriate. For matters involving transfer of funds or contractual actions between these parties, the interface will include the appropriate government office.

4. EAST Facility and Test Requestor. During all phases of the test project, the test requestor will interface directly with facility personnel. Agreements and other exchanges between these parties will include:

- a. Statement of general capability of the EAST Facility (by facility test engineer).
- b. Statement of test objectives (by requestor),
- c. Description of test articles and precursor data (by requestor),
- d. Requirements for test support (by requestor),
- e. Time/safety/environmental/dollar constraints affecting test project (by requestor),
- f. Test Plan, including schedule (by facility test engineer),
- g. Test Article Quality Assurance Plan (by facility test engineer),
- h. Data Acquisition Plan (by facility test engineer),

- i. Safety/Environmental Protection Plan (by facility test engineer),
- j. Statement of Capability (pertains to specific test project) (by facility test engineer),
- k. Cost Estimate for test project (by facility test engineer).
- l. Exceptions/Agreement (by requestor),
- m. Commitment of funds (by requestor),
- n. Test Progress Reports (by facility test engineer),
- o. Test Article Deficiency Reports (by facility test engineer),
- p. Failure Analysis/Corrective Actions/Changes Report (by facility test engineer),
- q. Test Report or other data package (by facility test engineer), and
- r. Cost Accounting Reports (by facility personnel).

5. EAST Facility and Test Article Suppliers. Prior to selecting test articles for EAST, the official interface with test article suppliers will be the Government or its designee, with the understanding that technical communications with other parties are not to be inhibited. After a test article is selected by the Government and scheduled for testing at the EAST Facility and during all phases of the test project, the official interface and line of technical direction will be from the facility test engineer to the equipment supplier.

6. EAST Facility and Potential Test Article Users.

Potential users of test articles will serve an active role throughout the life of the test project, with heavy emphasis on participation in initial test planning, and will provide continuing feedback data regarding equipment performance in situ. The establishment of this interface activity for a confidence test project is an important one which should be considered very early.

7. Physical Interfaces. Physical interfaces will include:

- a. Connections between the EAST Facility and SRP,
- b. Connections between the test article and the EAST Facility,
- c. Connections between the EAST Facility or the test article and external receptors (i.e., utility services and effluent),
- d. Flows of materials, supplies, and other goods to and from the EAST Facility or the test article, and
- e. Interrelationships between various test articles and other elements within the EAST Facility.

III. Preliminary Information for EAST Facility Design

A. Introduction

Analyses conducted under the management of the South Carolina Energy Research Institute (ERI) and reported in its Systems Analysis Report, dated October, 1980, and submitted under this contract, described large capacity prototype heat pump and electrical power generation systems as examples for future testing. The prototype system characteristics were used to generate preliminary design requirements, determine physical size and arrangement, and develop instrumentation and data analysis equipment specifications. These data are being used by ERI to develop an EAST Facility Requirements Document to enable design and construction of the facility. The following paragraphs describe the rationale for selecting specific sizes of prototype heat pump and electrical power generation systems. This is followed by discussions of test requirements associated with this equipment, including listings of some key test parameters, and a table of some preliminary specifications for the facility. Then, detailed discussions are presented on requirements for effluent temperature and flow control, auxiliary equipment, and instrumentation, followed by a conceptual design for the EAST Facility. Finally, estimates are given for the costs of designing, constructing, and equipping the EAST Facility and for staffing it to accommodate multi-shift, multi-bay, multi-test operations.

This preliminary information is based upon conceptual test articles and may be amended or superseded by subsequent conclusions which will be presented in the EAST Facility Requirements Document.

B. Preliminary Specifications and Requirements

1. Prototype System Characteristics - Heat Pump System

A large capacity, heat engine driven, dual fluid Rankine cycle system has been identified as the most economical heat pump for utilizing large liquid residual heat sources from Federal facilities, utilities and industries. Due to the economies of scale and other factors, large heat pump systems are more attractive than small systems. Hence, process heat requirements for large single industries as well as industrial parks would best be met by relatively large systems (i.e., $>100 \times 10^6$ Btu/hr). The analysis presented in the Systems Analysis Report showed that for systems above an output of 100×10^6 Btu/hr, the increase in return-on-investment becomes relatively small. Thus, the maximum prototype system size selected for testing at EAST is 100×10^6 Btu/hr. Refer to the Systems Analysis Report for a detailed discussion.

Testing a 100×10^6 Btu/hr prototype heat pump system permits demonstrating a system with applications in Federal facilities, utilities, and large industrial plants. The physical sizes of the system components represent reasonable estimates of floor area and building volume requirements for heat pump system test installations in the EAST Facility. Table III-1 summarizes the waste heat flow and temperature conditions required to test a 100×10^6 Btu/hr heat pump system.

2. Prototype Systems Characteristics - Electrical Power Generation System

An organic Rankine cycle system employing two stages of evaporation was selected for application in a Federal facility, i.e., the Portsmouth Gaseous Diffusion Plant. The output of this system was approximately 17 MW_e, consisting of 4.25 MW_e from each of four turbogenerators. The issues behind this selection are discussed in the Systems Analysis Report. Because the 4.25 MW_e

size units can be economically coupled to produce larger output capacity systems, this size was selected as a reasonable upper limit for electrical power generation system testing at the EAST Facility.

3. Specifications/Requirements - Heat Pump Systems

The EAST Facility will have access to large quantities of water at approximately 150°F. The prototype 100 x 10⁶ heat pump will obtain its input heat from approximately 10,000 gpm of this water as it is cooled approximately 10°F. After heat removal, the water will be returned to the normal SRP cooling channels. To overcome the pressure loss in the heat pump evaporator and to ensure that the waste stream water flow is continuous, a pump capable of pressurizing the 10,000 gpm to 10 psig is required. The provision of lower temperature residual heat sources would require a dilution system using either SRP cooling water or a recirculated stream.

During the test program, the output of the heat pump in the form of 300°F saturated steam will be dissipated and pressurized water returned to the system. This heat dissipation could be accomplished by utilizing 10,000 gpm of 70°F cooling water in a condenser. The temperature of this cooling water would rise 15° to 20°F, depending on whether or not the exhaust boiler were in use.

As a result of the preliminary design, a 100 x 10⁶ Btu/hr heat pump using a gas turbine drive and an exhaust boiler will require an equipment floor area of 36 ft. by 56 ft. and a ceiling height of 20 ft. A total test cell area of approximately 2400 sq. ft. will allow for aisle and work space. In addition, an auxiliary power requirement of up to 500 kW may be needed for pump drives and up to 125 tons of building cooling may be needed to dissipate heat generated by the equipment. This cooling load may be reduced considerably by using large air circulating fans.

TABLE III-1
PROTOTYPE SYSTEM CHARACTERISTICS

	<u>Heat Pump System</u>	<u>Power Generation Steam</u>
System Output	100×10^6 Btu/hr	4.25 MW _e Net
Residual Heat Input	50×10^6 Btu/hr	236×10^6 Btu/hr
Residual Heat Stream Input Flow, GPM	10,000	22,500
Residual Heat Stream Temperature, °F	150	146*
Residual Heat Stream Temperature Drop, °F	10	21*

* Seasonal averages, Portsmouth Gaseous Diffusion Plant

Several controls are required to permit control room operation of the unit. Among these are the driver controls and the various residual heat stream pump controls. Finally, there is a requirement for an exhaust stack capable of handling 80,000 cfm of 850°F effluent, if no exhaust boiler is used, or 300°F effluent if an exhaust boiler is used. A complete list of test facility requirements is given in Table III-2.

If justification should exist for testing larger units in the future, minor modifications of the EAST Facility would permit testing a heat pump with an output of 400×10^6 Btu/hr. This could be done by utilizing the test cell area being designed for the electrical power generation equipment.

As part of the prototype testing program, the temperatures, pressures, flow rates and rotor speeds listed in Table III-3 would be measured to determine whether or not the components and the entire system are functioning according to design. While there is no need for short response time measurements in near term testing, this type of instrumentation may be desired for later tests.

4. Specifications/Requirements -- Electrical Power Generation Systems

In the prototype tests at the EAST Facility, the power generation system will obtain its heat input from a reactor effluent and will reject heat to SRP cooling water. The performance of the intermediate heat exchanger and of the cooling tower should be regarded as predictable. Thus, the EAST Facility would test the portion of the power plant between the hot water inlet to the high pressure evaporator and the cooling water inlet to the condenser cooling water pumps. The reactor effluent would simulate the water from the intermediate heat exchanger at Portsmouth while the SRP cooling water would simulate the water returning from cooling towers at Portsmouth. A hot water flow of

TABLE III-2

EAST FACILITY REQUIREMENTS
(Based Upon UTRC Proposed Systems)

<u>Heated Water</u>	<u>Heat Pump System</u>	<u>Power Generation System</u>
Flow rate	10,000 GPM	22,500 GPM
Temperature	150 F	146 F
Source	"P" Reactor Coolant	"P" Reactor Coolant
Required Pressure	20 psig	15 psig
<u>Cooling Water</u>		
Flow rate	10,000 GPM	72,000 GPM
Temperature	70 F	60 F
Source	Par Pond	Par Pond
Required Pressure	20 psig	5 psig
<u>Test Cell Specifications</u>		
Length	60 ft.	80 ft.
Width	40 ft.	40 ft.
Height	25 ft.	70 ft. **
Pit Depth	N/A	30 ft.
Crane Capacity*	5 tons	5 tons
<u>Additional Fluid Handling & Storage</u>		
	R11 No. 2 Fuel Oil Lubricating Oil	Ammonia Lubricating Oil
<u>Electrical Power Required</u>		
	500 kW	600 kW
<u>Auxiliary Requirements</u>		
	Gas Turbine Control Hot Water Control 300°F Steam Dissipator G/T Exhaust Stack (80,000 CFM @ 300°F) 125 Tons Space Cooling Cooling Tower	Grid Connection (Induction Gen.) 25 Tons Space Cooling Leak Detection

* Outside crane used to bring in large equipment

** No roof in this test cell area

TABLE III-3
HEAT PUMP TEST MEASUREMENT REQUIREMENTS

<u>Location</u>	<u>Temperature</u>	<u>Pressure</u>	<u>Flow Rate</u>	<u>Speed</u>
Residual Heat Stream Inlet	X		X	
Waste Heat Outlet	X			
R11 Evaporator	X	X		
R11 Compressor Inlet	X	X	X	X
R11 Compressor Outlet	X	X		
Interfluid Heat Exchanger Hot Side	X	X		
Interfluid Heat Exchanger Cold Side	X	X		
Steam Compressor Inlet	X	X	X	X
Steam Compressor Outlet	X	X		
Condensate Return	X		X	
Prime Mover Exhaust Exit	X	X	X	
Boiler Exhaust Exit	X	X		
Boiler Feed Water	X	X	X	
Boiler Steam Output	X	X		

Note: Standard prime mover control parameters such as fuel flow and shaft speed will also be measured.

22,500 gpm at a nominal temperature 146°F and a cooling water flow at a nominal temperature of 67°F would be desired.

The operating conditions of the actual power plant at Portsmouth vary seasonally; during most of the year a realistic power plant operating condition could be duplicated at the EAST Facility. The hot water temperature available from an SRP reactor would probably average 4°F or 5°F hotter than the desired average of 146°F. It could be adjusted to the desired temperature by dilution with SRP cooling water.

Facility electric power requirements are mainly for pump drives, assuming that operation of the pumps independently of the turbogenerators would be desirable to achieve flexibility of testing procedures. The pumping power for hot water circulation, ammonia feed supply, and cooling water supply is 508 kW if the cooling water and hot water sources are at the same elevation. Allowing a reasonable margin for miscellaneous requirements, a power need of 600 kW is estimated.

Service pumps or a throttled gravity circulation arrangement should be provided for the hot water since the power plant circulating pumps are designed for the additional head loss in the intermediate heat exchanger and would require more electric power than necessary. Circulating pump performance is predictable and could be verified by separate tests not in combination with tests of the power plant.

For testing the power plant without the intermediate heat exchangers, a bay area of approximately 40 ft. by 80 ft. is required. The maximum vertical height above grade of the power plant is 57 ft. Allowing clearance for removing vessel covers, a clear height of about 70 ft. is necessary. The cooling water pumps require a pit about 28 ft. below grade for their intakes.

The heaviest components are the condensers and evaporators. They would probably be hoisted into place by a portable crane of

90 ton capacity, available when required. A permanent travelling crane would be required for lifting the turbines, generators, pumps, and vessel heads. The 3600 rpm generator driven by the high pressure turbine appears to be the heaviest of these components; it would require a crane capacity of 5 tons.

The test program should employ sufficient instrumentation to measure the performance of each component as well as the overall system, and would use instrumentation to provide warning in advance of component malfunctioning. Table III-4 lists the temperature, pressure, flow, speed, power, and trouble shooting measurements required.

C. EAST Facility Conceptual Design

A conceptual facility design has been formulated from available site information, heat recovery technology assessments, and applications studies under this and related Department of Energy contracts. The facility was designed to enable testing of heat pump and electrical power generation equipments as described in the Systems Analysis Report under this contract. Test requirements for these equipments were addressed in the preceding section.

It must be pointed out that this is just one approach toward facility design, based upon a specific set of assumptions. This design concept was used to determine preliminary requirements for core facility support equipment, facility construction costs, and operating manpower strength. These matters are addressed in the following sections.

Drawings of the EAST Facility layout and site plan are shown in Fig. III-1 and III-2 respectively. The core of the facility consists of one indoor test bay for heat pump systems, with a maximum input capacity of 10,000 gpm of hot water from the reactor effluent, and one outdoor test bay for electrical power generation systems, with a maximum input capacity of 32,000 gpm

TABLE III-4

POWER CONVERSION TEST MEASUREMENT REQUIREMENTS

	<u>Temperature</u>		<u>Pressure</u>		<u>Vapor Quality</u>		<u>Flow Rate</u>	<u>Speed</u>	<u>Power Output</u>	<u>Power Input</u>	<u>Voltage</u>	<u>Current</u>	<u>Fluid Level</u>	<u>Vibration Amplitude</u>
	<u>Inlet</u>	<u>Outlet</u>	<u>Inlet</u>	<u>Outlet</u>	<u>Inlet</u>	<u>Outlet</u>								
Condensate Pumps (2)	X		X	X			X	X		X				
Feed Pumps (2)	X		X	X				X		X				
Feed Heater (1)														
Ammonia	X	X	X	X										
Water	X	X	X	X										
Evaporators (2)														
Ammonia	X	X	X	X		X	X						X	
Water	X	X	X	X			X						X	
Turbines (2)														
Ammonia	X	X	X	X	X	X		X						X
Lube Oil	X	X	X	X										X
Condensers (2)														
Ammonia		X		X									X	
Water	X	X	X	X									X	
Cooling Water Pumps(2)			X	X			X			X				
Alternators (2)									X		X	X		

PROPOSED EAST FACILITY FLOOR PLAN

FIGURE III-1

PROPOSED EAST FACILITY

SITE PLAN

FIGURE III-2

of hot water. Each bay has been sized to accommodate one test system at a time. It was decided to place the electrical power generation system on a concrete pad attached to the main building and to not build walls or ceilings for such large size equipments so as to avoid the high costs of installation and removal. The basic building is approximately 200 ft. by 200 ft. A listing of the sizes of the test bays along with other requirements is presented in Table III-2.

The site for the facility building was selected close to Par Pond to minimize the cost of supplying large amounts of cooling water (approximately 100,000 gpm) for the test equipment. The option of raising the elevation of the building was chosen to minimize the complexity of returning the facility effluent (processed water, hot and cold) to Par Pond. This is shown in the site plan drawing. It necessitates a pumping station at Par Pond to pump the cooling water from Par Pond to the facility. Approximate costs of a variety of water transfer ducts or pipes are shown in Fig. III-3.

Provisions for engineering office space, shop area, control rooms, a means to temper the input hot water, flow distribution areas, and an electrical power room are included in the layout drawing. Facility expansion capabilities were specified and limited only to heat pump test bays, capable of accommodating full systems and/or limited component systems. Expansion was not provided for electrical power generation system testing due to the large size of this type of equipment and its large demand for cooling water.

PIPELINE COSTS

FIGURE III-3

D. Effluent Control and Temperature Conditioning

A system to direct the heated effluent to various test cells at the EAST Facility and moderate the temperature of the effluent as desired is shown schematically in Fig. III-4. This system would provide the control necessary to direct heated effluent to both the heat pump and electrical power generation test cells simultaneously, if desired. It would also provide a means to either elevate or reduce the temperature of the effluent to the test cells independently so as to provide a range of effluent temperatures for the evaluation of candidate test configurations. This system would be equipped with manual shutoff valves for each cell as well as a system of motorized valves to provide the operator with control of each effluent stream to each test cell from a centralized control station. Included in this plumbing schematic is a system to control flow to and from each of the four auxiliary boilers which would permit the heat pump cell to run when hot water is not available from the reactor site. The system also would have check valves to prevent water from inadvertently mixing between the electrical power generation supply and the heat pump supply during valve manipulations.

Specifications for an auxiliary boiler system are shown in Table III-5. The table lists pertinent features for a fast response boiler system. The system is comprised of four units of 16.7 million BTU's per hour each, providing a total of 2000 boiler horsepower. Additionally, a comparison of the size of these fast responding steam generators with conventional boilers is presented. It is seen that the conventional boiler is almost 2 1/2 times larger than the fast response steam generator and weighs considerably more, although each costs about the same. Additionally, much more cell area would be necessary to provide cleaning and access to the tubes of the boiler, resulting in an overall installation on the order of 10 times that necessary for the installation of a fast response steam generator system. The comparison shown pertains to both oil and gas fired units.

WATER DISTRIBUTION FLOW SCHEMATIC FOR EAST FACILITY

(MAJOR COMPONENTS)

FIGURE III-4

TABLE III-5

AUXILIARY BOILER SPECIFICATIONS

Total Output (net)	- 66.8 MBTU/hr. (4 units x 16.7 each)
Boiler Model	- E-500 (Oil or Gas)
Manufacturer	- Clayton
Design	- DZ
Efficiency	- 80%
Maximum Press.	- 305 psi
Oil Consumption	- 149 GPM per unit
Power Consumption	- 37 kW per unit
Water Supply	- 2650 GPM per unit

COMPARISON WITH CONVENTIONAL BOILER

(Oil or Gas Fired Units)

	<u>Steam Generator Model E-500</u>	<u>Conventional Boiler Model CB-500</u>
Unit Dimensions	L - 148 in. W - 81 in. H - 129 in.	L - 260 in. W - 113 in. H - 128 in.
Unit Weight	12,770 lbs.	41,500 lbs.
Unit Cost	\$70K	\$70K

E. Auxiliary Equipment

Major items of the auxiliary equipment necessary for the EAST Facility are listed in Table III-6. This equipment will be necessary to support the heat pump system test bay, the electrical power generation system test bay, and fluid handling and fluid storage systems. Budgetary and planning installed costs are included for each item. While no specific components have been costed via quote or directly from a catalogue, the costs of representative items have been estimated for the operational systems.

The majority of the items listed in Table III-6 are conventional. However, the hot water control system is innovative. A Modicon logic controller has been incorporated with the hot water control system to allow system flexibility. This control system is similar to those presently used on high power lasers and commercially installed heat pump systems. It allows a variety of programming functions to be incorporated in one common control unit. The Modicon logic controller utilizes solid state circuitry to allow the flow functions to be pre-programmed and varied with no wiring changes. Additionally, this system can be programmed for a variety of control valve functions. Thus, the EAST Facility hot water distribution system could accommodate both heat pump system testing and electrical power generation system testing simultaneously and could control individual valves in each cell for variable flow conditions. The Modicon control system is a modular system; it could accommodate additional test cells with the addition of modularized logic packages. The system includes a display screen for the operator.

Costs for items such as the steam dissipator, the gas turbine exhaust stack, and the cooling tower are based on preliminary information presented in the Systems Analysis Report; specific units have not been costed due to the uncertainty of eventual heat pump test configurations.

TABLE III-6

MAJOR AUXILIARY EQUIPMENT FOR EAST FACILITY

	<u>B & P Installed Cost</u>
<u>Heat Pump System Test Bay</u>	
Gas Turbine Control System	\$ 40 K
300°F Steam Dissipater	22 K
G/T Exhaust Stack (not including boiler)	35 K
125 Tons Space Cooling	56 K
Cooling Tower with Circulating Pumps	62 K
<u>Electrical Power Generation System Test Bay</u>	
Induction Generator	\$ 90 K
25 Tons Space Cooling	15 K
Leak Detection System (6 sampling stations) (Automatic Sequence)	10 K
Switch Gear & Transformers	210 K
<u>Facility, General</u>	
Hot Water Control System Modicon Logic Controller Control Valves	\$ 15 K 120 K
Fluids, Handling/Storage Systems: R11 (pumping system only)	40 K
Fuel Oil (No. 2) or Jet Fuel	70 K
Lubricating Oil	15 K
Ammonia	100 K
Total	\$ 900 K

One of the major components in the auxiliary equipment list for the power generation system is an induction generator set. An induction generator system was selected for harnessing the shaft power generated in the mechanical portion of the electrical power generation system. While the induction generator does not have quite as high an efficiency as a synchronous generator, it has many other advantages over the latter. These include:

1. Substantially lower first cost.
2. Simple squirrel cage rotor with low maintenance.
3. Tends to dampen undesirable frequency harmonics.
4. Can automatically balance speed and load swings among several machines with a common drive train.
5. Will not contribute sustained current to a system short-circuit.
6. Simple controls; minimum switching gear.
7. No DC excitation; only winding is on stator.
8. Needs no synchronizing control; can be closed on the line without regard for shaft speed.

The commonly used synchronous generator needs a tight prime mover speed control to maintain its output at the correct frequency. When connected to a public utility system, it cannot be allowed to deviate more than a small fraction of its specified frequency without being intentionally tripped off the line. Speed changes do not affect the voltage or power output of the synchronous generator; only the frequency is affected. With the induction machine, however, the voltage and frequency remain constant. Changes in the shaft speed directly affect the power output of the generator and the temperature of the windings;

therefore, swings in the drive speed should be minimized for the induction system as for the synchronous generator.

Some protective devices are necessary for the induction system. Over-current relays should be used to guard against current overloads. Current limiting fuses are available as short circuit protection. In this particular application the machine should never operate as a motor; therefore, a reverse power relay should be used to sense a change in electric power flow, which is always away from the machine in the generator mode. Additionally, a speed-sensing device in the drive train should be used to trip the generator off the line if the shaft speed falls below a prescribed critical level.

An additional item which is not standard is a leak detection system for the ammonia used in the power generation system. The leak detection system proposed is a six-station system that automatically sequences from one station to another. Typically, these types of systems sample at each station for a one minute period of time. A complete sample of the various subset locations could be accomplished every six minutes. The detector system would have an annunciator station at the facility control center to immediately identify which of the six stations would be registering an alarm. Additionally, the leak detection system would be coupled to the Modicon controller which could instruct the programmed shut-down sequence to commence, thereby reducing the severity of any leak in the system.

Costs for fluid handling storage systems for R11, No. 2 fuel oil or jet fuel, lubricating oil, and a refrigerant such as ammonia are listed under the auxiliary equipment in Table III-6. The cost of the auxiliary equipment necessary to support the office, such as air conditioning systems, have not been included here. The cost of the induction generator system does not include the cost of electrical grid connections to the transformers.

F. Instrumentation and Data Acquisition

A data acquisition system consisting of a 40-channel capacity advanced calculating data logger is proposed for each of the heat pump and power generation test bays. Data logger systems of this type can handle data from a variety of types of sensors, such as thermocouples, resistive thermal devices, and flowmeters, and record a wide range of AC and DC electrical signals. Data can be recorded on paper tape, magnetic cassettes, or floppy discs. The capability exists for entering the basic test data into a larger remote computer or an MST link. A functional flow schematic of such a calculating data logger system is shown in Fig. III-5.

The Autodata Ten/10 automatic data logger is recommended specifically. This microprocessor-controlled, calculating data acquisition system is designed for industrial, laboratory, or process control environments. Two Intel 8085 processors allow this system to provide data acquisition flexibility of a high order but the system does not require a sophisticated computer language for programming. The system is programmed using simple English language statements in a tabular format. The built-in cathode display enhances the programmability by allowing the operator to select from a variety of possible programming steps and to display data simultaneously while checking printed output data from randomly accessed channels. The scan rate of this device is 40 channels per second for standard resolution and 10 channels per second for high resolution, with excellent noise rejection capability. Additionally, each test system can be wired to a system of annunciators to provide interlock warnings if one of a variety of preset parameters is exceeded. An automatic clock is built into each system to allow a wide variety of data scans on a 24 hour basis. Additional or back-up power supplies are built into each data scanner; these permit power line sag down to 90 volts. A back-up battery clock maintains the correct time even if the system were inadvertently turned off. The system can be programmed to scan data at some predetermined

FUNCTIONAL SCHEMATIC OF DATA SYSTEM

FIGURE III-5

rate or on demand by the control operator. It has the capability of linearly scaling as many as twenty functions in the form of $Y = MX + B$. These scaling functions are used to convert analog inputs to their appropriate engineering units and to display and/or record them. The flexibility of these units is improved by an automatic full scale and zero calibration function. It is performed at periodic intervals automatically, precluding the need for manual calibration during the test program. The calibration standard is directly traceable to the National Bureau of Standards.

A listing of the system costs is presented in Table III-7. This listing includes the data logger main frame as well as auxiliary components. The system specified has sufficient capability to record all the test measurement requirements noted in Tables III-3 and III-4.

G. Preliminary Cost Estimate

A preliminary budgetary and planning cost estimate for the EAST Facility is presented in Table III-8. This table shows the estimated cost of the core structure as well as the estimated costs of the major facility support systems necessary to perform tests on currently envisioned heat pump and electrical power generation systems. The estimated core structure cost is based on an average of \$75 per square foot of building and power generation pad area. Where it was possible, costs for other items were developed in preceding sections of this report.

TABLE III-7

ADVANCED CALCULATING DATA LOGGER SPECIFICATIONS AND COSTS

<u>Quantity</u>	<u>Item</u>	<u>Cost</u>
1	Mainframe A-Ten/10	\$ 6,950
1	Mini-MATHPAC 1020-05	550
1	24K Bytes Expanded Memory 1032-04	5,200
1	Remote Scanner 1016-01	1,290
1	Messages 1022-05	400
1	Time Averaging 1020-06	250
2	3-wire Multiplexer 1060-31	550
2	5-wire Multiplexer 1060-51	700
1	Voltage Input Module 1061-31	70
4	RTD Input Module 1061-51	600
2	Contact Output Cards 1070-01	800
1	Alarms 1021-05	400
1	Pulse Counting Input Module 1078-25	990
1	RS-232-C Interface	850
1	Cassette Recorder 1040-10	1,450
TOTAL		\$ 21,050

TABLE III-8

BUDGETARY AND PLANNING COST ESTIMATE FOR EAST FACILITY

● Facility Building (nominally 22,500 ft ² at \$75/ft ²)	\$ 1,690 K
● Additional Structures	500 K
● A & E Cost (3% overall facility cost)	235 K
● Facility Electrical Power Installation	500 K
● Machine Shop Equipment	400 K
● Cooling Water System	1,800 K
● Hot Water Piping	1,800 K
● Hot Water Back-up System	300 K
● Control Systems & Leak Detectors	65 K
● Instrumentation and 2 Data Loggers	70 K
● Safety & Security Provisions	100 K
● Fluid Handling & Storage System	225 K
● Miscellaneous Auxiliary Equipment	315 K
● Contingency (20%)	<u>1,600 K</u>
TOTAL	\$ 9,600 K

H. Manpower

To determine manpower requirements for the EAST Facility, it was first necessary to formulate a functional flow-scheme for programs that will be conducted at the facility. This functional flow-scheme indicates two main operational areas, Program Operations and Facility Operations, and is shown in Fig. III-6.

The Program Operations staff will interact with the customer or supplier of the given test apparatus to initially define the objectives of the specific test program. Facility Operations staff will assist in this activity as necessary to ensure that facility capabilities are fully understood, that special test requirements can be satisfied, that preliminary estimates of schedules and costs are reasonable, etc.

Once the objectives of the test have been defined, a test plan will be formulated with the customer's interaction. This test plan will be a comprehensive document designed to describe all the proposed testing activities to be performed in order to satisfy test objectives, the facility services which will be utilized, the facility manpower which will be required, a schedule for these requirements, and the direct and indirect costs of testing. With customer's concurrence and project funds made available, detailed test operating procedures will be formulated and a detailed test apparatus geometry will be developed. This geometry will be based on the customer's installation drawings and instructions and will include specific provision for instrumentation requested by the customer and/or believed to be necessary by the Program Operations staff.

After developing the test apparatus geometry, the Program Operations staff will interact with the Facility Operations staff to mutually define the facility modifications necessary to install the specific test apparatus and new structures, equipment, supplies, and/or services needed to support the test project. During this interaction, critical interface points will

be identified and a plan formulated to ensure that the facility will be ready to accept the test apparatus on time. The plan and the test project schedule will incorporate lead times for these activities. The Facility Operations staff will design the needed facility modifications and new structures, perform or overview the actual modifications and fabrications, order new equipment and supplies, and arrange for special support services.

Upon receiving the hardware from the customer, the Program Operations staff will be responsible for inspecting the hardware to ensure that it matches the drawings that were initially supplied by the customer and that the correct equipment was received in satisfactory condition. Deviations will be dealt with in accordance with configuration management requirements addressed in the test plan. After the received test apparatus has been inspected by the Program Operations staff, it will be turned over to the Facility Operations group for assembly, installation, and integration with the EAST Facility. The customer may have a representative on hand to overview the assembly and installation of the hardware to insure that it is consistent with the manufacturer's approach. In some instances, the test plan may call for a manufacturer support team to be utilized in a more active role at this time.

After the test apparatus is in place, the test plan and test procedures will be modified to coincide with any amendments of the test objectives or the hardware. When the altered test plan/procedures have been reviewed by facility personnel and the customer and approved by all parties, the checkout of the test apparatus will begin. The Facility Operations group will be responsible for actual day to day test conduct. This group will regulate and monitor the conditions to which the test apparatus is subjected in accordance with the test plan. It will regulate and monitor the acquisition of test data, in accordance with the test plan. This group will interact frequently with the Program Operations staff to insure that there is mutual understanding of test objectives, test procedures, priorities, and other matters.

The acquired test data will be reviewed for validity and provided regularly to the Program Operations personnel who will reduce, analyze, and document these data in accordance with the test plan. Regular monitoring of these data and data trends will require frequent interactions between Program Operations and Facility Operations personnel with regard to daily test operations.

As part of the test program, the data analysis will be conducted in a timely fashion to ensure that all trends from the data are consistent with the trends expected by the testers or by the customer. At the conclusion of a specific test program and at specified time periods, the Program Operations staff will prepare and submit reports detailing the performance of the test equipment, the actual test environments and test conditions, the test objectives, data packages in prescribed forms, and interpretation of these data based on analyses conducted by Program Operations personnel. These data will be forwarded to the customer and the sponsoring agency and distributed further per the latter's direction.

The functional flowchart shown in Fig. III-6 depicts one of several variations of coordinated group activities. This scheme was chosen for its separation of test conduct and other test project functions, i.e., planning, data analysis, and reporting.

Using this flowchart as a model, a staff organization chart was prepared, shown in Fig. III-7. In this organization, a facility director would be supported by a program operations manager, a facility operations manager, plus legal and financial staffs. There has been no attempt in this report to define or detail the size requirements of the legal/financial staff. The two operating arms would each have several sub-groups. Program Operations would include a Project Engineering staff and a Data Planning, Reduction, and Analysis staff to support its activities; Facility Operations would include a Facility

Engineering staff, a Test Operations staff, and a Plant Services staff.

The specific staffing for each of these groups is shown in Fig. III-8 and is based on the assumption that the EAST Facility will have two main test bays, one electrical power generation test bay and one heat pump test bay, operating simultaneously. Three project engineers are required to maintain program operations. One engineer will be assigned to each test bay, with a third engineer necessary to plan and organize the next test in line. These project engineers will perform test planning, including helping the customer define test objectives and writing the formal test plan documents; assist the Facility Operations Group in planning and effecting the modification of the facility to accommodate the test apparatus, installing the test apparatus, then integrating it and the facility; reduce and analyze test data, evaluate test apparatus performance on a frequent basis, and interact regularly with Facility Operations (Test Operations) personnel to ensure a continuing high quality in the conduct of testing; document test data, equipment performance evaluations, and matters of quality assurance including configuration management; and report test project results in accordance with the formal test plan. Additionally, an instrumentation engineer, a mathematician, and a computer programmer will assist these project engineers in formulating a project data plan, instrumentation requirements, data reduction and interpretation, analytical methods, data presentation, and reporting. Several engineering aides will help throughout the test program in planning, scheduling, data acquisition, data reduction/storage/retrieval/presentation, documentation, test monitoring, and interactions with other participants.

Under the Facility Operations Group, the Facility Engineering staff will maintain, operate, modify, and demodify the EAST Facility in accordance with the overall test program. It will design facility changes and test apparatus installations based on requirements provided by the Program Operations group.

FUNCTIONAL FLOW CHART FOR EAST OPERATIONS

Fig. III-7

PROPOSED STAFF ORGANIZATION FOR EAST FACILITY

Fig. III-8

PROPOSED MANPOWER STRENGTH FOR EAST FACILITY (3 SHIFT OPERATION)

<u>PROGRAM OPERATIONS</u> 1 Sr. Engineer		<u>FACILITY OPERATIONS</u> 1 Sr. Engineer		
<u>PROJECT ENGINEERING</u>	<u>DATA PLANNING/ REDUCTION/ANALYSIS</u>	<u>FACILITY ENGINEERING</u>	<u>TEST OPERATIONS</u>	<u>PLANT SERVICES</u>
3 Engineers	1 Engineer (Instrumentation)	1 Sr. Engineer	3 Engineers	1 Supervisor
3 Engineering Aides	1 Mathematician	4 Engineers	5 Controllers	1 HVAC Specialist
	1 Computer Programmer	- ME		1 Carpenter
6 - Staff Total	2 Engineering Aides	- Instrn.	8 - Staff Total	1 Machinist
		2 Engineers, Design		2 Technicians, Instrn.
	5 - Staff Total	3 Technicians, Mechanical		2 Plumbers
		3 Technicians, Electrical		2 Electricians
		2 Draftsmen		2 Supply Specialists
		3 Equipment Operators		2 Janitors
		3 Engineering Aides		
				14 - Staff Total
		21 - Staff Total		
<u>Facility Total:</u>				
12 - Program Operations Group				
44 - Facility Operations Group				
4 - Secretarial Staff				
1 - Director				
61 - Total			44 - Group Total	

It will effect these actions, drawing upon Plant Services personnel as necessary. Facility engineers will assist in customer interactions during planning and testing activities and in the formulation of the test plan and cost estimates for each test project. They will be responsible for overall facility operations, maintenance, and upgrade. An equipment operator for each shift will control operation of all valves, boilers, heat exchangers and other support equipment. Technicians will perform support equipment installation, maintenance, modification, calibration, etc.; assist in the installation and integration of test articles; and perform operations with support and test equipment. Engineering aides will assist in all facets of facility operations.

The Test Operations staff under this group will consist of engineers and controllers who will be primarily responsible for performing test functions in the two test bays. Controllers will operate test articles from central test control consoles. They will be responsible for ensuring that test sensors are in place and operating properly and that test data is being collected and recorded. Test engineers will formulate detailed test operations procedures and schedule test operations in accordance with the formal test plan; ensure the validity of collected test data and the recording/storage of these data; interact regularly with Program Operations personnel to provide them test data, assist them in data reduction/interpretation/analysis and equipment performance evaluations; and assume overall responsibility for test article operations, including matters of safety, environmental impact, and quality assurance.

Plant Services personnel will perform housekeeping functions, various logistical support functions, and various specialty support services. They will be called upon for both facility support and test apparatus support as necessary.

In addition to the above, legal, financial, and secretarial support services will be required. At this time it is assumed

that legal and financial services will be provided by contracts or other arrangements. Secretarial support will consist of one executive secretary, two word processor operators, and one file clerk.

Total staffing requirements for three-shift operations are:

Facility Director	1
Secretarial Staff	4
Facility Operations Group	44
Program Operations Group	12
Total	61

APPENDIX I

DEFINITION OF TERMS, PHRASES, AND ACRONYMS

The definitions and descriptions of terms, phrases, and acronyms given in this appendix are those used in the body of this document. Use of other meanings may alter the intent of the policies expressed or information presented.

1. Authority - Those instruments, methods, defined activities, authorized plans, and working documentation, assigned decision powers, organized management and fiscal powers, and other mechanisms or powers provided for the execution of responsibility.

2. Availability - The ratio of test article operating time to total time.

3. CEMS - Central Energy Management System, a system which converts residual heat energy to useful energy in the form of hot water, steam, and/or electrical power, depending on the site applications.

4. Confidence Level - The lower bound of the statistical confidence interval.

5. Configuration Management - A systematic and documented procedure to approve or disapprove changes in the test facility or test article and to provide the necessary records for the present condition and traceability of the system components.

6. Corrective Action - The measure taken to prevent or to alleviate failures based on the failure analysis.

7. Degradation - Reductions of performance or availability of a system, subsystem, or component under test.

8. DOE - U.S. Department of Energy.
9. EAST - Energy Applied Systems Test, part of the REAP program in which residual heat recovery equipment will be tested for performance and economic feasibility (See Introduction for EAST objectives).
10. EAST Facility - A test facility to be constructed at the Savannah River site to contribute to the national residual heat recovery program.
11. EAST Facility Requirements Document - A document being prepared by the South Carolina Energy Research Institute which will contain thoroughly detailed requirements for designing and constructing the proposed EAST Facility. Included will be definitions of existing residual heat resources, descriptions of heat recovery systems and devices, test requirements, facility support equipment and services requirements, and physical plant requirements.
12. ERI - The South Carolina Energy Research Institute (See item #29 in this listing).
13. Failure Analysis - The analysis of a failure event to determine its root cause and to identify the mode of failure.
14. GDP - Gaseous Diffusion Plant, a federal facility for nuclear materials production/ enrichment.
15. Government - The agency or entity that exercises technical, contractual, fiscal, and management authority over the EAST Facility.
16. High Temperature - 200°F to 1000°F, a range of interest for testing heat recovery equipments at the EAST Facility using supplemental heat resources.

17. Low Temperature - 100°F to 200°F, a range of interest for testing heat recovery equipments at the EAST Facility using nuclear reactor effluent as a natural resource and some supplemental resources.

18. P Reactor - One of three nuclear reactors currently operating at Savannah River Plant, the one likely to provide the low temperature residual heat resource for the EAST Facility.

19. Par Pond - A man-made lake at the Savannah River Plant used to provide cooling water for nuclear reactor operations. Par Pond obtains its water from the Savannah River.

20. Performance - The collective relationships between input and output of a test article, including such characteristics as controllability, operability, and quality of product.

21. Portsmouth GDP - The Portsmouth gaseous diffusion plant, a U. S. Department of Energy facility on the Clinch River near Portsmouth, Ohio. The primary mission of the installation is to produce enriched uranium.

22. Precursor Requirements - The items of data or other information required prior to test planning and test implementation to ensure the accomplishment of test objectives or the safety and environmental acceptability of the test.

23. Quality Assurance - An established program of procedural control applied to each test article throughout the period of its test operations and applied to the EAST Facility for its lifetime. Procedural control will include configuration management, quality control, inspection and review, documentation, reporting, and other activities which in the aggregate will help to ensure high levels of quality in all facility operations and in all products of testing.

24. Rankine Cycle System - An energy conversion system which accepts heat energy and produces mechanical shaft power which can be used for electrical power generation or other work.

25. REAP - Residual Energy Applications Program, a program under the U.S. Department of Energy aimed at recovery of residual heat energy in U.S. industries, utilities, and federal facilities (See Introduction for REAP objectives).

26. Residual Heat - Heat energy contained in the effluent flow from a plant or process. Flows may be gaseous, liquid, or a combination of both. Temperature ranges of 100°F to 1000°F are of interest to EAST.

27. Responsibility - Those actions, tasks, products, plans or other elements of programs explicitly or implicitly assigned to a particular organizational entity for execution and accountability.

28. Savannah River Plant - A U.S. Department of Energy facility near Aiken, South Carolina, on the Savannah River. The primary mission of the installation is to produce nuclear materials for national defense and some industrial uses.

29. South Carolina Energy Research Institute (ERI) - A nonprofit organization pursuing energy recovery and conservation objectives for the state and the nation. Currently, ERI is responsible to the Government for developing the EAST Facility Requirements Document.

30. SRP - Savannah River Plant.

31. Systems Analysis Report - A final report on heat recovery systems, including heat pumps and electrical power generation systems, prepared for DOE by ERI.

32. Types of Tests:

a. Exploratory Tests - Tests seeking engineering data for the purposes of initial design, proof of principle, extension of basic engineering understanding, limits of equipment, materials or other related data.

b. Development Tests - Tests associated with reduction to practice of the known engineering principles for equipment at or near a commercial design in order to further reduce or eliminate the uncertainties in the design.

c. Application Tests - Tests intended to provide data specific to users' particular applications.

d. Confidence Tests - Tests of complete systems or isolatable modules of systems, the goal of which is to demonstrate to the satisfaction of potential users and purchasers that the equipment meets manufacturers' claims for performance, operating cost, and availability.

APPENDIX II.

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APPENDIX III

PROS AND CONS OF SELECTED POLICY QUESTIONS

The following discussions constitute pro and con considerations and conclusions associated with some policy matters presented in section II of this report. This information is preliminary and generic and subject to being superseded by arguments which may be presented in the EAST Facility Requirements Document.

1. Question: Should the EAST Facility be designed to accept most sources of residual heat and known cycles of heat recovery devices?

Pro: The residual heat recovery program is in its early stages and it is not yet known which source or cycle characteristics will be predominant. The basic facility should be designed to accept all potential sources and cycles which are deemed to be practical and within the REAP high or low temperature residual heat recovery programs.

Con: Proper simulation of some residual heat sources such as gases with solid or corrosive content, batch content, or contaminated water may be difficult and expensive. This breadth of capability would necessitate higher user costs and incur larger demands for space, instrumentation, personnel, and services. Therefore, the facility should be limited in its scope of capability.

Conclusion: DOE should provide the most practical variations in a staged facility growth, in accordance with the REAP Plan. It would be premature to limit the facility capability as a matter of policy.

2. Question: Should the facility be designed to accept a wide range of residual heat recovery system sizes?

Pro: A principal objective of the EAST Facility is to assure potential users of residual heat recovery systems that satisfactory levels of confidence can be associated with specific equipment performance, maintainability, availability, and reliability and that acceptable economic and technical returns can be expected. Such assurances will require realistic demonstrations in the actual application modes to the fullest possible extent. Therefore, the facility should be designed to be capable of full scale tests of competing designs, with the exception that for very large, modularized systems testing would be limited to individual modules.

Con: Full scale components, subsystems, and some complete systems will be developed and tested by development contractors in their own facilities. These contractors are not likely to have facilities capable of testing some very large systems. Contractor tests and subsequent independent confidence tests of very large systems should be performed at test/demonstration installations in situ. Then, the EAST Facility could be limited in scope and capability to smaller system/module testing.

Conclusion: At the present time the ultimate sizes and capacities of competitive commercial heat recovery equipment cannot be predicted. It appears to be economically impractical to construct, equip, instrument, and operate more than a very few test/demonstration installations in situ in addition to creating an EAST Facility of moderate scope and capability. As a matter of policy, therefore, the EAST Facility should be designed with a growth capability to accept commercial size equipment as it is developed.

3. Question: Should the EAST Facility be used for most types of testing?

Pro: A facility containing the basic capability to test hardware in various stages of development should be fully utilized for the benefit of the national program of residual energy recovery. For large scale equipment it would be prohibitively expensive to replicate these testing capabilities at various developers' facilities. EAST Facility management can establish priorities among competing demands for facility time to allow most types of testing.

Con: Equipment manufacturers and development contractors prefer to perform their own testing and to retain control of their test programs. Therefore, the EAST Facility should be limited to confidence testing.

Conclusion: Maximum progress may be ensured by devoting both the EAST Facility and the facilities of manufacturers/developers to the development and confidence testing of residual energy recovery components and systems. Therefore, the EAST Facility should be committed to performing these types of tests.

4. Question: Should alternative modes of test program sponsorship and test article ownership be used?

Pro: Past experience in nationally owned facilities has shown that accomplishments are maximized when provisions are made to accommodate the testing needs of developers and users, as well as the Government program offices. Thus the precedent has been established for a composition of test projects which includes Government funded test projects with Government owned test articles, Government funded test projects with privately owned test articles, and privately funded test projects with privately owned test articles.

Con: Conflicts may arise in facility scheduling; complicated financial accounting may be required; test operations

may vary with the mode; and data handling and dissemination may differ with each mode.

Conclusion: The EAST Facility should provide for at least three modes of test article ownership and test project sponsorship, as described above. Priority and schedule conflicts can be resolved by a management committee. Financial accounting should be the same for all tests, but test project costs will differ for the type of test sponsor (direct costs for Government sponsor, direct and indirect costs for the private sponsor). Test operations and data handling/dissemination will vary with each mode, as described in following paragraphs.

5. Question: Should the Government determine precursor requirements for test projects in the EAST Facility?

Pro: The Government, as facility owner and ultimately responsible party, should determine such requirements with the assistance of the facility operator, the test requestor, and the test article manufacturer or developer. The requirements should range from minimal, safety-related technical data for exploratory development test projects being privately sponsored to extensive manufacturer's design, fabrication, and test information for reliability test projects being sponsored by the Government. Conflicts between the facility operator and the equipment supplier can be minimized in this way.

Con: The precursor requirements are primarily technical and are intimately interrelated with the detailed test plan which is developed among facility personnel, the test requestor, and the manufacturer or developer. The addition of another party is unnecessary.

Conclusion: The Government should delegate responsibility for precursor requirements determination to EAST Facility management. Facility personnel will then be responsible for such

determinations during test planning activities for each test project. Disputes will be arbitrated by the Government.

6. Question: Should EAST Facility test data be broadly disseminated?

Pro: Data acquired in a government facility should be disseminated as broadly as possible to enhance technology, encourage competition, facilitate commercialization of satisfactory equipment, and discourage attempts to commercialize unsatisfactory equipment.

Con: A policy of broad dissemination of test data may inhibit participation by some equipment developers. Proprietary interests must be protected. Development testing results should not be made available to competitive equipment developers.

Conclusion: Confidence testing results should be broadly disseminated after proprietary information has been deleted. Development testing results should be provided only to the equipment developer or, with developer's permission, disseminated further after proprietary information has been deleted.

7. Question: Should the roles of EAST Facility participants be defined now?

Pro: Definition now would enable early planning by all potential participants and constructive discussions on test operations, test support, job descriptions, personnel recruitment, operating procedures, etc.

Con: It is too early to define roles. Needed now are better definitions of anticipated test articles and corresponding test requirements, the volume of business which will be expected, and the specific professional and technical capabilities of

facility personnel for test planning, test operations, and test management.

Conclusion: DOE should establish a roles policy for EAST Facility participants after completion of the EAST Facility Requirements Document.

8. Question: Should the Government establish schedules and priorities for EAST Facility operations?

Pro: The facility will be Government owned; the Government should establish schedules and priorities to ensure that the greatest benefit is derived for the national program of residual energy recovery.

Con: Facility personnel, working with the equipment industry, will be more intimately aware of conflicts in proposed test plans, problems with test article readiness and facility readiness, funding difficulties, personnel disputes, and other matters; it is more logical for facility personnel to establish schedules and priorities.

Conclusion: A management committee should be formed of DOE and key facility personnel. This committee should be delegated responsibility to establish test priorities and schedules and should be chaired by a facility manager. Committee decisions should be subject to DOE review.

9. Question: Should EAST Facility personnel have sole authority to start or stop test operations during a phase of active testing?

Pro: Facility personnel are ultimately responsible for safety and environmental protection and, therefore, should have this authority alone.

Con: The equipment developers have more intimate knowledge of test article performance characteristics and failure mechanisms and should have authority to stop or start test article operations.

Conclusion: For test projects which require active test support by developers' personnel, the matter of test control must be carefully defined during test project planning. Then, during active testing, EAST Facility testers should have overall authority for starting or stopping test operations. However, an equipment developer representative may be granted an authority to require termination of test article operations in cases of safety concern, impending damage to facility or test article, potential for adverse environmental impact, or other reason.

10. Question: Should failure analyses and corrective actions be performed by EAST Facility personnel?

Pro: In confidence testing there will be an expressed or implied certification by the EAST Facility that the test article configuration and the quality control performed during test operations were consistent with the commercial product and its intended mode of application. For this reason, EAST Facility personnel should be responsible for performing failure analyses and corrective actions associated with test articles as well as facility support equipment.

Con: Equipment developers have the ultimate responsibility to deliver an acceptable product to a user; therefore, they should have responsibility for failure analyses and corrective actions.

Conclusion: For exploratory and development testing, final authority should rest with the test requestor with review by facility personnel for safety, environmental impact, and facility compatibility. For confidence testing, initial determinations

should be made by the test requestor, but EAST Facility personnel should have review and veto/approval authority for matters involving safety, environmental impact, facility compatibility, quality control procedures used during testing, and configuration management associated with test article and facility.

APPENDIX IV.

CONFIDENCE TESTING

1. Introduction and Background

The EAST Facility may be expected to perform testing on waste heat recovery devices at various stages of their development, ranging from programs for establishing basic engineering design principles, through tests for establishing reduction of these principles to hardware applications, to test programs which provide confidence in the commercial version of the system in its intended application. It is the last of these types which will be discussed primarily in this appendix.

The overall objectives of confidence testing are to hasten the rate of commercialization of waste heat recovery devices necessary for the national goal of energy conservation. To accomplish this purpose the EAST Facility would provide data which should be of sufficient scope and accuracy to assure prospective investors that the system in question has the following attributes:

- a. System performance and system degradation are in accordance with prescribed specifications,
- b. The System is operable and controllable within prescribed specifications,
- c. The System is safe,
- d. Environmental impact is defined for the system,
- e. Operating, material, spare, and maintenance costs* are within prescribed specifications,

f. Scheduled and unscheduled maintenance times are within prescribed specifications,

g. The test article is consistent with commercial hardware; scaling, if any, is based on a sound technical framework.

*It is assumed that the EAST Facility will not be directly involved in issues of capital cost, installation cost, profit, etc.

2. DEGREE OF CONFIDENCE

a. General

Experience shows that very high confidence cannot be provided by any one test or small number of tests. Even in carefully controlled programs, problems emerge as operating time multiplies. Sometimes these problems are site or operation specific; sometimes they are generic with respect to the equipment. The question to be answered, therefore, is how much confidence is enough? There is no specific answer. The factors involved in satisfactory confidence include both technical and financial considerations. The maximum acceptable risk is usually set by extraneous considerations such as current company profitability, debt, and management philosophy. Each company will decide upon its own acceptable levels of risk.

Past experience indicates that for most users the acceptable risk for a new technology is low. The aim, therefore, is to demonstrate low risk without excessive testing.

b. Elements of Confidence

(1) Performance and Degradation

Operation of a test system for a reasonable duration under reasonable test conditions can reveal component or subsystem interactions that may have been overlooked in component or subsystem development programs. Such testing can provide data on realistic full scale performance. However, for confidence testing the following are also required:

- (a). Identification of failure mechanisms and degradation mechanisms at the component level,

- (b). Determination of failure rates and degradation rates at the basic level in component tests,
- (c). Correlation of component operating conditions against full-scale operating conditions to develop full-scale failure rates,
- (d). Sufficient test time and realistic operating conditions to excite the failure mechanisms, and
- (e). Post test verification of the full-scale versus component test data correlation.

(2) Operability and Controllability

Full scale system performance tests are needed to prove the risk of investment to be low or negligible. However, these tests must include the margins of operability and stability in order to be conclusive.

(3) Safety and Environmental Impact

Full scale system performance tests will include measurement and characterization of effluents, noise or other pollution components and will yield a realistic measure of the pollution risk. Safety will be ensured by comprehensive analyses of fault tree types and with adequate and accurate data bases for safety related components. If situations exist for which component data or simulation techniques are inadequate, then experimental simulation will be required.

(4) Operating, Material, Spare, and Maintenance Costs

Full scale performance tests are the principal source of these data. Rigorous planning, record keeping, and analysis will be required to assess the variability of these factors.

(5) Operating Endurance

The practices described in paragraph 2b (1) will provide information on endurance, expected failures or degradations, and the effects of these failures/degradations on the components and systems. The risk of failure to a potential buyer is primarily in terms of product cost, plus cost and time to restore the system to its original condition. Systems are not necessarily at high risk if they are not designed for zero failure. The combinations of predictable failure mechanisms, limited damage, and ability to repair within permissible downtime periods and at anticipated cost can reduce risk to acceptable levels. The performance tests should therefore demonstrate these characteristics.

(6) Scheduled and Unscheduled Maintenance

Component tests will establish the type, location, and signatures of failure mechanisms appropriate for monitoring in order to predict the onset of failure or degradation. In system performance tests these data will be applied in order to anticipate system failure or degradation primarily for the purposes of optimizing preventative and corrective maintenance actions and minimizing damage.

These activities will be integrated into an optimized maintenance plan, spares plan, training and tooling plan, and a test design which utilizes the maintenance concept to limit downtime. In this way, system availability will be provided with high confidence even in the presence of uncertainty in failure rates.

In addition, test design practices utilizing appropriate redundancies are necessary to ensure availability. However, redundant systems are unlikely to be available to the test agency. The performance tests should therefore include maintenance tests, both simulated and actual. These tests will help to establish maintenance repair times, scheduled and unscheduled, and their variances to a very high degree of confidence. Thus, availability confidence in the 90-95 percent range may be assured even in the presence of uncertainty of operating endurance.

(7) Commercial Hardware

System performance tests of prototype hardware are useful and sometimes necessary for determining systems interactions and establishing engineering principles. However confidence can be achieved only by testing commercial hardware. In the event that the system design is modularized and adequate isolation of the modules is realized, then tests of separate modules are realistic. Otherwise, full scale tests in the actual commercial configuration are required.

(8) Accelerated Life Tests

Another method for establishing confidence is to perform accelerated life tests where this is possible. Such testing is discussed in Appendix V.

APPENDIX V.

ACCELERATED LIFE TESTING

1. Introduction

Accelerated life or overstress testing is a commonly used technique to shorten test programs for long life equipment. Descriptions of some of the techniques in simplified terms are given in reference 1 of this appendix. Overstress testing is only one aspect of statistical testing.

2. Description

An accelerated life test is a test in which the failures or degradation mechanisms present in a machine are stimulated at a higher rate than in normal operation. The purpose of this procedure is to induce observable degradation or failure in a shorter test period than would be possible if the test were conducted at normal conditions. A necessary condition for accelerated life tests is that the observed degradation or failure rate can be analytically reduced to normal stress conditions or intelligently extrapolated to normal conditions.

3. Planning Process

a. Failure or Degradation Mechanisms

The mechanisms of failure must be known. They can be determined on the basis of failure mode and effect analysis, design reviews, component tests, previous experiments or analytical techniques. Some mechanisms are observable prior to failure; e.g., corrosion and erosion, material elongation or deformation, and fouling.

Some mechanisms are not readily detectable until failure occurs; e.g., brittle fracture, electronic shorts, and leaks. Mechanisms that are observable can be tested by supplying less than failure stress and determining the rate by measurement. Mechanisms that are not observable require test to failure or to maximum possible stress. The initial steps in planning therefore are:

- (1) Identify failure or degradation mechanisms,
- (2) Determine analytically or experimentally the relationship between stress, time, and each degradation or failure mechanism, and
- (3) Determine if tests must be conducted to failure or observable degradation.

b. Design of Programs

(1) Pre-Planning Analysis

Overstress testing is usually performed at component level during which the mechanism under study may be easily isolated and stimulated without potential for imposing other unacceptable stresses. However, in many cases, tests can also be performed at assembly levels. It is a required step in all cases to evaluate the effects of the stress level and the resulting failure in ways that will contribute to the knowledge of the failure mechanism and failure/degradation rate that is being sought.

(2) Approach

The general planning approach is to conduct tests at stress levels higher than design and determine degradation or failure rates at measured intervals. This process is illustrated schematically in Figure App. V-1. Tests are performed until measurable results are obtained. Distributions are determined and extrapolated to the service life analytically if the mathematical laws are known and empirically if they are not. In this illustration the sketch shows a satisfactory result; that is, at the service life there remains a significant margin. If there is overlap of the extrapolated results with normal stress then a determined failure and confidence are established.

An alternative approach increases stress in a stepwise mode until failure or impending failure is encountered. The test is repeated and distributions such as those in Figure App. V-1 are found.

(3) Combined Stresses

In many real situations the failure mechanism is responsive to more than one stress. In these cases the overstress test is conducted by increasing all stresses as indicated in Figure App. V-2. Overstress is applied along the diagonal when interrelated effects exist which cannot be separately evaluated. These tests are difficult to interpret and to reduce to simple numerical criteria. They are most useful in identifying complex failure mechanisms.

Fig. App. V-1

SERVICE LIFE EXTRAPOLATION, SINGLE STRESS

Fig. App. V-2

SERVICE LIFE EXTRAPOLATION, COMBINED STRESSES

4. Interpretation of Results

Interpretation of system overstress test data is greatly aided if the failure mechanism under investigation has first been evaluated at the component level. Such evaluations yield the physical laws or empirical relationships which will be used for extrapolation to extended life. The correlation of system overstress tests with component overstress results reveals the presence or absence and degree of severity of any combined effects. The planning and interpretation of overstress tests should encompass the whole system development program if maximum information return is to be realized.

Reference: John H. Fasal, Practical Value Analysis, Hayden Book Company, Inc., 1972.

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