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MANAGEMENT PLAN

HIGH-TEMPERATURE INDUSTRIAL HEAT PUMP

DEPARTMENT OF ENERGY
CONTRACT NO. EC-77-C-03-1480

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1. INTRODUCTION

1.1 PURPOSE

This document describes the management plan to be used by the AiResearch Manufacturing Company of California, a division of The Garrett Corporation, in the implementation of Department of Energy (DOE) Contract No. EC-77-C-03-1480 for the development and demonstration of a high-temperature industrial heat pump for milk drying. The program was initiated October 1, 1978

The management plan will provide the information and management framework required to establish and maintain effective program management. When fully implemented following DOE approval, the plan will serve as a baseline document for compliance with DOE financial reporting and performance monitoring requirements for the heat pump program. The plan will be updated on an ongoing basis and used as a working document throughout the program. The updated plan will be resubmitted prior to the start of each program phase.

1.2 PROGRAM SCOPE

The heat pump development program is divided into five distinct phases to ensure that the selected system (1) will be of optimum size and configuration and (2) will have performance and cost characteristics that will be economically attractive to a variety of industries. The five program phases are briefly described below. A program summary schedule is shown in Figure 1-1 and the major program milestones are shown in Figure 1-2.

Phase 1 - System Optimization. The selected size will be reviewed in detail and a heat pump will be designed that will maximize energy savings for the operator. The breadth of other potential applications of the heat pump will be investigated to determine what capacity and performance variations are necessary to increase market penetration. The baseline system has an electrical motor drive. During this phase of the contract, the potential advantages of driving the heat pump with a gas turbine will be studied.

Phase 2 - Design. The heat pump system and components selected will be designed for production, using commercial standards. An important part of this design task will be the installation design to ensure that all facets of installation and operation have been included. In addition, the design will be reviewed for possible improvements and to verify that system costs, including operating and maintenance costs, are within acceptable levels.

Phase 3 - Component Fabrication and Performance Testing. The heat pump system components will be fabricated, assembled into a system, and tested under full load prior to being delivered to the demonstration site. Proper system verification therefore will be verified prior to installation at the site.

Phase 4 - Installation and System Startup. The heat pump system will be installed at the demonstration site and integrated into the overall plant. After installation, but prior to on-line demonstration, the heat pump system will be tested to verify conformance with design requirements at the site.

Phase 5 - On-Line Demonstration and Business Plan. The heat pump system will be operated for a period of 6 months to demonstrate the concept. The system will be fully instrumented to fully document total energy savings. A detailed business plan for commercial production of the heat pump system will also be prepared.

S-36061

Figure 1-1. Program Summary Schedule

S-36060

Figure 1-2. Major Program Milestones

2. PROGRAM DESCRIPTION

This section describes the overall objective, technical approach, and program scope for development and demonstration of a heat pump system for use in an existing milk drying operation.

2.1 PROGRAM OBJECTIVE

The overall objective of the DOE-sponsored high-temperature heat pump program is to determine the technical feasibility and economic viability of using heat pumps to reclaim low temperature waste heat from industrial processes. Because of the noncontaminating nature of the Brayton-cycle heat pump and process operating conditions, ideal applications are found in the food process industries. Milk drying is a representative process and has been selected for concept demonstration.

2.2 TECHNICAL APPROACH

2.2.1 Existing Milk Drying Operation

A typical existing milk drying operation is depicted schematically in Figure 2-1. The milk is initially condensed in steam-heated evaporators from about 8 percent solids to 45 percent solids. The water vapor is condensed and leaves the process at 120° to 160°F. A portion of the condensed milk is normally used directly in other products. The portion of the milk to be dried is sprayed through nozzles into the dryer where the milk droplets meet hot, dry, filtered air and the solids content increases to at least 97 percent. All milk drying facilities also include refrigeration for storage of incoming milk and process milk products, since any curtailment in the fuel supply or any plant failure could otherwise lead to spoilage. The object of this program is to recover the waste energy from the process, in particular from the exhaust gas leaving the dryer, and to use it to reduce system energy requirements.

2.2.2 Heat Pump System Milk Drying Operation

Operation of the milk drying process with the heat pump system installed is depicted schematically in Figure 2-2. As shown, ambient air enters the turbine after being filtered in the existing filters. Expansion of the air through the turbine provides a portion of the power required to drive the system; the remainder of the power is provided by an electrical motor. The air cooled by this expansion is heated by the waste water produced by the milk evaporation process. The air is further heated by the dry milk processing bag house exhaust gas. The heated air is then compressed by the compressor to ambient pressure. This compression process further increases the air temperature to the desired value before it enters the dry house. The air entering the dry house will not contain any contaminants that could degrade the quality of the dry milk produced. For the conditions normally used for milk and whey drying, a heating coefficient of performance (COP) of between 3 and 4 can be obtained with the system described above.

COP is defined as:
$$\frac{\text{Total heat output of unit}}{\text{Electrical motor input power}}$$

It is anticipated that the only control required for the system is an anti-ice valve. The output temperature of the heat pump will be below that required for the process.

SPA 5681-1

Figure 2-1. Schematic of Existing Milk Drying Installation

SPA 5681-3

Figure 2-2. Schematic of Milk Drying Installation With High Temperature Heat Pump

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3. PROGRAM MANAGEMENT STRUCTURE

The high temperature industrial heat pump program organization, its relationships to higher-level AiResearch organizations, subcontractor relationships, and personnel responsibilities are discussed in this section.

To staff the heat pump program, AiResearch will draw upon senior personnel with extensive experience in waste heat recovery systems. The program manager will be Mr. T. L. Iles, who will provide DOE with a single-point authority for all technical and management matters.

3.1 COMPANY ORGANIZATION

AiResearch Manufacturing Company of California is an operating division of The Garrett Corporation (Figure 3-1), and a member of the Garrett aircraft and aerospace group. Each Garrett operational unit functions autonomously, conducting business independently of the other operational units.

The AiResearch division-level organization (Figure 3-2) has a structured matrix for management of a company with a diverse, multiproduct orientation. The company has two primary product groups--aerospace and industrial--with a total of five product lines:

- o Environmental and Energy Systems
- o Electronics Systems
- o Mechanical Power Systems
- o Heat Transfer and Cryogenics Systems
- o Rapid Transit and Electrical Power Systems

Within this organization, each AiResearch program is carried out by a team of engineers and designers from the appropriate product line, with specialists from other product lines and staff functions. Managers make assignments based on the skill and experience of their personnel. The arrangements ensure flexibility, efficiency, and effective use of time and resources. For each functional area there exists a counterpart at the corporate level, so that the total capability of The Garrett Corporation is available to support this program.

3.2 PROGRAM ORGANIZATIONAL STRUCTURE

The heat pump program organization (Figure 3-3) was formed within the environmental and energy systems product line, under the program manager, Mr. T. L. Iles. Mr. Iles is responsible for program performance to the product-line chief engineer, Mr. R. C. Kinsell, and to the product-line manager, Mr. K. F. Jackson.

Key members of the program staff are senior personnel, who were selected primarily from within the environmental and energy systems product line. The program organization is fully staffed and committed to the successful completion of the heat pump program.

REVISID March 1971

Figure 3-1. The Garrett Corporation Organization

10-011-1S

Figure 3-2. AiResearch-California Division-Level Organization

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Figure 3-3. Heat Pump Program Organizational Structure

Other supporting personnel will be drawn from within the environmental and energy systems department and other departments, as required. Supporting departments have been contacted and commitments made to supply selected personnel, when needed by the program.

3.3 PARTICIPATING FIRMS AND SUBCONTRACTORS

Land O'Lakes, Incorporated, of Minneapolis, Minnesota, will fully cooperate and participate in establishing the requirements and operating characteristics for a specific Land O'Lakes milk drying plant installation. They will assist AiResearch in obtaining the data required to complete Phase I of the program. It is also their present intention to participate in Phase II and III, providing results of Phase I clearly substantiate the benefits to be derived from the use of a Brayton cycle heat pump as a source of hot air for their milk drying plant.

The Land O'Lakes decision to participate in Phase II and III cannot be made at this time because the system configuration (and hence the installation cost, energy savings and operating characteristics) is the subject of the Phase I study effort. However, a contract defining the follow-on participation of Land O'Lakes will be submitted to DOE at least 4 weeks prior to the Phase I Preliminary Design Review.

3.4 PERSONNEL RESPONSIBILITIES

Major duties, responsibilities, and authorities of key personnel on the heat pump program are described below.

3.4.1 Program Manager

As program manager, Mr. T. L. Iles will have engineering management and technical responsibility for the program. He will work closely with program personnel to achieve all program technical goals. His primary responsibilities will be to:

- Provide single-point contact and response for program coordination with the DOE technical manager and with other program personnel

- Interpret contract technical requirements

- Translate technical requirements into work assignments

- Assign and coordinate AiResearch tasks between company departments

- Monitor and evaluate program costs

- Monitor technical progress, making available the appropriate resources and facilities from any point in the company

- Assist in resolution of program changes

- Inform division and corporate management of program progress

3.4.2 Contract Administrator

The contract administrator, Mr. J. D. McPherson, will be responsible for monitoring compliance with all contract requirements. This responsibility includes:

- Contractual and formal communications interface with DOE

- Contract negotiation, documentation, and closeout of contractual requirements

- Submittal of all correspondence to DOE

- Monitoring DOE/AiResearch requirements for compliance with the contract

3.4.3 System Engineer

Mr. G. E. Limberg, as the system engineer, will have overall responsibility for coordinating the technical effort required to design and develop the heat pump system. He will:

- Assist the program manager

- Coordinate all technical interfaces between the various AiResearch departments

- Develop engineering work tasks in conformance with the overall design objectives, budgets, and schedule

- Monitor technical progress and direct appropriate action concerning deficiencies or changes affecting the schedule or related activities

- Define design, development, and testing to be done in conformance with system specification, budget, and scheduling requirements

- Prepare technical and financial status reports

3.4.4 System Analysis and Development Engineer

As system analysis and development engineer, Mr. R. E. de Gaston, will be responsible for the following areas:

- Preliminary design and requirements definition

- System analysis relating to component and heat pump performance

- System development and test

3.4.5 Component Engineers

The two component engineers, Mr. F. A. Bescoby and Mr. S. Valentino, will have the responsibility of turbocompressor development and heat exchanger development, respectively. They will interact closely with the system engineer and system analysis and development engineer to ensure that system compatability requirements are being met.

3.4.6 Data Manager

The data manager, Mr. G. Deckman, will have the responsibility for coordinating all documentation functions. He will:

Assess the interdependence of the overall data task

Monitor the preparation progress of contractual plans and reports

Assure the timely submittal of all technical data to DOE

4. PROGRAM MANAGEMENT AND CONTROL PROCESSES

The program management and control function discussed in this section defines DOE-AiResearch relationships, provides management planning, and structures the administrative approach that will guide and direct program activity and monitor program cost, schedule, and technical performance. Data management techniques are also described.

Contract management relationships with many industrial firms and government agencies, through involvement with many commercial and U. S. Government programs, gives AiResearch a management experience base that can respond to any customer-imposed management system. Therefore, established AiResearch management methods and administrative routines will be used to manage and control the heat pump program. No new management procedures will be required.

4.1 CONTRACT MANAGEMENT

The heat pump program contractual arrangement establishes clearly-defined relationships and responsibilities between DOE and AiResearch. Fundamental relationships are defined as follows:

DOE, the responsible Government agency, will provide administrative and technical guidance for the program, through a technical manager.

AiResearch, the contractor, will provide personnel and facility resources, and the technical expertise, to design, fabricate, and test the heat pump and install it at the demonstration site.

The following paragraphs define in detail the relationships between DOE and AiResearch.

4.1.1 Contract Interfaces

The contractual interface on this program will take place between DOE and AiResearch. All formal finances, contractual obligations, and direct communications will be through AiResearch. Through AiResearch, DOE will have access to the Land O'Lakes program engineer. As a result, the free flow of information and open channels of communications will be provided.

4.1.2 Personnel Interfaces

Interface between DOE and AiResearch will be performed by two members of the AiResearch program organization: the program manager and the contract administrator. Their function and responsibility, with respect to this interface, are described below.

4.1.2.1 Program Manager

The program manager will be responsible for technical and administrative guidance of the program. He will interface directly with the DOE technical manager in all technical matters. As the direct AiResearch-DoE interface, he will:

- Be authorized to commit AiResearch in technical matters

- Serve as prime authority in negotiation of contract obligation in technical and administrative areas

- Report technical performance and program progress to the DOE technical manager

- Provide overall direction of program activities

- Monitor scheduling, authorize funds distribution, and review and control program expenditures.

4.1.2.2 Contract Administrator

The contract administrator will act as business manager for the heat pump program. As business manager, he will implement and serve as the final contact point for decisions between DOE and AiResearch. In performing this work, the contract administrator will coordinate contract activity, including: price quotations, contract terms and conditions, budget allocations, budget controls, and contract negotiations (cost, schedule, and terms). He will serve as communication liaison with DOE for all formal contractual and technical correspondence related to the program. All AiResearch reporting information will be submitted to DOE by the contract administrator.

4.1.2.3 Internal Contract Management

Contracts performed by AiResearch are administered through a well-developed management system, structured by Garrett/AiResearch policies and procedures. These provide broad operating policies and controls for company organizational groups. To ensure that all program cost, schedule, and technical performance tasks are accomplished, AiResearch uses the following internal planning management, and control tools.

- Work breakdown structure (WBS) (See Section 5)
- Program schedule (See Section 6)
- Cost and schedule control system (See Section 7)

The sequencing of program planning and control disciplines is depicted in Figure 4-1. The system provides internal control at AiResearch and produces data for reporting to DOE. Reporting will be in accordance with the Reporting Requirements checklist.

12-010-1

Figure 4-1. Contract Management Approach

A kickoff meeting, with all key program personnel present, formally initiates the program at the working level. In the meeting, DOE program objectives are discussed and baseline documentation given to all program personnel. With work under way, other program planning elements are created or formalized in compliance with DOE Statement of Work requirements. These elements include program scheduling and interfacing with the AiResearch cost and schedule control system.

The baseline program plans and schedule, in conjunction with the AiResearch cost and schedule control system described in Section 7, provide a reliable and accurate method of tracking costs, monitoring the schedule, and assessing performance. Cost control system reporting and performance data are produced by functional members of the program organization.

An overview of the AiResearch performance management system, which becomes effective upon contract initiation, is shown in Figure 4-2. Performance management is accomplished through program plans, controls, and responsibility assignments. After the plans are defined, schedules established, and responsibility assigned, the work can be monitored to track and identify progress, or to recognize problems that are inhibiting progress. The AiResearch cost and schedule control system provides the necessary information for direct visibility and performance information on individual work tasks. This information, coupled with close surveillance by the program manager and his continuing review of program progress, gives a measurement of performance that provides rapid recognition and identification of problems.

4.1.3 Subcontractor Selection and Monitoring

The AiResearch subcontractor selection and monitoring process is influenced by the types of subcontracted activity involved and the time at which the subcontracting activity takes place during a program. Two general subcontract categories exist:

- (a) Major subcontracts, in terms of technical complexity, cost, performance, and delivery
- (b) Routine procurements, such as machined parts of assemblies, fabricated sheet metal parts or assemblies, castings or forgings, and special process or test sources

Subcontracting decision making varies according to the procurement cycle, with greater flexibility allowed during design and development than during production, when more restrictive controls are in force.

All subcontracts are processed through the subcontracts group of the purchasing organization.

4.1.4 Materials, Hardware, and Services Procurement

Procurement of all materials, hardware, and services is made through the purchasing department. Procurement decisions are accomplished with a make-or-buy program that is implemented for each particular program, according to the needs and requirements of that program.

Figure 4-2. Performance Management System

4.1.4.1 Make-or-Buy Program

The AiResearch make-or-buy program, as established in company policies and procedures, is maintained to control fabrication and procurement expenditures so that maximum economy is realized, consistent with delivery and quality requirements. The make-or-buy program is a process (Figure 4-3) consisting of (1) day-to-day decisions affecting items fabricated in repetitive or continuous production, and (2) make-or-buy decisions involving major program procurements.

Make-or-buy committees, with membership determined by the type of procurement involved, have the responsibility for determining the point of manufacture. For normal production decisions, a make-or-buy committee, consisting of members from material and manufacturing departments and selected representatives from other areas, has sole decision making responsibility.

For major procurement decisions, involving critical components and services, the make-or-buy committee membership is significantly different. In these cases, the committee consists primarily of key decision-making members of the program organization who are responsible for development of given equipment or systems. The decision-making process leads to the same results (make-or-buy), but involves technical and administrative responsibility beyond the scope of the make-or-buy committee responsible for normal production hardware.

The bases for source determination are (1) cost, (2) quality, (3) delivery, (4) capabilities, (5) past performance, and (6) shop load. The point-of-manufacture decision, made by the committee, will generally result in a decision to:

- (a) Make--by AiResearch
- (b) Buy--from a subcontractor
- (c) Make--by either AiResearch or outside production, depending upon load, schedule, and cost

4.2 PROGRAM DIRECTION AND CONTROL

Competent program direction and control at AiResearch is performed by management personnel who use the following management tools:

- a) Work breakdown structure
- b) Master program schedule
- c) Cost and schedule control system
- d) Program plans

Using these management tools, the program manager plans an integrated program effort that identifies all elements of work required during the life of the program; schedules all elements of work, identifying constraining activities; monitors and tracks schedule status with respect to major milestones; and creates well defined, realistic program plans, which portray how each element of work will be accomplished with respect to all other elements of work.

Figure 4-3. Make-or-Buy Procedure

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With this well-planned approach, the program manager can monitor and control the program, assessing technical and cost performance accomplishments against discrete milestones. Careful monitoring of program activity will reveal true program status, and result in meeting the technical and cost goals of the contract. The AiResearch program-direction-and-control system will provide both the program manager and the customer with meaningful schedule, cost, and technical-performance information. AiResearch procedures, currently in place, will be extended to the DOE heat pump program. Information will be provided to all DOE groups which require cognizance of program activities and status.

4.3 TECHNICAL REVIEW METHOD AND SCHEDULE

The AiResearch management control system will be readily responsive to the DOE monitoring arrangement implemented on this contract. The basic elements of the system were discussed earlier in this section. A summary of those elements, and how they will function in response to the needs of the heat pump program, are described here.

4.3.1 Program Baseline

Program baseline objectives are established by DOE contractual documents, supported by program planning and control procedures. The overall scope of work is defined by the work breakdown structure (WBS) and task descriptions (refer to Section 5 of this document). The WBS defines all work required to ensure full contract compliance, and is the integrating framework for work authorizations, scheduling, cost accumulation, performance measurement, and reporting.

Management activity is based on well-organized program task and program planning and control tools. Technical management of the heat pump program will consist of implementing the plans and internal AiResearch controls. As development proceeds, technical management will assess and report to DOE the status of program technical performance and financial status. Technical performance and administrative reporting will indicate program status with respect to the original baseline, measuring each element of progress toward program completion.

4.3.2 Program Management Reviews and Status Monitoring

Program management reviews and status monitoring are the primary information channels for supplying information to DOE. Program status reports, submitted to DOE on a monthly basis, will include cost, schedule, and technical status information.

The AiResearch program manager will be responsible for keeping the DOE technical manager fully informed of program progress, problems, and solutions through program reporting documentation, formal correspondence, direct contact, and telephone contact. To serve the best interests of the heat pump program, direct and effective communications will be necessary.

4.3.3 Design Reviews

Two design reviews are planned during the heat pump program: a preliminary one at the end of Phase I and a final one at the end of Phase II.

4.3.3.1 Preliminary Design Review

A preliminary design review is planned for the end of Phase I. At this time the results of the Phase I activity will be presented by AiResearch along with a recommendation for continuing program activities including demonstration site and system selection. All three program participants (DOE, Land O' Lakes and AiResearch) must approve the go-ahead plans prior to start of Phase II.

4.3.3.2 Final Design Review

The final design review is scheduled at the end of Phase II so that the detail equipment and installation designs will be reviewed together by the three program participants (DOE, Land O' Lakes and AiResearch) prior to committing the funds for component procurement and fabrication.

4.3.3.3 Design Review Data

Design review data will include presentation material and design review reports. Presentation material will be prepared for the meetings and will be submitted to DOE for review two weeks prior to each meeting. The presentation material will contain an agenda for the meeting. Following the meetings, a report of meeting activities, results, and action items will be published.

4.4 DATA MANAGEMENT

The data management function at AiResearch will provide a control point for all data-related activities under the heat pump contract, and will be performed by the data manager as an adjunct to his other responsibilities.

During the course of the program, the data manager will remain cognizant of DOE reactions and needs by close coordination with the contract administrator, through whom all DOE contacts are made. Therefore, feedback from DOE, regarding quality, responsiveness, and completeness of data, is routed immediately to the data manager for follow-up action.

The primary objectives of data management are to assess accurately the scope of the overall data task, to remain aware of its progress, and to employ the most economical methods in its performance.

The content and submittal requirements for the heat pump program documentation are discussed in the task descriptions included in Section 5.

4.4.1 Data Control and Flow

The various steps to be used to ensure a smooth flow of documentation from the point of origin to the point of receipt are depicted in Figure 4-4.

Figure 4-4. Data Management Flow

5. CONTRACT WORK BREAKDOWN STRUCTURE

During the preparation of the DOE heat pump program proposal, a preliminary contract work breakdown structure (WBS) was prepared. The WBS defined all work packages required to ensure full contract compliance and served as an integrating framework for estimating task costs. A formal WBS now has been established, which is supported by an accompanying work package dictionary included in this section.

The WBS provides the framework for aligning schedules, budgets, and actual costs, from the total program level down to the work package level where work is performed. It will be used as the basic planning and control tool for associating schedules and budgets with specific elements of work.

The identification of work packages for each element of contract activity, in conjunction with contract requirements, assures that all conceptual, technical, and management requirements are considered. The WBS diagram for this program is presented in Figure 5-1.

5.1 TASK DESCRIPTIONS

The activity planned for each numbered WBS task element is described in the following paragraphs. All WBS tasks are described in sufficient detail to define the planned effort and to show the relationship of each task to the overall program.

Figure 5-1. CWBS Diagram

5.1.1 Program Management (01-0000)

Program management details are described in Sections 3, 4, and 7 of this plan. These sections present overviews of program organization, program planning and control, cost/schedule monitoring and control, and documentation control. The reports and documentation to be supplied under the program management task are described in Paragraph 5.1.7.

5.1.2 Phase I - System Optimization (10-0000)

5.1.2.1 Task 1.1 - Site Requirements Finalization (13-0000)

5.1.2.1.1 Site Requirements Identification

Initially, AiResearch and Land O'Lakes will review a representative number of their milk and whey drying facilities and evaluate them for candidate demonstration sites. Considerations will include:

- Physical plant layout*
- Utility rates
- Process conditions
- Exhaust gas filtration method
- Location

These parameters will be tabulated to provide the basis for the demonstration site selection.

5.1.2.1.2 Preliminary Demonstration Site Analysis

Using the data developed in the heat pump parametric analysis (see Task 1.2.2), a heating COP will be determined for each site based on the site considerations listed above. The cost to produce the dryer heat using the heat pump will then be determined and will be presented for each site in terms of $\$/10^6$ Btu. The net fuel savings will then be determined by subtracting the fuel cost presently used. Equipment cost estimates will include the following:

- Installed system cost
- Operating costs - maintenance, cleaning, present and future fuel and power costs
- Transportation costs
- Equipment life

*To be noted by Land-O-Lakes if there are any unusual restrictions limiting heat pump application, such as limited access.

AiResearch will prepare a report presenting the results of the parametric analysis. The following items will be covered for each site:

1. Dryer net energy savings (Btu/hr and Btu/yr)
2. Dryer net energy cost savings ($\$/10^6$ Btu and $\$/hr$)
3. Equipment size (physical and heat capacity)
4. Brief subjective site evaluation by AiResearch
5. AiResearch preliminary demonstration site selection

5.1.2.1.3 Preliminary Site Selection

AiResearch, Land O'Lakes, and DOE will then review this data and select the site on which the detailed analysis will be based. The analysis will accurately determine operational considerations, benefits, and costs associated with heat pump operation.

5.1.2.1.4 Demonstration Site Characterization

After the site is selected, AiResearch and Land O'Lakes will review the total plant operations at the demonstration site, taking into account all of the processes that use significant amounts of energy and devising ways in which heat integration and optimum utilization of waste heat streams could be accomplished. Refrigeration requirements as well as heat requirements will be considered in devising the ways in which the proposed HTHP can be designed for maximizing plant energy efficiency. Data will be correlated from facility instrumentation and additional key parameters will be measured directly as required to adequately define system parameters as required for Task 1.3.

AiResearch will perform the site/system analysis and will prepare a report presenting this data to Land O'Lakes and DOE four weeks prior to the preliminary design review (Task 1.5) so that sufficient time is allowed to review this data prior to the design review. It is expected therefore that Phase II go-ahead plans can be agreed to by all three participants at the design review.

5.1.2.2 Task 1.2 - Applications Analysis (11-0000)

5.1.2.2.1 Task 1.2.1 - Process Identification

The breadth of other potential applications of the HTHP to be demonstrated in the program will be investigated under this subtask. The effort will be undertaken while the heat pump is being designed and before the design is finalized, to facilitate the possibility for adaptation to other processes and other industries. Under this subtask, industrial applications other than those selected for demonstration will be evaluated to determine which are potential applications for the heat pump.

Applications that have already been identified as having waste heat and process supply conditions sufficiently close to that planned for demonstration to warrant further analysis are:

Tabacco drying

Textile drying

Food drying (includes grain, nuts, raisins)

Baking

Pulp and paper production

In addition, national survey information previously generated will be reviewed to determine other potential applications.

Process information that will be obtained to perform the initial screening of potential applications includes:

Process input and exhaust fuel and gas composition, temperature, pressure, flow, and contaminant levels

Process duty cycle

This process information will be determined by contacting the product producers as well as the equipment manufacturers. The AiResearch Marketing Department will be responsible for this market survey and market size estimate.

The data obtained will be compiled for use in Task 1.2.3, Conceptual Design, and will be included in the Phase I interim report.

The data shown below will initially be tabulated for each installation and then summarized by industry.

Industry

Dryer type(s)

Dryer manufacturer(s)

Process conditions:

Inlet temperature

Airflow

Exhaust temperature

Heat input

Duty cycle (hours per year of operation)

Fuel used

Fuel cost

An estimate will then be made of the market potential of the heat pump and the resultant energy savings available as a result of the estimated market.

5.1.2.2.2 Task 1.2.2 - Heat Pump Characterization

A parametric heat pump analysis will be conducted for design conditions that cover the range of the site requirements obtained in Task 1.2.1 above. The cycle to be analyzed is subatmospheric Brayton cycle and has previously been described in this document. Both electric motor and gas turbine power drives will be included. A range of heat exchanger effectiveness and the consequential impact on cycle efficiency will also be incorporated into the analysis. The results will be presented in a series of parametric curves from which optimum heat pump design conditions can be selected. COP will be plotted as a function of dryer inlet temperature, exhaust gas temperature, exhaust gas water content, heat exchanger effectiveness and pressure drop, and fan pressure rise.

These performance curves will then be used to determine the cost effectiveness of those system variables. The candidate heat exchanger constructions developed under Task 1.4 discussed later will be used for determining size and costs for the variance in effectiveness used in the cycle analysis. The increasing heat exchanger cost trend associated with increasing effectiveness and higher COP's will be compared to the reduced operating energy costs. Curves will be prepared for these system variables showing simple payback and cost of producing heat ($\$/10^6$ Btu) for electrical costs varying between \$0.01/KWH and \$0.05/KWH and gas costs varying from \$2/10⁶ Btu to \$4/10⁶ Btu. Those results will be included in the Plant Review Data Package.

5.1.2.2.3 Task 1.2.3 - Conceptual Design

To ensure that the conclusions reached as a result of the application analysis are accurate, a minimum of 10 plant visits to candidate sites that represent all industries where it has been determined in Task 1.2.1 that the heat pump can be applied will be made. Information to be obtained includes physical limitations, such as lack of floor space adjacent to the dryer for equipment placement requiring excessive duct lengths; plant duty cycle; process operating limitations; process input and exhaust condition; and plant fuel and power availabilities. During the visit, AiResearch will provide parametric data on the heat pump to the plant operators so that they may see how to apply the heat pump to other applications. This data will be in a brochure prepared for distribution to potential customers and will contain simplified parametric cost savings and performance curves.

Conceptual designs of potential configurations will be prepared to assist in obtaining an accurate cost benefit analysis. These designs will be carried out to the detail described below to determine the cost of modifications and the expected performance (heat delivery and COP). These designs will combine process flow diagrams and plant layout schematics derived from the information obtained from plant visits.

The process flow diagrams will identify process state points, site specific equipment such as additional controls necessitated by the specific application, and equipment performance. The plant layout schematics will identify equipment placement, interconnecting duct sizes and lengths, and existing facilities modifications required for equipment placement.

Using the above information, the total installed cost will be estimated so that an economic analysis can be made. The cost analysis will be presented in terms of return on investment (ROI) and cost of the heat energy product (\$10⁶ Btu).

Energy savings will be determined for each design and the individual results will be integrated to determine total potential energy savings in the United States over the temperature band that the demonstration heat pump services. In addition, the probability of acceptance of such technology by various industries will be investigated, installation costs will be estimated, realizable energy savings will be calculated in order to determine payback period, and data for management decisions will be obtained.

The results of this task will be a projection of the maximum and probable application of this technology to all relevant industrial processes, along with an estimate of energy savings based on the potential range of applications. These data will be included in the Phase I interim report.

5.1.2.3 Task 1.3 - Concept Selection and System Specification (12-0000)

Using the findings from Tasks 1.1 and 1.2, a system design specification will be prepared and the system evaluated for its applicability to other dry milk processing plants throughout the U.S. and to other industries identified in Task 1.2.3. Candidate system configurations will be defined and such HTHP modifications evaluated as may be necessary to increase acceptability based on ROI by numerous energy users. Components possibly susceptible to modification for this purpose would include the turbine and compressor wheels, heat exchangers, and possible substitution of an industrial gas turbine engine in place of the electric motor that might otherwise be coupled with the basic turbocompressor. In many applications, it will be desirable to drive the heat pump with a gas turbine. In this concept, the gas turbine shaft power is used to drive the heat pump and the turbine exhaust heat is used as an additional heat source for the process. All applications that are reviewed will be evaluated with an AiResearch IE-831 gas turbine drive for comparison with the baseline electrical drive.

The estimated process state points and thermodynamic constraints of the system at the demonstration site will be verified under this task. Computer modeling of the entire system will be performed to ensure good matching between the thermal, machinery, and control system. The effect of subsystem and component performance on system level performance (COP) will be evaluated in detail, and off-design point performance predicted. Initial cost, performance, safety, environmental, maintenance space, and site parameters will be analyzed to produce an optimum system design specification.

The output of this task will be a design specification that includes all performance and physical interfaces, describes growth (heat capacity and temperature level) capabilities, identifies alternate component arrangements, and identifies applications with projected energy savings.

5.1.2.4 Task 1.4 - Heat Exchanger Cost Reduction Study (15-0000)

5.1.2.4.1 Task 1.4.1 - Concept Analysis

This study will determine the feasibility of design variations that will reduce manufacturing cost while maintaining the high effectiveness of the heat exchanger.

There are four major areas of study related to this subtask.

Basic Heat Exchanger Design--Design variations that will reduce the labor required to manufacture and assemble the unit will be analyzed. Of particular interest are prime surface heat exchanger and combination prime and secondary heat transfer surface heat exchangers.

Assembly of Matrixes--Since the heat exchangers operate in a relatively benign environment, manufacturing techniques, other than fully brazed units, will be investigated. These may include concepts such as nonmetallic bonding, non-welded modular assemblies, etc. In addition, a study will be conducted of wrap-up and ducting designs to determine if simple sheet metal or non-metallic materials can be used and still result in the required structural integrity and life of the equipment.

Materials of Construction--The materials used in the heat exchanger will also be evaluated. The prime material under consideration is aluminum; however, depending on the design concept, it may be possible to effect a savings by use of other materials that may be structurally superior to aluminum, thereby requiring less material or supporting structure. The feasibility of other materials will be determined on a cost-comparison basis for selected candidate designs.

Tooling--A feasibility study will be performed to assess the cost impact of tooling necessary to produce the selected design concepts. Engineering sketches will be made as a part of this study of the individual concepts investigated and of the selected candidate designs that are most feasible for the proposed heat pump system.

5.1.2.4.2 Task 1.4.2 - Literature Review

A literature review of existing heat exchanger designs offered for sale by other manufacturers will be made to determine the effectiveness of applying such units to the high temperature heat pump system.

5.1.2.4.3 Task 1.4.3 - Maintenance and Cleaning

After preliminary results (cleaning schedule, identification of contaminants and performance degradation) are obtained from the model test unit fabricated in Task 1.4.4 indicating the characteristics of the exhaust streams, an analysis will be made to determine required cleaning methods and schedules for each exhaust stream considered. A determination will be made as to which heat exchanger configuration can be economically adapted to the different processes.

5.1.2.4.4 Task 1.4.4 - Model Test Unit

A small demonstration model will be fabricated of the heat transfer matrix selected in Task 1.4.1. This model will be used to determine clogging characteristics of heat exchangers in the proposed environment (such as the milk dryer exhaust). The test module will consist of a heat exchanger matrix approximately one foot cube, with selected heat transfer surfaces as determined from the study, and a circulating fan to blow the exhaust gas through the heat exchanger. The unit will be instrumented to measure hot and cold side inlet and outlet temperature, and hot side pressure drop. The unit will be installed in the milk dryer exhaust and operated for 30 days, or until the heat transferred is reduced by 30 percent, as measured by cold side ΔT , whichever occurs first.

5.1.2.4.5 Task 1.4.5 - Summary and Recommendations

The results of the heat exchanger evaluation will be summarized and a recommended approach will be documented in a report. This report will be included as part of the Phase I report and will cover results of the completed effort on Task 1.4, Heat Exchanger Cost Reduction Study. Included will be a recommendation of the selected approach, the performance obtained (COP, ROI, etc.), growth capabilities, cleaning method, and manufacturing cost of a mature unit.

5.1.2.5 Task 1.5 - Preliminary Design Review

A preliminary design review is planned for the end of Phase I. At this time, the results of the Phase I activity will be presented by AiResearch along with a recommendation for continuing program activities, including demonstration site and system selection. All three program participants (DOE, Land O'Lakes and AiResearch) must approve the go-ahead plans prior to start of Phase II.

5.1.3 Phase 2 - Design (20-0000)

5.1.3.1 Task 2.1 - Preliminary Design (21-0000)

The engineering design and layout of the machinery, heat transfer and flow system, and control system equipment for the complete heat pump system and its integration into the demonstration plant site will be performed in this subtask. Analysis of each component will be based on the system specification of Task 1.3. Types of analysis will include thermal, stress, vibration, mechanical, and aerodynamic design of system components. The output of this subtask will be a set of detailed engineering design and layout drawings for a recommended system. Should this recommended system incorporate any contractor proprietary information or items, an alternative design will also be presented, at that time, containing no contractor proprietary information or items. Based upon the review of these designs, DOE will select the system concept to be utilized as the reference design in all future tasks.

5.1.3.2 Task 2.2 - System Cost Analysis (22-0000)

After completion of the preliminary design, an on-going analysis of the eventual production cost of system hardware components, cost of installations, and any interface requirements will be conducted to determine and control heat pump costs. Parametric cost data will be generated to assist in component and system solution. Hardware component cost (including development and test) will be evaluated in terms of possible alternatives and system cost effectiveness for cost incurred. Under this subtask, system operating and maintenance costs will also be estimated.

5.1.3.3 Task 2.3 - Materials Test Plan (23-0000)

As a part of the first phase and at the time when selection of major components has been completed, a topical report describing a plan for pre- and post-operation materials tests will be prepared and submitted to DOE for review. The plan will cover the remainder of the design and demonstration program, with respect to the system components.

5.1.3.4 Task 2.4 - Detailed Machinery Design (24-0000)

Detail drawings suitable to produce hardware will be prepared for each system component from the engineering component analysis and design derived from Task 2.1. The machinery layout, machinery details, and final drawings for all heat exchangers, pumps, turbomachinery, and control hardware required in the complete heat pump system will be prepared and a design review meeting conducted with the DOE representative prior to drawing release. Turbocompressor long lead time items, which must be released for fabrication and procurement prior to the start of Phase 3 in order to maintain the program schedule, are as follows:

Turbine wheel and compressor impeller fabrication

Scroll and torus fabrication

Motor and gearbox procurement

5.1.3.5 Task 2.5 -- Design and Plan for System Installation (25-0000)

AiResearch and Land O'Lakes cooperatively will prepare for integration of the HTHP into the overall plant complex and will plan layout of instrumentation for monitoring performance of the heat pump system. Component specifications and installation/control drawings will be generated. Site-specific installation control drawings and schematics and associated bills of material and a plan for system installation of major components will be generated. The plan will include installation requirements, timing, personnel, and associated costs. A performance schedule will be developed to permit subsequent monitoring and control during actual system installation. The integration design will provide space for the system, electric power for controls, and flow lines to and from the process with such isolation as may be necessary. The necessary engineering drawings specifying the overall system configuration will be prepared in Task 3.5. The integration design will also contain control and instrumentation interfaces as required.

5.1.3.6 Task 2.6 - Environmental Analysis and Baseline Data (26-0000)

Data on air quality standards, stack emission allowances, noise pollution, water pollution, heat pollution, and any other process environmental parameters will be provided.

Baseline data will be developed for use in monitoring of system effects. Future requirements as well as current regulations will be explicitly treated to ensure that heat pump system development is compatible with environmental standards.

5.1.3.7 Task 2.7 - Final Design Review

A final design review will be held at the end of Phase II. At this time, the detail equipment and installation designs will be reviewed by the three program participants (DOE, Land O'Lakes and AiResearch) before funds for component procurement or fabrication are committed by DOE.

5.1.4 Phase 3 - Component Fabrication and Performance Testing (30-0000)

5.1.4.1 Task 3.1 - Hardware Procurement, Fabrication, and Assembly (31-0000)

Hardware will be procured from outside vendors or fabricated in-house, as required, and then assembled. The management plan will delineate any specific components and equipment to be procured from outside vendors and will be utilized to monitor and evaluate the criticality of deliveries and procurement cycles and provide critical path information affecting final delivery.

5.1.4.2 Task 3.2 - Test Facility Preparation (34-0000)

A test facility will be readied for checkout of the complete heat pump system prior to shipment to the demonstration site.

5.1.4.3 Task 3.3 - Test Item Assembly and Checkout (35-0000)

Individual items in the complete heat pump system will be tested and checked out initially and then finally tested as a complete assembly with any modifications that might be required at this time. It is intended to operate the unit at full power prior to shipment. A component and system test plan will be prepared as a section of the overall management plan. Component test results will be referenced to design point values and hardware modifications made as appropriate. The output of this task will comprise a set of major component and system test reports.

5.1.4.4 Task 3.4 - Acceptance Test and Startup System Test Plan (36-0000)

The complete assembly will be performance tested at the test facility. The test facility put in place in Task 3.2 will have the capability of generating full rated heat input for the system. A comprehensive test series will be performed to define system performance over the expected load range. Design and off-design point transient testing will be performed. A startup system test plan will be prepared for Task 4.2 as a section of the overall management plan.

5.1.4.5 Task 3.5 - Architectural Layout and Site Preparation (37-0000)

A detailed layout drawing of the total system installation will be provided. The layout will show connection techniques, valves, insulation, heat exchanger installation supports, turbine/compressor support, reject heat flow, electrical system, and control and monitoring system. The necessary building, construction, and site preparation required for installation of the system at the demonstration site will be accomplished in this subtask.

5.1.5 Phase 4 - Installation and System Startup (40-0000)

5.1.5.1 Task 4.1 - HTHP Installation and Checkout (41-0000)

Upon completion of the acceptance testing of the equipment, the equipment will be removed from the test facility and shipped to the demonstration site. The heat pump system will be installed at the demonstration site and integrated into that plant's overall system. Installation of the system will be documented by photographs.

After installation, but prior to on-line demonstration, the total HTHP system will be checked out to verify conformance with design requirements at the site. This will be performed during a period when the evaporators are shut down for cleaning (thus when no dry milk production is required). Water will be injected into the dry house to simulate the correct heat load on the system.

Also at this time, instrumentation will be checked out and performance verified. Eleven parameters are to be sampled, measured, and recorded. All parameters will be recorded on a single multipoint trend recorder so that variations of parameters relative to one another and with time may be easily observed. System parameters to be instrumented are tentatively identified as follows:

Inlet air mass flow
Water flow rate
Turbine inlet and outlet temperatures
Air-to-water heat exchanger outlet temperatures
Air-to-air heat exchanger outlet temperatures
Compressor outlet temperature
Water temperature
Bag house return air temperature

If necessary, other data sufficiently comprehensive to permit evaluation of the system and major components during the demonstration tests will also be recorded.

5.1.5.2 Task 4.2 - System Startup (42-0000)

Following complete installation, the system will be operated under startup testing and checkout conditions. Startup and operating documents and a phased startup schedule will have been developed in Subtask 3.4 to verify proper operation of the system. All components of the heat pump system will be operated in an integral manner to validate the application. Sufficient indoctrination will be provided to ensure that demonstration hose personnel can operate the system independently. The system test plan will be designed to provide for a safe startup of the system and to ensure continuous operation capability after startup. Safety and environmental considerations will be adhered to and procedures documented for planned levels of system operation. Certification that the system is ready for continued on-line operation and DOE notification of this certification will complete the system startup.

5.1.6 Phase 5 - On-Line Operation Demonstration and Business Plan (50-0000)

5.1.6.1 Task 5.1 - Demonstration (51-0000)

The heat pump system will be designed to be capable of continuous operation during a 6-month demonstration period. The system will be fully instrumented to provide information on both the operating condition of the equipment and the total energy efficiency of the process. Data will be taken as defined in Task 4.1 in regard to thermodynamic states; waste stream flow and temperature; and working fluid (air) flow, pressure, and temperature. These data will be sufficient to determine performance of individual components as well as the overall system.

Actual heat exchanger effectiveness; turbine, compressor, and motor/gear box efficiencies; and system COP will be determined. These data will be compared with the values used during the design of the equipment.

Specific instrument points as defined in Task 4.1 will provide the necessary information to measure the economic impact of the system, to determine plant safety (e.g., turbine speed, heat exchanger pressure, machinery vibration levels, etc.), and to run a complete plant heat balance. The total electric power load will be continuously recorded on a watt-hour meter and will be used in evaluating the net energy utilization of the system. Heat flow rate will be monitored and total quantity of heat produced over a given time period will be calculated. Totalized data also will be reported on the same quarterly basis.

During on-line operation, all performance data will be reported to DOE on a quarterly basis. Routine maintenance will be carried out during the course of the on-line demonstration; maintenance actions indicators, procedures, and frequency will be defined and analyzed during system evaluation periods. System design, installation, performance, and operational procedures will be fully documented in the final report. System performance will be analyzed.

5.1.6.2 Task 5.2 - Business Plan for Commercialization (52-0000)

A detailed business plan will be developed to delineate the guidelines, actions, and timing necessary for Garrett/AiResearch to enter into the commercial production of the heat pump system. The plan will show the market penetration required for a commercial production version of the demonstration unit to become a profitable commercial product in a timely fashion, and the decision processes and parameters needed by Garrett/AiResearch to optimize its entry into the market. Intermediate and long-term product plans will be developed from the industrial requirements and application information generated in Subtask 1.2. As a minimum, the plan will address the following:

- Sales projections

- Capitalization

- Production plan (sizes, configurations, performance, cost, price)

- Strategy to obtain UL approval

- Analysis of competition

- Risk and competitive factors assessment

- Sales distribution

- Warranty and service

- Production cost estimates versus various production volumes

- Penetration strategy

- Venture development

5.1.7 Task 10.1 - Reports and Documentation (01-0100)

5.1.7.1 Management Plan

A detailed management plan will be prepared at the inception of the program and will be due for submittal to DOE no later than twenty (20) working days after contract start. The plan will be updated on an on-going basis and utilized as a detailed monitoring tool and working plan throughout the program. The management plan will comprise the description of the project, the technical goals to be achieved, the overall schedule objectives, and all pertinent project cost considerations. The plan will also contain narrative regarding all issues and considerations involving any technical questions and uncertainties in the program and alternative sources of action.

The plan will present a contract Work Breakdown Structure (WBS) that divides and subdivides the requirements of the contract into element of manageable size and duration showing task and subtask interactions regarding the planning, estimating, scheduling, budgeting, work authorization, cost accumulation, performance measurement, and resulting management action performed in the program. The management plan will contain and show the timewise orientation of the program milestones. An updated plan will be submitted for each new phase.

5.1.7.2 Monthly Reports

Monthly reports (contract management summary report, project status report, and cost management report shortform) will be submitted monthly to DOE through Phase 4. They will contain project cost data, deviations from anticipated costs to date, changes in anticipated total project cost, schedule changes, and any anticipated slippage in major milestones. The cost management report will show cost and fee separately.

5.1.7.3 Quarterly Demonstration Report

Quarterly demonstration reports will be submitted at the third and sixth month of Phase 5 and will cover items indicated in Task 5.1, in addition to the information normally contained in the monthly reports.

5.1.7.4 Materials Evaluation Reports

Materials evaluation reports will be submitted covering details of the pre- and post-demonstration tests of materials and components used in the heat pump system and shall include recommendations concerning any possible need for further evaluation during the years beyond the contract demonstration period. These reports will be generated following field tear-downs and inspections during the on-line demonstrations. Two (2) reports will be submitted to DOE during Phase 3 and other reports will be submitted on a quarterly basis during Phase 5.

5.1.7.5 Formal Technical Reports

Formal technical (topical) reports will be submitted at phased intervals to be agreed upon. DOE topical reports on the overall program are tentatively planned to cover work during the course of the program and to follow major achievements in the program. The content of these reports will be as follows:

- Report No. 1 -- Phase 1 results to include: results of the site requirement study, potential applications as defined during the application analysis, description of the selected concept including the system specification, and the results and conclusions of the heat transfer cost reduction study. This report is to be submitted to DOE no later than ten (10) days after the completion of Phase 1.
- Report No. 2 -- Phase 2 results to include: system design details, system cost analysis, environmental analysis, system installation plan, and applications analysis. This report is to be submitted to DOE no later than ten (10) days after the completion of Phase 2.
- Report No. 3 -- Materials Test Report: topical report describing plans for pre- and post-operation materials tests to cover the working fluid, lubricants, and system components, and the probable interaction of these from a materials standpoint. This report is to be submitted to DOE no later than ten (10) days after the completion of Phase 2.
- Report No. 4 -- Phase 3 results to include: demonstration site preparation details, heat pump construction details, results of component tests, results of heat pump acceptance test, site layout and preparation details, and review of plans for installation and long-term demonstration at the host site. This report is to be submitted to DOE no later than ten (10) days after the completion of Phase 3.
- Report No. 5 -- Phase 4 results to include: documentation of system installation at demonstration site, system startup, and checkout test results. This report is to be submitted to DOE no later than ten (10) days after the completion of Phase 4.
- Report No. 6 -- Environmental Effects Report: summary of environmental analysis and environmental baseline data generated in Task 2.6. This report is to be submitted to DOE no later than ten (10) days after the completion of Phase 2.

5.1.7.6 Final Report

The final report will include comprehensive details of the entire program, including demonstration performance results and conceptual designs (with minor changes) of the demonstration heat pump in other applications. A preliminary draft copy will be distributed to DOE two (2) months prior to publication to allow time for implementation of any changes agreed upon between DOE and AiResearch.

6. PROGRAM SCHEDULE

The Phase I Milestone Schedule and Status Report (DOE Form 535), shown in Figure 6-1, has been prepared to the level of detail specified in the contract and is addressed to each specified task or work element. The charting symbols and legends used are those shown in the instructions for preparing the form. The Phase I Milestone Log is shown in Table 6-1.

The schedule and milestone log are based on an analysis of WBS work packages to determine task interrelationships. This analysis ensures that activity constraints are considered and that the overall schedule is consistent throughout all task phasing.

As a planning and control tool for defining program tasks, the WBS provides a basis for correlating cost and schedule information. In the AiResearch cost and schedule control system, all budgets are schedule-oriented. The correlation of WBS and program schedule permits time-phasing of AiResearch work authorizations (WA's) and cost management reports, which are described in Section 7.

The Phase I Task Logic Diagrams are shown in Figures 6-2 through 6-6. The Phase I Work Plan Diagram, delineating the relationship of the individual subtasks in Phase I, is shown in Figure 6-7.

AIRSEARCH MANUFACTURING COMPANY
OF CALIFORNIA

FORM ERDA 638
(11/30/76)

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MILESTONE SCHEDULE AND STATUS REPORT

PAGE 2 OF 2

Form approved
May 1976

1. Contract Identification											2. Reporting Period through										3. Contract Number									
4. Contractor (name, address)											5. Contract Start Date																			
											6. Contract Completion Date																			
7. Identification Number	8. Reporting Category (e.g., contract line item or work breakdown structure element)	9. Fiscal Years and Months FY 79															10. Percent Complete													
Phase I	Continued	O	N	D	J	F	M	A	M	J	J	A	S											Plan	Act					
10.1	Reports and Documentation																													
A	Management Plan																													
B	Monthly Reports																													
B1	Contract Mgt Summary Report																													
B2	Project Status Report																													
B3	Cost Mgt Report (Short form)																													
C	Phase I Interim Report																													
D	Management Plan Update																													
11. Remarks Baseline Date																														
12. Signature of Contractor's Project Manager and Date															13. Signature of Government Technical Representative and Date															

Figure 6-1 (Continued)

Figure 6-2. Logic Diagram for Task 1.1, Site Requirements Finalization

Figure 6-3. Logic Diagram for Task 1.2.2, Heat Pump Characterization

Figure 6-4. Logic Diagram for Task 1.2.3, Conceptual Design

Figure 6-5. Logic Diagram for Task 1.3, Concept Selection and System Specification

Figure 6-6. Logic Diagram for Task 1.4, Heat Exchanger Cost Reduction Study

S-38106

Figure 6-7. Flow Diagram for Phase I Work Plan

PHASE I MILESTONE LOG
CONTRACT NO. EC-77-C-03-1480

Identification No.	Description	Planned Completion Date	Actual Completion Date	Comments
1.1A	Select Demonstration Site	05/01/79		
1.1	Finalize Demonstration Site Requirements	07/01/79		
1.2.1	Identify and Characterize Candidate Process	05/01/79		
1.2.2	Characterize Candidate Heat Pump Configuration	05/01/79		
1.2.3A	Select Recommended Design	06/01/79		
1.2.3	Complete Conceptual Design Analysis	07/01/79		
1.3A	Issue Preliminary System Specification	06/01/79		
1.3	Complete Final System Specification	07/01/79		
1.4.1A	Preliminary Design Selected	04/15/79		
1.4.1	Complete Baseline Heat Exchanger Cost Reduction	06/01/79		
1.4.2	Complete Alternate Concepts Review	05/15/79		
1.4.3	Complete Maintenance and Cleaning Analysis	07/15/79		
1.4.4.1	Complete Model Heat Exchanger Fabrication	05/15/79		
1.4.4.2	Complete Model Heat Exchanger Test Program	07/01/79		
1.4.5	Complete Heat Exchanger Cost Reduction Study	08/01/79		
1.5	Preliminary Design Review	08/15/79

7. COST AND SCHEDULE CONTROL

This section describes the AiResearch cost and schedule control system (CSCS), shown in flow chart form in Figure 7-1. This computer-based information system is designed to provide cost and schedule information for use as a management tool in directing and controlling development programs. The system currently handles more than 5000 cost accounts, and provides direct visibility of performance of some 30,000 individual work-package tasks. The system provides semimonthly reporting, structurally keyed for appropriate organizational control levels. The cost and schedule control system is used in the management activity to provide the following:

Cost and schedule supporting data, in the detail required for integrated cost, schedule, and technical performance status reporting and analysis.

Development plan alternatives and supporting data necessary to resolve technical, cost, and schedule problems.

Cost and schedule information reports for internal management use and fulfillment of DOE reporting requirements.

The heat pump program cost plan will be prepared on Form ERDA 533P and submitted under separate cover. The plan will be organized by WBS identification number and will show the contemplated rate of accrued costs for the life of the contract. It will be time phased to allow for periodic measurement of cost performance. Basic information necessary for updating and forecasting budgetary requirements will be included. The cost plan will be revised at the start of each program phase.

Figure 7-1. Cost and Schedule Processing Cycle

14-002-1

7.1 INPUT DATA TO COST AND SCHEDULE CONTROL SYSTEM

The planning information constituting input data to the CSCS is the work authorization (WA), shown in Figure 7-2, which is used by the engineering and manufacturing departments. A WA is written for each work package described in the WBS and is derived from engineering estimates, created in a similar format. The WA reflects the negotiated dollar-value of a given budget. The assignment of account numbers relates directly to WBS work-package numbers and permits data summary to a level that is meaningful to program management and the customer. Data accumulation and reporting is correlated directly with the WBS. Since the WBS also is used for developing the detail schedule, this feature permits use of the detailed schedule as a performance-measurement tool. The program WBS correlates with DOE work statement requirements and thus ensures that cost data is related directly to detailed program requirements. A detailed description of the work authorization follows.

7.2 WORK AUTHORIZATION DESCRIPTION

The work authorization is the formal paperwork within the AiResearch system, and officially allows work to proceed. Information on the work authorization is aligned with the WBS, program activity schedule, and negotiated contract cost.

Figure 7-2. Input Data to the Cost System

7.2.1 Work Authorization Form

The work authorization form used by the engineering department is shown in Figure 7-3. The completed work authorization form will include the following information:

- Customer, program, and product identification
- WBS reference and responsible department/person
- Concise description of work
- Cost, budget, and schedule relationships
- Approvals
- Additional descriptive information

Within the CSCS, nonrecurring activities are segregated from recurring costs by using distinctive work-authorization release numbers for engineering and manufacturing. The planning-and-control functions deal predominantly with nonrecurring engineering-oriented activities. For this reason, the cost-schedule control system is devoted primarily to that aspect of cost and schedule control. The system organization, data structure, and program logic are generally applicable, however, to all aspects of company operation. This commonality is achieved by using a single data bank for all work-in-process budget and cost information. The use of a common data bank offers the further advantage that information contained in all reports has been analyzed and validated in a manner that meets accounting department standards. Through its semimonthly and on-call reports, the CSCS provides a periodic view of the program to all management levels.

7.2.2 Work Authorization, WBS, and Schedule Relationships

The work authorization, WBS, and program activity schedule are related closely. Major WBS tasks are itemized on the work authorization. Entries on the work authorization are tied directly to the schedule by entering the start and stop dates of each scheduled task. This is the first step in the AiResearch management system of tracking cost/schedule versus major milestones.

7.3 COST INFORMATION

Budget and schedule data contained in the work authorizations are entered into the computer job stream through a keypunching operation. The data processing phase of the cost management system is illustrated in Figure 7-4. New budget data are merged to update the existing master-budget file, containing all engineering budget information. The cost management data assembly subroutine processes this budget information to construct summary budget schedules. Also, at this stage, cost data are assembled for management report generation.

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AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA
ENGINEERING WORK AUTHORIZATION

CUSTOMER (22) _____ PROGRAM (22) _____ OUTLINE NO. (10) _____ PRODUCT (22) _____ SPECIAL CONDITIONS (110) _____ _____ _____	EWA CHARGE NO. _____ REV. ☐ LTR. ☐ TITLE (18) _____ (18) _____ AUTHORIZING PROJ. _____ SYS. PROJ. _____ PROJECT ENGINEER (10) _____
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SYSTEM NO. _____ SYSTEM NAME _____ SYSTEM ENG. _____
 S.O. ITEM NOS. _____ GOVT. CONT. NO. _____ CONTRACT ADM'R _____
 SPEC. REFERENCES _____
 NOTES _____

ITEM NO.	ELEMENTS OF COST (INCLUDE ALL LABOR AND NON-LABOR ITEMS)	SCHEDULE			BUDGET			
		REV. LTR.	START MO. - YR.	COMPL. MO. - YR.	REV. LTR.	DEPT. OR OTHER	LABOR HOURS	DOLLARS
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
TOTALS								

BUDGET RECORD AND APPROVALS

REV. LETTER	REV. CODE	INCREMENTAL ESTIMATES		DATE OPENED OR REVISFN	ENG. ADM'R	PROJECT ENGINEER	OTHER ENG. APPROVAL	QUOT. ADMIN. OR MGMT.	03-1
		PDR OR CBR NO.	DOLLARS						
ORIG.	X								
REV.									
REV.									
REV.									
REV.									
REV.									
REV.									
REV.									

REV. 1. CHANGE IN SCHEDULING
 CODE: 2. REDISTRIBUTION OF FUNDS
 3. CHANGE IN SCOPE
 4. PROJECTED OVER RUN

DATE CLOSED

 DIVISIONAL AND/OR PRODUCT
 LINE PRORATE REQUIRED ☐

FORM 3203 1-7-71

Figure 7-3. Work Authorization Form

 AIRESEARCH MANUFACTURING COMPANY
 OF CALIFORNIA

7.4 COST SYSTEM REPORT OUTPUTS

A number of semimonthly and on-call reports are obtainable from the cost and schedule control system. As indicated in Figure 7-5, these reports provide a periodic view of the program to all management levels.

7.5 ENGINEERING COST CONTROL REPORT

An engineering cost control report is issued bimonthly to provide cost and schedule visibility for in-house management review and DOE reporting. This comprehensive report contains the following cost and schedule information.

Earliest start date and latest stop date for the function described by the work authorization.

Total authorized budget for work identified on the report (to latest revision).

Inception-to-date (ITD) budget (man-hours and total dollars) representing the accumulated planned expenditures-to-date established by the budget schedule.

Accumulated actual expenditures-to-date levied against the reported charge number.

Incremental expenditures charged during the reported accounting period.

Management authorized budget exclusive of all budget overruns (or underruns).

Projected budget overrun (or underrun) of each work package in the work breakdown structure given in total dollars.

7.6 PRODUCING DOE FINANCIAL STATUS REPORTS

Using the engineering cost control report, documentation to monitor and assess program status is generated. These status reports, which provide the information listed below, are particularly useful in identifying problems and in analyzing alternate courses of action for each work package and its subtasks.

Plans--Semimonthly and monthly scheduled budget, budget-to-date, milestone dates, and total funding.

Performance--Semimonthly and monthly cost, cost to date, and actual start and stop dates.

Expectations--Estimated cost to complete, estimated total cost, anticipated start and stop dates, and schedule and cost variances.

How the engineering cost control report is used in constructing supporting documentation is described in the following paragraphs.

Figure 7-4. Cost Information Processing

Figure 7-5. Cost System Reports

7.6.1 Program Performance Record (Major Work Task Level)

The program performance record sheet (Figure 7-6) is used to analyze data outputs displayed on the engineering cost control report. The performance record sheet contains the following information pertaining to the WBS major work task level:

Sales order number

Total contract funding and limits

Cost accumulated through a given reporting period in terms of:

- (a) Current work authorization budget
- (b) Expended funds exception to date
- (c) Estimate to complete
- (d) Estimate at completion

Work authorization summary of major work tasks identified on WBS

Cumulative cost and budget schedule

The schedule shown on the performance record sheet is a summary version of the program activity schedule and permits comparison of cost and schedule performance.

The generated cost data provides information used in measuring performance of functional groups by coupling this information with schedule information and technical accomplishments. Therefore, cost information is presented, along with schedule information, to monitor cost performance at each level of the WBS. This concept of performance monitoring is illustrated in Figure 7-7.

Cost-to-date can be compared directly with the budget-to-date to determine how closely the efforts are conforming to plans. Also, the current cost estimate-to-completion, provided by the performing group, is added to accumulated expenditures to give the total cost at completion. Any differences between this projected cost and total authorized budget is considered as a forecast budget overrun or underrun. Schedule completion dates may be revised by the performer to forecast a schedule overrun.

Effective management requires that attention be given to those activities that are most critical to attainment of objectives. Large forecast overruns or underruns are leading indicators of these critical activities. By forecasting completion costs, corrective action can be taken to prevent costly overruns and to meet scheduled completion dates without merely increasing or decreasing budgets.

**AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA
PROGRAM PERFORMANCE RECORD**

PROGRAM 25-1-A-E12 CUSTOMER ERDA
PROGRAM ENGINEER GILMER ENGINEERING ADMINISTRATOR H. J. ...

PROGRAM	REVENUE		COST AS OF 15			
S.O. NO. <u>250433</u>	TOTAL CONTR.	FUNDING LIMITS	CURRENT WA BUDG.	EXPEND. I.T.D.	ESTIMATE TO COMP.	E.A.C.
ORIGINAL <u>\$203,802</u>						
CURRENT VALUE	325,267	325,267	325,163	247,934	77,233	325,267
PENDING REVISIONS	-	-	-	-	-	-
OTHER <u>UNNED-64-60</u>						
TOTAL	325,267	325,267	325,163	247,934	77,233	325,267

WA NO.	01-0100	01-0200	01-0300	01-0400	01-0500	01-0600	01-0700	01-0800	TOTAL
WA TITLE	595	EB	OPT SYS	CAVITY	CAVITY	INSTRU.	CAVITY SUP	SY	
AUTH. PROJ.	93000	43060	93000	93000	93000	93000	93060	93000	
ASSIGNED TO	117200	117200	117200	117200	117200	117200	117200	117200	
WA CUR BUDG	14371	117200	12,104	59,360	15221	20300	12,177	325,163	
DATE START	9-4-76	9-4-76	12-14-76	12-14-76	12-14-76	12-14-76	12-14-76	12-14-76	
DATE STOP	12-14-76								

TO	2-27-77	16,191	77,217	55,128	13,991	156	13,527	943	36	177,129
	11-3-77	16,191	77,217	55,128	13,991	156	13,527	943	36	177,129
ORIG.	29,121	78000	55,128	12,104	59,360	15221	20300	12,177	253,211	
E.A.C. PRIOR	14371	78000		12,104						
CURR.	16,181	117,200	77,125	13,991	59,360	15221	20300	9586	325,267	
DATE	1977									
YEAR										
MONTH

READ INSTRUCTIONS ON BACK

FORM 1127 (5-75)

S-14671

Figure 7-6. Program Performance Record Sheet

Figure 7-7. Cumulative Cost and Budget Schedules

7.6.2 DOE Cost and Performance Financial Reports

Monthly financial reports forwarded to DOE will consist of the Short Form Cost Management Report (Form ERDA 633M) and the Contract Management Summary Report (Form ERDA 536). These two reports will provide a complete overview of program cost and an assessment of program performance.

8. GOVERNMENT-OWNED PROPERTY

No Government-owned property (GOP) will be required for the heat pump program.