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Polonium Radioisotope Thermoelectric Generator

Development Program
Part I

P6124

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Polonium Radioisotope Thermoelectric Generator

Development Program Part I

MND-3612-8-1

December 1965

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FOREWORD

The United States Atomic Energy Commission awarded Contract AT(30-1)-3612 to the Martin Company, Baltimore Division on September 16, 1965. The contract provides for the investigation of the feasibility of producing a flight operational 400-watt, Po-210 radioisotope power system with the first flight system scheduled for delivery on January 1, 1968. The results of the study are presented in six documents:

MND-3612-6	Program Summary
MND-3612-7-1	Phase I Technical Conclusions, Part I
MND-3612-7-2	Phase I Technical Conclusions, Part II
MND-3612-8-1	Development Program, Part I ✓
MND-3612-8-2	Management Program, Part II
MND-3612-9	Specifications

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I. INTRODUCTION

The recommended development program for the Po RTG system is detailed in this document. For Phase II, a detailed task breakdown is provided to indicate the Martin approach to Program Management, Configuration and Integration Management, Safety Analysis and Testing, Component Analysis and Design, Component Fabrication and Process Specifications, Component Testing, Reliability Demonstration and Pre-prototype Assembly. In addition, Task 7 describes recommended concurrent development for alternate components not included in the Reference Design but which have the potential of improving the design for the planned and other missions.

The Phase III development plan describes in detail the prototype design, fabrication and testing of seven prototype generators of which three are delivered, the completion of the safety effort, and the delivery of an AGE system.

Phase IV completes the development plan with the fabrication of four RTG systems, three of which are delivered as flight operational systems, the delivery of final drawings, and the launch and safety support for the first launch.

Detailed Quality Control and Reliability program plans are presented in Chapter III. These plans describe the adaptation of Martin procedures to this program and the additional special procedures recommended to assure the Quality fabrication of a reliable system.

In Chapter IV, schedules are presented which include a master bar chart schedule, detailed bar charts, and detailed and summary PERT charts (under separate cover) for the recommended, minimum-time and minimum-cost program. A detailed facilities plan also is included in this chapter which describes the chronological application of facilities as required by the schedule.

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II. DETAILED PROGRAM PLAN

This program provides for design, component and system development, system qualification and demonstration and delivery of three flight qualified RTG power systems plus associated Aerospace Ground Equipment. It also provides a recommended concurrent development program for alternate components and improved design for the planned and other missions. The program is divided into three Phases as outlined in detail in Fig. II-1, and discussed in the following sections:

Phase II--RTG and AGE Design and Development

Phase III--Prototype System Design, Fabrication and Qualification

Phase IV--Flight System Design, Fabrication and Acceptance

Details of each phase, with its major objectives, are discussed in the following sections.

PHASE II--RTG AND AGE DESIGN AND DEVELOPMENT

This phase will consist of the final designs of the RTG components and the ground handling equipment. These designs will be determined by detail analysis and design, complemented by component development and testing. The necessary safety testing required to evaluate credible hazards and to prepare a preliminary safety analysis report will also be accomplished. The primary goal of this phase is to fabricate the RTG and AGE components and, by testing, demonstrate the achievement of system specifications. The results of this work phase will be used in the preparation of drawings, specifications and processes to fabricate a prototype RTG and the necessary ground support equipment.

Phase II efforts have been divided into the following tasks:

Task 1--Management and Controls

Task 2--Design and Analysis

Task 3--Safety and Shielding Analysis

Task 4--RTG Components Manufacturing, Development and Testing

Task 5--AGE Components Development and Testing

Task 6--Safety and Shielding Development and Testing

Task 7--RTG Component Advanced Development

The task breakdown and the work details under each task reflect the design efforts of the Phase I study.

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Phase II		Phase III		Phase IV	
RTG and AGE Design and Development		Prototype System Design, Fabrication and Quality Assurance		Flight System Design, Fabrication and Acceptance	
A	Task 1 0--Management and Controls 1. Program Management a. Reporting b. Controls c. Procurement and Subcontract Administration 2. Configuration and Integration Management a. Interface Liaison and Control b. Configuration Management 3. Reliability a. Reliability Program Plan b. Reliability Analysis and Verification 4. Quality Assurance a. Quality Program Plan b. Quality Verification 5. Manuals	A.	Task 1 0--Management and Controls 1. Program Management 2. Configuration and Integration Management 3. Reliability 4. Quality Assurance 5. Technical Manual(s)	A.	Task 1.0--Management and Controls 1. Program Management 2. Configuration and Integration Management 3. Reliability 4. Quality Assurance 5. Technical Manuals
B.	Task 2.0--Design and Analysis 1. System Integration Analysis and Design a. RTG System and Vehicle Integration b. AGE System and Launch Complex Integration 2. System Analysis and Design a. RTG Analysis and Design b. AGE Analysis and Design 3. Fabrication, Test Specifications and Evaluation a. RTG Fabrication, Test Specifications and Evaluation b. AGE Fabrication, Test Specifications and Evaluation	B.	Task 2.0--Prototype Design and Analysis 1. System Integration Analysis and Design a. RTG System and Integration b. AGE System and Launch Complex 2. System Analysis and Design a. RTG Analysis and Design b. AGE Final Design 3. Prototype Fabrication, Test Specification and Evaluation a. RTG Fabrication, Test Specification and Evaluation b. AGE Fabrication, Test Specification and Evaluation	B.	Task 2.0--Flight System Design and Analysis 1. Integration and Flight Support Analysis 2. System Analysis and Design
C.	Task 3 0--Safety and Shielding Analysis 1. System Safety Analyses 2. Shielding Analyses 3. Test Specification and Evaluation	C	Task 3.0--Safety and Shielding Analysis 1. Safety Analysis a. Final Safety and Shielding Analysis Report b. Flight Approval Liaison	C	Task 3.0--Safety-Monitoring and Support Activity
D.	Task 4.0--RTG Power System Components, Development, Manufacturing and Testing 1. RTG Test Preparation a. Test Procedures b. Instrumentation Calibration c. Test Setup 2. RTG Manufacturing Process Development and Tooling Fabrication a. Heat Source b. Emissive Coatings c. T/E Couples d. Thermoelectric Modules e. Thermal Control System 3. RTG Component and Test Fixture Fabrication a. Heat source b. T/E Couples and Modules c. Coolant Heat Rejection System d. Thermal Control System e. Operation Model RTG System 4. RTG Components Development and Reliability Testing a. Heat Source Dynamic Testing b. T/E Couple and Module Testing c. Coolant Heat Rejection Thermal Hydraulic Performance and Dynamic Testing d. Thermal Control Subsystem Performance and Testing e. Prototype Assemblies f. Engineering Model RTG System Performance Testing	D.	Task 4 0--Prototype RTG Manufacturing and Testing 1. RTG Test Preparation 2. RTG Assembly Process Development and Tooling Fabrication 3. Prototype RTG and Test Fixture Fabrication 4. Prototype RTG Testing a. Production Monitoring Tests b. Acceptance Testing c. Qualification Testing d. Performance and Life Testing e. Integration Contractor Testing Support	D.	Task 4 0--Flight System RTG Manufacturing and Testing 1. RTG Test Preparation 2. Flight System RTG Fabrication 3. Flight System Testing a. Production Testing b. Acceptance Testing c. Performance Testing d. Prelaunch and Launch Support
E.	Task 5.0--AGE Component Development, Fabrication and Testing 1. AGE Test Preparation a. Test Procedures b. Instrument Calibration c. Test Setup 2. AGE Manufacturing Process Development and Tooling Fabrication a. Fuel Handling Machine b. Electrical Heat Source c. Other AGE Items 3. AGE Components and Test Fixture Fabrication a. FHM Components b. Electrical Heat Sources c. FHM Test Fixtures d. Other AGE Items 4. AGE Components Development and Testing a. FHM Compliance Subsystem Engineering Development Test b. FHM Component Environmental Tests c. FHM Environmental Tests d. FHM Performance and Engineering Development Tests e. Electrical Heat Source Tests	E.	Task 5.0--AGE Development Plan, Fabrication and Testing 1. AGE Components Testing a. FHM System Tests b. FHM Checkout Equipment c. RTG Power System Shipping Container d. RTG Power System Field Test Equipment e. NaK Ground Service System f. Fuel Transportation Cask g. Electrical Heat Sources	E.	Task 5.0--AGE Quality Control and Testing 1. RTG Power System Container 2. Electrical Heat Sources
F.	Task 6.0--Safety and Shielding Development and Testing 1. Safety and Shielding Test Preparation a. Test Procedure b. Instrumentation Calibration c. Test Setup 2. Safety and Shielding Manufacturing Process Development and Tooling 3. Safety and Shielding Test Article Fabrication a. Re-entry Heat Source Models b. Capsules c. Shielding 4. Safety and Shielding Development Testing a. Re-entry Heat Source Testing b. Capsule Testing c. Shielding Tests				
G.	Task 7 0--RTG Component Advanced Development Activity 1. T/E Couple Development 2. T/E Module Development 3. Heat Source Development 4. Thermal Control Development 5. Heat Rejection System Development 6. Configuration and Fuel Development	G.	Task 7 0--RTG Component Advanced Development Continue per Phase II	G.	Task 7.0--RTG Component Advanced Development Complete per Phase II

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A. TASK 1.0--MANAGEMENT AND CONTROLS

The proposed program will be conducted in accordance with the Program Management concept. The Program Manager will have the responsibility and authority to direct the integration, technical program, financial expenditures and scheduling. It will be his responsibility to assure that all the contractual obligations are met and, further, to maintain the proper balance among the aforementioned factors. MND-3612-8-2 provides a detailed description of the Program Management and supporting staff functions.

Included in this management task are all of the functions essential to conducting a program of this magnitude. These functions involve the internal management scheduling and controls of the program and the external liaison, integration and communication with the AEC User Agency, Fueling Agency and subcontractors. In brief, it represents the focal point of the program, linking the external requirements to the internal execution of these requirements.

1. Program Management

a. Reporting

The following reports will be prepared and distributed during this program:

- (1) Informal monthly letter progress reports on a limited distribution. These reports will include a description of overall progress and a discussion of current problem areas.
- (2) Quarterly progress reports will be prepared and submitted in accordance with Category 92a of the Commission's Standard Distribution List of Classified Scientific and Technical Reports, M-3679.
- (3) Topical reports will be prepared and submitted in accordance with Category 92a of the Commission's Standard Distribution List for Classified Scientific and Technical Reports, M-3679.
- (4) Ten copies of a draft of the final report will be submitted to the Commission two weeks prior to the end of the contract period.
- (5) The final report will be distributed in accordance with Category 92a of the Commission's Standard Distribution List for Classified Scientific and Technical Reports, M-3679. An additional 15 copies shall be furnished to the Commission.

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- (6) Briefing aids such as photographs and 35-mm color slides in limited quantities will be supplied.

b. Controls

The Program Manager will use a number of management procedures to effect control and integration of this program, including:

- (1) Daily coordination meetings with the Project Engineer and Manager, Interface Specifications
- (2) Weekly program meetings with all members of the supporting staff
- (3) Monthly program review meetings by the Program Manager with the Baltimore Division top management to assure:
 - (a) Proper dissemination of information to top management levels
 - (b) Assistance of top management in applying the experience available throughout the Company to this program where required
 - (c) Top management that the program is proceeding properly or, if delinquent, to obtain their aid in correcting deficiencies
- (4) Engineering Design Reviews held at appropriate design milestones to assure compliance with specifications, adequacy of design and the consideration of alternate design approaches
- (5) Coordination among the Program Manager, his staff, the Atomic Energy Commission and, when appropriate, the User Agency as required throughout the program
- (6) Implementation of a system of schedule controls, employing the following elements:
 - (a) Major milestone charts showing the scheduled relationship of major milestones on each task of the program.
 - (b) Detailed gantt charts establishing the chronological time for minor milestones in each task, providing inputs on the progress toward major milestones.
 - (c) Page and line schedules of detailed day-to-day scheduling for each subtask listing all milestones to be accomplished (analysis, design, purchase order release, material

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available, quality inspection, fabrication, quality acceptance, etc.). These schedules are reviewed in detail on a weekly basis to assure schedule compliance or deficiencies. Results are fed into PERT and detailed charts. If deficiencies create critical path delays or major milestone delays, recovery action is immediately instituted.

- (d) PERT/Time charts such as summary and detailed PERT charts for each item of work included under each subtask. This technique identifies the detailed interrelationship among all work items. Computer runs establish the critical path, slack time and the effect of item delay on the major milestones and overall program.
- (7) Implementation of a system of cost control employing the following elements:
- (a) Layout of cost estimates by subtask per month. This expenditure plan establishes the base line of dollars for each subtask. Each subtask is assigned a separate cost control center.
 - (b) The funding limitations for each suffix number or work effort are issued to the affected departments by means of an Operations Directive which indicates the amount of direct dollars to be spent, by whom, for what, span time (by date) for the expenditure and suffix number to which the expenditure is to be charged.
 - (c) Weekly unaudited IBM cost runs are prepared and reviewed at the weekly Program Meeting and expenditures are related to accomplishments. If financial problems are present, corrective action is employed and the customer is notified at the earliest time if funding under the contract is affected.
 - (d) Monthly audited costs runs are reviewed in detail and are the basis for monthly financial reports to the AEC.
- (8) An input/output chart which develops a curve that integrates financial and schedule data (Fig. II-2) will be maintained.

The curve shows: how much was planned to be spent and how much was actually spent--the input; how much work was planned to be done and how much was actually done--the output; and the allocated funds for the segment of work plotted which must be in agreement with the contract allocation. Charts will be made for each area of work to be measured.

Fig. II-2. Input/Output Control Chart

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As money is actually spent and the work completed, actual input and outputs are plotted monthly. Input/output curves will be reviewed at each program review meeting.

At this time, the Planning and Finance Representatives must advise the Program Manager whether:

- (1) The spending is in accordance with plan.
- (2) The proper amount of work has been completed relative to the dollars expended.
- (3) Contract requirements in dollars and schedule will be achieved (estimate to complete).

If the answers to these questions show that a deviation from the norm exist and that satisfactory corrective measures are not under way, a course of remedial action is immediately set in motion by the Program Manager.

A Control Room will be located in the project area. It will be used by the Program Manager and his staff to maintain current schedule, financial, quality and performance data useful in controlling the program.

c. Procurement and subcontract administration

(1) Supplier performance evaluation. For several years, Martin has utilized a supplier evaluation system that was sensitive to performance data as reported by Quality Control and Procurement personnel. Recently, with increasing Government emphasis on contractor evaluation, Martin has incorporated a major improvement in the system which permits more timely, accurate and knowledgeable use of the acquired data and automates portions of the process.

The new system combines both a supplier performance record and a rating system on the same document. Every receipt is noted, with actual receipt and contract dates, variance and responsibility for the variance. Each rejection is shown, with origin and disposition dates, cognizant buyer, authorization for disposition, type of rejection, disposition of rejection, responsibility and notation as to whether source inspection was performed. This information, as well as the rating derived therefrom, is accessible in a single complete tabulation for every supplier.

The buyer having access to these tabulations can immediately detect any problem areas, recognize trends and intelligently plan future action. The performance tabulations are sufficiently detailed as to provide a basis for discussion of a supplier's performance without reference to other documents.

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In addition, management review is simplified. Since the record shows the actual performance along with the rating, questions of interpretation and weightings do not occur. The time span and volume of the data are immediately apparent to form a basis for judgment as to adequacy and control. All tabulations are cumulative and are released monthly, making a complete record of receipts and rejections available for permanent reference at the year's end.

(2) Subcontract administration. In the subcontract system the placement, the administration of changes, and the surveillance of subcontractor costs and schedules are more highly organized and involve more formal paperwork than may be required for ordinary procurements. Although the buyer still assumes major responsibility for the subcontract, he coordinates closely with Materiel management and has the assistance of supporting activities as well as specialists in other departments. He also has at his disposal, a variety of contractual formats for selection and adaption to the particular subcontract requirement; these may include letter contracts, personal service and agreement contracts, cost reimbursement, incentive and time and material formats.

Budgetary and schedule controls are frequently applied to the major subcontractor. Established forms are available including a series providing for a regular flow of reports, as necessary, from subcontractors to Martin control groups and the PERT controls. In addition, regular program review meetings are held with the major subcontractor, usually alternating between Martin and the subcontractor plants.

Management exercises the same monetary and other levels of surveillance over the subcontract amendment as over the original procurement action. Change notices, when required to expedite subcontractor direction, must be covered by formal contract paperwork within a specified period. Requirements for file documentation, management and customer approval and substantiation of reasonable pricing are applicable to amendments as well as subcontracts.

It is customary to provide for periodic visits by the buyer to his major subcontractors, accompanied by such other qualified technical or financial personnel as may be necessary. These visits serve to facilitate coordination.

Resident Materiel Representatives are utilized on the larger subcontracts to resolve problem areas by on-the-spot decisions, or by reference back to the responsible buyer.

Primary subcontracts to which these techniques will be applied include:

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- (1) MSA Research Corporation for EM pump development and liquid metal handling techniques and equipment.
- (2) General Electric Corporation for vacuum chamber test facilities.

2. Configuration and Integration Management

This subtask encompasses the procedures, documentation and coordination with Martin and other organizations necessary to establish and maintain an effective design requirement base line for design, development, test, fabrication and integration of a Po RTG power system with the satellite vehicle. Specifically, this effort can be further defined to include Interface liaison and control and Configuration management.

To define and maintain design and performance objectives and to provide a base for documentation, a series of interrelated specifications were prepared in Phase I. These specifications plus those to be prepared during the remainder of the program are shown as a specification tree in Fig. II-3 and encompass first level system specifications (design and performance base line), supporting interface specifications (interagency factors) and final product or contract end item specifications. System and interface specifications shown in solid outline, MND-3612-10, -11, -12, -13, and -30 are included in MND-3612-9. The preparation, content and contractor use of these specifications are based on USAF requirements per AFSCM-375-1 and AFSCM-310-1C. These USAF manuals will be used as a guide to prepare and control specifications during the Po RTG program. Military specifications and standards will be embodied insofar as possible and to the extent defined in the specifications prepared by the contractor.

a. Interface liaison and control

A complex technical, performance and responsibility interface exists between the contractor, the AEC, User Agency and associate contractors concerned with the total space mission requirement. Performance and design requirements at the system level, as generated during Phase I, must be coordinated and revised as they are clarified. It is anticipated that during the program, this interface relationship will continue in accordance with the diagram shown in Fig. II-4.

It is recommended that an interface working group be established representing agencies and contractors affected by the Po RTG power system. This group would review and establish an acceptable base for system changes affecting the respective contractors in preparation for the formal change negotiation cycle between the contractors and their procurement agency. In addition, Associate Contractor Agreements would be established to promote working relationship, for example, between Martin and the Integration Contractor.

NOTE:

Specifications within solid outlines have been prepared under Phase I as baseline criteria.
Specifications within dotted outlines will be prepared in Phase II.

Fig. II-3. Po RTG Specification Tree

Fig. II-4. Agency/Contractor, Contract/Specification Relationship

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*Updating, within the scope of work required to satisfy the requirements of the specifications prepared and submitted at the end of Phase I.

**Preparation of contract and specification changes after date of interface "freeze" or which are beyond the scope of specifications submitted at the end of Phase I.

Fig. II-5. Specification Sequence

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Interface management would also be responsible throughout the program for coordination of in-house actions with respect to interface and specification control activities and follow-up with the appropriate agency/contractors to assure actions as resolved in the interface specifications.

b. Configuration management

Procedures and techniques will be used to identify, control and account for contractor technical efforts and the articles to be furnished under the contract. Specifically, configuration management will perform the following:

- (1) Establish and define functional and physical interfaces between contractor-furnished articles and services and the equipments, facilities and activities of others.
- (2) Define the requirements for design, fabrication, test and delivery of contractor-furnished articles.
- (3) Define efforts and services to be furnished by the contractor.
- (4) Establish and define procedures and documentation to be implemented and supplied by the contractor and which are compatible with or necessary to both AEC, User and other agency activities.
- (5) Control contractor-procured articles and the efforts and products of subcontractors.
- (6) Establish and control the interrelation of contractual and technical requirements.
- (7) Provide for verification of compliance with contractual and technical requirements.
- (8) Furnish a basis for acceptance of contractor-furnished articles and efforts.

To establish comprehensive specifications, those documents indicated in Fig. II-3, as required, will be prepared by configuration management and coordinated with the AEC. Preparation and finalization of these documents will be accomplished as early as practicable in Phase II of the program, in the sequence indicated in Fig. II-5. However, the specific points in the span of Phase II at which the documents will be considered complete will be based on the scheduled point at which interface criteria between the contractor and the User Agency must be considered to be "frozen."

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This schedule point necessarily occurs at that time where changes by either the contractor or the User Agency will appreciably affect the effort and end articles of the other organization. In support of these changes, configuration management will establish and conduct a program change board to validate and establish a basis for negotiation.

Subsequent to the interface freeze, changes in contractor-prepared specifications will be accomplished by a Contract Change Proposal (CCP) and or Specification Change Notice (SCN). Coordination and approval of technical aspects of changes occurring after the freeze date will be accomplished via interagency working group relationships established by the AEC.

3. Reliability

Phase II is the most critical period of the development program from the standpoint of reliability achievement because it is during this phase that the design is made firm, parts, materials and vendors are selected, components and subsystems are assembled, manufacturing processes are qualified, and tests are conducted to explore failure modes and confirm design analyses. This is the primary period for reliability achievement.

a. Reliability program plan

During Phase I, a comprehensive Reliability program plan was prepared to identify effort necessary to meet the total reliability requirement for the Po RTG power system and associated AGE, and assure that the system components, parts and materials are selected to meet allocated reliability requirements. This plan is presented in Chapter III and is designed to provide criteria to guide system design, part and material selection, test programs and qualification of manufacturing processes.

The Reliability program plan will be implemented in Phase II to assure that designs are evaluated and tests performed as required for compliance with reliability objectives. The plan reflects the requirements of the interface and system specifications and will be modified to comply with any changes.

b. Reliability analysis and verification

The major areas of reliability emphasis during Phase II are:

- (1) Design analysis and prediction, tradeoff studies, failure analysis, trouble reporting and corrective action and preparation of design specifications.

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- (2) Part and material selection, procurement, control and handling, and vendor control.
- (3) Implementation and evaluation of the test program, review and approval of test specifications and procedures, monitoring of tests, analysis of test results, and review and approval of qualification test results.
- (4) Monitoring the qualification of manufacturing processes.

The special controlled parts covering receiving inspection, acceptance testing and internal handling and storage of purchased components and parts will be implemented during this phase.

Data associated with design and test reliability factors will be accumulated and analyzed to provide detection of reliability deficiencies and a basis for adjustment and/or correction.

4. Quality Assurance

a. Quality program plan

During Phase I, a comprehensive Quality program plan was prepared to identify and specify Quality tasks associated with the design, development, fabrication and test of the Po RTG power system and its supporting aerospace ground equipment (AGE) and the integration of these equipments into an earth orbit satellite program. This plan is designed to provide the management criteria to guide the implementation of the Quality tasks commencing with the Phase II generator and AGE subsystem development and continuing throughout subsequent phases, culminating in the delivery and integration of flight operational power systems. Chapter III contains the complete Po RTG Quality program plan.

The Po RTG Quality plan is patterned after those procedures and controls successfully proven on the Martin Gemini program and provides for the timely establishment and implementation of detailed process controls through preproduction qualification of all major production processes; evaluation, selection, identification and control of controlled parts to minimize degradation during fabrication, test, storage and transportation; integrated failure reporting, failed parts analysis and corrective action systems applicable to development, qualification, reliability and acceptance testing efforts; and an unbroken chain of Quality coverage at the Fueling Agency, Integration Contractor and launch site facilities.

Essentially, this plan encompasses Quality participation in all phases of the Po RTG program from contract inception to completion and includes: Quality program management, design and develop-

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ment controls, Quality technical planning, Procurement controls, Manufacturing controls and subcontractor and launch site activities. The depth of presentation of the material covered by the plan is aimed at providing, in addition to an itemization of those Quality functions that will be implemented on the Po RTG program, concise explanations of the systems that will be employed, supported by pertinent flow diagrams and illustrations.

Phase II effort will activate the Quality program plan. Quality functions associated with procurement and supplier selection, procurement document review, receiving inspection, process qualification, inspection/test, documentation and reporting will be exercised and proven.

b. Quality verification

Systems and procedures for collecting, processing and maintaining data records necessary for evaluating and controlling the quality and reliability of the Po RTG system will be implemented concurrent with the start of Phase II Engineering component development testing, thereby assuring precise traceable historical data. The testing program will include fuel capsule and fuel block development tests, thermoelectric couple and module development tests, NaK electromagnetic pump and actuator development tests, coolant heat rejection subsystem development and qualification tests, thermal control subsystem qualification tests and Po RTG power system qualification and reliability tests. In those areas where Quality witnesses or performs the testing, Quality will collect all operational data. Test data generated during certain development testing will be accumulated and retained by Engineering, subject to review by Quality Engineering.

Data associated with planned in-plant, subcontractor and launch site inspections will be accumulated and maintained by Quality Planning. Analyses of these data and the selection of pertinent data from the collected documentation will be utilized during Phase II to provide early detection of design and fabrication deficiencies, establish the need for improved process controls, and evaluate the need for specific training certification or recertification.

5. Manuals

This subtask covers the effort necessary to prepare and supply Po RTG power system manuals for use by Martin and AEC/User organizations. These manuals include operation-instruction and equipment-maintenance. They will also serve to clarify the RTG requirements relative to the overall launch vehicle system. At the present time no training effort for non-Martin personnel is anticipated.

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The planned effort for Phase II includes:

- (1) Development of a topical outline for the technical manual and determination of the variety of manuals to be produced (dependent on requirements of the total launch vehicle system).
- (2) Establishing of detailed requirements/specifications to which the manuals will be produced.
- (3) Determining to what degree Martin Company personnel will support operation and maintenance.
- (4) Completion and submittal of a manual preparation plan establishing dates for manual validation, preliminary release, verification, approval and final release.

In addition to the manual requirement, this task includes preparation of documentary film footage covering activity and efforts of the Martin Company with respect to the Po RTG power system program. This effort will be initiated during Phase II.

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B. TASK 2.0--DESIGN AND ANALYSIS

1. System Integration Analysis and Design

a. RTG system and vehicle integration

To establish RTG power system compatibility with the parent vehicle, an analysis and design effort evaluating the following integration criteria will be conducted:

- (1) Electrical and instrumentation
- (2) Thermal conduction, convection and radiation
- (3) Mechanical and structural.

The results of this effort will define the critical interfaces and present reference design and functional and performance characteristics of the major subsystems.

Preliminary assembly designs will develop into final designs as the satellite vehicle interface requirements and detailed components are firmed up throughout this phase. Liaison with associated parties will be carefully established and maintained throughout the program to assure optimization of the integrated launch vehicle system.

The integration analysis and design effort will be performed principally in three areas: electrical and instrumentation; thermal compatibility with the satellite vehicle relative to insulation and thermal shields; and, mechanical design encompassing primarily structural design and stress analysis.

The electrical and instrumentation integration design effort will consist of providing liaison with all involved agencies to provide proper interconnection means for electric power and for RTG instrumentation. Terminal or connector design will be coordinated to assure ease of installation during assembly.

The power characteristics of the RTG will be thoroughly coordinated with the User Agency so that proper design of the power conditioner will be accomplished.

All instrument sensor characteristics will be provided to the User Agency at a sufficiently early date to allow him to design his signal conditioning equipment to be compatible with the T/M system.

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The analysis effort in this phase of the program will result in system integration layout with the following factors considered:

- (1) Ground cooling requirements for the radiator, thermal control heat source subsystems and nearby thermally sensitive equipment.
- (2) Thermal insulation requirements for various vehicle components.
- (3) Thermal inputs to spacecraft heat sinks.
- (4) Transient thermal analyses of critical items during the fuel source loading and the generator launching phases.
- (5) Geometry and shadow effects on the radiator due to the spacecraft.
- (6) Geometry and shadow effects on thermal control system due to the spacecraft.

The thermal insulation design will be compatible with the results of the thermal analysis performed under this task. Minimum weight, along with ease of installation on the vehicle, will be primary considerations. The details of the design and mounting points will depend on the selected vehicle and the preferred mounting points in the selected vehicle.

The mounting provisions for the RTG system will be designed with minimum interfacing and minimum weight as goals. All structural supports will be stress analyzed for the shock and dynamic loadings consistent with those of the booster at the location of the RTG mounting points. Where necessary, a dynamic digital code will be used to determine the transmissibility of these loads to the generator system. All such calculated loads at attachment points will be forwarded to the vehicle manufacturer to ensure structural integrity of the missile structure to which the RTG system is mounted. These calculated loads will be substantiated by the shock and vibration tests performed during Task 4.0.

The physical arrangement of components into the spacecraft will to some extent be iterative. It is anticipated that the initially designed layouts of the integration schemes will be made and discussed with all involved parties to coordinate the details. New designs or design modifications will then be made.

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b. AGE system and launch complex integration

(1) Functional and performance integration analyses. Liaison shall be performed with the User Agency to support a design analysis of AGE requirements. Interface drawings and specifications shall be updated as required. An intensive effort shall be applied during the first month of Phase II to assemble the most up-to-date information on the AGE interfaces. At the end of the first month, updated interface drawings and specifications shall be issued for review by the Customer.

(2) Arrangement and physical integration design. After review, the interface drawings and specifications are returned with additions and comments to Martin and the site modifications design shall be completed. This effort is timed to occur at a point in fuel handling machine (FHM) design which permits an accurate description of FHM requirements.

2. Systems Analysis and Design

a. RTG analysis and design

During Phase II, detail designs of the various generator components will be made. The Reference Design will be the same as that conceived during Phase I. Certain components which require further development, such as the fuel block, will require special emphasis early in the phase. As the Phase II detail drawings are developed, it would be normal to anticipate that additional items will be uncovered requiring proof tests or the establishment of reliability values. These relatively minor proof tests would continue in parallel with the detail design efforts.

The detailing effort will be subdivided into the following basic RTG subsystems.

- (1) Heat source (includes fuel block and capsules)
- (2) T/E conversion module
- (3) Thermal control system
- (4) Coolant heat rejection (includes radiator coolant loop and NaK pump)
- (5) Support structures.

It is anticipated that integration inputs from the Satellite Vehicle Contractor will require additional iterations as more detailed information is received and the overall system is optimized.

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fuel block and capsule materials. The effectiveness of the final shield design will be substantiated by experimental data obtained with a Co-60 gamma source and a Pu-238 neutron source with the absolute magnitudes of each sealed according to source strengths for the polonium obtained from Mound Laboratory.

The thermoelectric conversion module design will be initiated based on the design evolved in Phase I. In addition, experience gained in the performance testing of the Martin-sponsored test module will be factored into the design. It is anticipated that this testing will indicate areas where design improvements can be made whether they be in design or fabrication techniques.

The thermal control system design will also be influenced by the results of testing of the NaK thermal control system being performed under Martin funds. Such factors as thermal response of the NaK actuating system to changes in hot plate temperature will have a bearing on the adequacy or inadequacy of the thermal control system conceived in Phase I. This test program will also provide information as to thermal performance of the shutter vanes. Particular attention will be given to parasitic conduction paths along the structure that supports the louvres and along the edges of the louvres themselves. The louvre design, as conceived in Phase I, can be made either of Min-K 2000 or polished foil, preferably of palladium. Investigation of Phase I indicates that palladium foils are more difficult to fabricate and are somewhat more expensive. The foils will be further investigated as a potential means of improving thermal performance of the generator, since the total insulation thickness is somewhat less than Min-K for the same heat loss. Min-K thickness greater than one inch becomes quite cumbersome for louvre designs.

The thermal control system design effort will include continued investigation of the electrical system for potential improvement. A detailed plan for this design is included in Subtask 7.4.

The detail design of the coolant heat rejection system consisting of the radiator, NaK pump and coolant pipes will depend on the vehicle finally selected. Therefore, vehicle selection should be made early in Phase II. The initial radiator design will be based on the use of the stainless steel aluminum composite tubing. Potential improvement through the use of an all aluminum system or stainless steel magnesium system will be investigated in Subtask 7.5.

Detailed weld joint designs for connection of the radiator tubes to the coolant headers will be made so that samples of the welds can be made. Radiographic examination and leak testing methods will be utilized to determine the best design. Reliability requirements may require that redundant type joints be used as discussed in the radiator design section.

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The thermal insulation requirements around the radiator for minimizing heat dump to the vehicle internals will be determined once a permissible heat load is specified.

Support structure detail design will again depend on the vehicle selected. This is again strong reason for selection of the vehicle early in Phase II. All support structure will be stress analyzed for the shock and dynamic loadings consistent with those of the booster at the location of the RTG mounting points.

This phase will also encompass a materials evaluation effort to establish materials properties, select the best material for each component, ensure compatibility and examine in more detail the problems of joining, welding and fabrication.

(1) Maintainability. During component detailed design, the engineers will continue to consider the generator maintainability as a design criterion.

Design reviews shall be regularly conducted to assure that maintainability aspects are being given adequate consideration. Recommendations resulting from these reviews shall be submitted to the designer for further evaluation and incorporation into the design when justified.

During RTG development, it is anticipated that certain tradeoffs in design will be required. Supervision will participate in these tradeoffs so that an equitable balance between performance requirements, maintainability, man-machine considerations, operations requirement and cost can be made.

Design liaison with the Satellite Vehicle Contractor will be more firmly established in this area. The interface effects of the RTG on space vehicle maintainability, and, conversely, space vehicle effect on the RTG shall be evaluated and mutual agreements reached on problem resolutions.

b. AGE analysis and design

Except for a continuing effort of small proportion, all analysis and design of the AGE equipment shall be completed in Phase II. The design will be fixed in all AGE areas to permit the majority of procurement orders to be written. The minor effort planned in Phase III would not change the basic layouts of Phase II.

(1) Component design and analyses of FHM. The design of the FHM will be conducted in three steps during Phase II:

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- (1) A prototype FHM design will be completed and the prototype fabricated and tested.
- (2) An intensive analysis of the results of prototype tests will be made.
- (3) The final design of the FHM will be completed.

The prototype design shall proceed approximately as follows. During the first month after go-ahead, an evaluation of the conceptual design will be completed. Concurrently, preliminary layouts of the machine system will be made as interface drawings are being updated in response to information gained by the liaison effort with the Customer. When the interface drawings are released for review and comment to the Customer early in the second month, the detail design of the FHM will be initiated.

Only the compliance subsystem will be fabricated and tested prior to prototype tests of the entire FHM system. The compliance subsystem and its closely related subsystems will be the first ones started into detail design. During the initial design work, analyses will be underway of thermal characteristics and radiation shielding. As the results of these analyses are available, the appropriate subsystem designs can be initiated. Human factors analysis will be performed that will lead into detail design of the work station. The schedule has been arranged to maintain a constant project design team workload. The design effort is conducted in a logical progression which fits in with the AGE system design requirements and produces a system design at minimum cost due to the continuity of the effort.

Many problems were cited in MND-3612-7-1 on the Phase I conceptual design. The problems are of the type which can be resolved by obtaining additional data from other agencies and by design analyses. No engineering development problems were noted which require materials, fabrication processes or components that are beyond present state-of-art.

In certain areas, the possibility for design improvement has been noted but it will require study during the prototype FHM tests. A special effort is planned to design specific prototype performance tests to allow evaluation of given operating modes. When prototype testing is completed, and the results have been analyzed, all information on needed design improvements will be available. Final design and final drawings will then be started.

(2) Design and analyses of transportation casks. Design of the fuel transportation cask will be started after the related interfaces have been established between the fuel transportation cask and the FHM, and

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the equipment and services of both the User and Fueling Agencies. The cask design can proceed in a straightforward manner after the mode of shipping and the general requirements are known. Analyses will be made to assure that the cask meets all applicable regulations. Particular attention will be given to analyses of emergency conditions that the cask must meet. The analyses will show that the cask can meet its design requirements in regard to radiation protection, resistance to effects of a drop and survival of a fire. It is anticipated that these analyses will be sufficient to obtain necessary shipping permits and thus no tests are planned. The design shall be completed in Phase II.

(3) RTG field test equipment. Equipment will be designed to permit setup and checkout of the RTG power system at three locations, the Martin plant, the Vehicle Integration Contractor's plant, and the launch site. A survey of available equipment at the launch site will be performed to determine its applicability to this program. Such equipment, however, must be sufficiently similar to that used by the Martin Company and Integration Contractor so as not to compromise the checkout requirements. The objective here is: first, no compromise; second, no duplication. The design shall be completed in Phase II.

(4) FHM checkout equipment. This equipment will be supplied to permit field service and maintenance of the FHM. The field maintenance will be limited to adjustment, cleaning, calibrating and minor replacement. For major repair or maintenance, the FHM will be returned to the Martin plant.

The checkout equipment will be designed concurrently with the FHM final design effort in Phase II.

(5) Electrical heat source. The electrical heat source will be development tested at the individual heater component level, and the electrical heat source assembly will be designed in accordance with test results. This effort will be completed in Phase II in time to permit fabrication of an electrical heater source for the FHM prototype testing.

(6) NaK handling system. A NaK handling system will be designed for Martin Company in-house application. The equipment will be arranged in a manner which permits shipment of the system to other locations, such as at the Integration Contractor's plant.

(7) RTG shipping container. The RTG shipping container, as presently planned, permits shipment of an RTG by common carrier from the Martin plant to the launch site.

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Analysis will be made to assure that the RTG power system is supported in the container in a manner which prevents damage during transportation. This work will be completed in Phase II.

3. Fabrication, Test Specifications and Evaluation

a. RTG fabrication, test specification and evaluation

This task encompasses preparation of all manufacturing process specifications, assembly specifications, test directives and specifications, detail test fixture design, instrumentation design, test data evaluation and preparation of test reports.

Engineering will prepare test directives which clearly define test objectives. The detail procedures for achieving these objectives will be established under Task 4. The necessary test fixtures to perform the required tests will be designed under this task as well as any required test loops. For example, the thermal harp loop used for performance tests of the NaK pump and test fixtures for the vibration and shock tests will be designed under this task.

Component fabrication and testing will be closely monitored by engineering. Whenever a component does not satisfy the design objective, it will be modified as required. As RTG components, i. e., modules, fuel block capsules, radiator, etc., proceed through their respective testing cycles and performance data are generated, the data will be analyzed to determine what modifications are necessary to improve the product. The data evaluation will be performed during and after the tests to ensure compliance with the planned test directives. Modifications to the design will be performed under Subtask 2.2.1. Any changes included in the final design will be subjected to proof tests if they affect the performance of the final overall system in any way. Revisions to specifications and manufacturing processes will also be made whenever a deficiency exists.

b. AGE fabrication, test specifications and evaluation

(1) Fabrication. Fabrication process specifications will be written for the prototype FHM under this subtask. The prototype FHM will be used in Phase II to verify the manufacturing process specifications. Any needed improvements will be incorporated into the deliverable unit in Phase III.

After the prototype FHM is fabricated, an evaluation will be made of the manufacturing process specifications. Any required revisions will be made and, if necessary, process evaluation tests will be performed.

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Manufacturing will assist the engineering effort by reviewing the drawings. This review will alert Manufacturing to the requirements and objectives and the test facilities required. Suggestions to decrease the cost and improve equipment performance will be encouraged.

(2) Test design and specification. Test procedures will be specified for all performance, reliability, production and life tests of the AGE. In regard to the FHM, both the prototype and operational unit will be treated.

Test equipment will be designed to support the test efforts. This will include a fixture for the compliance subsystem engineering development tests, a payload mockup for prototype FHM tests and an updated payload mockup for FHM acceptance tests. Other fixtures will be needed for testing of the RTG shipping container, FHM check-out equipment and RTG field checkout equipment.

(3) Test data evaluation. In Phase II, two important tests will require extensive evaluation:

- (1) The compliance subsystem test, which will have an influence on the payload mockup design, the FHM design and the prototype test planning.
- (2) The prototype FHM test which constrains the start of final design.

Other AGE testing in Phase II will be devoted to development and qualification of an electrically heated source. The evaluation of these test results will have an influence on the design of the RTG field test equipment.

Data obtained from these tests will be analyzed and the results fed back into the design effort on a timely basis. Formal test reports will be prepared in a later phase; preliminary releases of information will be made as available to permit design work to continue without delays.

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C. TASK 3.0--SAFETY AND SHIELDING ANALYSIS

During the course of system development, a detailed safety and shielding analysis will be performed which will produce a preliminary report covering program safety, philosophy and criteria requirements, fuel containment development and analyses, system safety evaluations, shield analyses and safety test evaluations. The objectives of this task will be to develop, evaluate and test, in detail, all possible design parameter combinations of the fuel source from a materials, structure, re-entry and a source acceptance point of view; and to indicate the risk of using such a system on the basis of a nuclear hazard to the general populace. Work will be divided into three general categories:

3.1--System safety analyses

3.2--Shielding analyses

3.3--Test specifications and evaluations.

1. System Safety Analyses

Under this subtask, all safety requirements will be established, liaison between the AEC, User and Fueling Agencies will be maintained, the fuel capsule and heat source configurations will be evaluated, and a mission safety evaluation will be made.

Safety requirements include the development of a philosophy, design criteria, safety engineering plan, classification of hazards and an operating plan for all nuclear and nonnuclear system safety operations.

The proposed fuel capsule configuration will be evaluated in terms of fuel form, material, containment integrity and re-entry. Conditions imposed on the capsule which must be considered during the development of the fuel capsule are internal pressure, hydrostatic pressure, impact, thermal characteristics, shock and vibration and earth burial. Also, a Quality Assurance program must be assembled in conjunction with the Fueling Agency. To complete the study, a re-entry evaluation will be made to investigate aerothermodynamic conditions on the capsule structure, especially terminal velocity.

The proposed design requires that the heat source be developed to protect the fuel under all conditions of system operations, normal and abnormal. To meet this end, heat source studies required include a material evaluation; an integrity analysis which will determine thermal effects during normal operation, emergency conditions, re-entry and land impact, external pressure on the heat source, impact effects, meteoric damage, shock and vibration; a Quality Assurance study; and

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a re-entry analysis. Since the heat source is designed to limit aerodynamic heating by control of shape and re-entry orientation, the re-entry study must establish, in addition to trajectory and heating conditions, stability parameters of the desired shape. Since the shape will have a considerable amount of aerodynamic lift, it will be imperative that the latter be verified by a detailed wind tunnel test program.

The scope of the mission safety evaluation will include a transportation, handling and storage analysis, a launch pad study, a liftoff failure evaluation, an orbital accident analysis, a post-orbital hazard evaluation and a nonnuclear safety analysis. During this phase of the work, a safety manual will be issued to indicate to the User Agency the problems and actions which must be taken under normal or abnormal system operation. All other work will be published in a preliminary safety report which will evaluate the system in terms of safety requirements established for the mission. Detailed analyses which will be performed during this time will include:

- (1) An accident evaluation of the fuel source during handling operations from factory to orbit.
- (2) A structural analysis of the transfer cask, shipping cask and heat source subsystem.
- (3) A fueling operation analysis including a work schedule for activities on the launch pad near the RTG.
- (4) A launch site safety evaluation including fuel recovery.
- (5) An abort plan for operations during liftoff.
- (6) Dispersion analyses for releases in the atmosphere, hydrosphere and lithosphere.
- (7) An aerothermodynamic analyses to study the effect of the launch vehicle and satellite on the re-entry of the RTG and heat source. This work will be accomplished by running the 3 σ variations of a single launch trajectory provided by the Government.
- (8) A study to determine possible fuel release modes in orbit and the consequences of such a release.
- (9) An analysis to determine the footprint of impact of the heat source after re-entry, taking into consideration the lifting effect of heat source shape.
- (10) A fault tree to show the operational and accidental risk to the general populace of using the system.
- (11) A nonnuclear hazard evaluation of the system.

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2. Shielding Analyses

Under this subtask, all shielding analyses will be undertaken. These will include analyses and radiation maps of the fuel capsules, heat source, shipping container, transfer cask, fueling machine and the RTG on board the spacecraft. Also, portable shields, if required, will be designed for launch pad operations around the RTG.

Neutron and gamma calculations will be performed using the DTK transport code, modified to obtain a more accurate representation of the angular dependence of the scattering integral. Point kernel calculations will be done to provide correction factors for the finiteness of source and shield geometries. Scattering contributions will be evaluated using Monte Carlo techniques, primarily for cases in which the heat source is not shielded in a 4π sense, i.e., during and after the heat source integration with the satellite vehicle.

Liaison will be maintained with the Fueling Agency to ensure that adequate measurements are performed to determine neutron spectra and gross emission rates for small, representative fuel samples. Final shield design will be based upon these measured quantities.

3. Test Specification and Evaluation

Under this subtask, fabrication specifications and procedures will be written for the fuel capsules and heat source, test procedures and designs to develop and qualify the heat source design will be determined, and the test data will be evaluated. Fabrication specifications shall include detail parts requirements, including materials, subassembly requirements and final assembly requirements. Since all assemblies will be accomplished by the Fueling Agency, all work will be carried out in strict coordination with that Agency. Tests which will be performed in Task 6 include: radiant heat tests of the heat source, capsule impact tests, external and internal pressure tests of the capsule, heat source drop tests, structural, materials compatibility and burial tests, wind tunnel tests and shield development tests.

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D. TASK 4.0--RTG POWER SYSTEM COMPONENTS DEVELOPMENT, MANUFACTURING AND TESTING

The principal objective of this task is to provide a comprehensive program encompassing manufacturing process development, tooling, RTG component manufacturing and RTG component development and reliability testing to demonstrate the achievement of system specifications.

The precise manner in which this objective will be realized during Phase II is outlined in the subtasks which follow:

1. RTG Test Preparation

a. Test procedures

Test procedures will be prepared for each test and will describe, in detail, the specific objective(s), the sequence of test events, data to be taken, and analyses to be made by the testing organization. Prior to commencing the tests, the test procedures will be approved by Reliability, Quality Control, the Project Engineer and the Program Manager.

b. Instrumentation calibration

Prior to commencing any test, all precision test instruments will be calibrated by the Quality Calibration Center or otherwise certified by Quality to be within the rated tolerances. Test machines (such as vibration tables, environmental chambers, etc.,) will be certified by Quality to be within calibration limits or properly functioning, whichever is applicable.

c. Test setup

The actual setup of all tests is covered in this task. Upon completion of this portion of the test preparation, Quality will certify that the test has been prepared according to the procedure and that testing can start.

2. RTG Manufacturing Process Development and Tooling Fabrication

During Phase II, this task will be devoted to manufacturing process development and tooling fabrication with the objective of producing qualified Manufacturing processes as they are applied to the heat source, T/E couples and modules, coolant heat rejection subsystem and the thermal control subsystem.

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a. Heat source

The heat source is a combination of machine details and Hexcell-type core honeycomb fabricated from Haynes-25 material which will be brazed utilizing a braze alloy capable of operation to 2300° F.

The necessary tooling fixtures for fabricating the heat source will be manufactured under this task.

b. Emissive coatings

It is anticipated that only minor process development will be required in the application of emissive coatings to the heat source, module hot plates, coolant heat rejection radiator panels, or thermal control system.

Tooling jigs will be fabricated for the application and firing of emissive coatings on the module hot plate. No other tooling is anticipated.

c. T/E couples

Upon receipt of the couple specification and process procedure from Engineering, Manufacturing will utilize a trial run of 100 couples to establish the process on manufacturing equipment. The 100 couples will be employed for the determination of any possible tooling modifications which may be necessary for meeting dimensional requirements, and for establishing the furnace controls to meet process specified heatup and bonding temperatures and times.

With the application of the SNAP 19 couple manufacturing process to this program, the need for couple development by Manufacturing is not required. The SNAP 19 process has been firmly established as a manufacturing process for more than a year.

Process qualification will be accomplished through a preproduction run of 150 couples and, if upon Quality testing to the specification requirements, 90% or more of the couples are found acceptable, the process will be considered qualified.

Product quality will be assured during manufacturing by maintaining a sampling plan which will control the couples to an AQL = 1. This will be accomplished by random selection of 13 couples out of every 100-couple production lot. If only one couple in this sample fails to meet the specification requirements, the remaining 87 couples of the lot must be 100% Quality inspected. If 10% of the couples in the 100-couple production lot fail to meet the specification requirements, the production process must be requalified.

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Previous manufacturing experience accrued from the fabrication of several thousand couples of similar design indicates only two areas of anticipated difficulty. The two problems are dimensional control and cross-vapor deposition between the couple elements during bonding. A direct solution to these problems will be accomplished through the design of the bonding tools. The current tool design was integrated into the fabrication process when dimensional rejects resulted in a 65 to 80% yield. After the current designed tool was instituted, the dimensional yield increased in excess of 90%. This same tool design will be used as the starting point for the tooling required on this program.

Based upon these requirements and previous experience, the following summarizes the tools that will be fabricated for couple assembly:

- (1) Couple bonding fixture for couple positioning during furnace bonding.
- (2) Loading jig to permit handling of multiple couple assemblies.
- (3) Couple limit gage for rapid dimension check.

d. Thermoelectric modules

The thermoelectric module fabrication requirements will be met by the assembly of 90 couples in a rectangular configuration. The module assembly process will be performed in a controlled inert atmosphere and be closely monitored. Couple assembly techniques will employ the use of conventional soldering techniques to bond a copper electrical output strap to the couple cold cap. The bonding agent will be commercially pure tin solder or similar alloy, and the soldering operation would be performed in a multiple station dry box employing a controlled inert atmosphere. The successful experience achieved under the SNAP 11 and 19 programs using this soldering technique will be applied during this activity. Completed couple assemblies will be electrically inspected for compliance to internal resistance specifications.

An anticipated problem occurring during the couple assembly soldering process is the specific heatup and cooldown rate used on the soldering tool. This will be dependent upon the material and mass of the tool. The specific cycle time will be optimized during initial tool checkout.

The final module assembly will contain the T/E couple assembly, a spring-load piston-button heat sink assembly, thermal insulation, electrical output terminals and evacuation port. The final assembly

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will be completed in a controlled inert atmosphere, leak checked and then removed to a manufacturing outgassing station. The completed module will then be completely outgassed and the evacuation port pinched off prior to delivery to the Engineering Test Group.

Prior to and during the initial stages of module fabrication and assembly, Manufacturing will develop and document process specifications and procedures. These proven processes will then be closely complied with to ensure product uniformity and reliability.

Potential module assembly problems center around the handling of the couple assembly Min-K once the couples are inserted. Min-K, after bakeout preparation, does not provide sufficient structural strength to support the weight of 90 couples during normal handling, therefore a special handling tool will be designed to facilitate handling during the assembly process. One approach is to design a tool which remains with the Min-K through all subsequent assembly operations, but is removed prior to final seal welding.

Another problem will be the ability of the module soldering tool to provide uniform pressure loading, and hence reliable solder bonds between the copper electrical output strap and couple cold caps on all 90 couples. Due to the highly successful SNAP 19 module soldering tool that employs individual spring pressures to each couple cold cap, this same concept will be used and the design approach modified to accommodate the handling problem. The soldering tool will be designed such that pressure may be applied in sections, rather than attempting to place the entire tool over 90 couples at one time. During module final assembly, an additional handling and assembly tool will be required to ensure successful integration of the couple assembly to the spring and piston heat sink assembly. Tools of the type required have been successfully employed in the soldering and assembly of three 84-couple modules of the type herein described.

Based upon these requirements the following summarizes the tools that will be fabricated for module assembly:

- (1) T/E module bonding fixture
- (2) T/E module handling fixture
- (3) T/E module assembly fixture.

e. Coolant heat rejection and EM pump

The coolant heat rejection system components will be fabricated and processes qualified. Included will be the coolant loop with headers, pump and heat exchangers. No problems are anticipated in the

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successful fabrication of the coolant loop based upon the accumulated experience of Martin in the fabrication of many test loops (heat transfer loop, PM-1, PM-3A, LFBR). Upon completion of initial components and system compatibility verification, the associated processes will be standardized and qualified.

Tooling and fabrication jigs will be manufactured to facilitate proper fabrication of the various components of the coolant heat rejection system.

f. Thermal control system

The thermal control louvres consisting of Min-K thermal insulation inserted between Haynes-25 clad material will be fabricated and assembled using the same technique now employed on the SNAP 11 thermal shutter door. The actuation mechanism will be integrated into a total subsystem for performance and interrelation verification.

Prior to, and during the initial stages of the thermal control louver development, Manufacturing will develop and document process specifications and procedures. These proven processes will then be closely adhered to to ensure product uniformity and reliability.

Fabrication of special tooling jigs will be performed under this task to permit proper assembly and alignment of the thermal control and louvres and actuation mechanism.

3. RTG Component and Test Fixture Fabrication

a. Heat source

Components will be fabricated and assembled for a total of 22 fuel blocks, the number required for development testing in this task and safety testing in Task 6.0. Dummy fuel capsules assembled at the Fueling Agency under Task 6.0 will be inserted and welded in three of the 22 blocks by Martin. Five assembled blocks will be shipped to the Fueling Agency for capsule insertion and welding. Fourteen fuel blocks will have electrical heaters inserted by the Martin Company.

This task also provides for fabrication of the test fixture for use in the following fuel block tests.

<u>Test</u>	<u>No. of Dummy Fuel Blocks</u>	<u>Capsule Insertion</u>
Drop test (Task 6.0)	3	Fueling Agency
Engineering structural test	3	Martin
Radiant heat test (Task 6.0) Electrical heaters added	7	No capsules
Vibration and shock test (Subtask 4.4.1) Electrical heaters added	7	No capsules

The two remaining fuel blocks are retained by the Fueling Agency for their test purposes.

b. T/E couples and modules

Two-hundred thermoelectric couples and 54 modules will be fabricated for engineering development and reliability testing under this task. Test fixtures for use in development and reliability testing of thermoelectric modules will also be fabricated.

c. Coolant heat rejection system

Five coolant radiator systems and one complete coolant heat rejection system will be fabricated together with three test fixtures for development and qualification testing. In addition to these requirements, nine heated loops with NaK pumps will be fabricated for reliability testing of the NaK pumps.

d. Thermal control system

Engineering development, reliability and qualification testing will require that 10 complete thermal control systems be fabricated. In addition to these requirements, 12 NaK actuators will be fabricated into test fixtures for development and reliability testing.

e. Operating model RTG system

A complete operating model RTG system will be fabricated for performance and environmental testing. Test fixtures will also be constructed to facilitate environmental testing of the operating model.

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A total of 54 modules, each composed of approximately 90 couples, will be tested during the program.

(2) Performance and drift test. Seven modules will be performance evaluated and life tested at operating temperatures as described in Appendix A. Each module will contain at least six calibrated hot and cold junction Cr-Al thermocouples, a gas pressure transducer and voltage taps. This test will be accomplished in a span of seven months.

The possible loss of electrical power in this test constitutes a problem which must be eliminated. The loss may stem from voltage regulator malfunction or general loss of all laboratory power. A central alarming system is provided within the laboratory to provide round-the-clock monitoring of all tests. In the event of an alarm, personnel will be notified, and the malfunction corrected.

(3) Overtemperature. Seven modules will be subjected to an overtemperature test as described in Appendix A. These modules will be instrumented in the same manner as described for the performance and drift test. The test will be performed by increasing the hot junction temperature in specific increments and maintaining each increment for a specified period of time.

The problems in this test are the same as those of the performance and drift test.

(4) Thermal cycle. Ten modules will be subjected to a thermal cycle test in a manner similar to that described in Appendix A. Three of these modules will be cooled after outgassing and reheated at different rates. A curve showing the heating and cooling rate as a function of the increase in internal resistance will be made in an effort to determine the optimum rate. The remaining seven modules will then be thermally cycled to failure using the optimum heating and cooling rate.

The thermal cycle test will be performed manually, with personnel manning the operation on a three-shift basis.

(5) Dynamic shock. To establish the worst case axis, three modules (one for each axis) will be subjected to shock loads, progressively increasing to and over the qualification level of 40 g peak (8 msc pulse width). The axis in which failure occurs at the lowest peak load will be used for testing six additional modules by the same incremental method.

These modules will be instrumented similar to those of the performance and drift tests. In addition, several transducers will be added to determine the mechanical response of the test article.

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(6) Thermal vacuum. Seven modules will be subjected to a thermal vacuum environment of 1×10^{-6} torr or lower, and at temperatures ranging from -250° to $+250^{\circ}$ F. The purpose of this test is to determine the integrity of the final design and its ability to perform in this environment, including deterioration of the emissive coatings on the module. A residual gas analyzer will be used to detect argon (above a reference ambient) and thus a possible leak in the module structure.

(7) Dynamic vibration. Twenty-one modules will be subjected to random vibration, seven in each of three major axes as determined by the spacecraft orientation. Each specimen will be first tested at the qualification level for random vibration. The vibration level will then be gradually increased, maintaining the specified random frequency distribution spectrum, until failure of the module occurs. If failure does not occur before the maximum capability of the vibration exciter is reached, that level will be taken as a minimum reliability point.

Each module will be instrumented as described previously. In addition, transducers will be added to detect resonance.

This portion of the test program requires that several dummy (without T/E couples) modules be tested prior to the actual test program. The purpose of this is to detect, and eliminate by redesign, any detrimental resonances which would serve to perturbate the actual system.

The only problem areas evident are those of component failure during the vibration testing. This includes such items as the electrical feedthroughs, welds, mounting brackets, etc. These are design problems which can only be eliminated by redesign and retest.

(8) Acoustic noise. One module will be subjected to acoustic noise by the random acoustic exciter. The sound pressure level will be 144 decibels over the frequency range of 20 cps to 10 kilocycles.

This module will be instrumented as described previously and will include transducers to detect adverse resonances in the module.

c. Coolant and heat rejection thermal hydraulic, performance and dynamic testing

All coolant radiator panels and EM pumps will be subjected to PMT tests (sinusoidal vibration at 25% of the qualification level) prior to testing.

(1) Radiator thermal-hydraulic tests. Two full-size heat rejection radiator assemblies will be fabricated for testing. These two radiators

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will have the emissive coating applied. One radiator will be tested in a water loop which is operated at 300° F. The loop facility to do this work is presently available. The radiator will be fully instrumented with thermocouples to establish the thermal profile of headers and coolant channels. Likewise, the radiator will be instrumented with pressure taps to establish the pressure profile of the headers and coolant channels. By measuring the difference between the inlet and outlet temperature and knowing the flow rate in the loop, the heat dump capacity in the air will be calculated. This will give some insight into the heat dump of the radiator during the periods prior to and during launch while the radiator is exposed to air, realizing that a correction factor between water and NaK is required. The module cold plate thermal-hydraulic tests will be run concurrently with the radiator. The cold plate will be located immediately upstream from the radiator.

Similarly, a second radiator will be operated with a NaK loop of about 10-kilowatt(t) capacity. The water flow tests will be verified with NaK. A one-inch austenitic stainless steel loop with a temperature capability to 1200° F which is much more than is required, is available. The loop is equipped with an electromagnetic pump and sufficient instrumentation to monitor loop temperatures and flow rates. Some modifications to the loop will be required. It will be necessary to drain the NaK presently in the loop and cut into it so the test radiator can be installed. Cold plate thermal hydraulic tests will be run simultaneously with the radiator. Both the radiator and cold plate will be instrumented so that thermal and hydraulic profiles can be established. No problem of thermocouple attachment is anticipated, however, a problem is anticipated with pressure readout. A possible way of reading the pressure involves using a small bore stainless steel tube which is attached to the radiator. The tube must be of sufficient length to allow the NaK to be cooled to ambient temperature at the point where the NaK contacts an anhydrous mineral oil manometer vented to the air through a Drierite column. The manometers would be calibrated by applying a known static pressure on the loop and reading the individual manometers. The cold plate used for these tests will be a dummy module, (i.e., a metal, whose thermal conductivity is close to that of the thermoelectric material, will be substituted for the lead (tin) telluride. The heat dumped into the loop through the cold plate will closely approximate the actual module operational conditions.

(2) EM pump reliability tests. Nine NaK electromagnetic pumps powered by dc power supplies and utilizing NaK filled, harp-type loops with necessary flow and temperature control instrumentation will be subjected to environmental testing. Three of the assemblies (one in each orthogonal axis) will be subjected to random vibration commencing at low levels and increasing to the qualification levels and beyond to failure. Three additional assemblies will be similarly tested in shock. The remaining three will be subjected to overtemperature tests to determine the limiting operating temperature point caused by failure of the permanent magnet.

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One problem area in this test will be the confinement of the NaK in the event of loop or pump failure (rupture). This problem can be solved by using an appropriately designed containment vessel which will not hamper or interfere with the vibration test itself.

(3) Radiator dynamic tests. Four radiator assemblies will be dynamically tested to failure, one in each orthogonal axis as dictated by spacecraft orientation, and one in shock along the thrust axis. These assemblies will be heated to operating temperatures for these tests with heat lamps or Lewis wire heaters to obtain a reasonable simulation of actual temperature operating conditions.

(4) Environmental testing

Thermal vacuum test. A complete duplicate of the piping, headers and pump, together with a portion of the radiator panel and a generator mockup, will be subjected to a thermal vacuum environment.

The coolant system and generator mockup will be heavily instrumented with calibrated thermocouples so the thermal distributions in all critical portions of the system can be accurately determined.

The thermal vacuum test will be performed at 1×10^{-6} torr or lower and at heat sink temperatures between -250° and $+250^{\circ}$ F. An exact selection of the heat sink temperatures will be made that closely duplicates the temperatures to which the spacecraft will be subjected while in orbit.

Dynamic testing. A complete duplicate of the piping, headers, pump, full-scale radiator and generator mockup will be subjected to qualification level random vibration in each of the spacecraft-oriented axes. The instrumentation, similar to that for the thermal vacuum test unit, will include transducers to detect adverse resonances. A possible weight problem exists with respect to testing the configuration as a unit. The excess weight arises from the test fixture needed to test the radiator and generator mockup. It will not be known until early in Phase II whether the qualification level tests can be done with the coolant radiator system connected to the RTG generator or not. In the event that the weight of the test fixture plus the RTG generator system mockup is too great for model C-210 shaker, the radiator panels will be tested separately from the generator mockup.

d. Thermal control subsystem performance and testing

All thermal control subsystem assemblies will be subjected to PMT testing (sinusoidal vibration at 25% of the acceptance level) prior to development and reliability testing.

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(1) Thermal vacuum testing. The development of the thermal control subsystem will be conducted in two stages. In the first stage, a thermal control system, based on preliminary system design, and dummy generator will be constructed. The control system will then be tested in a thermal vacuum environment of 1×10^{-6} torr or lower, and sink temperatures varying from -250° to $+250^{\circ}$ F to determine if it will maintain the hot junction temperature within design limits. It is expected that this test will be repeated as design modifications are made to improve the thermal performance of the control system.

The tests will consist of measuring temperature distribution in the model as a function of thermal input and door position. This will require that the test fixture be thermally calibrated before the system test.

(2) Dynamic testing. After achieving a satisfactory thermal control system (from the thermal standpoint), it will be subjected to random vibration testing starting at low levels and increasing gradually until the qualification level is reached. It is expected that some resonances and possibly failures will occur early in the testing and that several structure modifications will be made before the qualification level is achieved.

Failure of the door mechanism could consist of the door being unable to operate after it has been subjected to dynamic environments, or closing of the door during excitation. Strain gage and accelerometer instrumentation at critical locations of the assembly will allow recording and analysis of any structural response which might contribute to either of these conditions, and facilitate corrective design changes.

(3) Reliability testing. Upon satisfactory completion of the tests outlined, seven door assemblies will be fabricated and dynamically tested (random vibration at increasing levels) to failure or to the maximum capability of the vibration exciter.

To establish the reliability of the NaK actuator bellows that operate the thermal control shutters (louvres), life tests (cycles to failure) will be performed on nine actuator bellows (three each at three different cyclic rates).

The tests will be performed by attaching the NaK actuator bellows to a NaK reservoir pressurized with an inert gas to duplicate the pressure exerted by NaK at hot junction temperature of the T/E module (975° F). The bellows and NaK reservoir will be maintained at a temperature in the range of 300° to 500° F. By appropriate mechanical linkage to the bellows piston, the bellows will be cycled with a motor-driven cam (three each at three different rates) to failure.

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Precautions will have to be taken to contain the NaK that will be liberated as a result of the bellows failure. A fail-safe system to depressurize the NaK system at the time of bellows failure will have to be devised.

e. Prototype assemblies

(1) Environmental testing. Three control systems will be fabricated with any final design changes suggested by the results of the reliability tests incorporated. These will then be tested at the qualification levels of vibration, shock, acceleration and thermal vacuum.

(2) Life test. When the tests discussed previously have been completed successfully, each unit will be submitted to a cyclic life test program (in air).

f. Engineering model RTG system performance testing

An operating model or preprototype generator, consisting of the full complement of eight modules, thermal control mechanism, coolant heat rejection subsystem and electrical heaters, will be constructed for thermal vacuum and dynamic testing prior to the conclusion of Phase II. This model will serve to focus attention on the structural frames and any problems not evident previously. It will be heavily instrumented with calibrated Cr-Al thermocouples in such areas as the hot and cold junctions, heater plate and block, thermal control subsystem and coolant heat rejection subsystem.

The problems in testing the engineering model generator system are similar to those outlined previously. In particular, vibration, shock, and acceleration testing the engineering model RTG generator system as a unit at the qualification level becomes a problem. In the case of vibration at the qualification level, weight may be a problem. In the case of shock testing, the sand-drop shock tester will not accept the height of the full RTG system, thus necessitating the testing of each unit (radiator panels and generator) separately. The acceleration testing can be accomplished on existing equipment; however, there will be a wide distribution of the g forces in the direction of the acceleration. This distribution can be reduced considerably by testing the radiator panel separately from the generator system.

(1) Electromagnetic interference (EMI). The engineering model will be submitted to an EMI test while in an operating condition to determine the level of electromagnetic interference and ascertain whether or not that level will interfere with the mission of the spacecraft. The items of most concern are the coolant pump and thermoelectric system.

E. TASK 5.0--AGE COMPONENT DEVELOPMENT
FABRICATION AND TESTING1. AGE Test Preparation

a. Test procedures

A review will be made of the test requirements and a detail procedure written on each component test to be performed. All test procedures will be completed for all AGE items during Phase II, although only the prototype FHM, the compliance subsystem, and the electrical heater block are to be tested during this period. On these items, the test procedures will be revised as required after the results of prototype model tests have been evaluated.

b. Instrument calibration

Listings will be made, based upon test specifications and procedures, of the instrumentation required in each test. These lists will be made available to Engineering, Quality Control and Reliability for advance review and approval so that Quality Assurance can formulate an instrument calibration schedule to support the tests.

c. Test setup

The test procedures will be reviewed by mutual action between the design and test groups to arrange the design of special test equipment and to implement the procurement of supplies and test items that are to be expended in the tests.

The test group will arrange test details such as facilities, equipment and coordination with other test groups and will supply the manpower to make test setups. Also, the test group will coordinate these activities with Quality Control to assure that the tests are conducted to permit specified conditions to be met and in a manner that allows Quality inspections and verifications to be made of all specified parameters.

2. AGE Manufacturing Process Development and Tooling Fabrication

A potential problem in developing manufacturing processes and tooling for the AGE is recognized in the one-of-a-kind type production associated with most of the AGE items. To utilize the experience of Manufacturing in these matters, advance copies of Manufacturing specifications and design drawings will be made available for review sufficiently in advance of scheduled release to permit revisions to be implemented.

a. Fuel handling machine

A prototype is to be fabricated in Phase II, and an operational unit is to be fabricated in Phase III. It is likely that changes will occur in certain components of the machine. This factor will be evaluated in the implementation of the manufacture of parts that require special tools and fixtures. If unusual tooling costs are recognized on a particular part, liaison will be undertaken to assure that all possible consideration is given to the reuse of special tools. Review of the conceptual machine layouts indicates no serious problems. The large members of the machine do not require precision finishes or fitting.

b. Electrical heat source

Engineering and Manufacturing plan to develop the prototype unit and its manufacturing processes as a joint effort. No production problems are anticipated after the performance levels are achieved. However, extensive Quality Control testing and inspection are anticipated during the manufacturing and assembly steps in the production heaters.

c. Other AGE items

The other AGE items, such as the fuel transportation cask, FHM and RTG field test equipment, RTG shipping container, etc., are not manufactured in Phase II. Preliminary Manufacturing processes will be established during Phase II on these items as the designs are completed.

3. AGE Components and Test Fixture Fabrication

a. FHM components

Manufacture of FHM components for the prototype unit will be conducted in Phase II. Review of the conceptual design layout does not indicate any manufacturing problem areas.

b. Electrical heat sources

An electrical heat source will be designed and developed to provide the necessary thermal input for both the modules (14 scaled down units) and the full-size RTG system (14 full size units). This electrical heat source will be used throughout all module and RTG system qualification and acceptance testing. It must perform, therefore, without failure during these tests. The electrical heat source will closely simulate the size (in the case of the full size unit), shape and thermal distribution of the actual fueled heat source. During this Phase, 14 scaled down heat sources and 14 full scale test heat sources will be fabricated.

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Each heater element will consist of tantalum wire wound on a grooved alumina mandrel and encased in an alumina sleeve. Magnesium oxide powder will be used to fill the void spaces both within the heater element and between the element and the heater block. Each heater element will be hermetically sealed in an inert gas atmosphere.

The manufacture of a prototype unit is also planned in Phase II. This item has rigid performance reliability requirement associated with it, so extensive Quality Assurance inspection is planned during the fabrication. Because experience will have been gained in the fabrication of the heat sources for development testing, the amount of rework needed because of rejection is expected to be small, despite the nature of the materials and the expected strictness of the specifications. The outer casing of the heater block is anticipated to be identical to that of the fuel block, and the same fabrication techniques shall apply.

c. FHM test fixtures

Two major test fixtures are planned. One for engineering development testing of the compliance subsystem and a payload mockup for prototype FHM testing. The conceptual designs of these items do not indicate any problem areas. The payload mockup is planned for reuse, after reworking on the basis of prototype test findings, in Phase III acceptance testing of the FHM. The rework will not be performed until Phase III. Some small fixtures are to be fabricated that will be employed in environmental tests of selected components of the FHM. These are entirely conventional manufacturing throughout.

d. Other AGE items

No other AGE items are to be fabricated in Phase II.

4. AGE Components Development and Testing

During Phase II, the prototype FHM and some of its subsystems and the electrical heated source will be tested.

a. FHM compliance subsystem engineering development test

This subsystem is the only AGE system which will undergo engineering development testing prior to the testing of the assembled FHM. The compliance subsystem test shall be performed with a special test fixture, to which the compliance subsystem shall be mated during tests. The tests shall have two purposes:

- (1) To verify that the compliance subsystem can maintain a floating condition in reference to the launch vehicle

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Upon completion of a satisfactory design, 21 units will be tested. These tests will consist of endurance (7 units, 7 months, scaled down version), thermal cycling to failure if possible (7 full size units), and vibration and shock testing at the qualification level (7 full size units).

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F. TASK 6.0--SAFETY AND SHIELDING DEVELOPMENT AND TESTING

1. Safety and Shielding Test Preparation

a. Test procedures

After development of the test specifications in Subtask 3.3, test procedures will be written for each component test to be performed. All test procedures will be completed for the safety and shielding development and testing in Phase II.

b. Instrumentation calibration

Listings shall be made based upon the test specifications and procedures of the instrumentation required in each test. These lists will be made available to Engineering, Quality Control and Reliability for advance review and approval so that Quality Assurance can formulate an instrument calibration schedule to properly support the tests.

c. Test setup

The actual setup of all safety and shielding tests is covered in this task. Upon completion of this portion of test preparation, Quality will certify that the test has been prepared according to the procedure and that the test is ready to commence.

2. Safety and Shielding Manufacturing Process Development and Tooling

Manufacturing processes will be developed and specifications written for fabricating capsule components and assemblies for use throughout the program. The experience gained in other SNAP programs will be utilized wherever possible to simplify fabrication techniques and improve manufacturing processes and/or tooling. The final fuel capsule assembly processes developed by the Fueling Agency will be factored into Martin manufacturing process specifications.

Also as part of this subtask, manufacturing processes will be prepared and tooling fabricated for the re-entry heat source wind tunnel models to be used in Subtask 6.3.1.

3. Safety and Shielding Test Article Fabrication

a. Re-entry heat source models

Seven complete, electrically heated fuel blocks will be instrumented at Martin for use in the radiant heat test. These electrically heated fuel blocks will be fabricated under Subtask 4.3.1. In addition, six heat source models will be fabricated (three shapes) for performance of the wind tunnel tests discussed in Section F-4.

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b. Capsules

A total of 200 capsule containers, of 458 capsules and 468 liners will be fabricated by Manufacturing for shipment to the Fueling Agency for final assembly. Upon completion of the final assembly by the Fueling Agency, 418 of the completed capsules and 10 completed liners will be returned to Martin for testing.

c. Shielding

A test fixture for performing shielding development tests will be fabricated under this task.

4. Safety and Shielding Development Testing

a. Re-entry heat source testing

(1) Radiant heat test. A proof test of the system will be made in a radiant heat facility capable of testing the entire heat source assembly with a heat input exactly duplicating that of the re-entry. The test specimen will be instrumented internally to measure the temperature gradients across the system. At least 10 runs will be made.

(2) Drop tests. To verify the impact velocity of the heat source and to determine flight characteristics of the aerodynamic shape at low altitudes and velocities, 10 drop tests will be made using three test models. These will be conducted at a government-furnished facility such as the one operated by Sandia at Tonopa, Nevada. Measurements which will be made include terminal velocity and re-entry orientation. Models will not be heated; however, they will exactly simulate the physical characteristics of the heat source.

(3) Wind tunnel test. A wind tunnel test program is proposed which will provide the necessary force and heat transfer rates for determination of the total heat which must be absorbed by the capsule. In normal operation the carrier satellite will re-enter the atmosphere successfully upon completion of its mission, carrying the generator down with it. In this case, safety requirements can be met by obtaining selected heat transfer rates on the generator mounted on the satellite during the necessary wind tunnel tests which the satellite contractor must perform. Here, Martin will provide test requirements to the satellite contractor and have sufficient cognizance of wind tunnel test plans, techniques and parameters to ensure that these data can be used for safety analysis of the normal mode of re-entry.

In the event the carrier satellite is destroyed during re-entry, the generator capsule must be designed to return to earth intact without exposing the fuel. This requirement then establishes the external shape

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of the heat source. Designs considered are shapes which will inherently tumble, exposing the outer surface to uniform aerodynamic heating. Wind tunnel tests must be performed in sufficient detail to provide inputs for re-entry heat transfer analysis with a high degree of reliability since the design requirements will not permit large safety factors in the heating rates. The program will be divided into two parts: an exploratory program to determine the best aerodynamic shape, and a system evaluation program to flight qualify the design.

During the exploratory program it is expected that three shapes will be evaluated in a hypersonic force and heat transfer test at Mach 20. The test results will be used to select a configuration which can be designed to survive re-entry. The proposed facility is the Martin Hot Shot Wind Tunnel, and it is estimated 25 shots will be required to perform exploratory three-component force and heat transfer tests. To span the angle of attack range to 90 degrees, two models of each configuration are required. The models would be constructed of thin magnesium skin and each will be instrumented with approximately seven Martin heat gages for simultaneous force and heat transfer tests. It is expected that test data will be available to the project early in this phase.

Once the basic shape is determined, safety analysis and tests will be concentrated on detailed measurements of force and heat transfer rates on the heat source. As the design is frozen, inputs to the Martin wind tunnel test program will be made.

Most of the detailed force, moment and heat transfer data on the heat source and generator will be obtained by means of tests at Mach 20 in the Martin Hot Shot Wind Tunnel. These tests will span the necessary angles of attack and sideslip to provide sufficient inputs to the Martin six-degree-of-freedom (digital) stability program. Force models will be mounted on a six-component strain gage balance, and separate heat transfer models will be instrumented with some 35 Martin heat gages.

It is proposed the seven firings be made in the 1000-foot Hypervelocity Range located at Arnold Engineering Development Center, Tullahoma, Tennessee. This facility can test small models (approximately 1-1/2 in. in diameter) at velocities up to 20,000 fps, measuring interference-free forces and moments as well as dynamic stability. Data are recorded by means of cameras located along the 1000-foot long tank into which the model is fired.

A test at Arnold Engineering Development Center, Tunnel C is proposed to determine heat transfer rates at Mach 12. This test will permit using a large scale model of the fuel block and generator instrumented with some 90 thermocouples, permitting extensive heat transfer rate determination. This facility was selected on the basis of its test section size (50-in. diameter) and the fact that it is a continuously

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operating tunnel. Data from this test are necessary to provide thorough heat transfer rates over the surface to ensure re-entry survival.

b. Capsule testing

(1) Capsule terminal velocity and pressure. Since the fuel capsules must be designed to survive impact and internal pressure caused by the accumulation of helium gas, a series of impact tests, internal pressure tests and external pressure tests will be conducted to prove the integrity of the capsule and capsule container. The optimized capsule will be subjected to a Reliability test program to assure impact integrity. Pressure evaluations will be run on both cold capsule and heated ones.

(2) Thermal shock and environmental tests. Both thermal shock tests and tests simulating the effects of transient heat fluxes resulting from launch vehicle explosion and immediate conflagration shall be conducted on flight model fuel capsules to augment theoretical analyses. The thermal shock tests will be performed to investigate the induced effects on the fuel capsule of a hot fuel capsule (operating temperature) striking cold water as would occur upon water impact, and a fuel capsule being suddenly immersed in a fireball. Also, the total heat effect shall be investigated to determine fuel capsule behavior under simulated launch vehicle fireball heat fluxes. A plasma torch facility might be used to simulate the launch vehicle fireball heat fluxes.

(3) Material testing. The compatibility of the fuel with its liner will be ascertained by the Fueling Agency. In the development of the capsule closure design, it will be necessary to establish appropriate, reproducible welding conditions for each design to be tested. The technique must, to the extent possible, be compatible with their facilities and capabilities.

A fuel compatibility test program will be conducted in conjunction with the Fueling Agency. The purpose of the program will be to determine the corrosion rates of the selected fuel on the liner material. It will be a long duration test program conducted at conditions which simulate operational environments including re-entry. Since the liner material is specified, only one material evaluation will be made. The problems involved in developing this test will be the measurement of corrosion rates and holding the materials at specified test conditions. Both of these problem areas will be solved by repeating the tests in sufficient number so that reasonable assurance of results can be made and by conducting the test in an appropriate inert environment. Test conditions of interest will be fuel at operating temperature for a period of at least 134 days, fuel at re-entry temperatures for periods of time no less than 20 seconds and no greater than 800 seconds, and fuel at temperatures related to the decay of the fuel for long term encapsulation. Tests will be conducted in sealed capsules at the Fueling Agency.

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Current plans will be to hold the conditions indicated in at least 10 duplicating tests.

Corrosion of the heat source on a land site will be obtained by taking four of the electrically heated sources used in the radiant heat test and placing them in simulated or actual soil conditions, dry loose sand, wet loose sand, dry average soil and wet average soil. These tests might be done in an actual environment outside the plant where rainfall and other weather conditions can work on the source. Periodically, the source will be inspected to assess the corrosion effects. Tests would be run for a period of one year at various temperature conditions.

Structural tests on the honeycomb heat source will be those required by military specifications for Haynes-25 honeycomb structures operating at temperatures of 1800° F. Three assemblies will be made up for these tests.

c. Shielding tests

In the past, difficulties have been encountered with the continuity of shielding materials. This has been particularly true of castings which contain blow holes and shrinkage cavities. Accordingly, a thorough material specification governing shield fabrication will be prepared along with acceptance test specifications. Limitations will be imposed on deviations of localized material densities (mass/unit area) from the average so that, within specified tolerances, ICC and mission dose rate requirements will be met. Procedures will be specified for ensuring compliance with the density specifications.

The character of gamma radiation emitted by polonium fuel has been known for some time. Radiation analyses of this gamma radiation attenuated through individual materials have been confirmed by actual measurements. However, for the gamma attenuation through combinations of materials and particularly for the capsule, block and shield materials used in the generator, few experimental data are available. Similarly, there are no experimental data available for the attenuation, by individual or combinations of materials, of the neutrons produced by alpha neutron reactions in the polonium fuel form.

It is therefore proposed to conduct both gamma and neutron shielding experiments to:

- (1) Determine ultimately the required shield thicknesses to meet flight and ground handling requirements.
- (2) To verify the results of calculations against the experimental results.

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It would be desirable to use a polonium source for these experiments, but due to the short half-life of the polonium, meaningful results can be obtained with other radioactive isotopes. Thus, a cobalt-60 source with gamma energies of 1.17 and 1.32 Mev (compared with 0.8 Mev for polonium) will be used for the gamma experiments. A plutonium-oxide source will be used for the neutron experiments. Either Pu-238 or Pu-239 can be used because of the similarity of the alpha particle energies (5.5 Mev for Pu-238 and 5.1 Mev for Pu-239 and 5.3 Mev for Po-210).

In the gamma experiments, dose rates and spectral data will be obtained for varying thicknesses of fuel block and shield materials, yielding data applicable to the final shield design as well as the preparation of procurement specifications for shield materials. Similarly, neutron penetration experiments will be performed for individual and combinations of materials and thicknesses appropriate for the fuel block and shield design. Neutron detection will be performed with the instrument described in Ref. 1.*

Since the dose rates from the generator and the attenuation supplied by shielding are relatively small, no sizable contribution due to scattering from vehicle structure is anticipated. However, experiments will be performed to evaluate this supposition.

*Hankins, D. E., "A Neutron Monitoring Instrument." LA 2717.

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G. TASK 7.0--ADVANCED DEVELOPMENT ACTIVITY

In any program of the magnitude of the 400-watt Po RTG effort, it is highly desirable to continuously apply advanced development activity efforts throughout product development. This is important due to the interplay of several significant considerations which combine to provide both initial system effectiveness as well as continued growth and usefulness over an extended lifetime. These factors have demonstrated their importance frequently during programs of this size and type. The points of greatest significance include the following considerations:

- (1) Areas or systems concepts which may have appeared prohibitive due to schedule or development limitations in the early design stages may rapidly fall into place once a detailed evaluation or preliminary tests are made. Thus, significant advancements which were initially bypassed or overlooked will become available for the initial product and so improve its overall performance.
- (2) Continuous development of an advanced nature may disclose basic product deficiencies at an earlier date due to the more rapid pace allowed by its nonhardware orientation (i.e., use of noncertified material, advanced or partially developed processing techniques, readily available but off-size materials, or unrestricted tests beyond the planned or selected operating range).
- (3) Continuous application of developed product improvements expands the usefulness of a defined system into fields where its utilization was previously noncompetitive or prohibited by certain limitations such as size or weight.
- (4) Advanced development may disclose completely new or less restrictive applications that were previously overlooked or bypassed which could benefit fully by the application of the planned concept.

The benefits of these factors to a system being developed, especially a large or significant one, cannot be overemphasized. The following sections highlight some of the more promising areas which could provide one or more of the advantages listed. Initiation of an advanced development activity in these areas will ensure that both an optimum product is developed and that the initial large expenditures of funds on the basic product can be amortized over an extended useful system lifetime.

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1. T/E Couple Development

a. Improvements in Reference Design couple

The Reference Design couple is described in MND-3612-7-1. It consists of 3M TEGS 2N and 2P thermoelectric elements bonded to a FerroVacE iron hot shoe. FerroVacE iron cold caps are bonded to the end of each element. Nickel and tin are the N and P element bond materials, respectively. The bonds are developed during a furnace brazing operation. With the exception of element diameter, the Reference Design couple is identical to SNAP 9, 11 and 19 couples on which an unprecedented amount of operating time has been accumulated. This background experience allows confident prediction of performance and reliability and was the major consideration in selecting this couple configuration.

Improvement in performance of the Reference Design couple may be achieved by selective development efforts. Extensive experience with this couple has indicated the areas with the greatest potential for performance improvement. These are the P and N element bondings, the shoe material and configuration. More substantial changes, involving thermoelectric materials and element configurations, are discussed in Subtasks 7.1.2 and 7.1.3.

(1) P element bonding studies. The P element bonds in the Reference Design couple are made using pure tin. Recent work at Martin and other laboratories has indicated that tin telluride is a superior bonding material. The melting point of tin telluride, approximately 1455° F, is considerably greater than the service temperature. Not only does this factor assure a solid (rather than liquid) junction in operation, but it should also greatly reduce the tendency of the bond material to diffuse away from the junction. Initial contact resistivities are comparable using Sn and SnTe but tin telluride produces a stronger bond. SnTe bonds have been made by both furnace brazing and hot pressing processes; neither method has been conclusively shown to be superior.

In this task, Reference Design couples will be made using SnTe rather than tin P element bonds. Both furnace brazing and hot press bonding will be investigated. Couples will be fabricated and evaluated by operational testing, metallographic inspection and mechanical testing. Multi-couple modules will be assembled and tested to determine long-term operating characteristics of the improved couple.

(2) N element bonding studies. The N element bonds are made with nickel; the bond material is plated on the hot and cold shoes and the bond is developed in a furnace bonding operation. Experience with this bond has been generally good although occasional N bond separations have been noted during module assembly. Also, metallographic examination of as-bonded couples sometimes indicates only partial bonding due to inclusions or void areas.

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Several areas will be investigated in an attempt to further refine the N element bonds. Recent work at Martin has indicated an advantage in heat treating the nickel-plated hot and cold shoes prior to bonding to the element. This step promotes diffusion bonding of the nickel to the iron shoe; bond failure due to peeling of the plate from the shoe is eliminated. The incorporation of this step in the Po RTG couple fabrication process will be evaluated. Couple and shoe cleaning procedures will be investigated to ensure that surface contamination is not contributing to partial unbonding. Finally, process parameters--temperature, pressure and time--will be varied to determine whether improved bonds can be effected. Couples will be fabricated to investigate the effects of these parameters. Based on couple tests and metallographic studies, an improved process will be selected. Verification of the process will be achieved through endurance tests on multicouple modules.

(3) Shoe material and configuration. Pure iron (such as FerroVacE or Armco iron) is the usual choice for shoe material in lead telluride couples, primarily due to its nonpoisoning characteristics. Unfortunately, there is a substantial difference in the thermal coefficient of expansion between PbTe and iron; the values are $6.5 \mu\text{in. / in. } ^\circ\text{F}$ for iron and $10.3 \mu\text{in. / in. } ^\circ\text{F}$ for lead telluride. The usual result of this difference for bonded couples is cracking of the P element. Apparently, the better mechanical properties of the N-type lead telluride enable it to withstand the imposed stresses without fracturing.

Several approaches will be pursued in improving shoe material and configuration. First of all, substitution of austenitic stainless steel for iron as the shoe material will be evaluated. The expansion coefficient of stainless steel matches that of lead telluride relatively well. On the other hand, the resistivity of stainless steel is higher than that of iron, requiring a somewhat heavier shoe to achieve equivalent resistance. An additional problem involves the tendency of nickel to diffuse from the stainless steel into the P-type lead telluride and to poison it. To prevent this, a thin layer of iron is applied to the portion of the shoe in contact with the P element. The iron layer, which is sufficiently thin so that it expands and contracts at the same rate as the stainless steel substrate, may be applied by flame spraying, roll bonding of a thin iron foil, or spotwelding of a thin iron cup to the stainless steel. Couples will be fabricated and tested using stainless steel shoes with iron overlays applied by the techniques described above.

Another approach to shoe improvement is the use of semiconductor or composite (metal semiconductor) shoes instead of the conventional metallic ones. Martin has been actively pursuing this concept for telluride-based thermoelectric alloys for sometime. The use of semiconductor shoes precludes the necessity for braze material at the junction, i. e., diffusion bonds between elements and shoe are readily developed. By proper choice of a semiconductor, expansion coefficients can be closely

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Fig. II-6. Thermoelectric Efficiency for Nonsegmented Couples

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matched; for lead telluride elements, a tin telluride shoe allows a near perfect match of thermal expansion coefficients. Because of the chemical similarity of shoe and elements, the possibility of poisoning is eliminated. Recent Martin-sponsored work on this concept has evolved configurations which are markedly improved over earlier semiconductor shoes. The most promising configurations available will be applied in fabricating couples of the Po RTG design. Couple evaluation will be made by metallographic examination and operational testing.

A third approach to improved shoe design would retain the iron material but change such factors as the shoe counterbore depth and profile adjacent to the P element. The objective of these changes would be to control the stress patterns established in the element. Specifically, the objective would be to maintain compressive stresses in the element to the extent possible and to minimize tensile stresses, hopefully, to a level below the ultimate strength of the material. Some work along these lines was conducted by the Martin Company under the SNAP 21 program. Extension of this work through shoe development, couple fabrication and testing is proposed.

A number of approaches for shoe improvement have been outlined. After performing the requisite development work, couple fabrication and testing, the results will be evaluated on a comparative basis. The most promising approaches will be selected for further evaluation in multicouple module tests.

2. Improved Thermoelectric Materials

The preceding section described potential improvements which represented relatively minor departures from the Reference Design couple. More pronounced departures, with correspondingly greater potential improvement, are described in this section. Specifically, the incorporation of higher performance thermoelectric materials is discussed.

Figures II-6 and II-7 compare performance on the basis of thermoelectric efficiency for several combinations of thermoelectric materials. The 3M Company TEGS 2N and 2P materials of the Reference Design couple provide the basis for comparison. The alternate N material is a two-segment lead tin telluride element with variable dopant level (identified as segmented $\bar{M}$ -N). The alternate P materials are 3M TEGS 3P and TAGS, a Martin-developed silver-antimony-germanium-tellurium alloy. Reference will be made to Figs. II-6 and II-7 in the following sections.

a. Segmented N leg

In the temperature range of interest for the Po RTG, no N-type thermoelectric material is competitive with lead telluride. This

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Fig. II-7. Thermoelectric Efficiency for Segmented Couples

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material has a high figure of merit, is stable, has reasonably good mechanical properties and is bondable to metallic shoes.

Lead iodide is the preferred dopant for N-type lead telluride. As illustrated in Fig. II-8, the performance of the material is significantly affected by the dopant level. Specifically, higher dopant levels cause the maximum figure of merit to occur at higher temperatures. By joining segments of varying dopant levels, a more efficient N element can be synthesized for the particular temperature range of interest. This technology has previously been developed by the Martin Company under the SNAP 21 program* in which a two-segment N leg was used.

Figures II-6 and II-7 illustrate the advantages of segmenting. For example, a couple incorporating 3M 2N and 3P elements operating between 1100° and 300° F exhibits a thermoelectric efficiency of 7.1%. Changing only the N material to Martin segmented lead tin telluride, thermoelectric efficiency is increased to 7.6%. Similar increases are experienced with other P materials.

Two development efforts are proposed as extensions of the earlier Martin work on segmented N legs. Previously, a tin bond agent was used between the segments. Because the two segments are nearly identical chemically, it should be possible to directly diffusion bond them together. Some development work on surface preparation, as well as bonding time, temperature and pressure, will be required.

The second approach involves multiple segmentation of the N leg, possibly approaching a continuous gradation in dopant level. Some analytical work will be required to determine the point of diminishing returns as the number of segments increases. Experimental work will involve preparation of segments with the various dopant levels and, subsequently, diffusion bonding of the segments. Couple testing would then be performed to verify the improved performance. Later in the program, the segmented N leg would be combined in a couple with an improved P leg (see Task 7.1.3, a and b); multicouple modules utilizing this improved couple configuration will be built and tested.

b. Improved P-type lead telluride

The P-type element specified for the Reference Design thermoelectric couple is the 3M Company TEGS 2P material. This is a sodium-doped material and it exhibits a reasonably high figure of merit (Fig. II-9). Martin experience with this material has indicated that its degradation rate is predictable and is temperature dependent. Hot junction temperatures in the range of 925° F can be confidently specified with a design allowance for degradation.

*"SNAP 21A, Ten-Watt Deep Sea Isotopic Power Supply," Martin Company, MND-3322-25, June 30, 1965, CDI.

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Fig. VI-8. Figure of Merit for PbSnTe with Two Different Dopant Levels

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A newer lead telluride P material, 3M Company TEGS 3P, provides a higher temperature capability than the older 2P material. Although its figure of merit is lower than that of the 2P material (Fig. II-9), the higher Carnot efficiency achievable at higher hot junction temperature provides compensation. Thus, Fig. II-6 shows that the thermoelectric efficiency of a 3M 2N and 3P couple, operating between 1000° and 300° F, is slightly greater than that of a 3M 2N and 2P couple operating between 900° and 300° F. When the 3M 2N and 2P couple operates between 900° and 300° F, the 3M 2N and 3P couple at 1050° and 300° F has an absolute thermoelectric efficiency advantage of approximately 0.5%. The higher temperature capability of the 3P material can be utilized to advantage in the Po RTG system by increasing both hot and cold junction temperatures. The increase in cold junction temperature increases the mean coolant temperature and, consequently, decreases the required size and weight of the radiator.

The Martin Company has accumulated a considerable amount of experience, both Company- and contract-sponsored, on the utilization of 3P material. Several bonding techniques, including furnace brazing, hot press bonding and diffusion bonding to semiconductor shoes, have been investigated. In fact, very satisfactory bonds have been developed by all three methods. Presently, several modules containing 3P material are on test in addition to a number of individual couples. The low degradation rates exhibited by these units is most encouraging.

In view of the prior Martin experience with 3P material and its potential advantages to the Po RTG system, an accelerated development effort is considered to be justified in this case. It is proposed that seven modules of the type described in MND-3612-7 be built using 2N and 3P elements. Fabrication of these modules will start immediately after Phase II go-ahead and they will be placed on endurance test early in Phase II. The planned hot junction temperature is 1050° F. Thus, these seven modules will be operating over the same time period as the seven Reference Design modules of Subtask 4.4.2. A direct comparison of performance can be made during the course of the testing. If warranted by the test results, additional qualification of the 3P modules can be undertaken during Phase II.

c. TAGS P material

Another material which deserves consideration as a replacement for the sodium-doped lead telluride is a silver-antimony-germanium-tellurium thermoelectric alloy. The specific alloy referred to is one developed by the Martin Company and given the acronym TAGS. As shown in Fig. II-9, the figure of merit of TAGS is significantly higher than either 2P or 3P lead telluride. This was also illustrated in Figs. II-6 and II-7 where the thermoelectric efficiency of couples containing TAGS P elements is significantly higher than couples with lead telluride P elements.

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Fig. II-9. Figure of Merit Versus Temperature for TAGS-85 and Two Varieties of P-Type PbTe

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Several other characteristics of TAGS are significant and should be mentioned. It is an inherent P-type material; no dopant is required nor can the conduction properties be altered by dopant addition. By the same token, the material is not poisoned by the addition of potential contaminants. These characteristics are favorable from the viewpoint of material stability. TAGS has mechanical properties which are superior to P-type lead telluride. Its coefficient of thermal expansion is lower than lead telluride, easing problems of differential thermal expansion between element and shoe.

During early development of TAGS, testing was limited to hot junction temperatures of 900° F. Although higher temperature operation may well be possible, 900° F will be considered the maximum hot junction temperature for purposes of this discussion. Thus, TAGS has the unique advantage of providing very high thermoelectric efficiency at modest operating temperatures.

TAGS has been under development at the Martin Company for some time and this development effort is expected to continue, possibly at an accelerated rate. Consequently, it is assumed that the material and attendant fabrication and bonding processes will be available for use on the Po RTG program; that is, the TAGS effort will be applied rather than basic development. Using the recommended processes, TAGS elements will be fabricated and bonded into couples in the configuration appropriate to the Po RTG system. Couple tests will be performed to ensure that performance was not compromised in the configuration change. If TAGS displays the expected advantages for the Po RTG application, it will be further evaluated in multicouple module tests.

3. T/E Module Development

a. Diaphragm heat sink

An improved module configuration is illustrated in Fig. II-10. This design concept incorporates a thin diaphragm whose primary function is to seal the coolant within the channel. The pressure to the elements is provided by compression springs and buttons. The springs and buttons are inside the coolant channel. Each element has a spring directly in line with it so that the spring load is transmitted through the element and not the diaphragm.

The diaphragm is 0.020 inch thick and is fabricated from Type 321 stainless steel because of its excellent corrosion resistance and ductility. To achieve maximum flexibility and eliminate high membrane stresses around the edges of the diaphragm, the diaphragm is beaded. The stress in the diaphragm is insignificant since the coolant channel static pressure is relatively low. The diaphragm is not subjected to loads from the springs since these loads are transferred directly through it to the thermoelectric elements. The diaphragm may be slightly stressed due to the differential height of adjacent elements to which it must conform.

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Fig. II-10. Spring Loaded Diaphragm Design

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(3) Use coloring additives such as CoO , Fe_2O_3 and selenium.

The most promising approaches will be evaluated by preparing specimens, subjecting them to simulated service conditions (1200°F , 10^{-5} torr vacuum for at least 2000 hours) and determining the effects on emissivity.

c. Improved thermal conductance in cold end hardware

Improvement in performance of the Reference Design module can be made by increasing the thermal conductance in the cold end hardware; i.e., the combination of cold shoe, alignment button, piston and module heat sink. If the thermal conductance can be increased, the result will be a smaller temperature drop between the cold end of the thermoelectric elements and the NaK coolant. This temperature increment can be used to advantage in various ways, depending on the relation priorities for a specific application. The hot junction temperature could be decreased, reducing the degradation rate without affecting power output. Alternately, the temperature drop across the thermoelectric elements could be increased, yielding a greater electrical power output per couple. A third possibility is that the mean coolant temperature could be increased reducing radiator and system weight.

A relatively simple change which should improve the cold end hardware thermal conductance is to reduce the number of electrical insulating surfaces. This change concerns the aluminum alignment buttons and pistons. The mating spherical surfaces are hand-honed to a very close fit. Currently, both details are hardcoated on all surfaces. This results in four thermal barriers where only one (for electrical insulation) is necessary. The thickness of the film resulting from the hardcoat anodizing process is about 0.001 inch and can be as thick as 0.002 inch. Two things should be investigated: first, anodize one surface and evaluate the effectiveness and reliability of maintaining electrical insulation; and second, substitute chromic acid anodizing and evaluate it with the same criterion. The chromic acid anodized film has excellent dielectric strength, several hundred volts per mil, but more important the thickness of the film is in the order of 2×10^{-5} inch or about one hundredth the thickness of the film produced by the hardcoat process. Obviously, then a single, much thinner thermal barrier will decrease considerably the temperature drop across the cold end hardware.

Both approaches will be evaluated as to the adequacy of electrical insulation and the reduction in temperature drop which is achieved.

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d. Improved module assembly techniques

Further advanced development of thermoelectric module fabrication and assembly techniques will be pursued under this task. Areas of investigation will include the following:

- (1) Further evaluation as to the extensiveness of atmosphere controlled assembly environments.
- (2) Optimization of preconditioning internal components through outgassing which would include thermal insulation, hot plates, cold plates, cold straps and heat sink assemblies.
- (3) Investigation and standardization of mechanical crimping which may cover electrical output straps or instrumentation.
- (4) Standardization of types of instrumentation to be used on module assembly, together with methods for attachment.
- (5) Investigation of other techniques for soldering cold straps to the couple cold caps, such as the application of resistance soldering.
- (6) Possible investigation of other modular configurations from an assembly perspective only. (Objective is to optimize the physical boundaries feasible for module assembly and still ensure product reliability.)

4. Heat Source Development

For the heat source, optimization analyses will be carried out to determine if any alternate materials or configurations can be used to improve the structure, aerodynamic characteristics and thermal distribution of the assembly. Restrictions on materials, fabricated forms, etc., which were necessarily imposed during the Phase I and II efforts will be revised as deemed advisable due to potential performance gains and advancements that may reasonably be anticipated through further development efforts. Configuration studies will be carried out to improve on the stability and aerodynamic trajectory of the shapes selected. Also, integration schemes will be evaluated to determine if changes in the spacecraft might improve the safe re-entry of the block or allow basic changes in the block itself. Different fuel forms of polonium, as well as other isotopes, will be investigated and acceptable configurations determined for the prescribed safety criteria.

Further material evaluations, such as various grades of graphite, beryllium or beryllium compounds, boron or its compounds and even

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ceramic materials, will be investigated for incorporation into advanced heat sources. Of prime importance is the investigation of bonding these materials with others to form the desired integral structure. Also, since it is beneficial for the surface of the heat source to have as high an emissivity as possible, studies will be made on techniques or materials to improve the emissivity of the outer heat source surface. This is necessary due to the high vacuum space environment which limits the heat transfer solely to radiative transfer. One favorable method of increasing the effective surface emissivity is by cutting a series of fine grooves in the surface. This method is quite promising and is to be used in the Reference Design since the grooves do not tend to lose their effectiveness with time.

It is planned in this program to study those high emissivity coating materials that will be suggested by a literature search and by experimentation. The requirements of the emissivity coating for this application are:

- (1) High emissivity
- (2) Low sublimation rate at 1800° F in vacuum
- (3) Good bonding to substrate
- (4) Resistance to thermal cycling effects and operation in air for short periods.

The results of this investigation and necessary corroborating experiments will be factored into the evaluation of the designs developed in the analysis portion of this program. This will enable a more meaningful evaluation to be undertaken and a more optimum heat source developed.

5. Thermal Control Development

Advanced studies and development in the area of thermal control can logically and profitably proceed in two areas. The first would be an extension of the recommended NaK system to performance limits beyond those deemed feasible under current design and schedule criteria. The second would be more detailed study and experimental evaluation of the electromechanical concept as a possible replacement for the basic or improved NaK concept.

The NaK system design as conceived is relatively simple and currently holds a reliability advantage over alternate electrical or electromechanical systems which can be considered. Its major disadvantage is associated with the temperature swing that must be tolerated to provide the necessary thermal control shutter activation. This swing ($\sim 10^\circ$

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to 20° F on the current design) essentially reduces the end-of-life hot junction thermoelectric element temperature a like amount. Thus, the overall design must be based upon this lower value and a slight but definitely positive performance penalty paid. An optimum case, which is realizable with an electrical sensor, is to provide full shutter motion as the controlled temperature swings or drifts a minimum amount; say on the order of a few degrees.

Although it may be difficult to fully realize this in a NaK system, the design temperature swing necessary to actuate the control systems may be considerably reduced by one or a combination of three approaches. Full advantage could not be taken of these in the initial design stage due to schedule or reliability testing limitations. The design approaches planned for further detailed evaluation include:

- (1) Increasing the contained NaK volume thereby reducing the ΔT necessary to expand the contained NaK (and power bellows) in direct proportion.
- (2) Decreasing the effective area of the power bellows thereby reducing the volumetric expansion of the NaK necessary to provide the given stroke.
- (3) Incorporation of additional mechanical amplifications such that the stroke provided by a selected ΔT ($\sim 5^\circ \text{F}$) is increased to that necessary for complete shutter activation.

In the first approach, the required NaK volume may easily be doubled if the redundancy currently planned for the Reference Design is found to be unnecessary for reliability purposes. Other possibilities for increasing its volume may be found once the detailed design is tested and the space allotment for the NaK reservoir becomes better defined.

The second approach involves reducing the effective piston area of the power bellows such that its stroke could be maintained at a fixed operational NaK volume but reduced ΔT . This change would increase the pressure in the NaK system which when coupled with a reduced bellows diameter-to-stroke ratio would tend to reduce the design margin of safety for the bellows structure.

Mechanical amplification (the third approach) through use of a lever/linkage arrangement is an integral part of the proposed Reference Design. The degree of amplification allowed is a compromise between several conflicting factors. The theoretical infinite amplification which can be achieved as a pivot point or fulcrum approaches the applied input motion must be counterbalanced by practical considerations of bearing loads, free play and linkage deflections and loads. Similar restrictions exist with all amplification devices such as gears, slides, wedges, etc., arrangements.

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The planned Reference Design will re-evaluate factors such as these during detailed design and planned development stages of Phase II. However, restrictions will certainly be placed by schedule and reliability testing considerations on the final design proposed. The planned advanced development activity will study the arrangements and space limitations of the NaK system reservoir. Also, various components such as bellows or mechanical amplifiers which could not be utilized initially because of a lack in sufficient design, performance, strength or fatigue data to assure reliable performance will be further evaluated in detail. Tests to demonstrate component reliability will be established on the performance data obtained for overall thermal control system optimization.

a. EM concept

A completely different design concept, such as an electromechanical one, may also be considered which offers several promising design features over the Reference Design.

A more detailed study and experimental evaluation will be performed on the following electromechanical concept.

Block Diagram of EM System

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This system utilizes a resistance thermal device (RTD) as one element of a Wheatstone bridge which is excited from the reference oscillator. The bridge output is zero for the nominal hot junction temperature. A hot junction temperature deviation will result in an in-phase or out-of-phase signal from the bridge when compared with the reference oscillator. This temperature dependent in-phase or out-of-phase signal is amplified by an a-c amplifier and then demodulated by a phase-sensitive demodulator. The output of the demodulator will be positive or negative depending upon the direction of the temperature deviation.

When the demodulator output is positive and reaches a magnitude corresponding to an out-of-tolerance temperature deviation, relay K_1 will be energized. This will cause the d-c motor to run in the appropriate direction. Relay K_2 is energized under similar conditions except that the demodulator output is negative. The motor output shaft is coupled to the shutters by means of a gear train, clutch and rod drive mechanism.

This particular electromechanical concept contains the following advantages:

- (1) An RTD is employed as the temperature sensor. When this device is used in a properly designed bridge network, a given temperature change will produce a much larger voltage variation than can be obtained from a thermocouple. As a result, extremely high gain amplifiers are not required. Other advantages of the RTD are its high sensitivity, stability, linearity and interchangeability.
- (2) Since the bridge network is excited from an oscillator, a-c amplifiers are used. If the bridge network was excited from a d-c source, the d-c source must be closely regulated and d-c amplifiers must be used. All problems associated with highly stabilized d-c amplifiers are therefore eliminated in this system.
- (3) The d-c motor operates only when the temperature exceeds preselected limits. Average power required is therefore minimized.

The electromechanical system has certain inherent advantages over the NaK system. These are:

- (1) Ease of part replacement prior to flight.
- (2) Can be controlled or overridden by ground control signals.

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- (3) Greater operating flexibility than the NaK system.
- (4) Ease of checkout.
- (5) Use of standard parts.

Redundant systems will be utilized in the actual system to increase the reliability of operation.

b. Development program

The design criteria for the electromechanical system will be established to determine size, electrical, environmental and output characteristics. The engineering model of the selected system will be designed, fabricated and tested using simulated shutter loads. Additional models will be fabricated for environmental testing and reliability life testing. All components used in these models will be built or qualified in accordance with applicable military specifications. Physical size, weight and mounting techniques for this thermal control system will be compatible with spacecraft requirements. All phases of the development program will be formally documented and will be closely coordinated with all phases of the RTG design to assure compatibility.

6. Heat Rejection System

The detailed design of the heat rejection system, primarily the radiator, is strongly dependent upon its integration into a defined vehicle or complex. However, there are several factors which although quite developmental in nature offer considerable advantage in size, weight and cost. These may be broken into two general categories: first, items that maintain the proposed design concept but potentially offer substantial improvements; and, second, a more radical change to a new radiator concept or approach to meet the heat rejection requirements.

Items falling into the first category include substitution of aluminum for the stainless steel radiator tubing and associated plenums or use of a coextruded magnesium-stainless steel coolant tube for the radiator panels. A new concept or approach is best illustrated by a heat pipe waste heat rejection system.

Substitution of aluminum tubing in the NaK system coolant loop in place of stainless steel offers two primary advantages. In the radiator panel of the proposed design, the stainless steel tubing is clad (co-extruded) with aluminum to facilitate its attachment (by braze) to the aluminum skin of the vehicle. Substitution of aluminum for the stainless tubing, plenums and associated plumbing reduces weight, cost of the coextrusion and eliminates the extrusion interface and, hence, any existing interface thermal resistance.

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The second and perhaps major advantage of this substitution is the elimination of the contact interface in the thermoelectric module between the aluminum heat sink and the stainless steel coolant plenum. Because this is strictly a mechanical assembly depending upon machining and assembly tolerance to minimize the interface gap, detailed fit-up is most critical. Again, substitution of an aluminum coolant loop would eliminate this differential metal interface and reduce associated manufacturing costs. It is also the first step in achieving an integral heat sink and coolant plenum design which would offer further appreciable savings in weight and size.

Although only limited corrosion test data for NaK with aluminum contaminant exists at temperatures of interest (~300° F), qualified metallurgists at the Martin Company and consultants at facilities such as Mine Safety Appliances (MSA) and Battelle Memorial Institute (BMI) feel that minimal corrosion rates may be anticipated. Preliminary scoping tests are also under way at Martin which will provide further substitution. Once established, these advancements may easily be incorporated into the planned system.

Further corrosion tests planned for this advanced development activity would include a preliminary static-type screening test of various promising aluminum alloys. Upon evaluation of these, tests would be run in two dynamic loops: one at normal operational temperatures of the system (~300° F) and the other at a higher value to accelerate the corrosion results (~400° F). Metallurgical examinations after various exposure periods would provide the results necessary to qualify this material substitution.

Another approach to reducing radiator weight is the substitution of a magnesium clad, stainless steel tube for the Al-SS radiator tubing proposed in the Reference Design. This modification would allow subsequent attachment of these tubes to Mg-meteoroid armor with a resulting weight saving. Coextrusion of the Mg-SS tubing is believed feasible by the tubing manufacturers questioned. However, development effort is first required to establish conceptual feasibility. A similar approach was also conceived whereby the magnesium armor would be resistance spot or seam welded directly to the tubing. This is known to be conceptually feasible; however, detailed tooling and the heat transfer characteristics of this interface must be established.

In the area of advanced designs, an unarmored lightweight heat rejection system may be considered by eliminating the present single loop concept for the cooling system. Without armor, a single loop is highly vulnerable to meteoroid puncture since a single penetration anywhere in the system is tantamount to total system failure. Meteoroid armor is necessary to achieve the required reliability. However, the addition of the armor necessary to meet Reliability criteria results in a considerable

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weight penalty. If the radiator tubes were isolated from each other as an alternate approach, a limited number of tube penetrations could be tolerated. Unfortunately, such a multiple circuit system would be impractical since it involves complete system reproduction for every circuit (i.e., multiple pumps, lines, etc.).

An alternate arrangement, employing multiple heat pipes from the source to the radiator surface, would solve the meteoroid puncture problem. However, it appears somewhat impractical due to the distance between the cold junction heat exchanger and the radiator panel. A practical compromise system would combine a NaK loop to transfer heat from the thermoelectric module to a central point in the area of the radiator panel with heat pipes thus used to distribute the heat from this point to the entire radiator surface. The heat pipes in this case would employ water as a working fluid. Meteoroid armor protection would be required only on the NaK loop plumbing to the radiator panel area and the loop to heat pipe heat exchanger manifold. Heat pipe runs would be short and straight therefore requiring no new system development. Loss of an individual heat pipe to meteoroid puncture would result not in a loss of the entire cooling system but only in a reduction in radiator performance. Redundancy can easily assure maintenance of required performance within the reliability requirement.

Preliminary estimates of the characteristics of this system show the following advantages:

- (1) A weight saving in excess of 25 pounds
- (2) A saving in pumping power requirement (perhaps 50%)
- (3) Virtual elimination of catastrophic cooling system failure to meteoroid puncture
- (4) Development clearly within existing basic technological capability
- (5) Complete flexibility and adaptability to alternate radiator configuration.

The proposed plan of investigation would include:

- (1) Thermal parametric studies--determine optimum heat pipe geometry and spacing for minimum weight within required reliability objectives.
- (2) Design thermal mockup--prepare design for full size radiator system mockup to be used for systems demonstration.

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- (3) Component development--construct and test single heat pipe and manifold heat exchanger to evaluate characteristics of each.
- (4) Mockup development--construct and test one full-size radiator mockup in air under simulated operating conditions. Radiator will contain approximately 40 heat pipes in contact with the NaK manifold heat exchanger.

7. Configuration and Fuel Development

The basic purpose of this task is twofold. The first is to evaluate the proposed system concept under alternate or off-design conditions, i.e., new or variations in mission requirements and with alternate fuel considerations that may be of interest to various using agencies. The second is to provide overall design and integration support to the Task 7 efforts to assure that the proper perspective is maintained. This will prevent a disproportionate amount of effort from being spent on an item or phase of study that would only result in a minimal performance gain.

An overall evaluation of the proposed concept will be made for alternate fuels deemed practical for missions of interest (i.e., plutonium, curium), various satellite and launch vehicles, and for extensive variations to the proposed operational trajectory. These will include extended life systems for both orbital missions at various altitudes and for installations on the lunar surface or lunar vehicle. The effect on the heat source will also be established, limiting safety criteria determined, restrictive temperatures investigated and resulting gains or penalties in the power and weight performance of the system calculated. This phase will in effect supply the necessary support effort to logically extend the basic design, resulting from the extensive design and qualification efforts planned, to broader applications.

This type of investigation will also be extended to consider the significance of the various investigations and development efforts planned throughout the advanced development activity. Preliminary evaluations of each item discussed under Sections F-1 to F-6 will be made to assure that the potential gains to the system warrant the planned studies or development efforts.

Significant design factors or innovations will be investigated singly or in combination, as appropriate, and the net worth of each determined. Depending upon the design status at any point in time, recommendations will be made relative to: the technical and practical feasibility for incorporation of an improvement into the then current design; proposed additional development for promising features; or, the establishment of task milestone points where future incorporation would be better suited due to new or altered mission or system requirements.

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PHASE III--PROTOTYPE SYSTEM DESIGN, FABRICATION AND QUALIFICATION

The Phase III objectives are to fabricate and qualify prototype radioisotope thermoelectric generators using electrical heat sources in accordance with the drawings, specifications and processes developed during Phase II. In addition, two electrically heated prototype generators will be fabricated for User requirements.

Ground support equipment will also be fabricated and qualified. This equipment and one fueled prototype RTG will be integrated with the vehicle and launch complex and used for launch pad demonstrations during this phase.

The results of this and previous phase efforts will be used to prepare a final safety analyses report, based on the mission application.

The effort under this phase is broken down into the following tasks:

- Task 1. 0--Management and Controls
- Task 2. 0--Prototype Design and Analysis
- Task 3. 0--Safety and Shielding Analysis
- Task 4. 0--Prototype RTG Manufacturing and Testing
- Task 5. 0--AGE Manufacturing and Testing
- Task 7. 0--RTG Component Advanced Development.

Task 6 effort is completed during Phase II and does not reappear in Phase III.

A. TASK 1. 0--MANAGEMENT AND CONTROLS

1. Program Management

The Phase III program maintains the emphasis of management control on internal development progress but, in addition, the problems of total system integration are highlighted. This is the payoff of the configuration control procedure started in Phase II. Such a procedure minimizes the possibility of problems occurring during the marriage of subassemblies into a system, or the system to the vehicle. During this Phase, the Program Manager will use the same procedures described in Phase II, Task 1. 1.

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a. Liaison

With the delivery of three RTG (one fueled, two electrically heated) and the demonstration of the ground handling equipment, liaison with the User Agencies increases considerably. Training aids in the use of these equipments will be prepared including:

- (1) Operating manuals for both RTG and GSE
- (2) Instruction manuals for both RTG and GSE.

In addition, a User Agency training program will be instituted to instruct personnel in the proper use and fueling of the RTG. The actual training will be accomplished during Phase IV.

(1) Technical manuals. Based on the technical manual plan developed in an earlier phase of the program, and through continued liaison with the AEC and User Agency, a firm definition as to manual scope, level and organization will be made. A preliminary technical manual will be prepared prior to the time when launch pad qualification testing and fueling is performed on the prototype system.

A technical manual verification program will be conducted as a part of the RTG qualification program. The source of procedural data during qualification will be the preliminary manual. Discrepancies will be noted, and procedures will be changed or improved as necessary to permit qualification test completion. After the RTG qualification test and the technical manual verification are completed, the technical manual will be updated so it reflects the accepted procedures.

The manual will have sections on:

- (1) RTG description and basic operation
- (2) Generator installation and procedures
- (3) Generator test and checkout using an electrically heated fuel block
- (4) Fuel shipping, storage and handling procedures including safety aspects
- (5) Fueling and defueling procedures on the launch pad. This will include data on use of ground handling equipment
- (6) Checkout procedures for the fueled generator
- (7) Prelaunch and post-launch data collection and evaluation

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- (8) Maintenance procedures, and inspection and service instructions
- (9) Handling of RTG fuel capsules or block after abort and recovery. Procedures and warnings will be included.

Decisions will be made, based on the current operating plan, as to the feasibility of producing the manual in several small individual sections or as a unit.

The revised preliminary manual will be submitted to the AEC for review and approval. Any Customer comments will be incorporated into the final manual to be released in Phase IV.

b. Data

In addition to the reports listed in Phase II, Task 1.1, the following will also be prepared:

- (1) Topical reports on the integration of all subsystems
- (2) A final safety analysis report
- (3) A final report on AGE demonstration
- (4) Operating and instruction manuals.

2. Configuration and Integration Management

Interface liaison and control and configuration management as defined under Phase II of the Development Plan will be continued to support and document the design freeze occurring through Phase III. Emphasis will decrease on interface liaison efforts relative to that required for documentation and contract action. Contract end item specifications, well under way at the start of Phase III, should be essentially completed during this phase.

3. Reliability

In Phase III, Reliability emphasis will shift from design analysis, component development and qualification to prototype generator system development, fabrication and qualification. The subjects to be highlighted in the Phase III reliability effort are:

- (1) Failure mode and effect analysis, trouble reporting and corrective action
- (2) Design review and evaluation of reliability achievement

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- (3) Monitoring of the generator system qualification tests and analysis of results
- (4) Spacecraft Contractor and Customer coordination
- (5) Launch pad integration of AGE.

a. System review and evaluation

The objectives of this effort are to monitor the effort being accomplished in Phase III, Task 2 (Prototype Design and Analysis), to assure that the system, as finally defined through drawings and specifications, meets the User's operations and mission requirements. In addition, assistance in evaluating the prototype system qualification testing to determine how well the existing equipment integrates with the spacecraft and launch pad operations will be undertaken.

Engineering drawings and design specifications will be reviewed and evaluated. This review will be based on current contract specifications and data resulting from customer liaison with respect to operations and Spacecraft Contractor interface requirements.

During the testing of the prototype generator and ground support equipment at the launch site, operations and operating procedures will be monitored and evaluated. Recommended changes to design features and procedures will be made if indicated. These recommended changes would be in the area of increasing the effectiveness of RTG system integration with the spacecraft and launch pad.

4. Quality Assurance

a. Quality program plan

Quality systems, controls and disciplines applied and exercised throughout Phase II to assure material and fabrication compliance with drawing requirements and to assure test validity will have been proven prior to the start of Phase III prototype system fabrication and qualification. Phase III Quality effort will essentially consist of a continuation of the Phase II tasks applied to the assembly and installation, and qualification, reliability, production monitoring and acceptance testing of prototype generator systems and AGE. During this phase, detailed plans for Integration Contractor and launch site Quality functions will be drafted and published to supplement the plans currently included in the Po RTG Quality program plan presented in MND-3612-8-1, Chapter III-A.

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5. Technical Manual(s)

In Phase III, the plan developed under Phase II will be employed to produce a preliminary manual. The manual preparation, validation, revision and verification will be accomplished as follows:

- (1) Preparation of the initial draft will be accomplished during prototype fabrication, and will be based on engineering data developed during Phase II testing and Phase III design data. The manual(s) will encompass information and procedures on the RTG and its related ground equipment.
- (2) Draft copy of the manual(s) will be completed at such a time as to permit Martin Company to validate the procedures during in-house qualification testing of the various end items.
- (3) Changes that result from such validation and qualification testing shall be incorporated into the manual(s).
- (4) The manual will then be verified and customer approved.
 - (a) In the case of the FHM and fuel transportation cask, the revised manual will be verified at the launch site.
 - (b) In the case of the RTG, the checkout console and the electrically heated fuel block assembly, the verification will be accomplished during RTG integration into the prototype space vehicle at the Integration Contractor's facility.
- (5) Changes resulting from the verification program and from flight system design changes will be factored into the preliminary manual and it will be released as the flight system manual.

The initial draft and subsequent releases will be edited and reviewed for conformity to manual specification requirements and will be reviewed by personnel qualified to check for adequacy and accuracy. The preliminary manual will be released as soft copy (ditto, copyflo, or similar method) having paper covers.

The final manual will be produced in offset printed form and bound in plastic, three-post binders. This final manual will be released concurrent with the initial flight system RTG (during Phase IV).

Also during Phase III, documentary film footage will be continued concerning activities and efforts of the contractor.

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B. TASK 2.0--PROTOTYPE DESIGN AND ANALYSIS

1. System Integration Analysis and Design

a. RTG system and integration

This task will encompass arrangement and physical integration analysis and design, including:

- (1) Electrical and instrumentation
- (2) Thermal insulation
- (3) Mechanical and structural design.

The effort will be aimed at combining the integration details evolved during Phase II design and liaison into a final prototype integration design. It is expected that a firm location in the spacecraft will be established prior to the end of Phase II so that the final prototype integration drawings may commence early in Phase III. Approval for the selected location must be obtained prior to initiation of the final interface drawings.

Installation of the RTG system into the vehicle will be carefully coordinated with the Satellite Vehicle Contractor and personnel at the launch site to assure compatibility. In addition to the physical installation, factors such as thermal and radiation effects, test provisions, checkout equipment, fuel compatibility and scheduling will be thoroughly considered.

A liaison effort with the Integration Contractor will be provided over this entire phase to ensure close coordination.

In order to complete the final prototype integration design, final detail design drawings of the spacecraft must be made available at the beginning of the phase. Attachment points to the spacecraft structure will be subject to the approval of the Satellite Vehicle Contractor and other involved parties. Loads at those points from the RTG system will be specified by Martin, based on analytical calculations and results of the vibration tests. Backup structure in the spacecraft to take these loads is assumed to be the responsibility of the Satellite Vehicle Contractor.

b. AGE system and launch complex

(1) Function and performance integration analysis--final. Based on final design of the AGE and liaison activities with the User Agency, a detailed operating procedure will be prepared. This procedure will be arranged with reference tabs in which functional and performance analyses of the system components are presented in appropriate detail.

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(2) Arrangement and physical integration design--final. Liaison shall be performed with the User Agency to finalize AGE requirements. Approvals of the final interface drawings and specifications will be obtained in addition to approvals of the site modification drawings and planned operating procedures on fuel handling at the site.

2. System Analysis and Design

a. RTG analysis and design

During this phase, the final prototype design will be evolved. The analysis design effort will be subdivided into the following basic RTG subsystems.

- (1) Heat source
- (2) T/E conversion module
- (3) Thermal control system
- (4) Coolant heat rejection
- (5) Support structures.

The effort will involve combining the details and subsystems developed during Phase II into a final prototype design. The design changes or improvements are, of necessity, dependent on the results of component testing performed during Phase II. Any modifications found necessary to correct or improve system performance based on Phase II development testing will be incorporated into the final prototype design. Further design advancement may become apparent through further development tests. If so, each will be factored into the prototype design as the prototype test schedule allows.

Modification to the T/E conversion module design will depend on the performance testing of the modules during Phase II. Modifications are expected to be in the form of design improvements rather than design corrections. Special emphasis will be placed on minimizing cold end temperature drop and assuring proper flow distribution within the module.

The thermal control system design modifications will again depend on the Phase II testing. Appreciable testing will be made of the NaK actuating system as well as an electromechanical system. Based on the performance data, a decision will be made as to what system should be used in the final prototype design.

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Extensive testing of the coolant heat rejection system during Phase II will provide extensive information regarding flow distribution in the radiator manifold, NaK pump performance, thermal performance in a vacuum and structural integrity. No major redesign effort is anticipated for this subsystem based on performance testing. Modifications to the subsystem would probably be a result of spacecraft integration considerations such as the available mounting location for the radiator. Therefore, in order to finalize the radiator design in Phase III, approval of its basic size and shape and mounting location must be obtained prior to the end of Phase II.

Support structures for the various RTG system components will be commensurate with the spacecraft integration design evolved in Subtask 2.1.1. All support structures will be designed utilizing the results of the shock and vibration tests performed during Phase II. A stress analysis will be made to ensure structural integrity. Loads on the spacecraft due to the RTG system will be coordinated with the Satellite Vehicle Contractor through Subtask 2.1.1.

b. AGE final design

The larger part of the AGE final design will have been completed in Phase II. The Phase III effort shall consist of a small concluding effort, as in areas where final interface approvals are lacking. Design checking and drawing release will be performed. The design report will be written.

An intermittent effort is planned in manufacturing and testing follow-up. Close liaison will be conducted with Martin field test groups during field demonstrations of the system. Drawing maintenance will be conducted so that all Phase III modifications are reflected in as-built drawings at the end of the phase.

(1) Performance analysis. Performance analysis of the final design unit will be completed in Phase III prior to acceptance testing of the AGE systems.

A final report will be made on the results of a malfunction and recovery study. This study will include off-design point operation from findings of the prototype FHM testing, and from Phase III testing of the final AGE system.

3. Prototype Fabrication and Test Specification and Evaluation

a. RTG fabrication and test specification and evaluation

This task will encompass preparation of manufacturing process specifications, assembly specifications, test directives and specifications, test fixture design, instrumentation design, test data evaluation, and, finally, preparation of test reports for the prototype environmental testing and qualification.

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As the prototypes and other component test assemblies are made available for detailed evaluation, detailed test directives will be established that cover both testing techniques and performance evaluation criteria. All equipment will be covered by detailed specifications which precisely define function, performance and quality tests and evaluation procedures. Revisions to the specifications will occur throughout all phases of the program.

The necessary test fixtures required to perform the prototype tests will be designed during this task. Test loops required to simulate thermal inputs will also be designed under this task.

Prototype fabrication and testing will be closely monitored by engineering. As the prototypes sequence through their respective qualification tests, their performance data will be evaluated and compared to predicated performance. This data evaluation will be performed throughout and after tests to ensure compliance with the planned test directives. Any modifications to components found necessary will be made and will be subject to proof tests to verify that they meet the test performance requirements.

Final test reports will be written for all prototype qualification tests.

b. Prototype AGE fabrication, test specification and evaluation

(1) Manufacturing process specifications. The results of evaluation of prototype FHM fabrication processes and analysis of new requirements introduced in FHM final design will be utilized in preparing final process specifications on the FHM. The remainder of the AGE, with the exception of the electrical heat source, will require preparation of process specifications. The electrical heat source will have been developed concurrently with its process specifications, so that minor revision and updating are expected in Phase III.

(2) Test design and specification. Revision and updating of test specifications are expected for most AGE items. In all cases, acceptance testing planned will require design of acceptance test equipment and preparation of acceptance test specifications. The acceptance test specifications will be made available not less than three weeks in advance of acceptance test performance.

(3) Test data evaluation. The Phase III tests are planned to obtain performance verification of the design, and to demonstrate compliance with the acceptance criteria. The test evaluation of the AGE items will include the preparation of a final test report on the acceptance demonstrations. This report will present all details of the conditions under which the units were acceptance tested and the performance results that were obtained.

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C. TASK 3.0--SAFETY AND SHIELDING ANALYSIS

1. Safety Analysis

a. Final safety and shielding analysis report

A final safety report will be prepared that contains the results of safety analyses, experiments and tests performed during the program. Data will pertain specifically to the revised, final generator design. Malfunctions leading to deviations from the planned mission and fuel disposal will be analyzed on a probabilistic basis and their consequences evaluated.

The report will consist of:

- (1) Description of the generator system, its operating parameters and safety features
- (2) Description of the application, handling, transportation and installation procedures
- (3) Detailed description of all analytical and experimental safety and shielding studies performed during the program
- (4) Conclusions and recommendations.

b. Flight approval liaison

Technical assistance and data will be provided for the necessary approvals for the operational systems. Specifically, this effort will include:

- (1) Liaison with participating groups and cognizant agencies to resolve existing problem areas, justifying analysis and test results, and providing technical assistance to the User Agency.
- (2) Performance of any additional safety work necessary as a result of the preliminary safety report review.

It is anticipated that flight demonstrations will be required prior to obtaining final flight approval. Accordingly, effort will be performed at the beginning of Phase III to determine the relative merit of conducting such a test, similar in some respects to the recently completed RFD-2 program. Recent internally funded effort performed by Martin indicates that orbital flight tests may be feasible using a modified 16-inch naval gun for primary boost, augmented by successive solid fuel stages located on the projectile. Preliminary cost estimates for this type of launching device are less than those for conventional rocket launching devices by an order of magnitude. The potential low

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cost of the gun launching device would make it feasible to perform a number of launchings to allow observation of statistical fluctuations in trajectories, the extent of aerodynamic heating and the consequences of those fluctuations.

The availability and usefulness of this launching device to the present program will depend upon its state of development and payload weight and volume limitations. The status of this program, to be conducted by McGill University and supported by the Army Materiel Command, will be maintained to see if a projectile capable of orbital insertion when fired from a gun launching device can be developed.

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D. TASK 4.0--PROTOTYPE RTG MANUFACTURING AND TESTING

During Phase III, this task will be devoted to manufacturing a total of five complete RTG prototype generator systems. Three of these systems will be acceptance tested and shipped to the Customer, three of the systems will be tested at the qualification level with a fourth system serving as a backup.

The subtask descriptions which follow indicate in somewhat more detail the work to be accomplished in this task during Phase III.

1. RTG Test Preparation

As in Phase II, this task will be devoted to the preparation of test procedures which will assure that the specified environment requirements are met and will detail methods of handling the test specimens, operation of the specimen during test, and methods of data acquisition. As previously noted, the test procedures will be signed off by Reliability, Quality, the Project Engineer, the Program Manager and the Customer prior to issuance and commencement of the test.

Also included in this task is the necessary work involved in instrumentation and calibration and setup of each test.

2. RTG Assembly Process Development and Tooling Fabrication

a. Prototype RTG assembly process development and tooling

The fabrication of prototype RTG will be effected employing the concepts developed in Phase II, Task 4.2. The prototype RTG assembly technique, after successful demonstration, will then be qualified.

Tooling jigs, identical in layout to the support structure, will be fabricated under this task.

3. Prototype RTG and Test Fixture Fabrication

The full size generators will be assembled using qualified processes and procedures. Final generator assembly will include the integration of eight modules, one heat source assembly, one heat rejection system and one thermal stabilization system. A total of seven RTG systems will be fabricated for qualification and acceptance testing.

Additional test fixtures required for performance and environmental testing will be fabricated under this task.

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4. Prototype RTG Testing

a. Production monitoring tests

In addition to the Quality Assurance tests normally performed as part of the manufacturing process, vibration tests (sinusoidal at 25% of the acceptance level) will be performed on the module, thermal control and coolant heat rejection subsystems to verify structural integrity prior to final assembly.

b. Acceptance testing

Acceptance testing of the RTG prototype generator system will consist of a power check at end-of-life power input, a vibration test of the complete system at one-half the qualification levels (both sinusoidal and random) and a thermal vacuum test at beginning- and end-of-life thermal inputs. The vacuum chamber condition will be 1×10^{-6} torr or lower, and cold wall temperatures ranging from -150° F to +150° F. At the conclusion of these tests, a power check will be made (in air) at end-of-life thermal input followed by a parametric evaluation. Three RTG generator systems will be acceptance tested and shipped to the Customer.

c. Qualification testing

(1) RTG prototype Generator 1. One complete RTG generator system will be subjected to the thermal vacuum environment described in Appendix A. The test instrumentation will be sufficient for determining the operating temperatures and individual module behavior. The generator system will be subjected to complete orbital temperature conditions (temperature and rate of change of temperature) and generator performance determined for beginning-, middle-, and end-of-life thermal input.

Small dimensional changes will be made to the coolant radiator (keeping the total area) to allow proper clearance in the Martin 6- by 15-ft thermal vacuum chamber.

(2) RTG prototype Generator 2. This system will be tested separately as two major components--the coolant radiator panels and the RTG generator system--for the reason stated in Task 4. 4. 5. The generator system will be operated using a small auxiliary coolant system. The radiator panels will be NaK filled, and heated with auxiliary heaters to the operating condition. These major components will then be subjected to the complete launch environment (except vacuum) at the qualification levels discussed in Appendix A.

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d. Performance and life testing

(1) RTG Generator 3. RTG Generator 3 will be submitted to a performance and life test for a period of seven months for the purpose of obtaining drift information on the complete system. This test will be performed in an air environment. The details of such a test are documented in Appendix A.

(2) RTG Generator 4. RTG Generator 4 will be fabricated and held as a spare until the end of the acceptance and qualification testing. If it is not needed for replacement, it will be performance and life tested as in the case of this RTG 3.

e. Integration contractor testing support

Engineering support will be provided to the Integration Contractor to aid in the RTG system tests at the Contractor's site. Such support will ensure that the generator system is operated properly and that any necessary deviation from the test procedure will not damage the RTG system.

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E. TASK 5.0--AGE DEVELOPMENT PLAN

1. AGE Components Testing

During Phase III all of the AGE systems shall undergo testing, including acceptance testing.

a. FHM system tests

The FHM will undergo tests as follows:

- (1) Operable components will receive a functional test prior to installation in the FHM to verify that they perform as required.
- (2) The FHM will undergo a series of performance tests to verify system operation, especially of subsystems that changed from the prototype tests.
- (3) Acceptance tests performed so that the ability of the FHM to meet its requirements can be demonstrated to the User Agency.
- (4) Demonstrations of the system at the launch base, when the unit is GFE.

b. FHM checkout equipment

The FHM checkout equipment will undergo tests as follows:

- (1) Vibration and shock tests performed at shipping levels to assure ability of the equipment to survive transportation handling.
- (2) Performance tests conducted with the FHM to provide data on functional abilities of the equipment.
- (3) Acceptance tests performed, employing the FHM, to demonstrate adequacy of the equipment in meeting the requirements of its intended function.
- (4) Demonstrations of the equipment conducted at the launch base, when the unit is GFE.

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c. RTG power system shipping container

The RTG power system shipping container will undergo tests as follows:

- (1) Vibration and shock tests performed at shipping levels, with a dummy RTG system contained in the shipping configuration. The RTG shall be instrumented. The purpose of the test is to verify that the RTG would not be damaged in transit under normal handling.
- (2) Acceptance tests conducted to demonstrate the ability of the equipment to meet its required functions.
- (3) Demonstrations of the unit at the Integration Contractor's plant, when the unit is GFE.

d. RTG power system field test equipment

The RTG power system field test equipment will undergo tests as follows:

- (1) Selected components, such as the Variacs, which might not be located indoors will undergo environment-resistance tests as appropriate.
- (2) Performance tests conducted to verify functional ability of the equipment to check out an RTG power system.
- (3) Reliability tests conducted to establish confidence levels on the ability of the equipment to control the electrically heated source within the required tolerances, and on the ability of the equipment to function in a manner which has a low failure rate, commensurate with its heater control task.
- (4) Acceptance tests conducted with the equipment to demonstrate its ability to control an electrically heated source, and to monitor the operation of an RTG power system.
- (5) Demonstration of the equipment at the launch base when the unit is GFE.

e. NaK ground service system

The NaK ground service system will undergo performance tests that will be conducted to confirm the ability of the equipment to perform its required functions in a safe manner. The specifications shall be verified as to NaK purity requirements and similar matters.

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f. Fuel transportation cask

The fuel transportation cask will undergo tests as follows:

- (1) A thermal balance test conducted with an appropriate heat source to simulate the actual fuel block.
- (2) Compatibility of the fuel transportation cask with the FHM will be demonstrated.
- (3) Environmental tests, to include salt, fog, sand and dust, performed on selected components to assure that bolts, lids, etc., which are removable, are not adversely affected by environmental exposure.
- (4) Demonstration of the handling of the cask at the launch site when it is GFE.

g. Electrically heated sources

Tests of the electrically heated sources will consist of bench-type functional tests performed to verify operation of the unit, and correct responses of the attached thermal detection devices.

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F. TASK 7.0--RTG COMPONENT ADVANCED DEVELOPMENT

This task is a continuation of the development work started in Phase II.

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PHASE IV--FLIGHT SYSTEM DESIGN, FABRICATION AND ACCEPTANCE

All work and data evaluations and designs of the previous phases will be incorporated into a final flight operational system design. This will include any redesign or drawing changes that result from the prototype tests or safety test program.

Under this phase, four radioisotope thermoelectric generators will be fabricated, assembled and acceptance tested. Three of these units will be delivered to the launch site for flight testing. The fourth unit will be retained for performance testing.

The effort in this phase is broken down into the following tasks:

Task 1.0--Management and Controls

Task 2.0--Flight System Design and Analysis

Task 3.0--Safety Support

Task 4.0--Flight System RTG Manufacturing and Testing

Task 5.0--AGE Manufacturing and Testing

Task 7.0--RTG Component Advanced Development

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A. TASK 1.0--MANAGEMENT AND CONTROLS

1. Program Management

The management function during Phase IV is essentially identical to Phase III. Maintenance of reliability, quality, schedule and cost is the primary function during this phase. The same management techniques previously described will be employed.

a. Liaison

The liaison function should diminish somewhat during this phase since complete marriage of the RTG system and the vehicle, and required demonstrations, other than the training in the use of the RTG and GSE, will have been accomplished in Phase III. At this point the liaison function is one of training and housekeeping, and the integration of last minute changes into minor hardware modifications.

b. Data requirements

A final summary report will be prepared highlighting the total development, test, integration, fueling and flight performance of the RTG system.

A final summary 16 mm sound film of 30 minutes duration will be prepared for the visual presentation of the same information as contained in the summary report.

The final edition of the operating manuals and drawings will be released.

2. Configuration and Integration Management

Interface liaison will be limited to operational aspects of the RTG power system and to the polonium fuel effort. All specifications representing contractual obligations will be completed for final submittal during this phase. The contract specification compliance program will reach maximum effort and be completed along with specification changes (CCP and SCN) representing the final design and hardware.

3. Reliability

In Phase IV, Reliability emphasis will focus on vendor control, manufacturing process control, trouble reporting and corrective action, monitoring and analyzing the results of generator system acceptance tests, flight readiness tests and flight tests. The primary purpose of the Reliability effort in this phase is to assure that the flight test RTG units are fabricated, assembled, delivered to the launch site and tested so as to satisfy specification requirements.

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a. System review and evaluation

To aid in assuring that engineering drawing changes resulting from prototype testing do not cause any adverse effects on the systems, and do, in fact, add to system availability, dependability and capability, a system review and evaluation will be performed. This will consist of reviewing proposed drawing changes and evaluating the degree to which they affect the total system, particularly influences on interface requirements and performance specifications.

4. Quality Assurance

Emphasis during Phase IV will be directed toward fabrication inspection, acceptance testing and delivery of final flight operational Po RTG power systems. In-plant inspection activities, as described in the Quality program plan, will continue in effect; the failure reporting corrective action system will be extended to embrace field and launch site activities; and the Quality Engineer assigned to the launch site will implement the Quality program plan reported for integration and checkout of Martin equipment.

Generally, the Quality integration interface with the Integration Contractor at his facility and at the launch site will concern itself with receiving inspection of Po RTG and AGE equipments, installation and operational inspections, technical manual verification, maintenance of configuration control, and required storage, maintenance, calibration and safety inspections.

Upon the start of integrated system checkout operations by the System Integration Contractor, the Martin Quality representative will be responsible to the System Integration Test Conductor for the integrity of the entire Po RTG power system. This responsibility will be discharged by coordination of Martin Quality with the System Integration Contractor Quality. Coordination for all Po RTG program activity will be a continuous closed loop operation between Martin Quality and the System Integration Contractor Quality to accomplish all program requirements.

5. Technical Manuals

Based on the manual verification program in Phase III and engineering design data on the flight RTG, the manuals will be revised, printed, bound in plastic (three post) binders and released as the flight system manual(s). The release will be concurrent with the first flight RTG delivery to the AEC at Martin Company.

Film footage of the Contractor activities will be completed and delivered to the AEC.

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B. TASK 2.0--FLIGHT SYSTEM DESIGN AND ANALYSIS

1. Integration and Flight Support Analysis

During this phase, thermal and electrical interfaces of the flight hardware will be finalized by analyzing the Phase III prototype data. A power profile of the RTG after design end of life will be generated to show the effect of unexpected launch holds beyond the 14-day allowance. Analyses will be conducted in support of the final flight hardware integration with the spacecraft.

Prelaunch, launch and post-launch telemetry data will be analyzed to evaluate the performance of the RTG throughout the mission lifetime.

It is anticipated that some minor changes will be made to RTG system components and integration interfaces. Part of the effort will be devoted to keeping all drawings up to date with all such modifications.

a. AGE spares and replacements

Reports from Field Operations shall be reviewed and compared with estimates made previously of spares and replacement parts. These items shall be updated, as required, to suit the flight program. Attention shall be given to recurring items that indicate an area for possible design improvement. The changes that are needed shall be recommended to the User Agency.

(1) New configurations. Changes in RTG power system configurations shall be reviewed for possible effects on AGE design. This area shall be noted and defined for Customer review and action.

2. System Analysis and Design

The final drawings will be very similar to the prototype design constructed during Phase III with the primary changes being brought about by the final performance and proof tests of the prototype generators. The flight system design will, in effect, be less complicated than the prototype in that it will not be required to carry as many test provisions. The test provisions on the flight article will be limited to those essential for evaluating the installed system performance. Analysis of the results of Phase III prototype testing will be conducted in support of any design changes necessary. The effect of a design change on the remainder of the system will be determined before a design change can be finalized.

Detailed drawings will be made for all the system components. These components comprise the following major subsystems:

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- (1) Heat source (fuel block and fuel capsule)
- (2) T/E conversion module assembly
- (3) Thermal control system
- (4) Coolant heat rejection system
- (5) Support structures
- (6) Interface drawings.

These drawings will be identical to the actual flight hardware incorporating all changes and modifications found necessary during Phases II and III testing.

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C. TASK 3.0--SAFETY SUPPORT

The program safety aspects will be monitored continuously throughout the program to assure that the original design values and limitations are adequately met. In areas where planned overdesign is definitely confirmed, recommendations will be made for future program incorporation as a design advancement. The final safety report will be continuously updated, as required, should changes be made in any of the safety criteria, launch vehicle or ground support equipment.

Safety effort during this phase will also be devoted to support of the Customer and User Agency in obtaining acquired approvals for shipment and flight. To this end, presentations will be given, as required, delineating the basis for the generator design, disposal philosophy and summarizing pertinent analyses and tests performed during the course of the generator design, fabrication and qualification program.

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D. TASK 4.0--FLIGHT SYSTEM RTG MANUFACTURING AND TESTING

The emphasis in this task during Phase IV will be the manufacturing, assembly and acceptance testing of four flight systems. Three of these systems will be delivered to the Customer and the fourth system will be reserved for performance testing.

The subtask description which follows indicates, in somewhat more detail, the work to be accomplished in this task during Phase IV.

1. RTG Test Preparation

The test preparation in this phase will be reduced to upgrading the acceptance test procedures established in Phase III and securing final approval from Project Management and the Customer.

As in Phases II and III, the task includes the necessary calibration, instrumentation and test setup time required.

2. Flight System RTG Fabrication

A total of four flight RTG systems will be manufactured for acceptance testing. Three of these systems will be shipped to the Customer and the fourth retained for testing.

The fabrication of these systems will utilize the qualified manufacturing processes and tooling developed and fabricated during Phases II and III.

Minor design changes resulting from the qualification testing performed in Phase III will be incorporated into the flight systems.

3. Flight System Testing

a. Production testing

Production monitoring tests (sinusoidal vibration at 25% of the acceptance level) will be performed on all modules, thermal control and coolant heat rejection subsystems prior to final assembly.

b. Acceptance testing

Acceptance testing of the RTG flight system will consist of an output power check at end-of-life power input, an instrumentation operation check, a vibration test at one-half of the qualification levels (sinusoidal and random) and a thermal vacuum test at 1×10^{-6} torr or

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lower with an average cold wall temperature ranging from -150° to +150° F for beginning- and end-of-life thermal input.

A system output power check will then be made in air.

Acceptance testing will be performed on all four RTG flight systems.

c. Performance testing

One of the four RTG flight systems will be retained for performance testing. This test will consist primarily of power output, heat dump door position and coolant system performance for beginning- and end-of-life thermal input. These tests will be conducted in an air environment, thus necessitating some adjustment to the heat input to achieve simulated operating conditions.

d. Prelaunch and launch support

Engineering support will be provided at the launch site to aid in the checkout of the RTG flight system prior to, during and after launch.

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E. TASK 5.0--AGE MANUFACTURING AND TESTING

No changes are anticipated in manufacture of the follow-on units which shall include RTG power system shipping containers and electrical heat sources.

Testing shall be limited to Quality Control inspection in the case of RTG power system containers. The electrical heat sources shall have Quality Control inspections plus a bench-type performance test over the operating range.

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F. TASK 7.0--RTG COMPONENT
ADVANCED DEVELOPMENT

Work begun in Phase II and continued in Phase III will be carried over into this phase. The results of this development effort will be discussed with the Customer and recommendations made for incorporating improvements into flight hardware.

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E. TASK 5.0--AGE MANUFACTURING AND TESTING

No changes are anticipated in manufacture of the follow-on units which shall include RTG power system shipping containers and electrical heat sources.

Testing shall be limited to Quality Control inspection in the case of RTG power system containers. The electrical heat sources shall have Quality Control inspections plus a bench-type performance test over the operating range.

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F. TASK 7.0--RTG COMPONENT
ADVANCED DEVELOPMENT

Work begun in Phase II and continued in Phase III will be carried over into this phase. The results of this development effort will be discussed with the Customer and recommendations made for incorporating improvements into flight hardware.

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III. QUALITY AND RELIABILITY PROGRAM PLANS

A. QUALITY PROGRAM PLAN

The Baltimore Division of the Martin Company has an established Quality system which conforms to all the requirements of MIL-Q-9858A and is, in addition, supplemented by further controls developed by the Martin Company. This system provides positive and scientific managerial control for all phases of contract performance within the Martin Company, at subcontractors' and suppliers' plants, and at field or launch site installations. This Quality system is approved by and is under the surveillance of a Resident Air Force Plant Representative Office (AFPRO) that reports to the Air Force Contract Management District (AFCMD) in Los Angeles, California.

A detailed statement of Quality policy and functional philosophy and operating procedures is outlined in the Quality Procedures Manual. This manual describes operating principles, provides the necessary direction for overall quality, and fulfills the requirements for an integrated Quality system as specified by the Department of Defense and the National Aeronautics and Space Administration. Although existing detailed Quality operating procedures are not included in this document, they are referenced by procedure number and title throughout the text, and are available in the Martin Quality Procedures Manual. The current Martin Quality Procedures Manual (Volumes I and II) has been previously submitted to the U. S. Atomic Energy Commission, New York Operations Office.

The Po RTG Quality program plan will provide the management criteria to guide the establishment and implementation of the Quality tasks associated with the design, development, fabrication, and test of a Polonium Radioisotope Thermoelectric Generator (Po RTG) power system and its supporting Aerospace Ground Equipment (AGE) and the integration of this equipment into an earth orbit satellite program.

The Po RTG Quality program plan described is patterned after those procedures and controls successfully proven on the Martin Gemini program. In addition, this plan provides for:

- (1) The timely establishment and implementation of detailed process controls through preproduction qualification of all major production processes
- (2) Evaluation, selection, identification and control of "controlled parts" to minimize degradation during fabrication, test, storage and transportation
- (3) An integrated trouble reporting and corrective action system applicable to development, qualification, reliability and acceptance testing efforts

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Fig. III-1. ZD Program Awards

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- (4) An unbroken chain of Quality coverage at the Fueling Agency, the Integration Contractor, and the launch site.

Essentially, this plan encompasses Quality participation and responsibility in all phases of the program from contract inception to completion, as follows:

Quality program management
Design and development controls
Quality technical planning
Procurement controls
Manufacturing controls
Launch site activities.

The depth of presentation in this program plan is aimed at providing, in addition to an itemization of those Quality functions that will be implemented on the Po RTG program, concise explanations of the systems that will be employed. Pertinent flow diagrams and illustrations are included.

It is expected that this plan will be supplemented as more detailed design information, contract end item (CEI) specifications, and test results become available during Phase II. Additions or changes to this plan will be submitted to the AEC.

The Zero Defects (ZD) program, now in general use, was originated by the Martin Company for the Department of Defense in 1962. This quality motivation program is designed to prevent quality and reliability degradation during all phases of the manufacturing and acceptance process. Zero Defects is a program keyed to the individual employee and the part he plays in doing the job right the first time. The program provides specific quality goals for individuals and organizational units (Engineering, Quality, Manufacturing, Procurement, etc.) with recognition and regard for attainment of these goals. Figure III-1 is a composite of awards and pins given by Martin. Externally, vendors and subcontractors are also involved in the program since all procurement submitted is measured against a ZD goal. Approximately 1500 suppliers are involved in the ZD program. One year after its initiation at Baltimore, improvement in individual workmanship resulted in a 41% reduction in errors for man-hours worked. To date, Zero Defects awards for outstanding work performance have been awarded to 1500 Martin-Baltimore employees.

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Fig. III-2. Po RTG Quality Organization

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On November 4, 1965, the United States Air Force Zero Defects Achievement Award was presented to the Martin Company Baltimore Division for significant accomplishments in eliminating defects and reducing costs through this program.

1. Po RTG Quality Program

a. Organization

The Po RTG program Quality organization is shown in Fig. III-2. The Quality Program Representative is responsible directly to the Program Manager and will: assign specific tasks to the Quality sections of the line organization; plan, direct and control the performance of the Quality organization; establish Quality liaison with participating contractors (spacecraft, fuel, launch site), User Agency and the Atomic Energy Commission to the extent defined in approved interface specifications; and report quality progress and status to the Program Manager. The Quality Department has the authority and responsibility to stop work, terminate tests or reject assemblies or processes, permitting operations to resume only when the conditions which caused such action have been properly remedied. Quality Department personnel (particularly engineers, planners and supervisors) are selected on the basis of related experience, diversification of knowledge, technical aptitude, accomplishments and administrative ability.

The Quality Program Representative will exercise his authority through three line sections: Quality Engineering, product inspection, and source and site inspections, and will use the services of Quality procurement, Quality laboratories, Quality shipping, product inspection, and the Quality Calibration Center of the Martin-Baltimore (M-B) Quality Department. Utilization of existing specialized talents, skills, facilities and detail control methods and procedures of this department provides a vast amount of experience in these areas and applies economical considerations in connection with space, facility and manpower requirements.

Direction and authorization of Po RTG Quality tasks within the Quality sections will be accomplished through the Po RTG Quality program plan. This plan will be supplemented, when necessary, by Quality Project Directives which define specialized quality tasks or assignments that arise during program performance or are peculiar to the program. Figure III-3 illustrates the Quality Project Directive form that will be used on the Po RTG program.

The Po RTG Quality effort will span the full range of activities that collectively determine product quality and reliability. In particular, it extends beyond manufacturing to include other vital areas such as design, procurement, delivery and launch site operations and includes requirements for:

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QUALITY PROJECT DIRECTIVE		PAGE OF	DIRECTIVE NO.	
Q-79(1-64)		DATE	PROJECT	
			CONTRACT NO.	
TITLE:			ACCOUNT NO.	
		ATTACHMENTS	1	
		APPROVED BY	2	
DISTRIBUTION: INSERT AFFECTED SECTION NUMBERS AND CHECK BLOCKS FOR ACTION OR INFORMATION				
SECTION				
COPIES				
ACTION				
INFO.				
DESCRIPTION:				

This form is issued by the Quality Manager to convey official managerial and administrative intelligence of contractual requirements, to authorize the performance of special Quality functions, and to convey general planning information and program philosophy to Quality personnel.

Fig. III-3. Quality Project Directive

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- (1) Participation in formal design reviews to ensure incorporation of quality requirements
- (2) An effective supplier survey system and a continual supplier rating system
- (3) Quality planning to ensure that fabrication and test criteria are compatible with specification and drawing requirements, and to provide planned operations for 100% product inspection
- (4) Quality laboratories equipped for the analysis of materials and processes and development of nondestructive test techniques
- (5) Incoming inspection, fabrication and test inspections
- (6) Launch site operations inspections
- (7) A reporting and collection system for all defect and failure data
- (8) Failure analysis and subsequent requirement for corrective action
- (9) An effective audit program to point out those areas that could have a degrading effect on quality.

Through these organization and control disciplines, the Po RTG Quality Program Representative will assure the Atomic Energy Commission and Company management that product quality is maintained throughout the entire program in compliance with Specification MIL-Q-9858A, Quality Program Requirements.

b. Martin/Contractor/launch site quality coordination

(1) Fueling Agency/Martin quality coordination. Martin Interface Specification MND-3612-12 establishes interface requirements between Martin and the Fueling Agency pertinent to design, development, fabrication, test and delivery of fuel for the polonium radioisotope thermoelectric generator. Specific Quality relationships with the Fueling Agency that will be developed and implemented during Phase II are detailed in the following.

Martin will fabricate and furnish to the Fueling Agency all fuel capsule and fuel block components for use in fabrication of Phase II test specimens and nuclear-fueled capsules in Phases III and IV. In-plant inspection operations associated with the receipt of tantalum and Haynes-25 material and the fabrication of fuel capsule components are described

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in the section entitled, "In-plant Inspection and Test Operations," and will not be repeated here. This section will deal with the processing of the fuel containment details and assemblies from time of shipment from Martin to the Fueling Agency, including Fueling Agency operations and Martin source inspection.

Each shipment of fuel capsule and fuel block components will be accompanied by a Martin Quality certification log containing material certification and test report data and a record sheet listing the attribute data for each component. To assure uniformity in completed capsules, Martin will design, fabricate and furnish gages for use by the Fueling Agency to check exterior dimensions of completed fuel capsules.

During Phase I, it was agreed that a Quality control plan would be developed by the Fueling Agency to cover fuel encapsulation and end item inspection operations. This plan will be similar to the plan prepared to cover SNAP 19C2 fuel capsule fabrication and inspection and will describe, as a minimum, the following Fueling Agency procedures and processes:

- (1) Procedures required to inspect Martin-furnished capsule components and fuel block components upon receipt at the Fueling Agency
- (2) Procedures that will be used to qualify welder personnel and equipment
- (3) Processes used to weld the end caps to the fuel capsule liners and shells and fuel block closure welds
- (4) Procedures for fuel preparation and fuel loading
- (5) Decontamination procedures and contamination check procedures
- (6) Leak test, metallographic weld inspection, dye penetrant inspection, radiographic inspection, calorimetry measurement, thermal testing, and radiation survey procedures and processes
- (7) Final acceptance (visual and gaging) procedures
- (8) Procedures for handling and loading capsules into the fuel block and for loading the block into shipping containers
- (9) Description of records of inspections and tests performed
- (10) Procedures covering calibration control of measuring and test equipment

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- (11) Procedures for the control of discrepant materials.

In addition to these specific procedures and processes, the Fueling Agency's Quality plan will include a flow chart or tabulation showing the proposed Quality program operations in general terms of what, where, and how; the Fueling Agency's organizational structure, showing all elements which will perform Po RTG fuel encapsulation functions; and provisions for Martin source inspection to be performed at the Fueling Agency's plant prior to shipment of capsules to the Martin Company or to the launch site.

The Fueling Agency's Quality plan will be submitted to Martin for review by Quality, Engineering, and Reliability within 30 days after initial delivery of the fuel capsule components and applicable Martin drawings and specifications to the Fueling Agency.

Martin Quality will perform source inspection on each shipment of capsules and fuel blocks from the Fueling Agency's plant in accordance with a Martin prepared Contractor Acceptance Plan (CAP). This plan will list the verifications/documentation review that will be performed by the Martin source inspector and will include:

- (1) A review of the Fueling Agency's in-process and assembly inspection results
- (2) An examination of radiographs produced for liner and shell weld evaluation
- (3) A visual and gaging inspection of completed capsule assemblies (Phase II only)
- (4) An examination and verification of proper shipping documentation that must accompany shipments to the launch site (Phases III and IV).

(2) Integration Contractor/Martin Quality coordination. During Phase III, Po RTG system/spacecraft integration demonstrations will be conducted at the Integration Contractor's facility. To maintain Po RTG system integrity throughout the integration installation and demonstration, Martin Quality will assign a Quality representative to the Integration Contractor's plant to perform the following functions during integration demonstrations:

- (1) Monitor uncrating, receiving inspection, and handling of Po RTG equipment

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- (2) Observe installation of Po RTG system into spacecraft in accordance with interface engineering drawings and interface specifications
- (3) Verify applicable technical manuals
- (4) Witness checkout and operation testing performed after installation
- (5) Maintain Martin historical log records for the Po RTG equipment. Logs will be used to accumulate trouble reports and installation, reliability, maintenance, and operating/cycle data.

Upon completion of the spacecraft integration demonstrations, the assigned Quality representative will be utilized during Phase IV launch site integration operations at the Western Test Range (WTR) as described in the following section.

(3) Integration Contractor and launch site quality functions. During Phases III and IV, Martin will provide services, effort, and equipment at the launch site in accordance with the requirements of Interface Control Specifications MND-3612-10 and MND-3612-11.

During Phase III, a Quality Control program plan will be prepared by Martin defining Martin Quality services and effort at the launch site. This plan will comply with the requirements of Specification MIL-Q-9858A and will include any additional AEC and User Agency requirements deemed essential for effective quality and reliability disciplines at the launch site. Generally, the program plan will cover the receipt, installation, test, maintenance, storage, and shipment of Martin-delivered end items. During Phase IV, Martin will assign a Quality Engineer to the Integration Contractor and to the launch site to implement the Quality program plan and to perform the following functions:

- (1) Receiving inspection of the Po RTG and AGE for damage and records review
- (2) Installation inspections of Po RTG equipment and monitor checkout and operation tests. Operating manuals will be verified during these checks. Martin Quality will provide installation log records detailing the installation of Po RTG equipment in accordance with interface engineering drawings and specifications
- (3) Verify AGE operations including loading and unloading of fuel shipping and storage containers

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- (4) Verify generator fueling operations
- (5) Inspect authorized modification/repairs to Po RTG equipment and AGE
- (6) Assure compliance with Po RTG system safety requirements
- (7) Verify completion of periodic maintenance in accordance with the Po RTG program maintenance plan
- (8) Verify integrity of packaging and perform shipping inspection of Po RTG equipment and AGE being returned to Martin, the Fueling Agency, or the Integration Contractor.
- (9) For equipment in storage and spares, verify configuration, accountability, maintenance, calibration, environmental controls, and safety integrity
- (10) Maintain Martin-supplied historical records (system logs) for each Po RTG CEI.* These records will show accountability, configuration, maintenance and calibration, receipt, storage, movement, installation, operating time/cycles, interchangeability demonstrations (if required), etc.
- (11) Represent Martin Quality in all dealings with the AEC, User Agency, and Integration Contractor Quality personnel.

Quality planning efforts will be coordinated with the User Agency and the System Integration Contractor to establish collective needs in areas of trouble reporting, reliability data, historical record maintenance, test certifications, and equipment demonstrations.

Upon the start of integrated system checkout operations by the System Integration Contractor, the Martin Quality representative will be responsible to the System Integration Contractor Test Conductor (SICTC) for integrity of the entire Po RTG system prior to start of the integrated test. This responsibility will be discharged by coordination of Martin Quality with System Integration Contractor Quality. When the authority to proceed with the integrated test has been granted, all activity will be controlled by the SICTC. In the event of malfunction or shutdown involving the Martin Po RTG system, personnel authorized by the SICTC to proceed with corrective action will be accompanied by the Martin Quality representative during such activity. Martin Quality will perform the task of documenting all Po RTG system discrepancies occurring during the integrated tests.

It is anticipated that joint operating agreements will be drafted for purposes of defining the responsibilities of the various associate con-

*Contract end item.

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Fig. III-4. Proposed Generator and Thermoelectric Laboratories

Inspection Points and Stations
Couple, Module, Generator and AGE Assembly

- 1 T/E element Seebeck and resistivity tests
- 2 In-process inspections--module assembly
- 3 Module outgassing verification
- 4 Generator assembly and checkout
- 5 Quality station--module and generator assembly
- 6 Quality station--AGE fabrication, in-process fabrication and test inspection
- 7 In-process inspections--couple assembly
- 8 tool loading, furnace bonding, and resistance testing
- 9
- 10
- 11
- 12
- 13
- 14

F-File
D-Desk

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tractors for joint utilization of facilities after completion of activation for the launch operations phase. Martin Quality will participate in the drafting of such joint operating agreements since they concern the custodial responsibility of Po RTG and AGE equipment, records, maintenance of configuration control, and facility utilization for performance of Quality functions to complete the launch interface phase of the program.

c. In-plant inspection and test

Receiving inspection activities and procedures are defined in Section 12c of this chapter and are not repeated in this section. Figure III-4 illustrates the proposed production areas where the thermoelectric couple, module, generator, and ground support equipment assembly and test operations will be performed. Inspection will establish stations at strategically located points throughout these areas to ensure economical, effective control of the quality of Po RTG products. In-process inspection and test operations will be performed in accordance with detailed fabrication and test procedures (Nuclear Process Specifications and Manufacturing Operation Sheets) prepared by the Engineering Section of the Nuclear Components Department and Manufacturing Engineering, and approved by Quality Engineering. Both operators and inspectors assigned to perform assembly and test operations on Po RTG equipment will be trained and certified by examination as described in the section on training and certification of personnel. Complete records of all inspection and test results and objective evidence of quality acceptance of Po RTG equipment will be accumulated by Product Inspection and forwarded to Quality Engineering and/or Quality Planning for evaluation/retention purposes. Specific inspection methods and techniques that are planned for in-plant inspection and test operations are described here. Figure III-5 presents the Po RTG system and AGE Quality program plan.

(1) Detail parts. Detail parts (hot and cold junction shoes, alignment buttons and pistons, element connector straps, Min-K insulation, heat sink plates, hot plates, coolant channels, coolant plumbing, thermal shutter actuating (linkage and drive) mechanism details, shutter details, honeycomb panel details, Po RTG housing details, module frame details, radiator panel details, AGE structure clips, bracketry, angles, fittings, etc.) fabricated for the T/E conversion modules, the heat source subsystem, the coolant heat rejection subsystem, the thermal control subsystem, and AGE equipment will be processed and inspected as outlined below.

Detail parts fabrication will be performed in the Nuclear Manufacturing Pilot Shop, in the Advanced Manufacturing Technology Laboratory, and in existing Baltimore commodity shops which include sheet metal processing, welding, machining, heat treatment, plastics, bonding, cleaning, plating and finishing. Quality stations have been established throughout the commodity shop areas and within the Nuclear Pilot Shop and all

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Fig. III-5. Po RTG Power System and AGE Quality Program Plan

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detail parts will be processed through these stations for acceptance inspection. These stations are clearly identified, are equipped with or have ready access to all required measuring equipment and quality documentation, and are staffed with trained, qualified Quality personnel. Appendix B represents the current Quality measurement equipment inventory located in the Quality station in the Nuclear Manufacturing Pilot Shop. Similar equipment inventory and facility lists are maintained by each Quality section, i.e., Receiving, Quality Laboratories, Machine Parts Inspection, Calibration Center, etc. The inspector will acceptance-inspect and/or test all Po RTG system details for dimensions, material, finish, physical or functional characteristics, configuration level, identification requirements, measurements to be recorded, required documentation and serialization. Specific inspection and test procedures (Inspection Instructions, Form Q-257) will be prepared for use at the inspection station. They will provide step-by-step operations for conducting each inspection, the characteristics that are to be inspected, the inspection media, and any approved sampling plans, and will serve as the permanent inspection record. Appendix C includes representative examples of Inspection Instructions that will be prepared during Phases II and III for selected details.

Due to the criticality of the Po RTG fuel capsule, Martin-fabricated fuel capsule details (liner, shell and end caps) will be inspected prior to shipment to the Fueling Agency in accordance with the following procedures.

All purchase requisitions covering procurement of fuel capsule materials will specify the following Martin Quality requirements:

- (1) Four copies of actual vendor chemical and physical test reports for each lot, batch or heat of tantalum and Haynes-25 material must be attached to the packing sheet and accompany each shipment of material delivered to Martin.
- (2) Concurrent with the shipment of production quantities of material, the vendor shall furnish test sample(s) of each lot, batch, or heat in sufficient quantities for Martin to conduct acceptance tests. Each test sample must be clearly and permanently marked with: batch or lot number; specification or material control information number; vendor's designation; and purchase order number.
- (3) A certificate or statement of material and process conformance covering the material must be supplied by the vendor and must stipulate that the material supplied meets all specification and purchase order requirements.

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Upon receipt of fuel capsule materials at Martin, the Quality Materials Testing Laboratory will perform a chemical verification of the material certification, and general receiving inspection will perform required dimensional, visual, and vendor documentation verification as directed by the Quality Receiving Acceptance Plan (RAP). The Quality Materials Testing Laboratory will record test results of all material checked for physical and chemical requirements on a Materials Test Report Form (Q-57) and distribute copies to the Receiving Inspection group and the Nuclear Quality Planner.

Material accepted by Receiving Inspection will then be released to the Nuclear stockroom for subsequent issue to Nuclear Manufacturing for machining. Upon completion of all liner, shell and end cap fabrication operations, each part will be subjected to a detailed visual, dimensional, dye penetrant check, and helium leak test. Inspection personnel will record all variable data for each detail on Inspection Record Sheets. To facilitate in-plant dimensional inspections, Quality will utilize specially designed check gages to verify diameters, lengths and envelope configurations of the fuel capsule details. Check gage requirements will be determined early in Phase II and, after initial verification, will be periodically reinspected to assure continued accuracy. Prior to shipment of capsule details to the Fueling Agency, the Quality Materials Testing Laboratory will again perform a chemical verification of the material on sample specimens selected from the production details. This verification will confirm that fabrication operations have not altered or affected the fuel capsule basic materials. Completed inspection logs and test reports covering each shipment of fuel capsule materials and components will be forwarded to the Fueling Agency.

(2) Fuel block components and assembly. Details fabricated for the honeycomb fuel block assembly will be inspected in accordance with procedures outlined in the paragraph entitled, "Detail Parts." Inspection requirements for the honeycomb fuel block assembly will be determined during Phase II and will be patterned after the stringent controls that will be implemented on the fuel capsule processing. Quality check gages necessary to verify capsule cavities and overall configuration will be provided to assure fuel block uniformity and interchangeability.

(3) Thermoelectric couple inspection. With the SNAP 19 couple manufacturing process being applied to this program, extensive couple process development by manufacturing is not required. The SNAP 19 process has been firmly established as a manufacturing process for more than a year.

Starting in Phase II, the following inspections will be performed throughout couple fabrication operations to qualify processes and to assure that product quality and reliability are achieved and maintained. Martin will prepare a specification establishing the requirements for

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the manufacture and process qualification of thermoelectric couples for the Po RTG program. This specification will be used to establish necessary processes, standards, and quality control procedures for couple fabrication, inspection and test.

Prior to release of any couple details (thermoelectric N and P elements and hot and cold shoes) and bonding tools and fixtures to Manufacturing, all details and tools will have been inspected, accepted, and identified by Quality. After trial runs of bonding couples have been made to prove the tooling and to establish the furnace controls necessary to meet the process specified heatup and bonding temperatures and times, Nuclear Process Specifications (NPS) will be developed and finalized. Quality Engineering will monitor the process development phase and will approve each NPS prior to release for production. Processes, equipment, and personnel will be considered fully qualified after the successful production and acceptance of 150 couples which meet the following requirements:

- (1) Dimensional--all dimensions and finishes will be inspected for drawing and specification compliance. Specially designed go-no go gages will be provided for the dimensional inspection.
- (2) Resistance--each couple will be given a nine-point room temperature resistance check, and actual values will be recorded and evaluated for compliance with specification.
- (3) Operational performance--each couple will be operated under anticipated temperature conditions and power output, and internal resistance characteristics will be verified.
- (4) Interface contamination and bonding--sectioned couples will be examined metallographically at 80X minimum for interface contamination or unbonded areas in excess of established standards.

Following process qualification, the NPS will be authenticated by Quality Engineering and released for production use throughout Phases II, III and IV. Concurrent with process development and qualification, acceptance standards will be developed for use by Quality personnel when evaluating couple surface finish, pitting, chipping, cracking, and contamination.

During inspection and testing, complete records will be maintained to assure traceability of thermoelectric elements and couple assemblies. In the event of failures, the time of failure, its nature, description and corrective action will be documented on MARS Form No. MM-1024 and processed as described in Section 2 of this chapter.

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(4) Thermoelectric module fabrication. Inspection controls that will be applied during Phase II module development and qualification are detailed here. All module fabrication operations will be performed within dry boxes providing a controlled inert atmosphere, thereby precluding the introduction of harmful contaminants to the module. Module details and subassemblies received into the Manufacturing Laboratory for module assembly will have been previously inspected, accepted, and identified by Quality. Sequential assembly steps will be defined on a Manufacturing Operation Sheet (MOS), which will specify the operation, applicable NPS number, equipment requirements and integrated inspection operations. Quality line personnel will be stationed in the laboratory to monitor assembly operations, verify test equipment calibration and employee certification status, and to perform or witness specific in-process acceptance tests and inspections as well as final acceptance and test of completed modules. Individual certification log type records will be provided for recording pertinent historical data (serial numbers, operator identity, equipment, etc.), and these logs will reflect the status of each module in the dry box assembly pipeline. Specific inspection checks that will be performed by Quality during module assembly include the following:

- (1) Detail integration--insertion of couple assemblies into module Min-K insulation block in a pattern conforming to the required electrical circuit.
- (2) Module soldering--loading of soldering fixture, temperature elevation, cooling, and removal from soldering fixture.
- (3) Module electrical test--perform a complete electrical inspection to verify compliance with internal resistance requirements.
- (4) Module assembly fixture--loading of module assembly, spring loaded piston-button heat sink assembly, coolant assembly, and hot plate assembly into module assembly fixture.
- (5) Welding--verify welder qualification certification.
- (6) Leak test and final electrical check--perform leak test of all welds and verify electrical performance of module.

Module assembly processes, tooling and personnel will be considered qualified after the successful production and acceptance of three module assemblies.

(5) Coolant heat rejection subsystem. During Phase II development, reliability and qualification testing and during Phase III prototype fabrication of heat rejection subsystem (temperature stabilization doors and

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dynamic radiator) details and assemblies, Quality will exercise controls and perform inspections paralleling those previously described for detail inspection and module assembly inspection. Process development and qualification will be monitored by Quality Engineering and will be approved by Quality prior to release for production usage.

(6) Generator assembly. Final generator assembly processes and procedures development will begin during Phase II and will be finalized during Phase III prototype generator fabrication. In-process sequential inspections will be accomplished as directed by detailed certification sheets originated by Quality Technical Planning. The certification sheets will denote characteristics that require 100% inspection, special check items, serialization and documentation requirements.

(7) Aerospace ground equipment. Controls previously described for Po RTG system hardware will be applied throughout Phase II AGE component procurement, fabrication and test operations. Normal materials and component receiving inspection functions will be performed; inspection of details, subassemblies, and assemblies will be accomplished and documented; and component development, qualification, PMT, and reliability testing will be monitored.

In addition to the aforementioned inspections, Phase III deliverable AGE will require a formal final acceptance demonstration prior to shipment of the AGE CEI to the launch site, to the Fueling Agency, or to the Integration Contractor's facility. Each deliverable item (fuel shipping and storage containers, Po RTG shipping containers, fuel handling machine container, Po RTG power system test equipment, fuel handling machine, (FHM) and its container and field test equipment, and electrical heaters) will be subjected to a final acceptance demonstration on a functional mockup of the prototype RTG system. Technical manuals will be verified during this demonstration to ascertain that the AGE and Po RTG system can be properly connected and will function properly under simulated launch site conditions. This acceptance demonstration will constitute final acceptance of the AGE system prior to shipment of the AGE CEI to the launch site or to the Integration Contractor.

(8) Final factory acceptance. Quality responsibilities during final factory acceptance testing of deliverable CEI are itemized below. During acceptance test, Quality will:

- (1) Verify that test personnel have the proper documents (test procedures, test data sheets, etc.)
- (2) Survey the test equipment to be used during acceptance test for proper calibration dates

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- (3) Verify that all malfunction/discrepancy reports (MARS) have been evaluated and acted upon
- (4) Review applicable log records and prepare a list of open or incomplete work items. (Quality supervision will review the list and the disposition of each item prior to start of test.)
- (5) Give advance notice of the pending test to the Government representative
- (6) Witness the testing being performed by the test personnel and sign or stamp the certification log and data sheets as the test progresses
- (7) Ensure that any deviation from the test procedure by the testing personnel is documented and coordinated with the witnessing Government representative
- (8) Ensure that test personnel originate a MARS report for each malfunction or problem that occurs during test
- (9) Inspect and approve any rework performed as a result of a malfunction.

(9) Test completion. Upon successful completion of the factory acceptance test, Quality will update all log records, collect all data sheets, and obtain Customer and/or Government representative approval signatures on the certification log and test data sheets. Test equipment will be disconnected and Quality will perform an integrity inspection of the CEI.

Following the completion of the integrity inspection and the acceptance of any rework resulting therefrom, Quality will prepare a recap sheet and movement authorization form, obtain required signatures, and release the CEI to the shipping activity.

(10) Point of Customer acceptance. Customer acceptance of Phase II fuel capsule and fuel block test specimen components and Phase III and IV deliverable equipment will be accomplished in accordance with (1) and (2) of this paragraph. Material Inspection and Receiving Reports (DD250 Form (modified)) will be prepared and processed at time of Customer acceptance.

- (1) Customer acceptance of the fuel capsule components and fuel blocks fabricated for Phases II, III, and IV will be accomplished at Martin-Baltimore prior to shipment of these items to the Fueling Agency.

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- (2) Customer acceptance of the Po RTG power systems (excluding fuel blocks) and AGE CEI fabricated for Phases III and IV will be accomplished at Martin-Baltimore prior to shipment of these equipments to the Integration Contractor's facility or to the launch site.

2. Failure Reporting and Corrective Action

A failure reporting and corrective action system will be implemented by Quality to ensure the timely detection and resolution of problems that adversely affect quality, performance, reliability, maintenance, operation, and use of the Po RTG system and AGE. This system will encompass all phases of operation from initial Phase II engineering development, component qualification and reliability achievement testing through Phase IV User Agency usage.

The Quality Manager is responsible for the overall adequacy of the failure reporting and corrective action system. The Po RTG program Quality Corrective Action Engineer (CAE) is responsible for problem definition, corrective action planning and resolution of problems other than design problems. The Engineering Reliability Manager is responsible for defining and resolving of design problems.

Failure reports will be originated on discrepancies found during supplier acceptance test, receiving inspection tests, in-plant installations and tests, installation and integration demonstration at the Integration Contractor's facility, and launch site operations. All departments, both in-plant and in the field, are responsible for reporting failures. A record of the status of all problems and follow-up actions will be maintained and published periodically to Po RTG management and department heads until the problems are resolved. A description of the failure reporting, corrective action, and failed parts analysis system that will be implemented on the Po RTG program is presented in the following paragraphs.

a. Failure reporting

A failure is defined as the inability of an item to meet minimum specified requirements. Failure reports will be originated by any operator, technician, inspector or engineer encountering a failure during the processing or functional operation of a part, subassembly, assembly or system. Reports will be made of failures resulting from (but not limited to) the following occurrences: part failure, out-of-tolerance condition, unscheduled adjustment, manufacturing defect, design deficiency, accidental damage, installation error, operator error, and procedural error/deficiency.

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Attached to item

To Program Quality
 To Materiel Review
 To Factory Operations

To Production Control
 Into Quality Certification Log
 To Quality after final item disposition

Copy 1

MARTIN COMPANY
MARS R 23750

SHADED BLOCKS FOR CODING

002PR .008 PN .010 IN .016 C/BN .018 MFR .024 DOE .028 EC .0100 .0101 .0102

1 TYPE REPORT
☐ REJECT ☐ REWORK ☐ MRBR ☐ OTHER

2 PROGRAM MODEL SERIES 3 MASTER ACCOUNT NO 4 PURCHASE/WORK ORDER NO 5 DATE OF OCCURRENCE MO DAY YEAR 6 ACCRUED OPERATING TIME 1 TIME 2 CYCLES 7 INITIAL REPORT NO

8 ITEM PART NO 9 ITEM S/N 10 ITEM NAME 17 SYM DES 18 MANUFACTURER

11 NEXT ASSEMBLY PART NO 12 NEXT ASSY S/N 13 NEXT ASSY NAME 19 VEN/EQUIP S/N 20 REPLCMT REQ D? 21 F A REQ D? 1 YES 2 NO 1 YES 2 NO

14 COMPONENT SYS PART NO 15 COMP/SYS S/N 16 COMP/SYS NAME 22 23

24 DESCRIPTION OF EVENT (INDICATE ENVIRONMENT INCLUDING TYPE TEST/ OPERATION)

25 CAUSE OF EVENT 27 REPORTED BY 1 LOCATION CODE

28 SHOP SUPERVISOR 1 DEPT RESP

26 CORRECTIVE ACTION TAKEN REPLACING SERIAL NO 29 FLOOR DISP 1 MRB 2 RTV 30 QUALITY SUPERVISOR 31 ASSOC CONTRACTOR/CUSTOMER

32 DISPOSITION INSTRUCTIONS

33 MRB DISPOSITION 1 REWORK 2 SCRAP 3 USE AS IS 4 RTV 5 DEVIATION

34 MRB QUALITY 1 DATE

35 MRB ENGINEERING 1 DATE

36 ASSOC CONTR REP & CO 1 DATE

37 CUSTOMER REP 1 DATE

38 FINAL ACCEPTANCE STAMPS 1 SHOP 2 QUALITY 3 CUSTOMER

39 TIME TO RESTORE TO OPERATIONAL STATUS 1 DIAGNOSIS 2 OBT REPLY 3 REPLY ACTION 4 CHECKOUT 5 TOTAL 1 HR 2 MIN 1 HR 2 MIN 1 HR 2 MIN 1 HR 2 MIN 1 HR 2 MIN

MM 1024 (12 63)

TO BE REMOVED BY QUALITY ONLY R 23750

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The MARS Form provides a unified method of reporting on a single form, discrepancy, trouble, maintenance, consumption and followup data necessary in the product support effort (i.e., reliability and maintainability, material accountability, material review actions, etc., of the RTG program).

Fig. III-6. MARS Form

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Failures will be reported on the Martin Automatic Reporting System Form (MARS) (Fig. III-6). The MARS form provides a unified method of reporting discrepancy, failure, maintenance, consumption and follow-up data necessary for a successful corrective action system. Since this form is also the rejection/rework tag, replacement items can be neither drawn from stock nor reworked unless this report is completed adequately and properly. This control ensures that reports are originated for all failed/discrepant items.

The MARS form consists of four lightweight copies and one hard copy. The top lightweight copy is forwarded to the Po RTG Program Quality CAE for immediate review and action, as required. The hard copy remains with the discrepant item until the discrepancy is verified. The completed hard copy is then forwarded to the Po RTG Program Quality CAE to provide him with the total picture and to ensure that complete historical failure data are recorded. The remaining copies are used by Production, Procurement and Manufacturing for material control purposes.

The Po RTG Quality CAE will review, analyze and utilize MARS data to:

- (1) Provide early detection of design and fabrication deficiencies
- (2) Develop, improve or maintain required quality
- (3) Determine quality trends
- (4) Evaluate the need for further investigations and/or failure analysis
- (5) Establish the need for improved process controls
- (6) Evaluate and indicate the need for specific training certification or recertification
- (7) Evaluate quality of procured parts.

All reports of failures will be coded by the Po RTG Program Quality CAE and processed into a program trouble tabulation, which reflects information such as part number, serial number, type, cause, status, and manufacturer of failed items. These historical data, updated continually, will be utilized to emphasize, summarize and define problem areas and will reflect the status of resolution.

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b. Corrective action system

Failure Reports will be screened jointly by the Po RTG Program Quality CAE and a representative of Engineering Reliability. The purpose of initial screening is to review and analyze all failures and troubles reported so that potential problems requiring corrective action can be isolated and defined. Each failure is classified in either of two categories:

- (1) A problem requiring immediate investigation and corrective action
- (2) No immediate action; hold in suspense file for continued surveillance.

Subsequent to determining that particular failures represent potential problems, the circumstances surrounding the failure will be investigated either by the Quality CAE or the Engineering Reliability representative. In addition, all historical data and failure analysis reports will be reviewed. If analysis of these data indicates that a problem exists and corrective action is necessary, a Corrective Action Request (CAR) will be prepared and issued by the Quality CAE. The CAR will define the problem, specify action required, and impose a suspense date to ensure timely resolution; it will be directed to the responsible department manager for corrective action. The Quality CAE/Engineering Reliability representative will follow up the request to ensure that the problem is resolved to prevent reoccurrence and to ensure that the effectivity of the corrective measure is adequate.

A Delinquency and Unsatisfactory Report will be forwarded to the Quality Manager when a CAR reply date is exceeded or an unsatisfactory answer is received. The Quality Manager is responsible for taking the action necessary to correct the condition.

The CAR will be closed only after personal observation or evaluations by the Quality CAE that the action taken to resolve the problem is adequate and does in fact correct the unsatisfactory condition.

A Problem Summary and Status Report will be issued periodically, dependent upon Po RTG program requirements. This report provides a brief resume of the problems, the corrective action required by specific departments, and progress toward or final resolution of the specific problems. Each issue, which reflects all open problems and those problems closed since the previous issue, is forwarded to applicable management personnel to ensure a continued awareness of problems affecting the Po RTG program.

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Figure III-7 is a simplified flow chart of the failure reporting and corrective action system described. This chart includes information on what, when and how Quality functions will be performed as well as on the functions of other company departments in support of the failure reporting and corrective action system.

c. Failed parts analysis

Failed parts analysis will be performed by the Quality Laboratories on selected parts and components to support the corrective action function. All components on the Po RTG program controlled parts list will receive mandatory failure analysis, and, in addition, components exhibiting a high failure rate that could contribute to the degradation of quality and reliability will be selected for failure analysis. The failure analysis system provides complete information on the failure history of components, analysis methods used, analysis conclusions, recommendations and actions taken to preclude recurrence. Analysis Reports, issued upon completion of each failed part analysis, will be integrated into the corrective action system so that corrective actions may be assessed as complete and conclusive. Figure III-8 illustrates the forms that will be used in conjunction with the corrective action and failed parts analysis systems described.

Following is a tabulation of existing procedures which will be used to implement the Failure Reporting and Corrective Action System:

(1) Quality Procedure 20.1	Corrective Action
(2) Quality Procedure 20.3	Failed Parts Analysis
(3) Quality Procedure MM-1024	MARS Form

3. Audit of Quality Program Performance

The Quality audit system for the Po RTG program will consist of timely audits of the Po RTG Quality Program Plan, systems and procedures, fabrication processes and product inspections. Quality Program Plan and systems and procedures audits will be conducted to determine compliance to and the adequacy of Quality procedures, forms and documents. Audits of tests and process controls will be performed to ensure continuous and adequate conformance to standard processes by Quality and Manufacturing personnel. Product audits will be conducted to measure inspection effectiveness and outgoing quality levels and to provide necessary feedback information to management for the improvement of inspection effectiveness.

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Fig. III-7. Po RTG Corrective Action Flow Chart

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FAILURE ANALYSIS AUTHORIZATION

MARTIN COMPANY
SPACE SYSTEMS QUALITY

TO _____ DATE _____
MAIL NO _____ LOG NO _____
TROUBLE REPORT AND _____ DATE REQUIRED _____
WITHHOLDING TAG NO _____ PROJECT _____
PART NAME _____ CHARGE NO _____
PART NO _____
MANUFACTURER _____
SERIAL NO _____

MARTIN COMPANY
SPACE SYSTEMS QUALITY
QUALITY SYSTEMS ENGINEERING LABORATORY
FAILURE ANALYSIS REPORT

PROJECT _____ REPORT NO _____
MARTIN DISCREPANCY AND TROUBLE _____ PAGE _____ OF _____
REPORT NO / TRWT NO / TAG NO _____ DATE _____
ORIGIN OF FAILURE _____
PART NAME _____
PART NUMBER _____
PART MANUFACTURER _____

CORRECTIVE ACTION DIRECTIVE
QUALITY ENGINEERING

TO _____ CAD NO _____
CC _____
SUBJECT _____

REPLY
CORRECTIVE ACTION DIRECTIVE

MAIL NO _____
TO _____ PROGRAM QUALITY _____ CAD NO _____
DATE REPLY REQUIRED _____ DATE OF _____
CC _____ REPLY _____

SUBJECT _____

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Q 225 (2 63)

ORIGINATED BY _____
APPROVED BY _____
PLE _____

ORIGINATED BY	PHONE	MAIL	LOCATION
DEPARTMENTAL APPROVAL	PHONE	MAIL	LOCATION
FROM			
QUALITY MANAGER APPROVAL			

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NOTE:

Forms used by the Quality Corrective Action Engineer to identify problems and direct corrective action.

Fig. III-8. Failure Analysis and Corrective Action Forms

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All audits will be conducted by qualified procedures or inspection methods personnel, who are familiar with the procedures, plans, processes and products applicable to the areas being audited, but who do not have line responsibilities in these areas. In any instance in which a particular skill or technical knowledge is required to conduct an audit, the Quality auditor will select and supervise a technical team. A concise description of the Quality Audit System that will be used for the Po RTG program follows.

a. Po RTG Quality audit program

Audits will be performed at irregular intervals. Normally, the auditor will determine or select the area, product, system, procedure or process to be audited on a random basis or on the basis of information from customer or field reports, Quality measurement reports and corrective action requests.

In addition to random selection by the auditor, Quality and Po RTG program management personnel may request a formal audit of any area, system, process or procedure that warrants an independent review.

Prior to performing the audit, the auditor will define the objective and establish the need for the audit, complete an audit plan and make his presence known to the supervisor of the area to be audited. Pre-scheduled audits will be used except when, in the opinion of the auditor, prescheduling would bias the results.

The audit plan will include a prepared check list to be followed throughout the audit. Discrepant conditions found during the audit will be noted on this check list and reviewed with the Quality supervisor in the area, after which immediate correction action will be implemented.

Audit results will be formally documented and forwarded to the Quality section heads responsible for corrective action, the Po RTG Program Quality Representative and the affected Quality supervisors. When required, departments other than Quality will be formally notified to take corrective action.

The audit report (Corrective Action Directive, Form Q-347) will include the objective as originated or revised through audits, a summary of audit results, the audit procedure, the detailed audit results and corrective action recommendations.

b. Corrective action review and evaluation

Quality management will submit statements of corrective action (Corrective Action Reply Form Q-348) accomplished for any deficiencies reported by the audits. The Quality Auditor will review such

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statements for adequacy and obtain the Po RTG Quality Program Representative's evaluation of the acceptability of the corrective action replies. Periodic audit status lists will be prepared by the Audit Section and distributed to the Po RTG Quality Program Representative, section heads and other affected departments.

The Quality audit program is defined in Quality Procedure 1.4, Quality Assurance Surveys. A flow chart (Fig. III-9) illustrates the procedure for Quality audit origination, audit plan formulation, performance of the audit, reporting audit results and corrective action processing.

4. Quality Level Measurement

Quality is responsible for collecting and evaluating defect and discrepancy data, and for preparing reports and charts indicating current quality status, trends and out-of-control conditions.

Product inspection personnel will initiate Inspection Summary forms daily and forward to Quality Engineering; these forms report inspection and test results from Nuclear Manufacturing areas. Each summary form will be validated by Quality supervision and acknowledged by Manufacturing supervision prior to submittal to Quality Engineering. This immediate validation and acknowledgement will provide on-the-spot corrective action.

Quality Engineering will compile and evaluate the data and prepare Quality performance reports and Quality measurement charts indicating current quality performance and trends. The Quality performance report is prepared and distributed to program and company management, local Government representatives, and Manufacturing departments biweekly. It provides a detailed breakdown (by manufacturing work centers) of defects per 100 manufacturing hours and specifies the concentrations of major defects. This report serves as a valuable tool by which members of Management are made aware of quality levels and the cause(s) for out-of-control conditions. To implement effective corrective action, Quality will review each issue of the Quality Performance Report with affected Po RTG program personnel, at which time the current Nuclear quality level will be reviewed, necessary corrective action plans defined, and results evaluated.

The Quality performance report in current use at Martin-Baltimore is shown in Fig. III-10. This polygraph-type report indicates biweekly quality level averages and cumulative moving quality averages. On the back of the report, summaries of problems or potential problems are itemized and overall supplier performance and material review status are charted.

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Fig. III-9. Po RTG Audit Program

FOR MARTIN USE ONLY

Baltimore Division QUALITY PERFORMANCE

For Bi Weekly Period Ending 10/24/65

I. IN-PLANT MANUFACTURING

OVER-ALL PERFORMANCE

A. DEPARTMENTAL PERFORMANCE

SUBMITTALS 15180
DEFECTS 70
% DEFECTIVE 0.46

SUBMITTALS 1280
DEFECTS 2
% DEFECTIVE 0.16

SUBMITTALS 1750
DEFECTS 301
% DEFECTIVE 0.51

SUBMITTALS 16112
DEFECTS 172
% DEFECTIVE 1.06

SUBMITTALS 4400
DEFECTS 9
% DEFECTIVE 0.20

SUBMITTALS 11354
DEFECTS 300
% DEFECTIVE 0.38

SUBMITTALS 1017
DEFECTS 0
% DEFECTIVE 0.00

SUBMITTALS 8900
DEFECTS 244
% DEFECTIVE 0.51

LEGEND — PERCENT DEFECTIVE LEFT INDEX
— DEFECTS/100 MANHOURS RIGHT INDEX
DETAIL DATA ON REVERSE SIDE
PREPARED BY *[Signature]* APPROVED BY *[Signature]*

FOR MARTIN USE ONLY

I. IN-PLANT MANUFACTURING (CONT'D)

DETAIL DATA-DEPARTMENTAL PERFORMANCE

DEPT NO	DEPARTMENT NAME	MFG W/C	TOTALS FOR 2 WEEK PERIOD ENDING 11 7 65				PERCENT DEFECTIVE	DEF / 100 MAN HRS	DISPOSITION & QUANTITIES								
			SUBMITTALS	MAN HRS WORKED	DEFECTS	U-A 1 QTY			% OF DEF'S	REWORK QTY	% OF DEF'S	SCRAP QTY	% OF DEF'S	MRB QTY	% OF DEF'S	DISP QTY	UNKNOWN % OF DEF'S
8392	SHIPPING AND TRANSPORTATION CONTROL	30 31 32	888	6779	0	0.00	0.00	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
8812	ASSEMBLY VERTICAL TEST	11	-	1756	14	-	0.80	0	0.0	14	100.0	0	0.0	0	0.0	0	0.0
8812	ASSEMBLY GEMINI PAD	12	-	2889	0	-	0.00	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
8812	ASSEMBLY D' BLOC	13	-	7214	41	0.56	0.82	0	0.0	37	90.2	1	2.4	1	2.4	2	4.9
8814	ASSEMBLY ADVANCE RE ENTRY TEST PROGRAM	04	-	199	1946	0	0.00	0.00	0	0.0	0	0.0	0	0.0	0	0.0	0.0
8821	SHEET METAL AND WELDING	16 17 18 19 20 21 22	-	25024	16313	56	0.22	0.34	0	0.0	11	19.6	0	0.0	2	3.6	43 76.8
8822	MACHINE SHOP	26 27 28 29 30 31 32	-	18067	24714	184	0.97	0.74	0	0.0	190	70.6	4	2.2	0	0.0	50 27.2
8824	PLASTICS, BONDING AND FINISHING	33 34 35 36 37 38 39 40	-	47074	18950	28	0.06	0.14	0	0.0	24	85.7	2	7.1	0	0.0	2 7.1
8831	P. C. ASSY, TEST, PERISHING, GEMINI AGE AND SPECIAL PRODUCTS	50	-	530	2011	10	1.88	0.49	0	0.0	2	20.0	0	0.0	0	0.0	8 80.0
8831	DETAILS, S/A's, AND HARNESS & WIRE FAB	47	-	1017	1347	0	0.00	0.00	0	0.0	0	0.0	0	0.0	0	0.0	0 0.0
8831	P. C. DETAILS AND GEMINI AIRBORNE	45	-	786	949	0	0.00	0.00	0	0.0	0	0.0	0	0.0	0	0.0	0 0.0
8831	TEST TOOL FAB	52	-	195	1742	1	0.51	0.06	0	0.0	1	100.0	0	0.0	0	0.0	0 0.0
8831	DM, SUPPLY, AND MAINT & PROD	56 57	-	1870	1413	0	0.00	0.00	0	0.0	0	0.0	0	0.0	0	0.0	0 0.0
8841	TOOL MANUFACTURING	58 59 60 61 62 63 64	-	2279	10929	21	0.94	0.19	0	0.0	11	52.4	0	0.0	0	0.0	10 47.6
888X	NUCLEAR		-	1612	7095	2	0.12	0.10	0	0.0	0	0.0	0	0.0	1	0.6	1 99.4
				107610	100787	757	0.33	0.35	0	0.0	230						32.4

IV. JOBS SUBMITTED TO MATERIAL REVIEW DURING PERIOD: JOBS REQUIRING FORMAL M.R.B.R. ACTION:

1. Def mixed with lubricant. Evidence of T/N MOR28397 (Dept 8392).
2. Engineering level on part is 8/1, 8/2 should be 8/1, C/2 (traveler incorrect) 2 items (Dept 8392). T/N MOR28397 A/N 0338
3. Plug side bent. Evidence of corrosion. 1 item (Production Electronics) T/N MOR28352 A/N 4903
4. Nameplate to be replaced. 1 item (Dept 8822 and Dept 8930) T/N MOR28389 A/N 0457

2. STOCKBIN AUDITS

Open items as of 10/24/65

AREA	DEPT. RESP.	ITEM	DATE ITEM OPENED
DC 12 (Loc U14)	8920	Segregation of parts	9-24-65

Fig. III-10. In-Plant Quality Performance Report

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Departmental quality measurement charts are displayed in each manufacturing area covered by this reporting system. In addition to providing management and operating personnel with an overview of their operation, the quality performance report and the departmental quality measurement charts provide a stimulus to strive for improved quality.

Quality Procedure 20.4, Quality Measurement Reporting, describes the system for monitoring the product and personnel quality levels at Martin-Baltimore.

5. Design and Development Control

During Phases II and III, Quality Engineering personnel will review drawings, specifications, processes, and other technical documents (for Martin-fabricated and procured items) to accomplish the following:

- (1) Ensure incorporation of adequate acceptance criteria
- (2) Determine inspection and test methods
- (3) Review tolerance limits for appropriateness and measurement capability
- (4) Determine skill certification requirements
- (5) Evaluate fabricability of design

Engineering sketches, tests and layouts used for feasibility studies, exploratory programs, and breadboarding will not be reviewed.

a. Design review

The Project Engineer and Program Manager (with support provided by Quality as one of the major departments) are responsible for conducting design reviews during Phase II, generator subsystem development and Phase III, prototype system equipment development and qualification. Quality will perform the following functions during these reviews:

- (1) Ensure adequate definition of product characteristics and performance requirements to facilitate quality planning, inspection and test
- (2) Evaluate nonstandard test and inspection needs in personnel and equipment
- (3) Verify that engineering documents include quality assurance provisions

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- (4) Provide operational history related to Po RTG design
- (5) Identify any necessary restructuring of the planned Quality approach to cover procurement, fabrication, test, acceptance and launch site operations most effectively.

Formal, written reports of the findings and recommendations will be prepared by the Design Review Chairman and submitted to Engineering and Program Management.

b. Specification review

During Phase II, Quality Engineering will review and comment on all Martin-originated generator system and AGE specifications. Feedback will be provided to the Contract Technical Requirements department with positive recommendations pertinent to quality criteria and quality assurance provisions. The quality assurance provisions include items such as sampling frequency, method of inspection, consequences of noncompliance and necessary documentation.

Through the specification compliance inspection described in Paragraph 7 of this section of the report, Quality will conduct a complete review and examination of contract end items to verify that they comply with specifications.

Quality Procedure 14.1, Specification Compliance, covers organizational responsibilities necessary to control contract specifications.

c. Process specification review

Nuclear Process Specifications (NPS) will be used to define and control Nuclear fabrication operations used in the manufacture of RTG and AGE parts and assemblies. In addition, Martin Engineering Process Specifications (EPS) will be used to define and control fabrication operations other than those peculiar to Nuclear. Engineering drawings covering detail parts and assemblies will specify applicable NPS or EPS documents in the bill of material. Performance to defined process requirements will be monitored by Product Inspection personnel to ensure fabrication of quality parts.

During Phase II, process development and qualification will be required to establish fabrication techniques for which processes have not been developed and proven. Specific areas in which process qualification will take place include thermocouple fabrication and testing, module assembly operations and testing, heat rejection subsystem component fabrication techniques, seal braze or weld techniques for fuel capsule and fuel block closure, and thermal control subsystem fabrication.

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When new processes or revisions to existing processes are proposed, Quality Engineering will work with Engineering and Manufacturing in the development and qualification phases of process origination. At this time, evaluation of the Manufacturing and Engineering effort will be made by Quality Engineering to determine process capability, instrumentation and controls requirements, test methods, acceptance criteria and test procedures.

Information obtained will be fed back to the Engineering Section of the Nuclear Components Department and to Manufacturing for incorporation into the formal process specification. Quality participation throughout the development and qualification stages will ensure timely evaluation, determination and implementation of all Quality assurance provisions associated with process specifications. Availability of Quality test facility requirements will be ensured, determination of skill certification requirements will be made, adequacy of acceptance criteria will be proven, and required process control techniques and plans will be established.

Copies of all new and revised NPS's will be distributed by Quality Engineering to all affected Quality sections. Each Quality supervisor will discuss these specifications with his unit to ensure that they are fully understood and implemented. Quality Engineering will conduct periodic audits of selected processes to determine adequacy and conformance to the NPS as described in Paragraph 3 of this section of the report.

Quality Procedure 11.1, Process Specifications, describes Quality responsibilities associated with the origination, evaluation, and audit of process specifications.

6. Controlled Parts Inspection

To maintain the integrity of the Po RTG system design and to minimize degradation during fabrication, test, storage and transportation, a program to evaluate, identify and process certain selected parts (controlled parts) will be implemented during Phase II.

Knowledge and experience gained during the Martin Gemini "Critical Components and Parts" program and the recently implemented controlled parts program on the SNAP 19 contract will be utilized to implement a similar program on the Po RTG design and equipment. A description of how controlled part selection, identification, and handling will be accomplished is presented.

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a. Selection criteria

Engineering Reliability will evaluate and select controlled parts. A part will be classified as a controlled part if one or more of the following conditions exist:

- (1) Its failure mode will cause failure of the component or assembly of which it is a part.
- (2) Its failure mode will cause sufficient performance degradation to prevent attainment of minimum acceptable performance.
- (3) Normal handling, packaging or storing techniques may cause degradation of part performance or other failure mode which would result in (1) or (2).
- (4) Operating history or analysis indicates that the part may have an operating life below that required in normal usage.
- (5) Failure history indicates that the reliability of the part may be marginal.
- (6) The part is affected by highly specialized processes, materials or contaminants.
- (7) The part will be required to operate close to its environmental limits.
- (8) The part will be applied with more stringent limits because of its use in a long life nuclear device.

b. Identification of controlled parts

After selection of controlled parts by Engineering Reliability, affected engineering drawings (including procurement drawings) will be labeled with a controlled part note and the part callout in the list of materials will be flagged as a controlled part. Each controlled part will be serialized to permit traceability throughout all phases of fabrication.

Controlled components and parts will be physically identified by a decal or label on both the component and the shipping container. Identifying decals and labels will be maintained and controlled by the Engineering Reliability Manager and forwarded to suppliers through the Procurement Department. The controlled part label and decal planned for use on the Po RTG program are shown in Fig. III-11.

Fig. III-11. Nuclear Controlled Part Label and Decal

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c. Handling and storage of controlled parts

Special handling, storage or packaging requirements will be specified on the engineering drawing. In-plant routing and transporting of controlled parts will be accomplished by special handling. Controlled parts will be segregated from noncontrolled parts and stored in padded bins located in locked storage areas.

7. Configuration Control Support

The following Quality functions will be performed in support of overall configuration control:

- (1) Drawing Change Notice (DCN) verification
- (2) Verification of vendor and subcontractor incorporated changes
- (3) Specification Compliance Inspection (SCI)
- (4) Control of changes incorporated at the launch site.

A Quality representative, assigned to the Po RTG Program Change Review Board (PCRB), which will review all drawing changes to determine the effects on quality and reliability, will participate in the evaluation and validation of proposed changes.

a. Drawing Change Notice (DCN) verification

The basis for all configuration control during in-plant fabrication and test during Phases II through IV will be the Quality Drawing Change Notice (DCN) accountability system.

DCN's requiring accountability and the pertinent effectivity information will be determined by the Po RTG Program Change Review Board. To control DCN accomplishment and inspection, Quality will implement an existing change control system. Quality Planning is placed on automatic distribution to receive all DCN's as they are released. Master DCN books are prepared and placed in the Manufacturing area for maintenance (updating) by Quality Planning personnel. These master books always reflect the latest official applicable change for each unit or assembly being processed. Each DCN is screened and evaluated by Quality Planning and inserted into the appropriate master DCN books. Quality record sheets are prepared and inserted in Certification Log Books and used by Quality line personnel to document incorporation and acceptance of DCN's throughout all fabrication, assembly and test operations.

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Quality Procedure 14.2, Change Control--Engineering Drawing Change Notices, describes the control and accountability system that will be implemented on the Po RTG program.

b. Verification of vendor and subcontractor incorporated changes

Quality functions pertaining to verification of vendor and subcontractor changes are presented in paragraph 12-a; therefore, they are not repeated in this section.

c. Specification compliance inspection (SCI)

This inspection provides for the complete review and examination of specification requirements and deliverable end items to verify their compliance with contractual requirements and to resolve areas of difference between items and specification requirements. To implement this program, the Contract Technical Requirements (CTR) department will specify those items subject to specification compliance inspection, determine departmental responsibility for verifying compliance, convene and chair the SCI Board, and follow up to ensure compliance by affected departments. Quality functions associated with the SCI program are as follows:

- (1) Provide Quality representation and participation in SCI Board meetings convened by the Contract Technical Requirements department.
- (2) Establish Quality responsibility for verification of applicable portions of end item specifications.
- (3) Prepare and maintain SCI Certification Logs.
- (4) Conduct specification compliance inspections, document results in the SCI Certification Logs, and submit discrepancies to the SCI Board for review and corrective action.
- (5) Withhold acceptance and release of the product for delivery until all contract requirements have been demonstrated.

d. Control of changes incorporated at the Integration Contractor or at the launch site

Po RTG system equipment and related AGE delivered to the Integration Contractor or to the launch site will require log controls for data collection pertinent to the delivered equipment as well as for configuration control.

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Martin Quality will provide a system log for each deliverable Po RTG system and AGE CEI's. The system log will be included as part of the data package presented to the AEC (or the designated Government representative) at the time of end item factory acceptance and will accompany the end item(s) to the Integration Contractor's facility or the launch site. Each system log will be prepared initially from documents accumulated in certification logs during in-plant fabrication, inspection, and testing operations. Items normally requiring systems logs are the Po RTG system, fueling machine system, and ground checkout equipment.

Basically, a typical system log will contain, but is not restricted to, the following data:

- (1) System Log Index, which identifies the documents in the log and the order in which they are inserted
- (2) Recap Sheet and Movement Authorization, which identifies the status of the unit and reasons/authorization for incomplete work or shortages
- (3) Serialized Component Accountability Sheet, which is used to account for all serialized items incorporated in the end item
- (4) Equipment Time Record, which is used to record all operating time accumulated on the end items
- (5) Historical Records (DD829-1 and AFTO Series 200 forms) as determined by the AEC and Integration Contractor.

System logs, which will remain with Martin fabricated end items throughout the Phase III integration demonstrations and Phase IV integration, installation, and checkout effort, will be kept current by assigned Martin field personnel. Maintenance status, configuration level, replacement of serialized components, installations, failure reports and operating time/cycles will be documented in these logs.

8. Reliability Support

Engineering Reliability, a function primarily concerned with the development and reliability demonstration of the Po RTG system design, and Quality, a function concerned with control of the Po RTG system manufacture and measurement of system characteristics, have common activities and responsibilities established by specifications. Martin exercises these responsibilities through two independent but coordinated organizations--Engineering Reliability and Quality. Respective responsibility is carried out by one of the two organizations with required cognizance of the other maintained through established channels of communication.

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Starting in Phase II, and continuing through Phases III and IV, the Quality Manager will exercise his assurance function in the reliability program by performing and/or participating in the following quality and reliability tasks:

- (1) Review of the basic design of the Po RTG system equipment to ensure that an optimum design is used to meet the producibility, ease of inspection and calibration requirements
- (2) Determination and establishment of Quality standards for use in manufacturing, source, and receiving inspection
- (3) Identification of anticipated problem areas associated with Manufacturing limitations
- (4) Implementation of a program to control controlled parts
- (5) Control of manufacturing processes
- (6) Collection and analysis of failure and success data, the initiation of corrective action and the appropriate followup to assure adequate and timely problem resolution
- (7) Reporting of reliability problems introduced by GFE
- (8) Coordination of instructions and guidelines for:
 - (a) Selection of suppliers
 - (b) Surveys of suppliers and continued monitoring of supplier Quality Control Systems
 - (c) Review of procurement documents
 - (d) Supplier evaluation and rating
- (9) Inspection of Engineering development models for drawing compatibility
- (10) Review of specifications, test plans, test procedures, manufacturing processes, and drawings to ensure inclusion of adequate acceptance criteria
- (11) Surveillance of design, manufacture and calibration of test and measurement equipment
- (12) Maintenance of a data collection system which will provide necessary records of inspections and tests for assessment of reliability status and the retention of these data

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- (13) Indoctrination and training of Quality personnel to ensure that their skills and knowledge keep pace with technology changes
- (14) Participation with other departments to ensure compliance to specifications, drawings and technical manuals and changes thereto to maintain configuration control.

The integrated implementation of the preceding Quality reliability support functions is one of the dominating features of the Martin approach to achieving a highly reliable Po RTG system. The complete Po RTG Reliability program is described in Section B of this chapter. Quality Procedure 18.1, Reliability Assurance, defines reliability assurance activities performed by Quality in support of the overall reliability program.

9. Qualification Testing

Development testing will be conducted during Phase II on selected components and subsystems to demonstrate the achievement of specification requirements. Formal qualification testing will be conducted during Phase III on the prototype Po RTG system and AGE to prove the ability of production items (produced to the deliverable design and processes) to meet established specification and performance requirements under prescribed environmental conditions. Qualification test requirements will be defined in Martin-prepared CEI and system specifications. The complete qualification test program is described in the Martin-prepared Po RTG Reliability Program Plan (Section B of this chapter).

Prior to conducting qualification testing, Quality personnel will verify that:

- (1) Specimens designated for qualification testing are representative of the product to be delivered, and bear evidence of previous functional test and acceptance by Product Inspection personnel
- (2) Test facility equipment is within calibration
- (3) Test setup and installation conform with test procedure requirements
- (4) Required Government inspector coordination and notification has been effected.

During the testing phase, Quality will witness tests and record all problems encountered (failure, malfunctions, repairs, replacement of

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parts, etc.) during testing. This will include descriptions of any departures from the test procedure, and operating/cycle data. Visual inspections of the test specimen will be made during and at the conclusion of each phase of the test to determine if any deterioration, breakage or corrosion has occurred. Required failed parts analysis will be determined jointly by Quality and Reliability Engineering and will be performed as outlined in paragraph 2 of this section of the report.

Upon completion of the testing, Quality will identify the test specimen and ensure that the test specimen or any part thereof is disposed of in accordance with contractual requirements.

10. Quality Technical Planning

a. Inspection instructions and acceptance plans

Inspection Instructions will be prepared by Quality Technical Planning to provide specific detailed instructions, work plans, and acceptance criteria to Quality personnel for inspection and acceptance of procured items and in-plant fabricated detail parts and subassemblies. These Inspection Instructions and acceptance plans reflect product fabrication observations which are selected because of their significant characteristics; they define the inspection media, readings to be recorded, sampling techniques to be used, and, in turn, offer documentary evidence of compliance. The detailed information contained on the Inspection Instruction form is as follows:

Step/item. Used to identify each inspection operation sequentially.

Characteristic. A description of each distinct, describable, and measurable drawing or process characteristic that must be verified by Quality.

Inspection media. A description of the physical media to be employed in making the required inspection observation.

Shop/inspection. Manufacturing and Quality personnel affix their personal stamps in these columns to denote accomplishment and acceptance of all listed operations.

Appendix C includes examples of Inspection Instructions that have been prepared to cover typical thermoelectric module details and sub-assemblies.

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The nomenclature for these instructions and plans for the different areas are as follows:

Source Inspection - Contractor Acceptance Plans
Receiving Inspection - Receiving Acceptance Plans
In-Plant Fabrication - Inspection Instructions

Inspection Instructions will be prepared by Quality Technical Planning when one or more of the following requirements exist:

- (1) Special test or inspection techniques are required.
- (2) The use of special test or inspection equipment is required.
- (3) Complexity of item to be inspected warrants it.
- (4) Requirements exist for recording inspection data.
- (5) Quality history indicates the need.
- (6) Customer or military requirements exist.

b. Certification log records

Certification Log Books will be prepared for major subsystems and major assemblies of both the Po RTG equipment and AGE CEI's. These logs will contain in-process inspection records, work items, serialized accountability records, and test certifications and will reflect complete status of the equipment. The content format of the Certification Log will be sufficiently detailed to ensure that all information necessary for the inspector to perform the inspection operation is available and the in-process inspection operations are organized to permit the inspector to perform his duties with optimum efficiency and minimum effort.

Figure III-5 presents a generalized display of the Quality inspection documentation planned for use in the Po RTG program.

c. Serialization and traceability

During Phase II, a system for traceability covering selected components and controlled parts will be implemented to ensure that major items as well as specific details within the construction of these items considered critical to quality and reliability are traceable to supplier, lot, batch, quantity and usage. In the event a discrepant item is discovered which would necessitate the retrieval of all like suspect items, Quality accounting records must provide the means for recall of all details and components containing the suspect items.

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Currently planned applications for this degree of traceability are: all controlled parts, thermoelectric elements, couple assemblies, and semiconductors.

11. Statistical Quality Control

The Po RTG contract requirements, acceptable quality levels (AQL), production quantities and planned rate of production, engineering drawings, and specifications will be reviewed and evaluated to determine where and how statistical methods and techniques may be utilized without jeopardizing Quality. Specific areas to be investigated for sampling inspection applicability are receiving inspection of thermoelectric elements and module details, and noncritical generator and AGE hardware, and instances in which destructive testing is necessary. Sampling inspection will not be performed for those specific characteristics that require 100% inspection or when history, material review, or failure analysis results dictate a need for 100% inspection. In addition, the Po RTG Reliability Program Plan specifies categories of parts/items for which mandatory 100% inspection will be required.

a. Responsibilities

During Phases II and III (technical planning) of the program, Quality Engineering will apply statistical analysis and acceptance sampling applicability consistent with maintaining required control and obtaining maximum useful information from minimum data, time and personnel.

Quality Engineering is responsible for developing and implementing statistical quality control methods and techniques, and for providing data reduction and analyses services. Acceptance sampling plans, detailed instructions for applying sampling plans and process capability studies are originated and/or conducted by Quality Engineering. Unless otherwise specified by the contract, Quality will select sampling plans from Military Standard MIL-STD-105D or develop Martin sampling plans with the concurrence of the cognizant Government representative. If an AQL is not specified by the contract, it will be established by Quality.

b. Sampling of procurement items

Existing sampling plans and techniques will be reviewed during Phase II for compatibility with RTG requirements and will be used during receiving inspection to determine acceptability of noncritical raw materials and hardware. Inspection sampling tables defining normal and tightened inspection requirements are contained in the Statistical Quality Control Product Inspection Handbook. The sampling plan selected for receiving inspection use (normal or tightened) is dependent upon a supplier's past performance, as indicated on the

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Sampling Inspection Record. If the previous lot received from a supplier contained defective material, a tightened sampling plan is used for three successive lots received from that supplier. Normal inspection plans are used when the Sampling Inspection Record indicates the previous lots contained no defective items. A complete file of Sampling Inspection Records will be maintained in the Receiving Inspection area.

12. Procurement Controls

a. Control of subcontracted supplies

(1) Selection of suppliers. The Materiel Manager is responsible for developing of a list of selected, reliable suppliers as well as searching for new and improved sources of supply. Martin Company suppliers are designated by a process of progressive selection. Potential suppliers are considered on the basis of their ability to perform to program requirements. This consideration includes a review of their past performance; financial, technical, quality, security, management, and facility capability for the specific task; and their current and anticipated workload over the time period required for the specific task. Written evaluation procedures are followed in arranging for and performing evaluations of prospective suppliers. Coordination with other Martin Divisions is accomplished on an information exchange basis. Documentary data on suppliers are maintained in a central control group and are available for evaluation purposes. Quality functions associated with selection, evaluation and control of suppliers that will be implemented on the Po RTG program are described in the sections that follow.

(2) Supplier facility file and supplier history folder. Information relating to supplier product, capability, financial condition and performance will be accumulated and maintained in a Supplier Facility File. This file will contain trip reports, quality performance reports, technical evaluation reports, financial evaluation reports, supplier survey reports and other significant information and reports. The Quality Department will provide data inputs to this file and will use the file for reference when evaluating suppliers.

In addition to the Supplier Facility File, the Quality department will maintain a Supplier History Folder on each Martin supplier. The types of data maintained in this folder are tab runs containing accept-reject data, trouble reports submitted by in-plant and Martin field personnel and Quality survey reports from all divisions of the Martin Company. Use of these data by Quality Procurement personnel to perform supplier evaluation is described later in this section.

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Fig. III-12. Supplier Performance and Evaluation Rating System

(3) Supplier surveys. Surveys will be conducted at major suppliers' plants to ensure that supplier facilities, organization, and procedures are adequate for proper control of product integrity, for performance of qualification and acceptance testing, and for effective failure reporting and corrective action. A source evaluation team consisting of Quality and Materiel representatives, supported by personnel from Engineering, Reliability and Manufacturing (as required), will be used to make on-site surveys of prospective sources. Results of the surveys will be reported separately by each member of the team and combined by the Materiel Manager.

To ensure complete coverage of all important points relative to Quality, the Quality survey representative records his survey findings on a Supplier Capability Survey Report (Form Q-100), which is forwarded to the Quality Supplier Evaluation Office for required distribution and action.

Specialized supplier process surveys, including laboratory test facilities and methods, will be conducted by a Martin Quality Engineering Laboratory representative. Survey reports will be documented on a Supplier Special Process Survey Report (Form Q-100A), and the supplier will be rated either acceptable, not acceptable, or limited. Complete survey reports will be forwarded to the Quality Supplier Evaluation Office for required distribution and action.

(4) Supplier evaluation and rating system. Quality capabilities and performance of suppliers will be evaluated through field reports, percent-defective tabulations, surveys, and general quality history. A flow chart showing the supplier performance and evaluation rating sequence is shown in Fig. III-12. The following evaluation factors will be utilized, in conjunction with the Supplier Quality Performance and Evaluation Summary form (SQPES) (Fig. III-13) to rate a supplier:

- (1) Field Reports--to evaluate and enter pertinent data on the SQPES form
- (2) Trouble Reports and Failure Analysis Reports--to enter all trouble, failure analysis and corrective action on the SQPES form
- (3) Survey Reports--to document survey results on the SQPES form
- (4) Tabulated Monthly Summary of Incoming Supplies--to summarize a supplier's performance on supplies received in a given month.

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Fig. III-13. Supplier Quality Performance and Evaluation Summary Form

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Nonconformances will be categorized into three areas...critical, major, and minor...and recorded on the SQPES form. Data plots will be made continuously on the SQPES form whenever rejection rates exceed the predetermined maximum for each category of nonconformance. The SQPES forms will be reviewed continuously by a Quality Procurement representative; those indicating an out-of-control condition or trend will be removed and an analysis performed. The Quality Procurement representative will review the Supplier History Folder and analyze all data to determine the specific area(s) in which the supplier requires strengthening. Where necessary, technically competent personnel from the Quality Laboratories or Quality Engineering will visit the supplier facility to aid him in solving his technical problems. Also, Quality Procurement representatives, experienced in quality systems, will assist the supplier in elimination of pertinent problems. If the supplier does not demonstrate adequate response to Martin assistance and if his rejection rate continues to exceed predetermined control limits, he will be rated as unsatisfactory.

Periodically, the Quality Supplier Evaluation Section will issue a report indicating results of audits of supplier performance data. Probationary and unsatisfactory suppliers will be listed, and the reports will be forwarded to affected Po RTG program management and to the Materiel Department for use in the selection of quality suppliers for future procurement. Purchase requisitions will be monitored by Quality to determine that only approved suppliers are used.

(5) Review of procurement documents. Review of procurement documents, such as Non-Standard Authorizations (NSA) and Martin Purchase Requisitions, will be performed by Quality Engineering and Quality Procurement.

NSA forms, initiated by Engineering, describe all design, test, documentation, quality and delivery requirements for nonstandard purchased items. Quality Engineering will review NSA's to determine completeness and adequacy of the Quality assurance provisions listed. Discrepancies or omissions will be coordinated with Engineering, and followup will be maintained to incorporate revisions to the quality assurance provisions resulting from supplier, Procurement, or Engineering inputs. This coordinated effort will be continued until a finalized purchase order is placed.

Quality Procurement will review all purchase requisitions prior to the preparation of the purchase order. When necessary, the Quality Procurement representative will study drawings to evaluate the magnitude of the order and to select and apply applicable Quality clauses (codes) to the purchase requisition. Quality clauses describe the documentation and inspection requirements which must be fulfilled by the supplier. Documentation requirements include test reports,

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certificates of compliance forms, measuring and test equipment controls, specification compliance inspection requirements, and material, chemical and physical test reports. A detailed description of the Quality clauses (codes) is presented in Quality Procedure 3.2, Quality Requirements for Procurement of Materials and Services.

(6) Martin and Government source inspection. The Government reserves the right to inspect, at the source, supplies not manufactured or processed within the Martin Company. To ensure that proper Government and Martin source inspection requirements are specified on procurement documents, all purchase requisitions for materials procured for use on the Po RTG program will be processed as follows.

The Quality Procurement representative, in conjunction with the assigned program Quality Engineer, will be responsible for determining Martin source inspection requirements and coordinating Government source inspection requirements with the cognizant Government plant representative.

Government and Martin source inspection will be considered justified when any of the following criteria apply:

- (1) The article being procured is at a level of assembly which prevents verification of quality at the Martin Company or which requires uneconomical disassembly or destructive testing to permit verification.
- (2) In-process controls are closely related to production methods and quality cannot be determined solely by inspection or testing of the completed articles.
- (3) Special instruments, gages, or facilities for making inspections are available only at the source.
- (4) Inspection at any other point would destroy or require the replacement of costly special packing and packaging.
- (5) The article is listed on the Government-approved policy list which specifies those articles and conditions that warrant automatic Government source inspection.
- (6) The material is to be shipped directly to the launch site or to the Integration Contractor's facility from the supplier's or fuel contractor's facility.
- (7) Actions not mentioned in (1) through (6) are determined to be in the best interests of the AEC.

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The degree of Martin source inspection will vary from a surveillance plan to complete resident coverage, depending on the overall evaluation of the supplier's product quality, previous performance, facilities and organization. Martin source or resident inspectors will assist the supplier in organizing, maintaining or strengthening his Quality control and are responsible for performing the following functions:

- (1) Assist the supplier in the interpretation of specifications, drawings, and Quality requirements
- (2) Conduct a detailed first article inspection and participate in specification compliance verification with the supplier
- (3) Report in writing to the supplier's Quality Manager all unsatisfactory items requiring corrective action
- (4) Verify adequacy of supplier's files for process and personnel certifications
- (5) Coordinate the supplier's material review program
- (6) Witness and verify required interchangeability and replaceability demonstrations
- (7) Perform final Martin acceptance of spares and other direct shipments to the Integration Contractor or to the launch site
- (8) Transmit all supplier-submitted quality data to the Martin Procurement office for approval or information
- (9) Ensure incorporation of all changes to originally committed configuration at established effective points
- (10) Periodically review supplier's administration of statistical quality control to assure satisfactory function and application
- (11) Monitor supplier's packaging, shipping documents and/or inspection logs and complete a Martin Contractor Acceptance Plan (CAP) for all material shipped from the supplier facility.

Martin will perform source inspection of NaK electromagnetic pumps procured from MSA Research Corporation. Also, as previously described, Martin will perform source inspection of fuel capsules and fuel blocks shipped from the fueling agency's facility.

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(7) Control of supplier design changes. The configuration of supplier equipment or material is controlled originally through procurement documents, drawings and specifications. Adherence to the required configuration by the supplier will be determined and controlled through Specification Compliance Inspection and Quality surveillance. The procurement documents will define the procedures and manner in which suppliers will submit engineering change proposals for review and approval. Supplier-originated changes will be subject to the Po RTG Program Change Review Board for review, determination of impact on the entire program and approval. Following approval of a supplier-proposed change, implementation of the change will be authorized and accomplished by revision to specifications, drawings, and other procurement documentation. The Quality Source Inspector will review all changes to the originally committed configuration, verify the incorporation of the changes at the established effective points, and acknowledge compliance by acceptance stamping the proper documents and exhibits submitted by the supplier.

Following is a tabulation of existing Quality procedures which will be used to implement the supplier control system.

<u>Quality Procedure</u>	<u>Title</u>
3.1	Supplier Capability
3.2	Quality Requirements for Procurement Materials and Services
3.3	Non-Standard Authorization and Advance Information
3.5	Field Reports
3.7	Functions of Quality Representative in Order Processing Services
3.14	Material Approval and Implementation of Supplier's Material Review Board Authority

b. Control of Government-furnished property (GFP)

At present, it is not anticipated that there will be any requirement necessitating the consignment of Government property to the Martin Company for use on the Po RTG program. However, in the event that certain Government equipment or property is determined to be required and is subsequently supplied, Martin Quality will perform the following functions to ensure that the receipt, storage, maintenance and defect/damage reporting of GFP comply with contractual requirements.

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(1) Receiving inspection. Government-furnished material will be received into a controlled, segregated enclosure where GFP receiving and stores personnel will inspect the material for proper identification, documentation, damage, reinspection due and accountability. Material received in a preserved status will be maintained in this status until time of use, at which time the material will be inspected for shortage, defects and damage. When applicable, a functional test will also be performed, either prior to storage or prior to installation, to ensure satisfactory performance for its intended use.

(2) Storage. When storage is required, the material will be stored by GFP stores department personnel in accordance with Government storage requirements and good storage practice, ensuring that maintenance is performed when required, storage conditions are adequate, material is properly protected and checked for damage and deterioration, the proper condition and status tag is attached to the material, and the quality of the parts and equipment is maintained. Quality Receiving personnel will perform periodic inspections and audits to verify that the material is stored in accordance with Government storage requirements and that it is acceptable for its intended use when removed from storage.

(3) Bailed equipment. Receiving and storage of bailed equipment is the same as described for Government-furnished material. Identification, maintenance, requests for required periodic inspections, processing of any removed parts and return to GFP storage area is the responsibility of the using department (Manufacturing, Engineering, etc.). Quality will perform the required periodic inspections; inspect, categorize, and attach applicable Government 50 series condition tags to any removed parts; conduct a physical inventory of all bailed equipment in accordance with the conditions of the bailment agreement; and perform a complete integrity inspection of the bailed equipment prior to its return to the Government.

(4) Defect reporting. Any discrepancies (damage, lack of evidence of source inspection, missing parts, malfunctions, etc.) which are found during receiving inspection and during or after installation will be referred to the cognizant Government representative for information and/or disposition instructions. When GFP is rejected, Quality will prepare and attach a removal and disposition tag and the appropriate Government 50 series tag. GFP control personnel then will obtain disposition instructions from the Government, and the GFP will be processed in accordance with these instructions.

(5) Record maintenance. When contractually required, Government historical records received with GFP will be kept up to date by Quality. Quality will make all entries indicating receipt, periodic inspection accomplishments, TCTO compliance, change in status, removals and shipments.

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Incoming materials require evidence of test by supplier, by Martin or both. Scope of tests by Martin is based on the historical record of the supplier.

Fig. III-14. Laboratory Test of Incoming Material

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Existing procedures that will serve to implement the GFP control system are detailed in Quality Procedure 4.6, Receipt and Inspection of Government-Furnished Equipment, and Quality Procedure 4.7, Testing of Government-Furnished Equipment by Receiving Inspection.

c. Po RTG receiving inspection

Receiving Inspection functions described herein will be implemented on all material and equipment procured for Phase II development purposes as well as on all subsequent Phase III prototype and Phase IV flight procurements.

All materials, parts and components will be processed through the Receiving Inspection facility which consists of the following groups:

- (1) General hardware inspection
- (2) Casting and forging inspection
- (3) Raw material inspection
- (4) GFP inspection
- (5) Electrical/electronic test
- (6) Machined parts inspection
- (7) Specialized nuclear inspection

All incoming procured material and supplies will be accompanied to the inspection area by purchase order receiving reports. An inspection package, consisting of applicable drawings, specifications, Receiving Acceptance Plan (RAP) and history card, is then assembled. The RAP includes a sequential listing of characteristics to be checked. The degree of inspection required for received material is established after consideration of reliability requirements, qualification test reports, material application, controls exercised by the supplier and evidence of sustained quality performance. Typical RAP's used for receiving raw materials and thermoelectric elements are included in Appendix D. Inspection at this point is performed by the inspector or technician using the inspection package data.

Upon receipt, raw materials will be subjected to a physical inspection. Required chemical, physical or metallurgical testing and analysis of raw material, finishes, organic materials and test coupons received with semifinished or finished products will be performed by the Quality Engineering Materials Laboratories. Figure III-14 shows the quality operations associated with laboratory testing of incoming material.

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Fig. III-15. Trouble Report Form

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Bulk materials passing receiving inspection and Quality Laboratories verification will be stored in a controlled stock area. Immediately prior to release to fabrication, materials are again inspected to verify that they are as specified for the particular job.

Preliminary planning indicates that Martin Quality Laboratory testing/analysis will be required on the following procurements. Each lot or batch of tantalum and Haynes-25 material procured for fuel liner and shell fabrication will require, in addition to vendor-supplied metallurgical test reports, a complete chemical and physical analysis by Martin Quality Laboratories to verify vendor-supplied test reports. Procured element compression springs for use inside the module piston and button alignment components will be laboratory tested for spring load at operating length. In addition to normal functional testing, semi-conductors procured for ground support equipment will receive 100% radiographic examination to ensure absence of internal foreign particles, broken wires, case cracks and near shorts and to ensure internal integrity. Each procurement of Ferro-Vac-E iron will be processed through the Quality Laboratories for ultrasonic inspection to ensure that the material does not contain inherent laminations which could remain undetected throughout normal hot and cold shoe fabrication processes. During Phase II, continued Quality evaluation of proposed procurements (especially stainless steel tubing, thermal control bellows, various instrumentation devices and selected AGE components) will be performed to select those materials and components for which Quality laboratory-type examinations and analyses will be required.

When purchased material is not in compliance with engineering drawings or specifications, the receiving inspector originates and attaches a MARS form to the material, records the information on the supplier's history record, notes the rejection information on the receiving report and forwards the rejected material to a controlled procurement rejection rack for disposition.

Quality prepares a Martin Trouble Report form to provide immediate supplier notification of and effective corrective action for unsatisfactory conditions and major and/or repetitive discrepancies found during receiving inspection (Fig. III-15). This report summarizes the discrepancies and requires the supplier to conduct a complete investigation and submit a written report within 15 days, listing reasons, causes and corrective action. Inspection for acceptance or rejection of subsequent shipments from a supplier is dependent upon the timely receipt and approval of the supplier's corrective action reply.

Quality Procedure 4.1, Receiving Inspection of Procured Material, defines detailed operating instructions and will be used for the Po RTG program.

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MARTIN COMPANY
CERTIFICATE OF QUALIFICATION

(IF GLASSES ARE REQUIRED—SPECIFY HERE)

SER. NO. _____
 WELD SYM. _____
 C.T. NO. _____

THIS IS TO CERTIFY THAT:

HAS SUCCESSFULLY COMPLETED REQUIREMENTS AS PRESCRIBED BY SPECIFICATION AND/OR CERTIFICATION TEST FORM AND IS QUALIFIED TO PERFORM THE SPECIFIED SKILLS AS INDICATED HEREON.

 SIGNATURE OF CERTIFIED PERSONNEL

SEE P.P., OP-85, (O) FOR CERTIFICATION PROCEDURE

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 (SKILL TITLE)

SPECIFICATION OR
 CERTIFICATION TEST FORM NO. _____

10%
 CODE _____ RECERTIFICATION
 DUE EVERY _____

DATE _____ AUTHORIZED REPRESENTATIVE—SIGNATURE _____

Fig. III-16. Certification Card, Including Display at Inspector's Station

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13. Manufacturing Controls

a. Training and certification of personnel

Employees will be trained and certified in the skills required for manufacturing processes to ensure that they meet specified Quality standards. The training and certification system that will be implemented on the Po RTG program is presented in the following.

(1) Responsibilities. The Quality Procedures Manual contains general and specific procedures which ensure effective certification and control of employee manufacturing and inspection skills. Quality Engineering is responsible for determining those skills for which employee certification is required by government specification, Martin process specifications or Quality standards. Detailed performance requirements that must be met for the certification of employees in each skill are determined jointly by Quality, Engineering and Manufacturing. These performance requirements are detailed on formal forms, which specify the required training, written tests, fabrication of sample specimens by the trainee and inspection of the sample specimens by qualified personnel.

(2) Training for certification. For skills that require formal training, the selected employees will receive any required medical or eye examinations and will be enrolled in a training program for classroom instruction. These formal training courses are conducted by the Technical Education section of the Education Department. Quality Engineering will review the course content prior to certification approval of any operator so trained. For skills that require on-the-job training for certification, the Technical Education section and/or Quality will administer the training and verify through written tests and/or sample specimens that the employee qualifies. Upon completion of or during training, the trainee will be required to fabricate sample parts or perform operations applicable to the skill for which he is being trained. These sample parts will be inspected and/or tested by Quality personnel (and Government representatives where applicable) to ensure compliance with all process and specification requirements.

(3) Certification and training records. Upon successful completion of the required training and testing, the employee is considered a certified operator or inspector and is issued a Certificate of Qualification, which specifies the skill for which the employee is certified. This Certification Card, issued by Quality Engineering, must be carried or prominently displayed by the operator and inspector while on the job. Figure III-16 shows the Certification Card and the method of displaying it at the inspector's station. The Certification Card must be presented for inspection upon demand by Quality personnel or Government representatives. Quality Engineering will maintain mechanized master certification files of employees active in certified skills as well as maintaining an inactive status file.

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(4) Audit and surveillance controls. The certification status of every certified employee will be maintained (by IBM records) by Quality, and periodic recertification notifications will be distributed automatically prior to certification expiration. This IBM control, in conjunction with the required 100% surveillance performed by Quality line personnel, ensures that personnel without proper certification do not perform work requiring certified operators. Rigid controls permit recalling or revoking of certification cards of employees who perform unsatisfactory work, are terminated, become inactive in the skill for which certified or are not recertified when their period of certification expires.

(5) Po RTG program oriented training. Existing training programs involving welding, brazing, soldering, helium leak detection, penetrant inspection, isotope radiography, and contamination control will be utilized to train and certify Manufacturing and Quality personnel assigned to the Po RTG program. During Phase II, proposed manufacturing and test operations will be evaluated by Quality Engineering to determine the need for additional training in specialized skills. Specialized courses in trouble reporting, controlled parts handling and assembly and checkout techniques will be implemented as required.

Following is a tabulation of existing Quality procedures which will be utilized to implement the training and certification program.

<u>Quality Procedure</u>	<u>Title</u>
11.2	Employee Certification--General Procedure and Control
11.3.1	Certification of Electrical/Electronic Skills
11.3.5	Certification of Metal Inspection Skills
11.3.6	Certification of Welding Skills
11.3.7	Certification of Contamination Control Skills

b. Inspection, measurement and test equipment

Measurement and testing standards and their controlled traceability are inherent necessities to ensure the accuracy and uniformity of all instruments and equipment used for measurements that establish design criteria and record product performance. Since the Po RTG program will provide for delivery of small numbers of each system operating under tight schedules and requiring high reliability in the first as well as later models of each system, it is essential that a strict calibration control system be implemented during Phase II engineering

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development testing as well as during prototype and flight model testing. For this reason, the calibration control system will be applicable to all phases of the Po RTG program.

The system for calibration, repair and maintenance of electrical and electronic measuring and test equipment and linear measuring equipment to be used in the Po RTG program is described in this section and is in compliance with military specification MIL-C-45662A, Calibration System Requirements. The services of the Quality Calibration Center will be utilized to calibrate and control electrical, electronic and linear measurement and test equipment associated with the Po RTG program. Equipment located in the Nuclear Engineering Laboratories normally used for development studies and evaluation testing is currently included under these controls. Stationary equipment located in Manufacturing and Engineering Laboratories is serviced and calibrated on location by Calibration Center technicians utilizing transfer and reference standards maintained within the Calibration Center. Portable equipment will be cycled through the Calibration Center facility for required periodic servicing and calibration. Martin test equipment shipped to the Integration Contractor facility or to the launch site will be calibrated prior to shipment.

(1) Quality calibration center. Martin electrical/electronic measurement standards and measuring, testing and inspection equipment are controlled by the Quality Calibration Center. This facility is designed to provide the exacting environments necessary for the precise state-of-the-art measurements and calibrations. An area of 5100 square feet, subdivided into three individually controlled areas, provides a special measurements laboratory maintained at $72^{\circ} \text{ F }^{+2}_{-1}$, $40\%^{+1}_{-5}$ relative humidity, and a positive pressure absolute air filtration system. The floor is isolated from the main floor to attenuate vibration and is equipped with a seismic table for handling those instruments minutely sensitive to vibration. The repair/calibration area and the staging area are maintained at $74^{\circ} \text{ F }^{+1}_{-2}$ with a relative humidity of $40\%^{+1}_{-5}$. This rigid environment is provided by a dual air conditioner maintaining environmental integrity in the event of malfunction of one or more components. Calibration Center personnel maintain the master reference and transfer standards, prepare written calibration procedures, and calibrate and repair all electrical and electronic equipment in accordance with approved procedures.

(2) Traceability. Standards used to calibrate working instruments are checked at specified intervals against transfer standards which in turn, are checked against Master Reference Standards. The Center's Master Reference Standards and Transfer Standards--over 190 different

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instruments--are periodically recertified by the National Bureau of Standards. These standards encompass ac-dc voltage and current, resistance, temperature, time, frequency, inductance, capacitance, attenuation, Q, phase angle and magnetic flux density. Records of the accuracy and certification of all reference and transfer standards are maintained on a current basis and show the status of all standards.

(3) Calibration intervals. Measurement standards and equipment will be calibrated periodically as established by design, stability, characteristics, required precision, accuracy, experience data, degree of usage and other conditions affecting measurement control. Calibration frequencies are maintained to meet the requirement of T.O. 33K-1-01. Intervals are adjusted as required, based on variables and experience data, to ensure continued accuracy. In addition to the required periodic calibration intervals, calibrations will be performed after any event which casts doubt on the accuracy established at the last periodic calibration. Maximum calibration intervals are established by Quality and are lengthened only when the results of previous calibrations provide definite indications that such action will not adversely affect the accuracy of the system.

(4) Calibration procedures. Detailed written calibration procedures will be prepared and maintained on each type of equipment utilized for the Po RTG Program. As a minimum, the calibration procedure will:

- (1) Specify the equipment specifications
- (2) List the test equipment required to verify the calibration of the equipment adequately
- (3) List applicable documents
- (4) Describe the calibration procedure in a detailed step-by-step manner, utilizing block diagrams aimed at the technician's level
- (5) List pertinent calibration notes.

These procedures ascertain that uniform calibration methods are used, that a 10 to 1 or greater ratio of accuracy between the standard and the test equipment is maintained when the state of the art permits and that all measurements made are traceable to the National Bureau of Standards.

(5) Records and identification. Calibrated equipment will be labeled by the Calibration Center to indicate the calibration expiration date, equipment number, calibration technician stamp and the calibration procedure used. A visual Inspection Record Attribute Data Form

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(No. 060306) will be maintained on each master reference and transfer standard and each working instrument. An equipment Service Request and Calibration Notice Form (TE-267) will be maintained on all equipment. These records contain cumulative data on status, condition code, repairs, replacement parts installed and costs; they are used to make periodic analysis to determine equipment reliability, deterioration, and adequacy of span time between periodic calibrations. The Calibration Center will also maintain Calibration Certificates for all electrical/electronic and linear reference and transfer standards. These certificates indicate traceability to the National Bureau of Standards, date of the last calibration, by whom certified and the actual values measured. Figure III-17 illustrates the calibration labels that will be affixed to each calibrated instrument.

Following is a tabulation of existing procedures which will be used to implement calibration controls for the Po RTG Program.

<u>Procedure</u>	<u>Title</u>
Quality Procedure 12.4	Calibration System Requirements
TE-267	Equipment Service Request and Calibration Notice
TE-288	Initial Acceptance Sticker
MM-1067	Calibration Certificate
MM-1066	Calibration Deviation
Q-27	Tool Calibration Label
060306	Visual Inspection Record

c. Nonconforming material

(1) Control of nonconforming material. In accordance with MIL-Q-9858A, any material, part or product that fails to meet the requirements of the contract, specifications or drawings will be identified and withheld or removed from the production activity. The method of identification that will be used for the Po RTG Program consists of the MARS Form, which will be used universally to document withheld or rejected material and to effect Material Review Board actions.

Existing Quality procedures direct the use of the MARS form for both in-house and supplier applications, identify the list of authorized Material Review Board Members for both Martin and the Customer, identify the functions to be performed to achieve resolution of withheld, nonconforming supplies and define the system for identification and impounding discrepant supplies.

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- (a) Used to identify calibration status of measuring and test equipment that is necessary to ensure conformance of product to contractual requirements.

- (b) Used to identify calibration status of measuring and test equipment that is not required to ensure conformance of product, but may be necessary for efficient operation.

- (c) Used to identify the initial acceptance calibration of deliverable items (vendor items).

- (d) If one or more parameters of a unit cannot be brought within specified tolerance by adjustment or economical repair and the unit can be advantageously used "as is," this sticker will be applied adjacent to the Calibration Sticker.

Fig. III-17. Calibration Labels

A description of the system as it will be applied to the Po RTG Program is provided in the following.

(2) Preliminary material review action. Preliminary material review action will be conducted by the Quality area supervisor and the responsible Manufacturing area supervisor to determine initial disposition of nonconforming material. During preliminary review, the nonconforming material will be classified into one of the following disposition categories:

- (1) Rework/repair--where the nonconforming material can be reworked or repaired (in accordance with a standard repair, previously approved by the Material Review Board) to meet contractual requirements.
- (2) Use as is--where the nonconforming condition is identical to that which the MRB has determined to have no effect on safety, performance interchangeability or specified reliability.
- (3) Scrap--where the nonconforming condition is such that it renders the material unfit for use.
- (4) Major repair--where the nonconforming condition cannot be completed or otherwise disposed of by one of the aforementioned categories, the material is designated for formal MRB action.

Nonconforming material conditions which can be corrected by completion of operations, by reworking to drawing requirements, or are of such a minor nature that permits acceptance as-is will be returned to production channels for necessary rework or processing. Reinspection upon completion of any rework will be accomplished by Quality.

Nonconforming materials which cannot be completed or reworked to drawing requirements will be positively identified by stamping each article with the "Withheld for Material Review D Stamp." A Quality supervisor will then place this material in a locked material review cage for disposition by the MRB.

(3) Formal MRB. The MRB for the Po RTG Program will consist of an Engineering representative, who has design and reliability responsibility, and a Quality representative, who has product quality responsibility. Only those persons qualified in the functions described previously will be appointed to the MRB. They may call upon other personnel to act in an advisory or consulting capacity. Advisors or consultants, however, will have no vote in decisions made by the MRB.

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Selection and appointment of MRB personnel for the Po RTG Program will be made early in Phase II to ensure strict conformance with nonconforming material control procedures.

The MRB will make disposition of nonconforming material by deciding either to use the material as-is or to rework, repair or scrap it. It also will determine the cause of the nonconformance, affix responsibility for the defects and determine the corrective action necessary to prevent recurrence. Acceptance of nonconforming material will be by unanimous agreement of the MRB.

All MRB decisions will be supported by records of the nonconformance and the corrective action taken. The form that will be used for the Po RTG Program is the MARS tag (Fig. III-6). Nonconforming material, evaluated and accepted by the MRB, will be identified by stamping each article with the Material Review Disposition Stamp and the MARS form serial number. Parts which cannot be stamped due to size, RMS finish, cleanliness restrictions, etc., will be identified as described above except that unit identification will be made on attached metal or manila tags. Nonconforming material dispositioned scrap by the MRB will be identified by stamping each article with the Material Review Rejection Stamp and the article(s) will be impounded to preclude its use for production.

(4) Supplier material review. The extent of a supplier's authority to make independent material review decisions will be specified by Martin. Martin approval of a supplier's material review authority will be based primarily upon supplier recognition of the need for and systematizing of corrective action to prevent recurrent defects and for established procedures defining the methods for review, control and disposition of nonconforming supplies. Those suppliers approved to enact formal material review action will use their system and forms, with Martin reserving the right to reject the decision of the supplier's MRB within 30 days of receipt of the MRB form.

Suppliers not approved by Martin to conduct independent material review action may submit requests for MRB action to Martin by documenting the nonconforming condition(s) on his MRB form. This form will be submitted to the Martin resident inspector (if one is assigned) or through the Martin Procurement section for processing. Upon receipt at Martin, the nonconforming condition(s) will be evaluated and dispositioned by Quality and Engineering MRB Members. The Martin MARS form will be used to document this action, and copies of the dispositioned MARS will be transmitted to the supplier. Material(s) covered by supplier-originated MRB action will remain in a hold status until the condition(s) is approved by Martin on a MARS form and copies returned to the supplier.

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A tabulation of existing Quality procedures which will be applied to Po RTG Program follows:

Quality Procedure

13.1	Control of Nonconforming Material
13.2	Material Review Action
13.3	Material Review Board Representatives
13.4	Scrap, Rework and Material Review Cost.

d. Workmanship inspection standards

Established levels of acceptability and workmanship standards are required to eliminate individual opinions and to minimize interpretation. The following documents and practices serve to achieve a preferred workmanship standard by fabrication and inspection personnel. Workmanship standards and practices will be implemented and expanded during Phase II.

(1) Workmanship samples and aids. Where samples of acceptable workmanship standards are deemed necessary, the samples will be selected by Quality in the early phases of fabrication, identified as Quality-approved standards and utilized for the duration of the Po RTG Program. These samples will be properly protected throughout their use as standards, and when design changes are initiated or manufacturing processes are revised, the samples will be reviewed and replaced as necessary.

Thermoelectric element standards have been developed by Martin to cover acceptable/non-acceptable conditions in regard to element corner chipping, surface pitting, and surface grain grooves, surface deposits and internal defects. These standards will be imposed on the thermoelectric element supplier and will be used by Martin Quality during receiving inspection, thereby assuring uniformity for all thermoelectric element procurements.

During Phase II, Quality will determine the need for additional workmanship standards covering such conditions as cleanliness, finish, smoothness, color, and other appearance items as well as operational procedures such as soldering, welding, etc.

(2) Engineering Process Specifications (EPS) and Standard Processes.
EPS's represent processes approved by all using Martin divisions.
Standard processes represent specifications approved for use by the

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Martin-Baltimore Division. Eventually all standard processes will be superseded by EPS's. During the transition period, the Process Specification Manual will contain both standard processes and EPS's.

EPS's and standard processes are prepared by Materials Engineering to document engineering and customer requirements, equipment, fabrication control and product inspection for manufacture by Martin or subcontractor. These specifications cover all processing and fabrication operations including heat treating, metal fasteners, inorganic and organic finishes, assembly and installation operations, lubrication, identification, contamination control, soldering, brazing, welding techniques, bonding, plastics, sealants, and electrical/electronic part handling and assembly. Specific sequential installation notes, process control instructions and, where necessary, plan view, cross-sectional, exploded or isometric drawings are provided to facilitate adherence to and interpretation of the specification. Process Manuals are placed in the Nuclear Manufacturing Laboratory and other Manufacturing areas; Quality line personnel use the Process Specification Manual when performing inspection functions. This results in more uniform manufacturing standards and, correspondingly, enhances product quality and reliability.

(3) Nuclear Process Specifications (NPS). Process Specifications peculiar to Nuclear fabrication and testing operations are prepared by Nuclear Manufacturing Engineering or the Nuclear Engineering Components Department and approved by Nuclear Quality Engineering. NPS's will be prepared to cover each assembly and test operation that will be performed throughout the Po RTG Program, including thermoelectric element testing, tinning of hot and cold junction shoes, bonding of couple assemblies, determination of Seebeck voltage, nickel plating Ferro-Vac-E iron discs and hot junction shoes, bake-out of Min-K insulation, etc. These NPS's will be specified by Engineering on their drawings and will, in turn, be reflected in the Quality-prepared Inspection Instructions and Manufacturing Engineering-prepared, Quality-approved Manufacturing Operation Sheets (MOS). NPS Manuals are placed in the Nuclear Manufacturing Laboratory for use by Manufacturing and Quality personnel when performing operation and inspection functions.

Although the basic philosophy in designing the Po RTG power system was to make maximum use of current SNAP 19 technology, thereby minimizing process development needs, certain fabrication and assembly processes will require development and qualification during Phase II. Processes involving radiator dip-brazing, honeycomb fuel block panel brazing, module soldering heatup and cooldown rates, and module handling techniques will be proven and documented during Phase II component development, fabrication and testing.

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e. Control of Martin-fabricated articles

(1) Engineering drawings. Engineering drawings and their subsequent changes will be prepared by Nuclear Engineering and released to the Engineering Services Section of the Nuclear Engineering Department. This section is responsible for the distribution of all drawings and drawing change notices and the establishment and maintenance of files of all drawings for reference and general purpose use by all operating departments. To effect the timely preparation and maintenance of Quality documents (Certification Logs, Master Change Control Books, Inspection Instructions, Contractor Acceptance Plans, Receiving Acceptance Plans), Quality Technical Planning is placed on automatic distribution for all original drawing releases and any changes to the original drawings.

Drawings obtained from the Engineering Services Section by Quality line personnel for product acceptance use are considered current to the latest revision. Quality will audit the drawings in the Engineering Services Section files to ascertain that drawings are maintained current. After use by the line inspector, the drawings are either returned to the Engineering Services Section or properly destroyed, thus preventing the accumulation and use of obsolete drawings. Quality Procedure 14.5, Engineering Drawings--Identification and Usage For Quality Acceptance, defines released engineering and prohibits the use of marked up or illegible drawings.

(2) Fabrication controls. Existing fabrication control procedures will be implemented to ensure that all contract, drawing and specification requirements are obtained and maintained in the completed Po RTG system equipment. These controls and their application to all phases of fabrication will provide maximum assurance that the quality and reliability inherent in the design are maintained. Fabrication controls (workmanship standards, control of nonconforming materials, calibration of measuring and test equipment, indication of inspection status, quality level measurement, training and certification of personnel, etc.), described elsewhere in this report, will not be repeated in this section.

(a) Periodic inspection of production mechanical tools. Production jigs, fixtures, tool masters, Quality gages, and similar devices used as product acceptance media will be initially inspected, verified and subsequently reinspected or proved at established intervals.

Tool design evaluation and establishment of tooling inspection frequencies will be performed by Quality Engineering. Visual Inspection Record forms (VIR) will be prepared for each selected tool, and a file of all VIR's will be maintained in the Nuclear Quality inspection area.

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(b) Control of hand tools used for electrical and electronic fabrication operations. Certain small Company-owned hand tools assigned to manufacturing assembly and technician personnel (such as wire strippers, terminal crimpers, and taper pin insertion and check tools) require periodic certification to ensure that wear or accidental damage has not affected them. This inspection also serves to isolate tools in need of adjustment and recertification. Quality will determine the types of tools which require certification and will classify them prior to their issuance from the tool crib. Subsequent to the initial certification and issuance from the tool crib, surveillance inspections of periodic proof tests, new setups, and destructive tests will be performed or witnessed by Quality line personnel.

Detailed instructions defining responsibilities, certification procedures and calibration/certification frequencies are contained in the Quality Procedures Manual (Quality Procedure 8.3, Control of Wire Strippers, Crimpers, and Taper Pin Tools).

(c) Liaison call books. The liaison call book system will be used to document proposed changes not originated by Engineering to correct errors or deficiencies in the design of tools and to clarify or correct process plans, fabrication processes, etc. This system provides the line inspector with an expedient means of notifying Engineering, Manufacturing and Tooling Departments of errors, deficiencies and/or improvements affecting the manufacturing process, tooling and/or engineering drawings.

Liaison call books will be placed at appropriate work centers throughout the Manufacturing areas. Quality, Manufacturing and other affected departments will originate liaison call sheets to notify Engineering, Manufacturing, and Tooling of items requiring immediate investigation and corrective action. Each liaison call sheet entry is forwarded to the organization responsible for investigating the liaison entry and for making any necessary changes to remedy the reported condition. Quality will review all answered liaison call items and approve or reject them.

Movement and/or continued processing of articles which have unanswered liaison call items will be rigidly controlled by Quality. Final acceptance will be withheld until an acceptable reply to the liaison call item is received and official Engineering coverage is provided.

Quality Procedure 2.1, Liaison Call, defines the methods and forms used to originate and process liaison call items.

(d) Movement authorization. All movements of units between work centers or to the Shipping Department will be authorized and controlled by the inspector and Quality supervision. The authorization will be

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documented on a Recap and Movement Authorization form (Fig. III-18) originated by the line inspector. This form lists the status of the unit and reasons/authorization for incomplete work or shortages. The review by and approval signatures of Manufacturing, Production Control, and Quality representatives will ensure unit completeness, and control incomplete units prior to their movement by evaluating or certifying the following characteristics:

- (1) Manufacturing representative signature indicates that the cost for out-of-position work and the effect on delivery date of end product justify movement to the next work center
- (2) Production Control signature certifies part shortages
- (3) Quality representative signature indicates that the dimensional integrity of the unit is not affected, and that satisfactory operation and testing facilities are available in out-of-position areas.

(e) Acceptance inspection integrity seals. To maintain inspection integrity of RTG equipment, all articles (generator, test tooling, ground support equipment) will be sealed to provide evidence of unauthorized disturbance after acceptance inspection. Quality line personnel will apply approved inspection tamper proof seals in accordance with inspection instructions provided by Quality Technical Planning.

Quality Procedure 7.12, Tamper Proof Seals, establishes procedures for the application of integrity seals on Quality-accepted articles and test tooling.

(f) Stockroom control. Stockroom controls associated with storage and handling of Po RTG controlled parts are described in paragraph 3b of this section of the report. Stockroom practices for all other Po RTG material and parts are described here.

A bonded stockroom will be provided to control receipt, binning and issuance of parts, material, components and assemblies to manufacturing areas. Access to this stockroom will be restricted to authorized Production and Quality personnel. All incoming parts, components, and material will be verified for evidence of previous inspection, correct identification and configuration level and adequacy of protective packaging prior to binning. Upon issuance of material from the stockroom, Quality line inspection personnel will authenticate correctness of material for each particular work order. Periodic stockroom audits will be performed by Quality line personnel.

Quality Procedure 5.2, Audit of Stock Bins, defines the system and forms that will be used to conduct stockroom audits.

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PURPOSE: TO PROVIDE A MEANS OF DETERMINING THE STATUS OF PRODUCTION AND SUPPLY ITEMS AND TO PROVIDE AUTHORIZATION FOR MOVEMENT OF INCOMPLETE PARTS AND ASSEMBLIES

ORIGINATOR: QUALITY LINE INSPECTION PERSONNEL PRIOR TO MOVEMENT OF ASSEMBLY OR UNIT TO NEXT CONTROL POINT OR TO SHIPPING

RETENTION PERIOD: SEE RECORDS MANAGEMENT PROCEDURE (QDP 210)

DESCRIPTION OF ENTRY

ASSEMBLY OR UNIT INFORMATION	DATE OF CERTIFICATION LOG	INCASH DATE NO.	LATEST PSCH NO.	THE ASSEMBLY HAS CHECKED TO
				ENOUGH SPACES FOR

DESCRIPTION OF ENTRY
EMBLY OR UNIT INFORMATION
CLASSIFICATION LOG

OR TO MOVEMENT OF ASSEMBLY
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DESCRIPTION OF ENTRY

ASSEMBLY OR UNIT INFORMATION

NUMBER OF CERTIFICATION LOG INCLUDE DASH NO & LATEST PSGN NO THE ASSEMBLY WAS CHECKED TO
NUMBER OF LOGS TO INCORPORATION OF DONS AFTER TIME OF ORIGINAL RECAP (ENOUGH SPACES FOR

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[illegible]

DCN ITEMS & TESTS ACCOMPLISHED AFTER RECAP

15	DCN C N	DCN ITEMS THRU AND/OR REVISION DESIGNATION	ACCOMPLISHED AS APPLICABLE	18	SIGNATURES		19	DCN ITEMS THRU AND/OR REVISION DESIGNATION	ACCOMPLISHED AS APPLICABLE	20	DCN ITEMS THRU AND/OR REVISION DESIGNATION	ACCOMPLISHED AS APPLICABLE	21	DCN ITEMS THRU AND/OR REVISION DESIGNATION	ACCOMPLISHED AS APPLICABLE	22	DCN ITEMS THRU AND/OR REVISION DESIGNATION	ACCOMPLISHED AS APPLICABLE			
18	T P P	PERFORMED TO T P P		18	A	INSPECTOR	19	RETEST	T P P	20	RETEST	T P P	21	RETEST	T P P	22	RETEST	T P P			
17	COMPLETION STATUS		LESS FINISH	18	B	MANUFACTURING	19	DATE		20	DATE		21	DATE		22	DATE				
16	USE APPLICABLE CATEGORY PRIORITY NO. 1 PRIORITY NO. 2	COMPLETE	A	B	19	AUTHORITY TO MOVE COMPONENT		20	ASSEMBLY OR UNIT INFORMATION		21	ORIGINAL PART NUMBER		22	DASH NUMBER CHANGES		23	PAGE ____ OF ____			
		COMPLETE EXCEPT FOR ITEMS LISTED ABOVE	C	D	20	A	QUALITY	21	LATEST PSN		22	3 NAME		23	4 LOG C P		24				
		COMPLETE OK TO SHIP	E	F	21	B	MANUFACTURING	22			23	5 UNIT AND/OR ALLOCATION NO		24			25				
		INCOMPLETE OK TO SHIP (AUTHORITY LISTED ABOVE)	G	H	22	C	PRODUCTION	23			24			25			26				
19	COMPLETION STATUS		LESS FINISH	20	D	CUSTOMER (AS REQ D)	21			22			23			24			25		

Fig. III-18. Recap Sheet and Movement Authorization

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(g) Inspection stamps. Quality Procedure 19.1, Quality Stamp Control, defines the control of design, acquisition, distribution and use of inspection stamps utilized to indicate product inspection status.

Personal inspection stamps are issued to qualified Quality personnel for indicating product and document compliance with drawing, specification and contractual requirements. In addition to personal inspection stamps, special purpose and control stamps are utilized to designate material review action, heat treatment, pressure testing, magnetic particle and fluorescent penetrant inspection, rejection and other specialized identification as required in specific areas. All Martin personal and special purpose stamps are readily distinguishable from those used by Government Quality representatives.

(h) Indication of inspection status. In accordance with the requirements of Quality Procedure 19.2, Indication of Quality Acceptance of Materials, Parts and Assemblies, Quality personnel must ensure that all categories of materials, parts and assemblies are identified prior to final acceptance.

Methods for marking the part number and applying the inspection stamp are defined in this procedure. Forms and records related to control and analysis of inspection functions are described throughout the various sections of the report and will not be detailed in this section.

(i) Material handling and protection. Material handling practices will be established for all Po RTG equipment processed in the Nuclear Manufacturing Laboratories. These practices will emphasize prevention of material damage or deterioration and maintenance of cleanliness and will embrace the following basic material handling concepts:

- (1) Use of rubber bench mats when working assemblies on work benches
- (2) Cover all work when not in process of fabrication
- (3) Use of perforated foam pillows to process thermoelectric elements and couple assemblies throughout incoming inspection and assembly and test operations
- (4) Cap or plug all electrical outlets, connectors, plugs, etc., during fabrication
- (5) Provide protection from corrosion and damage for all cold and hot shoe details
- (6) Keep work areas clean and chip-free

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- (7) Provide required environmental equipment (oven, refrigeration, and inert atmosphere) for storage and processing of insulation materials, potting and sealant compounds, etc.

(3) Packaging and shipping. Specially designed shipping containers or casks will be used for shipment of the fuel source, generator and certain AGE CEI's from the Fueling Agency and Martin-Baltimore, respectively, to the launch site or to the Integration Contractor.

The fuel source shipping container will comply with Interstate Commerce Commission specifications and Bureau of Explosive requirements to ensure safe handling and transportation of the fuel block. In accordance with procedures prepared by the Fueling Agency, packaging of the fuel block in its shipping container, surveying the outer package for external radiation levels and recording of radiation measurements will be performed by the Fueling Agency.

Adherence to generator shipping requirements will be controlled by Quality personnel to prevent damage during shipment. During Phase II, Quality and Reliability will evaluate the necessity for providing chaperon services for each flight test generator shipped to the Integration Contractor or to the launch site. Generator chaperon responsibilities would begin during in-plant final acceptance testing and continue through installation of the generator into its shipping container, and would include witnessing of all subsequent handling and movement of the container, observing the loading of the generator and the stowage of the container during flight, verifying unloading operations and observing launch site and Integration Contractor receiving inspection.

Deliverable AGE and spares will be preserved and packaged to the extent necessary to provide protection in transit. Existing basic operating instructions associated with preservation, packaging, marking and shipping of military supplies will be utilized to process AGE and spares for shipment. These basic instructions satisfy all requirements of MIL-P-116 and define quality requirements, test methods, acceptance criteria, documentation, customer participation and record retention applicable to the shipping activity.

Specific processes and methods have been developed and installed in the shipping area to prevent reliability degradation during storage and shipment. The following in-process control measures will ensure continued adherence to specification and contract preservation, packaging, and marking requirements:

- (1) Cleaning fluids and preservative compounds are chemically checked monthly by the Quality Laboratories for residues and contamination; draining and cleaning of tanks will be accomplished when the contamination level exceeds acceptable standards.

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- (2) Daily temperature checks of the hot-dipping strippable compound are performed and results are recorded on check sheets attached to the tank.
- (3) Barrier, preservation, wrapping and boxing materials are purchased in accordance with military specifications.
- (4) Quality test apparatus and heat-sealing machines used in the shipping department are periodically calibrated to ensure continued accuracy.
- (5) Initial prooftesting (as contractually required) is witnessed and documented by Quality; these free-fall drop, rough handling, water-proofing, pressure retention, leak, vacuum retention, temperature and cyclic exposure tests are conducted to prove the ability of the unit pack or shipping container to withstand the effects of in-transit and storage conditions.

Quality Procedure 23.1, Quality Participation in the Preparation and Execution of Packaging and Preservation Requirements, defines Quality functions within the shipping activity.

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B. RELIABILITY PROGRAM PLAN

The prime objective of the reliability program is to assure that the Po RTG is designed and tested to demonstrate a reliability of 0.998 at a 50% confidence level. This reliability shall be demonstrated by testing to failure statistically significant quantities of selected components or subsystems in the most severe operational environments. In addition, endurance tests for durations in excess of mission lifetime shall be conducted using additional samples of the major components or subsystems.

The reliability program plan herein presented is in accord with MIL-STD-785. The plan explains the techniques to be employed during the reliability analysis, the components selection and control, and the reliability test and demonstration. The plan also explains the reliability program management and methods to bring the program into reality, including the control techniques, charts and reporting requirements.

1. Reliability Analysis

a. Prediction and apportionment

During Phase I, the RTG power system reliability requirement was apportioned to the subsystems, components and parts; and a prediction of the reliability potential of the system was prepared in detail. This prediction will be periodically updated throughout the subsequent phases of the development program as new data become available. Most of the new data will be produced by the integrated test program described in this plan. The failure mode analysis, described in the next paragraph, is also a part of the prediction process.

b. Failure mode and effect analysis

The failure mode and effect analysis begun in Phase I will be continued throughout the development program. The purpose of the analysis is to assure that each subsystem and its components are being designed to achieve the reliability requirement. Failure mode analyses will include the following:

- (1) A functional description and schematic diagram of the system.
- (2) A tabulation of reliability goals apportioned to the components and parts within the subsystems, plus the corresponding estimates of component, part and subsystem reliability.
- (3) Reliability block diagrams of the subsystems, showing component relationships.

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- (4) The probability of failure of each failure mode, its effect on mission success and the design features incorporated to counteract or overcome each mode.
- (5) As a part of the design analysis, which is a continuing process and is periodically updated until the final operational hardware is released, the Reliability engineer and the design engineer together will confirm the following prior to the release of drawings to Manufacturing for fabrication:
 - (a) That the qualification of every component and part in the assembly has been reviewed and has been found to be satisfactory, or that adequate qualification tests have been prescribed for unqualified parts.
 - (b) That reliability tests for designated critical parts components have shown them to be satisfactory, or that adequate reliability tests have been prescribed.
 - (c) The reliability allocations and predictions for all parts and components have been checked and found to be satisfactory.
 - (d) That part application analyses, environmental requirements, load factors, derating factors, tolerances and stresses have been checked and are satisfactory.
 - (e) That the theory of circuitry or layout is adequate, that the modes of failure have been investigated and that satisfactory means have been instituted to overcome, counteract or resist the critical modes.

2. Component Selection and Control

a. Component and part selection

Components and parts will be selected on the following bases:

- (1) To the maximum extent possible, components and parts will be selected to MIL standard specifications, qualified to specified reliability levels, and obtained from vendors with a history proven to be satisfactory through the Company supplier evaluation system.
- (2) Parts not meeting these requirements will be qualified before use in flight operational equipment. Since time will not permit demonstration of failure rates for the requirements of this

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Fig. III-19. Controlled Part Tags

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project, qualification will be based on satisfactory operation at higher-than-specified stress levels.

- (3) Where the design requires the use of parts from vendors with unknown performance histories, a survey of those vendors will be made by Reliability and Quality personnel to evaluate their capability to produce reliable parts. In addition to these surveys, a procurement specification will be made part of the purchase orders, specifying reliability requirements.
- (4) A parts qualification status list will be maintained throughout the project life.

b. Vendor selection and control

Materials and shelf items are procured from qualified vendors. Surveillance and control are exercised by Quality Assurance in accordance with conventional quality assurance practice (see Section A of this chapter--Quality Program Plan). Special components and parts are procured through a specially prepared procurement drawing which constitutes a complete specification for the component or part. These procurement drawings are an important part of vendor control. Two types of special procurement drawings are used: PN drawings, for new or nonstandard parts, and CCI (Controlled Commercial Items) drawings, for shelf items which have special requirements or changes added to satisfy the Po RTG program requirements. In addition, reliability specifications are prepared and imposed upon vendors of sensitive components or subsystems when required.

c. Controlled parts program

A special program for control and handling of sensitive parts and components has been implemented on the SNAP 19 program and will be employed on this program. All functioning parts (essentially all parts except hardware items such as nuts, bolts and washers) will be affected by this program. Controlled parts are identified on engineering drawings and on a special drawing which lists all controlled parts. When procurement is placed, the vendors of controlled parts are instructed in the details of the controlled parts program, which requires that the parts be serialized and identified with controlled parts tags and that shipping containers also be marked with controlled parts identification for special handling and transportation (see Fig. III-19). This is an additional form of vendor control. When packages containing controlled parts are received at the Martin Company receiving dock, they are recognized by

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the controlled parts tags and placed in special bins. After receiving inspection, they are moved via special handling to Quality Assurance acceptance inspection and testing. All controlled parts are inspected and functionally tested at bench environment to rated values (with the exception of a few nonfunctioning controlled parts, such as Min-K insulation, which is inspected only). All transistors and diodes are X-rayed in addition to functional test and inspection. Controlled parts that have successfully completed acceptance are transported, with special handling, to manufacturing areas, where they are stored in specially designated locked storage bins to await installation in Po RTG assemblies. Only certain designated personnel have access to the locked controlled parts bins. The controlled parts procedure is implemented on each project by operations directive (OD). A copy of the procedure will be found in Appendix E. This procedure has been implemented on SNAP 19.

d. Parts improvement program

A parts improvement program will be instituted in accordance with MIL-STD-785 and used to follow the advanced development efforts.

e. Qualification

All functioning components and parts, including electrical, electronic and mechanical will be qualified prior to fabrication and assembly in operational units. Qualification is defined as the production of valid evidence that a piece of equipment will perform satisfactorily as intended under the prescribed environment conditions. Valid evidence is usually in the form of test data or verified operational experience. The following will constitute adequate qualification on this program.

(1) Military standards and NASA preferred parts. Components and parts that have successfully passed qualification tests to environmental levels equal to or greater than the qualification levels prescribed for this program may be accepted as qualified.

(2) Prior usage. Components and parts having known prior histories of successful operation at environmental levels equal to or greater than the levels prescribed for this program may be accepted as qualified.

(3) Qualification test. Components and parts that cannot be qualified by either of the foregoing means will be qualified by test as a part of this program. A qualification test specification will be prepared by the appropriate design engineer for each component and part to be qualified by test. The qualification test specification will be approved by the Reliability representative as a prerequisite to release.

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(4) Qualification levels. The Reliability representative, together with the design engineer, will establish the environmental levels for qualification of all parts and components. These levels will provide an indication of margins of safety to assure successful functioning of the equipment in its operational environment.

(5) Qualification program. A qualification program will be prepared by the Reliability representative which will identify all functioning components and parts and explain the means by which each is qualified. For those requiring qualification by test, the test requirements, schedule and facility will be prescribed. The program will also explain the qualification philosophy, environmental levels selected and test quantities required. The Reliability representative will maintain a status of qualification on a monthly basis.

f. Human engineering

MIL-STD-803A will be used as a guide in designing the flight equipment and the AGE. Human engineering analyses and design studies will be conducted in Phase II to assure that the fuel loading equipment is designed to minimize the likelihood of human error.

g. Storage, shelf life, packaging, transportation and handling requirements

The requirements for storage, shelf life, packaging, transportation and handling will be prescribed by Engineering and evaluated by Reliability with a view to assuring that designed and built-in reliability is not degraded by these factors. Appropriate manuals are prepared by Logistic Support to facilitate the implementation of these requirements. Reliability will review the manuals with a view to preventing reliability degradation.

3. Specification Approval and Reviews

a. Engineering drawing approval

All engineering drawings are approved by Reliability as a prerequisite to release. The Reliability signature on an engineering drawing signifies:

- (1) That the qualification of every component and part in the assembly has been reviewed and has been found to be satisfactory, or that adequate qualification tests have been prescribed for unqualified parts.
- (2) That reliability tests for designated sensitive parts and components have shown them to be satisfactory, or that adequate reliability tests have been prescribed.

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Fig. III-20. Corrective Action System

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- (3) That the reliability allocations and predictions for all parts and components have been checked and found to be satisfactory.
- (4) That part application analyses, environmental requirements, load factors, derating factors, tolerances and stresses have been checked and found to be satisfactory.
- (5) That the theory of circuitry or layout is adequate, that modes of failure have been investigated, and that satisfactory means have been instituted to overcome, counteract or resist the critical modes.

b. Specification approval

Design specifications and program interface specifications are submitted to Reliability for review and comment as a prerequisite to release.

c. Design reviews

Design reviews will be conducted in general accordance with Company Operating Procedures OP-2-11 and OP-B2.213, copies of which have been sent to the AEC. Reviews will be scheduled and co-chaired by the program manager and project engineer. Members of the review group will be from Reliability, Quality, Manufacturing, Design Engineering, Test Engineering and Component Engineering. The Reliability representative will serve as secretary of the design review and will prepare the report of the findings of the review. He will also follow up recommendations to assure adequate completion thereof.

d. Trouble reporting and corrective action

Trouble reporting and corrective action will be conducted in accordance with Martin Company standard procedures. Implementation of the program is a function of Quality Assurance and the program is explained in detail in the Quality Program Plan.

Figure III-20 shows a typical trouble report and corrective action flow chart similar to the system that will be employed on this program.

4. Test and Demonstration

a. Test philosophy

The crux of a reliability program is the practical demonstration that the reliability requirement has been achieved, plus the confidence that can be placed in the validity of this demonstration. Confidence is a measure of the degree to which the demonstration is representative of the true per-

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formance of the equipment in its operational environment. The establishment of confidence involves the application of the mathematics of probability for reduction of data generated by the demonstration to real numbers. This necessitates the design of tests which will realistically assess the ability of the equipment, and produce results that can be evaluated in terms of statistical confidence.

The purpose of this test program is to achieve and demonstrate achievement of RTG power system reliability equal to or greater than the reliability requirement.

b. Demonstration

Engineering development and qualification tests are used for demonstration of achieved reliability. The failure mode exploratory tests, which fall under the category of engineering development tests, provide an indication of the ability of the components to withstand the operational environment, and an indication of the margin of safety that has been achieved. This margin of safety can be converted into a probability that the equipment will successfully withstand the operational environment. The primary purpose of these tests is to determine what the failure modes of the components are under the various environments, the conditions under which the failures occur, and an indication of the margin of safety. These tests are conducted in such a way that failures are intentionally produced, and the results are used for corrective redesign as necessary to achieve the reliability requirements.

The qualification tests to which the three RTG power systems will be subjected in Phase III will provide assurance that the RTG power system will withstand the operational environment; and, since the qualification tests are conducted at levels more severe than the operational environment, a margin of safety is shown. In addition to the environmental qualification tests, one of the three qualification RTG power systems will be placed on an endurance test to demonstrate the ability of the system to deliver the required power output for 144 days without failure. This test will serve to confirm the degradation rates determined during the T/E module development tests and the subsystem and component capabilities achieved during the development test program.

c. Integrated test program

A vital adjunct in designing and manufacturing a system to meet its reliability requirements is a test program designed and implemented to explore material and equipment characteristics, confirm design analyses and demonstrate performance and reliability. Since all of the tests planned for this program are important to the achievement of reliability, the test program has been integrated to achieve a logical and homogeneous progression of testing throughout the development program and provide

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a common objective for conducting all tests. By developing the overall test program in this manner, the interrelationship of the various types of tests is brought into focus and optimized. The result of this integration is presented in Tables III-1 and III-2 and Fig. III-21.

The process of implementing a test program in the Martin Company is as follows:

(1) Test program plan. A detailed and comprehensive test program plan is prepared which defines the purpose and scope of the program, the test philosophy, the results to be achieved, the schedule of tests to be performed, with start and completion dates, the number of test articles involved in each test, the major items of test equipment required, the personnel required, a description of each test to be performed, including its purpose and the results required, and the test group, location and facility that will perform the tests.

(2) Implementation. The test program plan is approved and funded by issuance of an operations directive. When this document has been promulgated, a test directive is prepared, approved and issued to implement the performance of each individual test. Upon receipt of the directive by the test conductor, a test procedure is prepared which defines precisely how the test will be performed in a step-by-step procedure. When the procedure has been approved (each test procedure is reviewed and approved by Reliability) and the test materials and equipments have been procured, the test is performed in accordance with the approved procedure. When the test has been completed, the test conductor and analysis group evaluate the results and prepare a report describing in detail what was accomplished, the results produced and an evaluation of the results. Test reports are reviewed and the results evaluated by Reliability. When reliability tests are conducted, including engineering development tests performed for the achievement of reliability, the test results are evaluated by Reliability.

(3) Acceptance testing. The second column of Tables III-1 and III-2 explains briefly the acceptance testing that will be performed on the major components and parts of the RTG power system and the AGE, respectively. In general, acceptance tests will be performed on all functioning parts (see controlled parts program in Appendix E). In most instances, acceptance tests for small parts will be performed by the vendor and verified by Quality Assurance and Receiving Inspection, but all diodes and transistors will be acceptance tested at the Martin Company, as acceptance of these items includes an X-ray examination. Acceptance testing will be performed on all procured functional parts, components, subsystems and systems in accordance with Quality Assurance requirements. Acceptance tests will be performed at the Martin Company on all RTG power systems prior to and as a prerequisite to conducting any other tests. The flight acceptance test is a separate test that will be performed only on RTG power systems designated as flight or flight backup systems.

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Fig. III-21. Development and Qualification Program Flow Diagram

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TABLE III-1

RTG Power System Integrated Test Program

I Nomenclature	II Acceptance	III Engineering Development	IV Qualification	V Production Monitor	VI Reliability Achievement	VII Flight Acceptance	VIII Flight Readiness
RTG power system	Functional performance--all electrically heated and fueled RTG systems		3 complete RTG systems with electrical heat source--dynamic and thermal vacuum tests at qualification levels and life performance test		Reliability performance demonstration	Functional performance and low level environmental test on deliverable systems Fueling demonstration with polonium fuel block in Phase III	Launch pad functional performance check
Thermo-electric conversion system	Functional performance test all generators	1 generator system, Phase II dynamic and thermal vacuum test of electrically heated generator system for resonance characteristics and thermal calibration	Qualified by generator system qualification tests				
Thermo-electric module	Performance and resistance check--all modules	7 modules--performance test* 7 modules--overtemperature test to failure 7 modules--(dummy) dynamic evaluation 10 modules--thermal cycling to failure 9 modules--shock to failure 21 modules--vacuum test (minimum of 7) then vibration test to failure (7 in each axis) 54 total modules	First 7 modules acceptance test will qualify mfg process modules qualified through engineering development tests and generator system qualification tests	100% PMT--low level dynamic test plus performance and burn-in tests	*7 modules life test to determine degradation rate		
Thermo-electric couples	Seebeck and resistance tests of all couples Only those lying within 1 σ will be used	25 couples-- Power test Resistance check Section metallographically 25 couples-- Power test Resistance check Cycle 15 couples to 20% degradation Life test 10 couples 2500 hr Section metallographically	Couples qualified through module engineering development tests and generator system qualification tests First 150 couples will qualify manufacturing process		Reliability demonstrated by module development and reliability achievement tests		
Thermo-electric elements	Seebeck and resistance check on all elements Only those lying within $\pm 1\sigma$ will be used		Qualified by T/E couple and module development tests and generator system qualification tests		Reliability demonstrated by module development and reliability achievement tests		
Coolant heat rejection subsystem	Functional performance test	Thermal-hydraulic test using water loops. NaK loop with electromagnetic pump tested to confirm water loop tests. 9 NaK pumps environmentally tested to failure RFI test. 4 radiators--dynamic tests to failure	1 complete duplicate of piping, headers, pump and portion of radiator tested at qualification test levels, dynamic and temperature 1 complete cooling system and portion of radiator tested in vacuum chamber for performance at qualification levels with varying sink levels	100% PMT	Reliability demonstrated by environmental tests to failure in development testing		
Thermal control subsystem	Functional performance test	7 heat dump door assemblies dynamically tested to failure RFI test. 3 NaK actuators--functional, dynamic and thermal tests 9 NaK actuators--cyclic tests to failure	3 complete systems qualification tested in vacuum, vibration, shock, acceleration and life tests. Life tests conducted 3 times	100% PMT	Reliability demonstrated by environmental tests to failure in development testing		
Module feedthru connectors	Resistance check plus vacuum leak check		Connectors qualified through module engineering development tests		Reliability demonstrated in T/E module development and life tests		
Emissive coatings		Exploratory tests of radiator panels, hot plates and fuel blocks with high emissive coatings to confirm analyses and select optimum	Qualified by engineering development tests				
Fuel sources (fuel block)	Acceptance inspection of all models, test articles and materials	Wind tunnel and plasma jet tests of 10% models of fuel block, generator and vehicle. Dynamics test of 7 full size fuel blocks and mounting bracket. Drop test 10 fuel blocks Bonding and strength tests	Fuel block qualified as part of generator system qualification test				
Fuel capsules	Acceptance by inspection--all fuel capsules	40 capsules and liners--weld development tests 140 capsules and liners--critical angle impact tests 10 capsules and liners--pressure tests 7 capsules and liners--thermal shock	Qualified by engineering development and reliability achievement tests		40 capsules--impact test at critical angle to determine margin of safety		

*Same seven modules

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TABLE III-2

Aerospace Ground Equipment Test Program

	Nomenclature	Engineering Development	Performance	Qualification	Acceptance	Performance Demonstration
Phase II	Compliance subsystem	Subsystem will be functionally operated with payload mockup and operational simulator until functional problems are corrected				
	Prototype fuel handling machine (including payload mockup)	Subsystem will be functionally operated with payload mockup and operational simulator until repetitive ease of operation is assured	The prototype FHM will be tested for adequate performance with payload mockup and operational simulator to demonstrate ability prior to design of operational hardware	Prototype FHM will be subjected to temperature test and water deluge		
	Electrical heat source	7 heater blocks will be thermally cycled and dynamically tested to explore failure modes	7 heater blocks--endurance and performance tests in bench ambient environment	21 heater blocks--performance in air 7 heater blocks--vibration 7 heater blocks--shock 7 heater blocks--thermal cycle		
Phase III	Operational fuel handling machine		Performance test		Inspection and functional test	Launch pad integration and launch readiness performance demonstration
	Fuel handling machine checkout equipment		Performance test	Vibration and shock test to shipping levels	Inspection and functional test	Launch pad integration and launch readiness performance demonstration
	RTG power system shipping container		Container performance test in air	Vibration and shock test to shipping levels	Inspection and functional test	
	RTG power system field test equipment		Selected components performance tested in bench ambient environment and system test of assembled components to demonstrate reliability	Selected components tested in salt fog, sand and dust, vibration, shock, temperature, water deluge and explosion	Inspection and functional test	Launch pad integration and launch readiness performance demonstration
	NaK ground service system		Performance demonstration test			
	Fuel transport cask		Performance test	Salt fog, sand and dust	Inspection	Launch pad integration and launch readiness performance demonstration
	Electrical heat source		Performance test		Inspection and functional test	
Phase IV	Electrical heat source				Inspection and functional test	
	RTG power system shipping container				Inspection and functional test	

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(4) Engineering development testing. Engineering development testing is described in the third column of Tables III-1 and III-2. Essentially all of these tests are included for the purpose of achieving reliability. The numbers of test articles are shown opposite the articles to be tested. These numbers were selected by Reliability as the minimum required for the attainment of approximately 50% confidence in the test results. Many of these tests involve testing the equipment to failure in dynamic and thermal environments in order to explore the modes of failure. By determining the environmental levels at which the equipment fails and the manner in which it fails, an indication of the margins of safety can be obtained and failure modes requiring corrective action can be ascertained. This testing will be accomplished in Phase II, well in advance of RTG power system qualification (Phase III) and, therefore, will provide assurance that the equipment is capable of successfully completing the qualification tests.

(a) RTG power system development tests. In Phase II, subsequent to component engineering development tests, a complete electrically heated RTG power system will be subjected to dynamic and thermal vacuum tests to obtain resonance characteristics and thermal calibration. By thoroughly exercising this system, failure modes requiring design changes should be uncovered, thus facilitating correction of unreliabilities during Phase II prior to commencement of RTG power system qualification tests.

(b) Thermoelectric couple engineering development tests. The first 25 thermoelectric couples accepted from manufacturing will be power tested and resistance checked, then sectioned metallographically to examine the interior of the couples for the test effects. The second 25 couples will be power tested and resistance checked, after which 15 will be thermally cycled to failure and 10 will be placed on endurance test for 2500 hours. At the end of these tests, the couples will be sectioned metallographically to determine the internal test effects and to compare the results with those of the first test of 25 couples.

(c) Thermoelectric module development tests. Seven modules will be performance tested and then placed on endurance test as early as possible in Phase II to verify the design allowance for degradation. Acceptance of these seven modules will also serve to qualify the manufacturing process for fabrication of thermoelectric modules (see Column IV of Table III-1).

Seven additional modules will be subjected to overtemperature conditions to determine the temperature at which failure occurs.

Seven dummy modules will be subjected to dynamic evaluation to determine resonance characteristics of the module and test fixtures and verify design analysis. Ten modules will be thermally cycled to

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failure to determine how many thermal cycles the modules can withstand before performance degrades below allowable limits and also to determine the effect of rate of thermal change. Nine modules will be shock tested to failure to determine the ability of the modules to withstand mechanical shock, the shock level at which they fail and how they fail. Twenty-one modules will be vacuum tested and then tested to failure dynamically in each of the three orthogonal axes, seven in each axis, to determine the vibration levels at which failure occurs and the mode of failure.

(d) Coolant heat rejection subsystem development tests. The radiator and coolant lines will undergo thermal hydraulic tests using water loops. A NaK loop with the electromagnetic pump will then be tested to confirm the water loop tests. These tests will confirm the design analyses. When these tests have been completed, four radiator assemblies will be dynamically tested to failure, one in each orthogonal axis and one in shock. In addition, nine NaK pumps will be environmentally tested to failure: three dynamically, one in each orthogonal axis, three in shock and three in overtemperature. These tests will explore the environmental margins of safety and the failure modes in order to effect corrective measures during Phase II and prior to qualification testing of the RTG power system.

(e) Thermal control subsystem engineering development testing. Twelve NaK actuators will be manufactured for use in engineering development testing. The first actuator with a thermal control subsystem will be functionally tested with a NaK reservoir and calibrated and modified as required to confirm design analyses. The second actuator, with a thermal control subsystem, will be subjected to control subsystem dynamic tests and modified as required to confirm design analyses. Then, nine actuators will be connected to NaK reservoirs and cycled to failure, three at each of three different cyclic rates. Figure III-22 is an illustration of the type of results expected from this test series. The extrapolation of the curve connecting the failure points of the nine actuators will provide an indication of the failure probability of the actuator and provide data upon which to base a production monitor test for actuators to be used on deliverable RTG power systems. Seven thermal control subsystems will then be dynamically tested to failure or to the maximum capability of the vibration exciter to determine the margins of safety and failure mode.

(f) Emissive coatings. Exploratory tests of radiators, hot plates and fuel blocks with high emissive coatings will be conducted to confirm design analyses and select optimum approaches.

(g) Fuel block development tests. Seven full-size fuel blocks will be dynamically tested to failure, one in each orthogonal axis and three in shock. Three fuel block samples will be subjected to bonding and

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Fig. III-22. Expected Failure Probability

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strength tests. These tests are designed to explore the modes of failure of the fuel block. Ten additional fuel blocks will be subjected to impact and radiant heat tests for safety and thermal purposes.

(h) Fuel capsules. Forty fuel capsules and liners will be manufactured for weld development tests and 18 capsules and 28 liners for internal pressure and hydrostatic tests thermally shocked to failure. These tests are designed to explore the failure modes of the fuel capsules. In addition, 140 capsules and liners will be fabricated and subjected to impact tests, 20 at each of 5 angles to determine the worst angle of impact. When the worst angle has been identified, 40 additional fuel capsules will be impact tested to demonstrate fuel capsule impact reliability. The results of these tests will be evaluated statistically by the Bruceton Method per NavOrd Report 2101.

(5) Qualification testing. Qualification was discussed previously, and the method of qualification of the RTG power system and the subsystems and major components is identified in Column IV of Table III-1. Separate qualification tests are planned for two subsystems, the coolant heat rejection subsystem and the thermal control subsystem. All other subsystems and major components and parts will be qualified as part of the RTG power system qualification tests.

(a) RTG power system qualification test. Three RTG power systems will be constructed in Phase III for qualification testing. These RTG power systems will be representative of the final engineering design and actual production run and will be subjected to an appropriate range of environmental tests at levels more severe than the anticipated operational environment. The engineering development tests to failure will be instrumental in the establishment of these test levels. These system qualification tests constitute a portion of the demonstration of reliability in that they demonstrate the ability of the equipment to withstand the operational environment of the intended mission. Furthermore, since qualification test procedures and reports will be submitted to the customer for approval, it will be necessary to prepare a detailed qualification specification for the performance of these tests to prescribe the tests to be performed and the criteria for successful passage of the qualification test. This qualification test specification for the RTG power system will be prepared by the Martin Company and submitted to the customer for approval as a prerequisite to preparation of test procedures and commencement of qualification tests.

(b) Coolant heat rejection subsystem qualification test. In order to qualify the coolant heat rejection subsystem for the operational environment, one subsystem will be subjected to dynamic tests at qualification levels and a second system will be thermal vacuum tested at qualification levels. The subsystems to be subjected to qualification tests will consist of one radiator subsystem with a simulated heat source. This

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will be sufficiently representative of the total subsystem to satisfy qualification test requirements, particularly when three complete subsystems will be subjected to qualification tests as a part of the RTG power system qualification test. The purpose of the subsystem qualification test is to provide assurance that the subsystem will withstand the operational environment sufficiently in advance of the RTG power system qualification tests to allow for institution of any design changes that may become necessary as a result of the subsystem qualification testing.

(c) Thermal control subsystem qualification tests. Three complete thermal control subsystems will be subjected to environmental tests at qualification levels to provide assurance that the thermal control subsystem will withstand the operational environment. In addition to dynamic and thermal tests at qualification levels, the systems will be subjected to short duration endurance tests involving accelerated operational cycles.

(6) Production monitor testing (PMT). PMT is acceptance testing in an environment of sufficient severity to uncover latent defects but not enough to cause significant damage to the equipment. A reduced stress level relative to the qualification and operational stress will be imposed on select equipment. Items selected shall have: (1) potential modes of failure which may adversely affect performance objectives, (2) sufficient evidence that normal inspection techniques cannot detect impending failures in the operational modes of the equipment and (3) a failure history which indicates with sufficient confidence that the production processes may require more rigid standards.

This program, as used on the Gemini, has demonstrated (5 GLV launches to date) not one single hardware flight failure out of approximately 350 functioning components, or 1750 total units. Column V of Table III-1 indicates that the components of the thermoelectric modules, the coolant heat rejection subsystems, and the thermal control subsystems will undergo PMT.

(7) Flight acceptance. Flight acceptance tests will be performed only on RTG power systems to be delivered to the customer for operational use. The flight acceptance test shall consist of subjecting the RTG power system to flight acceptance environment for a short period of time, followed by a short duration performance test. A flight acceptance test specification shall be prepared by the Martin Company which shall define the flight acceptance test requirements in detail and shall also define acceptance criteria. When the flight acceptance test specification has been approved by the customer, a flight acceptance test procedure will be prepared by the Martin Company and submitted to the customer for approval. Approval of the flight acceptance test procedure shall be a prerequisite to performance of flight acceptance tests.

(8) Flight readiness test. Flight readiness tests will be performed at the launch pad on the RTG power systems designated for flight operation that have been installed in the flight vehicle and are ready for operation. The flight readiness check is a precountdown check to assure that the RTG power system is in readiness for flight operation.

(9) Aerospace ground equipment test program. The aerospace ground equipment test program is presented in Table III-2. The program is designed to support the development, qualification, delivery and launch pad integration of AGE that has demonstrated its ability to perform as required. The tests that are planned have been tailored to the needs of the AGE subsystems and components, and are primarily aimed at achieving proficiency in performance. Except for the heater blocks, the equipment will operate in an essentially benign environment. Thus, the exploration of failure modes due to environmental stress, as in the case of the airborne equipment, is relatively unimportant, whereas assurance of proficient performance is vital. Performance in this instance is largely a question of tolerance, alignment, and closeness of fit.

(a) Acceptance. Acceptance testing of AGE occurs only in Phase III when the operational hardware is fabricated. Each subsystem except the NaK ground service subsystem will be inspected and functionally tested to assure that the subsystem is operating properly. This acceptance constitutes delivery acceptance by the AEC-USAF and occurs subsequent to qualification testing, which could cause design changes.

(b) Engineering development tests. Engineering development tests are performed in Phase II on three subsystems:

- (1) The compliance subsystem
- (2) The prototype fuel handling machine
- (3) The electrical heat source.

Development testing of the compliance subsystem and the fuel handling machine is entirely devoted to functional tests to achieve smoothness and ease of operation. Operational cycles will be repeated and evaluated and adjustments made until the required degree of performance proficiency is achieved.

The electrical heater blocks will be tested dynamically and thermally to explore failure modes and assure a margin of safety sufficiently large to prevent failure.

(c) Performance tests. In Phase II, the prototype fuel handling machine will be tested for performance with the payload mockup and the operational simulator to demonstrate performance capability and the reliability goal that has been internally established. This will be done on the basis of repetitive cycles without failure. The reliability goal is 90% probability of successfully completing a fueling cycle without failure, with a confidence of 50%. On the basis of the binomial

$R^n = 1 - C$, where R is the reliability goal, n is the number of cycles without failure and C is confidence; seven cycles without failure are required to demonstrate $R = 0.9$ with 0.5 confidence.

Seven heater blocks will be endurance tested at bench ambient environment to demonstrate performance and endurance capability. These tests will run until failure of the heater blocks. If no failures occur, the tests will be terminated at the end of 60 days of continuous operation. If failures occur in less than 14 days, the required time of operation without failure, failure analyses will be conducted, design changes incorporated as necessary, and the tests repeated. If failures occur after 14 days of operation, and before the completion of 60 days, the failure distribution will be evaluated, the mean and standard deviation computed and the demonstrated reliability calculated. The confidence level on the basis of seven tests will be 50%.

The performance testing shown in Phase III for the operational AGE will be a demonstration of adequate functioning of the equipment at bench ambient conditions. In addition, the RTG power system field test equipment will be subjected to endurance and cyclic tests to demonstrate reliability.

(d) Qualification. The prototype fuel handling machine will be subjected to temperature and water deluge tests in Phase II, as these are the only anticipated environments that could adversely affect this subsystem.

The heater block will undergo a severe qualification test in Phase II. As shown in Table III-2, 21 electrical heater blocks will undergo performance tests in air. These tests will supplement the seven heater blocks undergoing endurance tests mentioned in the previous paragraph. In addition, seven heater blocks will be subjected to vibration tests, seven will undergo shock tests and seven will be thermally cycled. When the ability of the heater blocks to endure qualification environmental levels has been demonstrated, the environmental levels will be increased until failure occurs in order to obtain an indication of margins of safety.

During Phase III, the fuel handling machine checkout equipment, and the RTG power system shipping container will be qualified by dynamic tests to shipping levels; selected components of the RTG power system

Fig. III-23. Reliability Organization

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field test equipment, primarily the Variac, will be exposed to salt fog, sand and dust, vibration, shock, temperature, water deluge and explosion tests. These tests are considered necessary because the Variac will probably be located on the launch pad in a relatively exposed position.

The fuel transport cask will be qualified by dynamic tests to transportation levels and by exposure to salt fog, sand and dust tests.

(e) Performance demonstration. In Phase III, all of the operational (deliverable) AGE subsystems will undergo launch pad integration, launch readiness and performance demonstration tests at the launch site.

5. Reliability Program Management

a. Program plan

This reliability program plan is in accord with MIL-STD-785. The paragraph headings differ somewhat from those of the specification in order to more conveniently adapt the functions and tasks to the Po RTG program. Nevertheless, all of the requirements of the specification (MIL-STD-785) are covered.

b. Organization

The Reliability project organization is shown in Fig. III-23. The Reliability Unit Head reports to the project engineer. Specialists in the fields of reliability engineering and reliability test and evaluation are assigned to the Reliability representative to assist in implementation of the reliability program and performance of the prescribed tasks.

c. Implementation

Table III-3 presents a breakdown of the major tasks of the reliability program, a reference to the procedures to be used in implementation of each task, and the control to be exercised to assure that each task is performed as intended and the desired result achieved. These tasks will be implemented on the project through the issuance of appropriate operations directives and engineering directives which are standard (Martin Company internal) vehicles for authorizing expenditure of funds and directing the performance of work. The reliability program will be managed and controlled by the Reliability representative. The program will be implemented through performance of the tasks identified in Table III-3. In addition to identifying the tasks which comprise the reliability program, Table III-3 identifies the procedure to be used in implementing each task and the control to be imposed to ensure adequate performance and completion of each task. The control charts referred to in Table III-3 are described as follows. Examples of chart format are also included.

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TABLE III-3
Implementation Program

Task	Procedure for Implementation	Control
1. Reliability design analysis	MIL-STD-756	Reliability analysis report and control chart (Fig. III-25)
2. Reliability apportionment and prediction	MIL-STD-756	Reliability analysis report and control chart (Fig. III-25)
3. Development of test program a. Prepare test program plan b. Review test directives c. Review and approve test procedures d. Evaluate test results e. Prepare certain test reports f. Review and approve all test reports	Section 4 hereof	Reliability approval of test procedures and test reports Control chart (Fig. III-26)
4. Selection of parts	Reliability engineering together with Component Application engineering reviews all part and component requirements, conducts part searches	Drawing sign-off by Reliability
5. Review and approval of engineering drawings	Engineering drawings and drawing changes are submitted to Reliability for approval prior to release	
6. Review and approval of specifications	Specifications are submitted to Reliability for review and approval as a prerequisite to release	Reliability receives copies of all specifications released
7. Schedule and participate in design reviews	OP-2-11 and OP-B2.213, copies of which will be found in Appendix F	Report of design review, design review schedule, control chart (Fig. III-27)
8. Schedule and participate in Reliability program reviews	Description in Section B-3	Report of Reliability program reviews and control chart (Fig. III-28)
9. Implement a program for control of sensitive parts	Nuclear procedure for controlled parts, reference Appendix E	Drawing sign-off, Reliability monitor of controlled parts program, control chart (Fig. III-29) and Quality Control audit of controlled part program
10. Vendor selection and control	Procedure described in Section B-2. See also MB-1053 Appendix F MB-1054 Appendix F MB-1055 Appendix F	Drawing sign-off, the controlled part program, Quality Control inspection of vendors, and Quality Control records of vendor performance
11. Prepare schedule of Reliability tasks and major milestones	Description in Section B-5	Reliability program review, progress reports, and control charts (Figs. III-24, III-25 and III-26)
12. Trouble reporting and correction action system	Procedure described in Section B-3. See also OP-B8.810 Appendix F QD-5.2 Appendix F QD-MN-1024 Appendix F QD-5.8 Appendix F	Copies of all trouble reports are submitted to Reliability for review. Quality Control maintains followup of corrective action system Control chart (Fig. III-30)
13. Reliability training	Description in Section B-5	
14. Reliability demonstration	Description in Section B-4	Test procedures and results approved by Reliability and Reliability will contribute to the test report
15. Reporting a. Analysis and prediction report b. Reliability program plan c. Demonstration plan d. Demonstration report e. Monthly progress report f. Quarterly progress report g. Special reports	Description in Section B-5	

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d. Program control

(1) Task schedule. The task schedule is shown in Task 1.3 of the master schedule in the previous chapter. This schedule is keyed to the program schedule, which indicates major milestones.

(2) Control charts. Reliability program control will be partly accomplished through maintenance of a series of control charts which will show the status of the major elements of the program. The charts will be updated weekly and will point out shortcomings and weaknesses in the program in time to take remedial action. The requirement for maintaining currency of the charts will impose a healthy discipline upon the program. The following control charts will be maintained:

- (1) Reliability Program Tasks (Fig. III-24)
- (2) Reliability Prediction (Fig. III-25)
- (3) Test Program (Fig. III-26)
- (4) Design Review and Follow-up (Fig. III-27)
- (5) Reliability Program Review and Follow-up (Fig. III-28)
- (6) Controlled Part Procurement (Fig. III-29)
- (7) Trouble Reports and Corrective Action (Fig. III-30)

(3) Reliability program reviews. A review of the reliability program will be conducted quarterly to ascertain program status, progress, and reliability achievement status. The results of the review will be reported in the program quarterly progress report.

e. Participation of other departments

Departments other than Engineering also perform important functions in the achievement of reliability objectives. These functions are identified as follows:

(1) Quality assurance

- (a) Inspection
- (b) Vendor control
- (c) Acceptance
- (d) Calibration

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Reliability Tasks	Starting Date		Completion Date		Responsibility	Remarks
	Planned	Actual	Planned	Actual		

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Fig. III-24. Control Chart of Reliability Tasks

 

Fig. III-25. Control Chart of Reliability Apportionment and Estimate

 

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Identification of Tests	Test Directive Issued		Test Procedure Reviewed/Approved		Test Completion		Test Report	
	Planned	Actual	Planned	Actual	Planned	Actual	Planned	Actual

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Fig. III-26. Control Chart of Test Program

Design To Be Reviewed	Review Team Briefed	Review Schedule Date	Review Team Report Submitted	Design Change Directed	Design Change Completed	Revised Drawings Issued

Fig. III-27. Design Review and Follow-up

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Reliability Program Review No.	Coincident Major Milestone	Scheduled Date of Review	Actual Date of Review	Report of Review Received	Follow-up Action Initiated	Follow-up Action Completed

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Fig. III-28. Reliability Program Review and Follow-up

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Controlled Part Nomenclature	Drawing or Part No.	Purchase Request No. and Date	Purchase Order No. and Date	Date and No. Received	Acceptance Inspection and Test Completed	No. Rejected and Reason	Action Taken

Fig. III-29. Controlled Part Procurement

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Identity of Trouble Report Requiring Corrective Action	Corrective Action Request Date and No.	Assigned for Action	Action Initiated	Action Completed	Description of Action Taken

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Fig. III-30. Trouble Reports and Corrective Action

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- (e) Trouble reporting
- (f) Failed parts analysis

(2) Manufacturing

- (a) Process control
- (b) Operating procedures
- (c) Test procedures
- (d) Evaluation of:
 - Produceability
 - Interchangeability
 - Materials
 - Processes

- (e) Training

(3) Logistic support

- (a) Prepare maintenance plan
- (b) Prepare handbooks
- (c) Establish spare parts requirements
- (d) Prepare shipping and handling requirements and arrangements

(4) Contracts

- (a) Provision of contractual coverage
- (b) Determine reliability procurement requirements with definitive terms
- (c) Negotiate reliability requirements with customer
- (d) Negotiate reliability requirements with subcontractors
- (e) Certify contractual compliance with plan
- (f) Submit reliability reports as scheduled

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(5) Finance

Provide adequate and proper funding and financial control for Reliability efforts

(6) Planning

- (a) Provide adequate planning schedule
- (b) Show significant reliability events in project master plan
- (c) Include significant reliability events in PERT network

f. Reliability training

Reliability personnel assigned to this program will be experienced Reliability engineers. Reliability training of these personnel is not required as a part of this program.

6. Reporting

a. Reliability program plan

Within 60 days of the receipt of go-ahead for Phase II, a revised reliability program plan shall be prepared and submitted to the customer for approval. It is anticipated that the reliability program plan herein presented is in sufficient detail to satisfy the Po RTG program requirement with minor modifications.

b. Reliability analysis and prediction report

Within 90 days of go-ahead, a formal reliability analysis and prediction report shall be prepared and submitted to the customer. The formal report shall be periodically revised and updated.

c. Reliability demonstration plan

During Phase II, a revised reliability demonstration plan will be prepared, based upon the preliminary demonstration plan herein presented. When this demonstration plan has been approved, it will form the basis for demonstration of the reliability achieved by the RTG power system. When the demonstration plan has been approved, a demonstration test procedure will be prepared and submitted for customer approval. The demonstration test will be conducted in accordance with the approved demonstration test procedure.

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d. Reliability demonstration report

When the reliability demonstration has been completed, the results will be evaluated and a report of the evaluation prepared and submitted to the customer.

e. Monthly progress report

The program monthly progress report will serve as the primary vehicle for transmission of reliability program information to the customer. It will contain information as to program progress, reliability achievement progress, information on activities conducted in accordance with each prescribed reliability program task, a summary of failure reports and corrective action, and information as to major problems being encountered, their status, and action in process.

f. Quarterly progress report

The Reliability contribution to the program quarterly progress report will contain essentially the same type of information as the monthly progress report, but will be in the nature of a summary of this information for the quarter.

g. Special reports

Special reports will be prepared and issued as needed to cover special subjects.

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IV. SCHEDULING AND FACILITIES PLAN

This chapter contains the scheduling plans for Phases II, III and IV in the first section. The second part is devoted to the facility plans.

A. SCHEDULE CHARTS

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Months After Contract Award		1966												1967												1968											
		F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S				
		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	26	27	28	29	30	31	32				
Task 1.0 Program Management and Controls																																					
1.1	Program Management																																				
1.2	Configuration and Integration Management																																				
1.2.1	Establish Configuration Control Procedure																																				
1.2.2	Contractor/AEC/User Key Interface																																				
	(1) Approval Contractor Spec MND-3612-10, -11, -12, -13 and -34 Partial Baseline Items																																				
	(2) Vehicle Configuration--Final																																				
	(3) Design Baseline Final of Spec Items																																				
	(4) Trajectory Data from AEC																																				
	(5) Approval of Test Programs																																				
	Component Testing																																				
	End Test Model Testing																																				
	AGE Prototype S/N 1 Testing																																				
1.3	Reliability																																				
1.4	Quality Assurance																																				
1.5	Manuals																																				
Task 2.0 Design and Analysis																																					
2.1	System Integration Analysis and Design																																				
2.2	System Analysis and Design																																				
2.2.1	RTG Analysis																																				
	RTG Component Design																																				
	RTG Engineering Model Test Design																																				
2.2.2	AGE Analysis																																				
	AGE Design--Preliminary																																				
	AGE Design--Final																																				
2.3	Fabrication and Test Specifications and Evaluations																																				
2.3.1	RTG Fabrication and Test Specifications and Evaluations																																				
	Specifications and Evaluations																																				
	Test Design and Specifications																																				
	Test Data Evaluation																																				
2.3.2	AGE Fabrication and Test Specification and Evaluation																																				
	Fabrication Specification																																				
	Test Design and Specification																																				
	Test Data Evaluation																																				
Task 3.0 Safety and Shielding Analysis																																					
3.1	Safety and Shielding Analysis																																				
	(a) System philosophy requirements																																				
	(b) Specification write-up, evaluation report																																				
3.1.1	Fuel Safety Analysis																																				
	(a) Fuel capsule																																				
	(b) Heat source																																				
3.1.2	Safety Analysis Report																																				
	(a) Scope and approach																																				
	(b) Transportation, handling and storage																																				
	(c) Launch pad safety																																				
	(d) Liftoff of operation																																				
	(e) Orbital operation																																				
	(f) Post orbital operation																																				
	(g) Nonnuclear hazards																																				
	(h) Preliminary report																																				
3.2	Shielding Analysis																																				
3.3	Fabrication and Test Specifications and Evaluation																																				
	(a) Fuel containment																																				
	(b) Shielding Test																																				
Task 4.0 RTG Component Manufacturing Development and Testing																																					
4.1	RTG Test Preparation																																				
4.2	RTG Manufacturing Process Development and Tooling Fabrication																																				
4.3	RTG Component and Test Fixture Fabrication																																				
4.3.1	Heat Source																																				
4.3.2	T/E Couple Fabrication																																				
	T/E Module Fabrication																																				
4.3.3	Coolant Heat Rejection																																				
4.3.4	Thermal Control System																																				
4.3.5	RTG Engineering Model																																				
4.3.6	RTG Structures and Shielding																																				
4.4	RTG Component Development and Reliability Testing																																				
4.4.1	Heat Source																																				
4.4.2	T/E Module																																				
4.4.3	Coolant Heat Rejection																																				
4.4.4	Thermal Control																																				
4.4.5	RTG Engineering Model																																				
Task 5.0 AGE Component Development and Testing																																					
5.1	AGE Test Preparation																																				
5.2	AGE Manufacturing Process Development and Tooling Fabrication																																				
5.3	AGE Component and Test Fixture Fabrication																																				
5.3.1	Fuel Handling Machine																																				
5.3.2	Electrical Heat Source																																				
5.4	AGE Testing																																				
5.4.1	Fuel Handling Machine																																				
5.4.2	Electrical Heat Source																																				
Task 6.0 Safety and Shielding Development and Testing																																					
6.1	Safety and Shielding Test Preparation																																				
6.2	Safety and Shielding Manufacturing Process Development and Tooling Fabrication																																				
6.3	Safety and Shielding Test Articles Fabrication																																				
6.4	Safety and Shielding Development Testing																																				
Task 7.0 RTG Component Advance Development																																					
7.1	T/E Couple Development																																				
7.2	T/E Module Development																																				
7.3	Heat Source Development																																				
7.4	Thermal Control Development																																				
7.5	Heat Rejection Development																																				
7.6	System Configuration and Different Fuels																																				

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Po RTG Master Summary Schedule Minimum Cost--Phase III

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Po RTG Master Summary Schedule - Minimum Cost--Phase IV

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Po RTG Master Summary Schedule - Minimum Time--Phase II

Months After Contract Award	1966												1967												1968											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S				
	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	26	27	28	29	30	31	32				
Task 1.0 Program Management and Controls																																				
1.1 Program Management																																				
1.2 Configuration and Integration Management																																				
1.2.1 Establish Configuration Control Procedure																																				
1.2.2 Contractor/AEC/User Key Interface																																				
(1) Approval Contractor Spec MND-3612-10, -11, -12, -13 and -34																																				
Partial Baseline Items																																				
(2) Vehicle Configuration--Final																																				
(3) Design Baseline Final of Spec Items																																				
(4) Trajectory Data from AEC																																				
(5) Approval of Test Programs																																				
Component Testing																																				
End Test Model Testing																																				
1.3 Reliability																																				
1.4 Quality Assurance																																				
1.5 Manuals																																				
Task 2.0 Design and Analysis																																				
2.1 System Integration Analysis and Design																																				
2.2 System Analysis and Design																																				
2.2.1 RTG Analysis																																				
RTG Component Design																																				
RTG Engineering Model Test Design																																				
2.2.2 AGE Analysis																																				
AGE Design--Preliminary																																				
AGE Design--Final																																				
2.3 Fabrication and Test Specifications and Evaluations																																				
2.3.1 RTG Fabrication and Test Specifications and Evaluations																																				
Specifications and Evaluations																																				
Test Design and Specifications																																				
Test Data Evaluation																																				
2.3.2 AGE Fabrication and Test Specification and Evaluation																																				
Fabrication Specification																																				
Test Design and Specification																																				
Test Data Evaluation																																				
Task 3.0 Safety and Shielding Analysis																																				
3.1 Safety and Shielding Analysis																																				
(a) System philosophy requirements																																				
(b) Specification write-up, evaluation report																																				
3.1.1 Fuel Safety Analysis																																				
(a) Fuel capsule																																				
(b) Heat source																																				
3.1.2 Safety Analysis Report																																				
(a) Scope and approach																																				
(b) Transportation, handling and storage																																				
(c) Launch pad safety																																				
(d) Liftoff of operation																																				
(e) Orbital operation																																				
(f) Post orbital operation																																				
(g) Nonnuclear hazards																																				
(h) Preliminary report																																				
3.2 Shielding Analysis																																				
3.3 Fabrication and Test Specifications and Evaluation																																				
(a) Fuel containment																																				
(b) Shielding Test																																				
Task 4.0 RTG Component Manufacturing Development and Testing																																				
4.1 RTG Test Preparation																																				
4.2 RTG Manufacturing Process Development and Tooling Fabrication																																				
4.3 RTG Component and Test Fixture Fabrication																																				
4.3.1 Heat Source																																				
4.3.2 T/E Couple Fabrication																																				
T/E Module Fabrication																																				
4.3.3 Coolant Heat Rejection																																				
4.3.4 Thermal Control System																																				
4.3.5 RTG Engineering Model																																				
4.3.6 RTG Structures and Shielding																																				
4.4 RTG Component Development and Reliability Testing																																				
4.4.1 Heat Source																																				
4.4.2 T/E Module																																				
4.4.3 Coolant Heat Rejection																																				
4.4.4 Thermal Control																																				
4.4.5 RTG Engineering Model																																				
Task 5.0 AGE Component Development and Testing																																				
5.1 AGE Test Preparation																																				
5.2 AGE Manufacturing Process Development and Tooling Fabrication																																				
5.3 AGE Component and Test Fixture Fabrication																																				
5.3.1 Fuel Handling Machine																																				
5.3.2 Electrical Heat Source																																				
5.4 AGE Testing																																				
5.4.1 Fuel Handling Machine																																				
5.4.2 Electrical Heat Source																																				
Task 6.0 Safety and Shielding Development and Testing																																				
6.1 Safety and Shielding Test Preparation																																				
6.2 Safety and Shielding Manufacturing Process Development and Tooling Fabrication																																				
6.3 Safety and Shielding Test Articles Fabrication																																				
6.4 Safety and Shielding Development Testing																																				
Task 7.0 RTG Component Advance Development																																				
7.1 T/E Couple Development																																				
7.2 T/E Module Development																																				
7.3 Heat Source Development																																				
7.4 Thermal Control Development																																				
7.5 Heat Rejection Development																																				
7.6 System Configuration and Different Fuels																																				

Po RTG Master Summary Schedule -Minimum Time--Phase III

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Po RTG Master Summary Schedule Minimum Time--Phase IV

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Po RTG Master Detail Schedule for Recommended Program--Phase II

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Po RTG Master Detail Schedule for Recommended Program--Phase II

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Po RTG Master Detail Schedule for Recommended Program--Phase II

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Po RTG Master Detail Schedule for Recommended Program--Phase II

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Po RTG Master Detail Schedule for Recommended Program--Phase III

Phase III	Months	8	9	10	11	12	13	14	15	16	17	18	19	20
Task 1.0 Management and controls														
1.1 Program management														
1.1.1 Reporting														
Monthly														
Quarterly														
Topicals														
Processes and dwgs														
Meetings and presentations														
Final safety report														
1.1.2 Schedules and cost control														
Operating plans, PERT and schedules														
Cost estimates and control														
1.1.3 Contract and subcontract liaison														
AEC--contractor														
Contractor--subcontractor														
1.2 Configuration and integration management														
1.2.1 Interface liaison and control														
coordination and followup														
1.2.2 Configuration management														
Spec prep.														
Documentation and changes														
Spec compliance														
1.3 Reliability														
1.3.1 Program implementation														
1.3.2 Reliability analysis and prediction														
1.3.3 Parts selection														
1.3.4 Dwg review and approval														
1.3.5 Controlled parts program														
1.3.6 Vendor selection and control														
1.3.7 Trouble reporting and corrective act.														
1.3.8 Reliability training														
1.3.9 Spec review and approval														
1.3.10 Design review														
1.3.11 Reliability program review														
1.3.12 Integrated test program														
1.3.13 Evaluation test results, reports														
1.3.14 Coolant heat rej subsys qual tests														
1.3.15 Thermal control subsys qual tests														
1.3.16 RTG pwr syst qual tests														
Reliability demonstration														
1.4 Quality assurance														
1.4.1 Quality program plan														
Implementation														
Supplement(s)														
1.4.2 Budget/manpower controls														
1.4.3 Technical document review														
1.4.4 Supplier controls														
1.4.5 Failure reporting/corrective action														
1.4.6 Audit program														
1.4.7 Controlled parts control														
1.4.8 Generator system and AGE fabrica-														
tion/test inspection														
Incoming parts/materials														
In-process														
Qualification/acceptance test														
1.4.9 Technical manual validation														
Technical manual verification														
1.4.10 Integration contractor demonstration														
1.4.11 Specification compliance (AGE)														
1.4.12 Quality documentation/reports														
1.5 Manuals														
1.5.1 Instruction and operation manuals														
1.5.2 Equipment and maintenance manuals														
1.5.3 Documentary film														
Task 2.0 Prototype design and analysis														
2.1 System integration analysis and design														
2.1.1 RTG system and vehicle														
Integration--final														
Functional and performance														
Integration analysis--final														
Electrical and instrumentation														
Thermal and nuclear radiation														
Mechanical and structural														
Arrangement and physical														
Integration design--final														
Electrical and instrumentation														
Thermal insulation and shields														
Mechanical and structural														
2.1.2 AGE system and launch complex														
Integration--final														
Functional and performance														
Integration analysis--final														
Electrical and instrumentation														
Thermal and nuclear radiation														
Mechanical and structural														

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Po RTG Master Detail Schedule for Recommended Program--Phase III

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Po RTG Master Detail Schedule for Recommended Program--Phase III

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Po RTG Master Detail Schedule for Recommended Program--Phase III

Po RTG Master Detail Schedule for Recommended Program--Phase IV

B. FACILITIES PLAN

The Po RTG development program has been carefully reviewed and a facility plan formulated. Each item of work was evaluated to identify the equipment and facilities required. Availability of equipment was then investigated and a facility and equipment utilization schedule prepared.

The main facilities and equipment that will be required are summarized in Table IV-1. All of these facilities are currently available within the Martin Company's Baltimore complex.

TABLE IV-1
Po RTG Facilities Requirement Summary

<u>Facility/Equipment</u>	<u>Po RTG Utilization</u>	<u>Major Equipment</u>
Digital Computations	Analysis and evaluation--nuclear safety, structural	IBM 7094 GE 625
Hot Shot Wind Tunnel, Revetment Test Area, Radiant Heat Equipment, Materials Lab Complex	Safety and shielding development testing and qualification of containment block	
Liquid Metal R&D Lab	Coolant heat rejection and EM pump testing	Water loop NaK loop
Environmental Laboratory	1. Component development and reliability testing 2. Production testing 3. Acceptance testing 4. Qualification testing 5. Performance testing	C-25 vibration system MB-210 vibration system Hyge shock machine Medium impact machine Rucker centrifuge Small vacuum chamber 6-ft x 15-ft thermal vacuum chamber
Small Power Plant Laboratory	1. Performance testing (modules and generators) 2. Production testing	Module and generator test consoles and benches Data logger Vacuum chamber
T/E Element and Couple Development Laboratory	Element and couple development and life testing	Bulk melters, pulverizers, casting equipment, hot and cold pressing equipment, couple testers

Fig. IV-1. Environmental Laboratory

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Fig. IV-2. Glove Box Area

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TABLE IV-1 (continued)

<u>Facility/Equipment</u>	<u>Po RTG Utilization</u>	<u>Major Equipment</u>
Metallographic Laboratory	Element and couple metallographic analysis	
Mockup Area AGE	Component testing; performance, qualification and acceptance testing	
AMT Lab	Development of mfg techniques for honeycomb structures, containment block, other special components	Brazing equipment, electron beam welders
Manufacturing Commodity Shops	Support AMT, Engr Labs, T/E element, couple, module and generator assembly areas for standard type hardware	Sheet metal, welding, machine shop, heat treat, finishing
T/E Module and Generator Assembly Area	Fabrication, assembly and production testing modules and generators	Seebeck voltage testers, dry box line, outgassing equipment
T/E Element and Couple Manufacturing Area	Fabrication and production testing of T/E elements and couples	Induction and resistance furnaces, pulverizers, bonding furnaces, dry boxes, temperature recorders, vacuum and purge equipment
Quality Control Laboratories	Monitoring of all materials, processes and controls used in all areas of fabrication	Receiving, engineering, product inspection and calibration

Detailed descriptions of the facilities directly applicable to the Po RTG development program were presented in MND-5137. Since preparation of the referenced proposal, several major facility acquisitions, directly applicable to this program, have been made. These include: (1) a 28,000-pound force shaker (MB-210 vibration system) which will be in operation on or before 1 April 1966 in the Environmental Laboratory (Fig. IV-1); (2) an expanded and improved module assembly line which will be in operation approximately 1 January 1966 with a "dry box" controlled atmosphere environment for the critical module assembly operations (Fig. IV-2).

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Additional equipment, minor in nature, will be required to augment our existing capabilities. Martin will provide approximately \$170,000 in capital funds early in the program to ensure timely availability of the necessary facilities to accomplish the RTG program.

Consistent with normal practice, the plan provides for the conduct of several specialized manufacturing operations, as well as some off-site testing due to the special nature of the operation or the single-purpose use of a facility. These include the following probable operations and/or testing capabilities:

- (1) Brazing fuel containment structure--a large high temperature brazing capability
- (2) Aircraft drop tests--Tonapah, Nevada
- (3) Wind tunnel tests--Arnold Engineering Development Center, Tullahoma, Tennessee
- (4) Performance and acceptance testing--Large Space Thermal Vacuum Chamber, General Electric, Valley Forge
- (5) Electromagnetic testing--NASA-Goddard.

Table IV-2 depicts the total facility requirements for the Po RTG program and shows, by phases, the facilities required for a particular major component or system from the beginning of the subsystem development to the delivery of the flight demonstration system. Subcontracted facilities and additional equipment requirements are noted.

Figure IV-3 shows the utilization schedule for these facilities.

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TABLE IV-2
Po RTG Facility Requirements

Facility Description		Months	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	26	27
Engineering	Digital Computations		▲																										
	Hot Shot Wind Tunnel			▲																									
	Materials Laboratory Complex			▲																									
	Revetment Test Area					▲																							
	Radiant Heat Equipment					▲																							
	Liquid Metal R&D Laboratory			▲																									
	C-25 Vibration System			▲									▲							▲									
	Hyge Shock Machine			▲																									
	MB-210 Vibration System											▲					▲												
	Rucker Centrifuge											▲						▲											
	Small Vacuum Chamber					▲																							
	Acoustic Facility						▲																						
	6- by 15-ft Thermal Vacuum Chamber											▲					▲												
	Medium Impact Machine																	▲											
	T/E Element and Couple Development Laboratory	▲										▲								▲									
	Metallographic Laboratory	▲																											
	Mockup Area--AGE			▲																									
	Additional Requirements																												
	Voltage Regulators			▲																									
	Wattmeters			▲																									
	Residual Gas Analyzer			▲																									
	T/E Couple Testers			▲																									
	Subcontract Requirements																												
	Drop Test--Tonopah, Nevada								▲																				
	Wind Tunnel--AEDC					▲																							
	Electromagnetic--NASA Goddard														▲														
	Large Space Thermal Vacuum Chamber--GE																		▲	▲	▲			▲		▲		▲	
Manufacturing	AMT Laboratory																												
	Brazing Furnace			▲									▲						▲										
	Electron Beam Welder			▲									▲						▲										
	Manufacturing Commodity Shops			▲																									
	T/E Module and Generator Assembly Area																												
	Dry Box Line				▲								▲							▲									
	T/E Element and Couple Manufacturing Area	▲											▲																
	Quality Control Laboratories	▲																											
	Additional Requirements																												
	New Dry Boxes			▲																									
	Vacuum Pump			▲																									
	Leak Detector			▲																									
	Resistivity Testers			▲																									
	Outgassing Equipment			▲																									
	Bonding Furnace			▲																									
	Temperature Recorders			▲																									
	Subcontract Requirements																												
	Large Brazing Capability				▲											▲					▲								

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RTG Item	Phase II Development		Phase III Prototype		Phase IV Flight Demonstration	
	Fabrication	Test	Fabrication	Test	Fabrication	Test
Heat Source	AMT Lab Mfg Commodity Shops Quality Labs *Subcontract Brazing facility	Digital Computations Hot Shot wind tunnel Materials Lab complex Revetment test area Radiant heat equipment *Subcontract Tonapah, Nevada AEDC tunnels	Mfg Commodity Shops Quality Labs *Subcontract Brazing facility	See RTG system	Mfg Commodity Shops Quality Labs *Subcontract Brazing facility	See RTG system
Coolant Heat Rejection System	Advance MTL Mfg Commodity Shops Quality Labs	Digital Computations Liquid Metal Research & Development Lab C-25 vibration system Hyge shock machine	Mfg Commodity Shops Quality Labs	Production Testing C-25 vibration system MB-210 vibration system Performance, Qualification and Acceptance See RTG system	Mfg Commodity Shops Quality Labs	Production Testing C-25 vibration system Performance and Acceptance See RTG system
Radiator	Same as above	Digital Computations Materials Lab complex MB-210 vibration system	Same as above	Production Testing Same as above Performance testing 6- x 15-ft thermal vacuum chamber Qualification Testing MB-210 vibration system Medium impact machine Acceptance Testing Same as above at reduced levels	Same as above	Production Testing C-25 vibration system C-210 vibration system Acceptance Testing Same as above
Thermal Controls	Same as above	Digital Computations Environmental Lab	Same as above	Production Testing Same as above	Same as above	Production Testing Same as above Performance and Acceptance See RTG system
T/E Modules	T/E Module & Generator Assembly Area Quality Control Labs *Additional requirements New dry boxes Vacuum pumps Leak detector Resistivity testers Outgassing equipment	Small Power Plant Lab C-25 vibration system Hyge shock machine *Additional requirements Voltage regulators Wattmeters Residual gas analyzer	T/E Module & Generator Assembly Area Quality Control Labs	Production Testing C-25 vibration system Electrical instrumentation Performance, Qualification and Acceptance See RTG system	T/E Module & Generator Assembly Area Quality Control Labs	Production Testing C-25 vibration system Electrical instrumentation Performance and Acceptance See RTG system
T/E Elements	T/E Element and Couple Development Lab Metallographic Laboratory T/E Element and Couple Mfg Area Quality Control Labs *Additional requirements Bonding furnace Temperature recorders	T/E Development Lab Production Testing Seebeck and resistivity testers Couple testers	T/E Mfg Area Quality Control Labs	Production Testing Seebeck and resistivity testers Performance, Qualification and Acceptance See RTG system	T/E Mfg Area Quality Control Labs	Production Testing Seebeck and resistivity testers Performance and Acceptance See RTG system
RTG System Components	Advance MTL Mfg Commodity Shops Quality Control Labs	Environment Lab *Subcontract Electromagnetic capability				
Preprototype	Same as above	Performance Testing Small Power Plant Lab MB-210 vibration system 6-ft x 15-ft space thermal vacuum chamber Medium impact machine Rucker centrifuge (D)				
Prototype Units			Mfg Commodity Shops T/E Module & Generator Assembly Area Quality Control Labs *Subcontract Brazing facility	Production Testing Electrical inspection equipment C-25 vibration system Seebeck and resistivity testers Performance Testing Small Power Plant Lab Electrical inspection equipment Generator test console Qualification Testing C-25 vibration system MB-210 vibration system 6-ft x 15-ft space thermal vacuum chamber Rucker centrifuge (D) Electrical inspection equipment Generator test console *Subcontract Large space thermal vacuum chamber Acceptance Testing Same as above at reduced levels		
Flight Demonstration Units					Mfg Commodity Shops T/E Module & Generator Assembly Area Quality Control Labs *Subcontract Brazing facility	Production Testing C-25 vibration system MB-210 vibration system Small Power Plant Labs Electrical inspection equipment Performance and Acceptance Testing *Subcontract Large space thermal vacuum chamber Generator test console Electrical inspection equipment
AGE	Mfg Commodity Shops Precision mfg Wood shop Quality Laboratories	Mockup Area Misc support equipment C-25 vibration system MB-210 vibration system	Mfg Commodity Shops Quality Labs	Production Testing Normal inspection equipment Performance Testing Mockup area Misc support equipment Qualification and Acceptance Testing Same as above	Mfg Commodity Shops Quality Labs	Production Testing Normal inspection equipment Performance and Acceptance Testing Mockup area Misc support equipment
RTG Component Advanced Development	T/E Development Lab _____ (as required) _____					
	AMT Laboratory _____ (as required) _____					
	Materials Laboratory Complex _____ (as required) _____					
	6- x 15-ft space thermal vacuum chamber _____ (as required) _____					
	C-25 and MB-210 vibration systems _____ (as required) _____					
	Small Power Plant Laboratory _____ (as required) _____					
	Hyge shock machine _____ (as required) _____					
	T/E Module & Generator Assembly Area _____ (as required) _____					
	Quality Control Laboratories _____ (as required) _____					
	Mfg Commodity Shops _____ (as required) _____					

NOTES *Additional and/or subcontract facilities

Fig. IV-3. Facility Utilization Schedule

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APPENDIX A

GENERATOR TESTING REQUIRED

This appendix describes the various types of tests to be performed on the generator and its components in determining reliability and performance.

A. TEST DESCRIPTIONS

1. Performance and Drift

Performance testing comprises an electrical parametric evaluation of module output at a constant heat input. The results of this evaluation are plotted to show load voltage, power output, hot and cold junction temperature and internal resistance as a function of load current.

The drift study (power and voltage degradation versus time) is accomplished by maintaining a fixed heat input to the module and a fixed resistive load on the module output for test durations of many thousands of hours. Drift information is obtained by observing the behavior of power output, hot and cold junction temperatures, internal resistance and open circuit voltage as a function of time.

2. Thermal Cycling

Thermal cycling is accomplished by alternately heating the module to operating temperatures and cooling it to room temperature at some specified rate for a specific number of times or until failure, whichever is specified.

During this test, particular attention is paid to internal resistance and power output. Ultimately, these parameters become statistically significant, and curves may be plotted showing their behavior as a function of the number of cycles.

Initially, the heating and cooling rates will be established by submitting three modules to three different heating and cooling rates after initial outgassing. A curve of these rates as a function of module internal resistance will be plotted to determine the best rate for testing the seven modules.

3. Over-temperature

Over-temperature tests are basically off-design performance tests used to determine the extent to which output power and voltage may be affected by the over-temperature. Such tests usually require test-

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ing to failure either by increasing the time held at the above-normal temperature or by increasing the temperature in specific increments and maintaining each increment for some specified period of time.

4. Dynamic Testing

Dynamic tests will be conducted on the various power system components and assemblies during the development and manufacturing phases of the program. These tests will demonstrate the ability of the system to withstand and function under the mechanical environments of its planned mission. In addition, the program is designed to establish reliability and to verify the integrity of all components of the power supply system, as well as the complete system, under the most critical mechanical environments experienced during vehicle launch and powered flight. Except where specified, the test items will be in their normal mode of operation during application of the environments.

Each component tested will be instrumented in a manner designed to reveal deficiencies in mechanical design. All functional components will be maintained at stabilized operating conditions throughout the environmental exposures. During application of the dynamic conditions, critical operating parameters such as specimen temperatures, electrical input and output, etc., will be monitored continuously by permanent oscillograph recording.

Design qualification tests will include the following dynamic environments, applied at the specified levels.

a. Sinusoidal vibration

5 to 15.5 cps at 0.4-inch peak-to-peak displacement

15.5 to 400 cps at 5 g peak

400 to 2000 cps at 15 g peak

The frequency range of 5 to 2000 cps will be swept three times in each of three orthogonal axes at a logarithmic rate of one octave per minute. The major axes selected will be the launch vehicle thrust axis and two lateral axes.

b. Random vibration

Random vibration with a white gaussian distribution will be applied with the following bank limits and acceleration spectral densities:

20 to 400 cps at $0.20 \text{ g}^2/\text{cps}$

400 to 2000 cps at $0.40 \text{ g}^2/\text{cps}$

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Three frequency bands will be applied simultaneously for a duration of five minutes in each of three orthogonal axes.

c. Shock

One shock pulse, having a half-sine wave form with a peak of 40 g and a duration of eight milliseconds, will be applied in the thrust axis and in each direction of the two lateral axes.

d. Acceleration

A constant acceleration of 15 g will be applied for a duration of five minutes in the positive thrust direction.

e. Acoustic noise

To be isolated from chamber wall influences, the test item will be suspended in the acoustic chamber and will be subjected to random acoustic excitation with a sound pressure level of 144 db over the frequency range of 20 cps to 10 kc.

5. Thermal Vacuum

Thermal vacuum testing will be performed on components, modules and the complete generator to verify proper operation in the harsh environment of outer space. The thermal vacuum testing will be performed at pressures of 1×10^{-6} torr or lower and for ambient temperatures and temperature cycles similar to those of orbital operation.

Three vacuum chambers are available for use in this Program. They are:

- (1) Martin 3- x 4-foot ultrahigh vacuum chamber
- (2) Martin 6- x 15-foot vacuum chamber
- (3) GE 12- x 26-foot vacuum chamber.

All chambers are capable of attaining pressures below 1×10^{-6} torr. The two Martin chambers can achieve cold wall temperatures of -250° to +250° F; the GE chamber is capable of -150° to +150° F.

B. TEST SPECIFICATION DEVELOPMENT

1. Test Procedures

Test procedures will be prepared for the various tasks involved in the test program. These procedures will ensure that specified environmental requirements are met and will detail failure and retest

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criteria as well as methods of handling test specimens. Operation of the specimen during test, required instrumentation and methods of data acquisition will be studied, and necessary test equipment listed.

Each task also includes establishing the details of the acceptance tests and issuing the appropriate test documents, establishing the operating requirements, issuing test directives and writing test procedures for the qualification tests to be performed on components and complete systems.

2. Test Fixture Designs

Test fixtures will be designed to incorporate heaters, insulation or other features necessary for proper operation of the various specimens during test. For excitation in all test axes, the fixtures will provide for adequate mounting to the acceleration, shock and vibration exciters. Mounting of each component in the fixture will simulate its attachment in the power supply assembly or spacecraft application. The dynamic design will ensure that fixture resonances do not occur in the test range and that mechanical inputs of the specimen mounting points comply with those specified.

3. Test Reports

A detailed report presenting the results of each task in the test program will be prepared. The reports will include all functional data recorded, tabulation of significant data reduced from oscillograph recordings and engineering observations made during the tests. All test setups and any failures incurred will be fully documented by photographs.

The test reports will include curves of load voltage, power out, hot and cold junction temperatures as a function of load current, curves of these functions and internal resistance as a function of time. Curves showing power input as a function of temperature distribution and the aforementioned parameters as a function of time will also be included. The reports will also include analyses of the data, conclusions and recommendations.

C. PROBLEM AREAS AND METHODS OF SOLUTION

1. Dynamic Testing

Compliance with specified qualification vibration levels is limited by the capabilities of existing vibration exciters. Due to a practical displacement limit of 0.4 inch on all electrodynamic shaker systems, the low frequency portion of the sinusoidal vibration test has been stated

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as 5 to 15.5 cps at 0.4-inch peak-to-peak displacement rather than 0.5 inch. Similarly, the upper frequency limit of this system is 2000 cps, precluding vibration in the 2000- to 3000-cps range. Neither of these limitations, however, is considered to be a significant problem. The 0.1-inch reduction in peak-to-peak displacement is rather inconsequential with respect to acceleration level at the low frequencies involved. The 2000- to 3000-cps range, although a design requirement, is not normally tested, due to the low stresses imposed on a structure by the extremely small displacements involved, the practical difficulty of obtaining a shaker system capable of responding to these frequencies without internal resonances, and the inability of most structural interfaces to transfer vibrational energy at such high frequencies.

Vibrational testing of all generator system components can be accomplished with equipment presently available at the Martin Company. A vibration facility with ample capacity for performance of all specified RTG system testing at flight acceptance levels has been purchased for the Company's new environmental laboratory, and will be available early in Phase II. Because of test fixture and RTG system weight, qualification level testing of the complete RTG system will have to be accomplished for the generator and radiator panels separately.

While all acceleration testing could be accomplished at Martin, it is felt that an undesirably large acceleration gradient (approximately 15 g) would be produced over the length of the RTG system by testing on the existing centrifuge with its nominal radius of gyration of 54 inches. Acceleration tests of the RTG and coolant heat rejection subsystem will be performed at the Martin test facility in Denver, Colorado, where a 17.5-foot radius accelerator is available.

2. Scheduling

The size of the developmental effort of Phase II requires a three-shift operation with prudent use of overtime on weekends.

3. Outgassing

Outgassing of modules and generators has been a consistent problem in past thermoelectric development programs. The goal of each has been the same, i. e., elimination of oxygen and other contaminants from the system, but the methods have varied. The problem areas consist of: (1) some rapid thermal cycling when beginning the evacuation or backfilling and (2) inability to achieve sufficiently low pressures when near the BOL operating temperature.

One method of eliminating or reducing the thermal cycle is to shut off the power input to the module or generator prior to backfilling and allowing the heater plate temperature to begin to fall off, then reducing the thermal energy for transfer to the T/E elements.

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The second problem can be eliminated by using pumps of ample capacity and the hard (stainless steel or copper) evacuation lines. A residual gas analyzer will be used as an aid in determining when outgassing is complete.

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APPENDIX B

QUALITY NUCLEAR INVENTORY

NOTICE

All equipment listed is on loan from the Nuclear Division Facility. The tools and equipment are used in an area of high incidence of RADIOACTIVE CONTAMINATION and can not be moved from the work area identified as the Nuclear Lab and Pilot Shop of the Nuclear Division.

Decontamination is mandatory and in some instances where fixed contamination exists, removal from the Nuclear Facility is prohibited.

QUALITY FACILITIES INVENTORY

ITEM	NOMENCLATURE	MOD	PARAMETER	RANGE	ACCURACY	MFG.	EQUIPMENT NO.	COST \$	APPLIC.
1	Attachment Ball	960	Like Conversion	N/A	N/A	Do-All	None	1	
2	"	"	"	"	"	"	"	1	
3	"	"	"	"	"	"	"	1	
4	"	"	"	"	"	"	"	1	
5	Surface Indicator Acc. 31618		Surface Finish	"	"	Brush	50-002	1300	
6	Angle, Univ. Box	-	N/A	13x8x8	± .0005	Challenge	13-051	105	
7	"	-	"	"	"	"	13-052	105	
8	Block, Hoke (Sq.)	/86-S	Transfer Gages	.050-4"	"A"	Do-All	18-003	510	
9	" " (Mfg. Std.)		Attachments	N/A	N/A	"	18-004	200	
10	" "V"	550-750-2	Set Up	2"x2 ¹ / ₂ "x2 3/4"	± .0002	B & S	13-032	150	
11	" "	VR-667	"	6"x6"x7"	± .0005	Challenge	13-056	150	
12	" "	"	"	"	"	"	13-057	150	
13	" Hoke	2-.050	Transfer Gages	.050	"A"	Do-All	18-005-1	30	
14	" "	"	"	"	"	"	18-005-2	30	
15	" "	2-.100	"	.100	"	"	18-006-1	30	
16	" "	"	"	"	"	"	18-006-2	30	

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QUALITY FACILITIES INVENTORY

ITEM	NOMENCLATURE	MOD	PARAMETER	RANGE	ACCURACY	MFG.	EQUIPMENT NO.	COST \$	APPLIC.
32	Clamp, Parallel	754B	N/A	1"	N/A	B & S	18-008	10	
33	"	"	"	"	"	"	18-009	10	
34	"	754D	"	2"	"	"	18-010	12	
35	"	"	"	"	"	"	18-012	12	
36	"	"	"	"	"	"	18-013	12	
37	"	754F	"	3 $\frac{1}{2}$ "	"	"	18-014	20	
38	"	"	"	"	"	"	18-016	20	
39	"	"	"	"	"	"	18-017	20	
40	Calipers, Vernier	75-6	Length	6"	$\pm .0005$	Do-All	03-012	45	
41	"	-	"	0-6"	"	Mausser	03-033	18	
42	" (conventional)	I.D.O.D. 75-6	"	0"	"	Do-All	03-013	45	
43	" "	I.D.O.D. 122	"	-6"	"	Starrett	03-014	30	
44	Calipers, Vernier (Conventional)	"	"	12"	"	Do-All	03-017	30	
45	"	"	"	"	"	"	03-016	-	
46	" (conventional)	122	"	"	"	Starrett	03-015	36	
47	" (U.C.)	"	"	24"	"	Do-All	03-018	115	
48	" Vernier (conventional)	75-36	"	36"	"	"	03-019	160	

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QUALITY FACILITIES INVENTORY

ITEM	NOMENCLATURE	PARAMETER	RANGE	ACCURACY	MFG.	EQUIPMENT NO.	COST \$	APPLIC.
49	Calipers, Vernier (Conv.) 75-72	Length	72"	± .0005	Do-All	03-020	420	
50	Calipers, Transfer #36	N/A	6"	N/A	Starrett	11-017	2	
51	Centers, Bench 763	Concentricity	36"x3"	± .002	B & S	51-001	375	
52	Comparator-Surf.Fin. 81-34-30	RMS	4-2000	N/A	B & L	50-013	30	
53	Gage, Vernier 95-6	Depth	6"	± .0005	Do-All	03-022	30	
54	Gage, Set-Radium 167CH	Radii	1/64"x1/2"	N/A	Starrett	14-011	2	
55	Gage, Blocks -	Angle	45°	± 1"	Webber	18-008	5	
56	Gage, Vernier 96-0-12	Depth	0-12"	± .005	Do-All	03-021	40	
57	Gage, Feeler 802T	N/A	1/8" .025	± .0002	"	14-C12	6	
58	Gage, Vernier -	Height	36"	± .003	Tunico	15-010	275	
59	" -	"	12"	± .001	Chesterman	15-005	275	
60	" -	"	"	"	"	15-006	275	
61	" -	"	24"	± .002	"	15-007	275	
62	" -	"	"	"	"	15-008	275	
63	Gage, Half-Hole 830F	Hole Size	1/8"-1/2"	N/A	Starrett	10-010	20	
64	Gage, Optical -	Weight	37"	.00005	Webber	15-009	2150	
65	Gage, Pin (Fractional) -	Drill Size	3/64-1/2	± .0000	Horberg	18-011	90	
66	Gage, Pin (Number) -	"	1-60	"	"	18-010	90	

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QUALITY FACILITIES INVENTORY

ITEM	NOMENCLATURE	PARAMETER	RANGE	ACCURACY	MFG.	EQUIPMENT NO.	COST \$	APPLIC.
67	Gage, (Letter) -	Drill Size	A-Z	± .0001	Horberg	18-009	90	
68	Gage, Planer 995L	Set Up	1 ¹ / ₂ -6 ¹ / ₄	NA	Starrett	19-007	30	
69	" "	"	"	"	"	19-008	30	
70	" "	"	"	"	"	19-009	30	
71	" "	"	"	"	"	19-010	30	
72	Gage, Taper Parallel 672	Hole Size	1 ¹ / ₂ "-1"	"	B & S	13-030	40	
73	" "	"	"	"	"	13-031	40	
74	Gage, Telescope 579H	"	1 ¹ / ₂ "-6"	"	Starrett	10-009	18	
75	Hammer, Plastic 592	NA	1 ¹ / ₂ oz.	"	Stanley	26-011	1	
76	" 594	"	8 oz.	"	"	26-015	2	
77	Indicator (Jeweled contact)	Small bore	.187-.500 x 13 ¹ / ₂	± .001	Boice	02-026	240	
78	"	"	"	"	"	02-027	240	
79	Indicator 3L110	Surface Finish	0-1000RMS	± 10%	Brush	50-002	850	
80	Indicator, Universal 599-7025	NA	.030	.0005	B & S	02-015	30	
81	" "	"	"	"	"	02-016	30	
82	" "	"	"	"	"	02-017	30	
83	" "	"	"	"	"	02-018	30	
84	" "	"	"	"	"	02-019	30	

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ITEM	NOMENCLATURE		PARAMETER	RANGE	ACCURACY	MFG.	EQUIPMENT NO.	COST \$	APPLIC.
85	Indicator, Universal	599-7025	N/A	.030	.0005	B & S	02-020	30	
86	"	"	"	"	"	"	02-021	30	
87	"	"	"	"	"	"	02-022	30	
88	"	"	"	"	"	"	02-023	30	
89	"	"	"	"	"	"	02-024	30	
90	Indicator, Electronic	1A-505R	Height	0-24"	± .000050	Cleveland	02-25	675	
91	Kit, (Portable Elect.)	-	Marking	N/A	N/A	Ideal	52-004	15	
92	Indicator, Dial	-	N/A	± .004"	.00005	Federal	02-048	37	
93	Level, Mechanics 18"	98	Leveling	.030	± .005	Starrett	06-010	15	
94	Balls		Balancing	20" x 66"	N/A	Carcy	51-002	90	
95	Scale, Flex.	C3052	Length	12"	"	Starrett	07-022	2	
96	"	"	"	"	"	"	07-023	2	
97	Scale, Rigid	C604RE	"	"	"	"	07-019	2	
98	Screw Driver (Set)	-	Jewelers	N/A	N/A	"	27-048	3	
99	Screw Driver	-	Torque	22 in. lbs.	"	Go-All	27-014	16	
100	"	-	"	"	"	"	27-015	16	
101	"	-	"	"	"	"	27-046	16	
102	Scribe, Std.	701	Mark	N/A	N/A	Starrett	25-006	1	

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QUALITY FACILITIES INVENTORY

ITEM	DESCRIPTION	MOD	PARAMETER	RANGE	ACCURACY	MFG.	EQUIPMENT NO.	COST \$	APPLIC.
103	Sineometer (Mfg.Std.)	1775	Angles	180°	$\pm \frac{1}{2}^{\circ}$	Cleveland	18-017	160	
104	Square (Tool Marker)	-	Squareness	6"	$\pm .0001$	Starrett	04-005	16	
105	Stand-Surface Plate(Granite)		NA	4' x 6'	NA	Do-ALL	E084935	160	
106	Straight Edge & Base Blocks		Calibration	36"x1 $\frac{1}{2}$ "x5"	$\pm .000050$	"	04-006	315	
107	Surface Plate (Granite)		Set Up	48" x 72"	$\pm .00015$	"	13-046	1860	
108	Tape, Vernier	-	Diameter	12"	$\pm .001$	Norm. Collins	07-013	15	
109	"	-	"	24"	"	"	07-014	17	
110	"	-	"	36"	"	"	07-015	19	
111	Wax Pot	-	NA	1 Qt.	NA	Benson	30-003	20	
112	Wrench (Adjustable)	A-16	NA	6"	NA	Crescent	08-063	1	
113	Weights(Stainless Steel)	842759	Gms/Kilograms	100/1	N.P.S."S"	Seeder K	8A2759	-	
114	Balance	650	GMS	1-1000	± 1 Gm.	Ohaus	None	-	
115	Balance	4030	Weight	To 111 Gms.	$\pm .01$ Gms.	Fisher	None	-	
116	Magnifier (Illum.)	81-34-34	$\frac{1}{2}$ " Field	10 x 1"	NA	B & L	50-008	30	
117	Magnifier (Measuring)	-	3/4" Field	7X	NA	"	50-007	38	
118	Micrometer-Comb.	CI	O.D.	0-1"	$\pm .002$	Tunico	01-038	*	Combined price

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QUALITY FACILITIES INVENTORY

ITEM	NOMENCLATURE		PARAMETER	RANGE	ACCURACY	MTG.	EQUIPMENT NO.	COST \$	APPLIC.
119	Micrometer - Comb.	C.I.	OD	1-2"	± .0002	Tumico	01-039	*	Comb.Price 160
120	"	"	"	2-3"	"	"	01-040	*	
121	"	"	"	3-4"	"	"	01-041	*	
122	"	"	"	4-5"	"	"	01-042	*	
123	"	"	"	5-6"	"	"	01-043	*	
124	"	"	ID	8.5"	"	"	01-044	*	
125	Micrometer	D5-6	Depth	0-6"	"	Do-All	01-063	37	
126	"	"	"	2 $\frac{1}{2}$ "-6"	"	"	01-073	30	
127	"	T-101	isc.	0-1"	"	"	01-072	35	
128	"	H-163	"	"	"	"	01-070	24	
129	"	-	Length	"	"	B & S	01-150	25	
130	"	-	"	"	"	"	01-150	25	
131	"	-	"	1"-2"	"	Starrett	01-131	36	
132	"	-	"	0-1"	"	"	01-132	29	
133	Micrometer (Vee Anvil)	-	"	.093"-1"	"	"	01-133	90	
134	Micrometer	-	"	0-1"	"	B & S	01-152	25	

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ITEM	NOMENCLATURE	PARAMETER	RANGE	ACCURACY	MFG.	EQUIPMENT NO.	COST \$	APPLIC.
135	Micrometer (Mul-T-Anvil)	Length	0-1"	$\pm .0002$	Starrett	01-080	38	
136	" 220	"	1"-2"	"	"	01-081	50	
137	" I-21	Inside	.200"-1"	"	Do-111	01-071	32	
138	" I-1536	"	1 $\frac{1}{2}$ "-36"	"	"	01-065	56	
139	" "CT-1	Outside	0-1"	"	"	01-064	25	
140	" -	"	1"-2"	"	"	01-146	280	
141	" -	"	2"-3"	"	"	01-047	280	
142	" -	"	3"-4"	"	"	01-048	280	
143	" -	"	4"-5"	"	"	01-049	280	
144	" -	"	5"-6"	"	"	01-050	280	
145	" -	"	0-1"	"	"	01-051	280	
146	" -	"	1"-2"	"	"	01-052	280	
147	" -	"	2"-3"	"	"	01-053	280	
148	" -	"	3"-4"	"	"	01-054	280	
149	" -	"	4"-5"	"	"	01-055	280	
150	" -	"	5"-6"	"	"	01-056	280	

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ITEM	NOMENCLATURE	MOD	PARAMETER	RANGE	ACCURACY	TEG.	EQUIPMENT NO.	COST \$	APPLIC.
151	Micrometer	CT-612	Outside	6"-7"	± .0002	Do-All	01-057	210	
152	"	-	"	7"-8"	"	"	01-058	210	
153	"	-	"	8"-9"	"	"	01-059	210	
154	"	-	"	9"-10"	"	"	01-060	210	
155	"	-	"	10"-11"	"	"	01-061	210	
156	"	-	"	11"-12"	"	"	01-062	210	
157	"	-	Super	10"	± .0001	P & V	EQ-84902	910	
158	"	-	Tube	0- $\frac{1}{2}$ "	± .0002	Do-All	01-066	21	
159	"	-	"	"	"	"	01-067	21	
160	"	-	"	"	"	"	01-074	21	
161	"	-	"	"	"	"	01-175	21	
162	"	"-161	Pin	0-1"	"	"	01-068	19	
163	"	"	Tube	"	"	"	01-069	19	
164	Parallel	S-154D	Adjustable	3/16"-15/16"	1/16"	Starrett	13-028	5	
165	"	"	"	"	"	"	13-029		
166	Parallels Set	-	Set Up	9x11x3	± .0005	Challenge	13-049	70	

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ITEM	NOMENCLATURE	MOD	PARAMETER	RANGE	ACCURACY	MTG.	EQUIPMENT NO.	COST \$	APPLIC.
167	Parallels Set	-	Set Up	9 x 4 1/2 x 8	± .0005	Challenge	13-050	70	
168	"	-	"	6 x 3 x 4	"	"	13-047	35	
169	"	-	"	"	"	"	13-048	35	
170	Parallels Precision	C	"	1 1/2 x 3	± .0002	T & P	13-043	360	
171	"	"	"	1 3/8 x 2 3/4	"	"	13-044		
172	"	"	"	1 x 2 1/2	"	"	13-045		
173	Plate	AP-187	angle	18"x18"x18"	± .0015	Challenge	13-046	270	
174	Protractor(Univ.Bev)	359F&G	"	360°	± 1°	Starrett	05-003	30	
175	Hardness Tester (Rockwell)		Superficial	NA	HA	Wilson	51-003	670	
176	Water Temp.Control Unit	11FV3	Cooling Sys.	85°-650°	NA	G.E.	83509	1900	
177	Film Cutter-Corner	50	NA	NA	NA	Laske	83510	70	
178	Film Dryer-Circular	1	"	"	"	G.E.	83510	490	
179	"	"	"	"	"	"	83529	490	
180	Illuminator	11FV1	X-Ray	14" x 17"	NA	"	83510	95	
181	"	"	"	"	"	"	83529	95	
182	Condensing Unit	-	Cooling	NA	NA	"	86082	750	
183	Dark Room Equipment	-	Storage	"	"	Metallab	86082		

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ITEM	NOTATION	MOD	PARAMETER	RANGE	ACCURACY	INF.	EQUIPMENT NO.	COST \$	APPLIC.
184	Degassing Gun	QD	Heat Source	500°F	NA	Vac. Elect.	EQ60606	35	
185	Calibrated Leak	SC-4	cc/Sec.	1 x 10 ⁶	± 10%	"	None	85	
186	Measuring Wires	LL	Thread	40-3½	± .0001	Flynn	None	4	
187	Borescope	-	Length	36"	NA	National	88157	295	
188	Vac. Pump Station	MUD1962	Leak Test	10 ⁻⁶ mm HG	30 CFM	Martin	EO60732	10468	
189	Microscope & Illum.	-	1/16-¼ Field	30X	NA	B & L	60746	632	
190	Leak Test System	MS9AB	Mass Spect.	1 x 10 ⁻¹⁰ cc/Sec.	± 10%	Vac. Elec.	60606	5290	
191	Calculator & Cover (Auto)		NA	NA	NA	Friden	100751	800	
192	Microscope, Desk	-	"	"	"	Metalab	30118	350	
193	Lead Top Table (Portable)		X-Ray	"	"	"	30119	230	
194	Microscope, Desk	-	NA	NA	NA	"	30350	180	
195	Dark Room Cabinet	-	X-Ray	"	"	P. X-ray	30376	38	
196	Dark Room Cabinet (Base)		"	"	"	"	30377	80	
197	Film Loading Cabinet (Metal)		"	"	"	"	30378	90	
198	Cabinet (Metal) 6' x 3' x 2'		NA	NA	NA	Lyon	40556	25	
199	Dip Tray Set for Illuminator		"	"	"	G.E.	-	6	

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QUALITY FACILITIES INVENTORY

ITEM	NO. ENCLATURE	PARAMETER	RANGE	ACCURACY	MFG.	EQUIPMENT NO.	COST \$	APPLIC.
200	Stacking Trin for 2 driers	X-Ray	NA	NA	G.E.	None	16	
201	S.S. Solution Tank 11FV3	X-Ray	5 Gal.	NA	G.E.	Part of DQ-83509	45	
202	" "	"	"	"	"	"	45	
203	" "	"	10 Gal.	"	"	"	55	
204	" "	"	"	"	"	"	55	
205	" " " Cover	EL080C Tank	"	"	"	"	8	
206	" "	"	"	"	"	"	8	
207	Interval Timer (Ivory)	Minutes	2 Hrs.	NA	"	None	12	
208	Paddles, Solution Mix 1-3822	Set of 2	NA	NA	"	"	7	
209	Brush, Tank Cleaning -	X-Ray	"	"	"	"	2	
210	" -	"	"	"	"	"	2	
211	Welded Tank Truck -	20" wheel to Cyl.	"	"	Air Eng.	"	-	
212	Oil Stream Gun H.V.	Spray Gun	"	"	"	"	10	
213	Calibrated Leak 1716	cc/Sec.	1/m/cf/hr	Not Avail	"	"	35	
214	Light Fixture (Float w/3X magn.)	Magnifier	3X	NA	Dazor	"	38	
215	" "	"	"	"	"	"	38	

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SUPERVISOR L. Weinkam

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QUALITY FACILITIES INVENTORY

ITEM	DESCRIPTION	MOD	PARAMETER	RANGE	ACCURACY	MFG.	EQUIPMENT NO.	COST \$	APPLIC.
232	Sieve, U.S. Std.	#140	Microns	105 μ	$\pm$ 6%	Newark Wire & Cloth Co.	NBS #11634	-	
233	"	#170	"	88 μ	"	"	NBS #13048	-	
234	"	#200	"	74 μ	$\pm$ 7%	"	NBS #13049	-	
235	"	#230	"	63 μ	"	"	NBS #13050	-	
236	"	#270	"	53 μ	"	"	NBS 13051	-	
237	"	#235	"	44 μ	"	"	NBS #11305	-	
238	Scale, Surface	-	Roughness	3-2000 μ IS	NA	G.E.	None	29	
239	Intra Micrometer	281	ID	.350-.425	I .0001	B & S	None	112	
240	Stop Watch	14-647-20	Time	10 Min.	0.1 Sec.	Fisher	None	25	
241	Rivet Scope (Lico 382GN)		I.D. Visual	10' x 5/8"	NA	Lennox	None	-	
242	Contour Projector	-	Optical Meas.	14"	$\pm$.0001	Kodak	50-001	-	
243	Borescope (Lico 474P)		Length	4' x 3/8"	NA	Lennox	MEL9792	-	
244	Intralink	-	ID	.350-.425	$\pm$.0001	B & S	None	112	
245	Flowmeter	-	Flow Rate	50 Gms.	NA	M Dis.	53-016	-	
246	Indisquare	-	Squareness & Straightness	16"	I .0001	Indisquare Co.	None	-	

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QUALITY FACILITIES INVENTORY

ITEM	NOMENCLATURE	MOD	PARAMETER	RANGE	ACCURACY	MFG.	EQUIPMENT NO.	COST \$	APPLIC.
247	Monochromatic Light	C2-582	Flatness	NA	NA	VanHeuren	None	-	
248	Optical Flats	VK 1-1171-1 VK 1-1171-2	"	1" x 2"	± .000004	"	None	-	
249	Contour Copy	-	Surface Duplication	4" x 7"	NA	Master Med. Mfg. Co.	None	12	
250	"	-	"	"	"	"	"	12	
251	"	-	"	4" x 4"	"	"	"	8	
252	"	-	"	"	"	"	"	8	

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SUPERVISOR L. Weinkam

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APPENDIX C
INSPECTION INSTRUCTIONS

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INSPECTION INSTRUCTIONS										SHEET 1 OF 3		PART NO. N0023110-009	
TITLE: COUPLE ASSEMBLY										REVISED			
QUALITY PLANNER BEAL			DATE 10-11-65		DCN ACCOUNTABILITY A								
STEP ITEM	CHARACTERISTIC				INSPECTION MEDIA				SHOP	INSP.			
	FAILURE TO OBSERVE THE FOLLOWING CHARACTERISTICS AS DESCRIBED SHALL BE CAUSE FOR REJECTION.												
	NOTE: EACH "P" AND "N" ELEMENT AND EACH COMPLETED COUPLE ASSY. SHALL BE IDENTIFIABLE RELATIVE TO ITS MATERIAL LOT,												
	FABRICATION CYCLES, INSPECTION, AND TEST. THIS CONTROL IS TO BE MAINTAINED THROUGH THE USE OF RECORD SHEETS AND MARKED POLYETHYLENE												
	BAGS OR TRAYS. MARKS OR SCRIBES ON INDIVIDUAL ELEMENTS OR COUPLE ASSYS. ARE PROHIBITED.												
1	EVIDENCE OF PREVIOUS INSPECTION OF "P" AND "N" ELEMENTS, AND				OBSERVE COMPLETED THERMOELECTRIC RECORD SHEETS FOR 3M-TEGS-2PB								
	COLD AND HOT SHOES.				AND -2NB ELEMENTS AND COMPLETED MANILA TAG FOR N0023110-001, -003 & -005								
					SHOES. INTEGRATE THERMOELECTRIC RECORD SHEETS WITH THIS I.I.								
2	TIN PLATING OF HOT AND COLD SHOES PER NPS 03-029:				OBSERVE CLEANING OF SHOES WITH METHYL ALCOHOL & "KIMWIPES", COATING OF								
	N0023110-001 - TIN PLATE COUNTERBORED AREA ON "N"				SURFACES TO BE TINNED WITH KESTERS 817 FLUX, HEATING OF SHOES ON HOT								
	SIDE ONLY. N0023110-005 - TIN PLATE				PLATE (WITH FLUXED SURFACE UP), THOROUGH WETTING & EVEN COATING								
	ONE SIDE ONLY.				OF SURFACE WITH PURE TIN SOLDER (REFER TO TABLE I IN NPS 03-029 FOR								
					AMOUNT OF TIN TO BE USED) USING SOLDERING IRON OPERATING AT 465 TO 515°F, REMOVAL OF FLUX FROM SHOES USING METHY								

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INSPECTION INSTRUCTIONS			SHEET 2 OF 3	PART NO. N0023110-009		
STEP ITEM	CHARACTERISTIC	INSPECTION MEDIA	SHOP	INSP.		
2	CON'TD FROM PG. 1.	ALCOHOL & WIPING DRY WITH "KIMWIPES."				
3	STORAGE OF SHOE SETS (IF NOT USED IMMEDIATELY AFTER TINNING)	OBSERVE - SHOE SETS PLACED IN POLYETHYLENE BAGS FILLED WITH INERT GAS & SEALED.				
4	PC DRUG FIXTURE LOADING (PER NPS 01-032)	OBSERVE POSITIONING OF HOT SHOES, "N" & "P" ELEMENTS, & COLD SHOES IN LOCATION CUTOUTS IN TOOL. REFER TO DRAWING N0023110 FOR COUPLE CONFIGURATION.				
5	BONNING OF COUPLE ASSEMBLY (PER NPS 01-032)	OBSERVE THAT THERMAL BURNER IS WITHIN CALIBRATION.				
	NOTE: RECORD FURNACE NUMBER & OPERATOR IDENTITY FOR EACH COUPLE ASSEMBLY.	OBSERVE PLACING OF BONNING FIXT. IN GLASS ATMOSPHERE CHAMBER & CHAMBER EVACUATION TO LESS THAN 1" HG (ABSOLUTE PRESSURE) & BACKFILLING WITH NITROGEN (3 CYCLES).				
		OBSERVE PURGING OF CHAMBER WITH HYDROGEN. OBSERVE BONNING CYCLE:				
		(A) PLACING OF GLASS CHAMBER IN FURNACE OPERATING AT 1650 ± 25°F.				
		(B) HOLDING OF BONNING FIXTURE AT 1450 ± 25°F FOR THREE MINUTES.				
		(C) REMOVAL OF CHAMBER FROM FURNACE & COOLING TO ROOM TEMPERATURE UNDER HYDROGEN. (USE OF FAN OR BLOWER IS PERMISSIBLE).				
		(D) PURGING OF HYDROGEN FROM GLASS CHAMBER WITH NITROGEN.				
		(E) REMOVAL OF BONDED COUPLES FROM BONNING FIXTURE.				

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INSPECTION INSTRUCTIONS			SHEET 3 OF 3	PART NO. N0023110-009
STEP ITEM	CHARACTERISTIC	INSPECTION MEDIA	SHOP	INSP.
5	CONT'D. FROM PAGE 2	(F) REMOVAL OF FLASH AND OXIDE USING FILE 400 GRIT ABRASIVE PAPER.		
		(G) WIPING EACH COUPLE WITH "KIMWIPES" DAMPENED WITH METHYL ALCOHOL TO REMOVE DUST & FILINGS.		
6	DIMENSIONAL INSPECTION OF BONDED COUPLE	INSERT EACH BONDED COUPLE IN GO/NO-GO CHECK GAGE _____ TO VERIFY LENGTH,		
		SPACING, PERPENDICULARITY, PARALLELISM, AND DIAMETERS.		
7	9-POINT RESISTANCE CHECK NOTE: ACTUAL RESISTANCE VALUES MUST BE RECORDED FOR EACH COUPLE.	USE RESISTIVITY TESTING FIXTURE. OBSERVE THAT RESISTANCE READINGS ARE TAKEN AT POINTS SPECIFIED BY THE SCHEMATIC DIAGRAM ON DRAWING N0023110 & THAT RECORDED VALUES DO NOT EXCEED VALUES LISTED IN THE 9 POINT RESISTANCE CHECK TABLE ON DRAWING N0023110.		
8	STORAGE AND HANDLING	OBSERVE - EACH COUPLE IS PLACED IN A STYROFOAM CONTAINER (15 COUPLES PER CONTAINER WITH INDIVI- DUAL RECESSED COMPARTMENTS PER COUPLE) & PLACED IN ARGON FILLED SEALED POLYETHYLENE BAG.		
9	IDENTIFICATION	OBSERVE - EACH COUPLE HAS AN "ASSIGNED S/N" (AND HAS ITS "N" & "P" ELEMENT NO.'S RECORDED.		

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INSPECTION INSTRUCTIONS						SHEET 1 OF 2		PART NO. N0023112-001															
TITLE: HEAT SINK						QUANTITY INSP'D.						REVISED											
QUALITY PLANNER BEAL				DATE 10-4-65		DCN ACCOUNTABILITY		A															
STEP	ITEM	CHARACTERISTIC				INSPECTION MEDIA										SHOP	INSP.						
		FAILURE TO OBSERVE THE FOLLOWING CHARACTERISTICS AS DESCRIBED SHALL BE CAUSE FOR REJECTION:																					
		NOTE: CHARACTERISTICS IDENTIFIED WITH THE FOLLOWING SYMBOL Δ ARE TO RECEIVE 100% INSPECTION. (PERMISSABLE SAMPLING IS LISTED BELOW)																					
	1	MATERIAL IDENTIFICATION				AL ALLOY 6061-T6PL (QQ-A-327-T651)																	
	2	OVERALL DIMENSIONS .81 X 9.656 $\pm$.000 $\pm$.010 X 8.656 $\pm$.000 $\pm$.010				VERNIER CALIPER																	
	3	.5625 DIA. X .688 DEEP .5630				HEIGHT GAGE, GO/NO-GO HOLE GAGE, INDICATOR, & DEPTH MIKE, PROFILOMETER																	
		COUNTERBORES - 168 PLCS. (REFER TO DWG. FOR HOLE PATTERN LOCATIONS)				ALTERNATE - PICOM.																	
		E.D. = .375 $\checkmark$ 32																					
	4	.125 DIA. HOLES - 168 PLCS. THRU BASE OF COUNTERBORES-				HEIGHT GAGE, GO/NO-GO HOLE GAGE, INDICATOR - ALTERNATE - PICOM																	
		LOCATIONS - SAME CENTERS AS COUNTERBORES.																					
	Δ 5	.25 DIA. HLS. - 143 PLCS. (REFER TO DWG. FOR HOLE PATTERN & LOCATIONS) NORMAL - AQL 2.5				HEIGHT GAGE, GO/NO-GO HOLE GAGE, INDICATOR - ALTERNATE - PICOM																	
		BOTTOM SURFACE FLATNESS .002				SAMPLING PLAN - INSP. 20 RANDOMLY SELECTED HLS. ACCEPTANCE NO. 1 REJECTION NO. 2																	
	6					HEIGHT GAGE, INDICATOR																	

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INSPECTION INSTRUCTIONS			SHEET 2 OF 2	PART NO. N0023112-001		
STEP ITEM	CHARACTERISTIC	INSPECTION MEDIA	SHOP	INSP.		
7	SURFACE FINISH OF .5625 DIA. X .688 COUNTERBORES AND .5630	PROFILOMETER & VISUAL				
	BOTTOM SURFACE OF HEAT SINK 16 ✓					
8	SURFACE FINISH OF ALL MACHINED SURFACES (EXCEPT AS NOTED IN	PROFILOMETER & VISUAL				
	ITEMS 3 & 7 ABOVE) TO BE 63 ✓					
9	.031 X 45° CHAMFER ALONG 4 EDGES OF BOTTOM SURFACE.	SCALE - VISUAL				
10	ALL SHARP EDGES TO BE BROKEN .010 - .030 (EXCEPT AS NOTED IN					
	ITEM 9 ABOVE).					
11	IDENTIFICATION, CLEANLINESS, & PACKAGING	OBSERVE - MANILA TAG LISTING PART NO. QUANTITY, DCN STATUS, FOLDER LIST NO.,				
		& ACCEPTANCE STAMP. CLEANLINESS - OBSERVE SURFACE				
		APPEARANCE OF PTS. FOR ABSENCE OF CONTAMINATION OR CORROSION.				
		PACKAGING - CUSHIONING MATERIAL TO PROTECT EACH PART FROM NICKS				
		& SCRATCHES & POLYETHYLENE BAG TO PROTECT PT. FROM CONTAMINATION.				

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INSPECTION INSTRUCTIONS						SHEET 1 OF 2		PART NO. N0023101-001																
TITLE: COVER HEAT R. ASSEMBLY						Quantity Inspected _____						REVISED												
QUALITY PLANNER			DATE		DCN ACCOUNTABILITY		New																	
STEP ITEM	CHARACTERISTIC					INSPECTION MEDIA										SHOP	INSP.							
1	READ AND UNDERSTAND THE CONTENTS OF PAGES 1 THRU 2 OF THESE INSTRUCTIONS. FAILURE TO OBSERVE THE FOLLOWING CHARACTERISTICS AS DESCRIBED SHALL BE CAUSE FOR REJECTION.					RECORD FOLDER NUMBER																		
2	Material identification					SST Type 304 ASTM-A-240																		
3	Form cover to inside dimension 15.5 ^{+0.3} / _{-0.0} x 16.66 ^{+0.3} / _{-0.0} and outside height of 1.53					Vernier caliper and radius gage																		
	in. inside bend radius = .19																							
4	Bend relief radius .25 typ. 4 places.					radius gage																		
5	Cover cutout 3.00 edge distance typ. 9.656 x 10.656					Vernier caliper																		
6	Cutout radius .06 maximum. Typ. 4 places					radius gage																		
7	Spotweld edge distance .31 x .31 spaced 1.65 in. 5 places Typ. 4 corners					SPS 55031 welding, res. spot.																		
8	Drill cover mount holes .218 typ. 16 places. Edge distance .38 x 1.56 + 3					Vernier caliper																		
	equal spaces on 10.66 in. side and .38 x 1.62 + 3 equal spaces on 15.66 in. side																							
9	Break all sharp edges approximately .010					Visual																		
10	All surfaces finish 125					Profilometer																		
11	Identification					Observe manila tag listing part number, quantity, folder number, DCN status and acceptance stamp. Observe detail for corrosion/contamination.																		

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INSPECTION INSTRUCTIONS						SHEET 1 OF 1		PART NO. N0023101-003									
TITLE: BOTTOM COVER HEATER ASSEMBLY				Quantity Inspected		REVISED											
QUALITY PLANNER White		DATE 10/19/65		DCN ACCOUNTABILITY		New											
STEP	ITEM	CHARACTERISTIC				INSPECTION MEDIA				SHOP		INSP.					
	1	READ AND UNDERSTAND THE CONTENTS OF PAGE 1 OF 1 OF THESE INSTRUCTIONS. FAILURE TO OBSERVE THE FOLLOWING CHARACTERISTICS AS DESCRIBED SHALL BE CAUSE FOR REJECTION.				CORD FOLDER NUMBER											
	2	Material identification				SST Type 304 ASTM-A-240											
	3	Cover dimensions .063 x 16.66 $\pm .00$ x 15.00 $\pm .00$ x 2.25. $\pm .03$				Vernier caliper											
	4	Inside bend radius = .19 End relief radius = .25				radius gage											
	5	Cutout side panels to maintain .75 flange typ. 4 places & 2.00 in. legs ea. end of flange typ. 4 places to form 8 legs				scale											
	6	Radius flange cut .25 typ. 8 places (See drawing)				radius gage											
	7	Chamfer each leg 2 places 12 x 45° Typ. 16 places				scale											
	8	Break all sharp edges .010 R approx.				visual											
	9	Identification				Observe manila tag listing part number, quantity, DCN status, folder number and acceptance stamp. Observe detail for evidence of corrosion and/or contamination.											
	10	Packaging				Packing - Cushioning material to protect from distortion, nicks and scratches. Polyethylene bag detail to protect from contamination.											

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INSPECTION INSTRUCTIONS						SHEET 1 OF 1		PART NO. N0023101-005											
TITLE: INSULATION HEATER ASSEMBLY						Quantity Inspected		REVISED											
QUALITY PLANNER			DATE		DCN ACCOUNTABILITY		New												
STEP	ITEM	CHARACTERISTIC				INSPECTION MEDIA				SHOP		INSP.							
	1	READ AND UNDERSTAND THE CONTENTS OF PAGE 1 OF 1 OF THESE INSTRUCTIONS. FAILURE TO OBSERVE THE FOLLOWING CHARACTERISTICS AS DESCRIBED SHALL BE CAUSE FOR REJECTION.				RECORD FOLDER NUMBER													
	2	Material identification				MIN-K Type 2000 Johns Manville 20'/'ft ³													
	3	Detail machined to dimension 3.00 x 3.72 x 15.66 $\pm .00$ $\pm .03$				Vernier caliper													
	4	Chamfer outside corners .25 x 45° Typ. 5 places. (See drawing)				Scale													
	5	Corner offset dimension .44 $\pm .03$ $\pm .03$ x 11.06 $\pm .03$ $\pm .00$ edge distance of offset				Vernier caliper													
		equal 2.30 in. Note: .62 dimension is into the 3.00 dimension.																	
	6	Radius inside angles .03 maximum Typ. 3 places				Radius gage													
	7	Identification				Observe manila tag listing part number, quantity, DCN status, folder number and acceptance stamp. Observe part is clean free from contamination.													
	8	Packaging				Packing - Cushioning material to protect from distortion, nicks and scratches. Polyethylene bag part to protect from contamination.													

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INSPECTION INSTRUCTIONS						SHEET 1 OF 1		PART NO. N0023101-007												
TITLE: INSULATION HEATER ASSEMBLY						Quantity Inspected		REVISED												
QUALITY PLANNER			DATE		DCN ACCOUNTABILITY		New													
White			10/20/65																	
STEP	ITEM	CHARACTERISTIC				INSPECTION MEDIA				SHOP		INSP.								
1		READ AND UNDERSTAND THE CONTENTS OF PAGE 1 OF 1 OF THESE INSTRUCTIONS. FAILURE TO OBSERVE THE FOLLOWING CHARACTERISTICS AS DESCRIBED SHALL BE CAUSE FOR REJECTION.				CORD "OLD" TYPE R														
2		Material identification				1 III-V type 2000 Johns Manville 20,000 ft ³														
3		Machine dim. part 10.66 $\pm .00$ x 3.12 x 3.00				Vernier caliper														
4		Machine offset to .75 $\pm .00$ x .44 $\pm .00$ x length of part. note: .75 dim. into 3.00 dim.				Vernier caliper														
5		Chamfer diagonal corner .25 x 45° x length of part.				Scale														
6		Radius inside angle of offset .03 max.				Radius gage														
7		Identification				Observe manils tag listing part number, quantity, lot status, folder number and acceptance stamp. Observe part to be clean and free of contamination.														
8		Packaging				Packing - Cushioning material to protect from distortion, nicks and scratches. Polyethylene bag to protect from contamination.														

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INSPECTION INSTRUCTIONS				SHEET 1 OF 2		PART NO. N0023101-009	
TITLE: HEATER ASSEMBLY				REVISED			
QUALITY PLANNER White		DATE 10/20/65	DCN ACCOUNTABILITY New				
STEP ITEM	CHARACTERISTIC	INSPECTION MEDIA			SHOP	INSP.	
1	READ AND UNDERSTAND THE CONTENTS OF PAGES 1 thru 2 OF THESE INSTRUCTIONS. FAILURE TO OBSERVE THE FOLLOWING CHARACTERISTICS AS DESCRIBED SHALL BE CAUSE FOR REJECTION.	RECORD FOLDER NUMBER					
2	Evidence of previous inspection of NS3106A-22-12S shell, 22-12P plug insert, AN3057-12 clamp, 2 type 2C-10 connectors and 1001 heater assembly.	Receiving inspection certification (Visual)					
		Type 56-TSS Lindberg, Watertown, Wisconsin					
3	Evidence of previous inspection of -001, -003, -005, -007 and -011 details	Visual - See manila tag					
4	Assemble -005 and -007 into -001 cover. Insert 1001 heater. Cut clearance in -005 and/or -007 and holes in -001 cover for leads. Cover with insulation.	Visual - document Hole size _____ Location _____					
		Insulation material used _____.					
5	Install - oil assuring fit on 1001 heater base	Visual					
6	Install -003 base (legs up) and drill .218 dia. holes loc. from -001 cover. Typ. 16 places. (See drawing)	Plug gage					
7	Install NS35207-261 machine screws and NAS671-10 nuts 16 places.	Visual					
8	Assemble details call out in Item No. 1 +2 #16 wire, wattmeter leads, and 2 #10 wire power leads, 48 in. long.	Visual - document hook up #10 wire to pin _____ #16 wire to pin _____ #16 wire to pin _____ EPS 85101 applies.					
9	Potting of plug assembly	EPS 85101					
10	Splice plug assembly wires to heater assembly wires using 2C-10 two-way connector 2 places. Wrap with glass tape.	Visual - Record crimp tool number _____ Record hook up data #10 and #16 wires from pins _____ and _____ to heater leads _____					
		_____. #10 and #16 wires from pins _____ to heater leads _____					

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PART NO. N0023101-011

TITLE: INSULATION
HEAT RESISTIBLE

Quantity Inspected

REVISED

QUALITY PLANNER

White

DATE _____

10/20/65

DCN ACCOUNTABILITY

25

STEP

ITEM

CHARACTERISTIC

INSPECTION MEDIA

SHOP

INSP.

1

READ AND UNDERSTAND THE CONTENTS OF PAGE 1 OF 1 OF THESE INSTRUCTIONS.
FAILURE TO OBSERVE THE FOLLOWING CHARACTERISTICS AS DESCRIBED SHALL BE CAUSE
FOR REJECTION. RECORD FOLDER NUMBER

2

Material identification

MIN-K Type 2000
Johns Manville 20#/ft³

3

Machine dim. part 16.06 $\pm$.03 x 15.66 $\pm$.03
x 3.00 $\pm$.03 (See drawing.

Vernier caliper

1.

Machine offset 11.88 x 11.06 x .18 $\begin{smallmatrix} +.03 \\ -.00 \end{smallmatrix}$
edge distance 2.38 x 2.30

Vernier caliper and depth gage

5

Inside radius angles .03 maximum
Typ 8 places

radius game

6

Chamfer corners (3 in dimension)
.25 x 45° typical 4 places

Scale

7

Identification

Observe manils tag listing part number, quantity, DCN status, folder number and acceptance stamp. Observe that part is clean and free from contamination.

Packaging

Packing - Cushioning material to protect part from distortion, nicks and scratches.
Polyethylene bag part to protect from contamination.

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INSPECTION INSTRUCTIONS						SHEET 1 OF 1		PART NO. N0023101-013			
TITLE:		SUPT. OF ANGLE HEATER ASSEMBLY				Quantity Inspected _____		REVISED			
QUALITY PLANNER White		DATE 10/20/65		DCN ACCOUNTABILITY							
STEP	ITEM	CHARACTERISTIC				INSPECTION MEDIA				SHOP	INSP.
1		READ AND UNDERSTAND THE CONTENTS OF PAGE 1 OF 1 OF THESE INSTRUCTIONS. FAILURE TO OBSERVE THE FOLLOWING CHARACTERISTICS AS DESCRIBED SHALL BE CAUSE FOR REJECTION.				RECORD FOLDER NUMBER					
2		Material identification				SST Type 304 ASTM-A-240					
3		Finish detail dimensions 13.56 x 1.00 x 1.00 x .125 inches				Vernier caliper					
4		Drill holes .437 ± .010 typ. 2 places				Plug gage					
5		Hole location dimension, edge distance .38 x 1.76 x 10.031 in. space				Vernier caliper					
6		Break all sharp edges .010 R Approx.				Visual					
7		Identification				Observe manila tag listing part number, quantity, DCN status, folder number and acceptance stamp. Observe detail for contamination/corrosion.					
8		Packaging				Packing - Cushioning material to protect from distortion, nicks and scratches. Polyethylene bag part to protect from contamination.					

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APPENDIX D
RECEIVING ACCEPTANCE PLAN

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CONTROL PT. <u>1100</u>		SPACE SYSTEMS QUALITY RECEIVING ACCEPTANCE PLAN								MARTIN P/N -2PB 3M-TTGS -2NB	
SHEET <u>1</u> OF <u>3</u>										PART NAME Thermoelectric Element -"P" & "N" Type	
RECEIVING ACCEPTANCE PLAN VALIDATION	STAMP	DRAWING NUMBER				R. A. P. REVISIONS				R. A. P. NUMBER N0023110	
		REV.	DATE	REV.	DATE	REV.	DATE	REV.	DATE		
	A	10/65			New	10/65					
TYPE OF TESTS (Components) (Sub- system) Verification (system)										SAMPLE PLAN None	
QUALITY ENGINEER		DATE		REFERENCE - REMARKS							
STEP C. C.	SAMPLE PLAN	CHARACTERISTIC									
		IDENTIFICATION & TRACEABILITY - Observe that positive identification exists for each element relative to its Purchase Order No., basic element batch, inspection, & Elect. Tests. Maintain this identification throughout incoming inspection operations.									
		NOTE: At no time shall an element be physically marked.									
		DIMENSIONAL INSPECTION:									
1		Diameter & Length - .502 ± .002 dia. x .500 ± .005 Lgth ("N" Element)				Use hole gage T-0000X for dia. check Use Go/No-Go gage T-0000X for length check					
2		.504 ± .002 dia. x .500 ± .005 Lgth. ("P" element)				Alternato: Micrometer set-up for dia. & vernier cal. set-up for length.					
3		Perpendicularity - Surface - B - Perpendicular to surface -A- .003				Height gage, V Block & indicator					
4		Parallelism - Top & bottom surfaces paralld within .004				Height gage & indicator					
5		Flatness - Top & bottom surfaces Flat within .002				Height gage & indicator					
6		Surface Finish - a) Corner chipping - Max. allowable decrease in end surface area = 5%				Quality approved visual standards (Nos. 1 thru 5) will be used when examining elements for surface finish & internal defects. Those standards pictorially describe acceptable/non-acceptable conditions & provide (cont.					

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CONTROL PT. <u>1100</u>		SPACE SYSTEMS QUALITY RECEIVING ACCEPTANCE PLAN		MARTIN P/N -2PB 3M-TEGS -2NB
SHEET <u>2</u> OF <u>3</u>				R. A. P. NO. N0023110
STEP C.C.	SAMPLE PLAN	CHARACTERISTIC	INSPECTION PROCEDURE/MEDIA	
6	-continued	-continued	precise acceptance criteria for receiving inspection. Visual - Comparison with Standard 1.	
7		b) Surface Pitting & Grain Grooves - Max. allowable groove depth = .005	Visual - comparison with Standards 2 & 3. (Use optical mike to measure questionable grooves.)	
8		c) Surface Deposits - Not to exceed 25% of surface area nor more than 3 localized deposits greater than 1/16" in the largest dim. No deposit exceeding 1/8" in largest dim.	Visual - Comparison with Standard 4.	
9		d) Cracks - Observe absence of cracks	Visual	
10		Seebeck Voltage - All elements to be tested to requirements of Para. 3.3.3.2 (Spec. MN-10126). Record voltage output and the hot and cold junction temperatures on record sheet. (Tests to be performed in acc/with NPS 11-024) (Record test results on thermo-electric record sheet)	MNO-86655-Seebeck testing equipment. Tests & recordings to be performed by Mfg. tester. Quality to verify equip. is within calibration, witness initial set-up & test, then monitor (10%) of remaining tests. Quality will review all recorded test results for compliance with values listed in para. 3.3.3.2	
11		Electrical Resistivity - All elements to be tested to requirements of Para. 3.3.4.1. Calculate resistivity & record on record sheet. (Tests to be performed in acc/with NPS 11-023) (Record test results on thermo-electric record sheet)	Resistivity tester Model #1. Tests & recordings to be performed by Mfg. tester. Quality will verify test equip. is within calibration, witness initial set-up & test, then monitor (10%) of remaining tests. Quality will review all recorded test results for compliance with values listed in Para. 3.3.4.1.	

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CONTROL PT. <u>NO023</u>		SPACE SYSTEMS QUALITY RECEIVING ACCEPTANCE PLAN								MARTIN P/N <u>ASTM-C 152</u>	
SHEET <u>1</u> OF <u>2</u>										PART NAME <u>COPPER BAR</u>	
RECEIVING ACCEPTANCE PLAN VALIDATION	STAMP	DRAWING NUMBER				R. A. P. REVISIONS				R. A. P. NUMBER	
		REV.	DATE	REV.	DATE	REV.	DATE	REV.	DATE		
TYPE OF TESTS (Components) (Sub- system) Verification (system)										SAMPLE PLAN Table No. 1	
QUALITY ENGINEER		DATE	REFERENCE - REMARKS								
STEP C.C.	SAMPLE PLAN	CHARACTERISTIC								INSPECTION PROCEDURE/MEDIA	
		LAKING									
3		a) Type									
3		b) Temper									
2		Dimensions per Purchase Order									
		Tolerances per Section 14									
2		Rockwell Hardness per Table II									
		Controlled laboratory test									
2		Electrical Resistivity per Section 13.									
		See page 2 for resistivity formula									
		specimen size = 1" x 2" x 1"									
2		Chemical Properties per Table I									
		specimen size = two ounces minimum									
		Lot Size Sample Size Accept Reject									
		2-9 1 0 -									
		9-100 2 0 1									
		101-500 3 0 1									
		501-1000 5 0 1									
		1001-1300 7 0 1									
		1301-3200 10 0 1									
		3201-8000 15 0 1									
		8001-22000 25 1 2									
		22000 & over 35 1 2									

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A 5x10 grid of dots forming the letters 'DEC 2021'. The dots are arranged in a way that the letters are clearly visible against the background of empty dots.

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APPENDIX E

CONTROLLED PARTS PROGRAM

A. GENERAL DESCRIPTION

The purpose of the controlled parts program is to assure that selected parts critical to mission success are identified, shipped, received, inspected, tested, accepted and handled so as to minimize performance and reliability degradation. Such parts shall be identified as controlled parts.

Controlled parts shall be serialized and identified with controlled part tags or stickers. Vendors from whom controlled parts are purchased shall be furnished with appropriate controlled part labels and tags for identification of controlled parts and the packages in which they are shipped.

Controlled parts shall be identified on procurement drawings (PN and CCI drawings) and on assembly drawings, with callouts flagged; and Engineering Reliability shall prepare and maintain a current drawing of all controlled parts.

Inspection and functional testing shall be required 100% for all controlled parts, and all semiconductors shall be X-rayed in addition to inspection and functional testing.

After receipt by the Martin Company, controlled parts shall be transported only by special transporter and shall be stored only in specially designated storage bins.

Figure E-1 is a flow diagram for the handling of controlled parts. Responsibilities and functions of the controlled parts program are described in Section B.

B. RESPONSIBILITIES AND FUNCTIONS

1. Engineering Reliability

Engineering Reliability shall identify controlled components and parts. A part will be classified as a controlled part if any of the following conditions exist:

- (1) Its failure mode will cause the failure of the components or assembly of which it is a part.
- (2) Its failure mode will cause sufficient performance degradation to prevent minimum acceptable performance of the part from being attained.

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Fig. E-1. Controlled Parts Flow Diagram

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- (3) Normal handling techniques, packaging, or storing techniques may cause a degradation of its performance or other failure mode which would result in (1) or (2) above.
- (4) Operating history or analysis indicates that the part may have an operating life below that required in normal usage.
- (5) Failure history indicates that the reliability of the part may be marginal.
- (6) The part is affected by highly specialized processes, materials or contaminants.
- (7) The part will be required to operate close to its environmental limits.
- (8) The part will be applied with more stringent limits because of its use in a long-life nuclear device.

A list of controlled parts on an Engineering drawing will be published and maintained.

A selection of controlled part stickers and tags for identification of parts will be maintained.

Acceptance and functional tests and trouble reports on controlled parts will be monitored, along with failed parts analysis, when necessary.

2. Engineering Design

- (1) Label component drawings with a controlled part note.
- (2) Flag controlled part callouts in the list of materials on assembly drawings with a ▷ and identify under "Notes" as a controlled part.
- (3) Each controlled part will be serialized and the following will be added to each controlled part drawing near the title block to assist recording S/Ns in Receiving Inspection:
"This is a serialized controlled part."
- (4) Specify that serial numbers be applied to nameplate on Martin manufactured equipment where nameplates are used. If a nameplate is not used, specify the location, when appropriate, and the method of applying a serial number in a permanent manner.

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- (5) Specify any special handling, storage or packaging requirements on the engineering drawings.
- (6) Assign top priority to failure analysis on controlled part failures.
- (7) Call out acceptance testing on drawings.

3. Manufacturing

- (1) Include the following restrictions and provisions in processes for controlled parts:
 - (a) Where any controlled part has exhibited a transient malfunction (erratic behavior) during testing, that part shall not be used in a controlled assembly, nor in the hardware to be delivered.
 - (b) Call out the engineering requirements of special handling, stocking, installation and labeling of controlled parts through the manufacturing processes.
- (2) Identify shop folders and processes with the controlled part stickers and tags.
- (3) Controlled parts shall be identified by means of an external identification (tag or sticker) as soon as possible. These tags and stickers may be obtained from the Reliability manager. Assemblies containing controlled components shall be handled as a controlled part with the note "Controlled Part Installed."
- (4) Controlled parts shall be segregated from noncontrolled parts and stored in locked storage areas with padded bins. Special handling shall be provided. Routing and transporting shall be in special vehicles.
- (5) Shipping containers/packages for controlled components shall carry controlled part stickers on at least two sides of the container or package. Containers for items so designated shall be marked "Fragile" in red in accordance with MIL-STD-129D, para 5.2.2.8.

4. Quality

- (1) Control disposition of nonconforming parts.

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- (2) Control configuration and exercise process controls on these parts to make certain that their qualification configuration is not degraded.
- (3) Audit and report compliance with this procedure during procurement, fabrication, test, shipping, handling, storage and use.
- (4) Monitor handling, storage, packaging and functional performance of controlled parts as single parts or as assemblies containing controlled parts.
- (5) Identification of a controlled part shall remain in place until it is transferred to its next assembly, which will then be marked.
- (6) Control disposition of discrepant parts.
- (7) Inspect parts and packages to ensure compliance with these requirements.
- (8) Assign serial numbers to Martin-built parts.
- (9) Assure that log books contain a listing of controlled parts and are up-to-date.
- (10) Assign top priority to corrective action on controlled part problems.
- (11) Conduct functional testing of controlled parts when received from the vendor.
- (12) Perform 100% X-ray inspection of all semiconductors.
- (13) Handle and ship controlled parts as per this procedure.

5. Logistics

- (1) The technical manual shall contain appropriate instructions for shipping, handling and packaging of controlled parts and shall identify controlled parts under the parts listing.
- (2) Provide training necessary to acquaint handling personnel with the requirements of this procedure.

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6. Purchasing

- (1) Require vendors to mark and handle controlled parts according to the provisions of the purchase order.
- (2) Provide identification stickers to vendors for marking and packaging.
- (3) Upon receipt, controlled parts shall be segregated from other parts and shall be picked up by special transportation per Paragraph 3.(4).

7. Vendor

- (1) Controlled parts shall be identified by external means as soon as possible, using stickers provided by Martin Purchasing.
- (2) Controlled parts shall be segregated, handled and shipped according to the purchase order.
- (3) Controlled parts shall be serial numbered.

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