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Polonium Radioisotope Thermoelectric Generator

Specifications

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Polonium Radioisotope Thermoelectric Generator

Specifications

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MND-3612-9
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

This volume includes the system and interface Specifications developed during Phase I of Contract AT(30-1)-3612. They are based upon Phase I contract specifications, interface information obtained from AEC/USAF-SSD/Aerospace Corp/Mound Laboratory and engineering design effort during the Phase I program. In addition, Manufacturing process specifications are included defining processes to be used in fabricating SNAP M components and systems. The system and interface specifications are listed below, and are related as shown in Fig. II-3, Volume 3612-8-1.

MND-3612-10	Interface Control Specification for Po RTG Power System (SNAP M System)
MND-3612-11	Interface Control Specification for Aerospace Ground Equipment for Po RTG Power System (SNAP M System)
MND-3612-12	Interface Control Specification for Fuel and Fuel Encapsulation, Po RTG System (SNAP M System)
MND-3612-13	Specification for Po RTG Power System (SNAP M System)
Appendix A List of Applicable Documents	
Appendix B Deliverable Data Items	
MND-3612-30	Specification for Aerospace Ground Equipment for the Po RTG Power System (SNAP M System)

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INTERFACE CONTROL SPECIFICATION
FOR Po RTG POWER SYSTEM
(SNAP M SYSTEM)

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AEC

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24 November 1965

REVISED PAGE INDEX

As of November 24, 1965

This Revised Page Index identifies all authorized changes to, and all current pages of, this Specification as of the date shown above. This RPI is cumulative and supersedes all previous RPI's. Detailed information on each change may be found on the applicable Specification Change Notice.

<u>Page No.</u>	<u>Para. No.</u>	<u>SCN</u>	<u>CCP</u>	<u>Effectivity</u>
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This specification consists of a Title Page, this Revised Page Index Sheet, No SCN's, 2 Table of Contents Sheets, 17 Pages of Text, (Page 17 is the last page).

File this page after the
Table of Contents

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FOREWORD

This specification and supporting subsidiary specifications have been prepared to provide a basis for Contractor liaison and coordination activity with the AEC and the User of the Po RTG power system. The specification includes interface criteria relating to other Government agencies who will act in coordination with the Contractor's effort to develop and furnish the Po RTG system.

The content of this specification reflects interface controls established under Phase I of the Po RTG program (Contract AT(30-1)-3612), and is not restricted to any particular phase of generator system design, development and production but covers interface areas and responsibilities applicable to a complete program. Emphasis is placed on definition of interfaces applicable to the initial portion of a complete program. It is expected that this document will be completed and made more definitive through appropriate modifications as integration of efforts is accomplished and as more firm design information and test results become available. In final form, representing the results of mutual agreements reached, it is expected that this specification will be referenced in contractual agreements between the Contractor and the AEC and also in understandings between the AEC and the User of the system.

The relation of this specification to other Contractor prepared specifications and the Contract is shown in Fig. II-3, MND-3612-8-1.

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24 November 1965INTERFACE CONTROL SPECIFICATION
FOR Po RTG POWER SYSTEM

1.0 SCOPE.-- This Interface Control Specification establishes interface baselines for the integration of a radioisotope fueled thermoelectric power system (Po RTG) into the equipment and activities of an earth orbit satellite program. This specification covers the interfaces between Contractor furnished articles and effort with articles and effort of others in the development, fabrication, test, delivery, installation, and demonstration of the Po RTG power system.

1.1 Areas of Responsibility.-- The general areas of responsibility of the Contractor and cognizant agencies shall be as stated in this section. The responsibilities stated are those of a direct nature and also those necessary to permit others to carry out their responsibilities.

1.1.1 AEC.-- The AEC will be responsible to the User Organization for the performance of the Contractor in accordance with the provisions of the contract between the Contractor and the AEC. In addition, with respect to design and fabrication of the system, the AEC will:

- a. Provide specifications covering the physical and performance characteristics of the fuel.
- b. Establish the nuclear safety of the fuel through study and test programs conducted by Government agencies and/or the Contractor.
- c. Furnish and encapsulate the radioisotope fuel in containment structure and fuel block components provided by the Contractor.
- d. Furnish direction and assistance to the Contractor in the conduct of liaison and coordination activity with the User.
- e. Furnish, in conjunction with Contractor furnished articles, the equipment and services necessary to accomplish radiation monitoring and control of nuclear safety during all prelaunch, launch and post launch operations at the launch site.

Note: For definition of terms herein see Section 7.

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1.1.2 User Organization.- The Government agency having cognizance of the satellite program will make available to the Contractor requirements, constraints, design data, specifications, test results, mission objectives and parameters affecting and/or to be met in the design and programming of the RTG power system. Data made available will be that selected and furnished by the User or alternatively, that data and documentation which the User elects to provide in response to specific requests by the Contractor. Data requested by the Contractor will be made available within two weeks after such request or in lieu thereof the Contractor and the AEC shall both be provided with recommendations as to the basis to be used in design and programming of the system (see also 1.1.3 following).

The User, in conjunction with the Contractor and AEC, will furnish facilities and equipment, perform work and furnish services and carry out responsibilities, all as provided for herein, upon acceptance of this document.

1.1.3 Contractor.- The Contractor shall perform design and development studies, design, fabricate, test and deliver Po RTG power systems, provide support services and furnish associated equipment, including ground support equipment, all in accordance with the provisions of its contract with the AEC. Effort, articles and services provided shall be in accord with program phasing as established by the contract and shall be in conformance with the interface requirements of this specification.

Requests to the User for data and documentation shall state the specific kind or nature of the information required, the purpose or reason in requesting the information, and the general basis on which the Contractor will proceed in the event the information will not be provided. In the event requested information or appropriate recommendations (see 1.1.2) are not provided, the Contractor shall document, in reports required under the Contract, the bases used in lieu of User furnished information.

1.1.4 Joint Responsibility.- The User/AEC shall issue and maintain a set of interface control specifications and drawings (prepared and coordinated in certain instances by the Contractor) to assure compatibility between the satellite program and the RTG power system. All such specifications and drawings shall be applicable only after incorporation by direct or indirect reference in this specification. Subsequent to approval and acceptance of this document, changes and additions shall only be accomplished in the manner provided for in Section 5 herein.

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The performance of work and the furnishing of articles as provided for under this specification shall be in accord with the provisions of the Security Classification Guide referred to in Section 2.2.1.

2.0 APPLICABLE DOCUMENTS.

2.1 General.-

2.1.1 Extent of Applicability.- The documents listed in this section form a part of this specification only to the extent specified in the text of this specification. Where a document or its provisions are to be "used as a guide" (or other similar phrases) the extent of applicability shall be based on the Contractor's management and technical judgment. For reference purposes only, the paragraph(s) in this specification where each document is called out are shown opposite each document in the following listing.

2.1.2 Dates of Issue.- References to documents in the text of this specification are made by basic number only. Such basic reference shall designate the exact issue as specified in this Section 2, including the cited amendments, changes, etc.

2.1.3 Rules of Procedures.- In case of conflict between this specification and the Contract, the Contract shall govern. In case of conflict between this specification and any document referenced herein, this specification; including any authorized changes, appendices, or addendums hereto, shall govern.

2.2 Applicable Documents.-

2.2.1 <u>AEC.-</u>	<u>Para. Ref.</u>
Contract AT(30-1)-3612 Phase I, Po RTG Programs	3.0
Classification Guidance for Polonium Fueled RTG Program (AEC ltr. of 14 October 1965)	1.1.4
2.2.2 <u>User Organization.-</u>	
IFS-TIIIX-33000* Attachment 1	Interface Infor- mation for the Preliminary Design of Fuel Capsule Insertion Equipment 3.0

*Document extracts as made available to the Contractor on 14 Oct. 1965.

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2.2.2 User Organization.-

Para. Ref.

Report No.	Aerospace Meteoroid	3.1.1.3
TOR-269(4560-40)-2	Environment and Pene-	
17 August 1964	tration Criterion	

2.2.3 Military.-

Specifications:

MIL-Q-9858A	Quality Program	4.1
16 December 1963	Requirements	
MIL-STD-785	Requirements for Re-	3.1.1.2
28 June 1965	liability Program	
	(Systems & Equipments)	
MIL-E-6051C	Electric-Electronic	3.1.1.1
10 September 1964	System Compatibility	
	& Interference Control	
	Requirements	
MIL-STD-826 (USAF)	Electromagnetic Inter-	3.1.1.1
20 January 1965	ference Test Require-	
	ments and Test Methods	

2.2.4 Contractor.-

Specifications:

MND-3612-11	Interface Control Specifi-	3.0
24 November 1965	cation for AGE for Po RTG	(etc.)
	Power System	
MND-3612-12	Interface Control Specifi-	3.1.1.4
24 November 1965	cation for Fuel and Fuel	
	Encapsulation	
MND-3612-13	Specification for Po RTG	3.0
24 November 1965	Power System	(etc.)
MND-3612-30	AGE Ground Equipment	3.0
24 November 1965	Specification, Po RTG	

Drawings:

NSK 516**	SCS/RTG Interface Drawing	3.1.2
NSK 525**	RTG System Radiator (SCS Concept	3.1.2)

**Drawings of the issue provided the AEC at the end of Phase I.

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2.2.5 Other.-

Para. Ref.

Dept. of Commerce:

3.1.1.4

Handbook 69
5 June 1959

Maximum Permissible Body
Burdens and Concentrations
of Radionuclides in Air
and in Water for Occupa-
tional Exposure

3.0 INTERFACE REQUIREMENTS.- The following establishes the require-
ments and/or baselines for:

a. Functional, physical and installation interfaces and control of interfaces between the Po RTG power system as described in MND-3612-13 and the equipment, facilities, and operations for an earth orbit satellite program.

b. The specific effort and responsibilities to be performed by the Contractor, AEC, User and other cooperating Government agencies to effect integration of the RTG system into the satellite complex.

The requirements of this document shall be applicable to the Po RTG power systems, whether electrically heated and nuclear fueled, to be furnished and delivered by the Contractor. Accordingly, except as specifically noted, requirements herein are applicable to "prototype" and "flight demonstration" operational power systems as defined by Contract AT(30-1)-3612. The Contractor furnished aerospace ground equipment (AGE) associated with the Po RTG power system and interface criteria applicable to the AGE shall conform with specifications MND-3612-11, MND-3612-30, and the document listed in 2.2.2.

3.1 Satellite Complex and Po RTG Interfaces.- For purposes of interface control and development and design of the Po RTG power system, the satellite complex shall be construed as consisting of those facility and equipment items specified by the User and described in documentation made available by the User, as making up the complex. However, in the absence of such definition, interface control shall be based on data derived in accordance with 1.1.2 and 1.1.3 above.

3.1.1 Functional Interface Requirements.- The RTG power system to be installed in the satellite vehicle shall furnish electric power for vehicle use, dissipate excess and waste heat of the nuclear fuel, and sense certain operating characteristics of the RTG power system for use in ground and flight operations.

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3.1.1.1 Electro-Electronic Requirements.- The RTG shall furnish electric power to a regulated bus of the satellite vehicle and also provide power required for operation of the RTG coolant pump. Interface circuitry shall consist of power leads (2) and sensor leads. Electric and operating characteristics of the RTG shall conform with the following:

a. Output Power.- Subsequent to delivery, the flight operational RTG power system shall be capable of supplying a minimum of 400 watts (e) of d.c. electric power to a regulated satellite vehicle bus for a space mission life of 90 days duration, after 14 days of fueled operation (ground operation) plus 30 days of electrically heated operation. The satellite vehicle shall use or dissipate the RTG power, including use or dissipation of up to 550 watts (e) output from the RTG corresponding to beginning of life (BOL) conditions.

b. Output Voltage.- The output voltage of the RTG during the mission period and under mission ambient conditions shall not be less than $28 \pm 10\%$ volts measured at a power level of 400 or more watts.

c. External Load Limits.- The RTG shall be capable of sustaining external loads anywhere within the range from short circuit to 0.88 ohms, for periods of operation up to 45 days, without degradation which results in out-of-tolerance performance.

The RTG when fueled shall be capable of sustaining an "open circuit" external load for a period of five minutes without resultant degradation resulting in out-of-tolerance performance.

d. Electromagnetic Interference.- The RTG power system shall be designed to meet the electromagnetic interference standards of MIL-E-6051C and MIL-STD-826. The standards shall be applicable to both nuclear fueled and also electrically heated operation of the RTG. Within 120 days after initiation of Phase II, the Contractor shall furnish the calculated interference characteristics of the electromagnetic pump used in the system along with a recommended plan for control of electromagnetic interference. The plan shall identify parametric tests to be performed by the Contractor to determine interference characteristics during electrically heated RTG operation and detail tests required to assure electromagnetic compatibility of prototype generator systems with the launch vehicle and launch vehicle ground operations. Requirements for Contractor performance of electromagnetic testing of generator systems for flight use shall be considered unspecified pending the results of tests of prototype equipment.

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e. Protection Devices.- Devices to limit the RTG hot junction operating temperatures shall be furnished by the Contractor. Devices and circuitry to furnish a regulated load to the generator system in integration or pre-launch tests conducted at other than the Contractor's facility and in operational use of the generator system shall be furnished by the User.

3.1.1.2 Operation and Reliability Interfaces.-

a. Thermal Cycling.- Subsequent to delivery and prior to mission use, electrically heated thermal cycling of an RTG intended for flight operational use shall be limited. The maximum number of cycles within the limiting 30 days of electrically heated operation and within any six month span shall be as determined by Contractor tests of similar units. A thermal cycle shall consist of heating to an operating temperature and return to a lesser temperature.

RTG power systems furnished to the User for test purposes (non-flight) when electrically heated, shall be capable of being thermally cycled from ambient temperature to operating temperature and back to ambient temperature. The maximum number of permissible cycles prior to degradation which results in out-of-tolerance performance shall be determined by Contractor conducted tests.

The rate of temperature change in performance of thermal cycles shall conform to limits specified by the Contractor.

Ground operation of the RTG shall be performed under test conditions which simulate orbital operation or which provide auxiliary cooling to maintain RTG components within design thermal limits.

In handling, storage, test and operation of the RTG, the liquid coolant shall never be subjected to temperatures which result in freezing.

b. Operation Requirements.- Operation capabilities of the RTG shall satisfy requirements herein and those in specification MND-3612-13.

c. Mission Reliability.- Reliability levels to be satisfied by the RTG and tests to demonstrate attainment of required levels shall conform to criteria of MND-3612-13 and a reliability program plan established by the Contractor in conformance with MIL-STD-785.

3.1.1.3 Thermal Requirements and Interfaces.- Temperature pattern distribution and thermal flow characteristics of the RTG as installed and operated in the space vehicle shall be established by the Contractor and coordinated with the User. Thermal data shall be determined for prelaunch, launch, and in orbit conditions for both normal operation and credible emergency operating conditions.

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a. Normal Operation.- For design purposes, thermal interfaces during operation shall be based on configuration characteristics, thermal conduction paths, heat flows, temperature distribution data and surface emissivities of the launch vehicle as specified by the User in accordance with the provisions of 1.1.2 and 1.1.3. On the basis of such data the Contractor shall determine (calculate) coordinate and establish with the User the thermal interrelation between the RTG and the launch and satellite vehicles during pre-launch and orbital operation.

During pre-flight ground operation the User shall provide the following cooling media to the RTG through the service towers umbilical connection.

- (1) Water flow - 25 gallons per minute.
- (2) Air cooling or flow at ambient temperatures as required.

b. Thermal Control.- The RTG shall embody heat sensing and heat dumping provisions to automatically dissipate excess heat of the nuclear fuel during normal ground and flight operations. The heat dump system shall dissipate sufficient heat to maintain fuel containment structure integrity under emergency operation conditions such as loss of the liquid coolant. Emergency heat dump provisions need not consider maintaining electrical output of the RTG nor incorporating provisions to return to normal operation. The heat dump system shall operate under all intended satellite vehicle and launch vehicle operations and functions.

c. Meteoroid Protection.- Exposed surfaces of coolant lines and the heat dissipating radiator shall be designed to withstand with a .9999 probability the puncture effects of meteoroid impact during the mission lifetime. Design of equipment to meet this requirement shall comply with the criterion of Report No. TOR-269(4560-40)-2.

3.1.1.4 Nuclear Safety and Radiation.- Nuclear safety and radiation levels shall conform to overall governing criteria of AEC regulations in effect on 1 December 1965, and radiation limitations defined in the System Specifications which form a part of Contract AT(30-1)-3612. Within constraints so established, the RTG shall conform to, or satisfy, the following safety and radiation criteria.

a. Nuclear Safety.- Evaluation, definition and provision for nuclear hazards in the design, development and fabrication of the Po RTG power system shall be based on criteria of MND-3612-12 and conditions arising from:

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24 November 1965

- (1) Location of the launch site (WTR); limits of launch azimuths (range safety limits) and pre-orbit flight trajectories; an orbital inclination of 97° (sun synchronous) at an altitude varying between 120 to 250 nautical miles; one re-entry angle at an altitude of approximately 400,000 feet as a consequence of controlled re-entry provisions of the satellite vehicle; one re-entry angle at approximately 400,000 feet as a consequence of natural orbital decay of the satellite vehicle; and the modes, ballistic coefficients and trajectories of the satellite vehicle in controlled re-entry and natural orbital decay.
- (2) Area of intended impact of the satellite vehicle and the intended techniques and reliability for controlled re-entry of satellite vehicle.
- (3) Inter-relation of satellite vehicle and RTG heating, stability, aerodynamic and ablation effects during atmospheric re-entry.
- (4) Features of a launch vehicle and launch complex to be defined affecting the nature and magnitude of accidents on, or in the vicinity of the launch complex, such as: predominant materials of construction and the type and quantity of propellants of the vehicle and provisions for launch site personnel safety other than that furnished for reasons of nuclear safety.
- (5) The techniques, operating procedures, and sequence of events in generator system installation, check-out, fueling and monitoring during prelaunch operations.

NOTE: Handling and use of the RTG fuel block at other than the launch site is not provided for under this specification.

b. Radiation.- The RTG in conjunction with fueling and ground handling equipment supplied by the Contractor shall, when fueled and utilized in accordance with Contractor prepared operating and instruction manuals, limit radiation dose rates to launch site personnel to occupational hazard levels established by Department of Commerce Handbook 69.

Equipment and services to monitor and assure conformance with limiting radiation levels shall be provided by the AEC.

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3.1.1.5 Instrumentation and Telemetry.- Instrumentation and telemetry sensors shall be incorporated in the RTG as required by specification MND-3612-13. Leads from such sensors shall be as specified by the User and calibration data of each sensor including leads (if applicable) shall be furnished by the Contractor prior to delivery.

Circuitry and signal conditioning of the RTG sensor outputs for the satellite vehicle telemetry system shall be the responsibility of the User.

3.1.2 Physical Interfaces.- The physical relationships of the RTG with the space vehicle shall conform to the arrangement shown in Drawings NSK 516 and NSK 525. Physical interrelations of RTG power system AGE with the space vehicle and launch complex shall conform to requirements and constraints of specification MND-3612-11.

Responsibility for design, fabrication, and assurance of the adequacy of interrelated physical areas shall conform to the following:

a. Heat Dissipation and Control.- Structure or panels in the launch vehicle shroud to be used for dissipation of heat from thermal control subsystem devices of the RTG shall be provided by the User. In conjunction with User furnished cooling aids, the panel shall accomplish both normal and emergency transfer and dissipation of heat during ground operation and lift-off (0 plus 120 seconds). Design of the panels shall be based on temperature, thermal flow and heat dissipation criteria furnished to, and coordinated with, the User. Panel provisions may require provision for ejection of the panel after the 120 second interval of life-off, in the event such ejection provides the most feasible scheme of required heat dissipation.

b. Mounting Provisions.- Mounting surfaces and structure, but not including attaching hardware (bolts, nuts, clamps, etc.), required to install the RTG shall be the responsibility of the User. The Contractor shall furnish locating templates of mounting hole patterns, if required, for Contractor furnished articles.

c. Interchangeability.- Complete prototype RTG power systems shall be physically interchangeable with respect to the mounting provisions of each of the systems and shall be functionally interchangeable within the limits of required performance characteristics. Flight demonstration RTG's shall be functionally and physically interchangeable with each other to the same extent required of the prototype units.

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d. Electric Interconnection.-

- (1) Electric leads and connectors, including those for instrumentation and telemetry shall be of the type requested by the User. Identification, redundant circuitry, provisions for grounding, and installation shall be in accordance with MND-3612-13.
- (2) Incorporation of Trouble-shooting test points in the RTG need not be provided except as required to accommodate check-out using Contractor furnished AGE items.

e. Nuclear Radiation.-

- (1) Except as required to meet limiting radiation levels specified herein and in MND-3612-13, and protection of the fueling operator during nuclear fueling (see MND-3612-11) provisions to limit radiation dose levels external to the RTG need not be furnished for either personnel and/or equipment of the launch vehicle.
- (2) The Contractor shall provide the User with nominal calculated RTG radiation dose levels as a function of time, distance and location with respect to the RTG, as the User may require to evaluate and provide for the effects of nuclear radiation.
- (3) The AEC (or its agents) shall be responsible for development and conduct of a test and control program to verify the radiation characteristics of the fuel block as necessary to provide conformance with applicable radiation standards and regulations in the contemplated handling, storage and use of the RTG fuel block.

f. Weight and Weight Distribution.- The Contractor shall compute the weight and center of gravity location of: the RTG and each of its principal components. After submittal, such data shall be kept current to reflect the results of changes. Calculated data shall be verified by actual measurements at the earliest practicable date. Differences between calculated and actual data shall be made available to the AEC, within 10 days after determination of such differences.

g. Instrumentation, Telemetry, Structural Strength and Environmental Design Criteria.- See MND-3612-13

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h. Other Interfaces.-

- (1) Mechanical torque and surge characteristics of the generator system coolant shall be determined by calculation. Except for use of good design practices to minimize torque and surge effects on the launch and satellite vehicles, the required control of these characteristics shall be considered as unspecified. The Contractor shall provide all thermal insulation (insulation, insulators, gaskets, coatings on Contractor furnished items, etc.) required between the generator system and the structural equipment of the satellite vehicle to limit heat transfer to limits as derived under 3.1.1.3. Thermal insulation, surface coatings and emissivity requirements between the generator system and the booster shall be based on Contractor analyses of thermal interrelationships and recommendations to the User for development and furnishing of required insulation and techniques for control of thermal characteristics.

3.1.3 Installation Interfaces.- The Contractor shall provide services and articles at/to the launch site and also at/to an Integrating Contractor's facility selected by the User. The services, effort, equipment, and data to be supplied by the Contractor shall conform to requirements herein and shall be furnished to the extent provided for under the contract with the AEC.

Items to be supplied directly to the launch site from the Contractor's facility shall be transported by the Contractor to the site. Items to be supplied to the Integrating Contractor's facility shall be transported to that facility by the Contractor. Where required, reshipment of items to the launch site shall be the responsibility of the Integrating Contractor. Po RTG power systems (including electric heaters to simulate the nuclear fuel heat source) shall be packaged by the Contractor in re-useable shipping containers for use by Integrating Contractor in reshipment. The mode of transportation used in reshipment shall be equivalent to that used by the Contractor in initial transportation.

3.1.3.1 Support of Integrating Contractor.- The Contractor shall furnish the following items and services in support of the User's Integrating Contractor:

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a. Technical consultation services will be made available at the Integrating Contractor's facility (one) during integration checkout and tests of the RTG power systems.

b. Instruction and operating manuals, in the Contractor's format, shall be provided covering the procedures and precautions to be observed in handling, transportation, use and testing of the RTG and other equipment shipped by the Contractor.

3.1.3.2 Support of Launch Site Activities.- At the launch site the Contractor shall provide technical consultation services, demonstrate the operating procedures and use of equipment, accomplish fueling of Po RTG power systems, and perform routine maintenance and adjustment of Contractor furnished articles. Specifically, the services to be provided shall include those listed below.

a. Demonstration of generator fueling procedures in either a User furnished test set-up or with operational equipment and vehicles. Demonstration of procedures can be performed with both an electrical heater and a nuclear fueled heat source. If requested, such demonstration with the electrical heaters will be performed at the Integrating Contractor's facility.

b. Check-out and operation monitoring of generator systems or portions thereof in User furnished test set-ups and/or operational equipment. Effort shall include performance of quality assurance programs to assure retention of required reliability capabilities.

c. Performance of all fuel handling and RTG nuclear fueling operations, excluding those related to fuel storage and nuclear safety monitoring.

The User will be responsible for modification and operation of equipment supplied by others and which is necessary to the performance of the Contractor's services. In addition, the User shall provide access to site facilities and furnish facilities required to store and safeguard Contractor furnished articles and other items which may be provided on a loan or other temporary basis by the AEC and/or Contractor.

See MND-3612-11 for Contractor services related to AGE.

3.1.4 Standardization.- In the design and fabrication of the RTG power system and items thereof, the selection and use of standards, parts, materials and processes shall conform to the criteria of MND-3612-30 and MND-3612-13.

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4.0 QUALITY ASSURANCE PROVISION.-

4.1 Inspection Requirements.- A quality control program covering all Contractor furnished end items shall be implemented in strict conformance with the requirements of specification MIL-Q-9858A. All records, certifications, test results, etc., prepared in accordance with the provisions of the specification shall be made available to AEC/User representatives.

4.2 Test Program.- The performance of tests to substantiate Contractor conformance with design and fabrication requirements of this specification shall be accomplished in accordance with the requirements of specification MND-3612-13.

5.0 DOCUMENTATION CONTROLS.-

5.1 Procedural Interfaces.- Control of interface requirements shall be accomplished by interface documentation consisting of interface specifications and interface control drawings. Preparation and maintenance of interface documentation shall conform to the following:

5.1.1 Interface Specifications.- These documents shall consist of this specification and subsidiary appendices and lower tier interface specifications incorporated by reference herein.

Subsequent to approval of this specification by the AEC and the Contractor, all subsequent modifications to this document shall be subject to the approval of the AEC.

5.1.2 Interface Control Drawings.- Applicable interface control drawings (ICD) shall be referenced (directly or indirectly) in Section 2.0 herein. These drawings shall be prepared to contain only those data necessary to define interfaces. Only dimension, details, views, or notes that specifically apply to interface definition shall be shown. Additional detail shall only be shown as required for drawing clarity. Interface details shall clearly identify respective responsibilities with respect to the interface.

5.1.3 Contractor Furnished Documentation.- The Contractor shall prepare and furnish interface reports and plans, and other technical data in accordance with requirements of the contract and this specification. Data and documentation furnished by the Contractor may be in the Contractor's form.

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5.1.4 Modification and Maintenance of Interface Documentation.-

The particulars of a procedural system, that is, determination of, and establishment of the membership of an inter-agency working group, the drawing and specification change notice formats to be used, and the requirements for obtaining both contractual and technical approval of the respective cognizant agencies and contractors shall be established through coordination activities and documented in this specification.

6.0 GOVERNMENT FURNISHED ARTICLES.-

6.1 The Contractor shall (under subsequent program phases) prepare and coordinate a specification covering items and functional requirements of Government furnished equipment and facilities required in conjunction with Contractor furnished articles and services.

7.0 NOTES.-

7.1 Definition of Terms.- Certain terms as used herein are defined as follows:

7.1.1 Fuel Capsule.- An individual container of radioisotope fuel; consisting of the fuel provided by the Fueling Agency within a tantalum cladding and further encapsulated within capsule shell components furnished by the Contractor.

7.1.2 Fuel Block.- A containment structure for individual fuel capsules. The fuel block serves as the RTG heat source.

7.1.3 Po RTG Power System(or RTG).- The complete power system which furnishes electric energy to the satellite vehicle during an earth orbit mission. Basically, the RTG consists of a radioisotope (or electric) heat source, a subsystem of thermoelectric elements to convert heat to electric energy, and subsystems to control and dissipate the heat of the radioisotope fuel.

7.1.4 Aerospace Ground Equipment (AGE).- All equipment required on the ground to make a system operational in its intended environment. Includes all equipment to install, launch, guide, control, direct, inspect, test, adjust, calibrate, appraise, gauge, measure, assemble, disassemble, handle, transport, safeguard, store, activate, service, repair, overhaul, or operate the satellite system. OGE (Operational Ground Equipment) is that AGE which is a functional part of a system and which operates with that AGE required to restore a system or end items to operation condition. For purposes of this specification the term means AGE furnished by the Contractor.

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7.1.5 SNAP M System.- The complete RTG power system plus the associated AGE furnished by the Contractor.

7.1.6 Satellite Vehicle (or SCS).- The items launched by the booster.

7.1.7 Payload.- The portion of the Satellite Vehicle forward of the control section. The combination of satellite control section and payload make up the Satellite Vehicle.

7.1.8 Booster.- The item which boosts the Satellite Vehicle into its initial trajectory.

7.1.9 Launch Complex.- The primary facilities, property and AGE used to launch a Launch Vehicle. Includes blockhouse, launch pads, etc. Usually one complex is peculiar to a specific booster, and sometimes to a specific launch vehicle. Excludes multipurpose support facilities such as range safety, tracking stations, etc. The launch pad is the area immediately surrounding the launch vehicle, its composition varies according to needs.

7.1.10 Launch Vehicle.- The combination of a Satellite Vehicle and a Booster in the launch condition.

7.1.11 Contract End Item.- A deliverable item which is formally accepted by the procuring agency as an entity, on a DD Form 250, in accordance with the requirements of a specification. The prime level of assembly for technical and contractual management (customer) control (schedule, configuration, etc.) and accountability for provisioning spares and preparing manuals.

7.1.12 AEC.- The United States Atomic Energy Commission. For purposes of this specification the term implies, but is not restricted to, the New York Operations Office of the AEC.

7.1.13 Contractor.- The Martin Company of the Martin-Marietta Corporation, Baltimore, Maryland 21203.

7.1.14 Fueling Agency.- The Government agency selected by the AEC to furnish and encapsulate the radioisotope fuel.

7.1.15 User Organization (or User).- The Government agency having overall cognizance of the satellite program. The term encompasses Contractors and agencies working under the direction of this agency to carry-out the satellite program.

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7.1.16 Integrating Contractor.- A particular contractor of the User Organization, selected to integrate the RTG and AGE into the launch vehicle and launch complex.

7.1.17 Cognizant Agencies.- Government agencies, including the User, participating in the satellite and SNAP M system programs.

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THIS DOCUMENT CONSISTS OF 27 PAGES

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INTERFACE CONTROL SPECIFICATION
FOR AEROSPACE GROUND EQUIPMENT
FOR Po RTG POWER SYSTEM
(SNAP $\bar{M}$ SYSTEM)

Group 3

Downgraded at 12-year intervals,
not automatically declassified.

This document contains information affecting the National
Defense of the United States within the meaning of the
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Basic
Approved By:
Martin Marietta Corp.

Basic
Approved By:
AEC

Date

Date

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REVISED PAGE INDEX

As of November 24, 1965

This Revised Page Index identifies all authorized changes to, and all current pages of, this Specification as of the date shown above. This RPI is cumulative and supersedes all previous RPI's. Detailed information on each change may be found on the applicable Specification Change Notice.

<u>Page No.</u>	<u>Para. No.</u>	<u>SCN</u>	<u>CCP</u>	<u>Effectivity</u>
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This Specification consists of a Title Page, this Revised Page Index sheet, (none) SCN's, 3 Table of Contents Sheets, 21 Pages of Text, (Page 21 is the last page).

File this page after the
Table of Contents

Martin Approval _____

The undersigned certifies that all superseded classified pages have been destroyed in accordance with the appropriate security regulations.

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24 November 1965FOREWORD

This specification and supporting subsidiary specifications have been prepared to provide a basis for Contractor liaison and coordination activity with the AEC and the ultimate Using Organization of the Po RTG power system Aerospace Ground Equipment. The specification includes interface criteria relating to other Government agencies who will act in coordination with the Contractor's effort to develop and furnish the Po RTG System AGE.

The content of this specification reflects interface controls established under Phase I of the Po RTG program, (Contract AT(30-1)-3612). However, this specification is not restricted to any particular phase of design, development or production but covers interface areas and responsibilities applicable to a complete program. Emphasis is placed on definition of interfaces applicable to the initial portion of a complete program. It is expected that this document will be expanded and made more definitive through appropriate modifications as integration of efforts is accomplished and as more firm design information and test results become available. In final form, representing the results of mutual agreements reached, it is expected that this specification will be referenced in contractual agreements between the Contractor and the AEC and also in understandings between the AEC and the Using Organization.

The relation of this specification to other Contractor prepared specifications and the contract is shown in Figure II-3 of MND-3612-8-1.

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INTERFACE CONTROL SPECIFICATION
FOR AEROSPACE GROUND EQUIPMENT
FOR Po RTG POWER SYSTEM
(SNAP M SYSTEM)

1.0 SCOPE.-- This Interface Control Specification establishes interface baselines for the integration of the Aerospace Ground Equipment associated with a radioisotope fueled thermoelectric power system (RTG) into the equipment and activities of an earth orbit satellite program. This specification covers the interfaces between Contractor furnished articles and effort with articles and efforts of others in the development, fabrication, test, delivery, installation and demonstration of the AGE.

1.1 Areas of Responsibility.-- The general areas of responsibility of the Contractor and cognizant agencies shall be as stated in this section. The responsibilities stated are those of a direct nature and also those necessary to permit others to carry out their responsibilities.

1.1.1 AEC.-- The AEC will be responsible to the Using Organization for the performance of the Contractor in accordance with the provisions of the contract between the Contractor and the AEC. Conformance with interface requirements herein shall be considered a part of contract conformance. With respect to design and fabrication of the AGE, the AEC will:

a. Furnish direction and assistance to the Contractor in the conduct of liaison and coordination activity with the Using Organization.

b. Perform functions and responsibilities as provided for under the contract with the Contractor.

The AEC shall be responsible for establishing a radiation control area, during RTG fueling, in the vicinity of the Mobile Service Tower level assigned to the Fuel Handling Machine.

1.1.2 User Organization.-- The Government agency having cognizance of the satellite program will make available to the Contractor requirements, constraints, design data, specifications, test results, mission objectives and parameters affecting and/or to be met in the design and programming of the AGE. Data made available will be that selected and furnished by the User Organization or alternatively, that data and documentation which the User Organization elects to provide in response to specific requests by the Contractor. Data requested by the Contractor will be

Note: For definitions of terms herein see Section 6.

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made available within two weeks after such request or in lieu thereof the Contractor and the AEC shall both be provided with recommendations as to the basis to be used in design and programming of the equipment (see also 1.1.3 following).

The User Organization, in conjunction with the Contractor and the AEC, will furnish facilities and equipment, perform work and furnish services and carry out responsibilities, all as provided for herein, upon acceptance of this document.

1.1.3 Contractor.- The Contractor shall perform design and development studies, design, fabricate, test and deliver AGE; provide support services and furnish associated equipment, all in accordance with the provisions of its contract with the AEC. Effort, articles and services provided shall be in accord with program phasing as established by the contract and shall be in conformance with the interface requirements of this specification. Contractor requests to the User Organization for data and documentation shall state the specific kind or nature of the information required, the purpose or reason in requesting the information, and the general basis on which the Contractor will proceed in the event the information will not be provided. In the event requested information or appropriate recommendations (see 1.1.2) are not provided, the Contractor shall document, in reports required under the contract, the bases used in lieu of User Organization furnished information.

1.1.4 Joint Responsibility.- The User/AEC shall issue and maintain a set of interface control specifications and drawings (prepared and coordinated in certain instances by the Contractor) to assure compatibility between the satellite program and the AGE. All such specifications and drawings shall be applicable only after incorporation by direct or indirect reference in this specification. Subsequent to approval and acceptance of this document, changes and additions shall only be accomplished in the manner provided for in Section 3.8.9 herein.

1.2 Equipment Identification.- The following major items of AGE are considered herein.

- a. Fuel Handling Machine
- b. Fuel Handling Machine Shipping Container
- c. Shipping Container for Nuclear Fuel (Fuel Transport Cask)
- d. RTG Power system Shipping Container

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- e. RTG Field Test Equipment
- f. NaK Ground Service System
- g. Fuel Handling Machine Checkout Equipment

1.3 Government Furnished Property.- The following items, related to the field support of the SNAP M System, shall be the responsibility of the Government.

- a. A secure, sheltered storage area suitable for storing a fuel block(s) (in a shipping container per Section 3.3 herein).
- b. All equipment and services for health physics monitoring (such as film badges and dosimeters) at the Launch Site.
- c. Radiation detection and warning equipment.
- d. Mobile Service Tower modifications as defined herein.
- e. All telemetry and telemetry signal conditioning equipment.
- f. Cranes at the Launch Site receiving area, radioisotope fuel storage area and Launch Pad for handling the fuel shipping container, fuel handling machine and fuel handling machine checkout equipment.

2.0 APPLICABLE DOCUMENTS.-

2.1 Extent of Applicability.- The documents listed in this section form a part of this specification only to the extent specified in the text of this specification. Where a document or its provisions are to be "used as a guide" (or other similar phrases) the extent of applicability shall be based on the Contractor's management and technical judgment. For reference purposes only, the paragraph in this specification where each document is called out are shown opposite each document in the following listing.

2.2 Dates of Issue.- References to documents in the text of this specification are made by basic number only. Such basic reference shall designate the exact issue as specified in this section, including the cited amendments, changes, etc.

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2.3 Rules of Procedure.- In case of conflict between this specification and the contract, the contract shall govern. In case of conflict between this specification and any document referenced herein, this specification, including any authorized changes, appendices or addenda hereto, shall govern.

2.4 Specifications.-

<u>Number</u>	<u>Title, Dates, Amendments</u>	<u>Ref. Herein</u>
MND-3612-12	Interface Control Specification for Fuel and Fuel Encapsulation, Po RTG System (SNAP M System)	(4.3.2.b)
MND-3612-13	Specification for Po RTG Power System (SNAP M System)	(3.8.8)
MND-3612-30	Specification for Aerospace Ground Equipment for the Po RTG Power System (SNAP M System)	(3.1.5)

2.5 Drawings*.-

NSK-411	Nuclear Fuel Handling Machine (FHM) Man/Machine Concept	(3.1.2)
NSK-413	FHM/Site Interface Drawing	(3.1.5)
NSK-414	FHM Field Test Equipment	(3.7.2)
NSK-415	Shipping Container for Nuclear Fuel (Fuel Transport Cask)	(3.3.2)
NSK-517	FHM/RTG/Satellite Vehicle Fuel Loading Interface Drawing	(3.1.7 d)

*Drawings of the issue furnished to the AEC at the end of Phase I or to be prepared in Phase II.

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2.5 Drawings (Cont'd).-

<u>Number</u>	<u>Title, Dates, Amendments</u>	<u>Ref. Herein</u>
NSK-416*	Shipping Container for RTG	(3.4.2)
NSK-417*	RTG Field Test Equipment	(3.5.2)

2.6 Other Documents.-

IFS-T III X-33000 (CDI) Sept. 13, 1965	Launch Facility Manual and Attachment I "Interface Information for the Pre- liminary Design of Fuel Capsule (Block) Insertion Equipment	(3.8)
Department of Commerce Hand- book 69, June 5, 1959	Maximum Permissible Body Burdens and Concentrations of Radionuclides in Air and In Water for Occu- pational Exposure	(3.8.3)
	Classification Guidance for Po RTG Program (Attachment to AEC ltr. of Oct. 14, 1965	(3.8.10)
AFWTIRM 550-2	Range Safety Manual	(3.8.6)

3.0 INTERFACE REQUIREMENTS.- The interface requirements defined herein are the functional, physical and installation interfaces, and related responsibilities, between Contractor furnished AGE and other equipments, services and facilities at the Launch Site and at the Integration Contractor's facility.

3.1 Fuel Handling Machine (FHM).-

3.1.1 Functional.- The Fuel Handling Machine shall include the following major elements providing the functions described.

*Drawings are of the issue furnished to the AEC at the end of Phase I or to be prepared in Phase II.

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a. Personnel Provisions.-

- (1) Provides auxiliary shielding to protect the fuel handling machine operator from the nuclear radiation of the fuel block handling operations.
- (2) Provides a fuel handling machine operator's work station including seat (with safety belt) and controls for fuel handling machine operation.
- (3) Provides an alignment device for final visual alignment of the fuel handling machine with the RTG installed in the launch vehicle.
- (4) Provides viewing device(s) to aid the fuel handling machine operator in observing and controlling fuel handling machine travel.

b. Support Structure and Alignment System.-

- (1) Provides a structural base for the entire fuel handling machine.
- (2) Provides for the gross movement of the fuel handling machine between the parking position on the Mobile Service Tower and the fueling position.
- (3) Provides for the pre-alignment of the fuel handling machine to the Mobile Service Tower and satellite vehicle prior to fueling operations.
- (4) Provides for positioning the FHM cask and electrical heater container to their proper positions during fueling operations.
- (5) Provides the basic structural support for such accessories as lights and utility connectors.

c. Compliance System.-

- (1) Provides flexible (compliant) contact between the fuel handling machine and the launch vehicle such as to be capable of following changes in relative positions during fueling operations.

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- (2) Provides automatic centering and attachment of a fuel transfer tunnel connecting the fuel handling machine to the RTG installed in the launch vehicle.
- (3) Provides a passive conveyor for the movement of fuel blocks between the fuel handling machine and the installed RTG.

d. FHM Casks.-

- (1) Provides cooling and radiation shielding for the fuel block while stored in the fuel handling machine.
- (2) Provides a clamping arrangement for retaining the fuel block in place during FHM transportation.

e. Electrical Heater Container.- Provides electrical connection to, and cooling for, the simulated (electrically heated) fuel block while stored in the fuel handling machine.

f. Fuel Gripper Device.-

- (1) Provides for manually controlled movement of the fuel block and simulated fuel block into and out of their respective containers in the fuel handling machine, through the fuel transfer tunnel and into and out of the installed RTG.
- (2) Provides a locking device to assure positive grip on the fuel block.
- (3) Provides a device for preloading the fuel block (mechanically) during fastening into the installed RTG.

g. Pallet.-

- (1) Provides for handling and tiedown of the entire fuel handling machine during transportation.

3.1.2 Physical.- The fuel handling machine will have physical characteristics as shown on Contractor Drawing NSK-411.

3.1.3 Utilities.- Operation and use of the fuel handling machine requires the following utility services.

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a. At checkout site (if FHM checkout is performed at a location other than on the Mobile Service Tower).

- (1) Compressed air: clean, dry air at a pressure of not less than 300 psig.
- (2) Electricity (does not include requirements of electrically heated fuel block): 220 volts 60 cps, 3 phase, Y, 5000 watts.

b. At assigned level of the Mobile Service Tower.

- (1) Compressed air: clean, dry air at a pressure of not less than 300 psig.
- (2) Electricity (does not include requirements of electrically heated fuel block): 220 volts 60 cps, 3 phase, Y, 5000 watts.
- (3) Water: 20 gpm of 80 °F water.
- (4) Drain: Adequate to handle the required 20 gpm flow of cooling water (discharge temperature _____ °F maximum.

3.1.4 Transportation and Handling.- Transportation and handling of the fuel handling machine at and about the Launch Site will require:

a. Standard site trucking to 5000 pounds capacity and volume of 3 feet wide, 6 feet long and 6 feet high. The FHM will be transported on Contractor provided pallet.

b. Lifting crane at the Launch Site receiving location with capacity of 5000 pounds. FHM will be handled on Contractor provided pallet.

c. Lifting crane at the Mobile Service Tower of 5000 pounds capacity. FHM will be removed from pallet and raised to its assigned level on the Mobile Service Tower by means of 4 lifting eyes provided on the outer container.

d. Storage for re-useable FHM shipping container.

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3.1.5 FHM to Launch Site.- The following information and requirements are applicable to the interface between the fuel handling machine and the Launch Site.

- a. Fueling cycle time: As an objective, the total time required to fuel an installed RTG will not exceed 60 minutes with actual fuel block transfer time (FHM to RTG) not exceeding one minute.
- b. The maximum dose rate from the FHM with a fuel block stowed in the FHM cask will not exceed 20 mrem/hr.
- c. The FHM will be fully operable in winds (including gusts) up to 40 mph.
- d. The reuseable container used for shipping the FHM will be stored at the Launch Site during launch operations. Space required: 6 x 6x 3 feet.
- e. AGE Specification MND-3612-30 and Contractor Drawing NSK-413.

3.1.6 FHM to MST.- The following information and requirements are applicable to the interface between the fuel handling machine and the Mobile Service Tower.

- a. Assumed MST/Satellite Vehicle relative motions:
 - (1) Thermal effects
 - Vertical: 0.020"
 - Lateral: 0.051"
 - Rotation: 0.005°
 - (2) Propellant loading accomplished prior to radioisotope fueling
 - (3) Tower repositioning capability.
 - In direction of MST motion: $\pm 0.5^\circ$
 - Lateral and vertical at FHM level: $\pm 0.06^\circ$
 - Angular: $\pm 0.01^\circ$
- b. FHM weight: 5000 pounds (without operator but including fuel block and electrically heated fuel block).

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c. FHM travel:

- (1) On tracks from parking position to fueling position:
8' at 10'/min.
- (2) Carriage travel normal to tracks: $\pm 3''$ at 6"/min.
- (3) Vertical travel: 6" at 10"/min.
- (4) Pitch and roll adjustment: $\pm 1^\circ$ manually adjusted.
- (5) Yaw adjustment: $\pm 1^\circ$ manually adjusted.

d. FHM float (to accommodate the relative motions in a., above):

In direction of loading motion: $\pm 1.68''$
Normal to direction of loading: $\pm 1.68''$
Vertical: 0.08"
Pitch, roll and yaw: $\pm 0.5^\circ$

e. MST modifications: The installation and operation of the fuel handling machine requires the following modifications to the Mobile Service Tower.

- (1) Installation of tracks for moving FHM between its parking position and the fueling position.
- (2) Arrangement of removeable platform sections, tower hoisting rig, etc. to permit raising the FHM from the tower base to the assigned level and placing it on its tracks.
- (3) Re-arrangement, if required, of other equipment on the assigned level to assure non-interference between the FHM and other equipment and to permit FHM tiedown.
- (4) Installation of the required utilities at the assigned level.
- (5) Installation of intercommunication facilities and closed circuit television facilities (if required by Using Organization) and radiation alarm facilities (if required by the AEC).

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- (6) Installation of facilities to provide a safe (or propellant free) atmosphere in the vicinity of the FHM (including purging of the FHM itself) if necessary as a result of the type of launch vehicle propellants used, the sequence of propellant loading or other Launch Site conditions introducing a potentially explosive atmosphere.

The Contractor shall coordinate FHM design with the Using Organization to minimize modifications to the MST and other Launch Site equipment/facilities. The contractor shall furnish Interface Control Drawings delineating FHM requirements and required MST modifications. Actual changes to Launch Site facilities and equipment (such as the MST) and the changes in design to incorporate these modifications will be the responsibility of the Using Organization.

3.1.7 FHM to Satellite Vehicle.- The following information and requirements are applicable to the interface between the fuel handling machine and the Satellite Vehicle.

a. The FHM will be aligned (for fueling operations) with the RTG installed in the Satellite Vehicle to within:

+ 0.12" in both horizontal axes.
± 0.06" in the vertical axis.

b. The RTG will be located in the Satellite Vehicle within ± 0.25" on any axis (± 0.05° in any direction).

c. The Satellite Vehicle radioisotope fueling door size, configuration, method of operation and control(s) shall be coordinated with the Using Organization and the Contractor.

d. FHM to Launch Vehicle interface details shall be as shown on Drawing NSK-517. Unreacted forces applied to the Satellite Vehicle by the FHM will not exceed 300 pounds.

3.2 Fuel Handling Machine Shipping Container.-

3.2.1 Functional.- The fuel handling machine shipping container (provided by the Contractor) will protect the entire FHM during shipment by ground transportation (Contractor responsibility) between the Contractor's facility and the Launch Site.

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3.2.2 Physical.- The FHM shipping container will be approximately 6'x3'x6' feet.

3.2.3 Handling.- The FHM shipping container will be arranged for crane lifting by means of Contractor furnished slings.

3.2.4 Storage.- The FHM shipping container shall be stored (secure, sheltered area) at the Launch Site for the duration of the flight phase of the satellite program.

3.3 Shipping Container for Nuclear Fuel (Fuel Transport Cask).-

3.3.1 Functional.- The shipping container for nuclear fuel will receive, contain, and protect and provide biological shielding for a fueled fuel block during ground transportation between the Fueling Agency and the Launch Site (transportation is Contractor's responsibility) and during storage at the Launch Site (storage is Using Organization's responsibility).

3.3.2 Physical.- The shipping container for nuclear fuel will have physical characteristics as shown on Contractor Drawing NSK-415.

3.3.3 Handling.- The following information and requirements are applicable to the interface between the shipping container for nuclear fuel and the Launch Site.

a. The ambient temperature (air) in the vicinity of a loaded container shall not exceed 120°F. At this ambient temperature, the container's surface temperature shall not exceed 180°F $\pm$ 10°.

b. The container shall include hoisting provisions, including hoisting sling, to allow the container to be lifted by standard crane handling equipment of proper capacity. The approximate weight of the loaded container will be 8000 pounds.

c. Loading and shielding equipment (except standard hoists, etc.), if necessary for transfer of fuel blocks between the container and the FHM cask (or intermediate container, if used) shall be furnished by the Contractor.

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3.3.4 Storage.- In the event that it is necessary to store a loaded shipping container for nuclear fuel at the Launch Site, the Using Organization shall provide:

a. Remote, secure, sheltered storage area not less than 10 feet by 10 feet by 10 feet.

b. Facilities for area heat removal to maintain the ambient air temperature in the vicinity of the loaded container at or below 120°F.

c. Instrumentation and alarms for monitoring container surface temperature, if required.

3.4 RTG Power System Shipping Container.-

3.4.1 Functional.- The RTG Power System Shipping Container will receive, contain and protect the complete, assembled and tested RTG power supply system (less fuel) during ground transportation (Contractor's responsibility) from the Contractor's facility to the point of installation of the RTG into the Satellite Vehicle (assumed to be the Integrating Contractor's facility).

3.4.2 Physical.- The RTG power system shipping container will have physical characteristics as shown on Contractor Drawing NSK-416.

3.4.3 Handling.- The Contractor will provide (along with the container) any special equipment necessary for handling and/or removal of the system from the container. In handling, storage, test and operation of the RTG, the liquid coolant shall never be subjected to temperatures which result in freezing.

3.5 RTG Field Test Equipment.-

3.5.1 Functional.- The RTG field test equipment provides special equipment for system startup and monitoring. It includes the electrically heated fuel block and its controls and the test instrumentation for monitoring and recording the electrical and thermal functions of the RTG.

3.5.2 Physical.- The RTG field test equipment will have physical characteristics as shown on Contractor Drawing NSK-417.

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3.5.3 Utilities.- The operation of the RTG field test equipment requires the following electrical service:

220 volts a.c., 60 cps, 3 phase,
50 amperes, 18000 watts

3.5.4 Test Equipment To Launch Site.- The following information and requirements are applicable to interfaces between the RTG field test equipment and the Launch Site.

a. Simulated Fuel Block Control.- The Using Organization will provide blockhouse space and cabling (power, control and instrumentation) between the control console and the MST level assigned to the FHM for the heater block control console and control equipment provided by the Contractor.

The control console will include temperature instrumentation for the heater block.

b. RTG Monitoring.- The Satellite Vehicle (and its associated AGE) will provide monitoring, measurement indication and recording (if required) of the RTG system electrical and thermal functions during countdown and flight. Monitored data shall be transmitted by telemetry or closed-loop cabling furnished by the Using Organization as required. The RTG system electrical and thermal functions to be monitored or measured by the Satellite Vehicle AGE are as follows:

- (1) 32 RTG temperatures
- (2) 4 radiator temperatures
- (3) 16 coolant temperatures
- (4) 2 output voltages
- (5) 2 output currents
- (6) 10 of the above 56 channels shall have alarm provisions.

c. Handling.- The RTG field test equipment shall include provisions for handling and transportation by the Using Organization's Launch Site equipment.

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3.5.5 Test Equipment to Integrating Contractor.- The following information and requirements are applicable to interface requirements between the RTG Field Test Equipment and the Integrating Contractor's facility.

a. Simulated Fuel Block Control.- The Contractor will provide a control console and control equipment (including block temperature instrumentation) for the simulated fuel block.

b. RTG Monitoring.- The Integrating Contractor will provide monitoring, measurement, indication and recording (if required) of the RTG system electrical and thermal functions during testing at the Integrating Contractor's facility. The functions to be monitored are as listed in 3.5.4. b., above.

3.5.6 Test Equipment at Contractor's Facility.- The Contractor will provide control equipment for the simulated fuel block and test instrumentation (RTG Test Console) for monitoring, measurement, indication and recording (if required) of the RTG system electrical and thermal functions during testing at the Contractor's facility. The functions to be monitored are as listed in 3.5.4. b., above.

3.6 NaK Ground Service System.-

3.6.1 Functional.- The NaK Ground Service System will provide for: the safe transportation of NaK coolant from the supplier's facility to the Contractor's facility (and/or elsewhere, if necessary), the purification (contaminant removal) of the NaK, and the charging and draining, when necessary of the RTG power system.

3.6.2 Physical.- The NaK Ground Service System will have physical characteristics as shown on applicable Contractor drawings. The system will include a NaK shipping container, a pump, a flow-meter, scales and various controls and accessories. It will be completely self contained and portable.

3.7 Fuel Handling Machine Checkout Equipment.-

3.7.1 Functional.- The fuel handling machine checkout equipment will provide for the electrical and mechanical checkout of the FHM. It will include an alignment fixture for the pre-fueling set up of the FHM alignment adjustments and those tools, equipment and parts necessary for the on site routine maintenance of the FHM. Approximately two hours will be required for FHM checkout.

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3.7.2 Physical.-- The fuel handling machine field test equipment will have physical characteristics as shown on Contractor Drawing NSK-414.

3.7.3 Handling.-- The fuel handling machine field test equipment will be integrated and packaged into a single container on a suitable pallet to facilitate its transportation at the Launch Site and its handling on the MST (if necessary).

3.8 General.-- The following general information and requirements are applicable as baselines for establishing detail responsibilities in coordination efforts between the Using Organization, the AEC, the Contractor and the Integrating Contractor. The criteria of Manual IFS-T IIIIX-33000 (CDI) shall apply.

3.8.1 Installation Interfaces.-- The Contractor shall provide services and articles to the Launch Site and to an Integrating Contractor's facility (as selected by the Using Organization). The services, effort, equipment and data to be supplied by the Contractor shall conform to requirements herein and shall be furnished to the extent provided for under the contract with the AEC.

Items to be supplied directly to the Launch Site from the Contractor's facility shall be shipped by the Contractor to the Site. Items to be supplied to the Integrating Contractor's facility shall be shipped to that facility by the Contractor.

Where required, reshipment of items from the Integrating Contractor's facility to the Launch Site shall be the responsibility of the Integrating Contractor. The mode of transportation used in reshipment shall be equivalent to that used by the Contractor in initial shipment.

The Contractor furnished AGE will be for use on AFWTR, PALC-2, Pad 3 or 4. AGE installation requirements at the Launch Site are dependent on the launch pad selected, features of the launch vehicle and launch complex equipment and facilities available. Installation interface requirements will become more firm when technical data on the launch complex systems have been made available to the Contractor by the User and after technical installation interface coordination between Contractor and the Using Organization.

The MST level assigned for nuclear fueling operations shall be compatible with the FHM characteristics described herein.

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3.8.2 Manuals, Training and Technical Support.-

a. The Contractor shall prepare operating, maintenance and instruction manuals for the Po RTG System AGE based on coordination with other cognizant agencies. These documents shall cover the operating procedures for all fuel loading operations including those of monitoring and checkout.

3.8.3 Nuclear Safety.- The AGE supplied by the Contractor for use at the Launch Site will limit radiation dose rates to Launch Site personnel to the occupational hazard levels established by Department of Commerce Handbook 69, when the equipment is utilized in accordance with Contractor prepared operating and instruction manuals.

Biological shielding, if required, will be provided by the fuel block loading AGE such as the fuel handling machine, fuel recovery cask and cask loading equipment (if this equipment is required).

3.8.4 Generator Cooling.- The requirements for cooling of the generator system during thermal electric heating shall be as specified in Section 3.1.1.3 of Specification MND-3612-13.

3.8.5 Maintenance.-

a. The Contractor shall provide any special AGE tools and equipment, unless available at the Launch Site, required for the maintenance of the SNAP M System. Special tools shall be considered as those items not available through commercial sources of supply. Requirements for maintenance and for special tools and equipment shall be kept to a minimum. Actual maintenance, of a routine nature and as can be performed without removing equipment from the Launch Site will be performed by the Contractor.

3.8.6 Range Requirements.- The Contractor will comply with the applicable AGE sections of the Range Safety Manual, AFWTRM 550-2 for Po RTG System AGE operating at the Launch Site.

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3.8.7 Emergency Recovery Requirements.- Items described herein, in conjunction with site equipment may be used to effect the recovery and disposal of the nuclear fuel in the event of an accident or Launch Vehicle catastrophic abort at the launch complex. (Emergency recovery interface analysis will be coordinated with the Using Organization and the equipment requirements for emergencies at the Launch Site will be resolved at a later date.)

3.8.8 RTG Protection Devices.- Protection devices for the RTG shall be as specified in Specification MND-3612-13. Devices and circuitry to furnish a regulated load to the generator system in integration tests conducted by the Using Organization and in operational use of the generator system shall be furnished by the Using Organization.

3.8.9 Documentation Controls.-

3.8.9.1 Procedural Interfaces.- Control of interface requirements shall be accomplished by interface documentation consisting of interface specifications and interface control drawings. Preparation and maintenance of interface documentation shall conform to the following.

3.8.9.2 Interface Specifications.- These documents shall consist of this specification and subsidiary appendices and lower tier interface specifications incorporated by reference herein.

Subsequent to approval of this specification by the AEC and the Contractor, all subsequent modifications to the document shall be subject to the approval of the AEC.

3.8.10 Classification.- All effort and documentation provided hereunder shall be subject to the classification requirements set forth in the "Classification Guidance for Po RTG Program."

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4.0 AGE TEST AND ACCEPTANCE.-

4.1 Test Data and Documentation.- Test data and test results shall be furnished to the AEC in accordance with the requirements for data submittal as contained in MND-3612-13.

4.2 Witnessing of Test.- The testing specified herein to be conducted by the Contractor may be witnessed by the AEC or his designated representative; however, such witnessing of tests shall not be a condition for the satisfactory completion of the tests.

4.3 AGE Acceptance Criteria.-

4.3.1 Contract End Item Tests.- The Po RTG System AGE Contract End Items (CEIs) shall undergo final acceptance tests in accordance with test requirements in the applicable AGE CEI detail specifications, at the Contractor's plant in Baltimore, Maryland.

4.3.2 AGE Acceptance.-

a. The Contractor shall perform a final performance demonstration of the Po RTG System AGE on a functional mockup of the prototype RTG System (radiator installed) and utilizing an electrically heated fuel block. These performance tests shall constitute the final acceptance of the AGE System prior to shipment of the AGE CEIs to the Launch Site. See AGE System Spec. MND-3612-30 Section 4.1.2.1.e.

b. Quality assurance during actual fuel block loading into the shipping container at the Fueling Agency will be the responsibility of the Fueling Agency as provided for in MND-3612-12.

4.4 AGE Installation Checkout.- After the delivery of the AGE CEIs to the Launch Site, the Contractor shall provide services at that location as provided for under MND-3612-10.

5.0 PREPARATION FOR DELIVERY.- Not applicable.

6.0 NOTES.-

6.1 Definitions.-

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6.1.1 Abort.- Stopping a planned launch after start of countdown. For planning purposes several modes must be considered.

- a. Before nuclear fueling.
- b. After nuclear fueling, before launch.
- c. After ignition, before lift-off.
- d. After lift-off while in vicinity of launch complex.
- e. After launch - away from complex.

6.1.2 AEC.- The United States Atomic Energy Commission, for purposes of this specification the term implies, but is not restricted to, the New York Operations Office of the AEC.

6.1.3 Aerospace Ground Equipment (AGE).- Those implements or devices, other than facilities, which are required on the ground to make a space system, support system, control system, subsystem or equipment operate in its intended environment. This includes ground equipment required to install, launch, control, direct, inspect, test, service, adjust, calibrate, appraise, gauge, measure, repair, overhaul, assemble disassemble, handle, transport, safeguard, record, store, actuate, maintain or operate the system, subsystem, end item, or component.

6.1.4 Contract End Item (CEI).- A deliverable item which is formally accepted by the Procuring Agency as an entity, on a DD Form 250 in accordance with the requirements of a specification. The prime level of assembly for technical and contractual management (customer) control (schedule, configuration, etc.) and accountability for provisioning spares and preparing manuals.

6.1.5 Contractor.- The Martin Company, Division of the Martin Marietta Corporation, Baltimore, Maryland, 21203.

6.1.6 Facility.- The support services and equipments which are a permanent part of the Launch Site, regardless of the flight system being launched.

6.1.7 Fueling Agency.- The Government agency selected by the AEC to furnish and encapsulate the radioisotope fuel.

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6.1.8 Fuel Block.- A containment structure for individual fuel capsules. The fuel block serves as the RTG heat source.

6.1.9 Launch Complex.- The primary facilities, property and AGE used to launch a launch vehicle. Includes blockhouse, launch pads, etc. Usually one complex is peculiar to a specific booster, and sometimes to a specific launch vehicle. Excludes multipurpose support facilities such as Range Safety, tracking stations, etc.

6.1.10 Launch Pad.- The launch pad is the area immediately surrounding the launch vehicles, its composition varies according to launch vehicle needs.

6.1.11 Launch Site.- The area for support of a launch system and includes launch complex, launch pad and all multipurpose support facilities.

6.1.12 Launch Vehicle.- The combination of a Satellite Vehicle and a Booster in the launch condition.

6.1.13 Mobile Service Tower (MST).- A platformed tower on which work and services on a launch vehicle may be performed and which moves away clear of the launch area just prior to launch.

6.1.14 Po RTG Power System (or RTG).- The complete power system which furnishes electric energy to the satellite vehicle during an earth orbit mission. Basically, the RTG consists of a radioisotope (or electric) heat source, a subsystem of thermoelectric elements to convert heat to electric energy, and subsystems to control and dissipate the heat of the radioisotope fuel.

6.1.15 Satellite Vehicle.- The item launched by the booster.

6.1.16 User Organization.- The Government agency having overall cognizance of the satellite program. The term encompasses Contractors and agencies working under the direction of this agency to carry out the satellite program. Also referred to as User Organization.

6.1.17 Integrating Contractor.- A particular contractor of the User Organization, selected to integrate the RTG and AGE into the launch vehicle and launch complex.

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INTERFACE CONTROL SPECIFICATION
FOR FUEL AND FUEL ENCAPSULATION

Po RTG SYSTEM
(SNAP M SYSTEM)

Group 3

Downgraded at 12-year intervals;
not automatically declassified.

This document contains information affecting the National
Defense of the United States within the meaning of the
Espionage Laws, Title 18, U.S.C., Sections 793 and 794,
the transmission or revelation of which in any manner to
an unauthorized person is prohibited by law.

Basic

Approved By: _____

Martin Marietta Corp.

Date _____

Basic

Approved By: _____

AEC

Date _____

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REVISED PAGE INDEX

As of November 24, 1965

This Revised Page Index identifies all authorized changes to, and all current pages of, this Specification as of the date shown above. This RPI is cumulative and supersedes all previous RPI's. Detailed information on each change may be found on the applicable Specification Change Notice.

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This Specification consists of a Title Page, this Revised Page Index Sheet, (no) SCN's, two Table of Contents Sheets, 10 Pages of Text, (Page 10 is the last page).

File this page after the Table
of Contents

Martin Approval _____

The undersigned certifies that all superseded classified pages have been destroyed in accordance with the appropriate security regulations.

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FOREWORD

This specification and supporting subsidiary specifications have been prepared to provide a basis for Contractor liaison and coordination activity with the AEC and the ultimate Using Organization of the Po RTG power system Aerospace Ground Equipment. The specification includes interface criteria relating to other Government agencies who will act in coordination with the Contractor's effort to develop and furnish the Po RTG System.

The content of this specification reflects interface controls established under Phase I of the Po RTG program, (Contract AT(30-1)-3612). However, this specification is not restricted to any particular phase of design, development or production but covers interface areas and responsibilities applicable to a complete program. Emphasis is placed on definition of interfaces applicable to the initial portion of a complete program. It is expected that this document will be expanded and made more definitive through appropriate modifications as integration of efforts is accomplished and as more firm design information and test results become available. In final form, representing the results of mutual agreements reached, it is expected that this specification will be referenced in contractual agreements between the Contractor and the AEC and also in understandings between the AEC and the Using Organization.

The relation of this specification to other Contractor prepared specifications and the contract is shown in Figure II-3 of MND-3612-8-1.

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INTERFACE CONTROL SPECIFICATION
FOR FUEL AND FUEL ENCAPSULATION
Po RTG SYSTEM
(SNAP $\bar{M}$ SYSTEM)

1.0 SCOPE.- This specification establishes functional, physical and administrative requirements pertinent to interfaces between the Contractor, the AEC and the Fueling Agency relative to the processing, testing and delivery of radioisotope fuel for the radioisotope thermoelectric generator (RTG) used in the SNAP $\bar{M}$ Po RTG Space Power System.

1.1 Item Identification.- The specific items (not necessarily contract end items) considered in this interface specification are:

- a. Capsule and block components
- b. Fuel Capsule
- c. Fuel Block
- d. Shipping Container for Nuclear Fuel (Fuel Transport Cask)

1.2 Government Furnished Property.- Provision of the items listed below is the responsibility of the Government.

- a. Radioisotope fuel (polonium-210, metallic form) for loading fuel capsules.
- b. Simulated fuel material (non-radioactive) for loading fuel capsule test specimens.
- c. Fuel capsule and fuel block components for fuel loading (after AEC acceptance at Contractor's facility).
- d. Fueled fuel blocks (after fueling by the Fueling Agency) for installation in RTG's.

2.0 APPLICABLE DOCUMENTS.- The following documents, of exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced below and detail requirements specified herein, the requirements specified herein shall prevail.

See Section 6.1 for definition of certain terms contained in this specification.

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2.1 Contractor .-

NSK-415*	Fuel Transport Cask
NSK-521*	Heat Source Fuel Block
NSK-522*	Fuel Capsule Assembly
MND-3612-11 24 Nov. 1965	Interface Control Specification for Aerospace Ground Equipment for Po RTG Power System (SNAP M System)

2.2 Fueling Agency.-

MD-20373-A1 dated 20 Oct. 1965	SNAP 19C-2 Fuel Capsule Fabrication Procedure
MLM-1273 dated 31 Oct. 1965	Fuel Characteristics
Mound Laboratory letter dated 25 October 1965 (Fueling Schedules)	

2.3 AEC.-

Classification Guidance for Polonium-Fueled RTG
Program (Attachment to AEC letter MC-LCC-3612
dated 14 October 1965)

3.0 INTERFACE REQUIREMENTS.-

3.1 General.- Coordination of capsule, liner, fuel block and shipping cask design shall be such as to assure feasibility of fabrication/assembly to dimensional limitations and compatibility with Fueling Agency handling and processing facilities. Coordination of fuel processing, encapsulation, assembly and testing requirements and procedures shall be such as to assure the necessary quality level of delivered items.

*Drawings are of the issue furnished to the AEC at the end of Phase I of Contract AT(30-1)-3612.

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3.2 Capsule and Block Components.-

3.2.1 Functional.- Fuel capsule (including liner) components will receive and contain radioisotope (or simulated) fuel material. Fuel block components will receive and contain fuel capsules.

3.2.2 Physical.- Fuel capsule (including liner) components and fuel block components will have physical characteristics, as shown on capsule detail and assembly drawings NSK-521 and NSK-522.

3.2.3 Responsibility.-

3.2.3.1 Contractor.- The Contractor shall be responsible for the following.

a. Design capsule (including liner) and block components (based on MLM-1273). Prepare capsule and block detail and assembly drawings (based on NSK-521 and NSK-522) and coordinate with the Fueling Agency.

b. Fabricate capsule (including liner) and block components in accordance with the coordinated drawings.

c. Ship capsule and block components to the Fueling Agency on a mutually satisfactory schedule based on program requirements as coordinated among the Using Organization, the AEC, the Contractor and the Fueling Agency.

Quantities of components provided by the Contractor during the program will be based on normal manufacturing requirements for the following approximate yields.

	<u>Test Articles</u>	<u>Flight Articles**</u>
Liners	468	200
Capsules	458	200
Blocks	5*	4

*2 retained by Mound Laboratories

**includes one spare set

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3.2.3.2 Fueling Agency.- The Fueling Agency shall be responsible for the following.

a. Accept or reject capsule and block components (on the basis of suitability for fueling) for use in encapsulation and assembly.

b. Determine the compatibility of the fuel form with the tantalum capsule liner by suitable tests. Test procedures and results shall be coordinated with the Contractor.

3.2.3.3 AEC.- The AEC shall be responsible for the following.

a. Inspection and acceptance or rejection (for purposes of contractual acceptance via DD 250 Forms) of capsule and block components at the Contractor's facility prior to shipment to the Fueling Agency. Acceptance will be based on material certification, examination of the Contractor's quality control records and visual examination for conformance to the coordinated drawings. Components shall become GFE at this point.

3.3 Fuel Capsule.-

3.3.1 Functional.- Fuel capsules containing simulated fuel will serve as test articles in the Contractor's test program. Fuel capsules containing radioisotope fuel will be inserted into fuel blocks as the source of thermal energy for Po RTG power systems.

3.3.2 Physical.- Fuel capsules will have physical characteristics as shown on Contractor Drawing NSK-522.

3.3.3 Responsibility.-

3.3.3.1 Contractor.- The Contractor shall be responsible for the following.

a. Perform quality control surveillance at the Fueling Agency facility and source inspection of liners and/or capsules containing simulated fuel in accordance with Section 4 herein.

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b. Accept or reject GFE non-fueled (simulated fuel) liners and/or capsules for use in the Contractor's test program.

c. Ship non-fueled liners and/or capsules from the Fueling Agency to the Contractor's facility.

3.3.3.2 Fueling Agency.- The Fueling Agency shall be responsible for the following.

a. Prepare manufacturing procedures (process specifications) for fuel capsules and coordinate the procedures with the Contractor.

Processes and procedures shall be at least equivalent to those set forth in MD-20373 which shall be used as a preparation guide.

The following shall be considered a minimum list of required processes.

- (1) Welding
- (2) Weld, Welder and Welding Operator Qualification
- (3) Capsule Assembly and Test (Fuel Loading)
- (4) Plating (if used)

b. Encapsulate fuel (and simulated fuel) in liners in accordance with the coordinated procedures.

Thermal loading of fueled capsules shall be $0.876 \text{ KW}_t \pm 5\%$ at the time of fuel block acceptance. Actual loading shall be determined within an accuracy of $\pm 2\%$.

c. Assemble and test fuel capsules (fueled and with simulated fuel) in accordance with the coordinated procedures and the applicable requirements of capsule assembly drawings and/or specification. Any plating of the tantalum liner shall be performed by the Fueling Agency.

d. Deliver capsules and liners containing simulated fuel (as GFE) to the Contractor (at Fueling Agency facility) on a mutually satisfactory schedule based on the Contractor's test plan.

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3.4 Fuel Block.-

3.4.1 Functional.- Fuel blocks will be installed (by the Contractor) in radioisotope thermoelectric generators as the source of thermal energy for conversion to electrical energy.

3.4.2 Physical.- Fuel blocks will have physical characteristics (dimensional, structural and nuclear) as shown on Contractor Drawing NSK-521.

3.4.3 Responsibility.-

3.4.3.1 Contractor.- The Contractor shall be responsible for the following.

a. Perform quality control surveillance and source inspection (at the Fueling Agency facility) of Fuel Blocks in accordance with Section 4 herein.

b. Accept or reject GFE non-fueled fuel blocks for use in the Contractor's test program.

c. Perform final inspection of fueled fuel blocks on behalf of the AEC at the Fueling Agency facility on R -4 days (see vehicle launch schedule). This inspection will be the basis for AEC acceptance of fueled fuel blocks. Fueled fuel blocks shall become GFE at this point.

d. Ship GFE non-fueled fuel blocks from the Fueling Agency facility to the Contractor's facility.

e. Ship GFE fueled fuel blocks from the Fueling Agency facility to the Launch Site.

3.4.3.2 Fueling Agency.- The Fueling Agency shall be responsible for the following.

a. Prepare fuel block loading and assembly procedures and coordinate the procedures with the Contractor.

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The following shall be considered a minimum list of required procedures.

- (1) Brazing
- (2) Welding
- (3) Weld, Welder and Welding Operator Qualification
- (4) Block Assembly (including loading of capsules into block and application of mechanical fasteners).

b. Provide all necessary facilities and/or tooling and assemble fuel blocks in conformance with the coordinated procedures and the applicable requirements of block assembly drawings and/or specification. Schedules, based on Schedule No. 7 and No. 10 as contained in Table 1 of Mound Laboratory letter of 25 October 1965 shall be as coordinated among the Using Organization, the AEC, the Contractor and the Fueling Agency.

The total fuel loading of fueled fuel blocks shall be 17.51 KW_t + 5% at the time of fuel block final inspection (3.4.3.1 c, herein). The actual loading shall be determined within an accuracy of $\pm 2\%$.

c. Load fueled fuel blocks into a Contractor furnished shipping container.

d. Deliver non-fueled fuel blocks (as GFE) to the Contractor on a mutually satisfactory schedule based on the Contractor's test plan.

e. Deliver the data listed below (for each fueled fuel block) to the Contractor.

- (1) Certified results of calorimetric tests on each capsule contained in the block versus capsule serial number.
- (2) Location of each capsule in the block (by serial number).
- (3) Certified results of radiation survey of the block.
- (4) Certification of the fuel purity and composition for each batch of fuel used in the block.
- (5) Certification of contamination level (measured by wipe test prior to shipment) of block surface and shipping container interior.

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3.4.3.3 AEC.- The AEC shall be responsible for the following.

a. Accept or reject (for purposes of contractual acceptance) fueled fuel blocks. Acceptance will be based on the final inspection performed by the Contractor (3.4.3.1 c., herein).

3.5 Shipping Container for Nuclear Fuel.-

3.5.1 Functional.- The shipping container for nuclear fuel will receive, contain, and protect a fueled fuel block during transportation between the Fueling Agency facility and the Launch Site and during storage at the Launch Site.

3.5.2 Physical.- Shipping containers for nuclear fuel will have physical characteristics as shown on Contractor Drawing NSK-415 and as described in Specification MND-3612-11.

3.5.3 Responsibility.-

3.5.3.1 Contractor.- The Contractor shall be responsible for the following.

a. Design the shipping container for nuclear fuel and coordinate with the Fueling Agency.

b. Deliver container (or containers, as necessitated by block delivery requirements established by the User Organization) to the Fueling Agency in sufficient time for loading to meet block delivery requirements.

c. Ship loaded container(s) between the Fueling Agency facility and the Launch Site.

3.5.3.2 Fueling Agency.- The Fueling Agency shall be responsible for the following.

a. Proper loading of fuel blocks into the container and proper preparation of the container for shipment.

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4.0 QUALITY ASSURANCE PROVISIONS.-

4.1 General.- The Contractor and the Fueling Agency shall maintain quality control programs which are in general accordance with the Contractor's quality control plan, Fueling Agency Document MD-20373 and which are adequate (as mutually agreed during coordination of design, drawings, specifications and procedures as required herein) to assure the quality and integrity of fuel and fuel blocks used in the Po RTG.

4.2 Specific.-

4.2.1 Contractor.- The Contractor shall be responsible for the following.

a. Surveillance inspection of fabrication and test operations performed by the Fueling Agency and including dimensional check of non-fueled articles, review of Fueling Agency inspection documentation and review of radiographs.

b. Source inspection of non-fueled, assembled liners, capsules and blocks at the Fueling Agency facility prior to shipment to the Contractor.

4.2.2 Fueling Agency.- The Fueling Agency shall be responsible for the following.

a. Detailed quality control of fuel processing, fuel loading and assembly of liners, capsules and blocks including all tests and measurements required prior to shipment.

5.0 PREPARATION FOR DELIVERY.- Not Applicable.

6.0 NOTES.-

6.1 Definitions.-

Contractor.- The Martin Company, Division of Martin Marietta Corporation, Baltimore, Maryland.

Fueling Agency.- The Government Agency (Mound Laboratory) selected by the AEC to process and encapsulate radio - isotope fuel.

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Fuel Capsule.- An individual container of radio-isotope fuel; consisting of the fuel provided by the Fueling Agency within a tantalum cladding and further encapsulated within capsule shell components furnished by the Contractor.

Fuel Block.- A containment structure for individual fuel capsules. The fuel block serves as the RTG heat source.

Launch Site.- The area for support of a launch system. Includes launch complex, launch pad and associated support facilities. (Western Test Range.)

RTG Power System (or RTG).- The complete power supply which furnishes electric energy to the satellite vehicle during an earth orbit mission. Basically, the RTG consists of a radioisotope (or electric) heat source, a subsystem of thermoelectric elements to convert heat to electric energy, and subsystems to control and dissipate the heat of the radioisotope fuel.

User (or User Organization).- Government agency having overall cognizance of the satellite program. Includes other agencies and contractors working under the direction of this agency to carry out the satellite program.

Coordination.- As used herein, coordination shall mean the preparation of drawings, specifications, procedures designs, etc. by either the Contractor or the Fueling Agency in cooperation with and by mutual agreement of the other.

SNAP M System.- The complete generator system plus the associated AGE furnished by the Contractor.

6.2 Supplementary Information.-

6.2.1 Security Classification.- All work performed and/or articles provided hereunder shall be subject to security classification as set forth in "Classification Guidance for Polonium-Fueled RTG Program."

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24 November 1965

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SPECIFICATION FOR
Po RTG POWER SYSTEM
(SNAP M SYSTEM)

Group 3

Downgraded at 12-year intervals,
not automatically declassified.

This document contains information affecting the National
Defense of the United States within the meaning of the
Espionage Laws, Title 18, U.S.C., Sections 793 and 794,
the transmission or revelation of which in any manner to
an unauthorized person is prohibited by law.

Basic

Approved by: _____

Martin-Marietta Corp.

Date _____

Basic

Approved by: _____

AEC

Date _____

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FOREWORD

This specification and contractor prepared subsidiary specifications referred to herein have been established to define requirements, characteristics, and interface criteria for a radioisotope fueled thermoelectric power system (Po RTG) and associated support equipment. The content of this specification reflects the results and efforts of Phase I of the Po RTG program (Contract AT(30-1)-3612) and is not restricted to any particular phase of design, development and production.

In the preparation of this document, emphasis has been placed on definition of areas applicable to the initial portion of a complete program. It is expected that this document will be made more definitive and completed through modifications as integration of efforts is accomplished and as more firm design information and test results become available. In final form, representing the results of mutual agreement, it is expected that this specification will be referenced in contractual agreements between the Contractor and the AEC.

The relation of this specification to other Contractor prepared specifications and the contract is shown in Figure II-3 of MND-3612-8-1.

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REVISED PAGE INDEX

As of 24 November 1965

This Revised Page Index identifies all authorized changes to, and all current pages of this Specification as of the date shown above. This RPI is cumulative and supersedes all previous RPI's. Detailed information on each change may be found on the applicable Specification Change Notice.

<u>Page No.</u>	<u>Para No.</u>	<u>SCN</u>	<u>CCP</u>	<u>Effectivity</u>
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This Specification consists of a Title Page, this Revised Page Index Sheet, No SCN's, 3 Table of Contents Sheets, 36 Pages of Text (Page 34 is the last page, 5 Pages of Appendix A and 11 Pages of Appendix B.

File this page after the
Table of Contents

Martin Approval _____

The undersigned certifies that all superseded classified pages have been destroyed in accordance with the appropriate security regulations.

Destruction Certification No. _____
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SPECIFICATION FOR Po RTG POWER SYSTEM

1.0 SCOPE.-

1.1 Scope.- This specification establishes the performance, design, configuration, test, acceptance and transportation requirements for a radioisotope fueled (polonium) thermoelectric power system (Po RTG).

1.2 Mission.- The Po RTG power system covered by this specification is intended to be a primary power source for unmanned Satellite Vehicle applications on earth orbital missions. Provisions for application to specific Satellite Vehicles are as defined herein.

2.0 APPLICABLE DOCUMENTS.-

2.1 General.-

2.1.1 Extent of Applicability.- The following documents form a part of this Specification only to the extent specified in the text of this Specification. Where a document or its provisions are to be "used as a guide" (or other similar phrases) the extent of applicability shall be determined by the Contractor based on management and technical judgement. For reference purposes only, the paragraph in this Specification where each document is called out are shown opposite each document in the following listing.

2.1.2 Dates of Issue.- References to documents in the text of this Specification are made by basic number only. Such basic reference shall mean the exact issue specified in this Section 2, including the cited amendments, changes, etc.

2.1.3 Rules of Procedure.-

2.1.3.1 In case of conflict between this Specification and the Contract, the Contract shall govern. In case of conflict between this Specification and any document referenced herein, this Specification including any authorized changes, appendices, or addendums hereto, shall govern.

2.2 Applicable Documents.- In addition to the following listing, the documents referred to in Appendix "A" hereto are also applicable to the extent described in the appendix.

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2.2.1 AEC.-

Para. No.

Contract AT(30-1)-3612; Phase I,
Po RTG Program

3.1.2.1e
(etc.)

Classification Guidance for Polonium
Fueled RTG Program (AEC ltr of
14 October 1965)

Part of this
document

2.2.2 Military.-

2.2.2.1 Specifications.-

<u>Number</u>	<u>Title, Dates Amendments</u>	
MIL-P-116D	Preservation, Methods of, dated 4 December 1962, with Amend. 1	5.1.1
MIL-C-6021F	Castings, Classification & Inspection of, dated 4 November 1964	3.3.12.3
MIL-W-6858C	Welding, Resistance, Aluminum, Magnesium, Non-Hardening Steels or Alloys, Nickel Alloys, Heat Resisting Alloys, and Titanium Alloys, Spot and Seam, dated 20 October 1964	3.3.12.3
MIL-W-8160D	Wiring, Guided Missile, In- stallation of, General Specifications for dated 24 December 1963, with Amend. 1	3.3.12.2
MIL-I-8500B	Interchangeability and Re- placeability of Component Parts for Aircraft and Missiles, dated 10 October 1960	3.3.6
MIL-W-8604	Welding of Aluminum Alloys, Process for dated 8 October 1959, with Amend 1	3.3.12.3
MIL-W-8611A	Welding, Metal Arc and Gas, Steels, and Corrosion and Heat Resistance Alloys, Process for, dated 24 July 1957	3.3.12.3

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<u>Number</u>	<u>Title, Dates, Amendments</u>	<u>Para. No.</u>
MIL-Q-9858A	Quality Program Requirements dated 16 December 1963	4.1.1
MIL-W-16878D	Wire, Electrical, Insulated, High Temperature, dated 5 July 1961, with Supl. No. 1	3.3.12.2
MIL-W-18326A	Welding of Magnesium Alloys Gas and Arc, Manual and Machine Processes for, dated 14 June 1956	3.3.12.3
MIL-C-26482C	Connectors, Electrical, Circular, Minature, Quick Disconnect, dated 20 Feb. 1963, with Amend. 1, Supl. No. 1A, and Change 1	3.3.12.2
MIL-W-45223	Welding, Spot, Hardenable Steels, dated 26 June 1962	3.3.12.3
MIL-C-4566A	Calibration System Require- ments, dated 9 Feb. 1962	4.3.1.5
2.2.2.2 <u>Standards.-</u>		
MIL-STD-143A	Specifications and Stan- dards Order of Procedure for the Selection of, dated 14 May 1963	3.3.2
MIL-STD-803A Parts 1 & 2	Human Engineering Design Criteria for Aerospace Systems and Equipment, dated 27 January 1964 and 1 December 1964	3.1.4.6

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2.2.3 Contractor.-

2.2.3.1 Specifications.-

Para. No.

MND-3612-10 24 November 1965	Interface Control Specification for Po RTG Power System	3.1.2.1 (etc.)
MND-3612-11 24 November 1965	Interface Control Specification for AGE for Po RTG Power System	3.1.3 (etc.)
MND-3612-12 24 November 1965	Interface Control Specification for Fuel and Fuel Encapsulation Po RTG Power System	3.1.4.3 (etc.)
MND-3612-30 24 November 1965	AGE Ground Equipment Specification; Po RTG	3.2.1 (etc.)

2.2.3.2 Drawings.-*

NSK-516	Interface Drawings - SCS
NSK-520	Generator Assembly
NSK-521	Heat Source Fuel Block
NSK-522	Fuel Capsule Assembly
NSK-523	Thermal Control System
NSK-524	Shutter Vane - Thermal Control System
NSK-525	RTG System Radiator - SCS Concept

*Drawings of the issue submitted to the AEC at the end of Phase I of the program.

3.0 REQUIREMENTS.- This Section 3 establishes the requirements for performance, configuration, arrangement, design and construction of the RTG power system.

3.1 Performance.-

3.1.1 Mission Performance Characteristics.-

3.1.1.1 General.- The contents of Section 3.1.1 and its sub-

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paragraphs are for reference purposes only. Requirements for the interface of the elements of the RTG power system described herein with other items may be found in the Interface Control Specifications listed under 2.2.3.

3.1.1.2 Operational Concept.-

a. Employment - The system described herein is intended to be used with the "SCS" Satellite Vehicle as its primary power source. The Satellite Vehicle is intended to be launched into earth orbit by the Titan 3D Booster.

b. Deployment - The RTG power system described herein is intended to be a part of a Satellite Vehicle launched from Western Test Range by personnel other than the Contractor's employees.

3.1.1.3 Logistics Concept.-

a. Spares - The spare items to be used in maintenance of the RTG shall be those items specified as such in the Contract incorporating this Specification.

b. Maintenance - Except for maintenance by Contractor's personnel, maintenance of the equipment described herein, at all locations other than the Contractors Manufacturing Facility, shall be by simple mechanical removal and replacement only, except for certain soldering and unsoldering as described in RTG Maintenance Manuals, and then, limited to those spares specified in the Contract. Maintenance by Contractor personnel at other than the Contractor's facility shall be limited to certain welding operations and adjustment of RTG subsystems, all as specified in the aforementioned Maintenance Manuals.

c. Time Critical Actions - The Fuel Block shall not be installed in the RTG until it exhibits a thermal output of thermal watts (or less). The Satellite Vehicle shall be launched within 14 calendar days thereafter to meet a mission requirement of 90 calendar days.

3.1.1.4 Personnel and Training Concept.- Use of all end items described herein is intended to be as described in paragraph 3.1.1.2. All personnel who will handle, operate, or control the end items should receive training in their handling and use by the Contractor. All personnel who will be in the vicinity of the RTG when fueled, or in the vicinity of the fuel itself, should receive special Nuclear Safety Training by the AEC.

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3.1.2 RTG Primary Performance Characteristics.-

3.1.2.1 Generator System.-

a. General.- The RTG shall provide the following performance when subjected to the mission environments specified in paragraph 3.1.4.4.3b and after exposure to the transportation, and handling environments specified in paragraph 3.1.4.4.2. In addition, the RTG shall provide the same performance when subjected to the pre-launch environment specified in paragraph 3.1.4.4.2 when provided with cooling as specified in paragraph "d" below and after exposure to the forementioned transportation and handling environments.

b. Electric Output - See Specification MND-3612-10.

c. Weight - As a design objective the RTG system shall weigh approximately 430 pounds. This figure excludes mounting hardware, such as bolts, washers, (unless such items are specified as captive hardware) and radiation shields and thermal insulation shields not an integral part of the RTG.

d. Heat Rejection - The RTG system shall provide the required electrical performance during the ground operation in the Launch Vehicle when a heat transfer rate of * BTU's per minute is made available to the radiator by ground cooling provisions.

*Required thermal inter-relation between RTG and the satellite and launch vehicle to be established in accordance with the provisions of MND-3612-10.

e. Radiation Shielding - The maximum allowable total integrated dosage to the payload at the end of mission life shall be 20 Rads at a distance of 208 inches ahead of the forward bulkhead of the vehicle as specified in drawings referred to in Contract AT(30-1)-3612.

Shielding provisions shall be based on radiation from a bare source of polonium metal as follows:

	Energy (mev)	Abundance (particles/thermal watt-sec.)
Gamma	0.8	1.4×10^7
X-Ray	0.77	1.7×10^6
	0.01 to 0.015	3.4×10^8
Alphas	5.3	1.1×10^{12}
	4.5	1.4×10^7
Neutrons	1.0 to 4.0	2100

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The above data does not make provisions for self-shielding factors.

f. Nuclear Safety.- The RTG shall be designed and fabricated to assure complete containment of the fuel except under certain limited conditions where loss of containment does not subject the populace to undue hazards. Containment provisions shall not include safety allowances provided by re-entry and satellite vehicles. Safety provisions shall be based on re-entry parameters of MND-3612-10.

g. Reliability.- The RTG shall be designed and fabricated to provide a reliability of 0.998. This reliability shall be demonstrated by testing components or systems to failure in accordance with the Contractor's reliability program plan as approved by the AEC.

3.1.3 RTG Secondary Performance Characteristics.-

a. General.- In the case of conflict between any secondary performance characteristic requirement and a primary characteristic, the primary characteristic shall govern.

b. Instrumentation.- Instrumentation sensors shall be provided to permit determination of proper operation, operational status, and ground emergency conditions, via either land lines to the launch complex blockhouse, or via the Launch Vehicle. Sensors to be incorporated in the RTG shall consist of those required to furnish operating characteristics as listed in paragraph 3.5.4 of MND-3612-11.

c. Any RTG instrumentation sensors which would interrupt the launch operations if they fail in either short or open conditions shall have a _____ probability of achievement of function fulfillment.

d. Control -

- (1) Provisions need not be provided in the generator system to permit remotely controlled "start-up."
- (2) Provisions need not be provided for the use of an internal electrical load across the output of the RTG. All external load provisions shall be provided by the Satellite Vehicle.

e. Thermal Controls - As required by Interface Specifications and drawings listed in 2.2.3 herein.

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3.1.4 Operability .-

3.1.4.1 General.- The RTG shall be capable of meeting the following requirements, while providing the performance required by Sections 3.1.2 and 3.1.3 herein.

3.1.4.2 Maintainability.-

a. The RTG shall not require any scheduled maintenance during useful lifetime of 10⁴ days of continuous operation other than replacement of expended fuel blocks or electric heaters which simulate the fuel block, during pre-launch holds.

b. All maintenance by non-Contractor personnel on the Generator system, shall be performed by removal and replacement of bolt-on, plug-in, screw-in, clamp, or other similar mechanically restrained device, using simple tools. All such maintenance shall be conducted by personnel who have received special training in the operation, maintenance and nuclear safety aspects of the RTG.

c. Service and access provisions for the RTG shall be as specified in applicable Interface Specifications.

3.1.4.3 Life.-

a. RTG Power -

- (1) The RTG, less the Fuel Block, shall have a total useful life of years while in storage (non-operating) after acceptance and before subsequent initial operation.
- (2) The RTG, except for the Fuel Block, shall have a total operating life after acceptance of 13⁴ days, when activated by either radioisotope fuel or an electrically heated block capable of simulating thermal characteristics of the fuel block. Conformance with this requirement shall be required only for intended environmental conditions and induced loads.
- (3) The Fuel Block shall have an operational life as specified in Specification MND-3612-12.

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3.1.4.4 Environment.-

3.1.4.4.1 General.- The RTG shall be capable of withstanding the applicable environments specified below without degradation which results in out-of-tolerance performance. The exact applicability of the stated environments shall be as defined elsewhere herein and in subsidiary specifications hereto which will be prepared by the Contractor.

3.1.4.4.2 Ground.-

a. Transportation, Handling and Storage.-

- (1) General - Elements of the RTG and packaging including spares, shall withstand the following environmental conditions, when non-operating and packed for shipment.
- (2) Sustained Acceleration - 3G in any direction.
- (3) Temperature - Ambient temperature of from 32°F to + 140°F plus the effect of solar radiation for a period of up to four hours at a rate of 300 BTU per hour per square foot.
- (4) Humidity - Relative humidity up to 100 percent including the effects of condensation and frost.
- (5) Shock - Transportation shock loads as induced by the mode of transportation selected by the Contractor for shipment of the RTG. In any event, the equipment and its packaging need not be designed for shock loads in excess of 5 g's applied at the base of the transportation package. Provisions need not be made to sustain free fall drops in handling of the complete system.
- (6) Vibration - Any axes, the upper frequency shall depend on the packaged weight as follows:

<u>Wt. Lbs.</u>	<u>Frequency</u>	<u>Double Amplitudes or Acceleration</u>
All	5 - 15 cps	0.4 in.
Under 100 lbs.	15 - 500 cps	+ 5G
100 - 300 lbs.	15 - (inverse proportion to wt, 50 - 500 cps)	+ 5G
Over 300 lbs.	15 - 50 cps	+ 5G

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- (7) Temperature Shock - Exposure to 100°F ambient air plus solar radiation of 300 BTU per square foot per hour after stabilization at 32°F.

b. Sheltered.-

- (1) General - The RTG, including spares, shall be capable of normal operation (unless specified otherwise) under the following conditions.
- (2) Temperature - As provided for within MND-3612-10.
- (3) Sand and Dust - Not applicable.
- (4) Humidity - Up to 100% relative humidity including conditions wherein condensation takes place.
- (5) Salt Fog - Non-operating only. Salt characteristics of up to 20% by weight.

c. Unsheltered.-

- (1) General - RTG equipment which is required to operate in an unsheltered environment shall be capable of operation under any likely combination of the following conditions.
- (2) Temperature - As provided for within MND-3612-10.
- (3) Humidity - Up to 100% relative humidity including conditions wherein condensation takes place.
- (4) Salt Fog - Salt concentrations up to 20% by weight.
- (5) Sand and Dust - Airborne sand and dust at a velocity of 2500 ft/min. with a density of 0.1 grams per cubic foot or must be protected to withstand this environment. Requirement is applicable only to equipment intended for operation within 25 feet of ground level.
- (6) Fungus - Shall be incapable of supporting fungus growth.
- (7) Rain - Shall be capable of withstanding rain at a rate of 4 inches per hour.

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(8) Snow and Ice - Not applicable.

(9) Hail and Sleet - Not applicable.

3.1.4.4.3 Qualification and Flight Test Hardware.-

a. Qualification Levels - The RTG system shall demonstrate capability of satisfactory operation after subjection to qualification tests which impose the dynamic loads and environments specified in Contract AT(30-1)-3612. The specific qualification tests to be performed and the articles to be subjected to qualification test shall be as stated herein (See Section 4).

b. Acceptance Tests Levels - RTG systems intended for flight use shall demonstrate satisfactory operation:

- (1) After subjection to acceptance tests in which vibration loads are *% of the magnitude of test levels used to qualify the system.
- (2) During subjection to a simulated space environment, which imposes a pressure of 10^{-6} torr.

3.1.4.5 Transportability.- The RTG power system excluding isotope fuel shall be capable of transportation by aircraft when packaged. The design of the RTG and its shipping container shall include provisions for lifting points, tie-down points, forklift trucks, and other handling techniques covered by MND-6312-10 and Instruction and Operating Manuals.

3.1.4.6 Human Performance.- The RTG shall be designed using MIL-STD-803 as a guide.

3.1.4.7 Safety.- In accordance with the provisions of Contract AT(30-1)-3612, Specifications referred to in 2.2.3.1 and requirements herein.

3.2 System Definition.-

3.2.1 Interfaces.- Detail interface criteria for the RTG shall be as specified in MND-3612-10 and MND-3612-30.

3.2.2 Contract End Items.-

3.2.2.1 General.- Contractor furnished articles shall consist of the following Contract End Items. The quantities to be provided shall be as specified in the Contract Schedule.

*Value to be established in coordination with the AEC.

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3.2.2.2 RTG Power System.- The RTG shall consist of a thermoelectric module subsystem, a thermal control subsystem to sense and dissipate excess heat of the nuclear fuel during normal and emergency operation, a coolant heat rejection subsystem which uses a liquid metal coolant to maintain thermoelectric cold junction temperatures, and provisions for installing a fuel block assembly. The RTG when mounted in the launch vehicle shall be capable of receiving a Fuel Block using a locally operated, Contractor furnished, fueling machine. Configuration and arrangement of the RTG and its subsystems shall be in general accordance with the drawings listed in 2.2.3.

3.2.2.3 Fuel Block.- The Fuel Block shall contain Government furnished and encapsulated polonium-210 (metal) radioisotope fuel to provide the required heat for operation of the RTG. The Fuel Block and individual capsules of fuel therein shall conform with the requirements of; specification MND-3612-12, a Contractor prepared end item specification, and the following criteria:

- a. The safety report finalized during Phase III of the program.
- b. The outer fuel capsule containment shall be Haynes-25 or Ta-10W with suitable oxidation protection provided in conjunction with use of the latter material. The containment shall be designed to both retain its integrity for a period of five years when exposed to a salt water environment and survive impact at terminal velocity and operating temperature upon granite. Fuel capsule outer containment shall be welded by either TIG or EB processes. The maximum surface temperature of the fuel capsule shall never exceed approximately 1832°F (1000°C) except under conditions defined in the approved forementioned safety report.
- c. The polonium-210 shall be contained within a tantalum liner (inner fuel capsule containment) with a thickness between 20 and 60 mils. The liner shall be welded by TIG process.
- d. Design of the fuel capsules and block shall be based on the following isotope characteristics (for Po metal).

Half life (days)	138.4
Helium evaluation rate (CC at STP/curie)	0.0226
Power (thermal watts/curie)	0.03202
Density (g/CC)	9.4
Melting Point (°C)	252.0
Boiling Point (°C)	962.0
Heat of vaporization (K cal/mole)	24.6
Linear coefficient of expansion (cm/cm°C) (-196 to +30°C)	2.35×10^{-5}

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$$\text{Vapor pressure (438-745}^\circ\text{C)} \quad \text{Log P} = \frac{-5377.8 \pm 6.7}{\text{T}(^\circ\text{K)}} + 7.2345$$

(mm of Hg)

Power density (thermal watts/cc) 1355.0

3.2.2.4 Thermal and Radiation Shields.- Contract end items, such as thermal and radiation shields to be furnished by the Contractor, which are not an integral part of the RTG shall conform to requirements of contract end item specifications prepared by the Contractor and coordinated with the AEC.

3.2.2.5 Electrically Heated Fuel Block Simulator.- An electrically heated fuel block simulator shall be furnished with each RTG delivered by the Contractor. The fuel block simulators shall conform to specification MND-3612-30.

3.2.3 Government Furnished Property.- The AEC shall be responsible for furnishing and encapsulation of nuclear fuel (including inert simulated fuel required for test articles) for flight operational units. Articles and services to be provided will be in accordance with Interface Control Specification MND-3612-12.

3.3 Design and Construction.-

3.3.1 General.- All elements of the RTG shall conform to the following design and construction requirements, except where such compliance is in conflict with the requirements of Section 3.1, "Performance". In case of such conflict, the approval of the Procuring Activity shall be obtained, and the deviation documented in the appropriate specification.

3.3.2 Selection of Specifications and Standards.- The selection of Specifications and Standards subsidiary to this Specification and to Specifications referenced herein, shall be made by the Contractor based on the following criteria in the order of priority shown, using MIL-STD-143 as a guide. All four criteria shall be met where possible.

- a. Suitability for use for the mission.
- b. Previously qualified parts, processes, etc.
- c. Government standard parts, processes, etc.
- d. Low cost.

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Military Specifications and Standards shall be applicable to the design and construction of the RTG to the extent provided for herein and in Appendix "A" hereto. The performance of tests and the furnishing of data in accordance with the requirements of Military Specifications and Standards shall be accomplished to the extent specifically provided for herein and in other Contractor prepared documentation furnished in accordance with the provisions of the contract.

3.3.3 Materials, Parts and Processes.- The Contractor shall select materials, parts and processes, consistent with the other requirements herein, using the criteria and priorities specified in paragraph 3.3.2 above. All materials, parts and processes selected must be compatible with system performance and environmental requirements. Strategic or critical materials shall not be used unless essential to attainment of performance and conformance with environmental requirements.

3.3.4 Standard and Commercial Parts.- The Contractor may, at his own volition, use commercial or Contractor standards for materials, parts, and processes which meet the requirements for the RTG when:

a. Neither applicable Government or non-government standardizing organization documents exist or are satisfactory.

b. Or, the Contractor standards are equivalent to or exceed the requirements of the other documents.

3.3.5 Qualification of Parts.-

3.3.5.1 General.- All materials and parts used in the system must be qualified in accordance with qualification or qualification test requirements herein. Qualification shall be accomplished prior to flight of the first Generator System. Qualification of an item at any level of assembly shall constitute qualification of all items contained therein.

3.3.5.2 Previously Qualified Components and Parts.-

a. General - Components and parts shall be considered to be qualified where any one of the following applies.

b. Standard Parts - Standard components and parts shall be qualified if procured to Government Standards which are controlled by a Qualified Parts List and the standard or specification to which they are ordered meets the various applicable requirements herein.

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c. Qualification Through Use - Components and parts that have records of satisfactory performance in applications equal to or more severe than the various applicable requirements herein shall be qualified for use in the RTG.

d. Qualification Through Similarity - Components and parts identical to items previously qualified through "b" and "c" above, except for details which are not affected by the intended use shall be qualified for use in the RTG.

3.3.5.3 Un-Qualified Components.- All unqualified components shall be qualified through either qualifications test, or analysis. Qualification tests shall be as defined in Section 4.3.2.3 herein. Qualification through analysis shall substantiate to the satisfaction of the AEC that the items will adequately withstand the requirements of their intended use.

3.3.6 Interchangeability and Replaceability.- Specification MIL-I-8500 shall be used as a guide in the design and selection of interchangeable and replaceable parts. Demonstration of compliance and verification of the interchangeability or replaceability of articles shall not be required.

3.3.7 Workmanship.- During the fabrication of the RTG a high level of workmanship shall be insured by use of properly trained personnel equipped with correct tools and materials, by the selection of adequate fabrication and assembly techniques, and the application of uniform workmanship standards. All articles of equipment furnished shall be free from defects which will affect the mission. Particular attention shall be given to the following:

- a. Elimination of burrs and sharp edges.
- b. Accuracy of tolerances and dimensions including radii of fillets.
- c. Correct marking.
- d. Tightness of mechanical fasteners.
- e. Neatness and thoroughness of cleaning, soldering, wiring and welding.
- f. Assurance of circuit integrity.

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3.3.8 Electromagnetic Interference.- The RTG, either fueled or when electrically heated is intended to operate in conjunction with other equipment of the Launch Vehicle and in the launch complex without detriment resulting from electromagnetic radiation of other devices, and without causing detriment to the other devices. Requirements for electromagnetic compatibility shall be specified in the Interface Control Specification MND-3612-10.

3.3.9 Identification and Marking.-

a. Each RTG and all interchangeable units supplied as a part of the RTG shall be provided with an identification plate or decal conforming to MIL-STD-130 unless the availability of space, operating temperature, or other constraints prohibit such identification. In the event of such provisions, the items shall be marked as described in "b" herein.

b. All replaceable parts subassemblies, and assemblies shall be marked with an identifying number consistent with the Contractor's Drawing System except where the size of the item prohibits such practice. Modified Government furnished property shall be re-identified. Un-modified GFP shall retain its original identification.

c. All interchangeable units, and all End Items that weigh forty-five (45) pounds or more shall have the weight marked to the next highest five pound increment on at least one external surface easily visible to personnel concerned.

d. See Section 3.3.12 for other detail requirements.

3.3.10 Storage.- See paragraph 5.1.

3.3.11 Materials Compatibility and Corrosion.- The system shall be designed to prevent galvanic corrosion by contact of dissimilar metals. No two materials shall be placed in immediate contact with each other if detrimental results will exist in any applicable environment. All metallic parts shall be protected against corrosion by finishes, coatings or selection of suitable base metals except where such protection is impractical due to operating temperature and/or performance considerations. External color of AGE shall be as described in the AGE End Item Specification. Materials compatibility controls between the RTG and the launch vehicle shall be determined by Contractor coordination with the User and documented in specification MND-3612-10.

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3.3.12 Design Disciplines.-

3.3.12.1 General.- The following requirements shall govern the design in the indicated discipline.

3.3.12.2 Electrical - Electronic.-

a. Identification - All external electric wire and cabling shall be identified by appropriate color coding, using as a guide MIL-W-8160, except that it shall be accomplished by imprinting on the cable or sleeve within three inches of each termination or junction. This requirement is not mandatory where the thermal environment prevents use of any such method.

b. Grounding -

- (1) RTG output power - The output terminals (two) of the RTG provided for use by an external load shall not be grounded to the RTG.
- (2) All internal circuitry of the generator system which draw power from RTG thermoelectric modules shall have ground or return lines floating with respect to the system structure.
- (3) All electrical connections provided within the system shall provide for integral single lead grounds to their terminations except where electromagnetic interference characteristics dictates the use of individual ground or return circuits.

c. Bonding - All interchangeable or replaceable structure modules within the system shall be bonded in such a manner that an electrical path is available to the external structure on which the RTG is mounted.

d. Circuit Protection - Circuit protection devices such as fuses and circuit breakers need not be used in the RTG.

e. Wire - All wire used for electrical hookup shall meet or exceed requirements of MIL-W-16878. All wiring external to components shall be installed using MIL-W-8160 as a guide.

f. Electrical Connections - Electrical connectors shall be in accordance with MIL-C-26482 unless severe conditions dictate the use of other connectors.

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3.3.12.3 Mechanical.-

a. Handling and Servicing Provisions -

- (1) All interchangeable units weighing forty-five (45) pounds or more shall have convenient provisions for lifting by one or more persons as necessary. All units over ninety (90) pounds shall incorporate provisions for mechanically lifting the item.
- (2) All servicing and access provisions shall conform with paragraph 3.1.4.6.

b. Welding - All welding other than that provided for fuel containment integrity, and, dependent on the application, shall be in accordance with MIL-W-6858, MIL-W-8064, MIL-W-8611, MIL-W-18326, or MIL-W-45223, as applicable.

c. Castings - All castings shall be classified and inspected per the requirements of the specification MIL-C-6021.

d. Fasteners - All mechanical fasteners shall be secured by lock wire, adhesive binding material, lock washers, or other similar devices.

3.4 Performance Allocations.- The performance capability and reliability allocations for subsystems which comprise the RTG shall be as specified in specifications for such subsystems. These subsystem specifications shall be prepared by the Contractor and coordinated with the AEC.

3.5 Product Configuration Control.- Any change to an RTG power system to be delivered under the contract which changes its interface characteristics or performance as defined herein and in MND-3612-10 shall require a change in RTG identification as well as a change in the appropriate specification.

4.0 QUALITY ASSURANCE PROVISIONS.-

4.1 General.-

4.1.1 Requirements.- The quality assurance provisions specified herein include the major requirements which will collectively assure adequate assessment, when coupled with a detailed quality control program, of development progress, verification of performance, and high standards of fabrication. The test program provided for herein will provide supplementary data for use in the Quality and Reliability

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Programs evaluations. The Quality Control Program used in conjunction with these requirements shall be in accordance with MIL-Q-9858.

4.1.2 Classification.- All inspections and tests conducted on the RTG shall be classified in one of the categories specified below, and when so classified shall be conducted in accordance with the requirements of that category. Any changes in the testing program, or the need to repeat a previously accomplished test, caused by an authorized hardware or program change, shall be proposed and authorized as a part of the change, including modification and addition to the requirements of this specification.

4.1.3 Compliance Verification.-

4.1.3.1 Methods of Verification.- All of Section 3.0 of this specification shall be subjected to Compliance Verification, when applicable. The verification shall be conducted either by inspection, analysis, demonstration, examination of records, or test. Compliance with the requirements of this Section 4 shall be verified by examination of records. Documented certification of all compliance verification shall be furnished to the Contracting Officer, and shall consist of proof of compliance of the requirements which have been verified.

4.1.3.2 Inspection.- Inspection shall be a detailed physical examination of an item to determine its conformance with the applicable contract requirements. The Contractor shall conduct inspection of all items from incoming inspection of parts and materials through final assembly. The Government may witness any such inspection at the Government's discretion upon prior notice to the Contractor and for those inspections which have not been completed.

4.1.3.3 Analysis.- Analysis shall be based on Technical data that is available in reports, test results, laboratory notebooks, etc. Preparation of detailed data or special reports shall not be required. The Contractor shall present the informal data to the designated Procuring Activity Technical or Contractual representative who shall execute a Certification of Compliance Verification upon satisfaction that the data does verify compliance.

4.1.3.4 Demonstration.- Demonstration shall consist of actual performance of a functional requirement. Items to be verified by demonstration will be verified prior to equipment delivery. If an opportunity for such demonstration is not available to the Contractor at that time, the compliance shall be considered to be an Excusable Delay to the Contractor.

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4.1.3.5 Test.- Tests which are performed to verify compliance shall be documented and the data certified by the Contractor and, if present, by the observing Government inspector. The certified data shall constitute compliance verification.

4.1.3.6 Examination of Data.- Compliance verification through examination of data shall consist of inspection of Contractor records by a Government inspector to ascertain that the requirements have been met.

4.2 Inspection.- The Contractor shall make all deliverable items and existing lower levels of assembly thereof of the RTG available for inspection at reasonable times, to authorized Government inspectors, at the discretion of the Inspector, upon prior notice to the Contractor for those inspections which have not been completed. The Government Inspector shall conduct or witness any inspection when so required by the Contractor.

4.3 Tests.-

4.3.1 General.-

4.3.1.1 Requirements.- The Contractor shall comply with all the requirements of this Section 4.3, as applicable, as a portion of the verification of compliance with Section 3.0 hereof. The Contractor is not required to conduct any tests not specified herein, but may conduct any additional tests at his own volition if the Contractor deems such tests necessary.

4.3.1.2 Witnessing.- The Contractor shall conduct any of the tests specified herein in the presence of the Authorized Government Inspector at reasonable times, at the discretion of the inspector upon prior notice to the Contractor, for those tests which have not been completed.

4.3.1.3 Failure Recording.- The Contractor shall make complete records and analysis of any failure, malfunction, or out-of-tolerance performance characteristics occurring during any test, in accordance with Quality and Reliability Program Plans.

4.3.1.4 Test Conditions.- Except where specified otherwise, all tests shall be conducted under the existing ambient conditions within the limits specified in paragraph 3.1.4.4.2 for sheltered equipment, at the volition of the Contractor.

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4.3.1.5 Instrumentation and Measurements.-

a. All equipment used for measuring and testing shall be calibrated with measurement standards, the calibration of which is traceable to the National Bureau of Standards. The Intervals of Calibration shall be established by the Contractor in accordance with paragraph 3.2.3 of MIL-C-45662A.

b. Tolerances - Unless specified otherwise in the individual test requirement, and as specified below, a ± 5% tolerance shall apply to all test requirements specified herein.

1. Temperature	<u>± 5%</u>
2. Vibration Level	<u>± 10%</u>
3. Vibration Frequency	<u>± 10%</u>
4. Shock Amplitude	<u>± 10%</u>
5. Shock Duration	-0 +60%
6. Overall Acoustic Level	<u>± 3 db</u>
7. Acoustic Spectrum Level	-3 +9 db

c. Measurements - Unless specified otherwise, the maximum allowable error due to environment and instrumentation in measurement of parameters shall be 10% of the smallest tolerance applicable at the point of measurement. If no tolerance is specified then the maximum allowable error shall be ± 2% of the measured quantity or the following, whichever is greater:

1. Temperature	<u>± 2°F</u>
2. Pressure	<u>± 2% gauge</u>
3. Relative Humidity	<u>± 4%</u>

4.3.1.6 Test Articles.- Unless specified otherwise, all articles to be subjected to any test, other than an acceptance test, shall be subjected to and shall pass a Functional Acceptance Test before being subjected to the intended test. Articles which have been subjected to Qualification Tests shall not be used in deliverable hardware unless specifically directed by the Procuring Contracting Officer.

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4.3.2 Pre-Production Tests.-

4.3.2.1 General.- Pre-production tests need not be completed prior to Acceptance of deliverable units unless specified otherwise.

4.3.2.2 Engineering Test.- Engineering tests shall consist of development tests and other tests selected by the Contractor in accordance with the provisions of the Program Plan approved by the AEC.

4.3.2.3 Qualification Tests.-

4.3.2.3.1 General.- Three prototype RTG Systems shall be used in the Qualification Tests specified herein. Additional qualification tests shall be conducted if, and as required, to verify design changes incorporated in the flight configurations. However, performance of such additional qualification testing is not covered by this specification issue. Unless specifically provided for in the following, the duration of each individual qualification test shall be considered as unspecified pending coordination and finalization of this document.

a. Qualification Criteria - Unless specified otherwise, all units shall satisfactorily pass the functional (i.e. non-environmental) portion of the applicable acceptance test after exposure to the qualification test involved, unless the functional tests performed during the qualification test equal or exceed the functional acceptance test.

b. Notification - The AEC and the authorized Government inspector shall be notified at least 7 working days prior to the anticipated start of the Qualification Test series of each item of equipment.

c. Reject and Retest Criteria - If any electrical or mechanical failure, malfunction or out-of-tolerance performance condition is sensed during a test, the test shall be discontinued, the trouble analyzed and corrected, and the pertinent test procedure repeated until completed successfully. If the Contractor determines that the corrective action substantially affects the validity or significance of results of previously completed tests, such tests shall also be repeated. (See paragraph 4.3.1.3)

d. Data -

- (1) Procedures - The Contractor shall prepare detailed test procedures for each item to be tested. A copy of the test procedure shall be furnished to the AEC for information at least 30 days prior to the start of the test sequence.

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- (2) Reports - The Contractor shall prepare and furnish a summary Qualification Test Report, on each item tested, to the AEC within 14 calendar days after completion of the test series on the component. The report shall contain copies of the certified test data, a summary of results, and a description of any failures and retests conducted. The report shall identify the item being tested, the manufacturer, the location of the testing and any other pertinent data.
- (3) Approvals - The AEC shall provide the Contractor with written approval or disapproval of the Qualification Test Report within 14 calendar days after receipt. If the Contractor does not receive any such notice within the 14 day period, the report shall be considered to be approved. Approval of the report shall constitute approval of the Qualification Tests reported on, and the items shall therefore be qualified.

4.3.2.3.2 Thermal Vacuum.- One complete RTG shall be installed in the test chamber at room temperature in a manner that will simulate service usage. The temperature control surfaces of the RTG shall not face any abnormal heat source. Plugs, covers, and inspection plates used in service shall remain in place. Mechanical or electrical connectors which are not used in the test installation, but which are normally protected in service, shall be adequately covered. The RTG shall then be operated to determine that no malfunction or damage was caused by faulty installation or handling. During operation a record shall be made of all data necessary to determine compliance with the applicable performance requirements of Section 3. herein. These data shall provide the criteria for checking satisfactory performance of the RTG during, or at the conclusion of the test. The test chamber pressure shall then be reduced to 1×10^{-6} torr and the chamber walls cooled to -250°F . Thermal energy shall then be applied to simulate mission orbital environments. During application of the thermal energy and throughout the test, the test article may be maintained in a stationary position.

RTG performance (or component performance where pertinent) shall be monitored at inputs representing beginning, middle, and end of life conditions, and the measurements shall be compared with the previously recorded values.

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As a part of the thermal vacuum test, the chamber pressure shall be cycled from ambient to 25 mm Hg within 90 seconds. During this period a reduction rate of 15 mm/Hg/sec shall be imposed for a duration of 30 seconds. In the event that these specified pressure rates of change exceed the capacity of the thermal vacuum chamber, this part of the test may, at the option of the Contractor, be performed in a separate altitude chamber.

At the conclusion of the test the chamber shall be returned to standard ambient conditions and the test system shall be visually inspected and a record made of any damage resulting from the test.

In performing functional tests, the RTG shall be operated in an air environment at ambient conditions, with appropriate resistive load, and thermal input representing end of life condition. Generator output voltage and current, and applicable instrumentation outputs shall be measured and recorded. Test measurements shall be adjusted in accordance with approved analytical procedures to correct for differences between test and operational environments. Acceptability of performance shall be determined by comparison of corrected test results with the requirements specified by Section 3.0 herein.

4.3.2.3.3 Dynamic Tests.- One prototype RTG system shall be employed for the dynamic environmental tests defined herein. For these tests the radiator panels may be tested separately from the RTG. Provisions shall be incorporated to adequately simulate the operation of these major components during the tests. During application of the environmental conditions, all functional components shall be maintained at stable operating conditions and critical operating parameters shall be continuously monitored. The test range of the applicable environmental conditions shall be as specified below:

a. Vibration Tests -

- (1) General - All pertinent inputs and outputs shall be monitored during each part of the test. Any distortion of signal or information, or deviation of parameters during or resulting from the vibration testing shall be limited to non-permanent conditions and less than the amount permitted as indicated in the End Item Specification or test procedure for the particular equipment. A complete record of each vibration test shall be maintained including the results of the equalization, all resonant frequencies detected and details regarding the operation of the equipment under test. A vibration pick-up placed at one of the specimen's mounting points, which most

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nearly represents the average of all the mounting points, shall be used for monitoring and determining conformance with the specification. In setting vibration equipment for proper filtering and control, it may be necessary to apply some vibrational energy to the test specimen prior to the actual test. In such cases, the rms value of vibration level being programmed will be kept to a minimum and if it is necessary (outside the actual test) that this rms value exceed 20% of that to be applied during the test, then the time duration of the application shall be recorded, along with the amplitude of such pre-testing. Each part of the vibration test shall be applied to the test specimen along each of the three mutually perpendicular axes as indicated in each test. Specification levels may be modified on approval by the AEC for components weighing over 45 lbs., at certain resonances, to avoid unreasonable force requirements.

- (2) Random Vibration Measurement - The random vibration levels designated herein shall be determined by use of a true rms meter. When setting acceleration loading coincident with a specified acceleration spectral density and bandwidth, the true rms meter shall be preceded by a band pass filter whose limits are coincident with the specified band pass limitations. The true rms level shall be that level determined by the test acceleration spectral density requirements and equation:

$$g \text{ rms} = \left[\int_{F_1}^{F_2} W(F) dF \right]^{1/2}$$

(Where W is the acceleration spectral density level in g^2/cps at frequency F and F_1 and F_2 are bandwidth limits at the half power points.) In determining the rms level required for narrow band random tests, consideration must be given to the energy passed by the filter outside of the 3 db bandwidth. For tests run at less than the full 2000 cps bandwidth, F_1 and

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F_2 in the above equation shall mean the "effective" bandwidth frequencies.

(3) Equalization for Random Vibration Test -

- (a) Random Equalization - The acceleration spectral density applied to the test article, as determined by an analyzing filter and a maximum bandwidth of 50 cps, shall be within ± 1.5 db over the frequency range of 5 to 500 cps. Peaks and notches may deviate by more than ± 1.5 db, but less than ± 3 db of the specified test level between 500 and 2000 cps provided the total frequency bandwidth of all peaks and notches deviating more than ± 1.5 db is less than 300 cps. The above tolerances are increased in rolled-off-regions of the spectrum by ± 0.1 db for every 1 db down from the maximum level specified. Random excitation for equalization purposes shall be a minimum of 14 db down from the highest test level, unless a "dummy" specimen or automatic equalization is used. Dummy specimens must be dynamically identical to the test article.
- (b) Sinusoidal Equalization - In the event that it is not possible to achieve Random Equalization per paragraph (a) above, the following sinusoidal equalization tolerances may be used as a substitute. With a sinusoidal generator, whose voltage is constant with frequency applied to the input of the equalization console, the shape of the acceleration input to the test article shall conform with Figure____ within ± 1.5 db about each frequency between 5 and 500 cps. Peaks and notches may deviate by more than ± 1.5 db, but less than ± 3 db between 500 and 2000 cps, provided the total frequency bandwidth of all peaks and notches deviating by more than ± 1.5 db is less than 300 cps. The tolerances above are increased in the rolled-off-regions of the spectrum by 0.1 db for every 1 db down from maximum level specified. The rms sinusoidal acceleration amplitudes for this determination shall be 20% of the maximum total rms acceleration as specified in Figure____

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or 10 g peak, whichever is less, unless a "dummy" specimen is used. Dummy specimens must be dynamically identical to the test article.

- (4) Procedure 1 - (Test procedure is not required if subsequent procedures will subject the test article to more stringent conditions than those which the equipment would experience in its packaged state.)
Sinewave Vibration - Non-Operating, Transportation and Handling - Sinusoidal vibration shall be applied for a total of 15 minutes in each of three mutually perpendicular axes, to the levels specified in paragraph 3.1.4.4.2.a (6). The 15 minute periods shall consist of sweeps up and down at a logarithmic rate of one octave per minute. The test may be interrupted during the sweep when changes in amplitude control are required. The units shall be packaged for shipment during the test.
- (5) Procedure 2 - Sinewave Vibration, Operating, Flight Hardware - Sinusoidal vibration applied for a total of 25 minutes in each of three mutually perpendicular axes, to the following levels:

<u>Frequency</u>	<u>Double Amplitude Acceleration</u>
5 - 14	0.5 inches (peak to peak)
14 - 400	+ 5G
400 - 3000	+ 15G

The 25 minute period (along each axes) shall consist of sweeps up and down at a logarithmic rate of one octave per minute. The test may be interrupted during the sweep when changes in amplitude control are required.

- (6) Procedure 3 - Random Vibration, Operating, Flight Hardware -
- (a) Random vibration shall be applied for a total of 5 minutes in each of three mutually perpendicular axes to the following levels:

<u>Frequency</u>	<u>Test Level</u>
20 - 400 cps	0.20 g ² /cps
400 - 2000 cps	0.40 g ² /cps

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Rolloff below 20 cps and above 2000 cps may be at any attenuation level.

- (b) Random Vibration Deviation- Should the vibration levels specified above require force inputs beyond the capability of vibration equipment, one of the following deviations may be applied. The division of the spectrum shall be limited to the minimum number of bands necessary to meet the acceleration requirements.
1. The random spectrum may be divided into 2 or 3 bands and applied as separate tests for the duration as indicated. The frequency division points shall be no lower than 300 cps and not higher than 1000 cps and shall be continuous at the 1 db roll off point of the filter.
 2. The random vibration may be applied over a 100 cps bandwidth as determined at the half power points and with a characteristic roll off of 24 db per octave or greater. The 100 cps band shall be swept from 20 cps to 2000 cps and back at a linear sweep rate in a time equal to five times the duration specified in paragraph 1. above. The level of vibration shall be varied with frequency in accordance with the specified spectrum shape, with the amplitude at each frequency as calculated using the equation given, paragraph (2) above.
 3. The random spectrum may be divided into four or more bands and applied as separate tests, each for a duration of 70% of the time shown in paragraphs above. The minimum bandwidth shall be 100 cps and the test bands shall be continuous at the 1 db roll off points.
- (c) Shock - Operating - Flight Hardware - The equipment shall be subjected to 3 shocks in each direction along three mutually perpendicular axes. The shock shall have a peak acceleration of 40 g's and a nominal duration of 8 milliseconds in accordance with Figure 516-1 of MIL-STD-810.

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- (d) Sustained Acceleration Tests, Operating -
The equipment shall be mounted on a centrifugal table in a manner simulating the Booster installation. The centrifugal table shall then be rotated so as to impose a 15 g minimum centrifugal acceleration on the mounted equipment. This acceleration, with equipment operating, shall be continued for a period of 5 minutes. The above procedure shall be repeated with the equipment, oriented on the centrifugal table so that the acceleration force has been applied in both directions on three mutually perpendicular axes. For equipment whose orientation with respect to the vehicle longitudinal axes is known and will not change, the acceleration test may be limited to 15 g's minimum along the forward direction of the vehicle longitudinal axes and 2 g's along both directions of the equipment's two lateral axes mutually perpendicular to the longitudinal axes. The equipment shall show no out-of-tolerance performance during this test.
- (e) Acoustic Noise - Operating - Flight Hardware -
The equipment shall be isolated from the acoustic test chamber in a manner to prevent the transmission of chamber vibration to the equipment. The acoustic level shall be determined by a transducer (microphone) placed near the equipment at the side nearest the sound source. The equipment shall be subjected to a random acoustic noise field for 5 minutes with a spectrum shape as shown in Figure 515-1 of MIL-STD-810 and overall level of at least 144 db (Ref. 0.0002 dyne/cm²). The equipment shall show no out-of-tolerance performance during this test.

4.3.2.3.4 Endurance Test.- A (one) complete RTG shall be operated in ambient air environment, at normal operating conditions for a cumulative period of 144 days, without service or adjustment other than replacement of heater elements and test set-up maintenance. In the event of a system failure or degradation of performance beyond specified tolerances, appropriate corrective action shall be taken and the test shall be repeated. Satisfactory completion of the test as demonstrated by acceptable performance throughout either test period shall constitute qualification in conformance with the system reliability requirement.

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Following completion of the test, the internal atmosphere of certain thermoelectric module assemblies as selected by the Contractor shall be determined using a residual gas analyser having a capability of 10^{-13} torr (for nitrogen) and capable of scanning a mass range of 2 to 300 AMU.

4.3.3 Production and Acceptance Tests.-

4.3.3.1 Production Tests.-

a. General - The Contractor shall conduct the necessary mechanical, electrical, thermal, chemical and other tests at each level of assembly from receiving inspection through End Item assembly, as determined by the Contractor and to the extent necessary to assure that the item under test is operating satisfactorily.

b. Data - All tests shall be conducted in accordance with written Contractor procedures. All results, including failures, and retests, shall be documented and accompany the unit to the next level of assembly.

4.3.3.2 Acceptance Tests.-

4.3.3.2.1 General.-

a. Test Sequence - Acceptance Tests shall be performed in the following sequence:

1. Functional Test
2. Environmental Acceptance Tests
3. Final Functional Test

b. Notification - The Authorized Government Inspector shall be notified at least 24 hours in advance of the anticipated start of Acceptance Tests on any item.

c. Reject and Retest Criteria - If any electrical or mechanical failure, malfunction, or out-of-tolerance performance conditions are sensed during a test, the test shall be discontinued. The trouble corrected, and the pertinent test procedure repeated. If the Inspector determines that the corrective action substantially affects the validity of results of previously completed tests, such tests shall be repeated. The Government Inspector may waive any portion of this paragraph by making proper notation on the Acceptance Test records.

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d. Data -

- (1) Procedures - The Contractor shall prepare detailed test procedures for each item to be accepted. A copy of the test procedure shall be furnished to the AEC at least 30 days prior to the start of the first Acceptance Tests on any item.
- (2) Test Data - The results of all Acceptance Tests shall be recorded on data sheets which are included as a part of the test procedure. Each entry and the overall data sheet shall be certified by both the Contractor and Governmental Authorized Inspection personnel.
- (3) Approvals -
 - (a) The Contracting Officer shall provide the Contractor with written approval or disapproval of all Acceptance Tests Procedures within 14 calendar days after receipt. If the Contractor does not receive any such notice within 14 day period, the Test Procedure shall be considered to be approved.
 - (b) The certification of the Authorized Government Inspector on the test data sheets shall constitute approval of satisfying completion of the Acceptance Tests.

4.3.3.2.2 Functional Tests.- Functional Acceptance Tests shall be conducted on each item to assure that every possible normal or planned emergency provision of the equipment is in operating condition in each of its possible modes.

4.3.3.2.3 Environmental Acceptance Tests.-

a. General - The following Environmental Acceptance Tests shall be conducted on items as indicated in the applicable portions of paragraph 4.3.2.3.3 herein, including those items below Contract End Item level when so specified.

b. Vibration - Operating or Non-Operating - While operating, the component shall be subjected to a random vibration level and spectrum shape which is (*)% of the g^2/cps level defined for qualification of the item applied to each of 3 orthogonal areas, for a period of 3 minutes per axis.

*Required proportion of the qualification test levels to be determined in coordination with the AEC.

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c. Thermal Vacuum - The unit shall be operated in a chamber having a pressure of 10^{-5} torr or less to demonstrate conformance with performance requirements. The duration of the test shall be sufficiently long to assure stabilization of operating temperatures and outputs.

4.3.4 Field Verification Tests.- Each End Item Specification shall specify the tests to be conducted by the User Organization to determine that the item under test is operating satisfactorily. The performance of tests other than those so specified shall make any warranty on the item under this Contract void, with all responsibility born by the Government.

5.0 DELIVERY.-

5.1 Preparation for Delivery.-

5.1.1 Preservation and Packaging.- All deliverable Contract End Items shall be preserved and packaged to provide protection in transit. (See MND-3612-30 for shipping containers.) Deliverable spares, if required, shall be preserved and packaged to the extent necessary to provide protection for periods of up to one year. MIL-P 116 shall be used as a guide in the packaging of spares.

5.1.2 Packing.- See paragraph 5.1.1.

5.1.3 Marking.- All unit packages and shipping containers shall be marked in accordance with the provisions of MND-3612-30.

5.1.4 Data.- A copy of Acceptance Test data and the quality logbook shall be shipped with every deliverable item.

5.2 Acceptance.- All deliverable items shall be accepted at the Contractor's facility upon satisfactory completion of Acceptance Tests and when packed ready for shipment. Subsequent to acceptance, the Contractor shall transport the RTG (and fuel block) to destinations as provided for in MND-3612-10.

6.0 NOTES.-

6.1 Intended Use.- This Specification is intended to provide the prime control over the design, development, manufacture, and test of the RTG system.

6.2 Ordering Data.- When ordering equipment to this Specification the applicable End Item Specifications, Part Number, Dash Number, and quantity of units shall also be specified.

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6.3 Supersession Data.- This Specification, when contractually authorized, shall supersede all other similar requirements in the Contract of which it is a part.

6.4 Authorization.- This Specification, and any changes thereto, shall be authorized for use upon receipt of written approval of the Procuring Contracting Officer and issuance of an appropriate Contract Change incorporating this Specification in the Contract.

6.5 Revisions and Changes.- This Specification shall be revised only upon written direction from the Procuring Contracting Officer. Changes to this Specification shall be authorized as described in MND-3612-10. All such changes shall be subject to the Contract clause entitled "Changes."

6.6 Definitions.-

6.6.1 Reference Purposes Only.- Whenever the term "Reference Purposes Only" is used herein, the provision concerned shall not be subject to inspection, acceptance or compliance verification.

6.6.2 Secondary Performance Characteristics.- "Secondary Performance Characteristics" are those characteristics which are not mission or use critical, but which must be specified to properly constrain complete design of a Contract End Item.

6.6.3 Malfunction.- A "Malfunction" is any repeatable or non-repeatable departure from normal, either temporary or permanent in nature.

6.6.4 Simple Tools.- "Simple Tools" are those hand tools, not power driven, which would normally be found in a retail hardware store.

6.6.5 Mission Fulfillment.- "Mission Fulfillment" is the achievement of specified power output to an external load, from the time of the successful completion of Fuel Block Insertion into the RTG until the end of the specified operational lifetime, when exposed to the environments specified as existing between the aforementioned times.

6.6.6 Sheltered Equipment.- "Sheltered Equipment" is that equipment which shall operate in laboratory, or other areas where a degree of environmental protection is provided. When so operated, it shall be furnished with necessary provisions to permit such operation, such as suitable heat sinks.

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6.6.7 Unsheltered Equipment.- "Unsheltered Equipment" is that exposed to the extremes of natural environment.

6.6.8 Po RTG Power System (or RTG).- The complete power system which furnishes electric energy to the satellite vehicle during an earth orbit mission. Basically, the RTG consists of a radioisotope (or electric) heat source, a subsystem of thermoelectric elements to convert heat to electric energy, and subsystems to control and dissipate the heat of the radioisotope fuel.

6.6.9 Fuel Block.- A containment structure for individual fuel capsules. The fuel block serves as the RTG heat source.

6.6.10 Aerospace Ground Equipment (AGE).- All equipment required on the ground to make a system operational in its intended environment. Includes all equipment to install, launch, guide, control, direct, inspect, test, adjust, calibrate, appraise, gauge, measure, assemble, disassemble, handle, transport, safeguard, store, activate, service, repair, overhaul, or operate the satellite system. OGE (Operational Ground Equipment) is that AGE which is a functional part of a system and which operates with that AGE required to restore a system or end items to operation condition. For purposes of this specification the term means AGE furnished by the Contractor.

6.6.11 SNAP M System.- The complete RTG power system plus the associated AGE furnished by the Contractor.

6.6.12 Satellite Vehicle (or SCS).- The item launched by the booster.

6.6.13 Contract End Item.- A deliverable item which is formally accepted by the procuring agency as an entity, on a DD Form 250, in accordance with the requirements of a specification. The prime level of assembly for technical and contractual management (customer) control (schedule, configuration, etc.) and accountability for provisioning spares and preparing manuals.

6.6.14 AEC.- The United States Atomic Energy Commission. For purposes of this specification the term implies, but is not restricted to, the New York Operations Office of the AEC.

6.6.15 Contractor.- The Martin Company of the Martin-Marietta Corporation, Baltimore, Maryland 21203.

6.6.16 User Organization(or User).- The Government agency having overall cognizance of the satellite program. The term encompasses Contractors and agencies working under the direction of this agency to carry-out the satellite program.

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LIST OF APPLICABLE DOCUMENTS

The following documents are applicable to design, fabrication, test and delivery of the Po RTG System, items thereof, and articles of AGE, which are to be provided by the Contractor. However, pending establishment of firm design and interface criteria and acceptance of contract end item specifications, the extent of applicability of the requirements of individual specifications listed shall be held in abeyance and determined in conjunction with definitization of interface and design criteria.

Specifications listed below represent selections based on RTG and AGE design and programming efforts under Contract AT(30-1)-3612 (Phase I). Selection and conformance with Specifications and Standards other than those listed below and in Section 2 of individual Contractor prepared specifications shall be accomplished in accordance with the requirements of paragraphs 3.3.2 thru 3.3.5 of MND-3612-13 and paragraph 3.2.1 of MND-3612-30.

SYSTEM PROGRAM DOCUMENTS

SPECIFICATIONS

Military

MIL-P-116D-1 4 December 1962	Preservation, Methods of -- Applicable except that the particular preservation method shall be selected by the Contractor for conformance with Level C of Fed. Std. No. 102B; tests and quality control shall conform to the Contractor's Quality Control Plan.
MIL-E-4158C-2 9 July 1964	Electronic Equipment Ground; General Requirements for -- Applicable as a guide in design and construction.
MIL-H-4440 28 November 1962	Handbooks, Operation and Service Instructions -- Applicable except that the form of reproduction shall be as specified by the AEC.

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MIL-T-4807A 7 October 1958	Tests, Vibration and Shock, Ground Electronic Equipment, General Requirements for -- Applicable as a guide. The test methods and test levels as applied to particular equipment shall be as provided in individual contract end item specifications.
MIL-T-5021C-1 12 June 1964	Tests; Aircraft and Missile Welding Operators' Qualification
MIL-M-005474C-3 (USAF) 15 April 1963	Technical Manuals, General Requirements for preparation of
MIL-C-6021F 4 November 1964	Castings, Classification, Inspection of
MIL-W-6858F-1 22 March 1962	Welding, Resistance: Aluminum, Magnesium, Non-Hardening Steels or Alloys, Nickel Alloys, Heat Resisting Alloys, and Titanium Alloys; Spot & Seam
MIL-M-7960A-1 13 February 1958	Handbook, Operation and Service Instructions (Test Equipment and Support Equipment)
MIL-I-8500B 16 October 1960	Interchangeability & Replaceability of Component Parts for Aircraft & Missiles-- Applicable except for deviations necessary to maintain the integrity of RTG coolant loop.
MIL-Q-9858A 16 December 1963	Quality Program Requirements
MIL-C-9883A-1 30 October 1961	Checklists for Missile and Space Systems Operation and Organizational Maintenance -- Applicable as a guide in preparation of operation and maintenance manuals.

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MIL-B-9972 16 May 1963	Brazing, Nickel Alloy, General Specification for
MIL-E-17555F 5 March 1965	Electronic & Electrical Equipment & Associated Repair Parts, Preparation for Delivery of
MIL-W-18326A 14 June 1956	Welding of Magnesium Alloys, Gas and Arc, Manual and Machine Processes for
MIL-S-19491B 13 April 1964	Semi-Conductor Devices, Preparation for Delivery of
MIL-M-26512C 13 December 1963	Maintainability Requirements for Aerospace Systems and Equipment -- Applicable as a guide in design and construction of equipment.
MIL-W-27076 (USAF) 29 September 1960	Workmanship Standards for Ground Electronic and Associated Equipment
MIL-S-38130 30 September 1963	Safety Engineering of Systems and Associated Subsystems, and Equipment: General Requirements for -- Applicable except that the analyses and data generated, thereunder shall be integrated into safety reports required by the contract and safety and warning devices shall be furnished as required by program specifications.

STANDARDS

Federal

Fed. Std. No. 102B 29 January 1963	Preservation, Packaging & Packing Levels-- Level C Applicable
Fed. Std. No. 151A & B 6 May 1959	Metals; Test Methods -- Applicable to tests performed by the Contractor, but shall not be considered as requiring tests.

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STANDARDS

Military

MIL-STD-8C 16 October 1963	Dimensions & Tolerancing
MIL-STD-9A 26 May 1960	Screw Thread Conventions and Methods of Specifying
MIL-STD-10A-2 25 November 1963	Surface Roughness Waviness and Lay
MIL-STD-12B 18 May 1959	Abbreviations for Use on Drawings and in Technical Type Publications
MIL-STD-15 Part 1 22 May 1963	Graphic Symbols for Electrical & Electronic Diagrams
MIL-STD-16C 4 December 1961	Electrical & Electronic Reference Designations
MIL-STD-22A 24 October 1956	Welded-Joint Designs -- Not applicable to fuel block or non-structural welding.
MIL-STD-105D 29 April 1963	Sampling Procedures & Tables for In- spection by Attributes
MIL-STD-108D 27 June 1958	Definitions of and Basic Requirements for Enclosures for Electric and Electronic Equipment
MIL-STD-109A 30 October 1961	Quality Assurance Terms and Definitions
MIL-STD-129D 28 December 1964	Marking for Shipment and Storage
MIL-STD-143A 14 May 1963	Specifications and Standards Order of Procedure for the Selection of
MIL-STD-280 4 April 1956	Definition of Terms for Equipment Divisions
MIL-STD-410A 13 August 1962	Qualification of Inspection Personnel (Magnetic Particle & Penetrant)

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MIL-STD-414 11 June 1957	Sampling Procedures & Tables for In- spection by Variables for Percent Defective
MIL-STD-415B 5 February 1961	Test Points and Test Facilities for Electronic Systems and Associated Equipment, Design Standard for
MIL-STD-447 28 May 1959	Definitions of Interchangeable Substitute & Replacement Items
MIL-STD-453-1 4 September 1963	Inspection, Radiographic
MIL-STD-756A 15 May 1963	Reliability Prediction
MIL-STD-785 30 June 1965	Requirements for Reliability Program (For System and Equipments)
MIL-STD-803A-1 27 January 1964	Human Engineering Design Criteria for Aerospace Systems and Equipment; Part 1 Aerospace System Ground Equipment
MIL-STD-808 22 December 1960	Finishes, Protective, and Codes for Finishing Schemes for Ground and Ground Support Equipment

BULLETINS

USAF Bulletin 515-2 29 July 1963	Control of Non-Conforming Supplies
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OTHER PUBLICATIONS

SSD Exhibit 63-3 24 June 1963	Engineering for Transportability
AFP 11-1-4 30 October 1959	Aerospace Terminology (Interim Reference)-- Applicable as a guide in preparation of documents.

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This appendix summarizes items of technical data which shall be prepared by the Contractor and furnished to the Contracting Agency, or other agencies as designated by the Contracting Officer, during Phases II thru IV of the Po RTG Power System Program

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DELIVERABLE DATA ITEMS
Po RTG PROGRAM

Title	Applic. Program Phase	No. Copies	Type of Copies	Distrib.	Submittal Requirements
<u>Contract Specifications</u>					
Specification for Po RTG Power System, MND-3612-13	All	(To be defined)	(To be defined)	(To be defined)	Initial submittal under Phase I contract. Definitization during Phase II of Contract.
Specification for RTG Aerospace Ground Equip- ment MND-3612-30	All	(To be defined)	(To be defined)	(To be defined)	To be issued upon approval.
Interface Control Spec. for RTG Power System, MND-3612-10.	All				Spec. maintenance shall be accomplished in ac- cordance with the pro- visions of the contract.
Interface Control Spec. Po Fuel and Fuel Encap- sulation MND-3612-12	All				
Interface Control Spec. RTG Aerospace Ground Equipment MND-3612-11.	All				

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DELIVERABLE DATA ITEMS
Po RTG PROGRAM

Title	Applic. Program Phase	No. Copies	Type of Copies	Distrib.	Submittal Requirements
Thermal Control Sub- system Spec. MND-3612-16	II III IV	(To be defined)	(To be defined)	(To be defined)	Submittal required during Phase II for co- ordination with Pro- curing Agency (AEC).
T/E Conversion Subsystem Spec. MND-3612-17	II III IV	(To be defined)	(To be defined)	(To be defined)	To be issued by the Contractor following approval by the Con- tracting Officer.
Coolant Heat Rejection Subsystem Spec. MND- 3612-15	II III IV				Revisions as required; to be issued in ac- cordance with Approved Contract Change Pro- cedures.
Fuel Capsule and Fuel Block Spec. MND-3612-14	II III IV				

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Po RTG PROGRAM

Title	Applic. Program Phase	No. Copies	Type of Copies	Distrib.	Submittal Requirements
GFE Requirements Spec. MND-3612-34	II III IV	(To be defined)	(To be defined)	(To be defined)	Submittal required during Phase II for coordination with Procuring agency and approval by Contracting Officer
Shipping and Handling Equipment Spec. MND-3612-31	II III IV				To be issued by the Contractor following approval by the Contracting Officer.
Fuel Handling Machine Spec. MND-3612-32	II III IV				Revisions as required: to be issued in accordance with Approved Contract Change Procedures.
Field Test Equipment Spec. MND-3612-33					

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Po RTG PROGRAM

Title	Applic. Program Phase	No. Copies	Type of Copies	Distrib.	Submittal Requirements
Sub-Contractor Procurement Specifications	II III IV	(To be defined)	(To be defined)	(To be defined)	Prepared as required consistent with Contractor established Make or Buy Plan. Submitted to AEC concurrent with release to sub-contractors for bids.
<u>Program Management and Technical Status Reports</u> Monthly Progress Report (Includes PERT analysis and cost/schedule integration data as well as technical progress and status information)	II III IV				Due on the 15th of each month covering the previous calendar month. Initial report due on the 15th of the month following the first complete calendar month after Phase II go-ahead. Not required for the third month of each quarterly reporting period.

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APPENDIX B to
Specification MND-3612-13
& MND-3612-30 dated 11/24/65

DELIVERABLE DATA ITEMS
Po RTG PROGRAM

Title	Applic. Program Phase	No. Copies	Type of Copies	Distrib.	Submittal Requirements
Quarterly Progress Reports	II III IV	(To be defined)	(To be defined)	(To be defined)	Due two weeks after close of each reporting period. Reporting periods shall be calendar quarters; Jan-Mar, Apr-June, July-Sept., Oct-Dec.
Program Summary Report	IV	(To be defined)	(To be defined)	(To be defined)	Due 45 days following completion of Phase IV.
<u>Engineering Data</u>					
Engineering Drawings (As required for contractor fabrication of follow-on units)	IV				To be furnished at the time of delivery of the applicable end item.
Electrical/Electromagnetic Interference Control Plan	II				Submittal required within 120 days of initiation of Phase II. Subsequent revisions as required.
Safety Analysis, Preliminary	II				Submittal required prior to completion of Phase II. Revisions not required (updated as necessary by progress reports).

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DELIVERABLE DATA ITEMS
Po RTG PROGRAM

Title	Applic. Program Phase	No. Copies	Type of Copies	Distrib.	Submittal Requirements
Safety Analysis, Final	III IV	(To be defined)	(To be defined)	(To be defined)	Submittal required prior to completion of Phase III. Subsequent revisions as required to maintain currency.
Weight & Balance Data	II III IV	(To be defined)	(To be defined)	(To be defined)	Letter report submitted prior to completion of Phase II. Updated by monthly and quarterly progress reports.
Topical Reports (up to three in each program phase)	II III IV				Submittal in response to specific Contracting Officer request. Available 30 days after completion of effort being reported.
<u>Test Data</u> Development Test Procedures	II				Required to be available for review at the Contractor's facility a minimum of 10 days in advance of scheduled date for initiation of applicable test or test sequence. Copies to be transmitted upon Contracting Officer request (7 day response).

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DELIVERABLE DATA ITEMS
Po RTG PROGRAM

Title	Applic. Progress Phase	No. Copies	Type of Copies	Distrib.	Submittal Requirements
Qualification Test Procedures	III	(To be defined)	(To be defined)	(To be defined)	Submittal required for Contracting Officer approval, a minimum of 30 days in advance of schedule date for initiation of applicable test or sequence of tests.
Acceptance Test Procedures	III IV				
Development Test Reports	II				Required to be available for review at Contractor's facility within 14 days following completion of applicable tests. Copies to be transmitted upon request of the Contracting Officer (14 days response).
Qualification Test Reports	III				Submittal required for Contracting Officer approval within 14 days of completion of applicable test or test sequence.
Acceptance Test Reports	IV				

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DELIVERABLE DATA ITEMS
Po RTG PROGRAM

Title	Applic. Progress Phase	No. Copies	Type of Copies	Distrib	Submittal Requirements
<u>Reliability Data</u>					
Reliability Program Plan	II	(To be defined)	(To be defined)	(To be defined)	Within 60 days of go-ahead for Phase II
Reliability Analysis and Prediction Report	II	(To be defined)	(To be defined)	(To be defined)	Preliminary issue within 60 days of Phase II go-ahead. Formal issue 30 days later. Revision as required to maintain currency of formal report.
Reliability Demonstration Plan	II				Submittal required prior to completion of Phase II. Revisions as required to maintain currency till approval of Demon. Procedure.
Reliability Demonstration Procedure	III				Submittal required within 2 months after start of Phase III.
Reliability Demonstration Report	IV				Submittal required 6 months after start of Phase IV.

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DELIVERABLE DATA ITEMS
Po RTG PROGRAM

Title	Applic. Progress Phase	No. Copies	Type of Copies	Distrib.	Submittal Requirements
Reliability Progress Reports		N/R	N/R	N/R	Included with progress reports; Monthly, Quarterly and Summary Reports.
Special Reliability Reports		N/R	N/R	N/R	See "Topical Reports"
<u>Quality Assurance Data</u>					
Quality Program Plan	II III IV	(To be defined)	(To be defined)	(To be defined)	Revisions as required to maintain currency of plan submitted under Phase I contract.
<u>Support Data</u>					
Instruction and Operating Manuals					Due:
Prototype System					At conclusion of Phase II, Rev. as required.
Flight Test System					At conclusion of Phase III, Rev. as required.
Operational System					At conclusion of Phase IV,

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DELIVERABLE DATA ITEMS
Po RTG PROGRAM

Title	Applic. Progress Phase	No. Copies	Type of Copies	Distrib.	Submittal Requirements
Maintenance Manuals	III IV	(To be defined)	(To be defined)	(To be defined)	Due at time of de- livery of applicable equipment.
<u>Documentary Data</u>					
Documentary Film of Program	II III IV				To be furnished with the Program Summary Reports.

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THIS DOCUMENT CONSISTS OF 27 PAGES

NO. _____ OF _____ COPIES, SERIES A

SPECIFICATION FOR AEROSPACE GROUND
EQUIPMENT FOR Po RTG POWER SYSTEM
(SNAP $\bar{M}$ SYSTEM)

Group 3

Downgraded at 12-year intervals,
not automatically declassified.

This document contains information affecting the National
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Basic

Approved By:

Martin Marietta Corp.

Basic

Approved By:

AEC

Date _____

Date _____

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REVISED PAGE INDEX

As of November 24, 1965

This Revised Page Index identifies all authorized changes to, and all current pages of, this Specification as of the date shown above. This RPI is cumulative and supersedes all previous RPI's. Detailed information on each change may be found on the applicable Specification Change Notice.

<u>Page No.</u>	<u>Para. No.</u>	<u>SCN</u>	<u>CCP</u>	<u>Effectivity</u>
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This specification consists of a Title Page, this Revised Page Index Sheet, No SCN's, 2 Table of Contents Sheets, 22 Pages of Text, (Page 22 is the last page).

File this page after the
Table of Contents

Martin Approval _____

The undersigned certifies that all superseded classified pages have been destroyed in accordance with the appropriate security regulations.

Destruction Certification No. _____
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FOREWORD

This specification and Contractor prepared subsidiary specification (including end item specifications) referred to herein have been established to define requirements, characteristics and interface criteria for the aerospace ground equipment associated with a radioisotope fueled thermoelectric power system (Po RTG). The content of this specification reflects the efforts and results of Phase I of the Po RTG program (Contract AT(30-1)-3612) and is not restricted to any particular phase of design, development and production.

In the preparation of this document, emphasis has been placed on the definition of areas applicable to the initial portion of a complete program. It is expected that this document will be made more definitive and complete through modification as integration of efforts is accomplished and as more firm design information and test results become available. In final form, representing the results of mutual agreement, it is expected that this specification will be referenced in contractual agreements between the Contractor and the AEC.

The relation of this specification to other Contractor prepared specifications and to the contract is shown in Figure II-3 of MND-3612-8-1.

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SPECIFICATION FOR AEROSPACE GROUND
EQUIPMENT FOR THE Po RTG POWER SYSTEM
(SNAP M SYSTEM)

1.0 SCOPE.-

1.1 Scope.- This specification defines the performance, design, test, configuration and delivery requirements of the Aerospace Ground Equipment to support a radioisotope thermoelectric generator (RTG) system. The RTG and AGE, together, comprise the SNAP M Space Power System.

1.2 Mission.- The AGE covered by this specification is intended to support (provide shipping, handling, testing and fueling capability) the RTG system when employed and deployed as set forth in Paragraph 3.1.2 below.

1.3 Equipment Identification.- The following major items of AGE are specified herein.

- a. Fuel Handling Machine (FHM)
- b. Fuel Handling Machine Shipping Container
- c. Fuel Transport Cask
- d. RTG Power Supply Shipping Container
- e. RTG Field Test Equipment
- f. NaK Ground Service System
- g. Fuel Handling Machine Checkout Equipment

2.0 APPLICABLE DOCUMENTS.-

2.1 Extent of Applicability.- The documents listed in this section form a part of this specification only to the extent specified in the text of this specification. Where a document or its provisions are to be "used as a guide" (or other similar phrases) the extent of applicability shall be based on the Contractor's management and technical judgment. For reference purposes only, the paragraphs in this specification where each document is called out are shown opposite each document in the following listing.

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2.2 Dates of Issue.- References to documents in the text of this specification are made by basic number only. Such basic reference shall designate the exact issue as specified in this section, including the cited amendments, changes, etc..

2.3 Rules of Procedures.- In case of conflict between this specification and the contract, the contract shall govern. In case of conflict between this specification and any document referenced herein, this specification, including any authorized changes, appendices or addenda hereto, shall govern.

2.4 Specifications.- Para. Reference

Federal - None

Military

MIL-E-4158C 5 July 1962 and Amend. 2, 9 July 1964	Electronic Equip- ment Ground; General Require- ments for	(3.2, 3.2.3)
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MIL-Q-9858A 16 Dec. 1963	Quality Program Requirements	(4.1)
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Contractor

MND-3612-10 24 Nov. 1965	Interface Control Specification for Po RTG Power System	(3.2.4)
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MND-3612-11 24 Nov. 1965	Interface Control Specification for Aerospace Ground Equipment for Po RTG Power System	(3.2, etc.)
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MND-3612-12 24 Nov. 1965	Interface Control Specification for Fuel and Fuel En- capsulation for Po RTG Power System	(3.3)
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MND-3612-13 24 Nov. 1965	Specification for Po RTG Power System	(3.4)
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2.5 Standards.-

Para. Reference

Federal - None

Military

MIL-STD-129 28 Dec. 1964	Marking for Shipment or Storage	(5.3)
MIL-STD-130-1 7 Feb. 1964	Identification Mark- ing of U.S. Military Property	(3.2.6)
MIL-STD-209B 11 May 1960 and Change Notice 1 of 12 May 1963	Slinging Eyes and Attachments for Lifting and Tying Down Heavy Military Equipment	(3.1.6)
MIL-STD-803A 27 Jan. 1964 (Part 1) 1 Dec. 1964 (Part 2)	Human Engineering Design Criteria for Aerospace Systems and Equipment	(3.1.2)
MIL-STD-808 22 Dec. 1960	Finishes, Protect- ive, and Codes for Finishing Schemes for Ground and Ground Support Equipment	(3.2.2)

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2.6 Drawings.- Para. Ref.

Contractor

NSK-411*	FHM Man/Machine Concept	(3.2)
NSK-414*	FHM Field Test Equipment	(3.2)
NSK-415*	Fuel Transportation Cask	(3.2)
NSK-416**	Shipping Container for RTG	(3.2)
NSK-417**	RTG Field Test Equipment	(3.2)

*Drawings are of the issue furnished to the AEC at
end of Phase I of Contract AT(30-1)-3612

**Prepared during Phase II

2.7 Other Publications.-

Manuals

IFS-T IIIIX-33000 (CDI) and Attach. 1	Interface Infor- mation For The Pre- liminary Design of Fuel Capsule (Block) Insertion Equipment	(3.2)
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Regulations

ICC Regulation Tariff No. 15 and Supplement (3.1.1.3)
No. 6 effective 22 Aug. 1965

Handbooks

Department of Commerce Handbook 69 (3.1.1.1)

Other

Bureau of Explosives (AAR) File 25-16-174 (3.1.1.3)

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3.0 REQUIREMENTS.-

3.1 Performance.- The Po RTG AGE shall provide the following performance under any combination of the operating environmental conditions specified in paragraph 3.1.7, below, after being subjected to the non-operating environmental conditions (transportation and storage) specified in paragraphs 3.1.6 and 3.2.7 below. Detail and/or peculiar performance requirements shall be as specified in the detail specifications for each contract end item.

3.1.1 Functional.-

- (1) The AGE shall provide for the safe transportation and handling of the RTG fuel block as well as for safe insertion and removal of the fuel block between the FHM cask to the RTG, when the RTG is installed in the satellite vehicle. The AGE shall also provide for electrical simulation of the thermal characteristics of the fuel block during test and checkout of the RTG and provide the means of insertion and removal of the simulation device.
- (2) The AGE shall provide biological shielding so that personnel concerned with transportation, handling, maintenance, and launch operations are provided with protection from radiation dose levels exceeding those established by applicable regulations, providing Contractor proposed procedures are followed (except that the AGE need not provide for radiation protection to the surrounding general area during insertion or removal of the fuel block into the Launch Vehicle).
- (3) The AGE shall provide for transportation and handling of the fuel block.
- (4) The AGE shall afford radiation protection to a fuel handling machine operator during fuel block transfer operations when the operator remains seated at his work station on the FHM.

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3.1.1.1 Fuel Handling Machine.- The FHM shall provide for the transfer of the fuel block and the electrically heated fuel block (simulated fuel block) between the RTG (installed in the satellite vehicle) and their respective FHM casks. This general function shall include the following specific functions as detailed in the applicable Contractor prepared end item specification.

- a. Radiation monitoring as necessary to assure operator safety.
- b. Biological shielding sufficient to assure meeting the radiation exposure limits of Department of Commerce Handbook 69.
- c. Positioning (travel, adjustment and alignment) of the FHM to the location (on the MST platform) required for fueling the installed RTG.
- d. Accommodation (by means of compliance devices) of changing relative positions of the satellite vehicle and the MST during fueling operations in winds (including gusts) up to 40 mph.
- e. Positive prevention of damaging or detrimental collision between the FHM and the satellite vehicle during FHM positioning.
- f. Interchange (transfer) of fuel block and simulated fuel block between the installed RTG and their respective FHM casks within a period of one minute (as a goal) after final alignment.
- g. Fueling (complete cycle of FHM positioning, fueling and FHM parking) within a period of one hour (as a goal).
- h. Cooling (using external water supply) of the FHM fuel block and simulated fuel block storage casks including such instrumentation and/or alarms as are necessary for safety purposes.
- i. Heating (using external electrical power and external control and instrumentation) of the simulated fuel block while stored in the FHM cask.

3.1.1.2 Fuel Handling Machine Shipping Container.- The FHM shipping container shall be designed to assure safe ground transportation of the FHM between the Contractor's facility and the launch site. The container shall be re-usable and shall include all necessary attachments and/or accessories (such as slings) for loading and off loading from standard trucks using standard materials handling equipment.

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3.1.1.3 Fuel Transport Cask.- The Fuel Transport Cask shall be designed to assure safe transportation of the fuel block between the Fueling Agency's facility and the launch site. The container shall be capable of repeated use, shall be readily decontaminated (if necessary) and shall include all necessary attachments and/or accessories (such as slings) for loading and off loading from standard trucks using standard materials handling equipment. The container shall meet the applicable requirements of ICC Regulation, Tariff No. 15 and Bureau of Explosives (AAR) File 25-16-174. The container shall be designed for passive dissipation of RTG fuel block heat in unobstructed, still air at a temperature not exceeding 120°F.

3.1.1.4 RTG Power System Shipping Container.- The RTG Power System Shipping Container shall be designed to assure safe ground transportation of an assembled and tested RTG system (less fuel block, but including electrically heated fuel block) between the Contractor's facility and the integrating Contractor's facility. The container shall be capable of repeated use and shall include any necessary special equipment required for handling and removal of the system from the container as well as all necessary attachments and/or accessories (such as slings) for loading and off loading from standard trucks using standard materials handling equipment.

3.1.1.5 RTG Field Test Equipment.- The RTG Field Test Equipment shall include all special equipment necessary for RTG startup and operation during test and pre-launch operations. The equipment shall consist of two major items providing the following specific functions.

a. Electrically Heated Fuel Block and Control System

- (1) The electrically heated fuel block shall be physically and thermally interchangeable with the fuel block (radioisotope fueled) and shall permit controlled heat-up and/or cool-down of the RTG and maintain the RTG at operating temperature during test or during extended launch pad holds. It shall be possible to connect the electrically heated fuel block to its control system either directly or by means of a connection built into the FHM.
- (2) The control system for the electrically heated fuel block shall include a remote controlled auto transformer for input power control and a console providing controls and instrumentation.

b. RTG Test Console

The RTG Test Console shall provide RTG instrumentation readout consisting of 56 channels as follows:

- (1) 32 RTG temperatures
- (2) 4 radiator temperatures
- (3) 16 coolant temperatures
- (4) 2 output voltages
- (5) 2 output currents

Alarm capability shall be provided on 10 of the above channels.

3.1.1.6 NaK Ground Service System.- The NaK Ground Service System shall provide the following specific functions as detailed in the applicable Contractor prepared end item specification.

- a. Safe shipment of NaK from the supplier's facility to the Contractor's facility (and elsewhere, if necessary).
- b. General purification of NaK as it is charged into the generator system.
- c. Charging (and draining, when necessary) of the NaK coolant into the RTG system.

3.1.1.7 Fuel Handling Machine Checkout Equipment.- The FHM checkout equipment shall provide the following specific functions as further detailed in the applicable Contractor prepared end item specifications.

- a. Pre-operational checkout of all mechanical and electrical functions of the FHM.
- b. Pre-alignment of the FHM to the satellite vehicle/MST.
- c. Routine maintenance of the FHM.

The FHM checkout equipment shall be provided in a single container for ease of transportation at the launch site and shall include all necessary accessories for transportation between the Contractor's facility and the launch site.

3.1.2 Operational.- The Po RTG AGE shall be capable of providing the functional performance required herein when employed and deployed as follows. Standard MIL-STD-803 shall be used "as a guide" in design of the equipment for operational use.

3.1.2.1 Employment.- The equipment specified herein shall be used to support the RTG Space Power System, when the system is installed in an SCS satellite vehicle and a Titan 3D launch vehicle, during pre-launch operations at the PALC-2 Launch Complex of the WTR. This general support shall include the safe transportation of radioisotope fuel from the Fueling Agency to the launch site.

3.1.2.2 Deployment.- The contract end items specified herein shall be deployed as follows:

<u>Item</u>	<u>Quantity</u>	<u>Location</u>	<u>Provided by</u>
Fuel Handling Machine	1	Launch Site	Contractor
FHM Shipping Container	1	Stored at Launch Site	Contractor
Fuel Transportation Cask	2	Note A	Contractor
RTG Power Supply Shipping Container	1	Note B	Contractor
RTG Field Test Equip.			
a. Control Equipment for electrically heated fuel block	4	Contractor's facility(1) Integrating Contractor facility (2) Launch Site (1)	Contractor Contractor Contractor
b. RTG Test Console	3	Contractor's facility(1) Integrating Contractor facility (1) Launch Site (1)	Contractor Integrating Contractor Using Organization
Nak Ground Service Sys.	1	Contractor's facility	Contractor
FHM Checkout Equipment	1	Launch Site	Contractor

Notes A and B see the following page:

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Note A: Moves between Fueling Agency facility and launch site as required by launch schedule.

Note B: Moves between Contractor's facility and Integrating Contractor's facility.

3.1.3 Reliability.- The Po RTG System AGE shall be designed, developed and fabricated in accordance with a Contractor established AGE reliability program to meet equipment reliability requirements of MND-3612-13. Testing to verify attainment of required reliability for the Contractor furnished AGE, shall be accomplished to the extent of the quality assurance requirements of Section 4 herein.

Reliability goals shall be allocated to AGE contract end items as detailed in the applicable Contractor prepared end item specifications.

3.1.4 Life.- The design life for Po RTG System AGE shall be five (5) years (after date of acceptance by the Procuring Agency) based on regular performance of preventive maintenance as specified in Contractor furnished instruction manuals.

3.1.5 Maintainability.- Po RTG System AGE shall be maintainable (routine maintenance only) by Contractor personnel at the Launch Complex (during launch periods only) by simple removal and replacement (mechanical fastenings, fluid and electrical connections and soldered electrical connections) of major components and/or sub-assemblies.

Maintenance, other than routine, shall be performed at the Contractor's facility (or other suitable facility selected by the User Organization/AEC) under separate repair/maintenance/overhaul contract.

3.1.5.1 Repair Parts.- Items to be used in routine maintenance of AGE shall be those specified as AGE Repair Parts in the contract and as furnished initially with the FHM Checkout Equipment.

3.1.5.2 Preventive Maintenance.- Preventive maintenance for AGE shall be as required by the applicable Contractor furnished instruction manuals.

3.1.5.3 Personnel.- Po RTG System AGE routine maintenance shall be performed by Contractor personnel at the launch site during launch periods.

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3.1.6 Transportability.- Po RTG System AGE Contract End Items shall be transportable by standard ground transportation when packed and packaged for shipment and shall be transportable by standard materials handling equipment when deployed as set forth herein. Special requirements for handling shall be as specified in the applicable Contractor prepared end item specifications and/or interface control specifications. Slings/attachments for lifting and tying down items of AGE weighing more than 2240 pounds shall be in accordance with Standard MIL-STD-209, Type III.

The AGE (except RTG Shipping Container), when prepared for delivery as specified in the applicable Contractor prepared end item specifications, shall be designed to withstand the transportation environments defined below without damage or degradation of subsequent performance.

a. Temperature - Ambient temperature of from -35°F to $+140^{\circ}\text{F}$ plus the effect of solar radiation for a period of up to four hours at a rate of 300 BTU per hour per square foot (except that equipment containing NaK coolant shall not be subjected to temperatures which will result in freezing).

b. Temperature Altitude - Pressure equivalent to 15,000 ft. altitude based on the 1959 ARDC Model Atmosphere with a temperature of -35°F . Altitude variations up to ± 1000 ft/minute.

c. Humidity - Relative humidity up to 100 percent including the effects of condensation and frost.

d. Shock and Vibration - That are experienced during normal handling and around transportation.

e. Temperature Shock - Exposure to 100°F ambient air plus solar radiation of 300 BTU per square foot per hour after stabilization at -35°F , except that equipment containing NaK coolant shall not be subjected to temperatures which will result in freezing. Shock, vibration and environmental requirements applicable to the RTG Power Supply Shipping Container shall be as specified in Section 3.1.4.4.2 of Specification MND-3612-13.

3.1.7 Environment.- The AGE shall withstand the operating environments specified below. Detail specifications for contract end items shall specify the applicability of sheltered, unsheltered or hazardous environment for each item of AGE.

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3.1.7.1 Sheltered.- (applicable to all AGE)

- a. Temperature - +25°F to +135°F without solar heating.
- b. Sand and Dust - Not applicable.
- c. Humidity - Up to 100% relative humidity at any temperature including condensation and frost.
- d. Salt Fog - Non-operating only. Salt characteristics of up to 20% by weight.
- e. Insects - Shall be incapable of penetration by flying and crawling insects larger than 1/8" in their smallest overall dimension.
- f. Atmospheric Pressure - 28 to 32.5 inches of Hg.

3.1.7.2 Unsheltered.-

- a. Temperature - +25°F to 135°F with solar heating for a period of up to four hours at a rate of 300 BTU per hour per square foot.
- b. Wind -
 - (1) Operating with a wind pressure up to 35 pounds per square foot.
 - (2) Non-operating with a wind pressure up to 70 pounds per square foot.
- c. Humidity - Up to 100% relative humidity at any temperature including condensation and frost.
- d. Salt Fog - Salt concentrations of up to 20% by weight.
- e. Sand and Dust - Airborne sand and dust at a velocity of 2500 ft./min. with a density of 0.1 grams per cubic foot or must be protected to withstand this environment. Requirement is applicable only to equipment intended for operation within 25 feet of ground level.
- f. Fungus - Shall be incapable of supporting fungus growth.
- g. Insects - Shall be incapable of penetration by flying and crawling insects larger than 1/8" overall dimension.

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h. Rain - Shall be capable of withstanding rain at a rate of 4 inches per hour.

i. Snow and Ice - Not applicable.

j. Hail and Sleet - Not applicable.

k. Atmospheric Pressure - 28-32 inches of Hg.

3.1.7.3 Hazardous.- (applicable only as specified in detail specifications and in addition to the sheltered or unsheltered environments specified above.)

a. Heat Transfer - Non-expendable equipment which may be exposed to launch vehicle exhaust gases shall withstand a heat transfer rate due to thermal radiation of 240 BTU per square foot per second for a period of 10 seconds.

b. Water Deluge - Water falling downward at a rate of 25 gallons per square foot of horizontal areas for two minutes with a 4 psi impact pressure. This requirement is not applicable to the RTG fuel block cask and heat rejection surfaces.

c. Propellant Compatibility - Equipment which is normally exposed during propellant loading and unloading operations shall withstand a spray of propellants (both but not simultaneously) falling from the vertical and at angles up to 45 degrees from vertical.

d. Explosive Atmosphere - Except for equipment to be operated in a controlled ambient atmosphere, equipment which will operate within 100 ft. of the launch vehicle or any propellant container shall be capable of operating in an explosive atmosphere without causing an explosion. Provisions for control of the ambient atmosphere shall be as specified in Interface Control Specification MND-3612-11.

3.1.8 Nuclear Safety and Radiation.- Nuclear safety and radiation levels at the launch site shall conform to overall governing criteria of Contract AT(30-1)-3612. Within the constraints so established, the SNAP M System AGE shall conform to, or satisfy, the following safety and radiation criteria:

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a. Evaluation, definition, and provision for nuclear safety in the design, development and fabrication of the AGE shall be based on conditions arising from the location of the launch site; features of the launch vehicle and launch complex affecting the nature and magnitude of accidents on, or in the vicinity of the launch complex, such as: predominant materials of construction and the type and quantity of propellants of the vehicle; provisions for launch site personnel safety other than that furnished for reasons of nuclear safety; the techniques, operating procedures, and sequence of events in generator system installation, checkout, fueling and monitoring during pre-launch operations.

b. The design and construction of the fuel transportation cask shall meet the following specific requirements. (See also Section 3.1.1.3 herein.)

- (1) The surface temperature of the container shall be less than 180°F at all times during shipment. (120°F max. ambient)
- (2) No material within the system shall approach within 300°F of its failure temperature during shipment.
- (3) Shielding shall be encased in suitable material such that the shielding will neither escape nor lose its efficiency if in a fire. Casing material shall be at least 1/8" thick for six (6) inches or less of shielding and at least 1/4" thick for more than six (6) inches of shielding.
- (4) Any material used, which might be damaged in a standard fire, shall be insulated from fire effect.
- (5) A means (direct or indirect) shall be provided for measuring internal container wall temperature at all times during shipment.
- (6) The container joints shall be 100% welded or brazed (where practicable) with closure secured by a positive fastening device capable of withstanding severe impact without failure.
- (7) Shielding shall be so designed that "beaming" cannot occur at joints and shall be supported internally such that it can neither change position nor open under any ordinary conditions.

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Manual IFS-TIIIX-33000 shall be applicable to the design of the AGE with respect to interfaces between the AGE and the launch site, mobile service tower and satellite vehicle where requirements for such interfaces are not stated in Specification MND-3612-11.

Specific items of AGE shall be as described on Contractor drawings NSK-411, 414, 415, 416, and 417.

3.2.1 Materials, Parts and Processes.- All materials, parts and processes used shall be compatible with the performance and environmental requirements specified herein and shall be procured, manufactured or produced in accordance with appropriate specifications and standards as stipulated herein and as further selected by the Contractor. The selection of applicable specifications and standards, subsidiary to this specification, shall be made by the Contractor based on the following criteria in the order of priority shown. All four criteria shall be met where possible.

- a. Suitability for use for the intended application.
- b. Previously qualified parts, processes, etc.
- c. Government standard parts, processes, etc.
- d. Low cost.

The Contractor may, at his own volition, use commercial or Contractor standards for materials, parts, and processes which meet the requirements for the RTG AGE when:

- a. Neither applicable Government or non-Government standardizing organization documents exist or are satisfactory.
- b. Or, the Contractor standards are equivalent to or exceed the requirements of the other documents.

Repair parts shall be procured, manufactured and/or processed to the same specifications, standards and requirements as the corresponding parts incorporated into the contract end items.

3.2.2 Protective Coatings and Finishes.- Paragraph 3.2.7 of Specification MIL-E-4158 and Standard MIL-STD-808 shall be used "as guides" for the selection of materials, finishes and protective coatings.

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3.3 Interface Requirements.-- Specific interface requirements applicable to the SNAP M System AGE shall be as set forth in Interface Control Specifications MND-3612-11 and MND-3612-12.

3.4 Data Requirements.-- Data pertinent to the Po RTG System AGE provided by the Contractor hereunder shall be prepared and delivered in accordance with the requirements of Appendix B to Specification MND-3612-13.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General.-- The Contractor shall develop a quality control program for inspection and test of the Po RTG Power System AGE. The program shall be in accordance with Specification MIL-Q-9858A with detail requirements as specified in applicable Contractor prepared end item specifications and as follows.

4.1.1 Inspection.-- Po RTG System AGE items shall receive source inspection, receiving inspection, in-plant inspection (manufacturing control and specification compliance inspection as detailed in the Contractor prepared quality control program and the applicable Contractor prepared end item specifications. The Contractor's quality control responsibility shall extend to and include surveillance and compliance verification of materials handling, safety, routine maintenance, fueling operations, and transport as performed at the launch site and involving Contractor furnished AGE.

4.1.2 Testing.-- The Po RTG System AGE shall be subjected to tests as follows. Detail requirements for each test applicable to each respective item of AGE shall be as set forth in Contractor prepared end item specifications and as follows.

4.1.2.1 Engineering Development Testing.-- The Compliance Subsystem of the FHM shall be subjected to engineering development tests to verify its ability to function properly. The results of these tests shall form the basis for subsystem acceptance criteria.

4.1.2.2 Environmental Testing.-- Components (as selected by the Contractor) of the FHM, Fuel Transport Cask, RTG Power Supply Shipping Container, RTG Field Test Equipment, and the FHM Checkout Equipment shall be subjected to environmental tests (selected by the Contractor from the following list) to demonstrate design adequacy for the intended service.

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Salt fog
Sand and dust
Water deluge
Temperature
Vibration
Shock
Explosion

In addition, the electrically heated fuel block shall receive thermal cycle and endurance tests.

4.1.2.3 Prototype Testing.- The Prototype FHM shall be subjected to tests, as follows, to verify the design adequacy of the assembled machine for the intended service and compliance with the design requirements specified herein and in the applicable Contractor prepared end item specifications. Testing shall include a functional test using a "mock up" representing the satellite/vehicle/RTG system structure, arrangement and anticipated relative motions.

4.1.2.4 Acceptance Testing.- The FHM, Fuel Transport Cask, RTG Power Supply Shipping Container, RTG Field Test Equipment and FHM Checkout Equipment shall be subjected to specific acceptance tests at the Contractor's facility prior to delivery. (See 5.4)

4.1.2.5 Final Inspection.- All AGE shall receive final inspection at the Contractor's facility prior to delivery to verify compliance with Contractor prepared drawings and/or specifications.

5.0 PREPARATION FOR DELIVERY

5.1 Preservation and Packaging.- All items of Po RTG Power System AGE (including repair parts, etc.) shall be preserved and packaged in accordance with the Contractor's standard practices for commercial surface transportation and subsequent immediate use.

5.2 Packing.- Packing shall be in accordance with the Contractor's standard commercial practices.

5.3 Marking.- Marking of items for shipment shall be in accordance with contract requirements and Standard MIL-STD-129.

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5.4 Acceptance.- All deliverable items of AGE (contract end items) shall be presented for final inspection and accepted by the AEC at the Contractor's facility prior to shipment. Acceptance shall be based on the following criteria.

a. Items shall have successfully completed the tests specifically required herein and as detailed in the applicable Contractor prepared end item specifications.

b. Items shall be in conformance with all applicable specifications and drawings as required herein.

6.0 NOTES

6.1 Definitions.-

6.1.1 Abort.- Stopping a planned launch after start of countdown. For planning purposes several modes must be considered.

- a. Before nuclear fueling.
- b. After nuclear fueling, before launch.
- c. After ignition, before lift-off.
- d. After lift-off while in vicinity of launch complex.
- e. After launch - away from complex.

6.1.2 AEC.- The United States Atomic Energy Commission, for purposes of this specification the term implies, but is not restricted to, the New York Operations Office of the AEC.

6.1.3 Aerospace Ground Equipment (AGE).- Those implements or devices, other than facilities, which are required on the ground to make a space system, support system, control system, subsystem or equipment operate in its intended environment. This includes ground equipment required to install, launch, control, direct, inspect, test, service, adjust, calibrate, appraise, gauge, measure, repair, overhaul, assemble, disassemble, handle, transport, safeguard, record, store, actuate, maintain or operate the system, subsystem, end item, or component. This definition applies regardless of method of development, funding or procurement.

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6.1.4 Contract End Item (CEI). - A deliverable item which is formally accepted by the procuring agency as an entity, on a DD Form 250, in accordance with the requirements of a specification. The prime level of assembly for technical and contractual management (customer) control (schedule, configuration, etc.) and accountability for provisioning spares and preparing manuals.

6.1.5 Contractor. - The Martin Company, Division of the Martin Marietta Corporation, Baltimore, Maryland 21203.

6.1.6 Facility. - The support services and equipments which are a permanent part of the launch site, regardless of the flight system being launched.

6.1.7 Fueling Agency. - The Government agency selected by the AEC to furnish and encapsulate the radioisotope fuel.

6.1.8 Fuel Block. - A containment structure for individual fuel capsules. The fuel block serves as the RTG heat source.

6.1.9 Launch Complex. - The primary facilities, property and AGE used to launch a launch vehicle. Includes blockhouse, launch pads, etc. Usually one complex is peculiar to a specific booster, and sometimes to a specific launch vehicle. Excludes multi-purpose support facilities such as Range Safety, tracking stations, etc.

6.1.10 Launch Pad. - The launch pad is the area immediately surrounding the launch vehicles, its composition varies according to launch vehicle needs.

6.1.11 Launch Site. - The area for support of a launch system and includes launch complex, launch pad and all multi-purpose support facilities.

6.1.12 Launch Vehicle. - The combination of a satellite vehicle and a booster in the launch condition.

6.1.13 Mobile Service Tower (MST). - A platformed tower on which work and services on a launch vehicle may be performed and which moves away clear of the launch area just prior to launch.

6.1.14 Radioisotope Thermoelectric Generator (RTG). - A thermoelectric generator which converts the decay heat of nuclear fuel to electric energy.

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6.1.15 Satellite Vehicle.- The item launched by the Booster.

6.1.16 User Organization.- The Government agency having over-all cognizance of the satellite program. The term encompasses Contractors and agencies working under the direction of this agency to carry-out the satellite program.

6.1.17 Integrating Contractor.- A particular contractor of the User Organization, selected to integrate the RTG and AGE into the launch vehicle and launch complex.

6.2 Supplemental Information.-

6.2.1 Government Furnished Property.- The following items, related to the SNAP M System AGE shall be the responsibility of the Government (AEC and its contractors and/or the User Organization and its contractors).

a. Fuel material and processing in accordance with Interface Control Specification MND-3612-12.

b. Site storage, health physics monitoring equipment and services, radiation detection and warning equipment, telemetry and telemetry signal conditioning equipment, Mobile Service Tower modifications and materials handling equipment at the launch site in accordance with Interface Control Specification MND-3612-11.

c. RTG Field Test Equipment as indicated in 3.1.2.2.

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PROCESS SPECIFICATIONS

These process specifications are the major specifications which will be used during the fabrication of the Po RTG power system. Their application to the various components of the system are noted in the drawings in MND-3612-7-II, Engineering Drawings.

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MND-3612-9

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~~SECRET~~THERMOELECTRIC COUPLE ASSEMBLYOPERATION: Bonding of the Couple Assembly

PROCEDURE:

1. Remove "N" type and "P" type iron discs and iron hot shoes from the storage bottle.
 2. Rinse in methyl alcohol and blot dry on a paper towel or "Kimwipes".
 - 3. Locate a hot shoe in the slotted area of the bottom graphite block, TN7-00851-001, of the bonding fixture with the "P" counter bore (tinned) against the closed end of the slot and against the side of the slot nearest the graphite alignment pin, TN7-00851-011. Locate spring, TN7-00851-007, between the hot shoe and the other side of the slot, firmly holding the hot shoe in place.
 - 4. Place the graphite element locator, TN7-00851-003, over the bottom block containing the hot shoe by sliding the locator on the graphite alignment pin.
 5. Place an "N" element in the proper locating hole in the bonding fixture, fitting it firmly in the nickel plated counter bore of the hot shoe.
- CAUTION: Maintain the identity (serial number) of each element through this and all subsequent operations.
- 6. Place a nickel plated iron disc on top of the "N" element with the plated side in contact with the element. Place graphite cap, TN7-00852-005, on top of the iron disc.
 7. Place a "P" element in the proper locating hole in the block, fitting it firmly in the counter bore of the hot shoe.

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THERMOELECTRIC COUPLE ASSEMBLY

OPERATION: Bonding of the Couple Assembly

PROCEDURE: (Continued)

- 8. Place a tinned iron disc on top of the "P" element with the tinned side in contact with the element. Place graphite cap, TN7-00852-005, on top of the iron disc.
 - 9. Place the graphite split ring, TN7-00851-005, carefully around the top of the bonding fixture and elements to hold the elements and discs in their proper location.
 - 10. Place the graphite bonding fixture containing couple details in loading jig, TN7-00852; place retaining spring, TN7-00852-007 over locating post TN7-00852-003; locate on graphite caps TN7-00852-005, depress and assemble split washer TN7-00852-011 to locating post.
 - 11. Place the loading jig, TN7-00852, in a vicor glass chamber and seal with a rubber stopper having attached gas ports.
 - 12. Evacuate the glass chamber to less than one (1) inch Hg (absolute pressure) and backfill with nitrogen.
 - 13. Repeat step #12 two (2) more times.
 - 14. Place a lighted Bunsen burner under the burn off tube and purge the chamber with hydrogen.
 - 15. Place the glass chamber in the furnace operating at $1650^{\circ} \pm 25^{\circ}$ F.
 - 16. After the furnace drops in temperature, to approximately 1470° F, allow the graphite bonding fixture, containing couple details, to come up to $1450^{\circ} \pm 25^{\circ}$ F and hold for three (3) minutes.
- Note: Locate thermocouple, measuring fixture temperature, at bonding point furthest inside furnace.
17. Remove the glass chamber from the furnace and allow to cool to room temperature under hydrogen (use a fan or blower if desired).

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THERMOELECTRIC COUPLE ASSEMBLY

OPERATION: Bonding of the Couple Assembly

PROCEDURE: (Continued)

18. Purge the hydrogen from the glass chamber with nitrogen.
- 19. Withdraw the loading jigs from the glass chamber and remove the bonded couples from the graphite bonding fixture.

CAUTION: If couples are not to be immediately dressed, as in step 20, they shall be stored until such time as in step 22.
20. Remove the flash from the bonded areas and the oxide from the top of the couples with a file and 400 grit abrasive paper. Wipe the couple with "Kimwipes" dampened with methyl alcohol to remove the dust and filings.
21. Identify each couple with an assigned serial number and record.
- 22. Couple assemblies shall be packaged and stored in accordance with NPS 12-004.

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NUCLEAR PROCESS SPECIFICATION

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~~SECRET~~THERMOELECTRIC GENERATOROPERATION: Bake-out of Min-K Module BlocksEQUIPMENT: Box type furnace - Capable of maintaining a temperature of $930^{\circ} \pm 10^{\circ}$ F ($499^{\circ} \pm 6^{\circ}$ C) with or without an evacuable chamber.

Evacuatable chamber.

Separators (stainless steel sheets or trays with supporting legs).

Hi-Vac 14 (or equivalent) Vacuum Pump, capable of maintaining a minimum vacuum of 26 ± 0.5 inches of Hg (corrected to sea level).

Gas Cold Trap.

Polyethylene bags.

Masking tape

Argon

PROCEDURE:

1. The furnace shall be operating at $930^{\circ} \pm 10^{\circ}$ F ($499^{\circ} \pm 6^{\circ}$ C).
2. Handling carefully, place module blocks on separators located so they do not touch each other.
3. Carefully place one or more separators in the furnace supported one above another and hold at temperature ($930^{\circ} \pm 10^{\circ}$ F) ($499^{\circ} \pm 6^{\circ}$ C) as specified on following page:

By <u>C. W. Mihle</u> Proc. Eng. <u>R. E. Harris</u> Mfg. <u>R. E. Harris</u>		
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THERMOELECTRIC GENERATOR

OPERATION: Bake-out of Min-K Module Blocks

PROCEDURE: (Continued)

Thickness of Part (inches)	Furnace Treating Time (hrs. minimum)
less than 3/4	24
3/4 to 1 1/4	36
1 1/4 and greater	48

- Remove from furnace and immediately proceed with Items 5 through 6 in order to maintain temperature of module blocks.
- Handling carefully, place baked-out module blocks on separators located so they do not touch each other.
- Carefully place one or more separators containing the blocks in the Bell jar supported one above another. Do not shake or jar separator.
- Evacuate Bell jar at room temperature with Hi-Vac 14 or equivalent to 26 ± 0.5 inches of Hg (corrected to sea level) for one (1) hour and backfill with argon that has been cold trapped.
- Open Bell jar and, using extreme care, rapidly transfer the blocks to individual polyethylene bags.
- Fold top of bag and partially seal with tape leaving one corner open.
- Insert argon tube in opening of bag until it touches bottom; purge with argon displacing all air.
- Remove argon tube and completely seal bag with tape.

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THERMOELECTRIC GENERATORSOPERATION: Fitting of Min-K Insulation to Inner and Outer Cans

PROCEDURE:

- NOTE: Trim the Min-K insulation to match the inner can and outer housing of the generator. The fit shall be as accurate as the Engineering Drawing with no interference between the insulation and the cans.

Note: (1) Use scalpel and emery paper.

(2) All grooves or recesses should be as accurate as originally called out in Engineering Drawing.

Lower Dome Min-K Insulation

1. Custom fit the lower dome insulation to match the retaining stud, threaded bosses, webs and contours of the inner and outer can of the generator.
2. Cut a groove on the bottom surface (spherical) of the lower dome for the thermocouple and output leads.
3. Cut a recess in the bottom surface (spherical) of the dome at the electrical connector location of sufficient depth to provide clearance for the connector plug wiring.
4. Cut a recess in the top surface of the dome to a depth and area large enough to accommodate packages of "Getter" material.

Lower Ring Min-K Insulation

1. Custom fit the lower ring to match the contours of the inner and outer can of the generator.
2. Cut slots in the ring of sufficient size to allow clearance for the wiring of each module.

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THERMOELECTRIC GENERATORS

OPERATION: Fitting of Min-K Insulation to Inner and Outer Cans

PROCEDURE: (Continued)

Upper Ring Min-K Insulation

1. Custom fit the upper ring to match the contour of the inner and outer cans of the generator. A large clearance is permissible between the radius on the inner can and the sharp corner on the insulation.

Wire Cover Ring Min-K Insulation

1. Custom fit the cover ring to match the contours of the outer can of the generator.
2. Segment the ring as required to provide clearance for the module wiring.

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THERMOELECTRIC GENERATOROPERATION: Special Handling for Space Type Generators

SCOPE: This process establishes the procedure and application for manually handling (i. e. without assistance from mechanical lifting devices) thermoelectric generators after completion of final assembly, finish coating, leak tests, environmental tests, and electrical tests. This process, when specified on Nuclear Process Specifications, Manufacturing Operation Sheets, and/or Engineering Drawings, shall be used without deviation for all work within the scope of this process.

EQUIPMENT: Clean, white, cotton gloves. *

*NOTES: (1) "Clean", as used herein, is defined as "being free from any foreign or extraneous matter that might contaminate or otherwise have a deleterious or harmful effect upon the parts being handled".

(2) New or freshly laundered gloves shall be used for this final handling operation of each generator. As soon as this handling operation has been completed, the gloves will be removed and placed in a receptacle for dirty gloves and will not again be used for the handling operation herein identified until they have been adequately laundered.

PROCEDURE: Using clean, white, cotton gloves and extreme care to prevent chipping, scratching or marring the finish coating, or otherwise damaging the generator, lift** the generator from the final test and acceptance area, and place and secure in the specified shipping container.

**CAUTION: The maximum weight that may be lifted waist high by one man, without assistance from mechanical lifting devices, is 45 lbs; and by two men without assistance from mechanical lifting devices, is 90 lbs. (Ref. MIL-STD-803).

Proc.		
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THERMOELECTRIC GENERATOR

OPERATION: Lubricating with Molykote X-15

EQUIPMENT
AND

MATERIALS: Kimwipes
Clean White Cotton or Rubber Gloves
Small Brush
Ultrasonic Cleaning Unit
Stainless Steel Burnishing Tool (1/4 to 1/2" dia. rod)
Molykote X-15 Dry Film Lubricant - Graphite
Sodium Silicate, Water Base
The Alpha-Molykote Corporation
Stamford, Conn.
Hydro-sonic Cleaning Solution - dilute with
8 parts water to 1 part cleaning solution.
L & R Manufacturing Co.
Kearny, N. J.
Ridosol 501 Detergent - 20 parts water to 1 part
detergent.

PROCEDURE:

1. Ultrasonically clean parts for ten (10) minutes, minimum, in diluted hydro-sonic cleaning solution.
2. Rinse parts for five (5) minutes, minimum, in cold tap water.
3. Place parts in dilute solution of Ridosol detergent, stir thoroughly and allow to soak for fifteen (15) minutes, minimum.
4. Rinse parts for five (5) minutes, minimum, in cold tap water.
5. Using clean, white cotton or rubber gloves, wipe parts dry with kimwipes.

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By <u>L. Flanagan</u> Proc. <u>W. Brittain</u> Mfg <u>R. E. Harris</u>		
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THERMOELECTRIC GENERATOR

OPERATION: Lubricating with Molykote X-15

PROCEDURE: (Continued)

6. Using a small clean brush, apply a thin uniform coat of Molykote X-15 to all surfaces of the connecting links including all holes and slots and those surfaces of the drive shafts as specified on the applicable drawing.
7. Place parts on clean slick paper (do not use kimwipes) and allow to dry in air for twenty-four (24) hours, minimum.
8. Burnish the parts after drying as follows:
 - a. Slide mating pins used in assembling generator back and forth several times in the slots and holes in the connecting links.
 - b. Using a 1/4" to 1/2" diameter stainless steel rod, lightly burnish the lubricated surfaces of the shafts and connecting links.
9. Wipe burnished surfaces of parts with kimwipes to remove excess lubricant.
10. Check shafts in bronze bushings for free fit.

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NUCLEAR PROCESS SPECIFICATION

~~SECRET~~OPERATION: Soldering of Terminal Lugs and Couples

PROCEDURE:

NOTE: The Min-K shall be baked out in accordance with NPS 02-035.

1. Remove couples from inert atmosphere (argon) and carefully remove all oxidation from the iron discs with 220-300 grit dry paper. Wipe clean with alcohol.
2. Place the couples on a hot plate with the temperature approximately 25°F above room temperature. Using a DC voltmeter and probes determine the positive and negative polarity of the couples.
3. Remove the K from the inert atmosphere (argon) of polyethylene bag.

CAUTION: The maximum allowable exposure time to air is five (5) minutes. If the exposure time in air is exceeded, the Min-K must be baked out for two (2) hours at 930°F and then evacuated until the Min-K cools to ambient temperature.

4. Position and fit the couple assemblies in the Min-K insulation in accordance with applicable drawing. Maintain a permanent record, by serial number, and by couple location in the thermoelectric module, of each couple.
5. Wipe the soldering surfaces of the iron discs and terminal lugs with "Kester's 817" flux using a "Q-Tip". Confine the flux to the immediate bonding areas.

CAUTION: Extreme care shall be exercised to avoid any contact of the flux to the elements. In the event that this occurs, the couple shall be rejected.

6. Instrument terminal lugs and straps with thermocouples at five (5) locations along the module; i.e., at the module ends and at three (3) equally spaced locations between the module ends.

NOTE: Instrumentation will not be required after the temperature differences and the temperature requirements are determined. It is estimated that a maximum of three (3) modules will require the above instrumentation. A cross reference on fixture thermocouple to module thermocouple should be recorded for future control.

~~SECRET~~

BY <u>C. Miller</u>		PROC. <u>R. E. Harris</u>	ENGR. <u>R. E. Harris</u>	QUAL. <u>W. Q. (G/L)</u>
ISSUED <u>November 10, 1964</u>	MARTIN NUCLEAR		NPS01-035	
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NUCLEAR PROCESS SPECIFICATION

DECLASSIFIED

THERMOELECTRIC MODULE ASSEMBLY

OPERATION: Soldering of Terminal Lugs and Couples

PROCEDURE: (Continued)

7. Position terminal lugs and straps in the soldering fixture.
8. Locate a disc of spectrographic grade tin, 1/4" x .008" thick, on each terminal strap.
9. Locate the Min-K insulation containing the couple assemblies in the recess of the cover of the soldering tool.
10. Slide the cover plate, containing the Min-K and couples, down the guide pins of the soldering fixture. Apply six (6) pounds (Approx.) pressure to mate the terminal straps to the iron discs.

*Note: Per element

11. Place the fixture in the soldering chamber; close, and seal chamber.
12. Evacuate the soldering chamber to -29" of Hg and backfill with argon. Continue pumping. Turn on power and increase temperature. Monitor temperature on all thermocouples and control by the coolest thermocouple. Temperature shall be raised at a rate not to exceed 30°F per minute or to take not less than 15 minutes to reach the soldering temperature of 530 ± 20°F ± 0°F on the strap and hold at this temperature for two (2) minutes, minimum.
13. Turn power off and cool thermoelectric module to 150°F.

NOTE: (1) Rate of cooling shall not exceed 30°F per minute.

(2) Cooling rate shall be controlled by passing water through a manifold system in the module fixture. Flow of water shall be increased slowly so as to produce a linear rate of temperature drop.

14. Remove the module from the soldering tool.

CAUTION: Care shall be taken so as not to break the Min-K insulation.

15. Scrub the serial number of the module on the top surface of the terminal lugs and also on the "N" and "P" polarity of the module at each end of the module (outlet leads).
16. Store the module in a desiccator cabinet in an argon atmosphere.

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~~SECRET~~THERMOELECTRIC COUPLE ASSEMBLY

OPERATION: Furnace Bonding Couple Assemblies: RTG Couple
N0023110-009

PROCEDURE:

1. Receive the hot shoes and the "P" cold shoes from the tinning operation and remove the "N" cold shoes from the storage bottle.
2. Rinse off the shoe details with methanol alcohol and wipe dry with "kimwipes".
3. Locate a hot shoe in the slotted area of the bottom graphite block, TN7-00902-001, of the bonding fixture with the "P" counter bore (tinned) against the closed end of the slot and against the side of the slot nearest the graphite alignment pin, TN7-00902-007. Locate spring, TN7-00902-013, between the hot shoe and the other side of the slot, firmly holding the hot shoe in place.
4. Place the graphite element locator, TN7-00902-003, over the bottom block containing the hot shoe by sliding the locator on the graphite alignment pin.
5. Place an "N" element in the proper locating hole in the bonding fixture, fitting it firmly in the nickel plated counter bore of the hot shoe.

CAUTION: Maintain the identity (serial number) of each element through this and all subsequent operations by recording all information on T/R Mfg. Form #C08.

6. Place a nickel plated iron disc on top of the "N" element with the plated side in contact with the element. Place graphite cap, TN7-00902-011, on top of the iron disc.
7. Place a "P" element in the proper locating hole in the block, fitting it firmly in the counter bore of the hot shoe.
8. Place a tinned iron disc on top of the "P" element with the tinned side in contact with the element. Place graphite cap, TN7-00902-011, on top of the iron disc.

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BY <i>AZiel</i>	PROC. ENGR <i>AZiel</i>	WFG <i>AZiel</i>
TECH. <i>Joe W. B.</i>	QUAL <i>W. B. B.</i>	
ISSUED <u>Oct. 21, 1965</u>	<i>MAINTENANCE</i>	NPS <u>01-041</u>
REVISED _____	NUCLEAR	PAGE <u>1</u> OF <u>3</u>
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THERMOELECTRIC COUPLE ASSEMBLY

OPERATION: Furnace Bonding Couple Assemblies: RTG Couple
N0023110-009

PROCEDURE: Continued

9. Place the graphite split ring, TN7-00902-005, carefully around the top of the bonding fixture and elements to hold the elements and discs in their proper location.
10. Place the graphite bonding fixture containing couple details in loading jig, TN7-00903; place retaining spring, TN7-00903-003, over locating post TN7-00903-005; locate on graphite caps TN7-00902-011, depress and assemble split washer TN7-00903-007 to locating post.
11. Place the loading jig, TN7-00903, in a vycor glass chamber and seal with a rubber stopper having attached gas ports.
12. Evacuate the glass chamber to less than one (1) inch Hg (absolute pressure) and backfill with nitrogen.
13. Repeat step #12 two (2) more times.
14. Place a lighted Bunsen burner under the burnoff tube and purge the chamber with hydrogen for one (1) minute. The hydrogen flow rate is to be 25 cfh.
15. Place the glass chamber into the horizontal resistance wound furnace operating at a 900°C (1652°F) controller setting, which yields a 1652° ± 25°F furnace temperature.
16. Due to the cold tooling in the furnace, the furnace temperature will drop to approximately 790°C (1454°F). As a result, the furnace controller will call for heat; allow the furnace to call for heat for the first five and one-half (5-1/2) minutes that the tooling chamber is in the furnace and then turn off the furnace as soon as the five and one-half (5-1/2) minutes elapse.
17. With the furnace off, the tooling will continue to increase in temperature. With the sheathed thermocouple inserted into the middle of the graphite loading jig, TN7-00903, and attached to a potentiometer, follow the millivolts being recorded from the thermocouple.
18. When a potentiometer reading of 32.22 millivolts (1425°F) is reached, start a three (3) minute timer. Bond the couples by allowing the tooling to remain three (3) minutes at 1450° ± 25°F (32.22 to 33.37 millivolts). The tooling will continue to increase in temperature during the three (3) minutes but must not exceed 1475°F (33.37 millivolts).

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THERMOELECTRIC COUPLE ASSEMBLY~~SECRET~~

OPERATION: Furnace Bonding Couple Assemblies; RTG Couple
NO023110-009

19. When three (3) minutes at 1450°F has elapsed, remove the glass chamber from the furnace, and allow to cool to room temperature under fan circulated air.
20. After the glass chamber has been removed from the furnace, turn the furnace back on so it can recover the furnace temperature for the next bonding run. A recovery time of approximately thirty (30) minutes is required.
21. When the temperature of the bonding tool reaches 300° + 25°F (5.53 to 6.65 millivolts), turn on the nitrogen and turn off the hydrogen in that order. Allow the tooling to further cool to approximately 110° to 120°F so the tools can be handled by hand.
22. Withdraw the loading jig from the glass chamber and remove the bonded couple from the graphite bonding fixture.
23. Place each couple into a separate compartment within the lot container. Pairwise couple identification by identifying the container compartments with the couple identification number.

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NUCLEAR PROCESS SPECIFICATION

030507030

~~SECRET~~THERMOELECTRIC COUPLE AND MODULE ASSEMBLYOPERATION: Nickel Plating Ferro-Vac-E Iron Discs and Hot Junction Shoes

EQUIPMENT: Tanks - Refer to NPS 03-000

Solutions:

- 1) Perchloroethylene - maintain at 250°F
- 2) Oakite - 10 ounces of Oakite No. 90 to 1 gallon of water, maintain at 180°F.
- 3) Concentrated Nitric Acid - 1.42 specific gravity.
- 4) Concentrated Hydrochloric Acid - 1.19 specific gravity
- 5) HVWM Bright Nickel Plating Bath (Watts Type Bath)
 - 40 oz/gal. Nickel Sulphate
 - 8 oz. Nickel Chloride
 - 5.5 oz. Boric Acid
 - 3 oz. NL-1 Addition
 - 3.5 oz. NL-2 Addition
- 6) Distilled Water
- 7) "Micro-Stop"
- 8) Acid brush or equivalent.

NOTE: Do not let the surface dry between plating steps.

PROCEDURE:

1. Degrease in perchloroethylene.
2. Immerse in hydrochloric acid for 15-30 seconds.
3. Rinse thoroughly in flowing tap water.
4. Immerse in nitric acid and remove immediately.
5. Rinse thoroughly in flowing tap water.
6. Immerse in hydrochloric acid for 15 seconds, minimum
7. Rinse thoroughly in flowing tap water.

NOTE: Detail parts must be nominally clean as per A-6k of Standard Process P-50051.

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BY <i>L. H. [Signature]</i>		PROC ENG <i>[Signature]</i>	QUAL <i>[Signature]</i>
ISSUED December 18, 1963	INTEGRITY		NPS 03-028
REVISED April 5, 1965	NUCLEAR		PAGE 1 OF 2
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NUCLEAR PROCESS SPECIFICATION

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THERMOELECTRIC COUPLE AND MODULE ASSEMBLY

OPERATION: Nickel Plating Ferro-Vac-E Iron Discs and Hot Junction Shoes

PROCEDURE: (Continued)

- 8. Coat areas that do not require plating with "Micro-Stop" (allow to flow evenly) and allow to dry thoroughly.
9. Clean cathodically in the Oakite solution at approximately 6 volts for 3 minutes.
10. Rinse in flowing tap water.
11. Dip in nitric acid.
12. Rinse in flowing tap water.
13. Activate in hydrochloric acid for 30 seconds.
14. Rinse thoroughly in distilled water.
15. Place in the nickel plating bath and plate at approximately 20 amperes per square foot to the thickness specified on the applicable drawing. (Plating rate is approximately .0007 inches per hour).
16. Rinse thoroughly in distilled water and dry.
- 17. Remove "Micro-Stop" manually; use "Micro-Stop Reducer" if necessary.
- 18. Dip in hydrochloric acid.
- 19. Rinse thoroughly in flowing tap water.
- 20. Rinse thoroughly in distilled water and dry.
21. Store parts in accordance with NPS 12-006.

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ISSUED December 18, 1963	MARTIN NUCLEAR	NPS 03-028
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NUCLEAR PROCESS SPECIFICATION

03-03-07-030

THERMOELECTRIC COUPLE ASSEMBLY~~SECRET~~OPERATION: Tinning of Iron Hot and Cold Shoes

PROCEDURE:

1. Clean shoes with methyl alcohol and "Kimwipes".
2. Coat surfaces, designated by the applicable drawing as tinned surfaces, with Kester's 817 flux. Confine flux to immediate bonding areas.
- 3. Place the hot shoes and cold shoes (discs) on a hot plate, operating at 510 to 560°F, with the "fluxed" surface up.
- 4. Place the amount of tin, as tabulated in Table I attached, on the "fluxed" surfaces of the shoes.
- 5. Allow solder to melt; spread evenly over the surface with a soldering iron operating at 465 to 515°F until completely wetted and coated.
6. Remove parts from the hot plate and cool to room temperature.
7. Wash excess flux from the shoes with methyl alcohol and wipe dry with "Kimwipes".
- 8. Store shoe sets in polyethylene bags filled with inert gas and seal, if the details are not used immediately after tinning.

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BY <i>AZ</i>	PROC. ENGR. <i>AZ</i>	MFG <i>AZ</i>	QUAL <i>A. Birds</i>
TECH.			
ISSUED December 19, 1963		NPS 03-029	
REVISED Sept. 22, 1965		PAGE 1 OF 2	
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NUCLEAR PROCESS SPECIFICATION

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TABLE I

<u>Approximate Element Diameter</u>	<u>Approximate Area of Bond</u>	<u>Amount of Tin</u>		<u>Referenced Examples of Application</u>
		<u>Hot Shoe</u>	<u>Cold Shoe</u>	
<u>Copper Strap Shoes</u>				
.365	.100 in ²	.005 gm	.005 gm	Gas Fired Gen. N0003025 Couple Design
<u>Counter Bore Shoes</u>				
.375	.111 in ²	.03 gm	.015 gm	SNAP 19 - 452A1300001 Couple Design
.500	.159 in ²	.05 gm	.025 gm	LCG - N0013103 Couple Design

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ISSUED December 19, 1963	MARTIN NUCLEAR	NPS 03-029
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NUCLEAR PROCESS SPECIFICATION

FURNACE BONDED THERMOELECTRIC COUPLES

SECRET

OPERATION: Clean-Up of Couples; RTG Couple N0023110 009

PROCEDURE:

1. Take couples from the furnace bonding tool or the lot container and maintain couple identity at all times.
2. Remove any bonding agent or element material protrusions from the edge of the cold shoes with a jeweler's file. Use a separate file identified "N" and "P" for each type of element.
3. Clean up all material protrusions until the couple fits into couple assembly checking fixture TNS-00908. If the couple does not fit into the checking fixture, the couple will be rejected
4. With the couple in checking fixture TNS-00908, determine the disposition of the couple meeting the elements center line to hot shoe edge with the "Go-Not-Go" gage.
5. Place a piece of 400 or 600 grit emery paper on a flat surface and holding the couple firmly, carefully sand the cold shoe surfaces by moving them across the emery paper in one direction until the cold shoes are bright. Do not round the edges of the cold shoes
6. Clean the couples thoroughly with methanol alcohol and wipe dry with "kimwipes" removing the dust generated in earlier steps
7. Measure those required dimensions on the couples which were not checked by the checking fixture: i.e. total couple height
8. Record all dimensions and check results on T/E Mfg. Form No. 003 along with the program name, part number and lot number.
9. Place the clean couples back into the lot container maintaining the couple identity.
10. After the lot is complete, place the lot container with couples into a polyethylene bag, insert the lot data sheets, fill the bag with argon and seal. Transfer the lot to the following operation.

BY <i>DZ ichell</i>	PROC. ENGR. <i>DZ ichell</i>	MFG. <i>DZ ichell</i>	
TECH. <i>Q. 1. 1. 1. 1.</i>		QUAL. <i>(W. Beal)</i>	
ISSUED Oct. 21, 1965		<div style="font-size: 2em; font-weight: bold;">05-173</div> <div style="font-size: 1.5em; font-weight: bold;">NUCLEAR</div> <div style="font-size: 1.2em;">PAGE 1 OF 1</div>	
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NUCLEAR PROCESS SPECIFICATION

031507030

TEMPERATURE CYCLE DURING FURNACE BONDING
Pb RTG THERMOELECTRIC COUPLES

THERMOELECTRIC ELEMENTS

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OPERATION: Determination of Room Temperature Resistivity

➔ APPLICATION: This process establishes the procedures for determining the room temperature resistivity of thermoelectric elements. This process, when specified, shall be used in conjunction with Engineering drawings and specifications within the scope of this process. Specific requirements as called for on the drawing and specification supersede the requirements of this process where a conflict exists.

➔ EQUIPMENT AND MATERIALS: Room Temperature Resistivity Tester
VTVM
Variac

PROCEDURE:

1. Place the element between the spring loaded contacts of the resistivity tester and pass a current of one (1) ampere AC through the element.
2. Lower the tungsten probes until they make contact with the surface of the element.
- ➔ 3. Measure the voltage drop between the probes and record on Thermoelectric Evaluation Sheet No. 006.
4. Rotate the element at intervals of 120°, repeating steps 2 and 3 until three (3) measurements are obtained.
5. Calculate the average voltage drop from the three (3) measurements.
- ➔ 6. Convert the average voltage drop to resistance, calculate the resistivity as follows and record on Thermoelectric Evaluation Sheet No. 006:

$$= \frac{RA}{L} \times 1000 \quad = \text{resistivity (micro-ohm-cm)}$$

R = resistance (milliohms)

A = area (cm²)

L = probe distance (cm)

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BY <u>J. J. Flanagan</u> PROC ENG <u>R. S. Harris</u> <u>R. E. Harris</u> QUAL <u>W. B. Binder</u>		
ISSUED <u>Jan. 29, 1964</u> REVISED <u>June 8, 1965</u> STATUS <u>STANDARD</u>	MARTIN NUCLEAR	NPS 11-023 PAGE <u>1</u> OF <u>2</u>

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THERMOELECTRIC ELEMENTS

OPERATION: Determination of Room Temperature Resistivity

PROCEDURE: (Continued)

7. Remove the element from the tester and place it in a storage container maintaining the batch number and serial number identification.

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NUCLEAR PROCESS SPECIFICATION

0115070

~~SECRET~~THERMOELECTRIC ELEMENTSOPERATION: Determination of Seebeck Voltage

APPLICATION: This process establishes the procedures for determining the seebeck voltage of thermoelectric elements. This process, when specified, shall be used in conjunction with Engineering drawings and specifications within the scope of this process. Specific requirements as called for on the drawing and specification supersede the requirements of this process where a conflict exists.

EQUIPMENT
AND

MATERIALS: Seebeck Voltage Tester ME 49613
Simpson Voltmeter
Argon (passed through a chip furnace and chemical dryer)

PROCEDURE:

1. Pre-set the nominal hot (T_H) and cold (T_C) junction temperatures on test unit ME 49613 as specified on the applicable drawing. Record the pre-set temperatures on the Element Location Data Sheet No. 005 and Thermoelectric Element Evaluation Sheet No. 006.
2. Close argon supply valve.
3. Release quick acting clamps and remove plexiglass cover from dry box.
4. Swivel heat sink assembly to the side to provide access to carbon discs and remove Min-K insulator.
5. Clean bottom surfaces of each heat sink thoroughly with copper wool.
6. Clean each carbon disc thoroughly with an acid brush.
7. Insert ground lead of Simpson voltmeter into ground jack located on test unit and check each carbon disc for proper ground. Value should not exceed 2 ohms.
8. Place Min-K insulator on top of carbon discs.

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BY <u>L. F. [Signature]</u>		PROC <u>RE Harris</u>	ENG. <u>RE Harris</u>	MFG <u>RE Harris</u>	QUAL <u>W. [Signature]</u>
ISSUED	Jan. 29, 1964	NUCLEAR		NPS 11-024	
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THERMOELECTRIC ELEMENTS

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OPERATION: Determination of Seebeck Voltage

PROCEDURE: (Continued)

9. Insert the elements in the holes of the Min-K insulation of the tester until they contact the carbon discs of the heater plate. Record box number, batch number and location of each element by serial number on the Element Location Data Sheet No. 006.
10. Place the water cooled heat sink over the cold junction end of the element and, using a Simpson voltmeter, check continuity of heat sink to insure good electrical contacts.
11. Place plexiglass cover on dry box and turn on vacuum pump and evacuate dry box to six (6) inches of mercury maximum; while evacuating, open argon valve and start argon purge at 10 cfh.
12. Turn off vacuum pump and continue argon purge. Hold at 1 to 2 psi throughout test.
13. Turn the heaters on and increase the temperature 50°F per minute until it reaches the pre-set temperature (Ref. step 1). Allow temperature to stabilize before proceeding, approximately 10 minutes.
14. Measure the Seebeck voltage output and the hot and cold junction temperatures. Record the measured Seebeck voltage output and the hot and cold junction temperatures on Thermoelectric Element Evaluation Sheet No. 006.
15. Calculate the correct Seebeck voltage at the measured hot and cold junction temperatures using the following formulae:

NOTE: Calculation is not required if the pre-set and the measured hot and cold junction temperatures are identical.

$$TC = T_H - T_C$$

$$T = T_{HM} - T_{CM}$$

$$E = \frac{TC \times S}{T}$$

Where: TC = Specified nominal temperature change

T = Measured temperature change

T_H = Specified nominal hot junction temperature

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THERMOELECTRIC ELEMENTSOPERATION: Determination of Seebeck Voltage

PROCEDURE: (Continued)

15. (Continued)

Where: T_C = Specified nominal cold junction temperature
 T_{HM} = Measured hot junction temperature
 T_{CM} = Measured cold junction temperature
 S = Voltage at T_{HM} (millivolts)
 E = Voltage corrected to T_H (millivolts)

16. Record the corrected Seebeck voltage output and whether the elements are accepted or rejected on Thermoelectric Element Evaluation Sheet No. 006.
17. Reduce the temperature 50°F per minute, maximum, by forcing air through the manifold in the heater block.
18. Remove the elements from the tester, after temperature has dropped to 150°F, maximum, and place them in the storage container maintaining the batch number and serial number identification.

ISSUED Jan. 29, 1964
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NUCLEAR PROCESS SPECIFICATION

~~SECRET~~ 07000

OPERATION: Diaelectric Test of Hard Coated Details and Assemblies

EQUIPMENT: Hewlett Packard VTVM 400H, or equivalent, 1 ampere current source at 25 volts

PROCEDURE:

Details

1. Inspect all details visually for broken areas in dielectric coating. Reject all parts with broken surface areas.
2. Randomly select 10 percent of the visually acceptable details and check dielectrically as follows:
 - a. Locate one probe of the VTVM on an uncoated area, e.g. internal threads, (see flag).
 - b. Using other probe, scan total coated surface area for dielectric coating breakdown. Reject details which do not show infinite resistance.

Assemblies

1. Apply 1 ampere at 25 volts to each completed assembly.
2. Locate one probe of the VTVM on an uncoated area, e.g. drilled holes, (see flag).
3. Using other probe, scan 10 percent of the coated surface area for dielectric coating breakdown. Reject assemblies which reflect a current flow.

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BY <u>L. H. Morgan</u>		PROC. ENGR. <u>R. E. Harris</u>	NFC	<u>R. E. Harris</u>
		QUAL. I. R. <u>(signature)</u>		
ISSUED <u>August 25, 1964</u>	INTENTION		NPS II - 054	
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NUCLEAR PROCESS SPECIFICATION

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SPECIFICATION FOR 3M-TYPE LEAD TELLURIDE

THERMOELECTRIC ELEMENTS

MARTIN SPECIFICATION NO. MN-10126

DATED: November 1965

Revision 1

Prepared by: W. M. Brittain
W. M. Brittain
Design Analysis Unit

Approved by: K. H. Dufrane
K. H. Dufrane
Supervisor
Design Analysis Unit

J. W. Mc Grew / ds
Materials Engineering

[Signature]
Reliability

Released by: Earl B. West
Contracts Technical
Requirements

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SPEC. NO. MN-10126 (Revision 1)

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DETAILS -001 & -003

*2. THESE ELEMENT DIMENSIONS ARE SHOWN ON THE DESIGN DRAWING REFERENCED IN 2.1.1

1. THE THERMOELECTRIC ELEMENTS SHALL BE MFG. TO THE MASTER SPECIFICATION: MN-10126

NOTES:

-003	'P' TYPE THERMOELECTRIC EL.
-001	"N" TYPE THERMOELECTRIC EL.
DETAIL NO.	DESCRIPTION

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MARTIN COMPANY

THE AEROSPACE DIVISION OF MARTIN MARIETTA CORPORATION
FRIENDSHIP INTERNATIONAL AIRPORT, MARYLAND

THERMOELECTRIC ELEMENT
DIMENSIONAL TOLERANCES

SCALE NONE	DATE 10/30/65	CODE IDENT. NO. 38597
DRAWN W. BRITAIN	NSK-242	
APPROVED —	SHEET 1 OF 1	

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SPEC. NO. MN-10126 (Revision 1)

1.

1.0 SCOPE

1.1 General - This specification establishes the requirements for the inspection, testing, preparation for delivery and product quality for "N" and "P" type thermoelectric elements for use in the applicable thermoelectric generators.

1.2 Type Elements - Thermoelectric elements applicable to this specification shall be limited to cold-pressed, sintered elements fabricated by the Minnesota Mining and Manufacturing Company (3M) with designations as follow:

"N" Type - 3M-TEGS-2N(M) and 3M-TEGS-3NB

"P" Type - 3M-TEGS-2P(M) and 3M-TEGS-3PB

(The 2N(M) and 2P(M) material shall be identical to that previously supplied under specification PN-7400000)

2.0 APPLICABLE DOCUMENTS

2.1 General - The following drawings, standards and specifications are part of this specification to the extent specified herein. No modifications or deviations from either this specification or the referenced drawing shall be allowed unless authorized by the Purchaser in writing.

2.1.1 Drawings - Thermoelectric element design drawings which reference this specification are applicable to the extent that such drawings shall specify basic element dimensions. Unless otherwise noted on the design drawing, tolerances shall be as shown on NSK-242 (attached).

2.1.2 Purchaser Standards

Standard 1 - Standard for Thermoelectric Element Corner Chipping

Standard 2 - Standard for Thermoelectric Element Surface Pitting

Standard 3 - Standard for Thermoelectric Element End Surface Grain Grooves

Standard 4 - Standard for Thermoelectric Element Surface Deposits

Standard 5 - Standard for Thermoelectric Element Internal Defects

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2.

2.1.3 Specifications

MIL-STD-105D Sampling Procedures and Tables for Inspection by Attributes

(Specifications to establish requirements for element materials and performance, to be established by 3M Company, will be included in this paragraph at a later date.)

3.0 REQUIREMENTS

3.1 General - All thermoelectric elements shall be manufactured, tested and inspected to assure the required quality level in accordance with the applicable 3M element product specifications denoted in 2.1.3, as well as this specification and the applicable element design drawing referenced in 2.1.1. Requirements herein apply to the completed product unless specifically noted.

3.1.1 3M Designation - The completed thermoelectric elements shall be cold-pressed and sintered type with 3M designations as follows:

"N" Type - 3M-TEGS-2N(M) and 3M-TEGS-3NB

"P" Type - 3M-TEGS-2P(M) and 3M-TEGS-3PB

3.2 Identification - Positive identification of each element must be maintained relative to its purchase order number, basic element batch, inspection, and electrical testing requirements. However, an element shall at no time be physically marked.

3.3 Completed Thermoelectric Elements

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3.3.1 Surface Finish

3.3.1.1 Chipping - Corner chipping on a thermoelectric element shall not be in excess of Standard 1 (a Purchaser approved physical standard). Standard 1 corresponds to a maximum allowable decrease in the element end surface area of 5%.

3.3.1.2 Pitting - Surface pitting on a thermoelectric element shall not be in excess of Standard 2 (a Purchaser approved physical standard). Maximum allowable pit depth is 0.015 inches.

3.3.1.3 Grain Grooves - Grain grooves on the element ends shall not be in excess of Standard 3 (a purchaser approved physical standard). Maximum allowable groove depth is 0.015 inches.

3.3.1.4 Surface Deposits - Localized surface deposits of lead and carbon shall not exceed that shown in Standard 4 (a Purchaser approved physical standard). These surface deposits do not exceed more than 25% of the surface area or have more than three localized deposits greater than 1/16 inch in the largest dimension; none exceed 1/8 inch in the largest dimension.

3.3.1.5 Cracking - There shall be no evidence of element surface cracking when examined with the unaided eye (without magnification).

3.3.2 Dimensions - Dimensions shall be in compliance with applicable design drawings referenced in 2.1.1.

3.3.3 Seebeck Voltage

3.3.3.1 900°F Hot Junction, 150°F Cold Junction: Pressure Contacts - The Seebeck voltage of the elements with 900°F hot junction and 150°F cold junction temperatures shall have an arithmetic average no lower than that indicated below. No individual element reading shall be less than indicated below.

<u>Type Element</u>	<u>Minimum Allowable Individual Value (millivolts)</u>	<u>Minimum Average Seebeck Voltage (millivolts)</u>
2N(M)	87.0	92.0
2P(M)	85.0	90.0
3NB	68.0	72.0
3PB	60.0	62.0

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3.3.4 Electrical Resistivity

3.3.4.1 Room Temperature, Pressure Contacts - Using pressure contacts for current electrodes, the room temperature resistivity of an element shall not exceed that indicated below.

<u>Type Element</u>	<u>Room Temperature Resistivity ($\mu\Omega\text{cm}$)</u>
2N(M)	660
2P(M)	610
3NB	350
3PB	1110

3.3.4.2 Elevated Temperature, Pressure Contacts - The elevated temperature resistivity of sample elements (taken from a batch) using pressure current electrodes shall not exceed that indicated below. This shall be considered a destructive test and elements so tested are not to be included in the total number of elements required in 6.2.

<u>Temperature °F</u>	<u>Resistivity ($\mu\Omega\text{cm}$)</u>			
	<u>2N(M) Type</u>	<u>2P(M) Type</u>	<u>3NB Type</u>	<u>3PB Type</u>
212	1065	837	560	1460
572	3575	3465	1760	2640
932	6095	7700	3970	4250

3.3.5 Internal Defects - Element porosity and internal cracking shall not be in excess of Standard 5 (a Purchaser approved photomacrographic standard).

3.3.6 Cleanliness - The finished thermoelectric elements shall be visibly free with the unaided eye (without magnification) of foreign material such as airborne dust, machine chips, and residues from tools or materials with which the elements come in contact. If necessary, element cleaning may be performed with a soft bristled brush, filtered, dry and oil-free pressurized air, or a dry, clean, lint-free cloth. In no case shall any other cleaning tools or agents be utilized without prior approval of the Purchaser in writing.

3.3.7 Storage - Storage of finished elements shall be in sealed, clean, polyethylene wrapping material.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General - Procedures to be used in quality sampling and electrical testing shall be submitted to Martin Nuclear Engineering for review and approval. The physical inspections and electrical tests required in 4.0 shall be performed in the following sequence:

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- a. Surface Finish (4.3)
- b. Dimensions (4.4)
- c. Seebeck Voltage (4.5)
- d. Electrical Resistivity (4.6)
- e. Internal Defects (4.7)
- f. Cleanliness (4.8)

In addition to the certification required in 4.2, all inspection and test results, including photomacrographs, shall be fully documented and supplied to the Purchaser with each delivery of elements.

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- 4.1.1 Inspection Tolerances - All equipment and personnel errors inherent in the use of mechanical, electromechanical, or electronic inspection and measurement devices shall be added in the most conservative manner to all measurements. All dimensional and room temperature resistance checks required herein shall apply at a correct temperature of 68°F.
- 4.1.2 Identification - Applicable component identification numbers required in 3.2 shall be referenced in all inspection and test records.
- 4.2 Element Certification - The thermoelectric elements shall be certified to have fulfilled the requirements of this specification, the referenced drawing in 2.1.1 and the Contractor's specification 2.1.3.
- 4.3 Surface Finish - All finished elements shall be visually examined and compared with referenced physical standards to demonstrate compliance with 3.3.1.
- 4.4 Dimensions - It shall be demonstrated that:
(1) each element passes freely lengthwise through a gauge hole having a minimum depth of one inch and a diameter 0.0005 inches greater than the maximum allowable element diameter as shown on the applicable design drawing in 2.1.1; (2) each element satisfies a go, no-go gauge test which assures that the element length does not exceed the maximum allowable and is not less than the minimum allowable length on the design drawing. The gauge cutouts demonstrating element length requirements shall not exceed the maximum or be less than the minimum allowable length by more than 0.001 inches. In addition, all dimensional requirements shall be evaluated on a sampling performed in accordance with MIL-STD-105D (see column B in Appendix), using a single sampling plan for normal inspection with an AQL of 1.0.
- 4.5 Seebeck Voltage - All elements shall be evaluated to demonstrate compliance with 3.3.3.1.
- 4.6 Electrical Resistivity - All elements shall be evaluated to demonstrate compliance with 3.3.4.1. To demonstrate compliance with 3.3.4.2, sampling shall be performed in accordance with column A in Appendix.
- 4.7 Internal Defects - A metallurgical examination at 7X magnification shall be performed on a sampling obtained in accordance with column C in Appendix. At least two copies of photomicrographs taken (at 7X) of the sampled elements shall be supplied to the Purchaser.
- 4.8 Cleanliness - All elements shall be inspected for compliance with 3.3.6 immediately prior to packaging for shipment.

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4.9 Consequence of Non-Compliance - The following actions shall be taken if any part of the material or completed product fails to meet the requirements of this and the referenced documents.

4.9.1 Dimensions - Any element failing to meet the dimensional requirements in 3.3.2 as determined by the gauge checks shall be rejected. If the elements in the sample taken from a batch fails to satisfy the dimensional AQL requirements, each element in the batch must be checked for the dimension(s) found to be out-of-tolerance on the defective sample element(s) and individually accepted or rejected on the basis of this measurement.

4.9.2 Electrical Properties

4.9.2.1 Seebeck Voltage - Any element failing to meet the minimum allowable individual Seebeck value in 3.3.3.1 shall be rejected. If an element batch fails to satisfy the minimum average value required in 3.3.3.1, elements with low Seebeck values may be rejected and the minimum average value satisfied. If this is not possible the batch shall be rejected.

4.9.2.2 Electrical Resistivity - Any element failing to satisfy the requirement in 3.3.4.1 shall be rejected. If any sample element in 3.3.4.2 fails to satisfy the requirement, the batch shall again be sampled at twice the initial sampling rate. If any element in the second sample taken fails to satisfy the requirement the batch shall be rejected.

4.9.3 Internal Defects - If any element examined in 4.7 does not satisfy the requirements, the batch shall again be randomly sampled at twice the initial sampling rate. If any element in the second sample taken fails to satisfy the requirements the batch shall be rejected.

4.9.4 Cleanliness - Any element failing to meet the requirements of 3.3.6 shall be rejected until recleaned to satisfy this requirement.

4.9.5 Other Non-Compliance - Any element failing to satisfy the other requirements herein, but not specifically mentioned above, shall be considered rejected.

5.0 PREPARATION FOR DELIVERY

5.1 Marking - Each shipping container shall be plainly marked with the purchase order number, manufacturer and product identification.

6.0 NOTES

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6.1 Definitions

6.1.1 Purchaser - The Purchaser referred to herein shall be the Martin-Marietta Corporation, Baltimore 3, Maryland.

6.1.2 Contractor - The Contractor shall be the Minnesota Mining and Manufacturing Company, St. Paul 19, Minnesota.

6.1.3 Element Batch - An element batch is defined as those elements which have successively received the same fabrication steps and originated from the same basic mill ingot or from a mixture of mill ingot basic material.

6.1.4 Element Designation (Ref. 3.1.1)

TEGS - thermoelectric generator, sintered element.

2N(M) and 2P(M) - 2N and 2P elements with untinned ends fabricated from selected material blends for Martin Nuclear to satisfy this specification.

3NB and 3PB - standard 3M elements with untinned ends.

NOTE: If element end tinning is desired use letter designation below after type element (2P(M), 3P, etc.):

A - one end tinned

C - both ends tinned.

6.2 Ordering Data Required - Number of each type of thermoelectric element required.

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8.

APPENDIX
ASSIGNMENT OF SAMPLE SIZE

<u>Batch Size</u>	<u>Column A</u>	<u>Sample Size</u>	
		<u>Column B¹</u>	<u>Column C</u>
3 to 8	2	100%	2
9 to 15	2	100%	2
16 to 25	3	13	2
26 to 50	4	13	2
51 to 90	5	13	3
91 to 150	6	13	3
151 to 280	8	50	5
281 to 500	10	50	8

¹ General Inspection Level II, Table I, page 9, MIL-STD-105D

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MARTIN
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SPECIFICATION

Code Ident. No. 38597

HARDENING OF 17-7PH AND PH15-7Mo STAINLESS STEELS TO TH1050
CONDITION (All Forms - Starting Condition A)

NOTE: EPS 10400, "Heat Treatment of Steels", forms a part of this specification and establishes applicable general requirements with reference to: 1. Scope, 2. Applicable Documents, 3. Requirements, 4. Quality Assurance, 5. Manufacturing Controls. This process establishes the additional requirements and manufacturing controls to harden 17-7PH and PH15-7Mo stainless steels to condition TH1050 (Rc 38 min. and Rc 40 min., respectively).

5. MANUFACTURING CONTROL:5.1 Fabrication Control:5.1.1 Process Sequence:5.1.1.1 Assemblies Other Than Fusion Welded or Brazed:

- A. Vapor degrease and alkaline clean immediately before heat treatment. (1)
- B. Heat to $1400 \pm 25^{\circ}\text{F}$ and hold at this temperature for 90 minutes.
- C. Cool in air, dry hydrogen, or inert atmosphere to room temperature (50°F min.). Cooling time from 1400°F down to 300°F is not critical, but cooling from 300°F to room temperature (and subsequent cooling to $50^{\circ} - 60^{\circ}\text{F}$ in D) must be completed within one hour.
- D. Cool further to $60^{\circ} + 0^{\circ}\text{F} - 10^{\circ}\text{F}$ (i. e. 50°F to 60°F).
- E. Heat to $1050 \pm 10^{\circ}\text{F}$ and hold at this temperature for 90 minutes.
- F. Cool to room temperature. If strength after E is too high, E may be repeated using $1050 \pm 10^{\circ}\text{F}$ for a maximum of 10 hours.

5.1.1.1.1 An inert protective atmosphere may be used. A reducing atmosphere other than dry hydrogen is not permitted. The dew point of the hydrogen shall be minus 42°F or lower.

5.1.1.2 Heat Treatment of Brazed Assemblies to Condition TH1050: Solution annealed material, when brazed into assemblies, must be rapidly cooled from the brazing temperature if brought to room temperature prior to heat treatment to the TH condition. If only slow cooling is attainable or permissible, such brazed parts must be directly heat treated to

NOTE (1): Turco Pre-Treat (or equivalent) may be applied at this time to protect the surfaces.

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**HARDENING OF 17-7PH AND PH15-7 Mo STAINLESS STEELS TO TH1050
CONDITION (All Forms - Starting Condition A)**

5.1.1.2 (Continued)

the TH condition without intermediate cooling below 1400°F. This is accomplished by cooling directly from the brazing temperature to Step B temperature of 1400°F. It is important that the Step B 90 minute period shall be increased to 3 hours and that it shall be timed only after the part has reached the 1400°F temperature. Steps C through F shall then be followed.

**5.1.2 Mechanical Properties Developed Through This Process: Shall be as required on
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Code Ident. No. 38597

HARDENING OF FUSION WELDED ASSEMBLIES OF 17-7PH AND PH15-7 Mo TO TH1050
CONDITION (All Forms - Starting Condition A in Parent Material Prior to Welding)

NOTE:

EPS 10400, "Heat Treatment of Steels", forms a part of this specification and establishes applicable general requirements with reference to: 1. Scope, 2. Applicable Documents, 3. Requirements, 4. Quality Assurance, 5. Manufacturing Controls. This process establishes the additional requirements and manufacturing controls to harden welded assemblies of 17-7PH or PH15-7 Mo stainless steels to the TH1050 condition, starting from the annealed condition. (Rc 38 min. and Rc 40 min. respectively).

5. MANUFACTURING CONTROL:

5.1 Fabrication Control:

5.1.1 Process Sequence:

- A. Vapor degrease and alkaline clean immediately before heat treatment.
- B. Heat to $1400 \pm 25^{\circ}\text{F}$ and hold at this temperature for 90 minutes.
- C. Cool in air or inert atmosphere to room temperature (50°F min.). Cooling time from 1400°F down to 300°F is not critical, but cooling from 300°F to room temperature (and subsequent cool to $50^{\circ} - 60^{\circ}\text{F}$ in Step D) must be completed within one hour.
- D. Immediately cool further to $60 \begin{smallmatrix} + 0^{\circ}\text{F} \\ - 10^{\circ}\text{F} \end{smallmatrix}$ (i.e. $50^{\circ} - 60^{\circ}\text{F}$).
- E. Heat to $1075 \pm 10^{\circ}\text{F}$ and hold at this temperature for 90 minutes.
- F. Cool to room temperature. If strength after Step E is too high, Step E may be repeated, extending the time to 10 hours maximum.

5.1.1.1 An inert protective atmosphere may be used. A reducing atmosphere other than dry hydrogen (minus 40°F or lower dew point) is not permitted.

5.1.2 Mechanical Properties Developed Through This Process: Shall be as specified on Engineering Drawing.

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SAFETYING DEVICES, INSTALLATION OF

1. SCOPE

1.1 APPLICATION: This specification establishes the requirements to be met by the Martin Company and subcontractors for the installation of safetying devices. Other processes may be used by subcontractors, providing these processes have prior approval by Martin Company. Quality and the requirements of this specification are met.

1.2 ENGINEERING INFORMATION: The Engineering Drawing shall specify this Engineering Process Specification, and, as applicable, provisions for:

- a. The safety-wire material.
- b. The safety-wire termination point, if such termination point is not provided.
- c. The lock clips to be used to safety turnbuckle assemblies.
- d. The cotter pins to be used in castellated nut-on-bolt, and clevis pin assemblies.
- e. Tie points to secure fastenings or fittings which are more than 6 inches apart.
- f. Torque values, if required.

1.3 EQUIVALENT GOVERNMENT SPECIFICATIONS: There is no equivalent government specification; however, items safetyed in accordance with this specification will meet the applicable requirements of MS 33540C and NAS 1074 Rev. 2.

2. APPLICABLE DOCUMENTS: The following specifications, standards, and publications form a part of this specification to the extent specified herein.

2.1 GOVERNMENT SPECIFICATIONS AND STANDARDS

- 2.1.1 MS 33540C, Safety Wiring, General Practices, For
- 2.1.2 MS 21332, Fastener Snapslide

2.2 INDUSTRY SPECIFICATIONS AND STANDARDS

- 2.2.1 NAS 1074 Rev. 2, Turnbuckle Assemblies, Clip Locking, Assembly and Safetying Of.

3. REQUIREMENTS

3.1 MATERIALS

3.1.1 Safety-wire used in conjunction with this specification shall be as specified on the Engineering Drawing.

3.2 EQUIPMENT: There is no applicable equipment to this specification.

3.3 PRODUCT

3.3.1 SAFETY-WIRING

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3.3.1.1 The size of the safety-wire shall be 0.032 inch minimum diameter with the following exceptions:

- a. 0.020 inch diameter wire may be used on parts having a nominal hole diameter of less than 0.045 inch or on parts having a nominal hole diameter between 0.045 inch and 0.062 inch with a spacing between parts of less than 2 inches.
- b. When using the single wire method of safety-wiring, the diameter of the safety-wire shall be the largest diameter that can be inserted through the applicable installation hole without forcing.

3.3.1.2 The safety-wire shall be free from defects, such as abrasions, cuts, nicks, or kinks which could cause vibrational failures.

3.3.1.3 Safety-wiring shall be tight but not overstressed.

3.3.1.4 Safety-wiring shall be applied to the assembly after the parts have been securely tightened.

Note: (1) Torqueing, if required, shall be as specified by the Engineering Drawing.

(2) The coupling ring, on the coupling ring-receptacle assembly, should only be tightened by hand before safety-wiring.

3.3.1.5 In safety-wiring, the double-twist method shall be used as the common method. See Figures 1, 2, 4-6 and 9-14. The single wire method of safety-wiring may be used in a closely spaced, closed geometrical pattern (triangle, square, rectangle, circle, etc.), on parts in electrical systems, and in places that would make the single-wire method more advisable. See Figures 3 and 7.

3.3.1.6 When safety-wiring widely spaced multiple groups by the double-twist method, three units, spaced 4 to 6 inches apart, shall be the maximum number permitted in a series.

3.3.1.7 When safety-wiring closely spaced multiple groups by the double-twist method, the number of units that can be safety-wired by a 24 inch length of wire shall be the maximum number in a series.

3.3.1.8 Safety-wiring shall not be used to secure fastenings or fittings which are spaced more than 6 inches apart unless tie points are provided on adjacent parts to shorten the span of safety-wire to less than 6 inches.

3.3.1.9 Safety-wire, installed by the double-twist method, shall be twisted at approximately 8 turns per inch.

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3.3.1.10 A "pigtail" of 1/4 to 1/2 inch in length (3 to 6 twists), to lock the safety after it has passed its termination point, shall be made at the end of the wiring. This "pigtail" shall be bent back or under the safety-wiring to prevent it from becoming a snag, a hazard to personnel, or untwisted.

3.3.1.11 Parts shall be safety-wired in such a manner that the safety-wiring will be put in tension when the part tends to loosen.

3.3.1.12 When the double-twist method is utilized, the twist shall be in the direction which tends to hold down the loop around the screw or bolt head; i. e., the wire will tighten as the loop is raised.

3.3.1.13 Safety-wire shall be new upon each application.

3.3.2 COTTER PINNING

3.3.2.1 Cotter pin installations shall be free from destructive cuts and abrasions.

3.3.2.2 The cotter pin shall be snugly positioned, but must not be deformed. See Figures 15, 16 and 17.

3.3.2.3 Cotter pins shall be new upon each application.

3.3.3 CLIP-LOCKING TURNBUCKLE ASSEMBLIES

3.3.3.1 After lock clips are completely installed, not more than 3 turnbuckle terminal threads of either of the two terminals shall be exposed outside the turnbuckle barrel. See Figure 18.

3.3.3.2 Lock clips shall not be reused.

3.3.4 SAFETYING HINGE PIN INSTALLATIONS ON CONTINUOUS TYPE HINGES

3.3.4.1 Continuous type hinge pins shall be safetyed in accordance with Figure 19 unless otherwise specified on the Engineering Drawing.

3.3.4.2 The hinge pin shall be 1/8 to 3/16 inch shorter than the hinge length.

3.3.4.3 The hinge pin shall be safetyed by slightly crimping the end of the hinge loop until it is approximately 1/2 closed.

CAUTION: Do not crimp the ends of the hinge to the extent that it will interfere with the normal hinge function.

3.4 FABRICATION CONTROL

3.4.1 SAFETY-WIRE APPLICATIONS

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3.4.1.1 Safety-wiring individual electrical connector coupling rings shall be accomplished as shown in Figure 1. For connectors not illustrated, safety-wiring shall be accomplished by the method shown for the most similar connector.

Figure 1. - Typical Methods of Safety-Wiring Individual Electrical Connector Coupling Rings.

3.4.1.2 Safety-wiring electrical connector coupling rings in pairs shall be accomplished as shown in Figure 2.

Figure 2 - Safety-Wiring Electrical Connector Coupling Rings in Pairs.

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3.4.1.3 Safety-wiring electrical connector back-shells shall be accomplished using single wiring as shown in Figure 3. For connector back-shells not illustrated, safety-wiring shall be accomplished by the method shown for the most similar type of back-shell.

Figure 3. - Typical Methods of Safety-Wiring Electrical Connector Back-Shells.

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3.4.1.4 When a single bolt or screw must be safety-wired, it shall be accomplished as shown in Figure 4.

3.4.1.5 Typical series safety wiring connections of screws or bolts are shown in Figures 5, 6 and 7.

Figure 4. - Double-Twist Method for Single Unit

Figure 5. - Double-Twist Method for Two Bolts in Series.

Figure 6. - Double-Twist Method For Three Bolts in Series.

Figure 7. - Typical Single Safety Wiring of Bolts in Series.

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3.4.1.6 Figures 8 through 11 show acceptable methods of safety-wiring miscellaneous parts not covered by previous sections.

3.4.1.7 Figure 12 shows an example where safety-wiring is used, in conjunction with an anti-tampering seal (attached by Manufacturing and sealed by Quality), for the prevention of unauthorized adjustments to settings of hydraulic units, etc.

Figure 8. - Drain Cocks

Figure 9. - Valves

Figure 10. - Tank Caps

Figure 11. - Cable Guard

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Figure 12. - Example of Safety-Wiring Methods Used in Conjunction with an Anti-Tampering Seal.

3.4.1.8 When castellated nuts are to be secured to a fastener with safety-wire, the nuts shall be tightened to the low side of the torque value required for the specific castellated nut-bolt assembly, unless otherwise specified on the Engineering Drawing. See Figure 13.

Note: If necessary, it is permissible to continue tightening the nut until a slot aligns with the hole in the bolt.

Figure 13. - Wiring of Group of Castellated Nuts

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3.4.1.9 Safety-wiring, when the double twist method is used, shall always be installed and twisted in the direction which tends to hold the loop around the screw or bolt head and will tighten if the loop is raised. See Figure 14.

Bend "pigtail" to
protect personnel

Figure 14. - Typical Method of Bending Pigtail.

3.4.1.10 Snapslide MS 21332 and those snapslides supplied on Customer Furnished Equipment (C.F.E.), Government Furnished Equipment (G.F.E.), or Outside Vendor Equipment (O.V.E.) shall be safety-wired by the single wire method with a loop run through the latch and through the attaching provision. A "pigtail" is then formed, locking the safety.

3.4.2 COTTER PIN APPLICATIONS

3.4.2.1 Cotter pins shall be installed as shown in Figures 15, 16 and 17.

Figure 15. - Castellated Nut on Bolt
Preferred Method

Figure 16. - Castellated Nut on Bolt
Alternate Method

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Figure 17. - Pin Application.

3.4.2.2 When castellated nuts are to be secured to a fastener with cotter pins, the nuts shall be tightened as previously stated in Paragraph 3.4.1.8 prior to the installation of the cotter pins.

3.4.2.3 If more than 50 percent of the cotter pin diameter is above the nut castellation, when one (1) washer is used under the nut, one (1) additional washer, of the type specified by the Engineering Drawing, may be used.

3.4.3 CLIP-LOCKING TURNBUCKLE ASSEMBLY APPLICATIONS

3.4.3.1 Before securing the turnbuckle with the safety lock clip, both threaded terminals shall be screwed into the turnbuckle barrel an equal number of turns. The cable assembly shall be so rigged that the required tension is obtained after 3 or less turnbuckle terminal threads are exposed. After the terminals are screwed into the barrel, no more than 3 terminal threads of either terminal shall be exposed outside the barrel.

3.4.3.2 Clip-locking shall be accomplished in accordance with steps 1, 2, 3 and 4 of Figure 18. These steps shall then be repeated on the opposite end of the turnbuckle barrel.

Note: Both locking clips may be inserted in the same turnbuckle barrel hole, or they may be inserted in the opposite holes.

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Figure 18. - Clip-Locking Turnbuckle Assembly Procedure.

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3.4.4 SAFETYING HINGE PIN INSTALLATIONS ON CONTINUOUS TYPE HINGE APPLICATIONS

3.4.4.1 Hinge pin installations on continuous type hinges shall be safetyed as shown in Figure 19.

Figure 19. - Safetying Hinge Pins on Continuous Type Hinges.

4. QUALITY ASSURANCE

4.1 Quality shall ensure conformance to this Process Specification.

5. MANUFACTURING CONTROL: This section is not applicable to this specification.

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Martin Company

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TORQUE VALUES FOR BOLT - NUT ASSEMBLIES

1. SCOPE:

1.1 APPLICATION: This process specification establishes the requirements to be met by the Martin Company and subcontractors to control and standardize the degree of torque to be applied to any bolt-nut assembly in structural applications including bolts or studs in tapped holes.

1.1.1 LIMITATIONS: This process does not apply to the tightening of nuts on welded studs. Torque values found in the detail processes refer to the first tightening only, any subsequent tightening of the nut must be approved by Stress and Materials Engineering.

1.1.2 The torque values shown in the subsequent processes are for unlubricated applications.

1.2 ENGINEERING INFORMATION: Whenever tightening of threaded fasteners is involved, the Engineering Drawing shall specify the particular detail process in this series which applies to the fastener called out on the drawing and, in cases of multiple fastener installation, the sequence of tightening to preclude distortion of the assembly. The torque for each size of the particular fastener-nut combination will be found in the same process. Bolt-nut combinations not included in the sub-processes shall be referred to Materials Engineering for disposition.

1.3 EQUIVALENT GOVERNMENT SPECIFICATIONS: There is no equivalent government specification.

2. APPLICABLE DOCUMENTS:

2.1 GOVERNMENT SPECIFICATIONS AND STANDARDS:

2.1.1 Those government standards which apply will be found in the detail processes.

2.2 INDUSTRY SPECIFICATIONS AND STANDARDS:

2.2.1 Those industry specifications and standards which apply will be found in the detail processes.

2.3 MARTIN COMPANY SPECIFICATIONS AND STANDARDS:

2.3.1 Those Martin Company standards which apply will be found in the detail processes.

2.3.2 MARTIN COMPANY SPECIFICATIONS:

2.3.2.1 EPS 35032 - Use of Extensions on Drive End of Torque Wrenches

2.3.2.2 EPS 35037 - Installation of Bolts, Screws and Nuts

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BALTIMORE 3-29-65 N. Miller
ORLANDO 3-9-65 B. Peterson
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3. REQUIREMENTS:

3.1 MATERIAL:

- 3.1.1 Sealant - Tamper Proof
Spec.: MMS M129A
Code: M129A
- 3.1.2 Tamper Proof Compound (Propellant Compatible)
Spec.: Valdura Division X31303
Code: M158A
- Note: Hazardous material. See Para. 3.6.

3.2 EQUIPMENT: Torqueing equipment, such as wrenches, adapters, sockets and extensions when required, shall be provided.

3.2.1 All torque wrenches shall be calibrated to the satisfaction of Quality before being used to torque any installation.

3.3 PRODUCT:

3.3.1 Fasteners shall be installed in accordance with EPS 35037 and tightened to meet the requirements of the applicable detail process as specified on the Engineering drawing.

3.3.2 Each fastener shall be striped, by Quality, after tightening to indicate that torqueing has been accomplished.

3.3.3 When required by Engineering drawing, each fastener, or those so designated, shall be sealed with the compound specified on the drawing.

3.4 FABRICATION CONTROL:

3.4.1 Bolt and nut assemblies are to be tightened to the torque values specified on Engineering Drawing. If the drawing does not specify a torque value, then the values listed in the subsequent processes are to be used. When a single value appears on the Engineering drawing, the drawing must specify whether the nut or the bolt is to be rotated to attain the specified value. Nut-Bolt assemblies shall be torqued to within $\pm 10\%$ of the specified values, shown either on the Engineering drawing or in the subsequent processes.

3.4.2 In the subsequent processes when two values are given for tightening, a high value and a low one, or if the same are given on drawings, the high value is to be used if the bolt head is turned to tighten the assembly, and the low value is to be used if the nut is rotated. The tension produced in the bolt by torqueing is quoted in the particular process or on the drawing, whichever applies.

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3.4.3 EXTENSIONS:

3.4.3.1 The use of extensions shall be avoided. If socket extensions must be used, care shall be exercised to prevent the application of side loads on the fastener being torqued.

3.4.3.2 If extensions must be used on the drive-end of a torque wrench, the proper correction for linear deviation must be made in reading the torque (See EPS 35032).

3.4.4 No lubricants shall be applied to nuts or bolts before or during tightening. Bolts and nuts shall be used in the "as-received" condition.

3.4.5 Castellated nuts shall be tightened to the required torque. If the cotter pin hole in the bolt does not align with the slot in the nut under these conditions, the assembly may be overtightened enough to bring about this alignment but not to exceed the limits of 3.4.1.

3.4.6 When torquing has been completed, Quality shall verify the correctness of the torque by stripping, before any locking devices or anti-tampering compounds are applied. Anti-tampering compounds shall not be applied to the threads of the bolt.

3.5 SPECIAL SKILLS:

3.5.1 No special skills are required to perform torquing according to this specification.

3.6 **SAFETY:** Materials called out in this specification are hazardous. Refer to Divisional Safety Procedures for precautions and handling instructions.

4. QUALITY ASSURANCE:

4.1 Quality shall assure conformance to this Process Specification.

4.2 Threaded fasteners shall be torqued to the value noted on the drawing or sub-processes and shall be so verified by Quality.

4.3 All wrenches used for torquing shall be periodically calibrated. Uncalibrated tools shall not be used at any time.

5. **MANUFACTURING CONTROL:** See detailed processes.

6. NOTES:

6.1 Bolts - Screws, Studs and Bolts are referred to as bolts in this specification.

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Martin Company

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BRAZING OF ALUMINUM AND ALUMINUM ALLOYS

1. SCOPE:

1.1 APPLICATION: This specification establishes the requirements to be met by the Martin Company and subcontractors in brazing aluminum and aluminum alloys by the torch, furnace or molten flux (dip) methods. This process shall not be specified or used for primary structural or critical applications. Other processes may be used by subcontractors, providing these processes have prior approval by Martin Company. Quality and the requirements of this specification are met.

1.2 ENGINEERING INFORMATION: Use of this process specification is restricted to the alloys listed in Table I. Parts shall be designed with adequate openings to allow escape of flux and gases generated during the brazing operation. Anodizing or "Hard Coating" shall not be specified as finishes for assemblies brazed to this specification. Areas where excess braze material would be unacceptable shall also be identified on the drawing (See 3.3.6).

1.3 EQUIVALENT GOVERNMENT SPECIFICATIONS: There is no equivalent Government Process Specification.

2. APPLICABLE DOCUMENTS: The following documents of the issue shown form a part of this specification to the extent specified herein:

2.1 GOVERNMENT SPECIFICATIONS AND STANDARDS:

MIL-I-6886A Inspection, Penetrant, Method of

MIL-STD-453 Inspection, Radiographic

2.2 MARTIN COMPANY SPECIFICATIONS AND STANDARDS:

EPS 50029 Deoxidation of Aluminum Alloys

EPS 50036 Non-Etch Alkaline Cleaning

3. REQUIREMENTS:

3.1 MATERIALS:

DENVER	12-1-64	BALTI	RE	1-26-65	ORLANDO	12-23-64
K. Mills	A	N. B.	Miller	C	B. R. Peterson	C

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3.1.1 Flux, Aluminum Brazing

Spec.: Commercial

Type	Code
(1) #30	Y414A
(1) #33	Y414B
(1) #34	Y414C
(1) #53	Y414D
(2) #44	Y414E

(1) Source: Aluminum Co. of America

(2) Source: Air Reduction Sales Co.

3.1.2 Brazing Alloys (Wire, Rod or Sheet)

Spec.: QQ-B-655

FS Class	Code
BAl Si-3 (716)	Y419A
BAl-Si-4 (718)	Y419B

3.1.3 Brazing Alloy Alumibraze, 718 Powder

Spec.: Commercial

Code: Y416A

Source: Handy & Harman

**3.1.4 Brazing Alloys, Aluminum; and Aluminum Alloys Sheets and Plates,
Aluminum Brazing Alloy Clad**

Spec.: MIL-B-20148

Class	Temper	Code
1	-F	Y418A
2	-F	Y418B
3	-F	Y418C
4	-F	Y418D

* **3.1.5 Lithium Chloride (Crystalline Powder-Reagent Code 1874)**

Spec.: Commercial

Code: K355A

Source: Baker and Adamson (Allied Chemical Corp)

* **3.1.6 Flux, Brazing, Aluminum Fluoride**

Spec.: Commercial

Code: Y417A

Source: Aluminum Co. of America

* **3.1.7 Sodium Fluoride (Technical Grade)**

Spec.: Commercial

Code: K354A

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- 3.1.8 Acid, Nitric (Technical Grade)
Spec.: O-N-350
Code: K822A
- 3.1.9 Acid, Hydrofluoric (Technical Grade)
Spec.: O-H-795
Code: K829A
- 3.1.10 Acid, Sulphuric (Technical Grade)
Spec.: O-S-809
Code: K844A
- 3.1.12 Rods, Welding, Aluminum Alloy
Spec.: QQ-R-566, Class 1100
Code: Y469A

- Hazardous material - 3.5

3.2 EQUIPMENT

3.2.1 TORCH METHOD: Torches, tips, regulators and accessory equipment shall be appropriate for the material thickness being brazed.

3.2.2 FURNACE METHOD: Furnace shall be a circulating air type capable of maintaining $\pm 10^{\circ}\text{F}$ in the range of 900 - 1200 $^{\circ}\text{F}$.

3.2.3 MOLTEN FLUX (DIP) METHOD

3.2.3.1 Salt bath furnace shall be a ceramic type capable of maintaining $\pm 5^{\circ}\text{F}$ in the range of 1050 $^{\circ}$ - 1200 $^{\circ}\text{F}$.

3.2.3.2 Preheat furnace shall be capable of maintaining $\pm 10^{\circ}\text{F}$ in the range of 900-1000 $^{\circ}\text{F}$.

3.2.4 CLEANING

3.2.4.1 A suitable tank for holding a nitric-hydrofluoric acid solution shall be provided.

3.2.4.2 A suitable tank for holding a 10% sulphuric acid solution shall be provided.

3.2.4.4 Hot and cold water rinse tanks shall be provided.

3.3 PRODUCT

3.3.1 Brazed joints shall show complete lines, of brazing alloy between component parts on both sides of the joint. Lack of penetration through the joint shall be cause for rejection.

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3.3.2 Pinholes, voids or filler metal skips extending into the faying surfaces of the joint shall be cause for rejection or rework of an assembly. The aggregate area of surface defects shall not exceed 10% of the surface of the respective braze fillet.

3.3.3 Cracks in braze material or adjacent base metal shall be cause for rejection.

3.3.4 BLISTERS: Overheating in the base metal resulting in blisters on the surface of the base metal shall be cause for rejection.

3.3.5 RESIDUAL FLUX: No residual flux shall be permitted on the surface of a brazed joint.

3.3.6 EXCESS BRAZE METAL: Braze filler metal in excess of that required for the joint is acceptable provided the excess filler metal does not interfere with the function of the completed assembly.

3.3.7 UNMELTED BRAZING ALLOY: The presence of unmelted brazing alloy in a joint is unacceptable, and shall be cause for rejection.

3.3.8 UNDERCUTTING: Melting or erosion of the base metal surface, adjacent to the brazed joint shall be limited to a maximum of 5 percent of base metal thickness, and 15 percent cumulative, of the braze length.

3.3.9 Fillets presenting a surface after cleaning similar to a cast surface shall be considered as satisfactory.

3.3.10 The total aggregate area of defects (unbrazed areas) including trapped flux) between the faying surfaces shall not exceed 20% of the area of the respective joint.

3.4 FABRICATION CONTROL:

3.4.1 GENERAL:

3.4.1.1 Dip brazing of assemblies after a fusion welding operation is prohibited. This restriction does not apply to tack welds made with 1100 aluminum welding rod for the purpose of positioning details. It is permissible to fusion weld assemblies subsequent to dip brazing operations. Resistance spot welds may be used for tacking details only when approved by Materials Engineering.

3.4.1.2 Furnace brazing of 5052 aluminum alloy is not recommended.

3.4.1.3 The clearance between mating parts being brazed shall not exceed 0.025". Recommended clearances are 0.006" - 0.010" for joints less than 1/4" length, and 0.010" - 0.025" for greater lengths.

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3.4.2 BRAZING TEMPERATURES:

3.4.2.1 Recommended brazing temperatures are listed in Table I for the various brazeable alloys. Where combinations of different base alloys exist in assembly, the lower of the brazing temperatures listed for the alloys involved should be used. When the brazing temperature approaches or equals the melting point of any base alloy in the assembly extreme care shall be exercised, or distortion or partial melting of assembly components may occur (Reference Table I).

3.4.3 BRAZING ALLOYS:

3.4.3.1 Brazing alloys and brazing sheet shall be in accordance with 3.1 requirements. Brazing alloy/base metal combinations shall be as listed in Table I.

3.4.4 FLUXING:

3.4.4.1 Fluxes shall be as listed in Table II for the various alloys.

3.4.5 CLEANING PRIOR TO BRAZING:

3.4.5.1 All details and brazing material shall be cleaned in the following manner:

- a. Alkaline clean in accordance with EPS 50036.
- b. Deoxidize in accordance with EPS 50029.

3.4.6 SOLUTIONS AND SOLUTION CONTROL:

3.4.6.1 Solution controls shall be as specified in Section 5.

3.4.7 BRAZING:

3.4.7.1 Torch method: Flux shall be applied to the brazing filler alloy and to joint areas of the details being joined. The assembly shall be heated locally in the joint area, using a reducing flame, taking care not to overheat the parent metal. Sufficient brazing alloy shall be introduced to the joint. When desirable, flow of brazing alloy may be restricted by employing a paste composed of sodium fluoride and water.

3.4.7.2 Furnace method: Flux shall be applied to joint areas of the details being joined. Sufficient brazing alloy shall be pre-placed in the joints. Preheating to 400°F is recommended to remove the water in the flux paste. Time necessary to obtain acceptable joints should be established through use of a pilot assembly. Solution treatment may be combined with the brazing cycle when heat treatment subsequent to brazing is a requirement, however, assemblies subject to distortion during quenching should be allowed to cool slowly from the brazing temperature, then solution heat treated. Flow of brazing alloy may be restricted as noted in paragraph 3.4.7.1.

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3.4.7.3 Dip Method: Sufficient brazing alloy shall be prepositioned in the joints. Assemblies shall be preheated to $1000 \pm 10^{\circ}\text{F}$, then transferred to the dip bath furnace and slowly immersed in the flux. Temperature of the flux bath shall be maintained within $\pm 5^{\circ}\text{F}$ of the recommended temperature. Time in the flux bath should be determined by a pilot assembly. Solution treatment may be combined with the brazing cycle when heat treatment subsequent to brazing is a requirement, however, assemblies subject to distortion during quenching should be allowed to cool slowly from the brazing temperature.

3.4.8 CLEANING AFTER BRAZING: Cleaning shall be accomplished as soon as practical after brazing, but in any event no longer than 4 hours. Assemblies which cannot be thoroughly rinsed of entrapped acid solutions shall not be dipped but shall be cleaned by local brush application of cleaning solutions. Cleaning shall be carried out as follows:

3.4.8.1 Soak in hot water to remove excess flux. Remove and drain.

3.4.8.2 Neutralize flux by soaking in 10% (by weight) sulphuric acid solution at $80 \pm 20^{\circ}\text{F}$. Remove and drain when all traces of flux have been removed. If doubts exists as to removal or neutralization of flux residues, assemblies shall be checked as follows:

- a. Clean brazed areas with distilled water.
- b. Place a few drops of 5% silver nitrate solution on the cleaned areas. Formulation of a white precipitate indicates the presence of flux residues. Assemblies showing the presence of flux residues shall be subjected to further neutralization until absence of the white precipitate indicates complete flux removal.
- c. Rinse in cold running water until all acid is removed.

3.4.8.3 Soak in 10-15% nitric plus 0.25-1.0% hydrofluoric acid (by weight) solution at $80^{\circ} \pm 20^{\circ}\text{F}$ for from three to five minutes. Remove and drain. Rinse in cold running water for five minutes minimum. Rinse in hot water; remove and dry by heat if necessary.

3.4.8.3 Barrel burnishing may be used when a uniform surface is required on small parts.

3.5 SAFETY:

3.5.1 Materials called out in this specification are hazardous. Refer to Divisional Safety Procedures for precautions and handling instructions.

3.5.2 Goggles, apron, gloves and respirator must be worn during cleaning operations. The ventilating hood must be operating whenever the tank is being used. (Ref. 3.4.8).

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4. QUALITY ASSURANCE:

4.1 Quality shall ensure conformance to this Process Specification.

4.2 Temperature controls on furnaces and dip bath furnace shall be checked to assure capability of maintaining the temperature ranges specified in 3. 2.

4.3 Flux composition of the dip bath furnace shall be checked to assure fluoride and chloride content and melting point of flux are in accordance with 5. 1. 2.

4.4 Cleaning solutions shall be checked to assure that solutions are in accordance with 5. 1. 1.

4.5 Radiographic inspection, when required, shall be carried out in accordance with MIL-STD-453.

4.6 Penetrant inspection shall be in accordance with MIL-I-6866A.

5. MANUFACTURING CONTROLS:

5.1 SOLUTION CONTROL:

5.1.1 The sulfuric acid content of cleaning solution, paragraph 3. 4. 8. 2, shall be maintained within the range of 8 to 12% (total weight). The acid content of the solution in paragraph 3. 4. 8. 3 shall be maintained within the range of 10 to 15% nitric acid and 0. 25 - 1. 0% hydrofluoric acid (total weight).

5.1.2 Control of #34 flux dip bath: The fluoride content of the bath shall be maintained within the range of 3. 4% to 4. 8%. The chloride content of the bath shall be maintained within the range of 52. 8 - 54. 8%.

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TABLE I - Brazing Temperatures and Base Metal/Brazing Alloy Combinations.

Base Alloy Being Brazed	Approximate Melting Range of Base Alloy Being Brazed (°F)	Optimum Brazing Range (°F)	Brazing Alloy	Approximate Melting Range of Brazing Alloy (°F)
EC	1195-1215	1085-1135	718	1070-1080
1100	1190-1215	1085-1135	718	
3003	1190-1210	1085-1135	718	
5052	1100-1200	1080-1100	718	
6061-6062	1100-1205	1080-1100	718	
6063	1140-1205	1080-1120	718	
A612 (cast)*	1105-1195	1080-1100	718	
C612 (cast)*	1120-1190	1080-1100	718	
43 (cast)*	1065-1170	1060-1070	716	970-1085
ML-B-20148				
Class 1	1190-1210 (Core)	1100-1140	713 (cladding)	1070-1135
Class 2	1190-1210 (Core)	1100-1140	713 (cladding)	
Class 3	1140-1210 (Core)	1080-1135	713 (cladding)	
Class 4	1140-1210 (Core)	1080-1135	713 (cladding)	

* Sand or Permanent Mold Castings Only.

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TABLE II - Flux Applications

Flux Designation	Approximate Melting Range (°F)	Brazing Method		
		Torch	Furnace	Dip
Alcoa #30	1013-1135	x	x(1)	x
Alcoa #33	914-1112		x(2)	
Alcoa #34	900-1033		x(3)	
Alcoa #53	952-1092		x(3)	
Airco #44	900-1095	x		

- (1) For use at higher brazing temperatures and in the brazing of relatively thick materials. Highly active. Produces good flow of filler alloy.
- (2) For use at lower brazing temperatures.
- (3) For use with thin sheet .020" and under. Less active than #30 or #33.

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Martin Company

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WELDING, RESISTANCE: ALUMINUM AND MAGNESIUM ALLOYS, SPOT
AND SEAM (STRUCTURAL)

1. SCOPE:

1.1 Application: This process specification establishes the requirements for materials, equipment and controls to be used by the Martin Company and subcontractors for the resistance spot, intermittent spot and seam welding of aluminum and magnesium alloys. Other processes may be used by subcontractors, providing these processes have prior Martin Company approval and requirements herein are met.

1.2 Permissible Materials Combinations:

1.2.1 Aluminum and Aluminum Alloys - May be welded in any combination, except that the following conditions shall not be welded without prior Materials Engineering and/or Procuring Activity approval.

a. Bare to bare 2014, 2024 or 7075 alloys.

b. Clad 2014 to bare 2024, clad 2014 to bare 7075.

c. Clad 2014 to bare 2014.

d. Bare to bare in any combination shall not be welded when parts are to be exposed to severe corrosive conditions.

e. Clad 7075 in thickness less than 0.020 inches.

1.2.2 Magnesium Alloys - May be welded in any combination except that applications that will be exposed to sea water shall have prior Materials Engineering and/or Procuring Activity approval.

1.3 Joint Thickness:

1.3.1 The total thickness of a welded joint shall not exceed four times the thickness of the thinner outer layer of material unless specifically approved by Materials Engineering and/or the Procuring Activity.

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WELDING, RESISTANCE: ALUMINUM AND MAGNESIUM ALLOYS, SPOT AND SEAM (STRUCTURAL)

1.4 Classification:

1.4.1 The weld symbols and class of welding (1.4.2) shall be designated on the Engineering Drawing in accordance with divisional procedures.

1.4.2 Welds shall be classified as follows based on function of the welded joint:

Class A - Use in joints, the single failure of which during any operating condition would cause loss of a weapons system or one of its major components, loss of control, unintentional release of, or inability to release any armament store, or which may cause significant injury to occupants of a manned system or to attending personnel.

Class B - Use in joints, the failure of which would reduce the overall strength of a weapons system or preclude the intended functioning or use of the equipment.

1.5 Equivalent Government Specifications:

1.5.1 Items produced as specified herein will meet the requirements of MIL-W-6858, however, shear strength values specified herein for Class A aluminum alloy spot welding exceed MIL-W-6858 requirements in that they are 125 percent of the Military Specification values.

2. APPLICABLE DOCUMENTS:

2.1 The following documents form a part of this process specification to the extent provided herein:

2.1.1 Military Specifications:

2.1.1.1 MIL-W-6858 Welding, Resistance: Aluminum, Magnesium, Non-Hardening Steels or Alloys, Nickel Alloys, Heat Resistant Alloys and Titanium Alloys; Spot and Seam.

2.1.2 Military Standards:

2.1.2.1 MIL-STD-204 Thickness of Sheet and Strip Metal.

2.1.2.2 MS 33528 Thickness, Sheet and Strip Metal.

2.1.3 Martin Engineering Process Specifications:

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- 2.1.3.1 EPS 50029 Deoxidation of Aluminum Alloys.
- 2.1.3.2 EPS 50039 Deoxidizing Magnesium Alloys.
- 2.1.3.3 EPS 75007 Handling of Dangerous and Toxic Materials

3. REQUIREMENTS:

3.1 Equipment:

3.1.1 Welding equipment shall include a suitable source of electrical energy, suitable electrodes, means of adequately cooling the electrodes, and a means of reliably controlling and indicating the magnitude of the current, the welding force, and the time of current flow to fulfill the requirements specified herein. The force and current controls shall operate so that no current flows until the welding force is applied at the welding electrodes. The current shall be cut off before the force is removed. Suitable electrode material shall be used to perform welding in conformance with this specification.

3.1.2 Testing Equipment:

3.1.2.1 Shear Test Machines: Spot weld shear testing machines shall be provided as required. The shear testing machines shall be checked for accuracy at intervals not to exceed 2 months. All testing machines shall be accurate within ± 2 percent of the indicated reading.

3.1.2.2 Metallographic Equipment: Metallographic apparatus adequate to section, polish and etch metallographic samples shall be provided.

3.1.2.3 Radiographic Equipment: Radiographic facilities suitable for examination of samples and production parts shall be provided.

3.1.2.4 Surface Resistance Indicator: Surface resistance indicating equipment shall be provided for checking the effectiveness of cleaning procedures used in preparing aluminum and magnesium alloys for welding. Indicators shall be checked for accuracy in accordance with divisional Quality Control procedures.

3.2 Product:

3.2.1 Class A spot welds in aluminum alloys shall meet the applicable shear strength requirements of Table I.

3.2.2 Spot welds (other than in aluminum alloys designated Class A) shall meet the applicable shear strength requirements of Table II.

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- 3.2.3 The completed assembly (spot welded or seam welded) shall meet the weld quality requirements specified in Table III for the class of welding designated.
- 3.2.4 Welds shall be located as shown on the Engineering Drawing.
- 3.3 Fabrication Control:
- 3.3.1 Fabrication shall be controlled in accordance with the requirements of Section 5, Manufacturing Control, of this specification.

4. QUALITY ASSURANCE:

- 4.1 Quality Control shall insure conformance with Section 3, Requirements, of this specification.
- 4.2 Inspection of Production Parts:
- 4.2.1 External Defects: Production parts shall be visually examined for the presence of external defects specified in Table III. The acceptable number of external defects shall not exceed the limits established in Table III.
- 4.2.2 Internal Defects: Inspection of production parts for internal defects is not required except when deemed necessary by Quality Control. In such cases samples of actual production work shall be selected for test purposes. Examination for internal defects may be accomplished by either radiographic or metallographic examination at the discretion of Quality Control. When metallographic examination is used, the number of welds having defects exceeding the limits of 5.4 shall not exceed the number established in Table III.

When radiographic examination is used, the internal defects shall have the following limits:

- a. Class A welds, 25 percent; Class B welds, 50 percent of the weld diameter or
- b. Extension to within 15 percent (of weld diameter) of the boundaries of the cast weld structure.

The number of welds exceeding these limits shall not exceed the number in Table III.

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4.2.3 Distribution of Defects: The maximum percentage and nature of defects which are acceptable without repair and which are acceptable with repair without recourse to M.R.B. procedures are indicated in Table III. Defective spot welds indicated in Table III as being acceptable with or without repair shall be randomly distributed unless it is determined that a particular cluster of defects, within the limits of Table III, is not detrimental to the service intended. Defects shall be considered clustered when there are more than two adjacent defective welds in the production part.

4.2.4 Any part containing welds with defects over and above the limits on permissible defects as defined herein shall be rejected subject to M.R.B. procedures. Special attention shall be given to a close grouping of defective welds.

5. MANUFACTURING CONTROL:

5.1 Cleaning of Materials for Welding:

5.1.1 Aluminum alloys shall be cleaned in accordance with EPS 50029 and magnesium alloys in accordance with EPS 50039. The contact surface resistance of cleaned material at the time of welding shall not exceed the values established in Table IV. Changes in the cleaning procedure are prohibited except when authorized by revision to the cleaning specification.

5.2 Qualification of Welding Equipment:

5.2.1 Prior to production welding qualification tests of welding machines shall be performed as specified herein, to determine the consistency of operation of the machines at or near the desired operating range. Machines shall be qualified to meet the weld requirements for the highest classification for which it is intended to be used in production. A machine qualified to weld requirements of a higher weld classification shall be automatically considered qualified for lower weld classification. One machine of each distinctive type shall satisfactorily pass the complete qualification tests described herein, prior to production welding.

5.2.1.1 Types of Equipment: Machines not differing in any of the following respects are defined as belonging to the same machine type:

- a. Manufacturer of machine or control panel, or type of machine or model number.
- b. Electrical rating or capacity.
- c. Type of electrical energy.
- d. Type of pressure application.

Additional machines of the same distinctive type as the approved machine shall be considered qualified after establishment of satisfactory production settings for each such machine.

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- 5.2.1.2 Machines qualified for seam welding shall be considered qualified for equal weld classification roll spot welding provided certification requirements established herein are met. Machines qualified for spot, roll or seam welding shall be considered qualified for equal weld classification intermittent spot welding.
- 5.2.1.3 Upon satisfactory completion of tests required the data on which the machines were qualified shall be recorded and approved by authorized Manufacturing, Quality Control and Customer Inspection personnel. After approval the data shall be posted in the neighborhood of the qualified machines.
- 5.2.1.4 Once a range of settings have been approved, the machine type for which qualification was granted may be used to weld any alloy, or thickness combination, and/or combination of dissimilar alloys in production providing a satisfactory welding schedule can be developed as required herein.
- 5.2.1.5 Requalification: When the equipment has once been qualified, it need not be re-qualified for future production provided no change in basic material or range of settings is involved. A change of location within the plant, not involving a change in power line, does not necessitate requalification. Requalification shall be required if the machine is rebuilt or significant operational changes are made therein.
- 5.2.2 Test Materials: Use of 2024-T3 alclad or 7075-T6 alclad aluminum alloy qualifies the machine for welding all aluminum and magnesium alloys. When such materials are not welded in production, the alloy most commonly welded shall be used.
- 5.2.3 Test Specimens: To qualify spot welding machines a minimum of two sets of test specimens shall be welded, one at each limit of the range of machine settings for which qualification is desired. Each set shall consist of multiple spot shear specimens containing not less than 105 consecutive welds as shown in Figure 1. Seam welding machines shall be qualified by making test specimens (one at each limit of the range) consisting of at least 24 inches of seam weld as shown in Figure 3.
- No maintenance attention or control adjustments are permitted during the welding of a set of specimens. The specimens shall be tested as required in 5.2.4.
- 5.2.4 Test Requirements: After welding, the specimens shall be examined for external defects. The specimens shall be free of cracks, tip pickup, pits, surface flashes, edge bulge cracks, blown spots, expulsion of metal between faying surfaces and other defects which indicate that the welds were made with dirty electrodes, improperly prepared surfaces, or that undue penetration of weld nugget has taken place. After visual examination the specimens shall be prepared and tested as follows:

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5.2.4.1 All class A welds shall be subjected to radiographic examination for determination of internal defects. Radiographs shall indicate that all welds are sound and free from cracks, spots, lack of fusion, cladding inclusions, and porosity within the following limits:

- a. Porosity, either singly or in combination, shall not have an aggregate area greater than 5 percent of the area of the weld nugget in the plane in which the radiograph is taken, nor
- b. A linear dimension greater than 15 percent of the weld diameter and shall not extend to within 15 percent (of weld diameter) of the boundaries of the cast weld structure.

In addition the fused zone of the weld shall be generally consistent in size and regular in shape.

5.2.4.2 Spot and Roll Spot Welding - The multiple spot specimens shall be cut into single spot weld specimens as shown, and to the dimensions given, in Figure 2. One hundred of the welds shall be tested in shear and five welds shall be sectioned for metallurgical examination.

5.2.4.2.1 Shear Strength Requirements - The shear strength of each weld shall be in accordance with the minimum requirements of Table I or II, whichever is applicable. The failure of one weld shall be cause for rejection of the entire set. The average shear strength of each set of welds shall equal or exceed the minimum average strength in Table I or II, whichever is applicable. In addition variation in shear strength shall not exceed $\pm 12 \frac{1}{2}$ percent of the average value in 90 percent of the specimens and ± 25 percent in the remaining specimens.

5.2.4.2.2 Metallurgical Examination - The specimens shall be sectioned, polished, and etched as closely as possible through the center of the weld. Class A welds shall be examined as a microsection at 25x minimum to 40x maximum. Class B welds shall be examined at 7x minimum to 10x maximum. Weld quality shall meet the requirements of 5.4.

5.2.4.3 Seam Welding - The specimens shall be sectioned, polished, and etched as shown in Figure 3. Longitudinal and transverse sections shall be examined at 25x minimum to 40x maximum for Class A welding, and at 7x minimum to 10x maximum for Class B welding. Weld quality shall meet the requirements of 5.4.

5.3 Certification of Welding Schedule:

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5.3.1 Prior to the welding of production parts Manufacturing shall establish a suitable welding schedule for each material or permissible combination of materials and each thickness combination to be welded in production from the machine under consideration. Thickness combinations falling within the following limits do not require separate schedules, provided acceptable welds can be produced without varying the control settings more than ± 5 percent (± 10 percent when only one setting is involved) from the established values:

- a. 0.004 inch or 10 percent, whichever is greater, variation in thickness of any outer sheet.
- b. 0.004 inch or 10 percent, whichever is greater, variation in the overall thickness of the combination to be welded.

The welding schedule shall include cleaning methods, details of machine setup, and control settings for each machine to be used in production welding. The suitability of the welding schedule shall be established by making and testing not less than the number of welds listed in Table V for the class for which certification is desired. The welding schedule and test results shall be approved by authorized Manufacturing and Quality Control personnel. Details from each welding schedule shall be posted on a standard machine setting chart established for each machine. The chart shall be available at all times to authorized Manufacturing and Inspection personnel.

5.3.2 Test Requirements:

5.3.2.1 Shear Specimens: Two thickness combinations shall be tested in accordance with Figure 4. Three or more thickness combinations shall be tested in accordance with Figure 5. When testing under Figure 5 conditions, the shear strength values shall be equal to or greater than the highest required for either pair of adjacent outer sheets. Under conditions where the shear strength of three or more thicknesses do not meet the required strength values, when tested in accordance with Figure 5, the specimens shall be tested by loading each outer plane separately as shown in Figure 5.

5.3.2.1.1 Minimum Shear Strength Requirements: The shear strength of each spot weld specimen shall be in accordance with the minimum requirements of Table I or II, whichever is applicable. The failure of one weld shall be cause for rejection of the entire set, and the welding methods or equipment shall be modified and the test repeated.

5.3.2.1.2 Average Shear Strength Requirements: The average strength of each set of spot welds shall be equal to or exceed the average strength given in Table I or II, whichever is applicable.

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- 5.3.2.1.3 Strength Consistency Requirements: A variation in shear strength of $\pm 12\frac{1}{2}$ percent of the average value is permitted in 90 percent of the specimens in Table V, and a variation of ± 25 percent in the remaining specimens.
- 5.3.2.2 Seam Weld Requirements: Seam welded test specimens shall conform to metallurgical requirements as specified in 5.4.
- 5.3.2.3 Nugget Diameter Measurements (intermittent spot welding): The number of welds, as specified in Table V for the class of welding involved, shall be sectioned through their centers (see Table V - note 2). Each weld and each separate interface, if more than 2 thicknesses, shall be measured and recorded. Each nugget diameter shall equal or exceed the minimum nugget diameters as established in Table VI. Class A intermittent spot welds shall also equal or exceed the average value given in Table VI.
- 5.3.2.3.1 Nugget Diameter (Class A magnesium alloy spot welds only - see note Table VI): When it is contemplated to use nugget diameter for routine check specimens (5.5.4.1.1), each weld in the metallurgical specimens shall be carefully measured and diameters recorded. Certification records shall show the average and minimum diameter of nuggets. (This will establish the basis for controlling nugget diameters when this method is selected over shear strength testing for production quality control).
- 5.3.2.4 Metallurgical Requirements:
- 5.3.2.4.1 Class A Welds: - Internal quality as indicated by metallographic examination shall meet the radiographic quality level as established for Class A welds in 5.2.4.1. Other internal requirements and the appearance and external defects shall conform to applicable portions of 5.4.
- 5.3.2.4.2 Class B Welds: - The internal and external quality shall conform with the applicable portion of 5.4.
- 5.3.2.5 Certification Outside of Qualification Limits:
- 5.3.2.5.1 The Class A welding machine may be certified to weld thicknesses greater than it was qualified for as long as the following three conditions are met:
- Ratio of the thicker material to the thickness for which the machine was qualified is not greater than 2.
 - Thickness of one material for which the machine was qualified is not increased.
 - Welding schedule can be established to meet requirements herein.

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- 5.3.2.5.2 **Class B welding machines** can be certified to weld material thickness greater than or less than it was qualified for as long as a welding schedule can be established to meet requirements herein.
- 5.3.2.6 **Recertification:** Recertification of a welding schedule may be required at any time, if Quality Control for any reason doubts the ability of a welding machine to make satisfactory welds.
- 5.4 **Weld Quality Standards:**
- 5.4.1 **Appearance:** The outer surface of all test specimen welds shall be smooth, and free of cracks, tip pickup, pits and other defects which indicate that the spot welds were made with dirty electrodes, improperly prepared surfaces, or that undue penetration of the weld nugget has taken place.
- 5.4.2 **External Defects:** Test specimen welds shall be free of the external defects listed in Table III.
- 5.4.3 **Sheet Separation:** Sheet separation, as measured at a distance from the edge of the weld approximately equal to half the diameter of the electrode indentation, is not acceptable if:
- a. In excess of 10 percent of the average thickness of the two outer sheets joined or 0.005 inch, whichever is greater, for Class A welds.
 - b. In excess of 15 percent of the average thickness of the two outer sheets joined or 0.006 inch, whichever is greater, for Class B welds.
- 5.4.4 **Surface Indentation:** Where aerodynamic considerations are a requisite, the electrode indentation shall not exceed 0.004. In other cases, electrode indentation shall not exceed 10 percent or 0.005 inch, whichever is greater, of the thickness of the sheet in which the indentation occurs.
- 5.4.5 **Penetration and Internal Defects:** Weld penetration and soundness shall be determined by examination of a metallurgical section through the center of welds in test specimens welded according to the production welding schedule. The outline of the fusion zone shall be generally consistent in size and generally regular in shape.

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- 5.4.5.1 Internal Defects: Weld defects such as porosity, cracks, lack of fusion, or voids are acceptable if the maximum extent of the defect does not exceed one of the following limits:
- a. For Class A welds, 10 percent and for Class B welds, 15 percent of the weld diameter (see Figure 6).
 - b. Twenty-five percent of the respective sheet thickness extension into an outer sheet (see Figure 6).
 - c. Extension within 15 percent (of weld diameter) of the boundaries of the weld nugget structure (see Figure 6).
- 5.4.5.2 Fusion Between Sections (clad aluminum): The outline of the nugget area at the interface shall be generally smooth and regular. There shall be no unfused cladding material within the weld nugget. The extent of the cladding into the columnar zone of the weld shall not exceed 10 percent of the weld diameter.
- 5.4.5.3 Nugget Zone (seam welding): The outline of the nugget zone on a plane perpendicular to the sheets joined and through the centerline of the seam weld shall show uniform overlapping of welds and consistency of penetration. The width of the fused zone shall be not less than the minimum spot weld diameters listed in Table VI. The width shall be determined by transverse sections as indicated in Figure 7.
- 5.4.5.4 Minimum Penetration (spot and intermittent spot welds): Penetration of the nugget zone into the outer sheets shall be no less than 20 percent of the original sheet thickness at any point over an area whose major axis is 80 percent of the weld diameter at the interface.
- 5.4.5.5 Minimum Penetration (seam welding): Penetration of nugget zone into each outer sheet at the nugget intersection shall be not less than 20 percent of the original sheet thickness.
- 5.4.5.6 Maximum penetration: Penetration into either or both of the outer sheets shall not exceed 80 percent of the reduced sheet thickness (thickness at weld centerline).
- 5.4.6 Unequal Thickness Combinations: In a joint between sections of unequal thickness, or alloys of different strengths, the minimum sheet strength requirements shall be based on the thickness of the thinner sheet or the strength of the weaker material, whichever requirement is lower. Minimum nugget diameter requirements shall be determined by the thickness of the thinner sheet.

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5.5 Production Welding and Routine Production Checks:

5.5.1 Production welding shall be so accomplished as to obtain welds of uniform strength above the accepted minimum and of acceptable metallographic structure, rather than welds of maximum strength irrespective of metallographic structures. All routine production check specimens shall be representative of manufacturing practice. Specimens shall be tested by or under the general supervision of authorized Quality Control personnel.

5.5.2 Tack Welds: Tack welds shall not be used on Class A parts unless finally removed or completely covered by subsequent production welding or allowed by the Engineering Drawing. Tack welds require no test specimens and are not subject to the requirements of this specification except to the extent of defects that may be detrimental to the production part. The defects, internal and external, shall not exceed limits established for production parts.

5.5.3 Mating Parts: Mating parts assembled for welding shall fit so that before the first and each successive weld is made the surfaces to be joined by the weld are in contact with each other or can be made to contact each other with manual pressure at the area where the weld is to be placed.

5.5.4 Routine Check Specimens:

5.5.4.1 Test Specimens: A three spot welded lap joint, or three single spot shear specimens, or specimens containing a minimum of three inches of seam weld, or three intermittent spot welds, as applicable, or simulated section of the production joint containing mentioned weld quantity requirements, shall be welded and tested or examined, as applicable, for routine check purposes for each of the following conditions:

- a. Class A welding - At intervals not to exceed 1 hour of production welding and at the end of a run, if more than 30 minutes has elapsed since the last check.
- b. Class B welding - At intervals not to exceed 2 hours of production welding and at the end of a run, if more than 1 hour of welding has elapsed since the last check.
- c. Upon replacement of the welding electrodes.
- d. At the start of each welding schedule.

Single spot shear specimens shall be tested for ultimate strength (see 5.5.6). Seam welds shall be metallurgically examined for weld quality (see 5.5.4.4.3). Intermittent spot welds shall be examined for nugget diameter size (see 5.5.4.1.1).

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- 5.5.4.1.1 When nugget diameter measurements are used in lieu of the shear test above for Class B aluminum alloy welding and Class A and B magnesium alloy welding (see note Table VI restricting Class A aluminum welding), or when examining intermittent spot welds, the following method shall be used.
- Test specimens or simulated section of the production joint containing three spot welds shall be examined. Specimens shall be cross sectioned, polished, and etched in accordance with Figure 8 as closely as possible through centers of welds and each nugget diameter measured and recorded. If the specimen contains more than two thicknesses, nugget diameter at each interface shall be measured and recorded.
 - For Class A welds, in magnesium alloys the average nugget diameter shall be not more than 10 percent or 0.02 inch (whichever value is greater) below the average nugget diameter obtained during certification of the welding schedule. On multiple thickness combinations of four or more thicknesses, this requirement shall apply to welds in between outer planes only. The minimum nugget diameter, at all planes, shall not be less than the minimum given in Table VI.
 - For Class B welds, each nugget diameter shall be not less than the minimum listed in Table VI.
- 5.5.4.2 The test specimens shall conform to the production parts they represent with respect to material, thickness combination, surface condition, machine settings (see 5.5.5), and electrode tip contours.
- 5.5.4.3 Shear Specimens: Shear test specimens and testing conditions shall be the same as specified in 5.3.2.1. Shear strength shall meet the applicable requirements of 5.5.6.
- 5.5.4.4 Metallurgical Specimens: In addition to the test specimens required in 5.5.4.1, the following metallurgical specimens shall be prepared and examined.
- 5.5.4.4.1 Class A Welding - Three or more welds or three inches of seam weld, as applicable, from a production joint or simulated section of a production joint (see Figure 8) shall be macrosectioned to reveal the structure of the welds at the lesser of the following intervals:
- At the beginning of a shift or job and approximately every four hours thereafter or
 - After approximately 5,000 production welds.

Under conditions where nugget diameter measurements are used for routine check purposes, specimens may be prepared as a microsection at the intervals stated above.

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- 5.5.4.4.2 Class B welding - Three or more welds or three inches of seam weld, as applicable, from a production joint or a simulated section of production joint (see Figure 8) shall be macrosectioned to reveal the structure of the welds at the start of each welding schedule.
- 5.5.4.4.3 All metallurgical specimens shall meet the applicable quality requirements of 5.4. When examining welds (excluding class A spot welds in aluminum alloys - see note Table VI) in multiple thickness combinations containing four or more thicknesses, each weld at each interface not subjected to shear test loading shall be evaluated for nugget diameter. Nugget diameter size shall equal or exceed the minimum nugget diameters as established in Table VI.
- 5.5.5 Control Adjustments: When routine check tests indicate that adjustment of the control settings is desirable, the settings may be varied by ± 5 percent (± 10 percent when only one setting is involved) from the established values. If satisfactory welding cannot be maintained within these limits of adjustment, welding shall be stopped and the machine checked for faulty operation. If conditions other than certified welding schedule requirements were the cause of faulty welding and with these conditions corrected the original welding schedule is capable of producing acceptable welds, the establishment of a new welding schedule in accordance with 5.3 is not required, otherwise a new welding schedule must be established. (For Class A welding, also see 5.5.6.5).
- 5.5.6 Routine Check Test Requirements:
- 5.5.6.1 For Class A welds, the average shear strength of the three specimens shall be not lower than 10 percent below the average shear strength value obtained during certification of the welding schedule, and the minimum shear strength shall be not lower than the minimum given in Table I or II, whichever is applicable. After shear testing, each fractured weld shall be visually (macroscopic) examined for fusion and evidence of obvious defects, such as cracks, porosity, lack of fusion, spits and cladding inclusions.
- 5.5.6.2 For Class B, the minimum shear strength of the three specimens shall be not lower than the minimum given in Table I or II, whichever is applicable. After shear testing, each fractured weld shall be visually examined for fusion, and evidence of obvious defects, such as cracks, porosity, lack of fusion, spits, and cladding inclusions.
- 5.5.6.3 When using nugget diameter measurements, the welds shall be visually examined for fusion and evidence of obvious internal defects such as cracks, porosity, lack of fusion, spits, and cladding inclusions.

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- 5.5.6.4 In addition to the shear strength requirements specified in 5.5.6.1 or 5.5.6.2, the variation in shear strength of the three welds shall not exceed 0.35 when calculated using the following formula:

$$\text{Variation} = \frac{\text{Range}}{\text{Average}} = \frac{\text{Difference between largest and smallest shear strength value}}{\text{Average of individual shear strengths}}$$

If and when the variation in shear strength is exceeded or when the shear strengths are below the permitted value, the previous production parts represented by the sample for that machine and any subsequent production on that machine under those conditions shall be rejected subject to M.R.B. action.

If investigation reveals that spot welding quality has deteriorated due to obvious causes, other than certified welding schedule requirements, and with correction of these conditions the original certified welding schedule is capable of producing acceptable welds, the establishment of a new schedule, in accordance with 5.3 is not required. (For Class A, also see 5.5.6.5).

- 5.5.6.5 Class A welds, under conditions where satisfactory conformance with previous machine qualification or certified welding schedules cannot be obtained (5.5.5 and 5.5.6.4) the machine shall be requalified and recertified. The new machine qualification tests shall be conducted in accordance with requirements in 5.2. All previously certified Class A welding schedules for the machine shall be discarded and new settings established in accordance with requirements in 5.3.
- 5.5.7 Surface Resistance Check: A daily check of the surface resistance in microhms shall be made. A minimum of five readings shall be made on samples typical of the material being welded and its surface condition. The resistance values obtained on these samples shall not exceed maximum values specified in Table IV.
- 5.6 Safety:
- 5.6.1 HK31A and HM21A magnesium alloys contain a radioactive element, thorium. Refer to EPS 75007 for specific handling and processing instructions.
- 5.6.2 Safety Department rules, equipment and devices as designated form a part of this specification.

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Nominal Thickness Of Thinner Sheet (inches)	Aluminum and Aluminum Alloys (Class A only)							
	Ultimate Strength 56,000 psi and above		Ultimate Strength 28,000 psi to 56,000 psi		Ultimate Strength 19,500 psi to 28,000 psi		Ultimate Strength Strength below 19,500 psi	
	(Pounds per weld)		(Pounds per weld)		(Pounds per weld)		(Pounds per Weld)	
	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.
0.012	95	110	80	95	40	45	25	30
0.016	135	160	115	145	90	105	65	75
0.020	175	205	165	195	125	150	95	115
0.025	230	275	220	260	180	215	140	165
0.032	325	385	295	345	265	310	205	245
0.040	430	510	390	455	375	440	280	330
0.050	600	705	555	650	515	605	375	440
0.063	865	1015	780	920	705	830	500	590
0.071	1055	1245	920	1080	820	965	570	670
0.080	1315	1545	1080	1275	970	1140	660	780
0.090	1595	1875	1290	1495	1100	1295	755	890
0.100	1920	2260	1590	1765	1190	1400	855	1010
0.125	2650	3120	2090	2390	1315	1545	980	1155
0.160	3745	4405	2805	3300	1450	1705	1050	1235
0.190	5000	5885	3640	4285	2000	2355	1350	1590

NOTE:

1. Strength of material shall be based on its guaranteed minimum ultimate tensile strength. In case of "O" temper the maximum tensile shall apply.

1

2014-T4, 2014-T6, 2024-T3, 2024-T36, 2024-T42, 2024-T6, 2024-T81, 2024-T86, 7075-T6, 7178-T6, 2219-T81, 2219-T87.

2

5052-H32, 5052-H34, 5052-H36, 5052-H38, 6061-T6, 7075-0, 5083-H34, 5086-0, 5086-H32, 5086-H34, 5086-H36, 5456-0, 5454-H343, 6061-T4, 7178-0, 2014-0, 2014-T3, 5052-0, 5083-0, 5083-H32, 2024-0, 2219-0, 2219-T31, 2219-T37, 2219-T62.

3

1100-H18, 3003-H14, 3003-H16, 3003-H18, 6061-0.

4

EC-0, EC-H12, EC-H14, EC-H16, EC-H18, 1100-0, 1100-H12, 1100-H14, 1100-H16, 3003-0, 3003-H12.

* Based on MS 33528 (Alternate MIL-STD-204).

TABLE I. Minimum Required Strength per Weld for Spot Weld Shear Specimens and Minimum Average Strength (Class A only).

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Nominal * Thickness of Thinner Sheet (inches)	Aluminum and Aluminum Alloys (Class B only)								Magnesium Alloys	
	Ultimate Strength 56,000 psi and above		Ultimate Strength 28,000 psi to 56,000 psi		Ultimate Strength 19,000 psi to 28,000 psi		Ultimate Strength below 19,500 psi		Ultimate Strength above 19,500 psi	Classes A & B
	Pounds per weld		Pounds per weld		Pounds per weld		Pounds per weld		Pounds per weld	
	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.
0.010	60	75	50	65	-	-	-	-	-	-
0.012	75	95	65	85	30	40	20	25	-	-
0.016	110	140	100	125	70	90	50	65	-	-
0.018	125	160	115	145	85	110	65	85	-	-
0.020	140	175	135	170	100	125	80	100	90	120
0.022	160	200	155	195	120	150	95	120	-	-
0.025	185	235	175	200	145	185	110	140	125	170
0.028	215	270	205	260	175	220	135	170	-	-
0.032	260	325	235	295	210	265	165	210	185	245
0.036	305	385	275	345	255	320	195	245	-	-
0.040	345	435	310	390	300	375	225	285	245	330
0.045	405	510	370	465	350	440	260	325	-	-
0.050	465	585	430	540	400	500	295	370	325	430
0.056	555	670	515	645	475	595	340	425	-	-
0.063	670	840	610	765	570	715	395	495	435	575
0.071	825	1035	720	900	645	810	450	565	490	650
0.080	1025	1285	855	1070	765	960	525	660	565	750
0.090	1255	1570	1000	1250	870	1090	595	745	660	875
0.100	1490	1865	1170	1465	940	1175	675	845	765	1015
0.112	1780	2225	1340	1675	1000	1255	735	920	-	-
0.125	2120	2650	1625	2035	1050	1315	785	985	975	1295
0.140	2525	3160	1920	2400	-	-	-	-	-	-
0.160	3120	3900	2440	3050	-	-	-	-	-	-
0.180	3725	4660	3000	3750	-	-	-	-	-	-
0.190	4035	5045	3240	4050	-	-	-	-	-	-
0.250	7350	9200	6400	8000	-	-	-	-	-	-

NOTE: 1. Strength of material shall be based on its guaranteed minimum tensile strength. In case of "O" temper the maximum tensile shall apply.

2014-T4, 2014-T6, 2024-T3, 2024-T36, 2024-T42, 2024-T6, 2024-T81, 2024-T86, 7075-T6, 7178-T6, 2219-T81, 2219-T87.

5052-H32, 5052-H34, 5052-H36, 5052-H38, 6061-T6, 7075-0, 5083-H34, 5086-0, 5086-H32, 5086-H34, 5086-H36, 5456-0, 5454-H343, 6061-T4, 7178-0, 2014-0, 2014-T3, 5052-0, 5083-0, 5083-H32, 2024-0, 2219-0, 2219-T31, 2219-T37, 2219-T62.

1100-H18, 3003-H14, 3003-H16, 3003-H18, 6061-0.

EC-0, EC-H12, EC-H14, EC-H16, EC-H18, 1100-0, 1100-H12, 1100-H14, 1100-H16, 3003-0, 3003-H12.

Based on MS 33528 (Alternate MIL-STD-204).

TABLE II - Minimum Required Strength per Weld for Spot Weld Shear Specimens and Minimum Average Strength

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Nature of Weld Defect	Acceptable Without Repair (Percent)		Additional Repairable (Percent)
	Class A	Class B	Class A	Class B
<u>External Defects</u>
Cracks open to surface	0	0	0	0
Edge bulge cracks	0	0	0	0
Sheet separation exceeding limits	3	5	0	0
Blown spots & spits more than 1/16" dia.	0	0	0	0
Pits less than 1/16" dia.	3	5	2	5
Metal expulsion between sheets (spits) and surface flashes	3	5	0	5
Tip pick-up	2	3	0	0
Excessive indentation	5	10	0	0
<u>Internal Defects</u>
Cracks or porosity	0	6	5	10
Duds (no fusion)	0	0	1	2
Cladding inclusions	0	5	0	0
Insufficient penetration	0	3	0	0
Excessive penetration	0	3	0	0

1

Total of all defects shall not exceed 10 percent for Class A, 15 percent for Class B.

2

Except for seam welds - cracks open to surface of seam welds shall be rejected subject to M. R. B. procedures.

3

In excess of limitations established in 5.4.

NOTE:

Percentage fractions shall be interpreted as the next highest number of welds for the purpose of determining the additional repair permissible.

TABLE III. - Maximum Acceptable Number of Defects

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Material	Thickness (Inches)	Desirable Resistance upon Deoxidation (Microhms)	Maximum Resistance at the Time of Welding (Microhms)
2024 Alclad	Under .020 Over .020*	20 30	35 100
7075 Alclad	Under .032 Over .032*	20 30	50 100
All Other Aluminum Alloys	.012 to .125	30	100
All Magnesium Alloys	.000 to .125	50	75

* From and including this size.

TABLE IV - Contact Surface Resistance.

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Class of Weld	Weld Method	Ultimate Shear Strength Specimens	Metallurgical Specimens (See Note 2)
A	Spot weld (See Notes 1 and 5)	20 Shear	5 Welds micro-section
B		10 Shear	5 Welds macro-section
A	Seam Weld (See Note 4)	None Required	12 inches of weld (See Figure 7)
B			
A	Intermittent spot weld (See Note 3)	10 nugget diameter measurements	20 welds (10 micro-sectioned) (See Figure 8)
B		5 nugget diameter measurements	10 welds (5 macro-sectioned) (See Figure 8)

- Notes:
1. Total number of ultimate strength shear specimens for each class, shall be multiple spot or single spot specimens conforming to Figure 1 or 2. Multiple spot specimens shall be cut into single spot shear specimens conforming to Figure 2 for testing.
 2. Metallurgical specimens shall conform to the requirements of Figure 8. Specimens shall be cross sectioned, polished, and etched closely as possible through the center of the weld. Microsections, for Class A shall be examined at a minimum of 25x to a maximum of 40x. Macrosections, for Class B shall be examined at 7x to 10x maximum.
 3. Nugget diameter measurements shall be obtained from the metallurgical specimens.
 4. Seam welds may be accomplished by the overlapping of spot welds with fixed type electrodes. Seam welding in this manner shall be certified and controlled in accordance with seam-welding requirements.
 5. Spot welds spaced less than 2 diameters apart utilizing fixed-type electrodes shall be certified and controlled in accordance with intermittent spot welding requirements.

TABLE V. - Specimens - Welding Schedules

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Nominal thickness of thinner sheet (inch) *	Spot Weld Diameter	
	Minimum (inch)	Lowest Average (inch)
0.010	0.08	0.09
0.012	0.09	0.10
0.016	0.10	0.12
0.018 to 0.020	0.11	0.13
0.022	0.12	0.14
0.025	0.13	0.15
0.028 to 0.030	0.14	0.16
0.031 to 0.032	0.14	0.17
0.035 to 0.036	0.15	0.18
0.040 to 0.042	0.16	0.19
0.044 to 0.045	0.17	0.20
0.050 to 0.051	0.18	0.21
0.056	0.19	0.22
0.060	0.20	0.23
0.062 to 0.064	0.20	0.24
0.070	0.21	0.25
0.071 to 0.072	0.22	0.26
0.078 to 0.081	0.23	0.27
0.090 to 0.091	0.24	0.29
0.093 to 0.094	0.25	0.29
0.100 to 0.102	0.26	0.30
0.109	0.26	0.31
0.110 to 0.114	0.27	0.32
0.125	0.28	0.34
0.140	0.30	0.36
0.156 to 0.160	0.32	0.38
0.180	0.34	0.40
0.189 to 0.190	0.35	0.41

Note: Nugget diameters in this table are based on minimum shear strength specified in Table II.
Nugget diameters listed above are not applicable to the shear strength values in Table I (Class A aluminum alloys).

* Based on MS 33528 (alternate MIL-STD-204)

TABLE VI - Nugget diameter

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(Values for W and A are shown in Table below)
 N = Number of spotwelds required.

FIGURE 1. - MULTIPLE - SPOT SHEAR SPECIMEN
 (To be cut after Welding).

Nominal thickness of thinner sheet	Width (W) Minimum		Length (A)
	Aluminum and Aluminum Alloys	Magnesium Alloys	
0.030 and under	5/8	3/4	As required to perform shear test
0.031 to 0.050	3/4	3/4	
0.051 to 0.100	1	1	
0.101 to 0.130	1 1/4	1 1/4	
0.131 and over	1 1/2	1 1/2

(Values for W and A are shown in Table above).

FIGURE 2. - SINGLE - SPOT SHEAR SPECIMEN

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1. When using multiple strips containing a sum of at least 24 inches of weld in place of a single strip as shown above, the maximum number of multiple strips shall be four. Longitudinal and transverse sections shall be equal in numbers per test strip and shall be not less than four cross sections.
2. Longitudinal sections shall be prepared in such a manner that at least a total length of 1 inch of seam weld is examined.
3. Transverse sections shall be of sufficient length to include the weld nugget, the heat affected zone, and portions of the unaffected base metal at each end.
4. Width of test strip(s) shall be as shown in the table of Figure 1 and 2 for the applicable thickness required.
5. Longitudinal and transverse sections shall be examined as microsections for Class A and as macrosections for Class B.

Figure 3. - Qualification test specimen, seam welding

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The required overlap (W) shall be maintained as specified (see table - Figure 1 and 2)

Figure 4 - Shear test specimens (two thicknesses)

The required overlap (W) shall be maintained as specified (see table - Figure 1 and 2).

Test strips not loaded (hatched) may be laid crosswise or parallel with loaded members, or may be short or bent out of the way.

Figure 5 - Shear test specimens (three or more thicknesses)

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- A = Maximum Extent of Defect (see 5.4.5.1)
B = Weld Diameter (see 5.4.5.1a)
C = Extension into Outer Sheet (see 5.4.5.1b)
D = Extension within Nugget Boundaries (see 5.4.5.1c)

Figure 6 - Internal Defects

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1. Longitudinal sections shall be prepared in such a manner that at least a total length of 1 inch of seam weld is examined.
2. Transverse sections shall be of sufficient length to include the weld nugget, the heat affected zone, and portions of the unaffected base metal at each end.
3. Width of test strip(s) shall be as shown in the table of Figure 1 and 2 for the applicable thickness required.
4. Longitudinal and transverse sections shall be examined as microsections for Class A and as macrosections for Class B.

Figure 7 - Certification test specimens, seam welding

Figure 8 - Metallurgical specimen (microsection or macrosection)

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EPS 55010

APPENDIX NO. 3
ISSUED 8-22-63

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WELDING, RESISTANCE: ALUMINUM AND MAGNESIUM ALLOYS.

SPOT AND SEAM (STRUCTURAL)

PROJECT: TITAN III (624A)

Exceptions to paragraph 1.2, 1

Welding of bare to bare, bare to clad 2014 aluminum alloy, is permissible in combinations within the range for which the respective machine is qualified.

Welding of bare 2024 aluminum alloy to bare 2014-T6 is permissible in combinations within the thickness range for which the respective machine is qualified.

DENVER	8-23-64	BALTIMORE	9-3-64	ORLANDO
K. Mills	R	N. B. Miller	R	

APPROVED:

L. O. Berman
MATERIALS ENGINEERING

H. Beckham
PROJECT

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EPS 55013
AMENDMENT NO. 2
ISSUED 12-23-64
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**MARTIN
COMPANY**

Ident. No. 38597

PROCESS SPECIFICATION

WELDING, FUSION: ALUMINUM AND MAGNESIUM ALLOYS

EFFECTIVITY: This Amendment forms part of EPS 55013 dated 12-6-63 and is effective on date of issue. This Amendment supersedes and replaces Amendment No. 1.

3. REQUIREMENTS

3.1 MATERIALS

Change 3.1.1 to read as follows:

3.1.1 Rods, Welding, Aluminum Alloy
Spec.: QQ-R-566, Class 1100
Code: Y469A

Change 3.1.1.1 to read as follows:

3.1.1.1 Spec.: QQ-R-566, Class 4043
Code: Y469B

Change 3.1.1.2 to read as follows:

3.1.1.2 Spec.: QQ-B-655, FS BALS-3(716)
Code: Y419A

3.4 Fabrication Control

3.4.2 Pre-Cleaning Add the following note:

Note: When deoxidation of aluminum alloys by mechanical means (scraping and/or filing) is necessary, chemical deoxidation per Method II, EPS 50029, may be omitted. Scraping or filing shall not be done until just prior to welding. Extreme care shall be exercised to avoid removing too much metal from the surfaces.

Approved: Norman B. Miller
Martin Company

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**MARTIN
COMPANY**

**PROCESS
SPECIFICATION**

Code Ident. No. 38597

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WELDING, FUSION: ALUMINUM AND MAGNESIUM ALLOYS

1.4.2 Magnesium alloys -

- a. Inert gas shielded tungsten arc (TIG)
- b. Inert gas shielded metal arc (MIG)

1.5 Equivalent Government Specifications: There is no equivalent government process specification, however, items produced as specified herein will meet the applicable requirements of MIL-W-8604-1, MIL-W-18326A, and ABMA-PD-W-45A.

2. Applicable Documents: The following specifications, standards and publications form a part of this specification to the extent specified herein:

2.1 Government Specifications and Standards

Military

MIL-T-5021C	Tests; Aircraft Welding Operators Certification
MIL-STD-453	Inspection, Radiographic
MIL-I-6866A	Inspection, Penetrant, Method of
MIL-W-8604-1	Welding of Aluminum Alloys, Process For
MIL-A-8625A	Anodic Coatings, for Aluminum and Aluminum Alloys
MIL-W-18326A	Welding of Magnesium Alloys; Process For
MIL-R-45774	Radiographic Inspection, Soundness Requirements for Fusion Welds in Aluminum and Magnesium Missile Components

Army Missile Center

ABMA-PD-W-45A	Welding, Fusion, Shielded Arc, Missile Components, Aluminum and Magnesium, Manual or Automatic
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2.2 Industry Specifications and Standards

American Welding Society

Welding Handbook, Section 1, Fifth Edition

American Standards Association

Z49.1-58 Safety in Welding and Cutting

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WELDING, FUSION: ALUMINUM AND MAGNESIUM ALLOYS

2.3 Martin Company Specifications and Standards

Engineering Process Specifications

EPS 10700	Heat Treatment of Magnesium Alloys
EPS 45007	Identification and Marking of Detail Parts and Assemblies
EPS 50018	Paint Removal
EPS 50029	Deoxidation of Aluminum Alloys
EPS 50038	Deoxidation of Magnesium Alloys for Fusion Welding
EPS 50046	Vapor Degreasing, Trichloroethylene

3. REQUIREMENTS:

3.1 Materials

- 3.1.1 Rods, Welding, Aluminum Alloy
Spec.: QQ-R-566, Type I, FS-RAL2 (Alloy 1100)
Code: Y469A
 - 3.1.1.1 Spec.: QQ-R-566, Type I, FS-RAL43 (Alloy 4043)
Code: Y469B
 - 3.1.1.2 Spec.: QQ-R-566, Type II, FS-RAL716 (Alloy 716)
Code: Y469J
- 3.1.2 Welding Wire, Aluminum Alloy (Alloy 4043)
Spec.: MMS Y478
Code: Y478A (Spooled)
Y478B (Rod)
- 3.1.3 Electrodes, Welding, Bare Aluminum Alloys
Spec.: MIL-E-16053, Type 5356 (Alloy 5356)
Code: Y463B
 - 3.1.3.1 Spec.: MIL-E-16053, Type 5556 (Alloy 5556)
Code: Y463C
- 3.1.4 Welding Rods and Wire Magnesium Alloy
Spec.: MIL-R-6944, Grade AZ92A (Alloy AZ92A)
Code: Y466B
 - 3.1.4.1 Spec.: MIL-R-6944, Grade EZ33A (Alloy EZ33A)
Code: Y466D

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WELDING, FUSION: ALUMINUM AND MAGNESIUM ALLOYS

- 3.1.5 Tungsten Electrodes (Pure)
Spec.: Commercial
Code: Y434A
- 3.1.5.1 Tungsten Electrodes (Thoriated)
Spec.: Commercial
Code: Y434B
- 3.1.5.2 Tungsten Electrodes (Zirconium)
Spec.: Commercial
Code: Y434C
- 3.1.5.3 Tungsten Electrodes (Linde 53N83)
Spec.: Commercial
Code: Y434D
- 3.1.6 Welding Gases
 - 3.1.6.1 Argon
Spec.: MMS Y441
Code: Y441A
 - 3.1.6.2 Helium
Spec.: MMS Y440
Code: Y440A
 - 3.1.6.3 Oxygen, Welding Grade - 99.95% Pure
Spec.: Commercial
Code: Y442A
 - 3.1.6.4 Hydrogen, Welding Grade - 99.8% Pure
Spec.: Commercial
Code: Y443A
- 3.1.7 Flux, Aluminum, Gas Welding
Spec.: MIL-F-6939
Code: Y433A

(• NOTE: HAZARDOUS MATERIALS SEE 3.6)

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**PROCESS
SPECIFICATION**

EPS 55013

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WELDING, FUSION: ALUMINUM AND MAGNESIUM ALLOYS

3.2 Equipment:

- 3.2.1 Welding equipment, such as welding machines, welding torches, regulators and filler metal feed mechanisms shall be capable of making satisfactory welds, when operated by a certified welding operator using a satisfactory filler metal and electrode where applicable.
- 3.2.2 Furnaces used for preheating parts prior to welding shall have suitable means of temperature control. Torches may be used for preheating provided the specified temperature range is maintained by using a suitable contact pyrometer, or temperature indicating sticks or liquids approved by Quality.

3.3 Product:

- 3.3.1 All weldments shall be free from cracks in weld deposit or parent metal, lack of fusion, incomplete penetration, burn through, and overlaps. Undercut shall not exceed $1/10T$ in depth or exceed one inch in length, nor shall any one undercut be closer than 4 inches to another undercut as measured from the end of one undercut to the adjacent end of the next undercut (T being material thickness).
- 3.3.2 Unless otherwise specified by the Engineering Drawing, weld size(s) shall conform to Table I (see 3.4.6)
- 3.3.3 Weld joint configuration shall be in accordance with Engineering Drawing requirements.
- 3.3.4 When radiographic examination is an Engineering requirement, the quality of welding shall meet the requirements of specification MIL-R-45774 for the class of welding specified on the Engineering Drawing.

3.4 Fabrication Control:

3.4.1 Certification requirements:

- 3.4.1.1 All welders (manual and semi-automatic welding) and welding operators (automatic welding) shall be certified in accordance with MIL-T-5021 or equivalent procedure approved by Quality.
- 3.4.1.2 Automatic welding equipment shall be certified to welding schedules approved by Quality. The welding schedule shall specify filler metal, electrodes, gas(es) and necessary parameters meeting this specification and Engineering Drawing requirements.

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WELDING, FUSION: ALUMINUM AND MAGNESIUM ALLOYS

3.4.1.3 When welding is performed by subcontractors, copies of certifications shall be forwarded to the cognizant Martin Company Division Quality.

3.4.2 Pre-Cleaning: Weld joint areas shall be free from oil, grease, dirt, moisture, paint films and other contaminants. Cleaning shall be accomplished as follows:

- a. Removal of grease and oil - EPS 50046
- b. Removal of paint films - EPS 50018
- c. Deoxidation of aluminum alloy parts - EPS 50029
- d. Deoxidation of magnesium alloy parts - EPS 50038

3.4.3 Fit up: Fit up prior to welding shall be in accordance with the following:

3.4.3.1 Root opening:

Thickness* (inch)	Manual and semi- automatic welding, max. (inch)	Automatic welding, max.
Up to 1/8 incl.	1/32	10% of
Over 1/8 to 3/8 incl.	1/16	thickness, but
Over 3/8	1/8	not to exceed 0.010 inch.

* Applies to root face of the thinner member

3.4.3.2 Mismatch:

Thickness* (inch)	Manual and semi- automatic welding, max.	Automatic welding, max.
Up to 0.049 incl.	15% of thickness	Details shall
0.050 to 0.099 incl.	0.018 inch	be in contact
0.100 to 0.199 incl.	0.025 inch	with backing
over 0.199	10% of thickness	bar at weld joint

* Applies to root face of the thinner member

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WELDING, FUSION: ALUMINUM AND MAGNESIUM ALLOYS**3.4.4 Preheating:** Preheating, when required, shall be in accordance with the following:

- a. Aluminum alloy assemblies consisting of components heat treated in detail - preheat temperature shall not exceed 200°F.
- b. Aluminum alloy assemblies other than as noted in a. - preheat temperature shall not exceed 400°F.
- c. Magnesium alloy assemblies - preheat temperature shall not exceed 300°F.

3.4.5 Welding materials:**3.4.5.1 Welding gases:** Welding gases, as required, shall be as specified in 3.1. Dew point specified shall be maintained to the welding head.**3.4.5.2 Tungsten electrodes:** Tungsten electrodes, as required for TIG welding, shall meet 3.1 requirements.**3.4.5.3 Filler rod or wire:** Filler rod or wire usage shall be in accordance with Table II or III for the specific alloy or alloy combination designated. In addition the applicable filler rod or wire shall meet 3.1 requirements.**3.4.5.4 Flux:** Flux used in gas welding aluminum alloy shall meet 3.1 requirements.**3.4.6 Deviations from weld size requirements (3.3.2)****3.4.6.1 Minimum deviations:** Deviations from minimum specified requirements are acceptable provided the aggregate length of deviation does not exceed 20 percent of the total weld length, with no one deviation exceeding 10 percent of the total weld length.**3.4.7 Weld penetration:** Unless otherwise specified on the Engineering Drawing, weld penetration shall be as noted below:

- a. Butt joints shall have complete weld penetration whether welded from one side or both sides of the joint.
- b. Lap joints and fillet welds (except as noted below) shall have complete weld penetration to the root of the joint. Fillet welds 60° or less are excepted from this requirement. In such cases the weld need not penetrate completely to the root of the joint, however, fusion between weld and parent material shall be adequate. (see 3.4.8).

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WELDING, FUSION: ALUMINUM AND MAGNESIUM ALLOYS

- 3.4.8 Fusion: All weld beads shall be completely fused to the base material and to underlying weld beads. Depth of fusion for fillet welds shall be 15 percent of T minimum with 85 percent T maximum (T = material thickness).
- 3.4.9 Cooling: Weldments shall be allowed to cool in air (or in the fixture) after welding is completed. Accelerated cooling, as by quenching, is not permitted.
- 3.4.10 Dressing: Weld beads may be "dressed" so long as the minimum weld size requirements specified herein are maintained.
- 3.4.11 Flux removal: Flux shall be completely and promptly removed after welding is completed. Flux shall be removed by one or a combination of the following methods:
- Scrub under hot running water.
 - Immerse in a ten (10) percent solution (by weight) of sulphuric acid. Rinse in cold water until all acid is removed.
- 3.4.12 Marking: Welder's (or welding operator's) symbol shall be placed on all weldments in accordance with EPS 45007.
- 3.4.13 Post weld treatment (Magnesium Alloys):
- 3.4.13.1 Magnesium alloy assemblies, except those fabricated from HK31A, HM21A, HM31A and EZ33A, shall be stress relieved, after welding, in accordance with EPS 10701.
- 3.4.14 Restrictions:
- 3.4.14.1 Aluminum alloys: The inert gas shielded arc processes shall be used in welding closed assemblies (tubular or otherwise), and lap joints from which flux cannot be removed.
- 3.4.14.2 Magnesium alloys: The welding of magnesium alloys is restricted to the processes listed in 1.4.2.
- 3.4.15 Repairs: Weld repairs and repair methods shall have prior Quality approval. Repaired weldments shall meet requirements specified herein.
- 3.5 Special Skills: Welders and welding operators shall be certified in accordance with 3.4.1.1.
- 3.6 Safety:
- 3.6.1 Materials called out in this specification are hazardous. Refer to divisional safety procedures for precautions and handling instructions when materials are indicated by a double asterisk.

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WELDING, FUSION: ALUMINUM AND MAGNESIUM ALLOYS

3.6.2 Ventilation requirements are those normally used for arc welding. (Refer to American Standards Association Z49.1-58).

3.6.3 Protective clothing, shields, safety devices, etc., designated by the Safety Department shall be used as directed.

4. QUALITY ASSURANCE:

4.1 Quality shall ensure conformance to the requirements of this process.

4.2 Penetrant Inspection: All weldments shall be inspected for defects in accordance with specification MIL-I-6866. If weldments are to be subsequently chromic acid anodized in accordance with specification MIL-A-8625, inspection may be by this method rather than by the penetrant method.

Inspection shall be carried out subsequent to any post weld heat treatment. Inspection prior to heat treatment is optional. (Note: see 1.3)

4.3 Radiographic Examination: When specified on the Engineering Drawing, radiographic inspection shall be carried out in accordance with MIL-STD-453. The criteria for acceptance shall be as specified in 3.3.4. If radiographic inspection is not an Engineering requirement and Quality deems such inspection necessary then the following criteria shall apply:

- a. Porosity, singly or in combination, shall not exceed ten (10) percent of a lineal inch of weld or of the cross section of a weld. For determination of the one inch increments, the radiograph shall be laid out in one inch increments, starting at one end of the radiograph and continuing to the opposite end.
- b. Inclusions (tungsten or otherwise) shall be considered the same as porosity (a) except that angular type inclusion are not acceptable. The combination of both (porosity and inclusions) shall not exceed the limits established in a.
- c. Cracks in weld deposit or adjacent base metal are not acceptable.
- d. Incomplete penetration and lack of fusion are not acceptable.

4.4 Test for flux removal: Leach the weld area with distilled water and add three (3) drops of five (5) percent silver nitrate. If a white precipitate forms further neutralizing in the sulphuric acid solution (3.4.11) is required.

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WELDING, FUSION: ALUMINUM AND MAGNESIUM ALLOYS

- 4.5 Previous certifications: Welders, welding operators and welding equipment certified to previous issues, revisions, amendments and documents superseded by this specification, shall be considered as qualified to this specification without additional tests. However, all certifications, recertifications or retests initiated subsequent to the release date of this specification shall comply with the provisions noted herein.

5. MANUFACTURING CONTROL:

This section is not applicable to this specification.

6. NOTES:

- 6.1 Definitions: Chapter I(Standard Welding Terms and Definitions), Section 1, of the Welding Handbook shall be considered a part of this specification.

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Material Thickness (in.)	(See Notes 1 & 2)						Butt Welds			
	Fillet Welds		Lap Joints		Throat (in.)		Bead Width(in.)		Bead Thickness (in.)	
	Leg (in.)	Throat (in.)	Face (in.)	Throat (in.)	Min.	Max.	Min.	Max.	Min.	Max.
.025	3/32	3/16	1/16	3/32	1/4	1/32	3/32	1/4	3/64	11/64
.032	3/32	3/16	1/16	3/32	1/4	1/32	3/32	1/4	1/16	3/16
.040	1/8	3/16	3/32	3/32	1/4	3/64	3/32	1/4	5/64	13/64
.050	3/16	9/32	9/64	3/32	5/16	1/16	1/8	1/4	5/64	13/64
.063	3/16	9/32	9/64	1/8	5/16	1/16	1/8	1/4	3/32	7/32
.071	3/16	9/32	9/64	5/32	5/16	5/64	5/32	1/4	7/64	15/64
.080	3/16	9/32	9/64	3/16	5/16	5/64	5/32	1/4	7/64	15/64
.090	3/16	9/32	9/64	3/16	5/16	3/32	3/16	5/16	9/64	17/64
.100	7/32	5/16	5/32	1/4	3/8	7/64	7/32	3/8	5/32	9/32
.125	1/4	3/8	3/16	1/4	3/8	1/8	1/4	3/8	3/16	5/16
.160	5/16	7/16	7/32	5/16	3/8	5/32	5/16	1/2	1/4	3/8
.190	3/8	1/2	17/64	3/8	1/2	3/16	3/8	5/8	9/32	13/32
.250	1/2	5/8	23/64	1/2	5/8	1/4	1/2	3/4	3/8	1/2
Over .250	As specified by Engineering Drawing									

- Notes 1. Fillet weld sizes 75 percent of those listed are acceptable in double fillet applications.
2. Weld sizes in corner joints (depending on joint geometry and fitup) shall meet the following requirements.

Leg A = T_1
 Leg B = $T_2 - a$
 t (throat) min. = $.707 \times \text{Leg A}$
 T_1 = Thickness of Member
 T_2 = Thickness of Member
 a = offset in fit up

FILLET WELDS ON INSIDE OF JOINT (WHEN REQUIRED) SHALL BE AS SPECIFIED IN THE ABOVE TABLE

WELDS IN SQUARE JOINTS
 GROOVED AND NON-GROOVED

FILLET WELDS IN CORNER JOINTS

3. Welds (including melt-thru welds) in edge-flange or corner-flange joints shall be as specified on the Engineering Drawing.

TABLE I - WELD SIZE REQUIREMENTS.

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Base Alloy	1100	3003	355	356	43	5052	5083 5086	5456	6061 6062 6063	6151
1100	1100	1100	4043* 716 *	4043* 716 *	4043 716 *	4043*	5356*	5356*	4043*	4043*
3003	1100	1100	4043* 716 *	4043* 716 *	4043 716 *	4043*	5356*	5356*	4043*	4043*
355	4043* 716 *	4043* 716 *	4043* 716 *	4043* 716 *	4043* 716 *	4043*	5356*	5356*	4043* 716 *	4043* 716 *
356	4043* 716 *	4043* 716 *	4043* 716 *	4043* 716 *	4043* 716 *	4043*	5356*	5356*	4043* 716 *	4043* 716 *
43	4043 716 *	4043 716 *	4043* 716 *	4043* 716 *	4043 716 *	4043*	4043*	5356*	4043* 716 *	4043* 716 *
5052	4043*	4043*	4043*	4043*	4043*	5356	5356	5356	4043	4043*
5083 5086	5356*	5356*	5356*	5356*	4043*	5356	5356	5356	5356	5356*
5456	5356*	5356*	5356*	5356*	5356*	5356	5356	5556 4043* 716 *	5556 4043* 716 *	5356*
6061 6062 6063	4043*	4043*	4043* 716 *	4043* 716 *	4043* 716 *	4043	5356	5556 4043* 716 *	4043	4043*
6151	4043*	4043*	4043* 716 *	4043* 716 *	4043* 716 *	4043*	5356*	5356*	4043*	4043*

• Requires Materials Engineering approval for each application.

TABLE II - FILLER ROD OR WIRE FOR ALUMINUM BASE ALLOYS

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Base Alloy	AZ31B	AZ91C	EZ33A	HK31A**	AZ61A	HM21A**	HM31A**
AZ31B	AZ92A	AZ92A*	AZ92A*	AZ92A*	AZ92A*	AZ92A*	AZ92A*
AZ91C	AZ92A*	AZ92A*	AZ92A*	AZ92A*	AZ92A*	AZ92A*	AZ92A*
EZ33A	AZ92A*	AZ92A*	E Z33A	EZ33A	AZ92A*	EZ33A	EZ33A
** HK31A	AZ92A*	AZ92A*	EZ33A	EZ33A	AZ92A*	EZ33A	EZ33A
AZ61A	AZ92A*	AZ92A*	AZ92A*	AZ92A*	AZ92A	AZ92A*	AZ92A*
** HM21A	AZ92A*	AZ92A*	EZ33A	EZ33A	AZ92A*	EZ33A	EZ33A
** HM31A	AZ92A*	AZ92A*	EZ33A	EZ33A	AZ92A*	EZ33A	EZ33A

* Requires Materials Engineering approval for each application.

** HAZARDOUS MATERIALS - see 3.6.

TABLE III - FILLER ROD OR WIRE FOR MAGNESIUM BASE ALLOYS

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WELDING, FUSION: ALUMINUM AND MAGNESIUM ALLOYS

EFFECTIVITY: This Appendix forms part of EPS 55013 dated 12-6-63
and is effective on date of issue.

Applicable to Titan Programs Only. When Titan Engineering Drawings call out this process specification, the following requirements shall be met in addition to the basic EPS requirements.

Add the following to paragraph 3.4.5.3:

Welding rod or wire meeting MMS Y478 requirements shall be used for all applications requiring 4043 aluminum alloy rod or wire.

Lytle Wallis

Titan Programs

Norman B. Miller 12/12/63
Materials Engineering SSD

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AMENDMENT NO. 1

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PROCESS SPECIFICATION

WELDING, FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

EFFECTIVITY: This Amendment forms part of EPS 55014 dated 3-20-64 and is effective on date of issue.

3. REQUIREMENTS

3.1 Materials:

Add the following material code numbers:

3.1.1	<u>Type</u>	<u>Class</u>	<u>Code</u>
	MIL-6012	1	Y465D
	MIL-6027	2	Y465E

3.1.4	<u>Type</u>	<u>Class</u>	<u>Code</u>
	MIL-308-15	1	Y474J
	MIL-309-15	1	Y474K
	MIL-349-15	1	Y474L

3.1.5 Add to description:

Electrodes, Corrosion Resistant 17-4 PH, Covered, Type B

Add code number:

Code: Y444B

3.1.6 Code: Y445B

3.1.7	<u>Class</u>	<u>Code</u>
	E3N19 (Inconel #69)	Y447A

<u>Type</u>	<u>Class</u>	<u>Code</u>
MIL-3N12	1	Y439A

3.1.8 Change to read:

Electrodes, Tungsten
Spec.: Commercial

<u>Type</u>	<u>Code</u>
Pure	Y434A
Thoriated	Y434B
Zirconium	Y434C
Linde 53N83	Y434D

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WELDING, FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

3.1.11	<u>Type</u>	<u>Code</u>
	Rod	Y472A
	Spool	Y472B
3.1.12	Code: Y448A	
3.1.14	Code: Y446A	
3.1.15	Code: Y449A	
3.1.16	Code: Y425A	
3.1.17	Code: Y424A	
3.1.18	Code: Y423 (See Material Source Appendix).	
3.1.19	Code: Y422A	
3.1.20	Change to read: Spec.: MIL-F-7516, Class 2 Add code number Code: Y421B	
3.1.21.1	Change to read: Spec.: Welding Grade - 99.95% pure Add code number: Code: Y442A	
3.1.21.2	Change to read: Acetylene, Dissolved Technical Grade Spec.: BB-A-106 Code: Y480A	

Approved: Norman B. Miller
Martin Company

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WELDING, FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

1. SCOPE:

- 1.1 Application: This specification establishes the requirements to be met by the Martin Company and subcontractors for fusion welding carbon (0.30 nominal C. max.) and low alloy (0.40 nominal C. max.) steels, corrosion-resistant and heat-resistant alloys. Other processes may be used by subcontractors, providing these processes have prior approval by Martin Company Quality and the requirements of this specification are met.
- 1.2 Intended Usage: Primarily for fusion welding critical, primary, and secondary structures fabricated from the steels and alloys listed in Table I. Steels or alloy other than those listed in Table I shall not be welded to this specification without prior Materials Engineering approval. Welding of combinations in Table I (except combinations of the unalloyed low-carbon steels) must have Materials Engineering approval. This specification does not restrict the heat treatment of heat treatable alloys covered herein, however, heat treatment after welding, when required, shall be specified on the Engineering Drawing.
- 1.3 Drawing Callout: This specification shall be specified on all applicable Engineering Drawings. Weld symbols shall be in accordance with the applicable Engineering Practices Manual. In addition, the weld size shall be noted on the drawing when the thickness of the thinner member joined exceeds 1/4 inch, or when a flanged joint is specified (see note 4 - table II) or when weld size requirements are other than as specified herein. When the weld may be in contact with LOX (liquid oxygen) or other oxidizer a cautionary note shall be added to the drawing stating "DO NOT USE PENETRANT (OR MAGNETIC PARTICLE) INSPECTION". Weld quality standard (ref. MIL-R-11468) shall be specified on the drawing when radiographic examination is an Engineering requirement. Filler metal usage must be noted on the drawing when mixed materials are in an assembly (see 1.2).
- 1.4 Processes: This specification covers the following processes and is applicable to manual, semi-automatic and automatic welding:
- Arc-covered electrode
 - Arc-inert gas shielded (consumable and non-consumable electrode)
 - Submerged arc
 - Oxy-acetylene

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WELDING, FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

- 1.5 Equivalent Government Specifications: There is no equivalent government specification, however, items produced as specified herein will meet the applicable requirements of MIL-W-8611A and ABMA-W-40.
2. APPLICABLE DOCUMENTS: The following specifications, standards and publications form a part of this specification to the extent specified herein:
 - 2.1 Government Specifications and Standards
 - Military
 - MIL-T-5021C Tests; Aircraft Welding Operators Certification
 - MIL-I-6866A Inspection, Fluorescent Penetrant, Method of
 - MIL-I-6868B Inspection Process, Magnetic Particle
 - MIL-W-8611A Welding, Fusion, of Steels and Corrosion and Heat Resisting Alloys
 - MIL-R-11468 Radiographic Inspection, Soundness Requirements for Arc and Gas Welds in Steel
 - MIL-STD-453 Inspection, Radiographic
 - Federal
 - Test Method Std. 151 Metals; Test Method
 - Army Missile Center
 - ABMA-W-40 Welding: Carbon, Low Alloy, and Stainless Steel, Manual or Automatic for Guided Missile Use.
 - 2.2 Industry Specifications and Standards
 - American Welding Society
 - Welding Handbook, Section I, Fifth Edition
 - American Standards Association
 - Z49.1-58 Safety in Welding and Cutting

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WELDING, FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

2.3 Martin Company Specifications and Standards

- EPS 10427 Annealing Procedure for Corrosion and Heat Resisting Alloys
EPS 45007 Identification and Marking of Detail Parts and Assemblies
EPS 50010 Derusting and Descaling Carbon and Alloy Steel Parts
EPS 50042 Descaling Stainless Steels
EPS 50046 Vapor Degreasing

3. REQUIREMENTS:

3.1 Materials:

3.1.1 Electrodes, Welding, Covered, Low and Medium Carbon Steels

Spec: MIL-E-15599

<u>Type</u>	<u>Class</u>	<u>Code</u>
MIL-6010	1	Y465C
MIL-6012	1	
MIL-6013	1	Y465A
MIL-6020	2	Y465B
MIL-6027	2	

3.1.2 Electrodes, Welding, Mineral Coated, Low Hydrogen

Spec: MIL-E-18038

<u>Type</u>	<u>Class</u>	<u>Code</u>
MIL-7016	1	Y487B
MIL-10016	1	Y487A

3.1.3 Electrodes, Welding, Coated, Low Hydrogen Steel

Spec: MIL-E-8697

<u>Type</u>	<u>Class</u>	<u>Code</u>
HT-4130	1	Y486A
HT-4140	2	Y486B
HT-4340	3	Y486C
HT-4340 (UHS)	4	Y486D

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3.1.4 Electrodes, Welding, Covered, Austenitic Steel

Spec.: MIL-E-22200/2A

<u>Type</u>	<u>Class</u>	<u>Code</u>
MIL-308L-15	1	Y474F
MIL-308-15	1	
MIL-309-15	1	
MIL-316-15	1	Y474E
MIL-347-15	1	Y474A
MIL-349-15	1	

3.1.5 Electrodes, Corrosion Resistant 17-4PH, Covered

Spec.: AMS 5827

Code:

3.1.6 Electrodes, Corrosion Resistant AM355, Covered

Spec.: AMS 5781

Code:

3.1.7 Electrodes, Nickel-Chromium, Covered

Spec.: ASTM-B295

<u>Class</u>	<u>Code</u>
E3N19 (Inconel #69)	

Spec: MIL-E-22200/3A

<u>Type</u>	<u>Class</u>	<u>Code</u>
MIL-3N12	1	

3.1.8 Electrodes, Tungsten (Pure, Thoriated, Zirconium)

Spec: Commercial

Code:

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3.1.9 Rod, Welding, Steel

Spec.: MIL-R-5632

<u>Class</u>	<u>Code</u>
1 (Plain Carbon)	Y473A
2 (Alloy)	Y473B

3.1.10 Wire, and Rod, Welding, Corrosion Resistant

Spec.: MIL-R-5031

<u>Class</u>	<u>Code</u>
1 (AWS-ER308)	Y464A
4 (AWS-ER316)	Y464D
5 (AWS-ER347)	Y464E
5A (AWS-ER347)	Y464F
6 (19-9 WMo)	Y464G
15 (AWS-ER308-L)	Y464U

3.1.11 Wire, and Rod, Welding, 17-7 PH Corrosion Resistant

Spec.: Commercial

Code:

3.1.12 Wire, Welding, WPH15-7 Mo Corrosion Resistant

Spec: AMS 5813

Code:

3.1.13 Rod, Welding, Nickel-Chromium

Spec.: MIL-R-5031

<u>Class</u>	<u>Code</u>
8A (Inconel #62)	Y464K
14 (Inco #69)	Y464T

3.1.14 Wire, Welding, 17-4PH Corrosion Resistant

Spec.: AMS 5825

Code:

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WELDING, FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

3.1.15 Wire, Welding, AM355 Corrosion Resistant

Spec.: AMS 5780

Code:

3.1.16 Wire, Welding, Carbon Steel

Spec.: Lincoln L-60, Linde Oxweld #29, Hobart #10

Code:

3.1.17 Wire, Welding, Corrosion Resistant Steel

Spec.: Lincoln L18-8

Code:

3.1.18 Flux, Welding

Spec.: Lincoln 840 and 760, Linde Grade #50, Hobart H-100

Code:

3.1.19 Flux, Welding

Spec.: Lincoln ST-100

Code:

3.1.20 Flux, Welding

Spec.: MIL-F-7516

Code:

3.1.21 Welding Gases

3.1.21.1 Oxygen

Spec.: Welding Grade - 99.5% pure

Code:

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WELDING, FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

3.1.21.2 Acetylene

Spec.: Welding Grade - 99.5% pure

Code:

3.1.21.3 Argon

Spec.: MMS Y441*

Code: Y441A

3.1.21.4 Helium

Spec.: MMS Y440*

Code: Y440A

* (See 3.4.4.1)

** (Note - Hazardous Materials - see 3.6)

3.2 Equipment:

3.2.1 Welding equipment, such as welding machines, welding torches, regulators and filler metal feed mechanisms shall be capable of making welds meeting the requirements specified herein when operated by a certified welder or welding operator using filler metal or electrodes where applicable.

3.2.2 Furnaces used for preheating parts prior to welding or for postheating parts after welding shall have suitable pyrometric controls such that the temperature varies not more than $\pm 25^{\circ}\text{F}$. Torches or induction heating coils may be used for preheating provided the specified temperature range is maintained by using a suitable contact pyrometer, or temperature indicating sticks or liquid approved by Quality.

3.3 Product:

3.3.1 All weldments shall be free from cracks in weld zone or parent metal. Lack of fusion, incomplete joint penetration, and overlaps are unacceptable. Pressure vessels shall be free from undercuts. Other than pressure vessels, undercuts less than 5/16 inch in length are acceptable provided the material thickness is not below 80% of the original thickness, and provided no more than one such defect is present in any consecutive 3 inches of weld, and not more than two such defects are present in any 12 inches of weld. Undercuts located within 1 inch of the ends of weld beads are not acceptable.

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WELDING, FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

- 3.3.2 Unless otherwise specified by the Engineering Drawing, weld size (s) shall conform with Table II. (see 3.4.6).
- 3.3.3 Weld joint configuration shall be in accordance with Engineering Drawing requirements.
- 3.3.4 When radiographic examination is specified on the Engineering Drawing the quality of welding shall meet the applicable requirements of MIL-R-11468.
- 3.3.5 Unless otherwise specified on the Engineering Drawing final condition (heat treatment, stress relieved, as welded) shall be in accordance with 3.4.12 or 3.4.13, whichever is applicable.
- 3.4 Fabrication Control:
- 3.4.1 Certification requirements:
- 3.4.1.1 All welders (manual and semi-automatic) and welding operators (automatic welding) shall be certified in accordance with MIL-T-5021 or equivalent procedure approved by Quality.
- 3.4.1.2 Automatic welding equipment shall be certified to welding schedules approved by Quality. The welding schedule shall specify filler metal, electrodes, gas(es) and necessary parameters meeting this specification and Engineering Drawing requirements.
- 3.4.1.3 When welding is performed by subcontractors, copies of certifications shall be forwarded to the cognizant Martin Company Division Quality.
- 3.4.2 Pre-cleaning: Weld joint areas shall be free from oil, grease, oxides, plating, and paint films. Cleaning shall be accomplished in accordance with the following:
- a. Removal of grease and oil - EPS 50046
 - b. Removal of scale, rust or plating from Group I (Table D) materials - EPS 50010, or by emery cloth, steel wool, wire brushing.
 - c. Removal of scale, rust, or plating from Group II and Group III materials (Table I) - EPS 50042, or by stainless steel wool, or stainless steel wire brushing.

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WELDING, FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

3.4.3 Preheat and interpass temperatures: Preheat and interpass temperatures are as follows:

<u>Carbon Content (%)</u>	<u>Hardenability Equivalent to</u>	<u>Preheat & Interpass Temp. (°F. Min.)</u>
0.15 or less		None required
0.16 thru 0.33	Plain carbon steels	(1) 200
0.16 thru 0.33	AISI-4130 & AISI-8630 and steels or alloys of equal or lower harden- ability	400
0.34 thru 0.43	(2) Steels with hardenability higher than above such as AISI-4140, AISI-4340 & AISI-8740	600-750

(1) When deemed advisable.

(2) Regardless of final condition, precautions shall be taken with these steels to insure that the temperature of the weld area, both during and subsequent to welding, does not drop below 500°F until after stress relief per 3.4.12.

3.4.4 Welding materials:

3.4.4.1 Welding gases: Welding gases, as required, shall be as specified in 3.1. Dew point requirements specified therein shall be maintained to the welding head.

3.4.4.2 Tungsten electrodes: Tungsten electrodes (inert gas shielded tungsten arc welding) shall meet 3.1 requirements.

3.4.4.3 Filler rod or wire: Filler rod or wire usage shall be in accordance with Table I for the specific alloy and welding process designated. In addition, the filler rod or wire shall meet 3.1 requirements.

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WELDING, FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

- 3.4.4.4 Flux: Flux shall be used in accordance with Table I for the material and welding process designated. Flux shall be as specified in 3.1.
- 3.4.4.5 Covered Electrodes: Electrode usage shall be in accordance with Table I for the specific alloy designated. In addition, the electrodes shall meet 3.1 requirements. Low hydrogen type electrodes, in unsealed containers, shall be stored in temperature controlled cabinets until used.
- 3.4.5 Tack welds: Tack welds containing cracks shall be completely removed. Welding over cracked tack welds is prohibited.
- 3.4.6 Deviations from weld size requirements (3.3.2)
- 3.4.6.1 Minimum deviations: Deviations from minimum specified requirements are acceptable provided the aggregate length of deviation does not exceed 10 percent of the total weld length, with no one deviation exceeding 3 consecutive inches of weld, and provided the throat dimension is at least 80% of minimum specified.
- 3.4.6.2 Butt joints welded without added filler metal (corrosion-resistant alloys): Butt welds in corrosion-resistant alloy types AISI-304, AISI-304L, AISI-316, AISI-321 and AISI-347 (thicknesses to and including 0.080") shall meet Figure 1 or Figure 2 requirements, whichever is applicable, when welded without the addition of filler metal.

- a. to max. of 15% of T.
- b. at least equal to T.
- c. 100% joint penetration with no evidence of a joint line.

W. = welding side.

T = base metal thickness.

Figure 1 - Equal thickness combination.

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WELDING, FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

3.4.6.2 (Continued)

- a. to max. of 15% of T_2 .
- b. at least equal to T_2 .
- c. 100% joint penetration with no evidence of a joint line.

W = welding side.

T = base metal thickness.

Figure 2 - Unequal thickness combinations.

3.4.7 Weld penetration: Unless otherwise specified on the Engineering Drawing, weld penetration shall be as noted below:

- a. Butt joints shall have complete penetration whether welded from one side or both sides of the joint.
- b. Lap joints and fillet welds (except as noted below) shall have complete weld penetration to the root of the joint. Fillet welds 60° or less are excepted from this requirement. In such cases the weld need not penetrate completely to the root of the joint, however, fusion between weld and parent metal shall be adequate (see 3.4.8), and minimum throat and leg requirements must be met.

3.4.8 Fusion: All weld beads shall be completely fused to the base material and to underlying weld beads. Depth of fusion for fillet welds shall be 15 percent of T minimum (T being material thickness).

3.4.9 Dressing: Weld beads may be "dressed" so long as the minimum weld sizes in Table II are maintained.

3.4.10 Marking: Welder's (or welding operator's) symbol shall be placed on all weldments in accordance with EPS 45007.

3.4.11 Post weld cleaning:

3.4.11.1 Cleaning of Group I (Table I) materials, when required, shall be accomplished by steel shot or sand blasting.

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WELDING, FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

- 3.4.11.2 Cleaning of Group II(Table I) materials shall be in accordance with EPS 50042.
- 3.4.12 Post weld treatment - Group I(Table I) materials: Welded assemblies (except those subject to heat treatment after welding and except as noted in 3.4.12.4) shall be in a final stress relieved condition. Stress relief shall be as follows:
- 3.4.12.1 Arc (including inert gas shielded and submerged arc) welded assemblies fabricated from Group I(Table I) materials (except AISI-4140, AISI-8740, AISI-4340 and steels of equivalent hardenability) shall be stress relieved at 1000°-1050°F for one hour per inch of greatest thickness, with one hour minimum in any case. Assemblies fabricated from AISI-4140, AISI-8740, AISI-4340 and steels of equivalent hardenability shall be stress relieved at 1100° - 1200°F for one hour per inch of greatest thickness, with one hour minimum in any case. (See precautionary note covering these steels under 3.4.3).
- 3.4.12.2 Group I(Table I) steels heat treated in detail prior to welding shall be stress relieved at a temperature 50° F. below the minimum temperature of the lowest tempering range of any detail in the assembly. Time at temperature shall be one hour per inch of greatest thickness, with one hour minimum in any case.
- 3.4.12.3 AISI-4130 steel tubing assemblies specified as Condition "N" (normalized) in the finished part shall be cooled to room temperature after welding, then stress relieved at 1000° - 1050°F. for one hour minimum.
- 3.4.12.4 Gas welded assemblies do not require a stress relieve treatment.
- 3.4.13 Post weld treatment - Group II(Table I) materials:
- Assemblies fabricated from Types 304 and 316 corrosion resistant alloys shall be annealed in accordance with EPS 10427 after welding unless otherwise specified by the Engineering Drawing.
- 3.4.14 Repairs: Weld repairs and repair methods shall have prior Quality approval. Repaired weldments shall meet requirements specified herein.
- 3.5 Special Skills: Welders and welding operators shall be certified as specified in 3.4.1.1.

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WELDING, FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

3.6 Safety:

- 3.6.1 Materials called out in this specification are hazardous. Refer to Divisional Safety Procedures for precautions and handling instructions for materials identified by double asterisk.
- 3.6.2 Ventilation requirements are those normally used for arc welding. (Refer to American Standards Association Z49.1-58).
- 3.6.3 Protective clothing, shields, goggles, safety devices, etc., designated by the Safety Department shall be used as directed.

4. QUALITY ASSURANCE:

- 4.1 Quality shall ensure conformance to the requirements of this process.
- 4.2 Magnetic particle inspection: The welds and adjacent areas of all weldments fabricated from Group I and magnetic Group II (Table I) materials shall be inspected for defects by magnetic particle inspection in accordance with MIL-I-6868. Weldments requiring post weld heat treatment or post weld treatment in accordance with 3.4.12 shall be inspected after the required treatment and prior to and after any blast cleaning operation. (Note: see 1.3)
- 4.3 Penetrant inspection: The welds and adjacent areas of all weldments fabricated from non-magnetic Group II and Group III (Table I) materials shall be subjected to fluorescent inspection or dye penetrant inspection in accordance with MIL-I-6866. Inspection shall be carried out subsequent to any required post weld treatment, (3.4.13) and prior to and after any blast cleaning (Note: see 1.3).
- 4.4 Radiographic examination: When specified on the Engineering Drawing, radiographic inspection shall be carried out in accordance with MIL-STD-453. The criteria for acceptance shall be as specified in 3.3.4. If radiographic inspection is not an Engineering requirement and Quality deems such inspection necessary then the following criteria shall apply:
 - a. Porosity and inclusions, either singly or in combination, shall not exceed ten (10) percent of a lineal inch of weld or the cross section of a weld. For determination of the one inch increments, the radiograph shall be laid out in one inch increments, starting at one end of the radiograph and continuing to the opposite end.
 - b. Cracks in weld deposit or adjacent base metal are not acceptable.
 - c. Incomplete penetration and lack of fusion are not acceptable.

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WELDING FUSION; STEELS, CORROSION AND HEAT-RESISTANT ALLOYS

4.5 Test Methods: Testing to establish conformance with requirements specified herein shall be in accordance with Federal Standard 151.

4.6 Previous certifications: Welders, welding operators and welding equipment certified to previous issues, revisions, amendments and documents superseded by this specification, shall be considered as qualified to this specification without additional tests. However, all certifications, recertifications or re-tests initiated subsequent to the release date of this specification shall comply with the provisions noted herein.

5. MANUFACTURING CONTROL:

This section is not applicable to this specification.

6. NOTES:

6.1 Definitions: Chapter 1 (Standard Welding Terms and Definitions), Section 1, of the Welding Handbook shall be considered a part of this specification.

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BASE ALLOY	ELECTRODES, WIRE OR RODS				FLUX
	ARC WELDING	INERT GAS SHIELDED ARC WELDING	OXY-ACETYLENE WELDING	SUBMERGED ARC WELDING	SUBMERGED ARC WELDING
<u>GROUP I</u> <u>Low Carbon Steels</u> QQ-S-698 MMS 2307 QQ-S-681 Class 1 & 2 QQ-S-635 Classes FS-1008 to FS-1030 incl.	Spec. - MIL-E-15599 Type MIL-6010 Type MIL-6012 Type MIL-6013 Type MIL-6020 Type MIL-6027 Spec. - MIL-E-18038 Type MIL-7016	Spec. - MIL-R-5632 Class 1	Spec. - MIL-R-5632 Class 1	Spec. Lincoln L-60 or Linde Grade #29 or Hobart # 10	Spec. Lincoln 840 and 760 or Linde Grade #50 or Hobart H- 100
<u>Low Carbon Alloy Steels</u> AISI-8620 AISI-8630 AISI-4130	When heat treatment subsequent to welding is not an Engineering requirement, i.e., final condition "as welded", "stress relieved" or "normalized": Spec. - MIL-E-18038 Type MIL-10016. When heat treatment (Subsequent to welding) from 100 to 200,000 psi tensile ultimate is an Engineering requirement: Spec. - MIL-E-8697 Type HT 4130 Class 1	When heat treatment subsequent to welding is not an Engineering requirement, i.e., final condition "as welded", "stress relieved" or "normalized": Spec. MIL-R-5632, Class 2 When heat treatment (Subsequent to welding) from 100 to 200,000 psi tensile ultimate is an Engineering requirement: Spec. - MIL-R-5632 Class 2	Usage and limitations on usage shall be the same as for inert gas shielded arc welding.	(THIS WHOLE BLOCK) APPLIES TO ARC WELDING ONLY!	
<u>Medium Carbon Alloy Steels</u> AISI-4140 AISI-8740 AISI-4340	When heat treatment subsequent to welding is not an Engineering requirement, i. e., "as welded" or "stress relieved" as final condition: Spec. - MIL-E-18038 Type MIL-10016 When heat treatment subsequent to welding is an Engineering requirement: AISI-4140 & AISI-8740 100 to 220,000 psi tensile ultimate required: Spec. - MIL-E-8697 Type HT 4140 Class 2 AISI-4340 100 to 220,000 psi tensile ultimate required: Spec. - MIL-E-8697 Type HT 4340 Class 3 AISI-4340 260 to 280,000 psi tensile ultimate required: Spec. - MIL-E-8697 Type HT 4340 (UHS) Class 4				

(THIS WHOLE BLOCK)
APPLIES TO ARC
WELDING ONLY!

TABLE I - ELECTRODE, FILLER ROD OR WIRE AND FLUX REQUIREMENTS.

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SPECIFICATION**

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Code Issue. No. 36697

BASE ALLOY	ELECTRODES, WIRE OR RODS				FLUX	
	ARC WELDING	INERT GAS SHIELDED ARC WELDING	OXY-ACETYLENE WELDING	SUBMERGED ARC WELDING	SUBMERGED ARC WELDING	OXY-ACETYLENE WELDING
<u>Group II</u> <u>Corrosion Resistant</u> <u>Alloys</u> AISI-304L	Spec. -MIL-E-22200/2A Type MIL-308L Class 1	Spec. -MIL-R-5031 Class 15	Spec. -MIL-R-5031 Class 15			Spec. -MIL-F-7516
AISI-304	Spec. -MIL-E-22200/2A Type MIL-308 Class 1	Spec. -MIL-R-5031 Class 1	Spec. -MIL-R-5031 Class 1	Spec. -Lincoln L18-8	Spec. -Lincoln ST-100	Spec. -MIL-F-7516
AISI-316	Spec. -MIL-E-22200/2A Type MIL-316 Class 1	Spec. -MIL-R-5031 Class 4	Spec. -MIL-R-5031 Class 4			Spec. -MIL-F-7516
AISI-321 AISI-347	Spec. -MIL-E-22200/2A Type MIL-347 Class 1	Spec. -MIL-R-5031 Class 5A	Spec. -MIL-R-5031 Class 5	Spec. -Lincoln L18-8	Spec. -Lincoln ST-100	Spec. -MIL-F-7516
16-3DL	Spec. -MIL-E-22200/2A Type MIL-349 Class 1	Spec. -MIL-R-5031 Class 6				
17-7PH		Spec. -Commercial 17-7PH				
17-4PH	Spec. -AMS 5827	Spec. -AMS 5825				
PH15-7Mo		Spec. -AMS 5813				
AM 350 AM 355	Spec. -AMS 5781	Spec. -AMS 5780				
<u>Group III</u> <u>Heat Resistant Alloy</u> Inconel	Spec. -MIL-E-22200/3A Type MIL-3N12 Class 1	Spec. -MIL-R-5031 Class 8A				
Inconel "X"	Spec. -ASTM-B295 Class E3N19	Spec. -MIL-R-5031 Class 14				

TABLE 1 - ELECTRODE, FILLER ROD OR WIRE AND FLUX REQUIREMENTS (Con't.)

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Material Thickness (In.)	FILLET WELDS (See Notes 1 and 2)				LAP JOINTS				BUTT WELDS (See Note 3)			
	LEG (In.)		THROAT (In.)		FACE (In.)		THROAT (In.)		BEAD WIDTH (In.)		BEAD THICK. (In.)	
	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.
.020	9/64	17/64	3/32	3/16	1/32	1/8	1/32	3/32	5/32	9/32	3/64	11/64
.025	9/64	17/64	3/32	3/16	1/32	1/8	1/32	3/32	5/32	9/32	3/64	11/64
.032	9/64	17/64	3/32	3/16	1/16	5/32	1/32	3/32	5/32	9/32	1/16	3/16
.050	9/64	17/64	3/32	3/16	3/32	3/16	1/32	3/32	5/32	9/32	5/64	13/64
.063	9/64	17/64	3/32	3/16	1/8	7/32	1/16	1/8	5/32	9/32	3/32	7/32
.080	11/64	19/64	1/8	7/32	5/32	1/4	1/16	1/8	3/16	5/16	7/64	15/64
.100	11/64	19/64	1/8	7/32	3/16	9/32	3/32	5/32	1/4	3/8	5/32	9/32
.125	13/64	21/64	9/64	15/64	7/32	5/16	3/32	5/32	9/32	13/32	3/16	5/16
.160	7/32	11/32	5/32	1/4	9/32	3/8	1/8	7/32	1/2	1/4	1/4	3/8
.180	15/64	23/64	11/64	17/64	5/16	13/32	5/32	1/4	13/32	17/32	9/32	13/32
.250	21/64	29/64	15/64	21/64	7/16	17/32	7/32	5/16	15/32	19/32	3/8	1/2
Over 0.250	As Specified By Engineering Drawing											

NOTES:

1. Fillet weld sizes 75 % of those listed are acceptable in double fillet applications.
2. Weld sizes in corner joints (depending on joint geometry and fitup) shall meet the requirements shown on the following page.
3. See exceptions for corrosion-resistant alloys in paragraph 3.4.6.3.
4. Welds (including melt-thru welds) in edge-flange or corner-flange joints shall be as specified on the Engineering Drawing.

TABLE II - WELD SIZE REQUIREMENTS.

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Fillet welds on inside of joint
(when required) shall be as
specified in TABLE II values.

Leg $A = T_1$
Leg $B = T_2 - a$
 t (throat) Min. = .707 X Leg A

T_1 = Thickness of member
 T_2 = Thickness of member
 a = Offset in Fitup.

FILLET WELDS IN CORNER JOINTS

WELDS IN SQUARE JOINTS (GROOVED AND NON-GROOVED)

TABLE II - WELD SIZE REQUIREMENTS (Con't.)

Approved Norman B. Miller
MARTIN COMPANY

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Code Ident. No. 38597

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APPENDIX NO. 1
ISSUED 11-25-64
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PAGE 1 OF 1

WELDING, FUSION, STEELS, CORROSION AND HEAT RESISTANT

FOR SPRINT PROGRAM ONLY

Add:

3.1.22 Wire Welding (Maraging Steel)
Spec.: MMS Y404
Code: Y404B

Add to Table I Group I (New category)

Base Alloy

Inert Gas Shielded Arc Welding

Maraging Steels

MMS Y404

Add:

3.4.3.1 Maraging Steels shall not be preheated and the interpass temperatures shall be a maximum of 250°F.

Add:

3.4.12.5 Maraging Steels shall not be postheated and shall be heat treated in accordance with drawing instructions.

Add:

3.7 Shielding Requirement, Maraging Steels: Maraging steels shall be protected against oxidation by shielding with inert gas on both sides of the joint.

Approved:

Norman B. Miller
Martin Company

Approved:

Ed Wallis
Orlando Programs

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BALTIMORE 11-25-64
ORLANDO
N. B. Miller

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EPS 55014

APPENDIX NO. 2

ISSUED 3-10-65

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**MARTIN
COMPANY**

ent. No. 38597

PROCESS SPECIFICATION

WELDING, FUSION; STEELS, CORROSION AND HEAT RESISTANT

PROJECT: 202 and 404 Aircraft

EFFECTIVITY: This appendix is to be used with EPS 55014 dated 3-20-64.

Add to para. 3.4.4.5.

Type MIL-6013 Electrodes (Spec. MIL-E-15599) shall be used in fabricating the following assemblies:

404-5000004
404-5000005
2021A10100
2021A16647-82

Approved: *P.W. Boone*
202 and 404 Aircraft

Approved: *Norman B. Miller*
Martin Company

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WELDING, FUSION, OF STEELS AND CORROSION RESISTANT ALLOYS

EFFECTIVITY: This Appendix applies to Saturn Hydrodynamics Support only, supersedes Appendix No. 3 and is effective on date of issue.

TABLE I - Add to Group I - Low Carbon Steels - the following:

ASTM A53*

Note: * Welding shall be accomplished with coated electrode meeting requirements listed under "Arc Welding". Root pass may be welded by the inert gas shielded arc method using filler metal meeting requirements listed under this method.

3.4.12 Post Weld Treatment - Add the following sentence:

Stress relieving of welded assemblies fabricated from ASTM A53 material is not required unless so specified on Engineering Drawing.

4. QUALITY ASSURANCE: Add

4.7 Radiographic examination - MIL-R-11468, Standard II

4.8 All welds shall be proof tested to 1.5 x operating pressure. Operating pressure shall be specified on Engineering Drawing.

Approved: Tyle Wallis
Saturn Hydrodynamics Support

Approved: Norman B. Miller
Martin Company

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BALTIMORE 5-24-65
ORLANDO
R
Miller

REMOVE: App. 3

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FORM D-188
JUL 62

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Code Ident. No. 38597

PROCESS SPECIFICATION

EPS 55030
Amendment No. 1
ISSUED JUN 10 1963
REVISED
PAGE 1 OF 1

WELDING, RESISTANCE; SPOT AND PROJECTION
(NON-CRITICAL)

EFFECTIVITY: This Amendment forms a part of EPS 55030 dated 5-8-63 and is effective on date of issue.

5. MANUFACTURING CONTROLS:

5.6.4 Change to read:

Macro specimens shall be visually examined at approximately 5X magnification. Examination shall reveal the presence of some cast weld structure between the sheets. Burned off wires and sheet indentation in excess of Table I requirements shall be considered unacceptable.

DEAR

SSD 6-27-63

SPD 6-11-63

ORLANDO 6-10-63

DEAR

G. E. Hollubach

A

V. Panari

C

B. Peterson

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DENVER

ORLANDO

NUCLEAR

C

B R Peterson

PROCESS COMMITTEE REPRESENTATIVE

SPACE SYSTEMS

ELECTRONICS

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C

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SPECIFICATION**

Code Ident. No. 38597

ISSUED 5-8-63

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WELDING, RESISTANCE; SPOT AND PROJECTION
(Non-Critical)

1. SCOPE:

1.1 Application: This specification establishes the requirements for materials, equipment and controls to be used by the Martin Company and subcontractors for resistance spot and projection welding of aluminum alloys, magnesium alloys, steels (low-carbon and austenitic stainless types), copper and nickel alloys for non-critical applications (See 1.4). Other processes may be used as equivalent by subcontractors, providing these processes are approved by the Martin Company and requirements specified herein are met.

1.2 Permissible Alloy Combinations:

1.2.1 Aluminum Alloys - May be welded in any combination.

1.2.2 Magnesium Alloys - May be welded in any combination.

1.2.3 Low-carbon Steels - Low carbon steels (0.15C. Max.) may be welded in any combination.

1.2.4 Austenitic Stainless Alloys - May be welded in any combination.

1.2.5 Copper Alloys - May be welded in any combination.

1.2.6 Nickel Alloys - May be welded in any combination.

1.2.7 Alloys or alloy combinations other than covered in 1.2.1 to 1.2.6 shall not be welded to this specification unless approved by Materials Engineering.

1.3 Joint Thickness Limitations (Spot Welds):

1.3.1 Unless specifically approved by Materials Engineering, the total thickness of welded joint shall not exceed five times the thickness of the thinner outer member.

1.4 Classification:

1.4.1 The quality of spot welding producible using this specification is such that it will not meet requirements of MIL-W-6858. The principle difference between this specification and the Military Specification are reflected in lower quality and production test requirements, and in shear strength requirements which, in this specification, are 80% (aluminum alloys) and 65% (other than aluminum alloys) of MIL-W-6858 requirements. This specification, therefore, shall be specified only for items of a non-critical nature.

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**WELDING, RESISTANCE; SPOT AND PROJECTION
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1.5 Equivalent Government Specifications:

1.5.1 There is no Government Specification covering this process.

2. APPLICABLE DOCUMENTS:

2.1 The following documents form a part of this specification to the extent provided herein:

2.1.1 Military Specifications:

2.1.1.1 MIL-W-6858 Welding, Resistance; Aluminum, Magnesium, Non-Hardening Steels or Alloys, Nickel Alloys, Heat Resisting Alloys and Titanium Alloys; Spot and Seam

2.1.2 Military Standards:

2.1.2.1 MIL-STD-204 Thickness of Sheet and Strip Metals

2.1.2.2 MS 33528 Thickness, Sheet and Strip Metal

2.1.3 Martin Engineering Process Specifications:

2.1.3.1 EPS 50010 Derusting and Descaling Carbon and Alloy Steel Parts

2.1.3.2 EPS 50029 Deoxidation of Aluminum Alloys

2.1.3.3 EPS 50039 Deoxidizing Magnesium Alloys

2.1.3.4 EPS 50042 Descaling Stainless Steels and Titanium

2.1.3.5 EPS 50046 Vapor Degreasing

2.1.3.6 EPS 50070 Cleaning, Descaling and Surface Preparation of Copper and Copper Alloys

2.1.3.7 EPS 55010 Welding, Resistance: Aluminum, and Magnesium Alloys, Spot and Seam

2.1.3.8 EPS 55011 Welding Resistance: Non-Hardening Steels or Alloys, Nickel Alloys and Heat Resisting Alloys; Spot and Seam

2.1.3.9 EPS 75007 Handling of Dangerous and Toxic Materials

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WELDING, RESISTANCE; SPOT AND PROJECTION (Non-Critical)

3. REQUIREMENTS:

3.1 Equipment:

- 3.1.1 Welding equipment shall include a suitable source of electrical energy, suitable electrodes, means for cooling electrodes, and means for reliably controlling the force, the magnitude of the current, and the time of current flow to fulfill requirements specified herein. The force and current controls shall operate so that no current flows until the welding force is applied at the electrodes. The current shall cut off before the force is removed. Suitable electrode material shall be used for welding.
- 3.1.2 Suitable shear testing facilities shall be provided. Each machine shall be checked for accuracy at intervals not to exceed 2 months and shall be accurate within ± 2 percent of the indicated reading.
- 3.1.3 Surface resistance indicating equipment shall be provided for checking the effectiveness of cleaning procedures used in preparing aluminum and magnesium alloys for welding. Indicators shall be checked for accuracy as specified in EPS 50029.

3.2 Product:

- 3.2.1 Spot welded items shall meet shear strength and weld quality requirements established herein.
- 3.2.2 Wire mesh to sheet or strip assemblies shall meet the weld quality requirements specified herein.
- 3.2.3 Projection welded items shall meet the minimum tensile strength requirement specified on the Engineering Drawing.
- 3.2.4 Welds shall be located as shown on the Engineering Drawing.

3.3 Fabrication Control:

- 3.3.1 Fabrication shall be controlled in accordance with requirements of Section 5, Manufacturing Control, of this specification.

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WELDING, RESISTANCE; SPOT AND PROJECTION (Non-Critical)

4. QUALITY ASSURANCE:

- 4.1 Quality Control shall insure conformance to Section 3, Requirements, of this specification.

5. MANUFACTURING CONTROLS:

5.1 Qualification of Welding Equipment:

- 5.1.1 Welding machines qualified to EPS 55010 and EPS 55011 or MIL-W-6858 requirements shall be considered qualified for welding to this process specification. In the event that welding equipment has not been properly qualified, then applicable requirements of the foregoing process specifications shall be met prior to production welding.

5.2 Procedures for Cleaning Prior to Welding:

- 5.2.1 Aluminum Alloys - Cleaning shall be accomplished in accordance with EPS 50029. Contact surface resistance at the time of welding shall not exceed the values established in Table IV.
- 5.2.2 Magnesium Alloys - Cleaning shall be in accordance with EPS 50039. Surface resistance at the time of welding shall not exceed the values established in Table IV.
- 5.2.3 Steels (low-carbon and austenitic stainless) and Nickel Alloys - Cleaning is not required if the surfaces to be welded are free from oxides, grease, dirt and ink. In the event the surfaces do not meet this requirement, cleaning shall be accomplished as follows:
- a. Degrease in accordance with EPS 50046 to remove grease, ink and dirt.
 - b. Treat in accordance with EPS 50010 to remove oxides from low-carbon steels.
 - c. Treat in accordance with EPS 50042 to remove grease, ink, dirt and oxides from austenitic stainless types and nickel alloys.

Surfaces coated with an oil film or coated with lacquer to EPS 30035 requirements are exempted from the foregoing cleaning cycles providing the requirements of this specification are met.

- 5.2.4 Copper Alloys - Cleaning shall be carried out in accordance with EPS 50070 requirements.

5.3 Machine Set Up:

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**WELDING, RESISTANCE; SPOT AND PROJECTION
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5.3.1 Prior to welding each production lot of parts, qualified machines shall be certified by developing a welding schedule for each alloy or permissible combination of alloys, and each thickness combination contained in the parts to be welded. Thickness combinations falling within the following limits do not require separate schedules:

a. Aluminum and Magnesium -

(1) 0.004 or 10 percent, whichever is greater, variation in thickness of any outer member.

(2) 0.004 or 10 percent, whichever is greater, variation in the overall thickness of the combination to be welded.

b. Steels, Copper and Nickel Alloys -

(1) 20 percent variation in thickness of any outer member.

(2) 10 percent variation in the overall thickness of the combination to be welded.

5.3.2 Welding schedules shall include the procedure for preparation of the material (including cleaning processes) all details of machine set up and the control settings. Machine settings used in the development of the welding schedule shall be within the range of settings established by Qualification of the machine. The certification data shall be available at all times to authorized Manufacturing and Quality Control personnel.

5.3.3 The suitability of the welding schedule shall be demonstrated by preparing (5.4) and testing (5.6) the appropriate number of specimens as follows:

a. Three single spot shear test specimens for spot weld applications.

b. Three macro specimens for wire mesh to sheet or strip applications.

c. Ten specimens duplicating the production item for projection weld applications.

5.4 Specimen Preparation:

5.4.1 Shear Test Specimens - Single spot shear test specimens shall conform to Figure 1, and shall be representative of the joint in the production part insofar as alloy, material thickness, and cleaning methods are concerned. When more than two members are joined by a single spot weld in the production item, representative multiple thickness single spot shear test specimens shall be prepared as shown in Figure 2.

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- 5.4.2 Peel Test Specimens - Peel test specimens shall conform to Figure 3 and shall be representative of the joint in the production item insofar as alloy, thickness of material, and cleaning methods. When more than two members are joined by a single spot weld in the production item, representative specimens shall be welded in such a manner that the welds will be tested at the interfaces of the outer sheets.
- 5.4.3 Macro Specimens - Macro specimens shall conform to Figure 4. The specimen shall be sectioned as shown in Figure 4, polished and etched to reveal weld areas, and examined at approximately 5 times magnification (5X). The specimen shall be representative of the production item.
- 5.4.4 Tensile Test Specimens - Tensile test specimens shall be representative of the production item insofar as alloy, thickness, configuration, and cleaning methods. Figure 5 illustrates a typical tensile test specimen.
- 5.5 Production Check Tests:
 - 5.5.1 In addition to the tests required for machine set up (5.3), the following tests shall be conducted once every 2 hours for set-ups lasting more than 2 hours, at the end of a run, and upon replacement of welding electrodes:
 - a. Spot weld applications - three single spot shear test specimens, or (in lieu of shear test specimens) one five spot peel test specimen, or one proof test of the production item.
 - b. Wire mesh to sheetrod strip applications - one macro specimen.
 - c. Projection weld applications - three tensile test specimens.

Specimens shall be prepared in accordance with 5.4.
 - 5.5.2 Machine settings shall not be varied more than + 5 percent (+ 10 percent when only one setting is involved) from settings established for the production item. Adjustments in excess of this requires a new welding schedule in accordance with 5.3. before production welding is resumed. When a production weld check fails to meet requirements, all items welded since the last check shall be withheld subject to Quality Control action.
- 5.6 Examination and Testing of Specimens:
 - 5.6.1 Shear test specimens and peel test specimens shall be visually examined for the external defects listed in Table I. The acceptable number of defects shall not exceed the limits specified in Table I.

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**WELDING, RESISTANCE; SPOT AND PROJECTION
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- 5.6.2 After visual examination, shear test specimen shall be tested in tension shear. The minimum load and minimum average load shall equal or exceed requirements of Table II or Table III, whichever is applicable.
- 5.6.3 After visual examination, peel test specimens shall be separated by applying force at right angles to the plane of the welds. The load shall be transferred successively from one weld to the next by failure of the preceding weld. Acceptable specimens are those in which failure has occurred in the parent metal around the periphery of the welds ("button type failure" - see Figure 3). Failure in a plane through one weld in a specimen shall be considered unacceptable.
- 5.6.4 Macro specimens shall be visually examined at approximately 5X magnification. Examination shall reveal the presence of some cast weld structure between the sheets and partially surrounding the individual wire strands. Burned off wires and sheet indentation in excess of Table I requirements shall be considered unacceptable.
- 5.6.5 Tensile test specimens (projection weld) shall be tested in such a manner as to apply direct tension loading to the weld. The specimens shall withstand the tensile load specified on the Engineering Drawing. In addition the minimum average tensile load for the specimens shall be 1.25 times the minimum tensile load specified.
- 5.7 Fit of Mating Parts:
- 5.7.1 Mating parts assembled for welding shall fit so that before the first and each successive weld is made, the surfaces to be joined by the weld are in contact with each other or can be made to contact each other with light manual pressure at the area where the weld is to be placed. Parts not meeting this requirement shall be rejected and corrective action initiated.
- 5.8 Tack Welds:
- 5.8.1 Tack welds require no test specimens and are not subject to the requirements of this specification except to the extent of defects that may be detrimental to the production item. Any defects present shall not exceed limits established for production items.
- 5.9 Production Parts:
- 5.9.1 Completed production parts shall be examined visually for the applicable defects listed in Table I. The acceptable number of external defects shall not exceed the limits established in Table I.
- 5.9.2 Parts not meeting 5.9.1 requirements shall be rejected subject to M. R. B. procedures.

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WELDING, RESISTANCE; SPOT AND PROJECTION

(Non-Critical)

Thickness of Thinnest Member (inch)	Width (W) min. Aluminum (inch)	Width (W) min. Magnesium (inch)	Width (W) min. Steels, Copper and Nickel Alloys (inch)	Length (A) All Alloys
0.030 and under	5/8	3/4	5/8	As Required to perform test
0.031 to 0.050	3/4	3/4	1	
0.051 to 0.100	1	1	1	
0.101 to 0.130	1 1/4	1 1/4	1 1/4	
0.131 and over	1 1/2	1 1/2	1 1/4	

Weld shall be
within 1/16" from
center

FIGURE 1 SINGLE SPOT SHEAR TEST SPECIMEN

Test strips may be laid crosswise
or parallel with loaded members or
may be short or bent out of the way,
however, overlap (W) must be
maintained.

FIGURE 2 MULTIPLE THICKNESS SPECIMEN

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WELDING, RESISTANCE; SPOT AND PROJECTION
(Non-Critical)

Thickness of Thinnest Member (inch)	Width (W) min. Aluminum (inch)	Width (W) min. Magnesium (inch)	Width (W) min. Steels, Copper and Nickel Alloys (inch)	Spot Spacing (S) All Alloys
0.030 and under	5/8	3/4	5/8	As Specified On Drawing
0.031 to 0.050	3/4	1	1	
0.051 to 0.100	1	1 1/2	1 1/2	
0.101 to 0.128	1 1/2	1 1/2	1 1/2	
0.129 and over	1 1/2	1 1/2	2	

FIGURE 3 PEEL TEST SPECIMENS. (Figure at top is a two member joint specimen. Lower figure illustrates a three member joint specimen after "peeling" showing weld "buttons".)

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- NOTES:
1. One or more layers of wire mesh may be used as required to simulate production joint as to thickness of individual wires, number of mesh openings per square inch and composition and temper of wire mesh.
 2. Cut along Section A-A for preparation of macro-specimens.
 3. Thickness, composition and temper of sheet and strip shall duplicate production joints.

FIGURE 4 MACRO SPECIMEN - WIRE MESH TO SHEET AND STRIP APPLICATIONS.

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(Non-Critical)

NUT TO SHEET ASSEMBLY

FIGURE 5 TENSILE TEST SPECIMEN - TYPICAL PROJECTION WELD ASSEMBLY.

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**WELDING, RESISTANCE; SPOT AND PROJECTION
(Non-Critical)**

Nature of Weld Defect	Acceptable Defects in Percent of Spot Welds (Nearest Whole Number)	3
Cracks open to the surface	5	
Edge bulge cracks	10	
Sheet separation exceeding limits	10	1 4
Pits more than 1/16" diameter	10	
Pits less than 1/16" diameter	10	
Metal expulsion between sheets (spits) and surface flashes	10	4
Electrode pick-up	5	
Excessive indentation	10	2

- 1 Sheet separation is not acceptable if in excess of 15% of the average thickness of the two outer sheets joined, or 0.006 inch, whichever is greater.
- 2 Surface Indentation - Electrode indentation is excessive when it exceeds 20% of the thickness of the sheet in which the indentation occurs or 0.005 inch, whichever is greater.
- 3 The total of all defects shall not exceed 20 percent.
- 4 These defects are not applicable to wire mesh to sheet and strip applications.

TABLE I - Maximum Acceptable Number of External Defects.

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Nominal • Thickness of Thinner sheet (inches)	Aluminum And Aluminum Alloys								Magnesium Alloys	
	Ultimate Strength 56,000 psi and above 1		Ultimate Strength 28,000 psi to 56,000 psi 2		Ultimate Strength 19,500 psi to 28,000 psi 3		Ultimate Strength Below 19,500 psi 4		Ultimate Strength Above 19,500 psi	
	(Pounds per weld)		(Pounds per weld)		(Pounds per weld)		(Pounds per weld)		(Pounds per weld)	
	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.
0.012	60	70	55	65	25	30	15	20	--	--
0.016	90	105	80	95	55	70	40	50	--	--
0.020	115	135	105	125	80	95	65	75	60	80
0.025	150	175	140	170	110	140	90	105	80	110
0.032	210	250	190	225	170	200	135	160	120	160
0.040	280	330	250	295	245	285	185	215	160	215
0.050	390	460	360	425	335	395	245	285	210	280
0.063	560	660	510	600	460	540	325	385	285	375
0.071	685	810	595	705	530	625	370	435	320	425
0.080	855	1005	705	825	630	740	430	505	365	490
0.090	1035	1210	825	970	715	840	490	580	430	570
0.100	1245	1470	975	1145	770	910	555	655	495	660
0.125	1725	2025	1320	1555	855	1005	610	750	635	840
0.160	2435	2865	1825	2145	945	1110	685	805	--	--
0.190	3250	3725	2365	2785	1300	1530	880	1035	--	--

NOTE: Strength of material shall be based on its guaranteed minimum ultimate tensile strength. In case of "O" temper the maximum tensile shall apply.

- 1 2014-T4, 2014-T6, 2024-T3, 2024-T36, 2024-T42, 2024-T6, 2024-T81, 2024-T86, 7075-T6, 7178-T6, 2219-T81, 2219-T87.
- 2 5052-H32, 5052-H34, 5052-H36, 5052-H38, 6061-T6, 7075-O, 5083-H34, 5086-O, 5086-H32, 5086-H34, 5086-H36, 5456-O, 5456-H343, 6061-T4, 7178-O, 2014-O, 2014-T3, 5052-O, 5083-O, 5083-H32, 2024-O, 2219-O, 2219-T31, 2219-T37, 2219-T62.
- 3 1100-H18, 3003-H14, 3003-H16, 3003-H18, 6061-O.
- 4 EC-O, EC-H12, EC-H14, EC-H16, EC-H18, 1100-O, 1100-H12, 1100-H14, 1100-H16, 3003-O, 3003-H12
- * Based on MS 33528 (Alternate MIL-STD-204).

TABLE II - Minimum Required Strength per Weld and Minimum Average Strength for Spot Weld Shear Specimens.

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**WELDING, RESISTANCE; SPOT AND PROJECTION
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Nominal * Thickness of Thinner Sheet (inches)	FERROUS, NICKEL-BASE, COPPER-BASE, AND HEAT RESISTING ALLOYS					
	Ultimate Strength 1 150,000 psi and above		Ultimate Strength 2 90,000 to 150,000 psi		Ultimate Strength 3 Below 90,000 psi	
	(Pounds per weld)		(Pounds per weld)		(Pounds per weld)	
	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.
0.006	60	75	45	60	---	---
0.008	100	120	70	85	60	70
0.010	135	165	105	125	75	90
0.012	180	220	130	160	100	120
0.016	260	320	190	235	140	170
0.018	320	390	220	270	165	200
0.020	345	425	255	310	180	225
0.025	470	580	345	425	260	320
0.028	610	755	460	565	330	405
0.032	680	830	505	620	365	450
0.036	850	1045	620	770	470	580
0.040	950	1170	690	850	530	650
0.045	1165	1435	835	1030	655	805
0.050	1380	1705	980	1205	775	960
0.056	1465	2045	1150	1420	950	1170
0.063	2210	2480	1370	1685	1145	1410
0.071	2430	2985	1650	2030	1350	1665
0.080	2865	3535	1955	2410	1495	1965
0.090	3310	4080	2285	2820	1875	2315
0.100	3720	4585	2600	3210	2145	2645
0.112	4135	5105	2955	3645	2465	3040
0.125	4600	5675	3290	4065	2795	3450
0.141	----	----	----	----	6260	6615
0.160	----	----	----	----	7995	8795
0.187	----	----	----	----	10335	11260
0.250	----	----	----	----	15700	18040

NOTE: Strength of material shall be based on its guaranteed minimum ultimate tensile strength.

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Corrosion Resistant Steels - Type 302 (1/2H), Type 301 (1/2H)

Corrosion Resistant Steels - Type 302 (1/4H), Type 301 (1/4H), 19-9DL

Corrosion Resistant Steels - Type 347 (annealed), Type 302 (annealed),
Type 301 (annealed), Type 321 (annealed), Type 304L (annealed), Type 304 (annealed)

Nickel Alloy - Inconel (annealed)

Low Carbon Steel - A1S1-1010, A1S1-1015, QQ-S-698 (0.15C. Max.)

All Copper Alloys

- * Based on MS33528 (alternate MIL-STD-204).

TABLE III - Minimum Required Strength per Weld and Minimum Average Strength for Spot Weld Shear Specimens.

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**WELDING, RESISTANCE; SPOT AND PROJECTION
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MATERIAL	THICKNESS (Inches)	Desirable Resistance upon Deoxidation (Microhms)	Maximum Resistance at the Time of Welding (Microhms)
2024 Alclad	Under .020 Over .020 *	20 30	35 100
7075 Alclad	Under .032 Over .032 *	20 30	50 100
All Other Aluminum Alloys	.012 to .125	30	100
All Magnesium Alloys	.000 to .125	50	75

- * From and including this size.

TABLE IV - Contact Surface Resistance

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SOLDERING ELECTRICAL COMPONENTS

1. SCOPE:

1.1 APPLICATION: This specification establishes the requirements to be met by the Martin Company and subcontractors to join electrical components by hand-soldering techniques. Other processes may be used by subcontractors provided these processes have prior approval by Martin Company Quality and the requirements of this specification are met.

1.2 ENGINEERING INFORMATION:

1.2.1 The Engineering drawing shall specify this process specification, the applicable type number, and the solder to be used if other than that specified herein.

1.2.2 All heat sensitive parts shall be designated on the Engineering drawing.

1.3 TYPES:

1.3.1 Type I - Soldering which meets the requirements of MIL-S-45743.

1.3.2 Type II - Soldering which meets the requirements of MIL-S-6872A.

1.4 EQUIVALENT GOVERNMENT SPECIFICATIONS:

1.4.1 Type I - MIL-S-45743 is an equivalent process specification.

1.4.2 Type II - There is no equivalent government process specification; however, items produced as specified herein will meet the applicable requirements of MIL-S-6872A, MIL-STD-440, and MIL-E-5400F.

2. APPLICABLE DOCUMENTS: The following specifications, standards and publications form a part of this specification to the extent specified herein.

2.1 GOVERNMENT SPECIFICATIONS AND STANDARDS:

2.1.1 MIL-STD-440 - Soldering Techniques for Standard Type Solder Terminals

2.1.2 MIL-E-5400F - Electronic Equipment, Aircraft, General Specification for

2.1.3 MIL-S-6872A - Soldering Process, General Specification for

2.1.4 MIL-S-45743 - Soldering Electrical Connections for Guided and Ballistic Missiles, with Electrically-Heated Soldering Irons and Resistance Soldering Apparatus, Procedures for

2.2 MARTIN SPECIFICATIONS AND STANDARDS:

2.2.1 EPS85092, Wire and Cable Preparation and Shield Termination.

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K. Mills	C	N. Miller	C	B. Peterson	C

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3. REQUIREMENTS:

3.1 MATERIALS:

3.1.1 Solder Wire, Energized Resin Core

SPEC: MMS Y452
CODE: Y452A (SN60)
Y452B (SN63)

3.1.2 Flux, Soldering, Liquid

SPEC: MMS Y491
CODE: Y491A

* 3.1.3 Isopropyl Alcohol, Technical

SPEC: TT-I-735
CODE: K564A

* Hazardous material.

3.1.4 Solder Bar - SN63

SPEC: QQ-S-571 SN63-B
CODE: Y454A

3.2 EQUIPMENT: Specialized equipment is not required for this process specification, however, tooling and equipment for Type I soldering shall meet the requirements of MIL-S-45743.

3.3 PRODUCT:

3.3.1 GENERAL: These are requirements applicable to both Type I and Type II callouts.

3.3.1.1 WIRE AND CABLE PREPARATION: Wires and cables shall be prepared for termination in accordance with the applicable paragraphs of EPS85092.

3.3.1.2 SOLDER APPEARANCE AND QUANTITY:

3.3.1.2.1 Solder joints shall be smooth, shiny, and clean. The contour of the wire and terminal (excluding solder cups) shall be clearly visible. Solder globules, sharp points, and pits are unacceptable.

3.3.1.2.2 There shall be no evidence of cold solder joints. The solder at such joints lacks metallic luster and usually presents a rough chalky piled-up appearance. Good solder joints have a smooth metallic appearance.

3.3.1.2.3 The use of solder shall be limited to that amount necessary to make a satisfactory joint.

3.3.1.3 REQUIREMENTS FOR TERMINALS:

3.3.1.3.1 Wires or leads must be confined to the portion of the terminal designed to accept the connection.

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3.3.1.3.2 Eyelet and slotted terminals shall have the wire leads placed through the slot or opening.

3.3.1.3.3 Lead extensions or service tabs shall not be permitted.

3.3.1.3.4 Conductors shall be sufficiently long to prevent tension; sharp bends with radius of curvature less than the conductor diameter shall be avoided.

3.3.1.4 SOLDER JOINT APPEARANCE:

3.3.1.4.1 There shall be no shorting path between conductive parts from solder splash or other conductive debris. All such debris shall be removed or preferably prevented with active cleanliness and technique procedures.

3.3.1.4.2 Charring, or melting of wires or components, shall not be acceptable. A slight discoloration of the insulation is permissible.

3.3.1.4.3 The insulation shall not have a frayed appearance.

3.3.2 TYPE I:

3.3.2.1 REQUIREMENTS FOR TERMINALS:

3.3.2.1.1 On wire AWG 12 and smaller, the bare conductor shall extend no further from the solder joint than a distance equal to the outside diameter of the insulation. For AWG 10 and larger, the distance shall be $1/8" + 1/16" - 0"$.

3.3.2.1.2 The reduction of conductor size, by any method, shall not be permitted.

3.3.2.1.3 The stranded conductors shall be positioned to avoid undesirable interference.

3.3.2.1.4 In no case shall a conductor be hooked more than a half turn around a terminal.

3.3.2.1.5 Slotted terminal connections shall be in accordance with Figure 1.

3.3.2.1.6 Turret type terminal connections shall be in accordance with Figure 2, 3, or 4. Conductors shall be placed along not more than 80% of the turret length at least 10% of the terminal must be left vacant on each end.

3.3.2.1.7 Eyelet type terminal connections shall be in accordance with Figure 5.

3.3.2.1.8 Hook type terminal connections shall be in accordance with Figure 6.

3.3.2.1.9 Solder cups shall be filled per Figure 8.

3.3.2.1.10 Conductors shall be positioned in solder cups in accordance with Figure 7.

3.3.2.2 SOLDER JOINT APPEARANCE:

3.3.2.2.1 Flux residue shall be removed.

3.3.2.2.2 No solder shall have run down the terminal.

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FIGURE 1 - BIFURCATED HOLLOW TERMINAL

FIGURE 2 - DOUBLE -ENDED TERMINAL

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FIGURE 3 - SOLID TERMINAL

FIGURE 4 - MULTI-TERMINATION

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FIGURE 5 - EYELET TERMINAL

FIGURE 6 - HOOK TERMINAL

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FIGURE 7 - WIRE INSERTED IN HOLE

FIGURE 8 - FILLING THE HOLE WITH SOLDER

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3.3.3 TYPE II:

3.3.3.1 REQUIREMENTS FOR TERMINALS:

3.3.3.1.1 Wires and leads shall be wrapped 1/2 to 1 turn around a terminal except solder cups.

NOTE: One turn equals 360° or 4 right angle bends in a lead.

3.3.3.1.2 Leads shall have been squeezed sufficiently to provide secure mechanical connections prior to soldering.

3.3.3.1.3 Insulated leads of AWG 12 and smaller may have been stripped back up to 1/8" from the terminal edge. Insulated leads AWG 10 and larger may have up to 1/4" of bare wire from the terminal edge to the insulation.

3.3.3.1.4 Unless otherwise specified by the Engineering Drawing, conductor strands shall not be removed from conductors to fit them into undersized solder cups.

3.3.3.2 SOLDER JOINT APPEARANCE:

3.3.3.2.1 Flux residue need not be removed unless it interferes with the operation of the part.

3.4 FABRICATION CONTROL:

3.4.1 GENERAL: These are requirements applicable to Type I and Type II callouts.

3.4.1.1 Wire and cable shall be prepared for termination in accordance with EPS85092.

3.4.1.2 SOLDER: Unless otherwise specified by the Engineering Drawing, MMS Y452, SN60 or SN63 (3.1.1) shall be used for all soldering applications. Solder pots shall be filled or replenished with QQ-S-571-SN63-B material. Solder pots shall be maintained at a minimum of 50% Sn at all times.

3.4.1.3 SOLDERING TECHNIQUE:

3.4.1.3.1 Solder shall be applied in a manner which ensures wetting of the parts to be joined.

3.4.1.3.2 Soldering shall be done in a manner which insures that the entire joint which is to be soldered has been heated above the temperature required for good solder flow.

3.4.1.3.3 Solder joints shall be cooled naturally and shall remain motionless until solidification of the solder has occurred.

3.4.1.3.4 Devices identified by the Engineering Drawing as being heat sensitive shall be soldered using heat sink protection. Heat sinks may also be used for other soldering operations, at the discretion of Manufacturing.

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3.4.1.3.5 Capillary flow of solder shall be held to a minimum.

3.4.1.3.6 Resoldering, when necessary, shall be done after the parts and wires have been cleaned and refluxed.

3.4.2 TYPE I - FABRICATION CONTROL:

3.4.2.1 LIQUID FLUX: Liquid flux, if used, shall be in accordance with MMS Y491.

3.4.2.2 SOLVENTS: Isopropyl alcohol (TT-I-735) shall be used for solvent cleaning of parts and flux removal.

3.4.2.3 SOLDERING PROCEDURE:

3.4.2.3.1 TINNING CONDUCTORS: All conductors shall be tinned before soldering. The tinning of a conductor shall extend only far enough to take full advantage of the contact area of the terminal or receptacle.

3.4.3 TYPE II FABRICATION CONTROL:

3.4.3.1 CLEANING: Parts may only be cleaned when sample soldering reveals the inability of the part to accept normal soldering techniques. Methods of cleaning or disposition of parts shall be under Quality cognizance. Cleaning techniques must not make the part unacceptable under its original procurement specification.

3.4.3.2 Wires and parts shall be pre-tinned. Items which are already pre-tinned do not require additional pre-tinning.

3.4.3.3 The quantity of solder used shall be sufficient to outline the joint.

3.4.3.4 FLUX REMOVAL: Flux shall be removed (when necessary) in a manner which will not effect the electrical or mechanical properties of the part being treated.

3.5 SPECIAL SKILLS: Only personnel holding valid soldering certification shall be permitted to perform soldering operations in accordance with this EPS.

3.6 SAFETY: Materials called out in this specification are hazardous. Refer to Division Safety Procedures for handling these materials.

4. QUALITY ASSURANCE:

4.1 Quality shall ensure conformance to this process specification.

4.1.1 Quality shall ensure conformance to MIL-S-45743 for Type I soldering.

4.1.2 Quality shall ensure that soldering personnel hold valid soldering certification cards.

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PROCESS SPECIFICATION

TERMINALS, SPLICES, AND FERRULES-CRIMPED TYPE, ASSEMBLY OF

EFFECTIVITY: This amendment forms a part of EPS 85081A and is effective on date of issue.

Change paragraph 2.1.1, 2.1.2, 2.1.3, 2.1.4, and 2.1.6 as follows:

2.1.1 MIL-T-7528E (ASG), Terminals; Lug and Splice, Crimp-Style, Copper

2.1.2 MIL-F-21608A, Ferrule, Shield Grounding, Insulated, Crimp-Style, Brass

2.1.3 MIL-T-7099D, Terminals, Lug, Grip Style, for Aluminum Aircraft Cable

2.1.4 MS25037C, Crimping Tool-Hand, for Copper Insulated Terminals

2.1.6 MS25312A, Tool, Crimping, Hand, for Insulated Shield Ground Ferrule

Change the last sentence of 3.4.1.4 as follows:

3.4.1.4 The insulated conductor shall be pulled through the shield with a blunt, smooth awl, a lead extractor, or the shield may be combed out and then twisted into a pigtail or three-plait braided.

Change 3.4.2.3 to 3.4.2.2

Add FIGURE 10C as follows:

C. PIGTAIL SPLICE WITH SHIELD CARRIED THROUGH

Change 3.4.4.2.2 as follows:

3.4.4.2.2 For one piece uninsulated ferrules the assembly procedure shall be the same as illustrated in Figure 12, except the crimped ferrule shall then be insulated.

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TERMINALS, SPLICES AND FERRULES-CRIMPED-TYPE, ASSEMBLY OF

1. SCOPE:
- 1.1 Application: This specification establishes the requirements to be met by the Martin Company and subcontractors for the assembly and installation of crimp type terminals, splices and ferrules for electrical equipment. Other processes may be used by subcontractors, providing these processes have prior approval by Martin Company Quality and the requirements of this specification are met.
- 1.2 Engineering Information: The Engineering drawing shall specify this process, and, as applicable, provisions for:
- (a) the type and size of hardware used.
 - (b) the type and size of ground wire.
 - (c) environmental protection for the terminals, ferrules, and/or splices in accordance with the applicable process specification.
 - (d) the type and size of insulation, if other than heat shrinkable tubing and the method of securing.
 - (e) the color of insulation tubing. If no tubing color is specified, white will be used.
- 1.3 There is no equivalent Government Process Specification.
2. APPLICABLE DOCUMENTS: The following specifications, standards and publications form a part of this specification to the extent specified herein.
- 2.1 Government Specifications and Standards:
- 2.1.1 MIL-T-928 (ASG), Terminals Lug and Splice, Crimp-Style, Copper
- 2.1.2 MIL-F-21608, Ferrule, Shield Grounding Insulated, Crimp-Style, Brass
- 2.1.3 MIL-T-9099, Terminals, Lug, Grip Style, for Aluminum Aircraft Cable
- 2.1.4 MS 25037, Crimping Tool - Hand, for Copper Insulated Terminals
- 2.1.5 MS 25020, Crimping Tool - Hand for Aluminum Terminals
- 2.1.6 MS 25312, Tool, Crimping, Hand, for Insulated Shield Ground Ferrule
- 2.2 Martin Specifications and Standards:
- 2.2.1 EPS85080, Heat Shrinkable Tubing and Molded Parts

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3. REQUIREMENTS:

3.1 Materials:

- 3.1.1 *Tubing, Polyolefin, Heat Shrinkable
SPEC: MMS F110
CODE: F110----

*NOTE: The last four digits are determined by tubing size required for the specific application.

3.2 Equipment:

3.2.1 Crimping Tools

- 3.2.1.1 All crimping tools used in conjunction with this process specification shall have a positive closing mechanism (a ratchet or similarly operating device) which will assure that the tool, once the closing operation is initiated, follows through to a fully closed position before the releasing operation can be effected. The travel of each indenter between the final mechanical release position and the fully closed position shall not exceed 0.005 inch.

NOTE: Hydraulic-pneumatic crimping tools which do not have a positive closing action shall be considered acceptable for use, if the full crimping cycle has been witnessed by a Quality inspector.

- 3.2.1.2 Copper or aluminum terminals and splices shall be crimped with tooling conforming to MS2503⁷ or MS25020, respectively, or with tooling which has demonstrated the capability of crimping applicable terminals and splices to the requirements of this process specification.

- 3.2.1.3 Ferrules shall be crimped with tooling conforming to MS25312 or tooling which has demonstrated the capability of crimping applicable ferrules to the requirements of this process specification.

- 3.2.2 Stripping tools - Mechanical or "Hot Blade" strippers of the hand or bench type, which are capable of adjustment and calibration, or fixed type which may be calibrated so that they strip the wire with no damage to the conductor strands, shall be used to accomplish stripping operation.

3.3 Product:

- 3.3.1 Crimped items shall exhibit no damage such as fracturing, spalling, or protruding sharp edges as the result of the crimping operation.

- 3.3.2 The conductor, ground wire, and/or shield, if applicable, shall be visible in all inspection holes or openings which allow for visual verification after crimping.

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- 3.3.3 When the applicable tooling employs proof marks, the proof mark shall be clearly visible on the crimped terminal, ferrule, or splice.
- 3.3.4 Preinsulated Devices - The insulation of preinsulated splices, terminals, or ferrules shall remain in its original position and shall overlap the conductor insulation. There shall be no evidence of fracture of the insulation of crimped devices or of damage to the conductor insulation due to the crimping operation.
- 3.3.5 Post-Insulated Devices - The insulation shall be positioned so as to extend over the conductor insulation a minimum of 1/8 inch or shall be centered over the crimped connection, whichever is applicable. If the post-insulation is crimped over the conductor insulation, there shall be only slight deformation of both insulations.
- 3.3.6 Tensile Strength - The mechanical connection of the wire and the terminal, splice, and/or ferrule shall not break or become deformed to the extent that it is unfit for further use before the minimum tensile strength requirements have been met. Tensile testing shall be accomplished on representative samples in accordance with Table I and Paragraph 4.2.1.
- 3.3.6.1 Aluminum splices, terminals, and ferrules shall meet the tensile requirements specified in Table II when tested on representative samples in accordance with Paragraph 4.2.1.
- 3.3.6.2 For multi-wire crimps, each wire crimped shall meet the tensile requirements of Table I or II.
- 3.3.7 Uninsulated splices, ferrules or terminals shall be insulated and the insulation shrunk in place in accordance with EPS85080, unless otherwise specified by the Engineering drawing. The insulation shall extend at least 1/4 inch beyond each side of the hardware.
- 3.3.8 The final crimped item shall be capable of meeting the requirements of MIL-T-928 for copper terminals and splices, MIL-F-21608 for brass ferrules, and MIL-T-999 for aluminum terminals.
- 3.4 Fabrication Control
- 3.4.1 Wire Preparation
- 3.4.1.1 Wire strip lengths shall be inspected prior to crimping for proper strip length and to insure that there are no nicked, cut, broken, shaved, or contaminated strands. The primary and/or secondary insulation shall show no evidence of fraying or charring. Slight discoloration shall not be cause for rejection, however, copper showing on coated conductor stranding after stripping is cause for rejection.

NOTE Inspection for strand damage shall be accomplished with the unaided eye.

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3.4.1.2

Conductors shall be prepared as illustrated in Figures 1 through 5, as applicable, to the method of termination. The proper strip length (dimension A) shall be the length of the crimp barrel of the device being crimped onto the conductor $+1/16$ -0 inch. The length of exposed conductor insulation of shield wire or cable (dimension B), shall be $1/2$ inch minimum and $2 1/2$ inch maximum.

SINGLE CONDUCTOR UNSHIELDED WIRE
FIGURE 1

SHIELD JACKET

SINGLE CONDUCTOR SHIELDED WIRE
FIGURE 2

MULTIPLE CONDUCTOR SHIELDED WIRE
FIGURE 3

*See Figure 11 for deviation from this requirement as specified in paragraph 3.4.4.1.

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SINGLE CONDUCTOR OR SHIELD BREAKOUT
FIGURE 4

MULTIPLE CONDUCTOR SHIELD BREAKOUT
FIGURE 5

- 3.4.1.3 When a ferrule or dead-end shield termination is required, the wire or cable shall be prepared as illustrated in Figures 2 or 3. The proper length of exposed conductor shall be determined by the termination method. The shield braid length (dimension C) shall be the length of the barrel to be crimped $+1/16$, -0 , unless otherwise specified. For deadending, shield braid length shall be flush within 1/8 inch to the shield jacket.
- 3.4.1.4 When shields are pigtailed for grounding purposes, either with or without hardware, the wire shall be prepared as illustrated in Figures 4 or 5. The proper length of pigtail (dimension C) shall be determined by the application. The insulated conductor shall be pulled through the shield with a blunt or smooth awl, a lead extractor, or the shield may be combed out and then twisted into a pigtail or free-plait braided.
- 3.4.2 General Crimping Operation:
- 3.4.2.1 All conductor or shield strands shall be inserted into the crimp barrel before crimping.

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TABLE I-TENSILE STRENGTH REQUIREMENTS (COPPER)			
Wire Size (AWG)	Tensile Strength (Lbs.)	Wire Size	Tensile Strength (Lbs.)
26	7	8	225
24	10	6	300
22	15	4	400
20	19	2	550
18	38	1	650
16	50	0	700
14	70	00	750
12	110	000	825
10	150	0000	875

TABLE II-TENSILE STRENGTH REQUIREMENTS (ALUMINUM)			
Cable Size AWG	Tensile Strength (Lbs.)	Cable Size	Tensile Strength (Lbs.)
8	130	0	900
6	200	00	1100
4	300	000	1300
2	500	0000	1500
1	700		

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- 3.4.2.3 All crimping operations shall be accomplished with tools qualified and calibrated for the items being crimped.
- 3.4.3 Splicing:
- 3.4.3.1 Splicing unshielded wire with single piece, uninsulated splices shall be accomplished in accordance with Figures 6 and 7. Tubing specified for insulation or sealing shall be positioned on wire(s) prior to crimping and centered over the splice area after crimping. Insulation shall cover all exposed hardware and conductor. The wires shall completely overlap within the splice barrel, except for double crimped splices.

NOTE: For pigtail splices insulation may be applied after crimping.

FIGURE 6-SINGLE PIECE, UNINSULATED SPLICE OPERATION

A) IN LINE SPLICE

B) PIGTAIL SPLICE

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C DOUBLE CRIMP OPERATION

FIGURE 7 - SINGLE PIECE UNINSULATED SPLICE OPERATION

3.4.3.2

Splicing unshielded wire with one piece pre-insulated splices shall be accomplished in accordance with Figure 8.

FIGURE 8 SINGLE PIECE, PRE-INSULATED SPLICE OPERATION

3.4.3.2.1

The conductor shall be visible when viewed through the inspection opening.

3.4.3.3

Splicing unshielded wire with one piece post-insulated splices shall be accomplished in accordance with Figure 9.

NOTE: When splicing 8 gage and larger wire, rotate the splice 180° after the first crimp to prevent misalignment.

3.4.3.3.1

The conductor wire shall be visible when viewed through the inspection opening.

3.4.3.3.2

Use of the bushing shall be applicable when filling voids inbetween the wire and post insulation in order to effect a seal on the splice, providing the bushing fits freely over the wire insulation and under the post insulation.

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A. PRE-CRIMPING OPERATION

B. COMPLETED SPLICE

C. POST-INSULATED SLEEVE CRIMPING

FIGURE 9 CRIMPING SEQUENCE FOR POST-INSULATED SPLICES

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3.4.3.4 Splicing shielded wire with single piece, uninsulated splices shall be accomplished in accordance with Figure 10.

3.4.3.4.1 The spliced conductors shall completely overlap in the splice barrel, and shall be insulated separately. The shield and hardware shall be insulated by the overall insulation. The whole configuration shall be sealed if applicable.

A. IN-LINE SPLICE

B. PIGTAIL SPLICE

FIGURE 10 - SHIELDED WIRE SPLICING OPERATION WITH ONE PIECE, UNINSULATED SPLICES

3.4.3.4.2 When positioning multi-wire splices, the splices shall be staggered to reduce the possibility of electrical shorting and to reduce bundle diameters. If possible, no two splices shall be touching each other in the staggered bundle.

3.4.3.4.3 The shielding on pigtail splices may be pigtailed and spliced together.

3.4.3.4.4 When the Engineering drawing specifies a splice size larger than the calculated circular mill area, the process plan or Manufacturing Process may specify the use of filler wire.

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3.4.4

Ferrule Crimping:

3.4.4.1

Shield grounding using, two piece, uninsulated ferrules shall be accomplished in accordance with Figure 11.

FIGURE 11 - COMPLETED FERRULE ASSEMBLY

3.4.4.1.1

Ground wire shall be as specified on the Engineering drawing, and when installed the bared wire shall not extend beyond the ferrule except at the end where the ground wire is terminated.

3.4.4.2

Shielded wire termination with one piece insulated ferrules shall be accomplished in accordance with Figure 12.

FIGURE 12 - ONE PIECE INSULATED FERRULE SHIELD TERMINATION

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3.4.4.2.1 Shield and ground wire, if applicable, shall be bottomed in the one piece insulated ferrule before crimping.

3.4.4.2.2 For one piece uninsulated ferrules the assembly procedure shall be the same as illustrated in Figure 12, except the crimped ferrule shall be insulated.

3.4.5 Shield Terminations and Grouping:

3.4.5.1 Individual Shield Termination.

3.4.5.1.1 Individual shield terminations shall be accomplished in accordance with Figure 13.

FIGURE 13 - INDIVIDUAL SHIELD TERMINATION

3.4.5.1.2 Pieces of tubing shall be used to cover; (1) the exposed shield, (2) the area where the shield breaks out, and (3) the area where the shield is crimped to the insulated wire.

3.4.5.2 Shield Grouping.

3.4.5.2.1 Shields which are pigtailed in a group shall be terminated in accordance with Figure 14.

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FIGURE 14 - GROUP SHIELD TERMINATION

- 3.4.5.2.2 For crimped terminations the shields shall overlap the wire in the splice barrel, and shall completely fill the hardware to be crimped.
- 3.4.5.2.3 Insulation tubing shall cover all exposed shields and hardware.
- 3.4.5.2.4 Shields which are terminated and grouped using a ferrule shall be terminated in accordance with Figure 15.

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a) FOR GROUND EQUIPMENT APPLICATIONS ONLY

b) FOR AIRBORNE OR GROUND EQUIPMENT

FIGURE 15 - SHIELD TERMINATION & GROUPING WITH FERRULES

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3.4.5.2.5 Floating shield terminations shall be in accordance with Figure 16.

FIGURE 16-FLOATED SHIELD TERMINATION

3.4.6 Terminal Crimping:

3.4.6.1 Terminal connections for wire shall be terminated in accordance with Figures 17, 18, and 19.

INSULATED CRIMP TERMINAL
FIGURE 17

NON-INSULATED CRIMP TERMINAL
FIGURE 18

FLAG TERMINAL CRIMP
FIGURE 19

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- 3.4.6.2 Flag terminal boots shall be positioned on the terminal and shrunk to a fit which can be moved only by deforming the insulation. Nicks, cracks, tears, and other damage detrimental to the insulation and/or terminal shall be cause for rejection.

3.4.7 End Cap Crimping:

- 3.4.7.1 Pre-insulated end cap termination shall be accomplished in accordance with Figures 20 and 21 for both single and multiple terminations, depending on the size cap specified by the Engineering drawing.

END CAP ASSEMBLY
FIGURE 20

CRIMPED END CAP
FIGURE 21

- 3.4.7.1.1 Wire(s) shall be bottomed in the cap prior to crimping.
- 3.3.7.1.2 For multi-wire configurations, the individual wires shall be stripped in accordance with the wire preparation section of this process.
- 3.4.8 Weld Tab Crimping:
- 3.4.8.1 Weld tab crimping shall be accomplished in accordance with Figure 22.
- 3.4.8.2 For AWG 28 and 30 gage wire, the tensile strength shall be considered acceptable if the wire breaks before the crimp becomes disconnected.

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PROCESS SPECIFICATION

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FIGURE 22 - WELD TAB CRIMPING OPERATION

4. QUALITY ASSURANCE:

- 4.1 Quality shall ensure conformance to the requirements of this process.
- 4.2 Quality shall make the required tensile pull tests to ensure conformance to this specification.
 - 4.2.1 Tensile Strength - Samples shall be placed in a standard tensile-testing machine and sufficient force applied to pull the wire out of the sample, or break the wire or sample. The mechanical connection of the wire and/or sample shall not break loose or become distorted to the extent that it is unfit for further use before the minimum tensile strengths as specified in Tables I and II, are obtained. The test shall be made with a speed-of head travel of 1 inch/minute.
- 4.3 Quality shall establish the necessary controls to ensure crimping operations are accomplished with properly calibrated tools.

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APPENDIX NO. 3

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**MARTIN
COMPANY**

Ident. No. 38597

PROCESS SPECIFICATION

TERMINALS, SPLICES, AND FERRULES - CRIMPED TYPE, ASSEMBLY OF

PROJECT: TITAN II & 624A

EFFECTIVITY: This appendix is effective on date of issue on drawings which have specified DP85012.

1. SCOPE:

1.1 APPLICATION: This appendix establishes the additional requirements to EPS85081-A which are to be met by the Martin Company and subcontractors to assemble crimp type devices when the Engineering Drawing has specified DP85012.

2. APPLICABLE DOCUMENTS:

2.2 MARTIN SPECIFICATIONS AND STANDARDS:

2.2.2 EPS85125, Contacts, Crimping of

3. REQUIREMENTS:

3.3 PRODUCT:

3.3.9 When 58D4 is specified and no size is given on the drawing, the correct size splice shall be selected from Table III.

TABLE III - 58D4 SIZES				
Approved Part Number	Wire Size	Circular Mil Area of Wire	Color	Insulation Dia.
58D4-1	8	13100-20800	Red	.335
58D4-2	6	20800-33100	Blue	.415
58D4-3	4	33100-52600	Yellow	.495
58D4-4	2	52600-83700	Red	.595
58D4-5	1/0	83700-119500	Blue	.745

3.3.10 When 58A9 is specified on the Engineering Drawing and no size is given, the correct size adapter will be selected from Table IV and crimping shall be accomplished in accordance with EPS85125.

TABLE IV 58A9 SIZES		
Approved Callout Number	Wire Size	Contact Size
58A9-1	AN12	16
58A9-3	AN8	12
58A9-5	AN12	20
58A9-6	AN16	20

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3. 3. 11 When 58A10 is specified and no size is given on the drawing, the correct size cap shall be selected from Table V.

TABLE V - 58A10 SIZES		
Approved Part Number	A Insulation Dia. of Wire	Insulator Color Identification
58A10-1	.048-.080	White
58A10-2	.080-.120	Red
58A10-3	.120-.150	Blue
58A10-4	.150-.223	Yellow

3. 3. 12 When 58D12 is specified and no sizes are given the correct sizes shall be selected from Table VI.

TABLE VI 58A12 SIZES							
Approved Part Number	Color	Outer Ring Dimensions		Approved Part Number	Color	Inner Ring Dimensions	
		A I. D.	B O. D.			A I. D.	B O. D.
58D12-1	Tin	.101	.124	58D12-20	Tin	.046	.070
58D12-2	Blue	.125	.156	58D12-21	Yellow	.058	.083
58D12-3	Purple	.149	.179	58D12-22	Red	.063	.088
58D12-4	Yellow	.156	.196	58D12-23	Green	.071	.096
58D12-5	Blue	.180	.204	58D12-24	Blue	.080	.104
58D12-6	Blue	.175	.215	58D12-25	Orange	.090	.114
58D12-7	Orange	.187	.227	58D12-26	Yellow	.101	.124
58D12-8	Tin	.199	.235	58D12-27	Red	.109	.131
58D12-9	Yellow	.207	.243	58D12-28	Tin	.115	.146
58D12-10	Green	.219	.250	58D12-29	Green	.124	.145
58D12-11	Orange	.235	.266	58D12-30	Yellow	.125	.156
58D12-12	Yellow	.261	.297	58D12-31	Orange	.134	.156
58D12-13	Purple	.281	.331	58D12-32	Blue	.150	.181
58D12-14	Green	.300	.335	58D12-33	Red	.156	.191
58D12-15	Yellow	.312	.362	58D12-34	Green	.180	.204
58D12-16	Orange	.344	.394	58D12-35	Blue	.194	.225
58D12-17	Blue	.375	.406	58D12-36	Tin	.219	.243
58D12-18	Red	.405	.453	58D12-37	Blue	.261	.297
58D12-19	Tin	.705	.755	58D12-38	Red	.297	.337

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3.3.13 When 58A15 is specified on the Engineering Drawing and no size is given on the drawing, the correct size splice shall be selected from Table VII.

TABLE VII 58A15 SERIES			
Approved Part Number	Wire Size	Color Identification	Insulation Dia. of Wire
58A15-1	26-22	Yellow	.050-.082
58A15-2	24-20	White	.055-.100
58A15-3	22-18	Red	.080-.125
58A15-4	16-14	Blue	.105-.150
58A15-5	12-10	Yellow	.150-.220

3.3.14 When 58D15 is specified and no size is given on the drawing the correct size splice shall be selected from Table VIII. In the event stock of 58D15 is depleted use 58D30 selected from Table IX.

TABLE VIII 58D15 SERIES		
Approved Part Number	Large End	Small End
58D15-1	14-16	18-22
58D15-2	10-12	18-22
58D15-3	10-12	14-16
58D15-4	8	14-16
58D15-5	8	10-12
58D15-6	6	10-12
58D15-7	6	8
58D15-8	4	8
58D15-9	4	6
58D15-10	2	6
58D15-11	2	4
58D15-12	1/0	4
58D15-13	1/0	2
58D15-14	2/0	2
58D15-15	2/0	1/0
58D15-16	3/0	1/0
58D15-17	3/0	2/0
58D15-18	4/0	2/0

TABLE IX 58D30 SERIES		
Approved Part Number	Large End	Small End
58D30-1	14-16	18-22
58D30-2	10-12	18-22
58D30-3	10-12	14-16
58D30-4	8	14-16
58D30-5	8	10-12
58D30-6	6	10-12
58D30-7	6	8
58D30-8	4	8
58D30-9	4	6
58D30-10	2	6
58D30-11	2	4
58D30-12	1/0	4
58D30-13	1/0	2
58D30-14	2/0	2
58D30-15	2/0	1/0
58D30-16	3/0	1/0
58D30-17	3/0	2/0
58D30-18	4/0	2/0

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3.3.15 When 58E84 (PD58C0005) is specified and no size is given on the drawing, the correct size shall be selected from Table X.

TABLE X 58E84 SERIES		
Approved Part No.	Circular Mill Area	
	Min.	Max.
58E84-1	509	3260
58E84-2	2050	5180
58E84-3	5180	13100
58E84-9	13100	20800
58E84-10	20800	33100
58E84-11	33100	52600
58E84-12	52600	83700
58E84-13	83700	119500

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624A PROJECT

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MANUFACTURING PROCESS

MP-55007

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DIVISION - Baltimore - Manufacturing

This document provides manufacturing data to accomplish the requirements of the Engineering Process Specification (EPS) of the same number dated - 1-26-65 and Appendix No. 1 dated 1-28-65.

SUBJECT: BRAZING OF ALUMINUM AND ALUMINUM ALLOYS.

NOTE see page 23 for acceptance criteria applicable Gemini Program.

1. SCOPE:

- 1.1 This process defines the requirements, safety instructions and controls to be met and the procedure, material and equipment and tools to be utilized in brazing aluminum and aluminum alloys by the torch, furnace or molten flux (dip) methods.
- 1.2 Aluminum brazing is restricted to secondary structure and non critical applications.
- 1.3 Assemblies brazed to this process will not be anodized or "Hard Coated".

2. APPLICABLE DOCUMENTS:

- 2.1 The requirements of the following are not incorporated in this process, and should be referred to as required.
 - 2.1.1 MIL-STD-453 Inspection, Radiographic
 - 2.1.2 MIL-I-6866A Inspection, Fluorescent Penetrant, Method of.
 - 2.1.3 MIL-B-20148A Brazing Alloys, Aluminum and Aluminum Alloy Sheets and Plates, Aluminum Brazing Alloy Clad.
 - 2.1.4 MP 50029 Deoxidation of Aluminum Alloy.
 - 2.1.5 MP 50036 Non-etch Alkaline Cleaning.
 - 2.1.6 MP 80M31 Operation of X-ray equipment.

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3. MATERIALS:

3.1 **Brazing Alloys**

3.1.1 **Brazing Wire (Type 716) 1/8 Dia.**

Spec: QQ-B-655

Code: Y4-19A-625 LB (Not stocked - Order as required)

3.1.2 **Brazing Sheet (Type 716) .003" x 2" wide**

Spec: QQ-B-655

Code: Y4-19A-100 LB (Not stocked - Order as required)

3.1.3 **Brazing Wire (Type 718)**

Spec: QQ-B-655

Code: 1/16 Dia. Y4-19B-563 LB

3/32 Dia. Y4-19B-594 LB (Not stocked - Order as required)

1/8 Dia. Y4-19B-625 LB

3.1.4 **Brazing Sheet (Type 718)**

Spec: QQ-B-655

Code: .003" x 2" wide Y4-19B-199 LB

.005" x 2" wide Y4-19B-120 LB

.010" x 2" wide Y4-19B-140 LB

.015" x 2" wide Y4-19B-160 LB

(Not stocked - Order as required)

3.1.5 **Brazing Powder (Alumibraze)**

Spec: Special Formula (See Note)

Code: 08-749-300 LB (Not Stocked - Order as required)

(EPS Ref. Y416A)

NOTE: Sole source, Handy and Harman, Bridgeport, Conn.

Must be manufactured from Alcoa Dip Brazing Flux (Aluminum Fluoride)

and #718 Aluminum Powder (Fine).

3.2 **Clad Brazing Sheet (Aluminum Alloy Sheets & Plates)**

Spec: MIL-B-20148 Class 1 Temper - F EPS Ref. Y418A

2 F Y418B

3 F Y418C

4 F Y418D

Code: (Not stocked - Order as required.)

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3.3 Flux:

3.3.1 Flux, Aluminum Brazing

Spec: Commercial

Code: Material Code Type Source

* 08-714-600 LB #30 Alcoa

Y4-14B-100 LB #33 Alcoa

⊕ ** 08-714-500 LB #34 Alcoa

Y4-14D-100 LB #53 Alcoa

Y4-14E-100 LB #44 Airco

*(EPS Ref. Y414A) ** (EPS Ref. Y414C)

(Not stocked - Order as required)

⊕ 3.3.2 Flux, Aluminum Fluoride

Spec: Commercial (Alcoa)

Code: 08-506-700 LB (Not stocked - Order as required.)
(EPS Ref. Y417A)

⊕ 3.4 Lithium Chloride (Crystalline Powder - Reagent Code 1874)

Spec: Commercial

Code: 08-504-400 LB (Not stocked - Order as required)
(EPS Ref. K855A)

⊕ 3.5 Sodium Fluoride (Technical Grade) Stop Off.

Spec: Commercial

Code: 08-506-600 LB (Not stocked - Order as required)
(EPS Ref. K854A)

3.6 Acid, Cleaning

⊕ 3.6.1 Nitric Acid (Technical Grade)

Spec: O-N-350

Code: 08-500-500 CA
(EPS Ref. K822A)

⊕ 3.6.2 Hydrofluoric Acid (Technical Grade)

Spec: O-H-795

Code: 08-500-300 CA
(EPS Ref. K829A)

⊕ 3.6.3 Sulphuric Acid (Technical Grade)

Spec: O-S-809

Code: 08-501-400 CA (Not stocked - Order as required)
(EPS Ref. K844A)

3.7 Gases, Torch Brazing

⊕ 3.7.1 Oxygen, Welding Grade (99-95% Pure)

Spec: Commercial

Code: 08-511-500 EA
(EPS Ref. Y442A)

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- ⊕ 3.7.2 Acetylene, Dissolved (Technical Grade)
Spec: BB-A-106
Code: 08-511-300 EA
(EPS Ref. Y480A)
- 3.8 Rods, Welding, Aluminum Alloy
Spec: QQ-R-566, Class 1100
Code: 1/16 Dia. 08-625-400 LB (Color Code Black & Yellow)
(EPS Ref. Y469A) (Not Stocked - Order as required)

⊕ NOTE: DANGEROUS MATERIALS: REFER TO SECTION 7 OF THIS PROCESS FOR PRECAUTIONS AND HANDLING INSTRUCTIONS.

4. EQUIPMENT (AND TOOLING)

- 4.1 Torch Brazing Equipment
- 4.1.1 Torch, Oxyacetylene
Ref. MDM F-402-1
- 4.1.2 Tips
Ref. MDM F-402-1
- 4.1.3 Tip Cleaners
Ref. MDM F-402-1
- 4.1.4 Goggles, Gas Welding
Ref. MDM F-402-2
- 4.1.5 Lens Shades #3, 4, 5 and 6
Ref. MDM F-402-2
- 4.1.6 Gas Regulators
Ref. MDM F-402-2
- 4.1.7 Wrench, Gas Bottle
Tool No. T-124M78
Ref: MDM F-402-2
- 4.2 Furnace Brazing Equipment
- 4.2.1 Furnace, Air Circulating
Spec: 900°F to 1200°F + 10°F
Ref. MDM E-416-1
- 4.2.2 Suitable racks, baskets, shelves, etc. to hold parts as required, during the brazing cycle.

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- 4.3 Dip Brazing Equipment
 - 4.3.1 Salt Bath Furnace #23
Spec: Capable of maintaining $\pm 5^{\circ}\text{F}$ in the range of 1050° - 1200°F .
inside dimensions 22" x 22" x 22".
 - 4.3.2 Preheat Furnace #24
Spec: Capable of maintaining $\pm 10^{\circ}\text{F}$ in the range of 900° to 1000°F .
inside dimensions 24" x 24" x 24".
 - 4.3.3 Misc Equipment:
Handling equipment, clamps, springs, sludge removers, etc.
- 4.4 Cleaning Equipment (Post Dip Brazing)
 - 4.4.1 Nitric - Hydrofluoric Acid Tank
Spec: Vented, protective lined
 - 4.4.2 Sulphuric Acid Tank
Spec: Vented, protective lined
 - 4.4.3 Hot Water Rinse Tanks (2 Minimum)
Spec: Equipped with steam heating to maintain temperature at or near the
boiling temperature. water supply and overflow provisions to assure
fresh water input.
 - 4.4.4 Cold Water Rinse Tank
Spec: Equipped with water supply and overflow provisions to assure fresh
water input.
 - 4.4.5 Suitable Baskets, Racks, etc. - to hold parts, as required, during the
processing cycle.
- 4.5 Apron, Rubber
Code: Tool Crib Stock.
- 4.6 Gloves, Neoprene, Rubber or Plastic
Code: Tool Crib Stock.
- 4.7 Goggles, Acid Type
Code: Hospital Stock
- 4.8 Gloves, Asbestos
Code: Tool Crib Stock.

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5. PROCEDURE:

5.1 General Requirements.

5.1.1 Select the brazing alloy and brazing temperature from Table I.

NOTE: QUALITY CHECK POINT.

Base Alloy Being Brazed (2)	Approximate Melting Range of Base Alloy Being Brazed (°F)	Optimum Brazing Range (°F)	Brazing Alloy	Approximate Melting Range of Brazing Alloy (°F)
EC 1100 3003 5052 (3) 6061-6062 6063 A612 (cast)(1) C612 (cast)(1)	1195 - 1215 1190 - 1215 1190 - 1210 1100 - 1200 1100 - 1205 1140 - 1205 1105 - 1195 1120 - 1190	1085 - 1135 1085 - 1135 1085 - 1135 1080 - 1100 1080 - 1100 1080 - 1120 1080 - 1100 1080 - 1100	718 Wire, Foil or Powder	1070 - 1080
43 (cast)(1)	1065 - 1170	1060 - 1070	716	970 - 1085
MIL-B-20148 Class 1 Class 2 Class 3 Class 4	1190 - 1210 (Core) 1190 - 1210 (Core) 1140 - 1210 (Core) 1140 - 1210 (Core)	1100 - 1140 1100 - 1140 1080 - 1135 1080 - 1135	713 (cladding)	1070 - 1135

TABLE I Brazing Temperatures and Base Metal/Brazing Alloy Combinations

NOTE: 1. Sand or permanent mold castings only.

2. Base alloys specified are easily brazable. Other aluminum alloys are not recommended for brazing because certain alloying elements, mainly zinc and copper, cause melting at or below the brazing temperatures affecting the properties of the base metal.

3. Furnace brazing of 5052 aluminum alloy is not recommended. Dip brazing of 5052 aluminum alloy may be accomplished under closely controlled conditions.

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- 5.1.2 Dip brazing of assemblies after a fusion welding operation is prohibited. This restriction does not apply to tack welds made with 1100 (2s) aluminum welding rod for the purpose of securing details and brazing alloy.

NOTE: Assemblies welded prior to dip brazing will not retain strength or will completely melt in the weld areas when immersed in the dip bath furnace.

NOTE: QUALITY CHECK POINT.

- 5.1.3 Assemblies may be fusion welded after dip brazing.

- 5.1.4 Where combinations of aluminum alloys exist in a brazed assembly, the lowest brazing temperature should be selected. Exercise extreme care to prevent the partial melting or heat distortion of the assembly components.

- 5.1.5 Flux composition of dip bath furnace shall be checked to assure fluoride and chloride content in accordance with Section 8.1.3.

NOTE: QUALITY CHECK POINT.

- 5.1.6 The sulfuric acid content of the cleaning solution, paragraph 5.7.1 step 2, shall be maintained within the range of 8% to 12% (total weight).

NOTE: QUALITY CHECK POINT.

- 5.1.7 The acid content of the cleaning solution, paragraph 5.7.1 step 4 shall be maintained within the range of 10% to 15% nitric acid and 0.25% to 1.0% hydrofluoric acid (total weight)

NOTE: QUALITY CHECK POINT.

5.2 Clearances:

- 5.2.1 Assemble details to provide normal gap clearances of 0.006" to 0.010" for braze laps 1/4" or less as shown in Figure 1a.

- 5.2.2 Allow gap clearances 0.010" to 0.025" for braze laps greater than 1/4" as shown in Figure 1b.

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- 5.2.3 Fit self-aligning butt braze joints for close tolerance assemblies to 0.002" minimum gap clearance as shown in Figure 1c.

FIGURE 1

- NOTE: 1. Gap clearance is governed by the braze material capillary action which pulls the brazing alloy in and washes the flux out, and by the design of the component parts.
2. Specific gap tolerances can be varied in some instances by the selection of brazing alloys or combinations of brazing alloys.
3. Normal gap clearance shown in Figure 1a is small enough to allow capillary flow and not too small to impede the brazing alloy flow to prevent flux entrapment.

NOTE: QUALITY CHECK POINT.

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- 5.2.4 Deburr the edges of braze faying surfaces by filing, scraping or light sanding.

NOTE: A burr will restrict brazing metal flow causing skips, voids and flux entrapment.

NOTE: QUALITY CHECK POINT.

5.3 Cleaning Prior to Brazing:

- 5.3.1 Clean brazing details, filler wire and foil brazing alloy in accordance with the following processes.

- 5.3.1.1 Alkaline clean in accordance with MP 50036.

- 5.3.1.2 Deoxidize in accordance with MP 50029 Method I.

NOTE: QUALITY CHECK POINT.

- 5.3.2 Surface abrasion of the braze area, in addition to chemical cleaning, is approved where removal of oxides helps brazing alloy flow, provided the surface appearance of adjacent surfaces is acceptable.

- 5.3.3 Braze the cleaned details as soon after cleaning as possible.

NOTE: If parts are properly wrapped or kept clean in paper bags, cleaning may be done several days prior to brazing.

NOTE: QUALITY CHECK POINT.

5.4 Brazing Alloy Application:

- 5.4.1 Position the brazing alloy firmly in place for furnace and dip brazing operations to prevent movement during the preheat until the alloy can flow. Torch brazing alloy is hand fed into the joint.

- 5.4.1.1 Alumibraz powder is mixed with water and applied to the joint in the form of a paste. The powder is used principally in dip brazing and contains flux.

- 5.4.1.2 Tack or fasten foil and wire brazing alloy securely in place to prevent movement.

- 5.4.1.3 Clad brazing sheets have brazing alloy on one or both sides as preferred.

NOTE: Brazing alloy thicknesses are 10% of the sheet thickness up to 1/16" sheet and 5% over 1/16" sheet thickness.

- 5.4.2 Apply sufficient brazing alloy to obtain a fillet which is smooth and free of voids. Figure 2 shows the relative sizes of braze fillets obtainable by use of wire, paste and foil forms. Figure 3 shows how a combination of alloy forms may be used to fill a large area. Figure 4 shows additional braze assemblies using alternate brazing alloy forms.

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NOTE: Excess brazing alloy producing large fillets does not greatly increase the strength of the joint, however, vertical and overhead braze joint should have excess brazing alloy preplaced to counteract the losses from run off.

Completed Braze

Wire Brazing Alloy

Alumibrazing Alloy

Foil Brazing Alloy

FIGURE 2

Combination Wire and Foil Brazing Alloy

FIGURE 3

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FIGURE 4

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5.5 Assembly

5.5.1 Alignment of parts.

5.5.1.1 Assemble details in relation to each other so that each detail is firmly held in place. A minimum of tooling or fixturing should be used for furnace or dip brazing assemblies.

5.5.1.2 Self-Jigging of parts should be used wherever possible holding the parts in proper relationship with simple springs and clips as shown in Figure 5.

NOTE: Avoid the use of screws or bolts in holding fixtures because the threads become filled with flux which freezes and prevents disassembly of tooling. Springs are best for easy removal and provides adequate pressure at temperature for proper alignment of parts.

5.5.2 Tack weld Heliarc details and brazing alloy in place where possible to prevent costly tooling and excess tooling mass. Use 1100 (2s) aluminum welding rod (paragraph 3.8) for filler metal in tacks.

NOTE: 1100 (2s) aluminum welding rod is used because of its high melting temperature so that the tack will not melt at the dip brazing or furnace temperatures. Other high temperature welding rods can be used for tacking purposes, where required, with the approval of the Manufacturing Brazing Engineer. Resistance spotwelds may be used for tacking only when specified on the Manufacturing Plan.

NOTE: QUALITY CHECK POINT

5.5.3 Restrict the flow of brazing alloy, where desirable, by the application of a thin paste coat of stop-off made from sodium fluoride and water.

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Typical Braze Assembly

Non-Aligning Details

Self-Aligning Details

Assembly of Self-Aligning Details

a

b

c

d

View "A" Typical

- a. Brazing results using foil in bottom of aligning groove.
- b. Brazing results using alumibraz on outside of tube.
- c. Brazing results using wire on outside of tube.
- d. Brazing results using wire on inside of tube.

FIGURE 5

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5.5.4 Fluxing

5.5.4.1 Use the type of flux recommended in Table II.

5.5.4.2 Apply flux to the brazing alloy filler material and to the joint areas of the details being joined except for dip braze assemblies. The flux for dip brazed assemble is in the dip brazing molten bath.

NOTE: QUALITY CHECK POINT.

Flux Designation	Melting Range (°F.)	Brazing Method		
		Torch	Furnace	Dip
Alcoa #30	1013 - 1135	X	X (2)	X (1)
Alcoa #33	914 - 1112		X (3)	
Alcoa #34	900 - 1033		X (4)	
Alcoa #53	952 - 1092		X (4)	
Airco #44	900 - 1095	X		

TABLE II Flux Applications

Note: 1. Molten dip bath flux.

2. Use at higher brazing temperatures and in the brazing of relatively thick materials. This flux is highly active and produces good flow of filler alloy.
3. Use at lower brazing temperatures. Very active.
4. For use with thin sheets .020" and under. This flux is less active than #30 or #33.
5. It is permissible to mix fluxes to obtain a more or less fluxing action.

5.5.4.3 Mix new flux for each lot of parts when small quantities are being processed. Powdered flux is mixed three (3) parts flux to one (1) part water and stirred until all the powder is dissolved. Methyl or Ethyl Alcohol can be used as a substitute for water where evaporation of water is a problem.

5.6 Brazing

5.6.1 Torch brazing.

5.6.1.1 Select the proper brazing rod and coat it lightly with flux.

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- 5.6.1.2 Adjust the torch to obtain a protective reducing flame.

NOTE: A reducing flame is identified by an inner white cone about an inch long with a larger surrounding blue flame.

- 5.6.1.3 Use a jig or holding fixture to hold the assembly in alignment during the brazing operation.

- 5.6.1.4 Manipulate the torch in a manner similar to gas welding, passing it back and forth over the work to heat the parts uniformly by playing the reducing flame directly on the joint.

NOTE: This pre-heating is done by holding the flame perpendicular to the work with the white cone 2 to 3 inches from the joint. Heating will quickly drive off the water in the flux leaving a white deposit of dry flux. Continued heating gradually melts the flux at which time it turns gray, becomes fluid and flows like water at the brazing temperature and reveals the silvery sheen on the metal underneath.

- 5.6.1.5 Bring the white cone of the torch to within 1/2 inch of the work at a slight angle and add brazing alloy to the joint. Point the flame toward the uncompleted portion of the joint. Capillary action will carry the molten brazing alloy into the joint. Allow sufficient time at temperature for the brazing alloy to penetrate throughout the joint.

CAUTION: Exercise care to avoid over heating the joint or melting the parent metal.

NOTE: QUALITY CHECK POINT.

- 5.6.1.6 Allow the assembly to cool until the brazing alloy has solidified and where practical quench in boiling water. If such a quench produces distortion, allow the parts to cool in air 10 to 15 minutes before quenching to lessen the thermal shock.

- 5.6.1.7 Clean the assembly as described in Section 5.7.

NOTE: QUALITY CHECK POINT.

5.6.2 Dip Brazing

- 5.6.2.1 Fasten the braze assembly by springs or clips to a stainless steel or inconel support plate as shown in Figure 6. The support plate must have a minimum amount of surface in contact with the braze assembly. Allowance must be made for the entrance and drainage of molten brazing flux.

NOTE: Simple, inexpensive and adaptable tooling is available in Manufacturing for dip brazing production usage. A quantity of inconel spring clips are adaptable to many set-ups. Complicated tooling for special purposes must be designed for each application. The tooling must be checked occasionally to prevent undue warpage of tool from affecting the quality of the brazed assemblies.

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FIGURE 6

- 5.6.2.2 Place assembled part or part and holding fixture in preheating furnace at $1000^{\circ}\text{F} \pm 10^{\circ}\text{F}$ and allow assembly to come to temperature.
- 5.6.2.3 Transfer assembled part to the flux bath furnace and immerse into flux slowly.

NOTE: The time required to attain preheat and brazing temperatures will be determined on a pilot assembly. Assemblies shall remain in furnace the minimum time necessary to attain a braze.

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5.6.2.4 Raise assembly slowly from the dip bath furnace allowing flux to drain from assembly as it emerges.

5.6.2.5 Remove assembly from furnace area and allow to cool from 5 to 10 minutes depending upon the mass of tooling and assembly.

5.6.2.6 Clean the assembly as described in Section 5.7.

NOTE: QUALITY CHECK POINT.

NOTE: See Section 8.1 for maintenance and control of the flux bath furnace.

5.6.3 Furnace Brazing

5.6.3.1 Place assembled part or part and holding fixture in furnace and allow sufficient time for the assembly to reach the brazing temperature recommended in Table I.

NOTE: Time cycle must be determined by pilot assemblies. Preheating of the assembly to 400° or 500°F is recommended to dry the flux prior to introduction to extreme heat of brazing.

5.6.3.2 Protect the furnace base from the corrosive action of the flux with a pan or plate of stainless steel to catch the excess flux.

5.6.3.3 Remove assembly from the furnace carefully to avoid disturbing the molten brazing alloy and allow the assembly to cool 5 to 10 minutes.

5.6.3.4 Clean the assembly in accordance with Section 5.7.

NOTE: QUALITY CHECK POINT.

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~~SECRET~~5.7 Cleaning After Brazing

5.7.1 Brazed assemblies shall be cleaned as follows:

STEP	OPERATION	REMARKS
1	Soak in Boiling Water	Immersion time must allow for removal of excess flux.
2	Soak in 10% Sulphuric Acid at room temperature	Immersion time 3 to 5 minutes maximum.
3	Cold water rinse.	Complete and thorough rinsing shall be accomplished.
4	Soak in 10 - 15% Nitric, 0.25 - 1% Hydrofluoric Acid at room temperature	Immersion time 3 to 5 minutes maximum. * See Note No. 1.
5	Cold water rinse.	Complete and thorough rinsing shall be accomplished.
6	Hot water rinse.	Optional to aid in drying of part as required.

TABLE III - Cleaning After Brazing

NOTE: 1. Parts containing surfaces which do not allow for free and complete rinsing shall not be immersed in this solution. Clean by local brush applications of cleaning solution.

2. Cleaning shall be accomplished as soon as practical after brazing but in any event not longer than four (4) hours after brazing.

3. Refer to paragraphs 5.1.6 and 5.1.7 for solution control.

5.7.2 If doubt exists as the complete removal of flux residues, after Step 2 of Table III. Assemblies shall be checked as follows:

5.7.2.1 Clean brazed area with distilled water.

5.7.2.2 Place a few drops of 5% silver nitrate solution on the cleaned area.

NOTE: The presence of flux is indicated by the formation of a white precipitate. Repeat Step 2 until absence of precipitate indicates complete flux removal.

5.7.2.3 Rinse in cold running water until all acid is removed.

5.7.3 Barrel burnishing may be used when a uniform surface is required on small parts.

NOTE: QUALITY CHECK POINT.

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~~SECRET~~5.8 Brazing Acceptance Criteria

- 5.8.1 The quality and acceptability of the brazed joint shall be in accordance with the standards and limits detailed in Table IV.

DEFECTS	ACCEPTABILITY LIMITS
Cracks	Cracks in brazing alloy or adjacent base metal shall be cause for rejection.
Penetration	Lack of penetration through the joint shall be cause for rejection. Joints shall show complete lines of brazing alloy between component parts on both sides of the joint.
Unmelted Brazing Alloy	Unmelted brazing alloy in a joint is not acceptable and shall be cause for rejection.
Excess Brazing Alloy	Brazing alloy in excess of that required for a joint is acceptable provided the excess does not interfere with the function of the completed assembly.
Blisters	Overheating in the base metal resulting in blisters on the surface of the base metal shall be cause for rejection.
Residual Flux	No residual flux shall be permitted on the surface of a brazed joint.
Undercutting	Melting or erosion of the base metal surface, adjacent to the brazed joint shall be limited to a maximum of 5% of the base metal thickness and 15% (cumulative) of the base length.
Holes and voids	Pin holes, voids or filler metal skips extending into the faying surfaces of a joint shall be cause for rejection or rework of an assembly.
Surface Defects	The aggregate area of surface defects shall not exceed 10% of the surface of the respective braze fillet.
Cast Surface	Fillets presenting a surface after cleaning similar to a cast surface shall be considered satisfactory.
Faying Surface Defects	The total aggregate area of defects (unbrazed areas including trapped flux) between the faying surfaces shall not exceed 20% of the area of the respective joint.

TABLE IV Defect Acceptability Limits

NOTE: QUALITY CHECK POINT.

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- 5.8.2 Radiographic inspection, when required, shall be in accordance with MIL-STD 453. Acceptance of radiographic or sampling by section tests, when required, shall be in accordance with faying surface defects listed in Table III.

NOTE: QUALITY CHECK POINT.

- 5.8.3 Penetrant inspection, when required, shall be in accordance with MIL-I-6866.

NOTE: QUALITY CHECK POINT.

5.9 Common Brazing Problems and Solutions

- 5.9.1 Porous structures form because of trapped flux. The clearance in a brazed joint must be small enough to draw brazing alloy in; however, if it is too small, it will draw in flux and impede brazing alloy flow. This condition is minimized in dip brazing where alumibraz paste can be used. In furnace and torch brazing the capillary action of the brazing alloy pushes the flux ahead until clean filler metal reaches the free end of the joint assuring a flux free joint.
- 5.9.2 Capillary attraction may not draw filler metal all the way into a joint if it is too long. Preliminary testing on pilot assemblies is necessary to determine if the brazing alloy has completely penetrated the joint.
- 5.9.3 Where brazing alloy flows from both ends or sides of a joint, the flux is trapped and collects in the center of a faying surface. Void thus formed can be eliminated by flowing the brazing alloy from one side of the joint.
- 5.9.4 The heating cycle must be long enough to allow complete metal flow. The first filler metal to appear at the edge of a joint will contain some flux and if additional time at temperature is allowed pure filler metal will form a complete braze line indicating a sound braze.
- NOTE: When a heat cycle is established the best brazing results are accomplished with rapid heating and a minimum of time at brazing temperatures. Too much time at the brazing temperature will cause deformation and excess alloying.
- 5.9.5 Too little brazing alloy has the same effect on brazing as too short a heating cycle.
- 5.9.6 Flux will not cause corrosion unless it is exposed to the air. Consequently, if a joint is sealed by firm, unbroken fillets the possibility of corrosion is practically eliminated even if some trapped flux does exist in the joint. This fact does not excuse poor design, faulty Manufacturing, or insure long lasting results, however, non-porous unbroken fillets do indicate superior brazes.
- 5.9.7 Position of assembly during brazing is important because all molten brazing alloy tends to run down hill collecting large fillets at the bottom and leaving small fillets at the top. Layup of details should have excess brazing alloy on top fillet in such cases.

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~~SECRET~~6. QUALITY REQUIREMENTS

- 6.1 Quality shall assure that the materials, equipment and tooling listed are used in performing this process.
- 6.2 At the option of quality, in-process checks shall be conducted at the Quality Check Point indicated in Section 5 to assure conformance to the procedure.
- 6.3 Quality shall accept only those items which have been processed as required by Section 5.

7. SAFETY INSTRUCTIONS:

- 7.1 Brazers shall wear the necessary clothing, gloves and goggles or shields as necessary for adequate protection.
- 7.2 Handle gas containers with care. Store in an upright position and secure to wall, stationary fixture or approved gas container cart.
- 7.3 Parts and tooling shall be thoroughly dry before being introduced into the molten flux bath for dip brazing. Explosions which occur when water or other foreign material touch the molten flux can cause serious injury to the operator and damage to the parts and equipment.
- 7.4 The #34 flux is toxic and irritating to the skin and eyes. The dry powder must not be handled with the bare hands. If contact occurs, wash the affected area immediately with large quantities of soap and water. Use a respirator when handling powdered flux.

8. SPECIAL NOTES:

- 8.1 Maintenance requirements for dip brazing furnace.
- 8.1.1 Preparation of flux bath.
- 8.1.1.1 Preheat the empty pot by a gas fired torch to a temperature of 950° to 1000°F.
- NOTE: This accomplishes two things. It drives out any moisture and eliminates hot and cold spots preventing the flux from freezing to the sides of the pot.
- 8.1.1.2 Add granular flux #34 to the pot around the electrodes and continue to heat the pot and flux until a liquid pool of flux is attained covering the electrodes.
- 8.1.1.3 Turn the furnace electrodes on and remove the gas torches.

NOTE: This operation is critical and close supervision is required to prevent the over heating of flux or freezing the flux by removing the gas torch before the electric heaters have taken over control.

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- 8.1.1.4 Continue to add flux slowly until the dip bath is near operating level.
- 8.1.1.5 Raise the temperature slowly to 1100°F and maintain.
- 8.1.2 Maintenance of flux bath.
- 8.1.2.1 Dehydrate the molten flux by immersing clean preheated coils (approximately 1000°F.) of type 1100 aluminum into the flux for 15 to 20 minutes. This is repeated using a clean coil until the aluminum emerges clean.

NOTE: The presence of moisture is indicated by black oxide deposits on the aluminum. The coils are cleaned for future use by a hot water rinse followed by a 10 minute immersion in a 10% sulfuric acid solution.

- 8.1.2.2 Remove sludge from the bottom of the pot at least twice a week to avoid rapid buildup of frozen flux in the bottom of pot.

NOTE: Excessive build up of sludge in the bottom of the pot can be removed or remelted by maintenance with gas flame torches.

- 8.1.2.3 Remove sludge from the sides of the pot daily to prevent excessive build up.

- 8.1.3 Control of flux bath.

- 8.1.3.1 The fluoride content of the bath shall be held within the range of 3.4 to 4.8%. Quality shall conduct chemical analysis of the bath and instruct Manufacturing as to the amounts of aluminum fluoride to be added.

- 8.1.3.2 The chloride content of the bath shall be held within the range of 52.8 and 54.8%. Quality shall conduct chemical analysis of the bath and instruct Manufacturing as to the amounts of Lithium Chloride to be added.

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- The following amends the Procedure Section as applicable for Gemini Program on P/N 424-7562070 and 424-7562072 only in accordance with EPS 55007 Appendix No. 1.

5.8.1 Omit "Surface Defects" from Table IV.

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AMENDMENT

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MARTIN HARD COAT

EFFECTIVITY: This Amendment becomes effective upon the date of issue.

A. APPLICATION:

Add to A-2:

A-2. Any alloys to be hard coated which are not listed should be referred to Materials Engineering for approval.

Add A-7 as follows:

A-7. The requirements section shall be referred to for further design criteria regarding thickness of coating, etc.

C. MATERIALS:

Add C-11 as follows:

C-11. Tape, Vinyl, Pressure Sensitive
SPEC.: MIL-T-4239
CODE: 05-587-000 RL

Add C-12 as follows:

* C-12. Unichrome Stop-Off Lacquer No. 323
SPEC.: Commercial
CODE: 02-193-100 GL
SOURCE: Metal & Thermit Corp.

Add C-13 as follows:

* C-13. Unichrome Thinner and Stripper No. 300-T
SPEC.: Commercial
CODE: 08-520-900 GL
SOURCE: Metal & Thermit Corp.

D. EQUIPMENT:

Add D-8 as follows:

D-8. Taber Research Model, or equivalent, abrasion testing machine.

E. SOLUTIONS:

Change E-3 to read:

E-3. Solution Make-Up. -

Change E-3a to read:

E-3a. <u>Sealing Solution</u>	
Potassium Dichromate	7 ounces avoirdupois (5% by weight)
Water	1 gallon
Temperature	170° ± 10°

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Mfg. *FOR L. L. L.* Qlty. Cont. *FOR L. L. L.*
Equip. *FOR L. L. L.* Safety *FOR L. L. L.*

Engineering *FOR L. L. L.*
Engr. *FOR L. L. L.*
Mat'l. Engr. *FOR L. L. L.*

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MARTIN HARD COAT

F. REQUIREMENTS:

Change F-5 to read as follows:

- F-5. Unless otherwise specified on the Engineering Drawing, the thickness of the hard coating shall be $0.002 \pm .0002$ inch on all surfaces which can be touched by a ball 0.75 inch in diameter. When a color coating is called out, the thickness of the hard coating shall be $0.001 \pm .0002$ inch. Coating thickness shall not be controlled on:
- Blind holes or recesses where the depth is greater than twice the diameter.
 - Surfaces of open holes which are deeper than seven times the diameter of the opening.

G. PROCEDURE:

Change G-1c to read:

- G-1c. Masking: Dry areas which are not to be hard coated. Apply pressure sensitive tape and roll down the edges with a hard rubber or metal roller, or mask with stop-off lacquer. Plug holes with rubber stoppers.

Change G-2 to read:

- G-2. Hard Coating: Immerse parts in hard coating solution. When completely submerged, apply the current slowly until the current density reaches 25 amperes per square foot (20 amperes per square foot for parts .020 inch and less in thickness). Apply agitation and hold for approximately 80 minutes. The resulting coating will be approximately .002 inch thick. Alloys to be dyed shall be coated to a thickness of approximately .001 inch. When specified on Engineering Drawings, other thicknesses may be obtained by varying the time in accordance with the following table.

Coating Thickness (Inches)	Approximate Time in Minutes for Wrought Alloys*
.001	40
.002	80

Coating Thickness and Time Required at 25 Amperes per Square Foot.

- * NOTE 1: Processing times for casting alloys will be shorter.

NOTE 2: For coating thicknesses greater than 0.003 inch contact Materials Engineering.

Do not allow parts (anodes) to touch cathodes (or tank walls when used as cathodes). Serious damage to parts, tank lining or generator may result from a short circuit.

During the process, the current must be constantly readjusted to maintain it at 20 or 25 amps/sq. ft. as applicable. The voltage is not controlled and will gradually increase as the coating increases in thickness.

Close tolerance parts may be removed from the electrolyte, rinsed, measured and returned to the bath an indefinite number of times providing that they are not allowed to dry in the process. No further coating can be applied if the parts are allowed to dry.

CAUTION: THOUGH CO_2 IN SMALL AMOUNTS IS HARMLESS, EXCESSIVE INHALATION MAY PRODUCE DROWSINESS. AVOID INHALATION OF FUMES OF CO_2 .

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MARTIN HARD COAT

Change G-4 to read:

G-4. Sealing: When specified on Engineering Drawings, seal by immersing in a 5% potassium dichromate solution at $170^{\circ} \pm 10^{\circ}\text{F}$ for 5 to 10 minutes. Omit if parts are to be dyed.

H. PROCESS CONTROL:

Change H-3 to read:

H-3. A continuous record of the bath temperature shall be kept on the recording temperature indicator.

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MARTIN HARD COAT

A. APPLICATION:

- A-1. This process outlines a method for applying Martin Hard Coat to aluminum alloys. The film is similar to films produced by chromic acid or sulfuric acid anodizing but differs in having a greater hardness, density, abrasion resistance and dielectric strength. Martin Hard Coat is used principally as an abrasion resisting and wear resisting coating particularly on sliding surfaces. Sealed Hard Coat may be used in place of anodizing when a coating of better corrosion resistance is desired.
- A-2. Martin Hard Coating may be applied to the following alloys (it is applied most easily to those at the top of the list):

<u>Wrought Alloys</u>	<u>Casting Alloys</u>
6061	
7075	356
7178	355
7178 Clad	43
7075 Clad	195
2024 Clad	220
2014 Clad	
5052	
1100	

The following materials are not recommended for hard coating; 2014, 2017 and 2024 bare alloys (and other alloys containing a total alloying content of 5.9% or more of silicon, copper and manganese).

- A-3. Martin Hard Coat may be dyed black, green, blue, orange, and red as specified in this process. When the coating is to be dyed, Engineering Drawings shall so specify by special note (e.g., "Dye Red").
- A-4. When parts are to be sealed, Engineering Drawings shall specify by special note (e.g., "Seal For Maximum Corrosion Resistance").
- A-5. This process, when specified, shall be used in conjunction with Engineering Drawings and Data for all work within the scope of this process under direct Martin Company Quality Control. There is no equivalent Government Process Specification.
- A-6. The area of each surface of a part to be Hard Coated shall be called-out, in square inches, on all applicable Engineering Drawings.

B. REFERENCES:

- B-1. Standard Process P-30020, "Chromic Acid Anodizing Aluminum Alloys".
- B-2. Standard Process P-30022, "Color Anodizing for Close Tolerance Parts".
- B-3. Standard Process P-50029, "Deoxidation of Aluminum Alloys".
- B-4. Standard Process P-50036, "Non-Etch Alkaline Cleaning".

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 ALTO: *H. H. H. H.* Equip. *L. E. Lane* Safety *H. H. H. H.* Mat'l. Engr. *W. A. Kogdis*

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MARTIN HARD COAT

C. MATERIALS:

- C-1. Sulfuric Acid (93%), Technical
SPEC.: O-A-115, Class A, Grade 1
CODE: 08-501-400 CA
- C-2. Chromic Acid, Flaked, Technical
SPEC.: O-C-303
CODE: 08-500-200 LB
- C-3. Phosphoric Acid, Technical
SPEC.: O-P-313
CODE: 08-501-300 BT
- NOTE: DANGEROUS MATERIALS. WEAR PROTECTIVE GOGGLES AND CLOTHING WHEN MIXING AND USING THESE ACIDS. WHEN MIXING, ALWAYS ADD ACID TO WATER. REFER TO STANDARD PROCESS P-75007 FOR PRECAUTIONS AND HANDLING INSTRUCTIONS.
- C-4. Nitric Acid (61%), Technical
SPEC.: O-A-88
CODE: 08-500-500 CA
- C-5. Potassium Dichromate, Technical
SPEC.: Commercial
CODE: 08-505-100 LB
- C-6. Carbon Dioxide Gas (Dry Ice)
SPEC.: Commercial
CODE: 05-250-000 LB
- C-7. Carbon Dioxide Gas (Bottled)
SPEC.: Commercial
CODE: 02-095-900 LB
- NOTE: DANGEROUS MATERIALS. A PURE CO₂ ATMOSPHERE CAN CAUSE DEATH BY SUFFOCATION. USE ONLY IN WELL VENTILATED AREAS. DO NOT HANDLE DRY ICE WITHOUT ASBESTOS GLOVES.
- C-8. Water - Distilled or deionized. Tap water may be used if chloride content is less than 0.2 grams per liter (calculated as NaCl) and is free from fluorides.
- C-9. Tape, Mylar, Pressure Sensitive
SPEC.: Minnesota Mining No. Y9016
CODE: Order as required.
SOURCE: Minnesota Mining & Manufacturing Co.
- C-10. Turco 657
SPEC.: Commercial
CODE: K5-38A-100 GL
- NOTE: DANGEROUS FLAMMABLE MATERIALS. KEEP AWAY FROM FIRE AND FLAME. REFER TO STANDARD PROCESS P-75007 FOR PRECAUTIONS AND HANDLING INSTRUCTIONS.

D. EQUIPMENT:

- D-1. Hard Coating Tank: mild steel tank with lead lining. Rubber, glass, acid proof brick, vinyl or methacrylate linings may also be used if auxiliary lead cathodes are supplied. The tank shall also be provided with a bottom drain outlet, an overflow drain at one end, ventillating facilities exhausting at the rate of 150 cu. ft. per sq. ft. of solution surface area, cooling coils, for maintaining the solution at operating temperature, provisions for bubbling CO₂ through the solution, mechanical agitation and insulation on the exterior sides of the tank (which operates at 25° - 32°F).

The tank shall be provided with a direct current generator or rectifier capable of producing 20 - 60 volts at 25 amperes per square foot of work area. Necessary ammeters, voltmeters, rheostats, timers etc., shall also be provided.

If a lead lined tank is supplied and the lining is used as the cathode, a plastic lattice shall be provided to prevent accidental shorting, between the tank lining and the anode.

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MARTIN HARD COAT

- D-2. Racks, spring coils, clamps etc., used for suspending parts in the hard coating tank shall be fabricated of 2024S-T4 aluminum alloy. Titanium or titanium tipped aluminum alloy may be used as a second choice.
- D-3. Rinse Tank: mild steel tank with bottom water inlet and constant overflow at top (for room temperature operation).
- D-4. Sealing Tank: mild steel tank with bottom drain.
- D-5. Chromic-Phosphoric Stripping Tank: mild or stainless steel tank with provisions for heating and maintaining contents at $190^{\circ} \pm 10^{\circ}\text{F}$. (Ref. Standard Process P-30020).
- D-6. Hydrometer calibrated to read specific gravity in the range 1.000 - 1.200.
- D-7. Drying Facilities: oil-free, compressed air or an oven capable of maintaining contents at a maximum of 200°F .

E. SOLUTIONS:

E-1. Hard Coating Solution:

E-1a. Make Up:

Sulfuric Acid (93%), Technical	9.5 gal.
Water	90.5 gal.

Add half of the water to the tank. Add the full amount of acid to the tank while stirring constantly. Finally, add the remaining amount of water.

Cool the bath to 70°F and check the specific gravity with an hydrometer. At 70°F , the specific gravity of the solution should be 1.102. Add water or acid as required to adjust the bath to this value.

Cool the bath further to $25^{\circ} - 32^{\circ}\text{F}$. Saturate the bath with carbon dioxide gas by bubbling bottled carbon dioxide through it. Dry ice may be added to lower the temperature to the required range.

- E-1b. Maintenance: during operation, the bath shall be kept saturated by passing carbon dioxide gas through it. Bottled gas shall be used for this purpose. If the temperature is allowed to raise above 40°F or if the bath is allowed to stand, the bath shall be re-saturated with carbon dioxide gas before being put to use.

As the bath is used, the aluminum dissolved in the solution will cause the specific gravity to increase. The bath shall be discarded when the specific gravity exceeds 1.128 (representing 10 grams of dissolved aluminum per liter of solution). Specific gravity shall be determined by weighing a known volume of solution or by other standard laboratory methods. Regardless of the method used, the specific gravity shall be determined at 70°F (See Figures 1 and 2).

The aluminum content of the bath shall be determined by standard titration procedures using sodium hydroxide, potassium fluoride and phenolphthalein indicator. The bath shall be discarded when the aluminum concentration reaches or exceeds 10 grams per liter.

- E-1c. Tank cleaning: when necessary to dump a solution, one of the following procedures shall be used:

Either pump out the solution from the tank and cart it to an approved disposal dump or neutralize it with alkali and flush it down the drain.

Remove sludge from the bottom of the tank; rinse with water under pressure and wipe the tank interior dry.

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After drying, remove greasy film from tank walls by wiping with Turco 657 and followed by scrubbing walls with soap and water. Rinse thoroughly.

Remove copper deposits from lead tank walls by swabbing with a dilute (10%) solution of nitric acid. Rinse the tank thoroughly. After this rinse, tank may be filled with a fresh hard coating solution and placed into operation.

E-2. Chromic-Phosphoric Stripping Bath: (Ref. Standard Process P-30020)

E-2a. Make-Up:

Phosphoric Acid, Technical	5 oz. (fluid)
Chromic Acid, Flaked, Technical	2 3/4 oz. (avoir)
Water	1 gallon
Temperature	190 - 200°F

E-2b. Maintenance: use until total aluminum oxide content reaches 5 grams per liter. At this point, solution may be reactivated by adding 3 ounces (fluid) of phosphoric acid per gallon of solution. Continue to use until aluminum oxide content reaches 10 grams per liter and then discard the solution.

E-3. Sealing Solution:

E-3a. Make-Up:

Potassium Dichromate or Chromic Acid	5% by weight (7 oz. avoir)
Water	95% by weight (1 gallon)

E-3b. Maintenance: maintain at 6 - 8 oz./gallon. The solution shall be discarded at the discretion of Quality Division.

F. REQUIREMENTS:

- F-1. Parts shall be hard coated after all forming, bending, machining, sanding, and welding operations have been completed.
- F-2. When a specific area of a part is to be hard coated, and other areas of the same part are to receive some other surface treatment (such as Alodine, Iridite or anodizing), the sequence of operations shall be as follows:
 - a. Anodizing and MHC: Anodize entire part first. Strip area to be hard coated after applying Minnesota Mining No. Y9016 Mylar Tape to the remaining area.
 - b. Alodine or Iridite and MHC: Hard coat first, mask off hard coated area and Alodize or apply Iridite to remaining area.
- F-3. Assemblies containing dissimilar metals or with open seam joints, lap joints or other areas which can entrap the hard coating solution shall not be treated unless such areas can be suitably masked. Suitable masking materials are Minnesota Mining No. Y9016 Mylar Tape and rubber stoppers (for plugging Holes).
- NOTE: Slightly jagged lines of demarcation due to slight lifting of the masking tape during processing is not cause for rejection.
- F-4. For close tolerance parts, a before and after coating dimension shall be specified on the applicable drawing.
- F-5. Unless otherwise specified on the Engineering Drawing, the thickness of the hard coating shall be $0.002 \pm .0002$ inch on all visible surfaces (i.e., 0.002 inch per surface). Coating thickness shall not be controlled on:

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- a. Blind holes or recesses where the depth is greater than twice the diameter.
 - b. Surfaces of open holes which are deeper than seven times the diameter of the opening.
- F 6. Since some of the basis metal is removed in the process of applying Martin Hard Coat, a thickness of 0.002 inch will not result in a total dimensional increase of 0.002 inch. This relationship is shown in Figure 3 where coating thickness is plotted with surface growth (i.e., dimensional change). Thus, a coating thickness of 0.002 inch will result in a dimensional change of only 0.00145 inch (0.00055 inch of metal having been removed and replaced by hard coat).
- When hard coat is stripped, the entire coating is removed resulting in a decrease in the "before plating" dimension. These dimensional changes must be considered when hard coating or stripping and reworking close tolerance parts.
- F-7. Coating thicknesses may be determined by any method assuring an accuracy of measurement of 10%.
- F-8. The cathode area must be equal to or greater than the total surface area of the parts (anodes) to be hard coated. The cathodes shall be spaced close to and equidistant from the parts in accordance with standard plating techniques to assure equal distribution of current. If necessary, internal auxiliary lead anodes shall be used in deep recesses or tubular structures.
- F-9. After each coating operation, the coating formed on racks and fixtures shall be removed. Non-critical areas of racks and fixtures (i.e., areas not making direct electrical contact with parts to be hard coated) shall be permanently masked-off to reduce the effective anode area to the area of the part to be hard coated.
- F-10. Work loads processed through the hard coating tank shall not be so large that the ability of the refrigerating system to maintain the bath at 25 - 32°F is exceeded.
- F-11. Work loads processed through the hard coating tank shall not be so large that the ability of the electrical generator to supply the necessary current density is exceeded.
- F-12. In order to keep the aluminum build-up in the hard coating tank and the stripping tank to a minimum, daily inspections shall be made to remove any parts which may have fallen into the tanks.
- F-13. The hard coating solution shall be discarded whenever parts take a chalky or mottled color coating which does not build-up to the required thickness. The bath shall be discarded whenever soft powdery films are obtained.
- F-14. Contaminants which form on the surface of the hard coating bath shall be removed as soon as they occur to prevent contamination of parts as they are immersed and removed from the solution.
- F-15. If the hard coating tank is to remain idle for any length of time, scrap sheets of 1100 or 5052 aluminum shall be suspended in the bath to plate out excess copper and lead from the electrolyte.
- F-16. Hard coatings shall be identified by the letters "MHC". Identification may be made by die-stamping the parts before hard coating or by rubber stamping after hard coating. Identification markings shall not be applied to areas which would impair the function of the part.

G. PROCEDURE:

- G-1. Cleaning:

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- G-1a. Solvent Clean: vapor degrease or wipe with Turco 657 to remove all grease, dirt, markings, paint films etc. After solvent cleaning, parts shall be free of all indications of residual marking inks. If necessary, stubborn markings shall be removed by hand rubbing with a Turco 657 soaked cloth.
- G-1b. Alkaline Clean: alkaline clean and rinse in accordance with Standard Process P-50036.
- G-1c. Masking: dry parts which are to be masked and apply masking tape by hand and then rolling down the edges with a hard rubber or metal roller. Plug holes with rubber stoppers. Repeat alkaline cleaning step after masking.
- G-1d. Deoxidize: immerse all parts except close tolerance parts in Diversey 514 deoxidizing solution (Standard Process P-50029) for 5 minutes (minimum) to 15 minutes (maximum). Immerse close tolerance parts in Diversey 514 for 5 minutes (maximum). After deoxidizing, parts shall be free of all evidences of discoloration and should exhibit a clean and bright or semi-bright surface.
- G-2. Hard Coating: immerse parts in hard coating solution. When completely submerged, apply current slowly until value reaches 25 amps/sq. ft. (20 amps/sq. ft. for thin gauge material). Apply agitation and hold for 80 minutes. The resulting coating will be approximately 0.002 inch thick. When specified on Engineering Drawings, other thicknesses may be achieved by varying the time in accordance with the following chart.

Coating Thickness (Inches)	Time in Minutes for Wrought Alloys *
.001	40
.002	80
.003	120
.004	180
.005	240

Coating Thickness Verses Time at 25 amps/sq. ft.

* NOTE: Processing times for casting alloys will be slightly shorter.

Do not allow parts (anodes) to touch cathodes (or tank walls when used as cathodes). Serious damage to parts, tank lining or generator may result from a short circuit.

During the process, the current must be constantly readjusted to maintain it at 20 or 25 amps/sq. ft. as applicable. The voltage is not controlled and will gradually increase as the coating increases in thickness.

Close tolerance parts may be removed from the electrolyte, rinsed, measured and returned to the bath an indefinite number of times providing that they are not allowed to dry in the process. No further coating can be applied if the parts are allowed to dry.

CAUTION: THOUGH CO₂ IN SMALL AMOUNTS IS HARMLESS, EXCESSIVE INHALATION MAY PRODUCE DROWSINESS. AVOID INHALATION OF FUMES OF CO₂.

- G-3. Rinse: rinse thoroughly in cold tap water for at least 3 minutes.
- G-4. Sealing: when specified on Engineering Drawings, seal by immersing in a 5% potassium dichromate (or 5% chromic acid) solution for 5 - 15 minutes. Omit if parts are to be dyed.
- G-5. Dying: when dying is specified on Engineering Drawings, immerse in dye tank as specified in Standard Process P-30022. NOTE: Dying of 7075 material will require at least 15 minutes.

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- G-6. Drying: dry in a stream of compressed air, oil-free shop air or in an oven (not over 200°F). All parts except sealed and dyed parts may be immersed in a hot water rinse (approx. 180°F) to facilitate drying. Parts shall be left in the rinse long enough to attain the temperature of the rinse water.
- G-7. Stripping: when necessary, parts may be stripped as follows: solvent clean and alkaline clean as specified in paragraphs G-1a and G-1b. Follow by immersing in hot chromic-phosphoric stripping solution until all coating is removed and rinse in cold running water.
- After stripping, parts shall be checked for dimensional tolerances before reworking. (see paragraphs F-6 and I-3) Parts to be reworked may be introduced directly into the hard coating tank while still wet or may be dried in warm air, with compressed air or with oil-free shop air and subsequently hard coated. Once dried, stripped parts shall be solvent cleaned and alkaline cleaned before re-hard coating.

Chromic-phosphoric acid stripping solution will not attack the basis metal (see paragraph F-6).

H. PROCESS CONTROL:

- H-1. Quality Division shall check the specific gravity and aluminum content of the hard coating bath at least weekly.
- H-2. The temperature of the hard coating solution shall be maintained within the prescribed range during all process runs. Work processed at temperatures greater than 32°F or less than 20°F shall be rejected.
- H-3. A daily record of process runs together with starting and finishing bath temperatures shall be kept by the Manufacturing Division.
- H-4. The hard coating bath shall be discarded whenever parts take a chalky or mottled color coating and the coating does not build up to the required thickness in the specified time. A satisfactory hard coating may range from light amber or light gray to jet black, depending on the alloy.
- H-5. Resistance to abrasion and wear shall be determined with a Taber Abraser, using H-38 wheels and a 1000 gram load. The test specimen shall consist of a panel of 6061 bare alloy, 4 x 4 x 0.063 inches in dimensions with a 1/4 inch hole in the center. The tester shall be operated according to the manufacturer's instructions. While in operation, the test panel shall be kept free of abrasive particles by use of a continuous air blast.
- Hard coating shall withstand 1250 cycles (i.e., rotations) without being reduced in thickness by more than 0.001 inch.
- Production shall be suspended and corrective action taken if the average of three specimens fails to meet this requirement. Abrasion resistance tests shall be conducted at least monthly.
- H-6. Chemical solutions at The Martin Company shall be analyzed with the frequency established in Quality Procedure 3.5, Sampling, Testing, and Control of Manufacturing Processing Solutions.
- H-7. Chemical solutions used by vendors in connection with this process shall be analyzed with the stated frequency.
- H-8. Discrepancies arising out of the use of this process shall be brought to the attention of Materials Engineering.
- H-9. Manufacturing Division shall be responsible for providing and maintaining the necessary equipment and facilities and for producing finished articles that meet the intent of this process.
- H-10. Quality Division shall be responsible for maintaining the materials and solutions within specification and process limits and for enforcing the requirements and procedures of this process.

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MARTIN HARD COAT

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I. PRODUCT ACCEPTANCE:

- I-1. All parts shall be inspected for freedom from breaks and other damage. Parts showing burned areas shall not be rejected unless it is evident that the degree of burning is sufficiently severe to interfere with the function of the part. Similarly, evidences of contact points shall not be cause for rejection unless it is evident that the function of the part will be impaired.
- I-2. Coating thickness shall be checked on one part from each lot processed. Thickness may be determined by micrometer measurement, microscopic measurement or any equivalent method assuring an accuracy of 10%.

At least once a month, separate specimens of 6061 alloy shall be hard coated and measured by microscopic examination of a cross section.

Production shall be suspended whenever thickness requirements are not met and production shall not be resumed until corrective action has been taken.
- I-3. Parts not acceptable as coated may be stripped and recoated providing dimensional tolerances will permit the rework.
- I-4. Dyed hard coated parts shall conform to P-30022 in all aspects relating to dyed coatings.

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0315587030

Code Ident. No. 38597

AMENDMENT

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PLATING, GOLD, CYANIDE (ELECTRODEPOSITED)

EFFECTIVITY: This Amendment becomes effective upon date of issue.

A. APPLICATION:

Change paragraph A-1 to read:

- A-1. This Process describes the requirements, procedures and controls for the application of semi-bright, hard gold electro platings on copper, steel, aluminum and zinc-base die cast alloys.

Change paragraph A-3 to read:

- A-3. Replace MIL-G-14548 (ORD) with MIL-G-45204.

Change paragraph A-5 to read:

- A-5. The gold electroplatings covered by this Process shall be of the following grades and classes:

Table I - Replace MIL-G-14548 (ORD) with MIL-G-45204 wherever it appears in the table.

B. REFERENCES:

Change paragraph B-1 to read:

- B-1. Specification MIL-G-45204, "Gold Plating (Electrodeposited)".

G. REQUIREMENTS:

Add paragraph G-15 as follows:

- G-15. When the base metal is a ferrous or non-copper alloy, such as zinc-base die castings, the thickness of the strike and underplating shall be a minimum of 0.001 inch less the thickness of the specified gold plating.

H. PROCEDURE:

Change Section H-1 to read:

- H-1. Surface Preparation. -

- H-1a. Aluminum - Prepare aluminum alloys for electroplating per Standard Process P-30055 except that the copper strike and plate shall meet the requirements of Standard Process P-30009, Type II.
- H-1b. Copper - Prepare copper alloys for electroplating and copper plate per Standard Process P-30009, Type II.
- H-1c. Steel - Prepare steel alloys for electroplating per Standard Process P-50010, Procedure I. If required, stress relieve in accordance with paragraph G-6, of this Process, prior to cleaning. Copper plate per Standard Process P-30009, Type II.
- H-1d. ~~Zinc-base~~ Die Cast Alloys - Prepare zinc-base die cast alloys for electroplating and copper plate per Standard Process P-30009, Type II.

Remove Figure 1. - Flow Chart for Gold Plating, page 10, in its entirety.

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Approved By: *[Signature]*
 D. WR BALTO: *[Signature]*

Mfg. *[Signature]* Equip. *[Signature]* Safety *[Signature]*

Qty. Cont. *[Signature]*Engineering *[Signature]*Edg. *[Signature]*Mat'l. Engr. *[Signature]*

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PLATING, GOLD, CYANIDE (ELECTRODEPOSITED)

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P-30044 - AMENDMENT NO. 1

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PLATING, GOLD, CYANIDE (ELECTRODEPOSITED)

A. APPLICATION:

- A-1. This process describes the requirements, procedures and controls for the application of semi-bright gold electroplatings on copper, steel, aluminum and zinc-base die cast alloys.
- A-2. Gold plating provides a durable, tarnish-resistant finish intended primarily for engineering application that requires a high electric conductivity, permanently low electrical contact resistance or an oxide free solderable surface.
- A-3. This process, when specified, shall be used in conjunction with Engineering Drawings and Data for all work within the scope of the process under direct Martin Company Quality Control. As such, it will enable the production of parts that will meet or exceed the minimum requirements of Specification MIL-G-14548 (ORD), Gold Plating (Electrodeposited) Type II, except that sampling and quality control tests other than visual inspection shall be accomplished once per week rather than for each lot unless otherwise specified.
- A-4. The application of gold plate to steel parts heat treated to or above 220,000 psi level, is beyond the scope of this process. If gold plate is required on such parts, consult Materials Engineering for approval and instructions to be placed as notes on drawings prior to release.
- A-5. The gold electroplatings covered by this process shall be of the following grades:
- Grade I - NICKEL-GOLD: Nickel undercoat plated to thickness of 0.0005 to 0.0007 inch plus gold electroplated to the thicknesses of the applicable class given in Table I.
- Grade II - SILVER-GOLD: Silver undercoat plated to thickness of 0.0003 to 0.0005 inch plus gold electroplated to the thicknesses of the applicable class given in Table I.
- Grade III - GOLD: No silver or nickel underplatings. Gold is plated to thicknesses of the applicable class given in Table I. Grade III plating may be used on copper and copper alloy substrates.

CLASS	THICKNESSES	DESCRIPTION
1	0.00005" to 0.00010"	Equivalent to MIL-G-14548 (ORD), Type II, Class 1 for electronic parts where a solderable, oxide-free surface is required.
2	0.0001" to 0.0002"	Equivalent to MIL-G-14548 (ORD), Type II, Class 2, for general use where a solderable, oxide-free surface is required.
3	0.0002" to 0.0003"	Equivalent to MIL-G-14548 (ORD), Type II, Class 3, for surfaces where additional wear-resistance is required.
4	0.0015 " to 0.0020 "	Equivalent to MIL-G-14548 (ORD), Type II, Class 6, for surfaces where special electrical properties are required.

TABLE I. - Classes of Gold Electroplatings.

- A-6. The Grade and Class of plating shall be called out on drawings by use of applicable Finish Code Numbers.

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ed By: 4-10-61 Mfg. Equip. *W. C. Schmitt* Qlty. Cont. *W. C. Schmitt* Safety *W. C. Schmitt* Engineering *W. C. Schmitt* Engr. *W. C. Schmitt* Mat'l. Engr. *W. C. Schmitt*

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PLATING, GOLD, CYANIDE (ELECTRODEPOSITED)

B. REFERENCES:

- B-1. Specification MIL-G-14548 (ORD), Gold Plating (Electrodeposited).
- B-2. Federal Standard 151, Metals; Test Methods.
- B-3. Standard Process P-85032, Soldering of Electrical and Electronic Equipment.
- B-4. Standard Process P-30009, Copper Plate (Electrodeposited).
- B-5. Federal Specification QQ-N-290, "Nickel Plating (Electrodeposited)".
- B-6. Standard Process P-30055, Electroplating on Aluminum Alloys.
- B-7. Standard Process P-50010, Descaling Carbon Steel Aircraft Parts.
- B-8. Standard Process P30013, Silver Plating.
- B-9. Standard Process P-75007, Handling of Dangerous and Toxic Materials.

C. MATERIALS:

- C-1. Bright Gold B-1 Salts
SPEC.: Commercial
CODE: Order as required.
SOURCE: Sel-Rex Corp.
Nutley, New Jersey
- C-2. Bright Gold M-2 Maintenance Salts
SPEC.: Commercial
CODE: Order as required.
SOURCE: Sel-Rex Corp.
Nutley, New Jersey
- C-3. Cyanide, Potassium, Technical Grade, 98%
SPEC.: Commercial
CODE: 08-503-000 LB
- C-4. Potassium Gold Cyanide (69%) C-P
SPEC.: Commercial
CODE: Order as required.
- C-5. Gold Coatalyte No. 317
SPEC.: Commercial
CODE: Order as required.
SOURCE: Rapid Electroplating Process, Inc.
Chicago 5, Illinois
- C-6. Coatalyte Anodic Cleaner
SPEC.: Commercial
CODE: Order as required.
- NOTE: DANGEROUS MATERIAL. EXTREMELY POISONOUS. WEAR RESPIRATOR, ACID TYPE GOGGLES AND PROTECTIVE CLOTHING WHEN HANDLING IN DRY OR SOLUTION FORM. REFER TO MARTIN PROCESS P-75007 FOR PRECAUTIONS AND HANDLING INSTRUCTIONS.
- • C-7. Acid, Sulfuric, Technical
SPEC.: O-A-115, Class A, Grade 1
CODE: 08-501-400 CA

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PLATING, GOLD, CYANIDE (ELECTRODEPOSITED)

- • C-8. Acid, Acetic, Glacial, Technical, 99.5%
SPEC.: Commercial
CODE: 08-500-000 BT

- • **NOTE:** DANGEROUS ACID MATERIAL. WEAR PROTECTIVE CLOTHING, GLOVES AND RESPIRATOR. REFER TO STANDARD PROCESS P-75007 FOR PRECAUTIONS AND HANDLING INSTRUCTIONS.

- C-9. Anodes, Stainless Steel, 18-8 Series
SPEC.: QQ-S-00766, C1 302, Cond. A
CODE: Order as required.

- C-10. Paper, Abrasive, No. 425
SPEC.: Commercial
CODE: 08-042-500 EA

- • • C-11. Turco-solv
SPEC.: Commercial
CODE: K5-36A-100 GL

- *** DANGEROUS AND FLAMMABLE MATERIAL. REFER TO STANDARD PROCESS P-75007 FOR PRECAUTIONS AND HANDLING INSTRUCTIONS.

D. EQUIPMENT:

- D-1. Sel-Rex Jet Plater or 18-8 corrosion resistant steel gold plating tank.
- D-2. Gold Strike Tank: 18-8 corrosion resistant steel.
- D-3. Dragout Rinse Tanks: 18-8 corrosion resistant steel.
- D-4. Acid Rinse Tanks: Plastic, ceramic, lead or rubber lined steel.
- D-5. Rinse Tanks: Mild steel with overflow dam and spray pipes for rinses.
- D-6. Demineralized Water Rinse Tanks: Polyvinylchloride or polyethylene lined mild steel.
- D-7. Plating Racks, conforming anodes and barrels: As required for production of plating.
- D-8. Rapid Portable Plater: Equipped with voltmeter, ammeter, anode sleeves, applicator and leads. Available from Rapid Electroplating Process, Inc., Chicago, Illinois.
- D-9. Electrical Equipment: Direct current power source, 6 volts maximum and associated voltmeters, ammeters, rheostats, and timing devices.
- D-10. Protective Equipment: Acid type gloves, goggles, aprons, and MSA "Dustfoe" filter type respirator or equivalent.
- D-11. Stainless steel baskets for acid dipping and rinsing.
- D-12. Facilities to provide distilled or deionized water.

NOTE: All tanks containing solutions which evolve noxious fumes shall be equipped with suitable ventilation facilities.

E. SOLUTIONS:

- E-1. Gold Strike Solution: The solution shall be prepared by filling the tank one-half full of distilled or deionized water, carefully adding the chemicals shown below, mixing, filling the tank to operating level with water and filtering to remove impurities.

Potassium Gold Cyanide 0.45 oz./gal. (final concentration)

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PLATING, GOLD, CYANIDE (ELECTRODEPOSITED)

- E-2. Gold Plating Solution: The solution shall be prepared by filling the tank one-half full of distilled or deionized water, carefully adding the chemicals shown below, mixing, filling the tank to operating level with water and filtering to remove impurities.

Sel-Rex Bright Gold B-1 Salts
Potassium Cyanide

Equivalent to 1.0 Troy oz. ~~metallic~~ gold per gal. (final concentration)
11.0 oz./gal.

- E-3. Acetic Acid Rinse Solution

Acetic Acid
Water

5% by volume
95% by volume

- E-4. Sulfuric Acid Dip Solution

Sulfuric Acid
Water

10% by volume
90% by volume

- E-5. Potassium Cyanide Dip:

Potassium Cyanide
Water

5 oz./gal. (final concentration)
As required.

F. SOLUTION CONTROL:

- F-1. Gold Strike Solution:

Gold (as metal)
Free Potassium Cyanide
Temperature

.2 - .35 Troy oz./gal.
1.8 - 2.2 oz./gal.
Room

- F-2. Gold Plating Solution:

Gold (as metal)
Free Potassium Cyanide
Temperature

0.8 to 1.2 Troy ounces per gallon
10.0 to 12.0 ounces per gallon
Room

Maintain metallic gold with Sel-Rex Bright Gold M-2 Salts according to analysis. Maintain brightness with Sel-Rex B-1 Salts additions.

- F-3. Potassium Cyanide Dip:

Potassium Cyanide
Temperature

4 - 6 oz./gal.
Room

- F-4. Brush Plating Solution:

The gold Coatalyte #317 brush plating solution shall be used as received. A separate container shall be provided for the plating solution being used. The applicator shall not be dipped into, nor shall the used plating solution be returned to the original container. The plating solution shall be used until exhausted and then discarded.

G. REQUIREMENTS:

- G-1. The ~~basis~~ metal shall be free from visible defects that will be detrimental to the appearance or performance of the plating.
- G-2. Unless otherwise specified on drawing callout, the plating shall be applied after all heat treatment and mechanical operations have been performed on the ~~basis~~ metal.
- G-3. Parts to be plated shall be finished to the surface smoothness (rms) required by drawing callout.
- G-4. The plating procedure shall be continuous.

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- G-5. Unless otherwise specified on Engineering Drawings, the thickness of the deposits shall be as specified in Table I on all visible surfaces which can be touched by a ball 0.75 inch in diameter.
- G-6. All steel parts, including springs, heat treated to 180,000 psi or greater shall be stress relieved as noted on drawings before cleaning and pickling. If stress relief before cleaning is not called out, stress relieve in accordance with Tables II and III before cleaning.
- G-7. Springs shall not be flexed during the period between stress relieving and embrittlement relieving.
- G-8. Embrittlement Relief After Plating. - Steel parts heat treated to 150,000 psi or greater and all steel springs shall be embrittlement relieved within 4 hours after plating in accordance with Table IV. In cases where two or more plating operations are required on the same part, embrittlement relief shall follow each plating operation unless the time between the first plating operation and embrittlement relieving following the last plating operation is less than 4 hours. In the latter case, only one embrittlement relief is required and it shall follow the final plating operation.

Steel Type	Heat Treat Strength Level (All figures inclusive except when noted.)	Stress Relief	
		Temp. (°F)	Time (Hrs.)
All (Except 1095)	180,000 up to but not including 220,000 psi.	700 $\pm$ 25	2
1095	Up to but not including 220,000 psi.	625 $\pm$ 25	1/2 minimum
Case hardened parts which have been machined.	All levels	300 $\pm$ 25	4

TABLE II. - Time and Temperature Required to Stress Relieve Steels at Various Heat Treat Levels. (Not applicable to springs or corrosion resistant steels.)

Spring Type	Stress Relief	
	Temp. (°F)	Time (Hrs.)
Cold drawn and music wire springs.	475 $\pm$ 25	1/2 minimum
Oil quenched and tempered springs.	625 $\pm$ 25	1/2 minimum

TABLE III. - Time and Temperature Required to Stress Relieve Steel Springs. (Not applicable to corrosion resistant steels.)

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- G-9. Cleaning, descaling and plating procedures shall follow in rapid sequence with a minimum time lapse and a minimum of handling of parts between steps.
- G-10. Parts having residual magnetism from the use of magnetic chucks, magnetic particle inspection techniques, etc., shall be demagnetized before plating.
- G-11. Parts dropped into the plating tank shall be removed immediately.
- G-12. Parts or assemblies which contain blind holes, joints, faying surfaces, etc., which might entrap cleaning, descaling, or plating solutions shall not be plated in accordance with this process unless

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Manufacturing Division can effectively rinse, seal, or mask the affected areas.

Steel Type	Heat Treat Strength Level (All figures inclusive)	Embrittlement Relief	
		Temp. (°F)	Time (Hrs.)
All (Except springs)	150,000 - 180,000 psi	375 ± 25	3 - 8
All (Except springs)	200,000 - 220,000 psi	375 ± 25	8
Case hardened parts	All levels	300 ± 25	4
Springs	All levels	375 ± 25	8

TABLE IV. - Time and Temperature Required to Embrittlement Relieve Steels at Various Heat Treat Levels. (Not applicable to corrosion resistant steels.)

- G-13. Electrical contacts shall be made in such a manner as will insure that no chemical or immersion deposition will occur.
- G-14. The use of brush plating is restricted to gold plating on copper, copper alloys, silver, carbon steel alloys or platings of these metals under the following conditions:
- For touch-up of damaged gold plated surfaces.
 - For selective, localized plating of small areas.
 - For production parts as authorized by Materials and Process Engineering.
 - For touch-up of copper-silver-gold plated parts provided the copper or silver underplatings are sound and provide a suitable plating base.

H. PROCEDURE:

H-1. Surface Preparation. -

- H-1a. Aluminum - Prepare aluminum alloys for electroplating per Standard Process P-30055. Apply 0.0002 to 0.0005 inch of copper plate.
- H-1b. Copper - Prepare copper alloys for electroplating per Standard Process P-30009, Type II or Process Bulletin P-85056 as applicable.
- H-1c. Steel - Prepare steel alloys for electroplating per Standard Process P-50010, Procedure I. If required, stress relieve in accordance with paragraph G-6 prior to cleaning.
- H-1d. Zinc-base Die Cast Alloys - Prepare zinc-base die casting alloys for electroplating per Standard Process P-30009, Type II.

H-2. Grade I: Nickel-Gold-Plating. -

- H-2a. Nickel plate in accordance with Spec. QQ-N-290, Class 1 to thickness of .0005 to 0.0007 inch.

NOTE: Processing must not be interrupted after nickel plating. A delay will cause passivation of the nickel surface and subsequent poor adhesion of the gold plate. If this occurs, consult Materials Engineering.

- H-2b. Rinse work in running water, spray rinse and drain. Do not allow parts to dry.
- H-2c. Rinse work in sulfuric acid dip solution for 60 to 90 seconds and drain.
- H-2d. Rinse work in running water, spray rinse and drain. Do not allow parts to dry.
- H-2e. Immerse work in potassium cyanide dip solution for 20 - 30 seconds.
- H-2f. Rinse work in demineralized water dip tank and drain. Do not allow parts to dry.
- H-2g. Immerse in gold strike solution with potential applied and plate for 45 - 60 seconds at 3 - 8 ASF.*
- H-2h. Immerse in gold plating solution and plate for the time specified in Table V to give the required thickness.

* Amperes per square feet

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NOTE: Interruption of plating current will cause laminated deposits.

- H-2i. Double rinse parts in gold dragout rinse tanks.
 H-2j. Immerse work in acetic acid solution for 1 to 2 minutes.
 H-2k. Rinse parts in water and dry at room temperature.
- H-3. Grade II: Silver-Gold Plating. -
 H-3a. Silver plate in accordance with Standard Process P-30013 to thickness of 0.003 to 0.0005 inch.
 H-3b. Rinse work in running water, spray rinse and drain. Do not allow parts to dry.
 H-3c. Rinse work in sulfuric acid dip solution for 60 to 90 seconds and drain.
 H-3d. Rinse work in running water, spray rinse and drain. Do not allow parts to dry.
 H-3e. Immerse work in potassium cyanide dip solution for 20 - 30 seconds.
 H-3f. Rinse work in demineralized water dip tank and drain. Do not allow parts to dry.
 H-3g. Immerse in gold strike solution with potential applied and plate 45 to 60 seconds at 3 - 8 ASF.
 H-3h. Immerse in the gold plating solution and plate for the time specified in Table V, to give the required thickness.

NOTE: Interruption of plating current will cause laminated deposit.

- H-3i. Double rinse parts in gold dragout rinse tanks.
 H-3j. Rinse work in acetic acid solution for 1 to 2 minutes.
 H-3k. Rinse parts in water and dry at room temperature.
- H-4. Grade III: Gold Plating. -
 H-4a. Copper plate carbon steel alloys per Standard Process P-30009, Type II.
 H-4b. Rinse work in running water, spray rinse and drain. Do not allow parts to dry.
 H-4c. Rinse work in sulfuric acid dip solution for 20 to 30 seconds, drain thoroughly.
 H-4d. Rinse work in running water, spray rinse and drain. Do not allow parts to dry.
 H-4e. Immerse work in potassium cyanide dip solution for 20 to 30 seconds.
 H-4f. Rinse work in demineralized water dip tank and drain. Do not allow parts to dry.
 H-4g. Immerse in gold strike solution with potential applied and plate for 45 to 60 seconds at 3 - 8 ASF.
 H-4h. Immerse work in the gold plating solution and plate, for the time specified in Table V, to give the required thickness.

NOTE: Interruption of plating current will cause laminated deposit.

- H-4i. Double rinse parts in gold dragout rinse tanks.
 H-4j. Rinse work in acetic acid solution for 1 to 2 minutes.
 H-4k. Rinse parts in water and dry at room temperature.

Approximate Time in Minutes to Plate Gold (Inches)								
A.S.F.	0.0001	0.0002	0.0003	0.0004	0.0005	0.0006	0.0007	0.0008
1	36.1	72.3	----	----	----	----	----	----
2	20.0	39.0	57.0	78.0	----	----	----	----
3	12.0	26.0	38.0	51.0	63.0	76.0	----	----
4	9.0	20.0	28.0	38.0	46.0	57.0	68.0	76.0
5	7.0	15.0	21.0	29.0	38.0	45.0	52.0	60.0
6	5.0	12.0	18.0	25.0	32.0	39.0	45.0	51.0

TABLE V. - Time Required to Deposit Various Thicknesses.

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- H-5. Brush Plating. -
 H-5a. Surface Preparation. -

- Degrease surface with Turco-Solv, using clean cloths to remove soils and oil.
- Lightly abrade surface, using No. 425 sandpaper to remove all rust, scale, and damaged platings. Burnish out all scratches using burnishing tool and No. 600 sandpaper or abrasive

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- eraser. Rinse well with cold water.
3. Anodic clean as follows:
 - (a) Fit an anode, with a cloth sleeve, to the applicator and connect to negative (-) pole of the rectifier. Connect the positive (+) pole to the part to be cleaned.
 - (b) Dip applicator in the "Coatalyte" anodic cleaner solution until sleeve is wet through.
 - (c) Adjust voltage until a current flow of 2 to 3 amperes is obtained.
 - (d) Move applicator in a circular motion until the entire surface has been covered. Keep applicator and part wet with solution at all times.
 4. Rinse well with cold water and check for water-break-free surface. If water-break occurs, repeat the above cleaning steps.

NOTE: The same applicator sleeves shall not be used for both cleaning and plating.

H-5b.

Plating. -

1. Mask off adjacent areas that do not require plating.
2. Fit an anode, with a cloth sleeve, to the applicator and connect to positive (+) pole of the rectifier. Connect the negative (-) pole to the part to be plated.
3. Dip applicator in the "Coatalyte" solution until the sleeve is wet through. New sleeves should be broken in by plating on clean scrap metal until the ammeter indicates current flow.
4. Adjust voltage to 6 to 8 volts and apply a quick bond coat.
5. Continue plating at 6 or 7 volts. Keep applicator in motion while plating and dip in "Coatalyte" at sufficient intervals to keep sleeve wet. Care should be exercised to see that the applicator is not picked up from the surface being plated while the current is on as this will result in arcing and burning of the part. Plate with a continuous circular motion. During plating the ammeter will register from 1 to 15 amperes depending on the size of the part being plated. The approximate rate of deposition is 0.0001 inch thickness per 16 square inches of work every 15 to 20 seconds.
6. On continuous plating, occasionally rinse the sleeve and anode in clean water, without removing sleeve, and shake off excess water before moistening with "Coatalyte".
7. Immediately after plating rinse part in cold water and wipe dry.

NOTE: As an alternate to "Coatalyte", the Sel-Rex gold solution may be used for brush plating purposes. Exercise care since high current density will result in burned deposits.

I. PROCESS CONTROL:

- I-1. Manufacturing Division shall be responsible for providing and maintaining the necessary equipment and facilities and for producing finished articles that meet the intent of this process.
- I-2. Quality Division shall be responsible for maintaining the materials and solutions within specification and process limits and for enforcing the requirements and procedures of this process.
- I-3. Chemical solutions used at The Martin Company shall be analyzed with the frequency established in Quality Procedure 3.5, Sampling, Testing and Control of Manufacturing Processing Solutions. Chemical solutions used by vendors shall be analyzed with the frequency stated in Section F of this process.
- I-4. Sampling. -
- I-4a. Preparation of Separate Specimens. - Separate specimens shall be plated concurrently with the lot they are to represent. They shall be of a base metal equivalent to that of the articles represented. Equivalent base metal includes chemical composition and finish of surface prior to plating. For example, a cold-rolled steel surface should not be used to represent a hot-rolled steel surface. Due to the impracticality of forging or casting separate test specimens, hot-rolled steel specimens may be used to represent forged or cast steel articles. The separate specimens shall be strips approximately 1 inch wide, 4 inches long and 0.04 inch thick for adhesion and

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and thickness tests. These specimens shall be introduced into a lot at regular intervals prior to the cleaning operations preliminary to plating and shall not be separated therefrom until after completion of the processing. Conditions affecting the plating of the specimens, including the spacing and positioning with respect to anodes and to other objects being plated, shall correspond as nearly as possible to those affecting the significant surface of the articles represented.

- I-4b. Selection of Random Samples for Thickness Tests. - Once per week the number of items specified in Table VI below shall be selected from one lot, for each basis metal normally plated, for testing. A lot is defined as a group of articles of approximately the same size, shape and type which are processed under similar conditions and submitted for inspection at one time.

Lot Sizes	No. of Samples	Permissible Number of Rejects in Samples
0 to 8	2	0
9 to 15	3	0
16 to 25	5	0
26 to 40	7	0
41 to 65	10	0
66 to 110	15	0
111 to 180	25	1
181 to 300	35	1
301 to 500	50	2
501 to 800	75	3

TABLE VI. - Table for Normal Inspection (A.Q.L. = 1.5) from MIL-STD-105B.

- I-4c. Selection of Samples for Adhesion, Solderability and Hardness Tests. - Once per week, a random sample of four items, for each basis metal normally plated, or four separate specimens as provided in paragraph I-4a, for each basis metal normally plated, shall be selected for each test.
- I-5. Requirements and Testing. -
- I-5a. Adhesion - Test specimens shall be repeatedly bent through an angle of 180° around a diameter equal to the thickness of the sample until the basis metal fractures. After probing with a sharp instrument, examination at four power magnification, shall reveal no appreciable area of the plating to be detached.
- I-5b. Thickness - Thickness determinations shall be made by microscopic test, chemical test or instrument methods on parts or separate specimens fully representative of and plated concurrently with production parts. The article shall be considered to be non-conforming if one or more measurements fail to meet the specified minimum thickness. If the number of non-conforming articles in any sample exceeds the acceptance number for that sample the lot represented by the sample shall be rejected.
- I-5c. Solderability - The samples shall be solderable without lump formation when fluxed and dipped in QQ-S-571, Composition Sn60, solder at a temperature of 500 to 600°F for three seconds. The samples shall be shaken lightly and examined for solderability.
- I-5d. Hardness - The minimum hardness of samples selected in accordance with I-4c shall be 110 on the Vickers Scale when tested in accordance with Method 244 of Fed. Test Method Std. No. 151.

I. PRODUCT ACCEPTANCE:

- J-1. The deposits shall be smooth, fine grained, adherent, and free from blisters, nodules, laminations and burning.
- J-2. Parts shall be visually inspected for conformance with the requirements specified herein and on the Engineering Drawing.

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FIGURE 1. - FLOW CHART FOR GOLD PLATING PROCESS.

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A. SUBJECT: INSERT INSTALLATION IN HONEYCOMB PANELS

B. SCOPE:

B-1. This Process Bulletin establishes the procedures and equipment requirements for the installation of inserts in bonded honeycomb panels.

B-2. This Process, when specified, shall be used in conjunction with Engineering Drawings and Data for all work within its scope.

B-3. There is no equivalent Government Process Specification.

C. MATERIALS:

C-1. Epon VI Adhesive (With Curing Agent A)
SPEC.: Commercial
CODE: 61-001-900 GL
SOURCE: Shell Chemical Company

NOTE: DANGEROUS MATERIAL; TOXIC; AVOID SKIN CONTACT, DO NOT BREATHE VAPOR. REFER TO STANDARD PROCESS P75007 FOR PRECAUTIONS AND HANDLING INSTRUCTIONS.

C-2. Naptha, Petroleum Aliphatic
SPEC.: TT-N-95
CODE: 08-504-500

NOTE: DANGEROUS MATERIAL; TOXIC AND INFLAMMABLE. DO NOT BREATHE VAPORS AND KEEP AWAY FROM FIRE HAZARDS. REFER TO STANDARD PROCESS P75007 FOR PRECAUTIONS AND HANDLING INSTRUCTIONS.

D. EQUIPMENT:

- D-1. CP 450 Riveter.
- D-2. Cherry Rivet Gun.
- D-3. Guide Plugs For Fasco Inserts.
- D-4. Anvils For CP450 Riveter.
- D-5. Puller Tools For Cherry Rivet Gun.
- D-6. Caulking Gun.
- D-7. Metal Spatula or Straight Edge.
- D-8. Clean Cloths.

E. REQUIREMENTS:

E-1. Both flush and non-flush type inserts may be used in non-structural honeycomb panels (type I evaluation). Secondary structures (type II evaluation) and primary structures (type III evaluation) shall use only non-flush type inserts. Any deviation shall require the approval of the Structure Design Department.

E-2. The grip lengths and the type of inserts used shall be checked prior to installation in accordance with the Engineering Drawing. A short grip length will result in excessive depression of the panel facing.

E-3. The proper weighing and mixing of the epoxy resin used in accordance with P60022 is essential.

E-4. A record of time limitation for the usable working life of the epoxy resin should be maintained to prevent the setting-up of the resin before any required insert replacement.

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NOTE: GUIDE PLUG MUST BE OF SUFFICIENT LENGTH TO PERMIT MAXIMUM DIAMETER OF PLUG TO EXTEND THROUGH PANEL .

- F-3b. Remove guide plug.
- F-3c. Apply epoxy resin to insert head of remaining section and place in panel.
- F-3d. Seat inserts into panel using most suitable method.
- F-3d(1). By tightening of nut and bolt of suitable size.
- F-3d(2). By use of CP 450 riveter with suitable anvils, using stops to prevent core crush.
- F-3d(3). By use of Cherry Rivet Gun with suitable puller.
- F-4. Remove any excess epoxy resin with clean cloth.
- F-5. Check alignment of insert with correct diameter bolt immediately after installation. If alignment is not satisfactory, remove and replace insert. Do not allow bolt or misaligned insert to remain since it will become fixed as the epoxy resin begins to cure at room temperature.
- F-6. For 1/4 rivets or 1/4 screws, the inserts shall be reamed .256/.258, if necessary.

G. PROCESS CONTROL:

- G-1. Quality Control shall be responsible for requiring complete adherence to the requirements and procedures of this Process.
- G-2. Inspect for proper hole size for inserts used.
- G-3. Inspect for proper type and length of inserts used.
- G-4. Inspect for proper procedure of weighing and mixing of the epoxy resin in accordance with P60022.
- G-5. Inspect for time of mix and working life span of epoxy resin used to prevent setting-up of resin in case of replacement of insert.
- G-6. The following inspection procedure shall be accomplished upon installation of inserts.
- G-6a. Check the insert heads for excessive tilt and gap. A gap of .004 inch is allowed under the head on any one side. Gaps caused by contour of the panel shall not be cause for rejection.
- G-6b. Check for alignment of the two sections of the insert.
- G-6c. If tilt, gap, or alignment are not satisfactory, the insert must be removed and replaced within one hour after inspection or within the working life of the epoxy resin used, whichever is the shorter time.
- G-7. Manufacturing Engineering shall be responsible for the equipment and tooling requirements of this Process.
- G-8. The Bonded Structures Group of Engineering Materials Laboratory shall be notified of major discrepancies arising in the use of this Standard Process.

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SAFETYING DEVICES, INSTALLATION OF

1. SCOPE

1.1 APPLICATION: This specification establishes the requirements to be met by the Martin Company and subcontractors for the installation of safetying devices. Other processes may be used by subcontractors, providing these processes have prior approval by Martin Company. Quality and the requirements of this specification are met.

1.2 ENGINEERING INFORMATION: The Engineering Drawing shall specify this Engineering Process Specification, and, as applicable, provisions for:

- a. The safety-wire material.
- b. The safety-wire termination point, if such termination point is not provided.
- c. The lock clips to be used to safety turnbuckle assemblies.
- d. The cotter pins to be used in castellated nut-on-bolt, and clevis pin assemblies.
- e. Tie points to secure fastenings or fittings which are more than 6 inches apart.
- f. Torque values, if required.

1.3 EQUIVALENT GOVERNMENT SPECIFICATIONS: There is no equivalent government specification; however, items safetyed in accordance with this specification will meet the applicable requirements of MS 33540C and NAS 1074 Rev. 2.

2. APPLICABLE DOCUMENTS: The following specifications, standards, and publications form a part of this specification to the extent specified herein.

2.1 GOVERNMENT SPECIFICATIONS AND STANDARDS

- 2.1.1 MS 33540C, Safety Wiring, General Practices, For
- 2.1.2 MS 21332, Fastener Snapslide

2.2 INDUSTRY SPECIFICATIONS AND STANDARDS

- 2.2.1 NAS 1074 Rev. 2, Turnbuckle Assemblies, Clip Locking, Assembly and Safetying Of.

3. REQUIREMENTS

3.1 MATERIALS

3.1.1 Safety-wire used in conjunction with this specification shall be as specified on the Engineering Drawing.

3.2 EQUIPMENT: There is no applicable equipment to this specification.

3.3 PRODUCT

3.3.1 SAFETY-WIRING

DENVER	6-30-64	C	K. Mills
BALTIMORE	6-30-64	C	N. B. Miller
ORLANDO	5-22-64	C	B. R. Peterson

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3.3.1.1 The size of the safety-wire shall be 0.032 inch minimum diameter with the following exceptions:

- a. 0.020 inch diameter wire may be used on parts having a nominal hole diameter of less than 0.045 inch or on parts having a nominal hole diameter between 0.045 inch and 0.062 inch with a spacing between parts of less than 2 inches.
- b. When using the single wire method of safety-wiring, the diameter of the safety-wire shall be the largest diameter that can be inserted through the applicable installation hole without forcing.

3.3.1.2 The safety-wire shall be free from defects, such as abrasions, cuts, nicks, or kinks which could cause vibrational failures.

3.3.1.3 Safety-wiring shall be tight but not overstressed.

3.3.1.4 Safety-wiring shall be applied to the assembly after the parts have been securely tightened.

Note: (1) Torqueing, if required, shall be as specified by the Engineering Drawing.

(2) The coupling ring, on the coupling ring-receptacle assembly, should only be tightened by hand before safety-wiring.

3.3.1.5 In safety-wiring, the double-twist method shall be used as the common method. See Figures 1, 2, 4-6 and 9-14. The single wire method of safety-wiring may be used in a closely spaced, closed geometrical pattern (triangle, square, rectangle, circle, etc.), on parts in electrical systems, and in places that would make the single-wire method more advisable. See Figures 3 and 7.

3.3.1.6 When safety-wiring widely spaced multiple groups by the double-twist method, three units, spaced 4 to 6 inches apart, shall be the maximum number permitted in a series.

3.3.1.7 When safety-wiring closely spaced multiple groups by the double-twist method, the number of units that can be safety-wired by a 24 inch length of wire shall be the maximum number in a series.

3.3.1.8 Safety-wiring shall not be used to secure fastenings or fittings which are spaced more than 6 inches apart unless tie points are provided on adjacent parts to shorten the span of safety-wire to less than 6 inches.

3.3.1.9 Safety-wire, installed by the double-twist method, shall be twisted at approximately 8 turns per inch.

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3.3.1.10 A "pigtail" of 1/4 to 1/2 inch in length (3 to 6 twists), to lock the safety after it has passed its termination point, shall be made at the end of the wiring. This "pigtail" shall be bent back or under the safety-wiring to prevent it from becoming a snag, a hazard to personnel, or untwisted.

3.3.1.11 Parts shall be safety-wired in such a manner that the safety-wiring will be put in tension when the part tends to loosen.

3.3.1.12 When the double-twist method is utilized, the twist shall be in the direction which tends to hold down the loop around the screw or bolt head; i. e., the wire will tighten as the loop is raised.

3.3.1.13 Safety-wire shall be new upon each application.

3.3.2 COTTER PINNING

3.3.2.1 Cotter pin installations shall be free from destructive cuts and abrasions.

3.3.2.2 The cotter pin shall be snugly positioned, but must not be deformed. See Figures 15, 16 and 17.

3.3.2.3 Cotter pins shall be new upon each application.

3.3.3 CLIP-LOCKING TURNBUCKLE ASSEMBLIES

3.3.3.1 After lock clips are completely installed, not more than 3 turnbuckle terminal threads of either of the two terminals shall be exposed outside the turnbuckle barrel. See Figure 18.

3.3.3.2 Lock clips shall not be reused.

3.3.4 SAFETYING HINGE PIN INSTALLATIONS ON CONTINUOUS TYPE HINGES

3.3.4.1 Continuous type hinge pins shall be safetyed in accordance with Figure 19 unless otherwise specified on the Engineering Drawing.

3.3.4.2 The hinge pin shall be 1/8 to 3/16 inch shorter than the hinge length.

3.3.4.3 The hinge pin shall be safetyed by slightly crimping the end of the hinge loop until it is approximately 1/2 closed.

CAUTION: Do not crimp the ends of the hinge to the extent that it will interfere with the normal hinge function.

3.4 FABRICATION CONTROL

3.4.1 SAFETY-WIRE APPLICATIONS

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3.4.1.1 Safety-wiring individual electrical connector coupling rings shall be accomplished as shown in Figure 1. For connectors not illustrated, safety-wiring shall be accomplished by the method shown for the most similar connector.

Figure 1. - Typical Methods of Safety-Wiring Individual Electrical Connector Coupling Rings.

3.4.1.2 Safety-wiring electrical connector coupling rings in pairs shall be accomplished as shown in Figure 2.

Figure 2 - Safety-Wiring Electrical Connector Coupling Rings in Pairs.

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3.4.1.3 Safety-wiring electrical connector back-shells shall be accomplished using single wiring as shown in Figure 3. For connector back-shells not illustrated, safety-wiring shall be accomplished by the method shown for the most similar type of back-shell.

Figure 3. - Typical Methods of Safety-Wiring Electrical Connector Back-Shells.

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3.4.1.4 When a single bolt or screw must be safety-wired, it shall be accomplished as shown in Figure 4.

3.4.1.5 Typical series safety wiring connections of screws or bolts are shown in Figures 5, 6 and 7.

Figure 4. - Double-Twist Method for Single Unit

Figure 5. - Double-Twist Method for Two Bolts in Series.

Figure 6. - Double-Twist Method For Three Bolts in Series.

Figure 7. - Typical Single Safety Wiring of Bolts in Series.

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3.4.1.6 Figures 8 through 11 show acceptable methods of safety-wiring miscellaneous parts not covered by previous sections.

3.4.1.7 Figure 12 shows an example where safety-wiring is used, in conjunction with an anti-tampering seal (attached by Manufacturing and sealed by Quality), for the prevention of unauthorized adjustments to settings of hydraulic units, etc.

Figure 8. - Drain Cocks

Figure 9. - Valves

Figure 10. - Tank Caps

Figure 11. - Cable Guard

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Figure 12. - Example of Safety-Wiring Methods Used in Conjunction with an Anti-Tampering Seal.

3.4.1.8 When castellated nuts are to be secured to a fastener with safety-wire, the nuts shall be tightened to the low side of the torque value required for the specific castellated nut-bolt assembly, unless otherwise specified on the Engineering Drawing. See Figure 13.

Note: If necessary, it is permissible to continue tightening the nut until a slot aligns with the hole in the bolt.

Figure 13. - Wiring of Group of Castellated Nuts

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3.4.1.9 Safety-wiring, when the double twist method is used, shall always be installed and twisted in the direction which tends to hold the loop around the screw or bolt head and will tighten if the loop is raised. See Figure 14.

Bend "pigtail" to
protect personnel

Figure 14. - Typical Method of Bending Pigtail.

3.4.1.10 Snapslide MS 21332 and those snapslides supplied on Customer Furnished Equipment (C.F.E.), Government Furnished Equipment (G.F.E.), or Outside Vendor Equipment (O.V.E.) shall be safety-wired by the single wire method with a loop run through the latch and through the attaching provision. A "pigtail" is then formed, locking the safety.

3.4.2 COTTER PIN APPLICATIONS

3.4.2.1 Cotter pins shall be installed as shown in Figures 15, 16 and 17.

Figure 15. - Castellated Nut on Bolt
Preferred Method

Figure 16. - Castellated Nut on Bolt
Alternate Method

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Figure 17. - Pin Application.

3.4.2.2 When castellated nuts are to be secured to a fastener with cotter pins, the nuts shall be tightened as previously stated in Paragraph 3.4.1.8 prior to the installation of the cotter pins.

3.4.2.3 If more than 50 percent of the cotter pin diameter is above the nut castellation, when one (1) washer is used under the nut, one (1) additional washer, of the type specified by the Engineering Drawing, may be used.

3.4.3 CLIP-LOCKING TURNBUCKLE ASSEMBLY APPLICATIONS

3.4.3.1 Before securing the turnbuckle with the safety lock clip, both threaded terminals shall be screwed into the turnbuckle barrel an equal number of turns. The cable assembly shall be so rigged that the required tension is obtained after 3 or less turnbuckle terminal threads are exposed. After the terminals are screwed into the barrel, no more than 3 terminal threads of either terminal shall be exposed outside the barrel.

3.4.3.2 Clip-locking shall be accomplished in accordance with steps 1, 2, 3 and 4 of Figure 18. These steps shall then be repeated on the opposite end of the turnbuckle barrel.

Note: Both locking clips may be inserted in the same turnbuckle barrel hole, or they may be inserted in the opposite holes.

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Figure 18. - Clip-Locking Turnbuckle Assembly Procedure.

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3.4.4 SAFETYING HINGE PIN INSTALLATIONS ON CONTINUOUS TYPE HINGE APPLICATIONS

3.4.4.1 Hinge pin installations on continuous type hinges shall be safetyed as shown in Figure 19.

Figure 19. - Safetying Hinge Pins on Continuous Type Hinges.

4. QUALITY ASSURANCE

4.1 Quality shall ensure conformance to this Process Specification.

5. MANUFACTURING CONTROL: This section is not applicable to this specification.

Approved: Norman B. Miller
Martin Company

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AMENDMENT NO. 1

EFFECTIVITY: This Amendment is effective on date of issue.

Delete paragraph A-2 and renumber succeeding paragraphs.

Add paragraph B-7 as follows:

B-7 **EPS 50059, "Contamination Control During Fabrication, Assembly and Testing of Fluid Systems".**

Change paragraph C-2 to read:

C-2 Liquid Detergent
Spec.: Commercial
Code: Order as required

Change paragraph D-4 to read:

D-4 Detergent Solution Tank - A stainless steel tank equipped with the necessary heating facilities to maintain the contents between 100° - 140°F and filtration equipment capable of removing particles over 40 microns, nominal.

Change paragraph E-1 to read:

E-1 Detergent Solution (make-up)

Detergent	Joy, Lux, Vel - 5 to 10 fluid ounces
or	Dri-It - 1/2 fluid ounce
Filtered Water	10 gallons
Operation Temperature	100° - 125°F.

Make up new as required for efficient operation.

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Approved By:
BNWR BALTO:
USAF: _____

Mfg. East Hill
Equip. East Hill

Qlty Cont. J. J. [unclear] Engineering J. B. [unclear]
Safety [unclear] Engr. [unclear]
Mat'l. Engr. [unclear]

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CONTAMINATION CONTROL CLEANING

F. REQUIREMENTS:

Change the second sentence of paragraph F-1a to read:

- F-1a. - - - Parts processed in this manner shall be considered nominally cleaned if they meet the requirements of paragraph A-5k and have been identified and sealed per EPS 50059. - - -

Change the following paragraphs to read:

- F-1b. Parts not identified as nominally clean shall be cleaned per EPS 50059.
- F-1c. The use of halogenated solvents as a final rinse is prohibited. All solvent flushes shall be followed by filtered tap water and demineralized or deionized water flushes to remove residual halides which might be a source of contamination, corrosion or propellant incompatibility.
- F-1o. The ultrasonic cleaning tank shall have power applied for sufficient time (minimum 5 minutes) to de-gas the solvent prior to cleaning any part.
- F-2a. The deionized or demineralized final water rinse and the gaseous air and nitrogen used for drying, in addition to meeting the applicable requirements established in Section C, shall be filtered to meet the following cleanliness requirements prior to use:

<u>Type of Contamination</u>	<u>* Millipore Count Requirements</u>
Particles	Maximum count/liter
0-25	Unlimited
25-40	250
40-150	50
150-500	5
Fibers	5
Total filterable solids - 2 mg. /liter (max.)	
** Hydrocarbon Content - 50 ppm	

NOTE: The two notes against the present para. are still applicable.

G. PROCEDURES:

Change the following paragraphs to read:

- G-1b(1) Completely immerse parts in the ultrasonic cleaning tank for a minimum of two to three minutes. Parts containing blind holes, grooves and recesses shall be positioned so that these areas are facing the transducer surface.
- G-3a. Blow parts free of contamination by means of filtered air or nitrogen.
- G-3b. Package and identify in accordance with paragraph G-1g.

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CONTAMINATION CONTROL CLEANING

Delete paragraphs G-3c and G-3d.

G-4b Delete the last sentence reading: "See paragraph F-3a".

G-4c. Add a sentence reading "See paragraph F-3a" to the end of the paragraph.

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CLEANING

CONTAMINATION CONTROL CLEANING

~~SECRET~~A. APPLICATION:

- A-1. This process specifies the materials, equipment, requirements and procedures necessary for contamination control cleaning of details, fittings, components and assemblies for use in aircraft, missile, space craft and related ground support equipment, fuel, oxidizer, hydraulic, pneumatic, air conditioning and plumbing systems. This process does not apply to installed plumbing systems or to components and assemblies where complete removal of cleaning, flushing and rinsing solutions cannot be assured.
- A-2. The use of trichloroethylene as a final rinse is prohibited. All solvent flushes shall be followed by filtered tap and demineralized or deionized water flushes to remove residual chlorides which might be a source of contamination.

A-3. Contents. -

<u>SECTION</u>	<u>TITLE</u>	<u>PAGE</u>
A	Application	1
B	References	2
C	Materials	2
D	Equipment	3
E	Solution Makeup and Control	4
F	Requirements	4
G	Procedure	7
G-1	Cleaning of all Descaled, Surface Treated and Plated Metallic Parts Except Hoses	7
G-2	Cleaning of Rubber and Plastic Parts	8
G-3	Cleaning of Leather Parts	8
G-4	Cleaning of Stainless Steel and Smooth Bore Teflon Lines, or Equivalent Hoses	8
H	Process Control	8
I	Product Acceptance	9

- A-4. This process, when specified, shall be used in conjunction with Engineering Drawings and Data for all work within the scope of this process. There is no equivalent Government Process Specification.
- A-5. This process does not cover mechanical and/or chemical cleaning, surface treatments or plating of details or assemblies. Preliminary cleaning and finishing shall be called out on applicable Engineering Drawings to be accomplished prior to final cleaning in accordance with this process.
- A-6. Definitions. - Words and terms listed in this paragraph are defined for the purpose of clarifying and standardizing their usage in this and all referenced processes.
- A-6a. Component. - A unit installed in a flow system which in some manner alters flow through the system, e.g., valve, pump, regulator.
- A-6b. Instrument. - Device for measuring a property of a fluid without interfering with the flow, e.g., temperature, pressure, flow rate.

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CONTAMINATION CONTROL CLEANING

- A-6c. Water Break Free Surface. - A surface which is sufficiently clean that, upon dipping in water free from wetting agents, the water drains evenly for five seconds without breaking around contaminated areas.
- A-6d. Significant Surfaces. - Surfaces of components or system parts which will contact the operational fluid or which could reasonably be expected to be a source of contamination.
- A-6e. Micron. - 1/1000 of a millimeter, or .00004 inches.
- A-6f. Non-Volatile Residue (N.V.R.). - Weight of solid residue remaining after fluid sample has been evaporated to dryness. To prevent charring of the residue, the boiling point of the liquid must not be exceeded.
- A-6g. Ultraviolet Light. - Light of approximately 2,500 to 3,700 Angstrom units wavelength.
- A-6h. Hydrocarbon Contamination Content. - The volatile and non-volatile hydrocarbon content of a fluid at ambient temperature expressed as elemental carbon.
- A-6i. Parts Per Million (PPM). - Parts of contaminant, by weight, per million parts by weight of the containing substance.
- A-6j. Fiber. - A thread-like particle of organic origin defined by the following dimensions:
Less than 40 microns in width and greater than 300 microns in length.
- A-6k. Nominally Clean. - A condition of surface appearance of parts when visual examination shows no evidence of corrosion products, metal chips, scale, weld scale, oil, grease, paint, preservatives, decals or other contamination or foreign matter.

B. REFERENCES:

- B-1. Standard Process P-50046, "Vapor Degreasing with Trichloroethylene".
- B-2. Standard Process P-50060, "Contamination Control Packaging Requirements".
- B-3. Standard Process P-50061, "Clean Room Process Control Specification".
- B-4. Standard Process P-75007, "Handling of Dangerous and Toxic Materials".
- B-5. IR-227, "Contamination Control Certification for Cleaning and Packaging".
- B-6. Quality Division Procedure 3.5, "Sampling, Testing and Control of Manufacturing Process Solutions".

C. MATERIALS:

- C-1. Trichloroethylene, Stabilized Degreasing
SPEC.: MMS K-529
CODE: K5-29A-100 GL

- NOTE: DANGEROUS AND TOXIC SOLVENT. AVOID BREATHING OR CONTACTING VAPORS. REFER TO STANDARD PROCESS P-75007 FOR PRECAUTIONS AND HANDLING INSTRUCTIONS.

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C-2. Liquid Detergent - Joy, Lux, Vel or equivalent
SPEC.: Commercial
CODE: Order as required

C-3. Nitrogen Pressurizing, Propellant Systems
SPEC.: MIL-P-27401A, Type I
CODE: Y4-98A-100 EA (Order as required)

C-4. Deionized or Demineralized Water. - The deionized or demineralized water used in conjunction with this process shall have a minimum resistivity of 50,000 ohm-centimeters and a pH of 5.5 to 7.5.

D. EQUIPMENT:

D-1. Vapor Degreaser. - Equipped with stainless steel heating and cooling coils and a spray lance attachment for flushing. The spray lance attachment shall be provided with filters capable of removing visible particle contamination.

NOTE: This equipment shall be located adjacent to but outside of the contamination controlled area.

D-2. Deionization or Demineralization Equipment. - To provide sufficient quantities of treated water meeting the requirements of paragraph C-4 of this process.

D-3. Deionized or Demineralized Water Cleaning and Flushing Trough. - A stainless steel tank equipped with a reservoir for deionized or demineralized water, a pump for supplying water under pressure at the ejection nozzles and filtration equipment capable of supplying filtered water to meet the cleanliness requirements of paragraph F-2 of this process.

D-4. Detergent Solution Tank. - A stainless steel tank equipped with the necessary heating facilities to maintain the contents between 100° - 140°F.

D-5. Filtered Tap Water Rinse Tank. - A stainless steel tank equipped with overflow dam, spray lance attachment and filters capable of removing particles over 40 microns, nominal.

D-6. Ultrasonic Cleaning Tank. - Stainless steel tank equipped with lid, thermostatically regulated heating and cooling coils capable of maintaining solvent at 130°F ± 10°F, filtration unit capable of supplying solvent which meets the requirements established by paragraph F-2 of this process.

D-6a. Generator. - The generator shall be matched to the transducer and shall be capable of delivering continuously 5 to 10 watts power per square inch transducer face area, at a minimum of 20 kilocycles.

D-6b. Transducers. - The transducers shall be mounted on the bottom of the ultrasonic tank and shall be of sufficient capacity to provide uniform cavitation throughout the tank. The transducers shall be capable of operating at a minimum of 20 kilocycles.

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- D-7. Solvent Flushing Booth. - Stainless steel construction equipped with pumps, spray lance attachment with filters capable of supplying solvent to meet the requirements of paragraph F-2 of this process.
- D-8. Drying Oven. - Stainless steel construction equipped with heaters and controls necessary to maintain a temperature of 100°F - 150°F and filters capable of supplying inlet air to meet the requirements of paragraph F-2 of this process.
- D-9. Adaptable Millipore Filtration Equipment. - To provide filtered gaseous nitrogen and air to meet the cleanliness requirements of paragraph F-2 of this process.
- D-10. Heat Exchanger Unit. - Capable of drying the required quantities of gaseous nitrogen to a dew point of -60°F or lower and/or heating the gas to a temperature of 100°F to 125°F.
- D-11. Contamination Controlled Room. - To meet the requirements of Standard Process P-50061, Class 5 or better.
- D-12. Clothing. - The clothing worn by personnel, for cleaning parts in accordance with this process, shall meet the requirements as specified in Standard Process P-50061, Class 5 or better.
- D-13. Hoses. - All hoses shall be constructed of stainless steel or lined with Teflon or polyvinylchloride.
- D-14. Ultra-violet Light. - A portable, 100 watt ultra-violet light source of 2500 to 3700 Angstrom units wavelength.
- D-15. Millipore Filtration Equipment (Laboratory Type). - Suitable for filtering liquid and gaseous products prior to particle count analysis.
- D-16. Brushes. - Nylon or other suitable synthetic fiber brushes without wooden handles.
- D-17. Binocular Microscope. - Dual magnification (40 x and 100 x) and associated illumination equipment suitable for particle counting techniques.
- D-18. Cleaning Picks, Tweezers, etc. - Stainless steel construction and of varying sizes suitable for cleaning out small holes, recesses, grooves, etc.
- D-19. Racks, baskets and tongs for handling parts during cleaning operations shall be made of stainless steel. Baskets used in the ultrasonic cleaner shall be made of stainless steel sheet with appropriate drain holes. Wire mesh having openings less than 1/2 inch shall not be used because smaller mesh will dampen the cavitation of the cleaning media.

E. SOLUTION MAKE UP AND CONTROL:

- E-1. Detergent Solution (Make-Up)
Detergent	1/2 to 1 fluid ounce
Filtered Water	1 gallon
Operation Temperature	100°F to 125°F
- Make up a new solution as required for efficient operation.

F. REQUIREMENTS:

- F-1. General. -

- F-1a. All mechanical and/or chemical cleaning and all chemical surface treatments and plating called out on the applicable Engineering Drawings shall be accomplished prior to cleaning in

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accordance with this process. Parts processed in this manner shall be considered nominally cleaned if they meet the requirements of paragraph A-6k and shall be identified and wrapped as such. Only nominally clean parts shall be acceptable for admittance to the contamination control cleaning area for final cleaning in accordance with this process.

- F-1b. Parts not identified as nominally clean shall be vapor degreased, if solution is compatible to material, in accordance with Standard Process P-50046 and sealed in a single polyethylene bag prior to admittance to the contamination control cleaning area. In the performance of the vapor degreasing operation particular care shall be exercised to insure thorough flushing of significant surfaces.
- F-1c. Rubber, leather and plastic "O" rings or seals shall be removed from paper container and if applicable, cure date stamped on metal tag and tag attached with wire to part or lot of parts. Parts shall then be cleaned by filtered shop air blast and placed in plastic bag. This shall be considered nominally clean for admittance to contamination control cleaning area.
- F-1d. Final cleaning of parts in accordance with this process shall be accomplished in a contamination controlled area meeting the requirements of Process P-50061, Class 5 or better, except where noted.
- F-1e. Parts that have been rejected because of defective protection seals or wrapping shall be re-cleaned in accordance with this process.
- F-1f. If, for any reason, rework is performed on a cleaned part, the part shall be reviewed by Manufacturing and Quality Divisions for disposition. Parts evidencing damage to surface finish called out on applicable Engineering Drawings shall be re-treated in accordance with applicable process and re-cleaned in accordance with this process. Parts not evidencing surface finish damage, due to reworking, shall be re-cleaned in accordance with this process.
- F-1g. Metal pressure plugs and caps used to close all opening on cleaned parts shall be cleaned and packaged in accordance with this process prior to installation.
- F-1h. Personnel operating within the scope of this process shall be certified to IR-227.
- F-1i. All parts shall be packaged and identified in accordance with Standard Process P-50060 as soon as possible after cleaning and drying in accordance with this process.
- F-1j. Rubber and plastic parts or any metal components with rubber or plastic inserts shall not be cleaned in trichloroethylene. Components shall have rubber "O" rings and seals removed prior to processing in trichloroethylene solvents, ultrasonic unit or degreaser. Where rubber or plastic parts cannot be removed, components shall be cleaned in the liquid detergent solution.
- F-1k. Parts shall be handled by operators only when necessary. Operators shall wear clean gloves at all times when handling final rinsed parts. Handling of significant surfaces shall be completely avoided.
- F-1l. Trichloroethylene only shall be used as the cleaning media in the ultrasonic tank.
- F-1m. The solvent in the ultrasonic tank shall be maintained at the manufacturer's recommended operating level.

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- F-1n. The temperature of the trichloroethylene in the ultrasonic tank shall be maintained at $130^{\circ}\text{F} \pm 10^{\circ}\text{F}$.

NOTE: Transducers may be damaged if the temperature of the solvent is allowed to rise above 160°F .

- F-1o. If the ultrasonic cleaning tank has been inoperative for an extended period of time or a solution addition has been made, power shall be applied for sufficient time (minimum 5 minutes) to de-gas the solvent prior to cleaning any part.

F-2. Processing Fluid Cleanliness Requirements. -

- F-2a. The trichloroethylene supplied to the solvent flushing booth, the cleaning and flushing trough, and the ultrasonic cleaner, the deionized or demineralized final water rinse and the gaseous air and nitrogen used for drying, in addition to meeting the applicable requirements established in Section C, shall be filtered to meet the following cleanliness requirements:

<u>Type of Contamination</u>	<u>* Millipore Count Requirements</u>
Particles	Maximum count/liter
40 microns and under	2000
40 - 150 microns	10
150 microns and up	0
Fibers	10
•• Hydrocarbon Content	50 ppm

* NOTE: The Millipore count requirements for gases shall be based on 1000 grams of gas.

•• NOTE: The hydrocarbon content refers to the non-volatile portion.

- F-2b. All solutions shall be continuously checked for visible contamination. If any is present, the solution shall be discarded, the tank cleaned and refilled with fresh, clean solution.

F-3. Inspection Requirements. -

- F-3a. After rinsing in filtered tap water, the pH of the drippings from the part shall be within 1 pH unit of the influent water.

- F-3b. The effluent from the final solvent or deionized or demineralized water rinse shall be sampled and shall meet the applicable contamination control specifications.

- F-3c. After cleaning and drying, but prior to packaging, significant surfaces of tubing, components and fittings shall be visually inspected, where possible, and meet the following requirements:

- F-3c(1). No residue or foreign material shall remain on any significant surfaces which could contaminate the system.

- F-3c(2). All parts shall be thoroughly dry.

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F-3c(3). Visual inspection, assisted by ultra-violet light, shall be accomplished on all accessible surfaces of parts used in oxidizer and gaseous pressurization systems, when required by Project Contamination Control Specifications, to insure absence of fluorescent contaminants. If fluorescence on parts cannot be removed, it shall be determined by Quality Control Laboratory if the fluorescence is a contaminant hazardous to the part or system. Slight discoloration of parts shall not be cause for rejection.

G. PROCEDURE:G-1. Cleaning of all Descaled Surface Treated and Plated Metallic Parts Except Hoses. -

G-1a. Check parts against applicable drawings and process plans to ensure that all operations prior to final cleaning, in accordance with this process, have been accomplished. See paragraphs F-1a, F-1b and F-1c.

G-1b. Ultrasonic Cleaning.

NOTE: If size and configuration of part does not make ultrasonic cleaning feasible, proceed directly to paragraph G-1c.

G-1b(1). Completely immerse parts in the ultrasonic cleaning tank for approximately two to three minutes or until all visible contamination is removed. Parts containing blind holes, grooves and recesses shall be positioned so that the recesses are facing the transducer surface.

G-1b(2). Intricately shaped parts and large parts that extend beyond the effective cavitation area of the solvent shall be rotated as necessary to provide effective cleaning to all surfaces.

G-1c. Flush Cleaning. - Solvent flush all surfaces with filtered trichloroethylene by means of the spray lance attachment provided in the flushing booth. Particular care must be exercised so that all significant surfaces are thoroughly flushed with a free flowing stream of clean solvent.

G-1d. Rinse parts thoroughly in filtered tap water rinse tank. Agitate and rearrange part or parts as necessary to provide complete rinsing of all surfaces. See paragraph F-3a.

G-1e. Rinse parts with filtered deionized, or demineralized water. Thoroughly force flush rinse all significant surfaces of parts with a free flowing stream of water. Flush all significant surfaces for a minimum of two minutes. See paragraph F-3b.

G-1f. Drying shall be accomplished by one or both of the following methods:

(1) Blow filtered, dry nitrogen or air heated to a temperature of 100 to 125°F over and through all areas of the parts until dry.

(2) Place parts in low temperature drying unit at 120°F to 150°F until dry.

NOTE: If air was used for drying in either of the above procedures, a final purge with dry nitrogen for 1 to 2 minutes shall be accomplished prior to packaging.

G-1g. Identify and package cleaned and dried parts in accordance with Standard Process P-50060.

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G-2. Cleaning of Rubber and Plastic Parts. -

- G-2a. Clean rubber parts by immersion in liquid detergent solution (E-1) for a period of 10 to 15 minutes. Agitate and rearrange parts where necessary to prevent entrapped air from prohibiting thorough cleaning of all surfaces.
- G-2b. Clean plastic parts by immersion for a period of 10 to 15 minutes or brush clean with a soft nylon brush and liquid detergent solution (E-1) at a maximum temperature of 125°F.
- G-2c. Rinse parts thoroughly in filtered tap water rinse tank. Agitate and rearrange parts as necessary to provide complete rinsing of all surfaces. See paragraph F-3a.
- G-2d. Rinse, dry and package in accordance with paragraphs G-1e, G-1f and G-1g in the order specified.

G-3. Cleaning of Leather Parts. -

- G-3a. Solvent clean by brushing thoroughly with soft bristle brush using filtered, room temperature trichloroethylene.
- G-3b. Rinse parts in filtered, room temperature trichloroethylene. See paragraph F-3b.
- G-3c. Dry in oven, temperature range of 120°F to 150°F.
- G-3d. Package and identify in accordance with paragraph G-1g.

G-4. Cleaning of Stainless Steel and Smooth Bore Teflon Lines, or Equivalent Hoses. -

- G-4a. Solvent degrease interior of hoses with filtered trichloroethylene by means of the spray lance attachment provided in the cleaning and flushing trough or flushing booth - first through one end and then the other for a minimum of two minutes for each operation.
- G-4b. Pressure flush with detergent solution first through one end and then the other for a minimum of two minutes for each operation. See paragraph F-3a.
- G-4c. Rinse parts with filtered tap water by force flushing over all exterior surfaces of parts. Thoroughly force flush all interior surfaces, first through one end and then the other, for a minimum of two minutes for each operation.
- G-4d. Rinse parts with filtered, deionized or demineralized water by force flushing over all exterior surfaces of parts. Flush all interior surfaces of parts with full flowing water, first through one end and then the other, for a minimum of two minutes for each operation. See para. F-3b.
- G-4e. Dry and package in accordance with paragraphs G-1f and G-1g in the order specified.

H. PROCESS CONTROL:

- H-1. Manufacturing Division shall be responsible for providing and maintaining the necessary equipment and facilities and for producing finished articles that meet the requirements of this process.

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- H-2. Quality Division shall be responsible for maintaining the materials and solutions within specification and process limits and for enforcing the requirements and procedures of this process.
- H-3. Sampling, testing and control analysis of processing solutions performed at the Martin Company shall be in accordance with the methods and frequency established by Quality Division Procedure 3.5.
- H-4. Prior to cleaning in accordance with this process, Quality Division shall verify that preliminary cleaning and packaging, as specified in paragraph F-1a, has been accomplished.
- H-5. All personnel performing work in accordance with this process shall be certified to IR-227.
- H-6. Materials Engineering shall be notified of major discrepancies arising through the use of this process.

I. PRODUCT ACCEPTANCE:

- I-1. Product acceptance shall be based upon complete adherence to the requirements and procedures established in this process. Continuous in-process control is an absolute necessity to insure that cleaned and packaged parts meet process requirements. Special attention shall be given to the following items.
- a. Quality shall verify that the effluent from the final deionized or demineralized water rinse meets the cleanliness requirements established by appropriate Project Contamination Control Specifications and Drawings.
 - b. Quality shall visually examine all parts for cleaning and drying before packaging.
 - c. Details, tubing and components for oxidizer and gaseous systems shall be examined with ultra-violet light for evidence of fluorescence. Any evidence of fluorescence shall be cause for rejection at the discretion of Quality Division, if the fluorescence is judged to be a contamination hazard to the part or system specified.
 - d. All tubing and components shall be identified, stamped and packaged in accordance with Process P-50060.

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Issued: 2-10-60

Revised: OCT 3 1962

1. R-1
- A T M O R E

STANDARD PROCESS

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P-50051

~~SECRET~~

Code Ident. No. 38597

AMENDMENT

WELDING, INERT GAS SHIELDED TUNGSTEN ARC, OF TITANIUM

EFFECTIVITY: This Amendment supersedes Amendment No. 1 and becomes effective on date of issue.

A. APPLICATION:

Add the following to the materials listed in A-1:

(c) the alpha-beta titanium alloy 6 Al-4V, MIL-T-9046 (Class 2).

C. MATERIALS:

Add the following under C-2, Filler Rods:

C-2d For 6 Al-4V alloy titanium
Dia.: As required
Code: Purchased as required
Spec.: 6 Al-4V alloy titanium wire
Color Code: White & Yellow

Change C-3a to read as follows:

C-3a Argon
Spec.: 99.995% pure - minus 75°F dew point or lower
Code: 08-510-900 EA

Change C-3b to read as follows:

C-3b Helium
Spec.: 99.99% pure
Code: 08-512-100 EA

E. REQUIREMENTS:

Change paragraph E-3 to read:

Detail parts and filler wire shall be free from grease and foreign matter. Cleaning shall be accomplished in accordance with EPS 50063. The end of the welding wire on which the color code has been added shall be discarded. Just prior to welding all edges to be joined must be "dressed" using aluminum oxide abrasive. After "dressing", clean with acetone or safety solvent MMS K544.

~~SECRET~~

Issued By: Norman B. Mills Mfg. John H. Lee Qty. Cont. John H. Lee Engineering Norman B. Mills
B. R BALTO: John H. Lee Equip. John H. Lee Safety John H. Lee STRESS Engr. John H. Lee
USAF: John H. Lee Mat'l. Engr. John H. Lee

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Revised:

BALTIMORE

STANDARD PROCESS P 55017

AMENDMENT No. 2

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~~SECRET~~

Code Ident. No. 38597

AMENDMENT

Change third sentence of E-5 to read:

'Dew point of inert gas(es) used must be minus 75⁰F or lower. "

Add the following as E-11d:

E-11d 6 Al-4V titanium alloy - Heat to 1200⁰ F and hold one-half hour at temperature. Air cool. (NOTE: Assemblies requiring heat treatment after welding need not be stressed relieved, instead, heat treatment shall be carried out in accordance with Engineering Drawing instructions.)

G. PROCESS CONTROL:

Change first sentence of (a) under G-4 to read:

"Porosity and inclusions, either singly or in combination, shall not exceed 5 percent of the area of a linear inch of weld or of the cross section of a weld".

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Revised:

MARTIN
BALTIMORE

STANDARD PROCESS P 55017

AMENDMENT No. 2

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01100000

SOLDERING, WELDING & BRAZING

WELDING, INERT GAS SHIELDED TUNGSTEN ARC, OF TITANIUM

SECRET

A. APPLICATION:

- A-1. This process establishes the requirements and procedure for the inert gas shielded tungsten arc welding of (a) unalloyed titanium conforming to one of the following specifications: MIL-T-7993 (Class II), MIL-T-7993 (Class I), MIL-T-9047 (Class 1), MMS 4627, MMS 4628, and (b) the all alpha titanium alloy A-110AT, MIL-T-9047 (Class 2), MIL-T-9046 (Class 3). Welding to this process can be performed either manually or with automatic welding equipment.
- A-2. BuAer Letter AER-AE-414 dated 12 Jan. 1954 authorizes use of this process so long as the minimum quality requirements of MIL-W-8611 (Aer) are met.
- A-3. This process, when specified, shall be used in conjunction with Engineering Drawings and Data for all work within the scope of this process. There is no equivalent Government Process Specification.

B. REFERENCES:

- B-1. Military Specification MIL-I-6866, "Inspection; Fluorescent Penetrant, Method Of".
- B-2. Military Specification MIL-I-6865A, "Inspection; Radiographic".
- B-3. Military Specification MIL-W-8611 (Aer), "Welding, Fusion of Steels and Corrosion and Heat Resisting Alloys; Process For".
- B-4. Military Specification MIL-A-4144, "Argon Gas, Welding".
- B-5. Martin Standard Process P-50018, "Paint Removal".
- B-6. Martin Standard Process P-80007, "Welding, Fusion, Operator's Certification Procedure".
- B-7. Martin Standard Process P-50042, "Descaling Stainless Steels and Titanium".
- B-8. BuAer Letter, Aer-Ae-414, dated 12 January 1954.

C. MATERIALS:

C-1. Tungsten Electrodes, -

Dia.	.040	CODE:	08-628-500 EA
	1/16		08-628-600 EA
	3/32		08-628-700 EA
	1/8		08-628-800 EA
	5/32		08-628-900 EA
	3/16		08-629-000 EA

SPEC.: AWS-EWTh-2

SOURCE: Sylvania, Air Reduction Sales Co.

C-2. Filler Rods, -

C-2a. For unalloyed titanium

Dia.	1/32	CODE:	08-623-900 LB
	1/16		08-623-600 LB
	3/32		08-623-700 LB
	1/8		08-623-800 LB

SPEC.: Commercially pure titanium wire, 55,000 psi nominal yield strength.

Color Code: Brown

C-2b. For A-110AT Alloy Titanium

Dia. 1/16 CODE: 08-621-200

SPEC.: A-110AT alloy titanium wire.

Color Code: White

SECRET

Issued: 2-10-54 Revised: 6-24-60	<h1 style="margin: 0;">MARTIN</h1> <h2 style="margin: 0;">BALTIMORE</h2>	STANDARD PROCESS P-55017 Page 1 of 6 Pages
<div style="display: flex; justify-content: space-between;"> <div> <p>1 By: <u>SL60</u></p> <p>IN: <u>SALTO</u></p> </div> <div> <p>Mfg. <u>L. E. Lane</u></p> <p>Equip. <u>L. E. Lane</u></p> </div> <div> <p>Qty. Com. <u>Engineering</u></p> <p>Safety <u>Engineering</u></p> </div> <div> <p>Mat'l. Engr. <u>John Halling</u></p> </div> </div>		

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SOLDERING, WELDING & BRAZING

WELDING, INERT GAS SHIELDED TUNGSTEN ARC, OF TITANIUM

C-2c. For welding unalloyed titanium to the A-110AT alloy, use A-110AT alloy wire (C-2b).

C-3. Inert Gases, -

SOURCE: Linde Air Products Co.
Air Reduction Sales Co.

C-3a. Argon

SPEC.: MIL-A-4144
CODE: 08-510-900 EA

C-3b. Helium

SPEC.: 99.99% pure with dew point of minus 65°F or lower.
CODE: 08-512-100 EA

D. EQUIPMENT:

(Manual)

D-1. Electrode Holders (Torch). -

D-1a. Air cooled shielded arc type 200 amp. (Commercial Model).

D-1b. Water cooled shielded arc type 200 amp. (Commercial Model).

D-1c. Air cooled shielded arc type 75 amp. (Commercial Model).

D-2. Pressure Regulator, - Low pressure, two stage type for helium or argon (Airco 8470-8474).

D-3. Wrench, - 6 way cylinder and hose wrench (T-104M78).

D-4. Helmet - furnished by operator.

D-5. Spare helmet glass - supervisibility #10 and #11 (Lincoln Electric).

D-6. Generator (DC), ampere rating 10-150; 15-200.

D-7. Ground clamps, T-106M34.

D-8. Screen six (6) feet - six (6) inches high pipe frame, castered and covered above two (2) feet height with 3/8 inch or 1/2 inch transite or heavy duck canvas.

D-9. Gas cup equipped with trailing shield.

(Automatic)

D-10. Airco Heliweld Automatic Head Model C or equivalent.

D-11. Heliweld Filler Wire Feeder No. 23150057 or equivalent.

D-12. Power supply - 200 amp. DC Arc Welding Machine - Commercial Model.

D-13. Heliweld Automatic Head Remote Control.

D-14. Airco Radiograph No. 41, Traveling Work Carriage or equivalent.

D-15. Collets for Heliweld Automatic Head, -

<u>Collet Size</u>	<u>Tool Number</u>
1/16	T-182M13
3/32	T-182M14
1/8	T-182M15
.040	T-182M12

D-16. Pressure Regulators, Low Pressure, Two Stage Type for Airco 8470 Helium or Airco 8474 Argon.

D-17. Wrench, six (6) way cylinder and hose wrench (Airco No. 809-0028), T-104M78.

D-18. Shield or Helmet, Lincoln Electric Co. or equivalent.

D-19. Spare shield and helmet glass, supervisibility #9, #10 and #11, Lincoln Electric Co.

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WELDING, INERT GAS SHIELDED TUNGSTEN ARC, OF TITANIUM

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- D-20. Ground clamps (Airco "Jackson Ground Clamps").
- D-21. Screen, six (6) feet - six (6) inches high pipe frame, casted and covered above two (2) feet high with 3/8 inch or 1/2 inch transite or heavy duck canvas.

E. REQUIREMENTS:

- E-1. Welding Operator Certification and Qualification of Automatic Equipment. -
- E-1a. Manual welders shall not be permitted to weld to this process unless certified in accordance with Standard Process P-80007.
- E-1b. Automatic equipment, as intended for use on production parts, shall demonstrate its ability to produce welds meeting the quality requirements of this process by qualifying to applicable portions of Standard Process P-80007 on the type of joint(s) for which the equipment will be used in production. It shall be the responsibility of the Welding Engineer (Mfg. Engineering) to qualify automatic equipment.
- E-1c. Prior to production welding, the operator shall demonstrate his ability to properly operate automatic equipment (after qualification by Mfg. Engineering) by satisfactorily welding applicable specimens, the requirements being the same as for equipment qualification (paragraph E-1b).
- E-2. All weldments shall be permanently marked with the welder's symbol. In meeting this requirement, marking methods such as metal stamping, electric-arc scribing and chemical etching are prohibited. Ink stamping is not suitable because this method lacks permanency. Dry grit blasting (Matthew's Airgrit Marking Unit) is an approved method for meeting this requirement.
- E-3. Detail parts and filler wire shall be free from grease and foreign matter. Cleaning shall be accomplished by vapor degreasing. Paint, when present, shall be removed in accordance with Standard Process P-50018. The end of the welding wire on which the color code has been added shall be discarded. Just prior to welding, all edges to be joined must be "dressed" using emery cloth or by filing lightly. After "dressing", clean with Taseb and clean gauze.
- E-4. Preheating is not required.
- E-5. The weld area must be effectively shielded to avoid weld contamination. Shielding may be accomplished by (1) welding in a gas tight chamber filled with inert gas, (2) standard metallic gas cup equipped with trailing shield in conjunction with either metallic back-up or inert gas back-up. Dew point of inert gas(es) used must be minus 65°F or lower. Assemblies having faying surfaces must be welded in a chamber (method 1). When not practical to use chamber due to size of assembly, then special precautions shall be taken to prevent contamination. (See paragraph E-12).
- E-6. Filler wire shall be used as specified in C-2 for the type of material(s) being welded.
- E-6a. Filler wire cooled from high temperatures in air, during welding, may be contaminated. In every instance that this happens, the end of the wire must be removed before welding is resumed.
- E-7. Weld sizes shall conform with Table I requirements except as noted otherwise herein.
- E-7a. The following applies to butt welds in material thicknesses .080 inch and under:
- E-7a(1). Thickness of the weld shall be at least equal to, but in no case less than the thickness of the base material.
- E-7a(2). Penetration shall be 100% of the material thickness as evidenced by a bead and absence of a joint line on the side opposite to the welding side.
- E-7a(3). The top side of the weld (side on which welding was performed) shall have a maximum allowable depression of 15% of the thickness of the base metal.
- E-7a(4). For joints of unequal thickness the thickness of the weld shall be at least equal to, but in no case less than the thickness of the thinner member as evidenced by a bead and absence of a joint line on the side opposite to the welding side. The top side of the weld in such cases shall have a maximum allowable depression of 15% of the thickness of the thinner member.

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SOLDERING, WELDING & BRAZING

WELDING, INERT GAS SHIELDED TUNGSTEN ARC, OF TITANIUM

SHEET SIZE (IN.)	FILLET WELD				LAP WELD				BUTT WELDS			
	LEG		THROAT		FACE		THROAT		BEAD	WIDTH	BEAD	THICK.
	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.
.025	9/64	17/64	3/32	3/16	1/32	1/8	1/32	3/32	5/32	9/32	3/64	11/64
.032	9/64	17/64	3/32	3/16	1/16	5/32	1/32	3/32	5/32	9/32	1/16	3/16
.050	9/64	17/64	3/32	3/16	3/32	3/16	1/32	3/32	5/32	9/32	5/64	13/64
.063	9/64	17/64	3/32	3/16	1/8	7/32	1/16	1/8	5/32	9/32	3/32	7/32
.080	11/64	19/64	1/8	7/32	5/32	1/4	1/16	1/8	3/16	5/16	7/64	15/64
.100	11/64	19/64	1/8	7/32	3/16	9/32	3/32	5/32	1/4	3/8	5/32	9/32
.125	13/64	21/64	9/64	15/64	7/32	5/16	3/32	5/32	9/32	13/32	3/16	5/16
.160	7/32	11/32	5/32	1/4	9/32	3/8	1/8	7/32	3/8	1/2	1/4	3/8
.180	15/64	23/64	11/64	17/64	5/16	13/32	5/32	1/4	13/32	17/32	9/32	13/32
.250	21/64	29/64	15/64	21/64	7/16	17/32	7/32	5/16	15/32	19/32	3/8	1/2
Over .250	As specified by Engineering Drawing.											

NOTE: 75% (min.) of the above sizes may be used in double fillet applications, i.e., when welding on both sides of joint.

TABLE I. - Weld Bead Sizes.

- E-7b. Weld beads exceeding the maximum allowable dimensions of Table I are not desirable, but shall not be rejected unless investigation reveals that interference of mating parts results due to the excessive bead size.
- E-7c. Deviations from the minimum requirements of Table I are acceptable provided the aggregate length of the deviations does not exceed 10% of the total bead length and provided the throat dimension has not been reduced to less than 80% of the minimum specified.
- E-8. The size of the weld beads joining materials of different thicknesses shall be based on the thinnest gage of material being welded.
- E-9. Welds shall not be "dressed" by removing metal from the joint unless further welding is to be performed in the "dressed" area, or unless so specified on the individual drawing.
- E-10. Flange Welds. - Flange welds shall, after welding, have a smooth round bead.
- E-11. Stress relieving and descaling shall be carried out after welding is completed except as noted below in E-12. Descaling shall be in accordance with P-50042 requirements. Stress relief shall be carried out as follows:
- E-11a. Unalloyed titanium assemblies. - Heat to 1000°F and hold one-half hour at temperature. Air cool.

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BALTIMORE

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SOLDERING, WELDING & BRAZING

WELDING, INERT GAS SHIELDED TUNGSTEN ARC, OF TITANIUM

- E-11b. A-110AT titanium alloy. - Heat to 1200°F and hold one hour at temperature. Air Cool.
- E-11c. Assemblies consisting of both unalloyed titanium and the A-110AT alloy. - Heat to 1000°F for one hour. Air cool.
- E-12. Assemblies having faying surfaces in which cleaning solutions may be trapped shall not be descaled after stress relieving. (Ref. Standard Process P-50042).
- E-13. Pressure tests, when required, shall be carried out in accordance with Engineering Drawing instructions.

F. PROCEDURE:

- F-1. Prepare details and filler wire prior to welding in accordance with E-3.
- F-2. Assemble details in jig or clamping devices and tack weld, when necessary, to assure proper alignment of details. Tack welds must be effectively shielded to avoid contamination. In making square butt joints without the addition of filler wire, the edges to be welded should be tightly butted together.
- F-3. Weld as required, using the equipment and materials listed in Sections C and D. The weld joint must be shielded on both sides to prevent embrittlement by atmospheric gases. Turbulence in the weld area should be avoided as this increases the possibility of weld contamination. In stopping a weld, the end of the filler wire should be allowed to cool in the shielding gas envelope. (Refer to paragraph E-6a). Thicknesses up to .063" may be welded without the addition of filler wire if fit-up permits. Thicknesses over .063" should be welded adding filler wire.
- F-4. Stress relieve and descale in accordance with paragraph E-11.
- F-5. Pressure test, if required.

G. PROCESS CONTROL:

- G-1. Paragraph E-1 requirements must be strictly enforced.
- G-2. Adequate checks shall be made to assure that the inert gases used in welding to this process meet the dew point requirements in paragraph E-5.
- G-3. Stress relief and descaling shall be carried out in accordance with paragraph E-11.
- G-3a. When applicable, paragraph E-12 shall supersede E-11 requirements.
- G-4. Radiographic examination is not required unless specified on the applicable drawing. Quality Division may, however, use radiographic inspection in cases where doubt exists as to weld quality. The following shall apply except in cases where radiographic requirements are noted on a specific drawing:
- a. Porosity and inclusions shall not exceed ten percent of the area of a linear inch of weld or of the cross section of a weld. Angular type inclusions are not acceptable. (Round or oval type only are acceptable).
 - b. Particles of tungsten (pick-up from tungsten electrodes) are acceptable provided they are not angular in nature and do not exceed the limits set forth in (a).
 - c. Cracks in weld deposit or parent metal are not acceptable.
 - d. Incomplete fusion is not acceptable.
- Radiographic examination, when required, shall be carried out in accordance with MIL-I-6865A.
- G-5. When required, paragraph E-13 requirements must be met.
- G-6. Materials Engineering shall be notified of major discrepancies arising through use of this process.

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WELDING, INERT GAS SHIELDED TUNGSTEN ARC, OF TITANIUM

H. PRODUCT ACCEPTANCE:

- H-1. Weld sizes shall conform with paragraph E-7 requirements.
- H-2. All weldments shall be examined visually and by means of the fluorescent penetrant method for cracks, joint penetration, undercutting and overlapping. Fluorescent penetrant inspection shall be carried out in accordance with Specification MIL-I-6866 requirements.
- H-2a. Cracks, lack of complete penetration in butt welds, undercutting or overlapping, are causes for rejection.
- H-2b. Welds shall not be "dressed" by removing metal from the joint unless so specified on the drawing.
- H-3. The requirements of paragraph E-2 must be adhered to.
- H-4. All weldments shall be examined visually before descaling to evaluate the color of the weld deposit. Welds having the appearance of newly polished silver are satisfactory. Weld surfaces having a bright metallic blue or gold appearance are satisfactory. This is merely a surface condition resulting from inadequate shielding at low temperatures where harmful contamination does not occur. A dull gray or white powderish appearance indicates severe weld contamination as a result of inadequate shielding at high temperatures. Welds having this appearance are not acceptable. Any discoloration on the underside of a weld deposit shall be taken as indication that the weld has not been properly shielded. Any weld exhibiting discoloration on the underside shall be rejected subject to investigation and rework.

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Issued: 2-10-54

Revised: 6-24-60

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WELDING, FUSION, OF ALUMINUM ALLOYS AND STEELS, GROUND SERVICE EQUIPMENT

A. APPLICATION:

- A-1. This process establishes the requirements and procedures necessary for the fusion welding of aluminum alloys, low carbon steel, low alloy high strength structural steel, and low carbon alloy steels, using either manual or automatic welding equipment.
- A-2. The quality of welding producible using this process is such that it will not meet the requirements of Government Specifications MIL-W-8604 or MIL-W-8611.
- A-3. This process is intended for use in the fabrication of certain ground support equipment such as platforms, tables, shelters, racks, support structures, electronic boxes and similar items of a non-critical nature. This process is not applicable to items of a critical or safety nature, nor is it applicable to steel assemblies subject to heat treatment after welding.
- A-4. When specified this process shall be used in conjunction with applicable Engineering Drawings and related Data. There is no equivalent Government Specification.

B. REFERENCES:

- B-1. Military Specification MIL-E-15599, "Electrodes, Welding, Covered; Low and Medium - Carbon Steel".
- B-2. Military Specification MIL-R-5632, "Rods, Steel, Welding (For Aircraft Applications)".
- B-3. Military Specification MIL-E-18038, "Electrodes, Welding, Mineral Covered, Low Hydrogen, Medium and High Tensile Steel As Welded or Stress Relieved Weld Application".
- B-4. Federal Specification QQ-R-566, "Aluminum and Aluminum Alloy Welding Rods".
- B-5. Martin Company Standard Process P-55013, "Welding, Fusion, of Aluminum and Magnesium Alloys, Missile and Aircraft Applications".
- B-6. Martin Company Standard Process P-55014, "Welding, Fusion, of Steels and Corrosion Resistant Alloys, Missile and Aircraft Applications".
- B-7. Martin Company Standard Process P-50010, "Descaling Carbon Steel Aircraft Parts".
- B-8. Martin Company Standard Process P-50018, "Paint Removal".
- B-9. Martin Company Standard Process P-50029, "Deoxidation of Aluminum Alloys".
- B-10. Martin Company Standard Process P-80013, "Pressure Testing Fuel, Oil and Water Injection Details and Assemblies".
- B-11. Martin Company Standard Process P-75007, "Handling of Dangerous and Toxic Materials".
- B-12. American Welding Society Handbook.

C. MATERIALS:

- C-1. Aluminum Welding. - Filler rods and wire shall meet Table I requirements. Gas and flux shall be in accordance with Standard Process P-55013 requirements.
- C-2. Steel Welding. - Electrodes, rods and wire used shall be the types listed in Table II of this process. Gases and anti-spatter compound shall be in accordance with Standard Process P-55014 requirements.

Issued By: 2-10-61 BALTO. <i>[Signature]</i>	Mfg. Equip. <i>[Signature]</i>	Qty. Cent. Safety <i>[Signature]</i>	Engineering <i>[Signature]</i> STUCT. Engr. <i>[Signature]</i> Mat'l. Engr. <i>[Signature]</i>
Issued: 1-4-58 Revised: FEB 14 1961	MARTIN BALTIMORE		STANDARD PROCESS P-55021 Page 1 of 11 Pages

SECRET

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Code Ident. No. 38597

SOLDERING, WELDING & BRAZING*

WELDING, FUSION, OF ALUMINUM ALLOYS AND STEELS, GROUND SERVICE EQUIPMENT

D. EQUIPMENT:

- D-1. Equipment used shall be in accordance with either Standard Process P-55013 or Standard Process P-55014 requirements whichever is applicable.

E. REQUIREMENTS:

- E-1. General. -
- E-1a. Certification of welders or welding procedure is not a requirement of this process.
- E-1b. This process is applicable only to the welding of the materials listed in Tables I and II.
- E-1c. Weld bead sizes shall be in accordance with Table III, Standard Process P-55013, or Table IV, Standard Process P-55014, whichever is applicable, or as noted on the applicable Engineering Drawing.
- E-1d. Welding electrodes, rods, and wire shall be used in accordance with Tables I and II for the type of material being welded.
- E-1e. Tubing shall have holes drilled at intersecting joints prior to welding.
- E-1f. Preheating, when required, should be carried out in a furnace whenever possible. However, a torch may be used provided the temperature is controlled by use of Tempil Sticks, or Tempilag.
- E-1g. Jigs, clamping devices and tack welding shall be used, wherever required, to control warpage and insure proper alignment of detail parts.
- E-1h. Welds shall not be "dressed" by removing metal from the joint unless further welding is to be performed in the "dressed" area, or unless so specified on the Engineering Drawing.
- E-1i. Fusion welding will be specified on Engineering Drawings by standard welding symbols and dimensions.
- E-1i(1). For complicated joints such as cluster welds, tubular scarf welds, etc. where symbols would not define the welded joint clearly, joint cross section details will be shown on the drawing.
- E-1i(2). Weld Symbol Characters and Their Application. -

Bead	Flange	Fillet	Square	"V"	Bevel	"U"	"J"	Convex	Weld All Around	Flush Weld Symbol

* These weld symbols are never used alone, they are used in combination with other symbol characters.

Near Side of Joint

Far Side of Joint

Both Sides of Joint

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SOLDERING, WELDING & BRAZING

WELDING, FUSION, OF ALUMINUM ALLOYS AND STEELS, GROUND SERVICE EQUIPMENT

Type of Welding	Continuous	
Exposed Welding		
Hidden Welding		

- a. Basic Weld Symbol
 b. Machine Finish (SRN)
 c. Length of Weld in Inches or Fractions Thereof
 d. Weld all Around
 e. Arrow Connecting Reference Line

Use only when necessary

E-2. Aluminum Alloys - Specific. -

E-2a. Flux shall be used in gas welding aluminum alloys and shall be applied to both the welding rod and the surfaces to be welded. Solar 202 flux is recommended as a back-up for corner fillet welds welded by the inert gas shielded arc method when it is desirable to eliminate oxidation of the penetration weld bead.

E-2a(1). Flux must be freshly mixed with water to produce a paste at the beginning of each day's work. Unused flux, left at the end of a day's work, shall be discarded.

E-2b. Detail parts may be prepared prior to the welding operation and stored for subsequent use.

E-2c. Scarfing, chamfering, or flanging shall be in accordance with the detail information contained on the individual drawing.

E-2d. When fillet weld beads will interfere with fasteners or attaching members J-shape chamfers are permissible.

E-2e. Welding of closed metal shapes such as tubing, in which flux cannot be easily removed, shall be limited to the inert gas shielded arc method.

E-2f. Surfaces to be welded shall be free from oil, oxides, protective coatings, and other foreign matter.

E-2g. Grease and oil shall be removed by vapor degreasing per Standard Process P-51003.

E-2h. Paint films shall be removed in accordance with Standard Process P-50018.

E-2i. All detail parts shall be deoxidized prior to welding in accordance with Standard Process P-50029. (Wire brushing or sanding with abrasive papers may be used on assemblies only.)

E-2j. Heat treatable alloys (Group I, Table I) that have been heat treated in detail may be preheated to a maximum of 200°F.

E-2k. A preheat not exceeding 850°F may be used when details have not been heat treated.

E-2l. Non heat treatable alloys (Group II, Table I) may be preheated to a temperature not to exceed 400°F.

E-2m. Assemblies shall be cooled in still air after welding.

E-2n. Soldered joints shall not be welded.

E-2o. Dip brazed joints, made with No. 718 brazing alloy, may be welded over when required.

E-2o(1). Welded joints, made with No. 43 welding rod, shall not be put through the dip brazing cycle.

E-2p. Lap welds shall be welded on all sides to prevent entrance of air or moisture, unless otherwise noted on the drawing.

E-2p(1). All lap weld beads shall be convex in shape.

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WELDING, FUSION, OF ALUMINUM ALLOYS AND STEELS, GROUND SERVICE EQUIPMENT

Filler Rods		Material	Welding Method	
Specification	Class	Group I (Heat Treatable)	Preferred	Alternate
QQ-R-566	Type I FS-RAL 43	6061 QQ-A-270 QQ-A-327 WW-T-789 QQ-A-325 MMS 2135 MIL-T-7081 6151 QQ-A-367 2014 QQ-A-255 QQ-A-266 QQ-A-367 QQ-A-261 2024 QQ-A-355 QQ-A-362 QQ-A-268 WW-T-785 QQ-A-267	Inert Gas Shielded Arc (Non-Consumable or Consumable Electrode)	Oxy-Hydrogen with Flux
		Group II (Non-Heat Treatable) 5052 QQ-A-318 WW-T-787 5154 MIL-A-17357 AMS-4018 AMS-4019 43 QQ-A-596 QQ-A-601		
MIL-E-16053G	Type 5183	5083 MIL-A-17358 MIL-A-19005 5086 MIL-A-19070		
MIL-E-16053G	Type 5556	5456 MIL-A-19842 MIL-A-21170		
QQ-R-566	Type I FS-RAL 2	1100 QQ-A-561 QQ-A-411		

TABLE I. - Aluminum Alloys with Recommended Welding Rods and Methods.

E-2q. Standard Flange Welds. - Flange welds shall have a smooth round bead showing little evidence that the sheets were flanged before welding.

Standard Flange Weld.

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- E-2a(1). Non-Standard Flange Welds. - When standard flange welds cannot be made due to large radii or insertion of a third member between the flanges, welds shall be made in accordance with weld dimensions noted on the applicable drawing.
- E-2r. Flux shall be removed from assemblies as soon as possible after welding to prevent corrosion from taking place.
- E-2s. Aluminum alloy welded assemblies do not require stress relief heat treatments.
- E-2t. Assemblies requiring heat treatment shall be heat treated in accordance with instructions noted on the applicable Engineering Drawing.
- E-3. Steels - Specific. -
- E-3a. Electrodes other than low hydrogen types shall be stored in a dry place. Low hydrogen types shall be baked prior to use as follows: Heat one hour at 200°F, raise furnace temperature to 600°F and hold one hour, then shut off the furnace and allow furnace to cool to room temperature. Immediately transfer electrodes to storage oven operating at 200°F - 250°F.
- E-3b. Welding over brazed or soldered joints is not permitted.
- E-3c. Searfing, chamfering or flanging shall be in accordance with the Engineering information noted on the applicable drawing.
- E-3d. Oil, grease, dirt, rust, scale, moisture or plating shall be removed from surfaces to be welded.
- E-3d(1). Use steel wool, emery cloth, brushes, sandblasting or pickling in accordance with Standard Process P-50010 to remove rust, scale or plating.
- E-3d(2). Degreasing in accordance with Standard Process P-51003 will remove oil, grease and dirt.
- E-3e. Apply anti-spatter compound to surfaces adjacent to joints when it is necessary to control spatter during arc welding.
- E-3f. A preheat temperature of 200°F - 400°F shall be used for welding AISI-4130 steel. No pre-heat is required for other steels covered by this process, except that Manufacturing may at their discretion use a preheat whenever it is deemed advisable.
- E-3g. If tack welds crack, chip out entire weld. Welding over cracked welds is not permitted.
- E-3h. In making multiple pass welds use skip method to reduce distortion. Apply first pass in the sequence noted below. On second, third, etc., passes apply a continuous weld,

Tubular Sections

Tee Sections

- E-3i. Lap Welds. - Lap welds shall be welded on all sides to prevent entrance of air or moisture, unless otherwise noted on the applicable drawing.
- E-3j. Flange Welds. - Unless otherwise noted on the applicable drawings, flange welds shall, after welding, have a smooth round bead showing little evidence the sheets were flanged before welding.
- E-3k. Cleaning after welding, when necessary, shall be accomplished by steel shot or sandblasting.
- E-3l. Unless noted otherwise on the drawing and except as noted in paragraph E-3i(1), welded assemblies of AISI-4130 steel shall be stress relieved, after welding, at 1000° - 1050°F for a period of one hour per inch of the thickness or a minimum of one hour. (Thickness shall be based on the heaviest part of the assembly.)

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- E-3l(1). Assemblies of AISI-4130 that are welded with detail parts in a heat treated condition shall be stress relieved at a temperature 50°F below the lowest draw temperature used in any detail part, unless noted otherwise on the drawing. Time at temperature shall be one hour per inch of thickness of heaviest section, but in no case less than one hour.
- E-3l(2). Assemblies fabricated from steels other than AISI-4130 do not require a stress relieve treatment after welding except when so specified on the drawing. When required, stress relieving of MMS-1307 steel shall be carried out at 1000°F - 1050°F for one hour per inch of heaviest section with a one hour minimum in any case. Under no condition should a temperature above 1050°F be used.
- E-3m. Pressure tests of welded fittings, tanks, tubing, etc. shall be made, in accordance with Standard Process P-80013 for the detection of leaks in the welds. Drain and relief holes shall be plugged using screws specified on the drawing.
- E-3n. The interior of steel tubing shall be finished in accordance with instructions given in the applicable finish specification.

F. PROCEDURE:

F-1. Procedure - Aluminum Alloys. -

F-1a. Oxy-Hydrogen Welding. -

F-1a(1). Choose the proper welding equipment and filler rod from Tables I and III, for the materials being welded.

F-1a(2). Prepare the equipment for the welding operations using the proper welding tip and gas pressures, as recommended in Table III, for the particular type and gage material being welded.

F-1a(3). Prepare flux in accordance with paragraph E-2a(1) of this process.

F-1a(4). Weld parts as required. Welds must conform with paragraph E-1c requirements.

F-1a(5). In the event it is impossible to complete the welding operation in one shift, all the flux shall be removed by brushing in hot running water.

F-1a(6). Cool all welded assemblies in still air after welding.

F-1b. Inert Gas Shielded Arc Welding. - (Non-Consumable Electrode)

F-1b(1). Choose the proper welding equipment and filler rod from Tables I and III, for materials being welded.

F-1b(2). Prepare the equipment for the welding operations, using the proper size electrodes as recommended in Table III, for the particular type and gage material being welded.

F-1b(3). Preheat, if required, in accordance with Section E.

F-1b(4). Weld the parts as required. Welds must conform with paragraph E-1c requirements.

F-1b(5). Cool all welded assemblies in still air after welding.

F-1c. Inert Gas Shielded Arc (Consumable Electrode). -

F-1c(1). Prepare equipment for the welding operations for the particular type and gage of material being welded.

F-1c(2). Preheat if required, in accordance with Section E.

F-1c(3). Weld parts as required. Welds must conform with paragraph E-1c requirements.

F-1c(4). Cool all welded assemblies in still air after welding.

F-1d. Post Welding. -

F-1d(1). Immediately after welding is completed, scrub parts under hot running water with a stiff plater's brush until the surface is clean.

F-1d(2). Immerse parts in a ten (10) percent solution (by weight) of sulfuric acid * for a sufficient length of time to remove all traces of flux.

* DANGEROUS MATERIAL. REFER TO STANDARD PROCESS P-75007 FOR SPECIFIC HANDLING INSTRUCTIONS.

F-1d(3). Rinse parts in cold water to remove all traces of acid.

F-1d(4). Heat treat weldments as required on the Engineering Drawing.

F-1d(5). Pressure test vessels and containers in accordance with Engineering requirements and visually examine for cracks. Plug drain and relief holes using screws as specified on the drawing.

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Materials	Methods		Electrodes Arc Welding	Filler Rods		Flux
	Preferred	Alternate		Inert Gas Shielded Arc	Oxy- Acetylene	
<u>Low Carbon</u> MMS-2307 QQ-S-636 QQ-S-681 Classes 1 & 2 <u>Carbon Structural</u> ASTM-A7 ASTM-A53 <u>Low Alloy Structural</u> MIL-S-7809 (SAE 950) <u>Low Carbon Alloy</u> (AISI-4130) MIL-S-6758 MIL-S-18729 MIL-T-6736 (AISI-8620) MIL-S-8690) <u>Low Alloy Structural</u> MMS-1307	Arc Weld Flux Coated Electrode ↓	Oxy- acetylene ↓ Inert Gas Shielded Arc ↓	<u>Spec. MIL-E-15599</u> (AWS-E6013) Recommended Airco 90A (Airco) Fleetweld 37 (Lincoln) (AWS-E6012) Recommended Fleetweld 7 (Lincoln) (AWS-E6010) Recommended Fleetweld 5 (Lincoln) (AWS-E6027) Recommended Jetweld 2 (Lincoln) <u>Spec. Comm.</u> (AWS-E6014) Any Source ↓	Oxweld No. 65 (Linde Air Pro- ducts Co.) ↑ <u>Spec. MIL-R-5632</u> Class 2 (CMS-32 Linde Air Products Co.) ↓	Oxweld No. 65 (Linde Air Pro- ducts Co.) ↓	None ↓
	↓		<u>Spec. MIL-E-18038</u> (AWS-E11016-18) Recommended Atom Arc T (Alloy Rods) <u>Note:</u> MMS-1307 steel must not be welded with other than AWS-E11016-18 type electrodes.			

TABLE II. - Steels with Recommended Electrodes, Rods, and Methods.

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WELDING, FUSION, OF ALUMINUM ALLOYS AND STEELS, GROUND SERVICE EQUIPMENT

Inert Gas Shielded Arc				Material Gage	Filler Rod		Oxy-Hydrogen		
C.F./H		Cup Size I. D.	Tungsten Electrode Size		Arc	Oxy- Hydrogen	Tip Size	Gas Pressure	
Argon	Helium							Oxygen	Hydrogen
8		1/4	1/16	.016	1/16	1/16	#2	2	3
8		1/4	1/16	.020	1/16	1/16	#2	2	3
8	1	1/4	3/32	.032	3/32	3/32	#3	4	4
8	1	1/4	3/32	.040	3/32	3/32	#3	5	5
8	2	1/4	3/32	.060	3/32	3/32	#4	5	5
8	4	1/4	3/32	.063	3/32	3/32	#4	5	5
10	4	3/8	1/8	.071	3/32	3/32	#5	7	7
10	4	3/8	1/8	.080	3/32	3/32	#6	7	7
10	5	3/8	1/8	.090	1/8	1/8	#6	7	7
10	5	3/8	1/8	.100	1/8	1/8	#6	7	7
12	6	3/8	1/8	.125	1/8				
14	6	1/2	5/32	.190	1/8				
14	8	1/2	5/32	.250	5/32				
14	14	5/8	1/4	.375	5/32				
				& over					

TABLE III. - Recommended Welding Data - Aluminum.

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WELDING, FUSION, OF ALUMINUM ALLOYS AND STEELS, GROUND SERVICE EQUIPMENT

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Material Gage	Arc Welding	Oxy-Acetylene			Filler Rod Dia.	Inert Gas Shielded Arc Welding				
	Electrode (Covered) Dia.	Gas Welding Tip Size	Gas Pressure PSI			Tungsten Electrode Dia.	Gas Ratio CF/H			Cup Size I. D.
			Oxy.	Acet.			Argon	Back Up		
								Argon	Helium	
.016	1/16	#1	2	3	1/32	1/16	8	10	15	1/4
.020	1/16	#1	2	3	1/32	1/16	8	10	15	1/4
.032	5/64	#1	3	3	1/16	3/32	10	10	15	1/4
.040	5/64	#2	4	4	1/16	3/32	10	10	15	1/4
.050	3/32	#2	5	5	1/16	3/32	10	10	20	1/4
.063	3/32	#2	5	5	1/16	3/32	15	15	20	3/8
.071	3/32	#3	5	5	1/16	3/32	15	15	20	3/8
.080	1/8	#3	5	5	1/16	3/32	15	15	25	3/8
.100	1/8	#3	6	5	1/16	3/32	15	20	25	3/8
.125	5/32	#3	6	5	1/16	3/32	20	20	25	3/8
.190	5/32				3/32	1/8	20	20	25	3/8
.250	3/16				3/32	1/8	20	20	25	3/8
& over										

TABLE IV. - Arc and Gas Welding Data - Steels.

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WELDING, FUSION, OF ALUMINUM ALLOYS AND STEELS, GROUND SERVICE EQUIPMENT

F-2. Procedure - Steels. -

F-2a. Flux Coated Electrode Arc Welding. -

F-2a(1). Clean all parts to be welded as per paragraph E-3d.

F-2a(2). Select and prepare the proper welding equipment from Tables II and IV for the particular gage being welded.

F-2a(3). Preheat parts to be welded, if required by paragraph E-3f.

F-2a(4). Weld parts as required. Welds shall be in accordance with paragraph E-1c requirements.

F-2b. Inert Gas Shielded Arc Welding. -

F-2b(1). Select and prepare the proper welding equipment from Tables II and IV for the particular gage being welded.

F-2b(2). Preheat parts to be welded, if required by paragraph E-3f.

F-2b(3). Use single pass welds whenever practical.

F-2b(4). Weld parts as required. Welds shall be in accordance with paragraph E-1c requirements.

F-2c. Oxy-Acetylene Welding. -

F-2c(1). Select and prepare the proper welding equipment from Tables II and IV for the particular gage being welded.

F-2c(2). Weld parts as required. Welds shall be in accordance with paragraph E-1c requirements.

F-2c(3). All acetylene cylinders shall be stored in the designated storeroom and the pressure of individual or group of cylinders shall not be allowed to fall below 15 psi. Indication on the master indicator of 15 psi or lower necessitates immediate replacement.

F-2d. Post Welding Procedure. -

F-2d(1). Stress relieving as required shall be done in accordance with paragraph E-31.

F-2d(2). All tubing assemblies shall be treated in accordance with paragraph E-3n.

G. PROCESS CONTROL:

G-1. The materials and methods of welding are to be limited to those specified in Tables I and II.

G-2. Heat treatment of aluminum alloy weldments, when required, shall be carried out in accordance with drawing requirements.

G-3. Stress relieving of steel weldments shall be as specified in paragraph E-31 except when noted otherwise on the applicable drawing.

G-4. Aluminum weldments requiring a frosted or anodized finish shall be dye checked (or equivalent) and examined for cracks prior to finishing.

G-5. Pressure tests, when required, shall be carried out in accordance with Standard Process P-80013 and Engineering instructions.

G-6. Materials Engineering shall be notified of major discrepancies arising from use of this process.

H. PRODUCT ACCEPTANCE:

H-1. Quality Division shall require adherence to the confines of this process by inspecting as follows:

H-1a. Welds may be tested by Quality Division to determine if the flux has been completely removed by leaching the welded area with distilled water and adding a few drops of five (5) percent silver nitrate to the leach solution. If a white precipitate is formed, further neutralizing time in the sulfuric acid bath shall be required.

H-1b. All weld joints shall be of the type specified on the drawing. Welds shall not be "dressed" by removing excess metal from the joint unless so specified on the drawing.

H-1c. Weld sizes shall conform with paragraph E-1c and drawing requirements.

H-1d. All weldments shall be examined visually for evidence of cracks and surface imperfections and shall be acceptable within the following limits:

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SOLDERING, CUTTING & BRAZING

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Cracks - Cracks in weld deposit or parent metal shall be cause for rejection.

Undercuts - Undercuts less than $\frac{1}{16}$ " in length are permissible provided the material thickness in the undercut region is not below 80% of the original thickness. No more than one such defect shall appear in any consecutive 3" of weld and not more than two such defects are permissible in one foot of weld. Undercuts shall not be permitted within 1" of the ends of a weld.

Fusion - Welds shall show complete fusion with the parent metal.

Butt Welds - Butt welds shall show complete penetration, except when noted otherwise on drawing. Rough appearance, weld spatter, overlapping, pin holes, inclusions, shall not be cause for rejection unless the condition is indicative of unusually poor workmanship.

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PROCESS: SPECIFICATION

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Specification: As specified on drawing or Purchase Order
(Foil Material to conform to AMS 5537B)
Code: None

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VACUUM BRAZING OF HAYNES ALLOY 25

- 3.1.1.2 Haynes Alloy 25 Sheet
Specification: AMS 5537B
Code: None
- 3.1.2 Brazing Alloys
 - 3.1.2.1 Coast Metals CM 60
Specification: Commercial - brazing temperature $2175^{\circ}\text{F} \pm 25^{\circ}\text{F}$, -
-325 mesh
Code: None
- * 3.1.3 Raffi and Swanson Lacquer, 1830
Specification: Commercial
Code: None
- * Hazardous Material. Refer to Paragraph 3.6.
- 3.2 Equipment
 - 3.2.1 Vacuum Furnace, capable of 10^{-4} torr. or less.
 - 3.2.2 Braze Tools
 - 3.2.2.1 Braze tools shall be made of Haynes 25 alloy or similar cobalt base material having the same coefficient of expansion as the base material.
- 3.3 Product
 - 3.3.1 Final tolerances of the completed product shall be as required in this specification (4.2 and 5.2).
 - 3.3.2 The presence of voids shall be as defined in 4.2 with respect to magnitude, location and distribution.
- 3.4 Fabrication Control:
 - 3.4.1 Procedural requirements and controls shall be as specified in Section 5.
- 3.5 Special Skills: Operators need not be certified, but shall be trained and experienced in the techniques required for effective brazing of honeycomb structural sandwich parts.
- 3.6 Safety: Certain materials called out in this specification are hazardous. Refer to Divisional Safety Procedures for precautions and handling instructions.

4. QUALITY ASSURANCE:

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VACUUM BRAZING OF HAYNES ALLOY 25

- 4.1 Quality shall assure conformance to the requirements of this process.
- 4.2 All brazed panels shall be radiographically and thermographically inspected to evaluate the voids in the brazed joints. The following inspection criteria shall apply for the panels.
 - 4.2.1 Faying Surface
 - 4.2.1.1 There shall be no void areas at the faying surface edges.
 - 4.2.1.2 No faying surface voids shall extend into core area.
 - 4.2.1.3 Voids in faying surfaces shall not exceed ten percent of the total area.
 - 4.2.1.4 No single void shall exceed 1/2 sq. in. in the faying surface.
 - 4.2.1.5 No unrepaired voids at fastener holes will be acceptable.
 - 4.2.1.6 Isolated node separations are acceptable.
 - 4.2.1.7 Uniform node flow is required.
 - 4.2.2 Core
 - 4.2.2.1 No single void shall be larger than four cells (of the core pattern).
 - 4.2.2.2 No more than two voids attributable to braze deficiency shall be acceptable.
 - 4.2.2.3 There shall be no evidence of crushed core in the panels.
- 4.3 After finish machining, the panels, excluding the edge members, shall be within ± 0.009 " tolerance in the thickness, and ± 0.010 " in length and width.

5. MANUFACTURING CONTROL:

- 5.1 Procedure
 - 5.1.1 Cleaning
 - 5.1.1.1 All Haynes 25 to be brazed shall first be cleaned by vapor degreasing according to EPS 50046 to remove ordinary shop soil and handling resins.

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VACUUM BRAZING OF HAYNES ALLOY 25

- 5.1.1.1.1 Haynes 25 sometimes has an adherent surface oxide, which must be removed by vapor blast. After vapor blast cleaning, it shall be cleaned by an acid dip of the following composition:
- 10 parts (by volume) nitric acid,
2 parts hydrofluoric acid,
balance - water
- 5.1.1.2 Only clean, white gloves shall be worn by personnel handling the clean materials.
- 5.1.1.3 All parts to be brazed shall be stored in clean, polyethylene bags and hermetically sealed until ready for assembly.
- 5.1.2 Panel Lay-Up
- 5.1.2.1 The braze alloy shall be applied to the panel faces, on one side only, as a slurry, using one of two methods:
- (a) spray slurry directly on panel
(b) paint slurry on surfaces
- 5.1.2.2 The slurry mentioned in the above paragraph (5.1.2.1) shall be a mixture of the lacquer and braze alloy powder compounded to produce a film on the panel which will have a weight of 40-44 grams per square foot when spread on the surface.
- 5.1.2.3 The slurry, after application to the faces, shall be dried by baking in an oven or by exposure to heat lamps. The temperature for drying shall be $275^{\circ} \pm 25^{\circ}\text{F}$. This drying shall be completed prior to brazing.
- 5.1.3 Thermal Straightening of Frame.
- 5.1.3.1 Creep straightening of frame, skins, and sometimes the doublers if required, is permissible before brazing. The maximum temperature for this operation shall be $2150^{\circ} - 2200^{\circ}\text{F}$.
- 5.1.3.2 The honeycomb core shall have a thickness tolerance of $\pm 0.002"$ prior to lay-up. Facing material thickness tolerance shall be as specified in the procurement specification or on the Purchase Order.
- 5.1.4 Finished (flat) panels shall have flatness of 0.02 percent, based on 36" length. For curved panels curvature tolerances shall be as specified on drawing.
- 5.1.5 Vacuum Brazing.
- 5.1.5.1 Panel(s) shall be placed in vacuum furnace and atmosphere shall be evacuated to 10^{-4} torr. Equipment to effect the braze joint shall be as described in 3.2.

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VACUUM BRAZING OF HAYNES ALLOY 25

5.1.5.2 The Haynes 25 panels to be vacuum brazed shall be fabricated with CM 60 braze alloy, and shall be brazed as follows:

- (a) Preheat at $1950^{\circ}\text{F} \pm 25^{\circ}\text{F}$ for 1/2 to 1 hour to assure uniformity of temperature.
- (b) Raise temperature to $2175^{\circ}\text{F} \pm 25^{\circ}\text{F}$ and hold for fifteen minutes.
- (c) Cool in vacuum to 275°F . Vacuum shall be 10^{-4} torr or better.

5.2 Brazing Accessories

5.2.1 Tooling shall be provided to prevent the panels from distorting excessively during the brazing cycle.

5.2.2 All tooling shall be manufactured to contour, dimensions and tolerances which will result in a product meeting the tolerances specified in 4.2 and 5.1.4.

Approved: Norman B. Miller

Martin Company

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