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ATOMICS INTERNATIONAL
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NAA-SR-MEMO COVER SHEET

REPORT TITLE

AUTHOR

NAA-SR-MEMO 11914

(This Document Contains 108 Pages.)
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TECHNICAL DATA RECORD

NAA-SR- TDR NO. 11914	APPROVALS: I. Villalva
PAGE 1 OF 108	
DATE 5-6-66	
GO NO. 7561	
S/A NO. 1211	TWR

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TITLE

SNAP 10A COMPONENT QUALIFICATION PROGRAM FINAL REPORT

SECURITY CLASSIFICATION

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SECRET	[ ]	[ ]	DEFENSE INFO.	[ ]

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PROGRAM

SNAP 10A

SUBACCOUNT TITLE

Reliability Evaluation

DISTRIBUTION

See Attached List

STATEMENT OF PROBLEM

Summarize Component Qualification Program

ABSTRACT:

The SNAP 10A component qualification test program has been successfully conducted over a three-year period in conjunction with extensive development testing plus the qualification and demonstration testing of flight systems. During the past 1-1/2 years sufficient endurance testing has been accumulated to enable authoritative reliability predictions for operating periods of up to 1 year in orbit.

The component testing has been mainly failure-free, although some components have been redesigned as a result of early failures. The qualification program has been directed at the determination of flight-suitability insofar as environments and major performance objectives are concerned. The objective was to determine the suitability of each component prior to the commitment of the FS-1 and FSM-4 qualification systems and the flight systems to their respective test programs. This primary objective was met except in the case of the first expansion compensator design which caused failure of the FS-1 during system acceptance test and necessitated its replacement with the FS-3 system.

The significant success of the ground test qualification system and of the flight test demonstration is due in large part to the conduct of the component qualification program. Thus, important design changes were incorporated early in the project's history, and sufficient familiarity was obtained such that very few human errors or oversights crept into the vital system test operations.

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I. INTRODUCTION

The SNAP 10A reactor development engineering program is unique in many ways which may interest the managers of future space projects. That portion of the program being conducted by Atomics International for the U.S. Atomic Energy Commission encompasses a range of compact nuclear reactors and conversion systems to supply electrical power of from 500 watts to 30 kilowatts for spacecraft systems. The low power range is illustrated by the SNAP 10A system. This system concept is approached by only one other known effort - the Russian Romashka reactor which has been operated as a ground development system.

The SNAP 10A project has been rewarded with highly significant overall success and a high degree of reliability has been demonstrated. The technical performance has been marked by the completion of more than a full year's continuous operation of FS-3, the first complete reactor flight system to be placed on ground test. The FS-3 system holds the record for the longest continuous full power operation of any nuclear reactor, and it operated unattended in a vacuum tank within an underground vault.

In its dramatic first space-flight the FS-4 system furnished more than 500 watts of electrical power to an Agena Space Vehicle for 43 days of a scheduled 90-day test in earth orbit. Prior to shutdown of the reactor by a failure of the spacecraft electrical system, the power equivalent of more than 20,000 pounds of batteries had been delivered by the 950 pound shielded reactor system. A corresponding increase in equivalent battery weight is associated with an increase in operating life. Thus, more than 40,000 lbs. of batteries are replaced in a 90-day mission.

No other power system has been operated at such combined extremes of vacuum, radiation and operating temperature. This orbital test of combined Atlas-Agena-Reactor systems demonstrated that no new environmental interactions or safety problems would plague the use of reactors for the electrical power requirements of future space payloads. The loss of command thru over-voltage showed that system interface considerations should be better resolved and that Agena-SNAP interactions can result in premature shutdown.

The flight test system, too, was a singular success, only one launch attempt having been made. The excellent reliability record initially demonstrated by the SNAP 10A project may have resulted by chance or because the product design was not much of a challenge considering the proven state-of-art of some elements of the system. However, for the purpose of this report, these theories are discounted and the hypothesis is advanced that the component development and qualification programs (coupled with superior engineering) enabled the successful outcome. It is expected that a subjective conclusion regarding acceptance or rejection of this hypothesis can be reached by the reader from this summary of the qualification test program.

The planning and conduct of the component qualification program was closely integrated with both component development and system qualification activities. It will not be meaningful to re-trace here all the failure symptoms and engineering considerations which led to component redesigns, specification or procedure changes, or to revisions of system configuration. Nevertheless, this integrated technical awareness and responsiveness is believed to be a very significant factor leading to initial success of the program at the level of complete system testing, both on the ground and in space.

The primary purpose of this final report is to serve both as a summary and as an index to the qualification test results in order that other; present and future, SNAP programs may ascertain whether these qualified and space-tested components should be considered for their applications. The goal is to reduce duplication of testing and of component development costs thru the use of proven components.

II. SCOPE

The SNAP 10A Component Qualification program encompasses more than 50 parts or major components. Their complexity varied from simple capacitors, diodes and fusistors to ejectable thermal shields and nuclear reflector assemblies. At the level of subsystems, the functional requirements become clear and are stated herein. The basic objective was to establish flight suitability of each component design, not to demonstrate a reliability goal or manufacturing quality level.

Flight suitability can be defined as the inherent capability of component designs to survive their specific space and system-imposed environments for missions of up to one year duration, while retaining their ability to perform all functions required by the system application of the component. The primary environments are those of space-vacuum, space-thermal conditions, launch shock-vibration-acceleration combinations, nuclear radiation from the reactor, and the thermal range imposed by full power operation of the reactor (up to 1060°F), following a startup in cold space.

Even though adequate reliability statistics cannot be obtained solely from the qualification of a very few items tested for minimum capability of performance, an estimate of component reliability can be derived from consideration of all development and system testing as well as proven part capability in other aerospace applications. Prior to and during qualification testing, estimates of component reliability were prepared through the use of analogy, learning curves, growth curves, and stress analysis. The reliability estimates prepared periodically, prior to complete-system testing, are compared in Figure 1 with those made during and following the completion of the successful component and system qualification testing.

The essential functions of each component are outlined in this report. A thorough reliability analysis requires more detailed listings of functional steps and failure modes than can be shown here, plus alternatives which are available during missions. The number of components required to be operable, and major redundancy features, are described. These considerations have been combined with a continual design review and up-dating of the reliability stress analysis technique which is fully exemplified in Reference 1. The result is an accurate estimate of the current state-of-art reliability inherent in the SNAP 10A system for missions of up to 1 year in duration. The increased reliability assessment of every subsystem since the publication of Reference 1 reflects the success of the qualification testing conducted subsequent to Reference 2 and 3. The salient failures and design changes occurring since these referenced status reports are discussed herein.

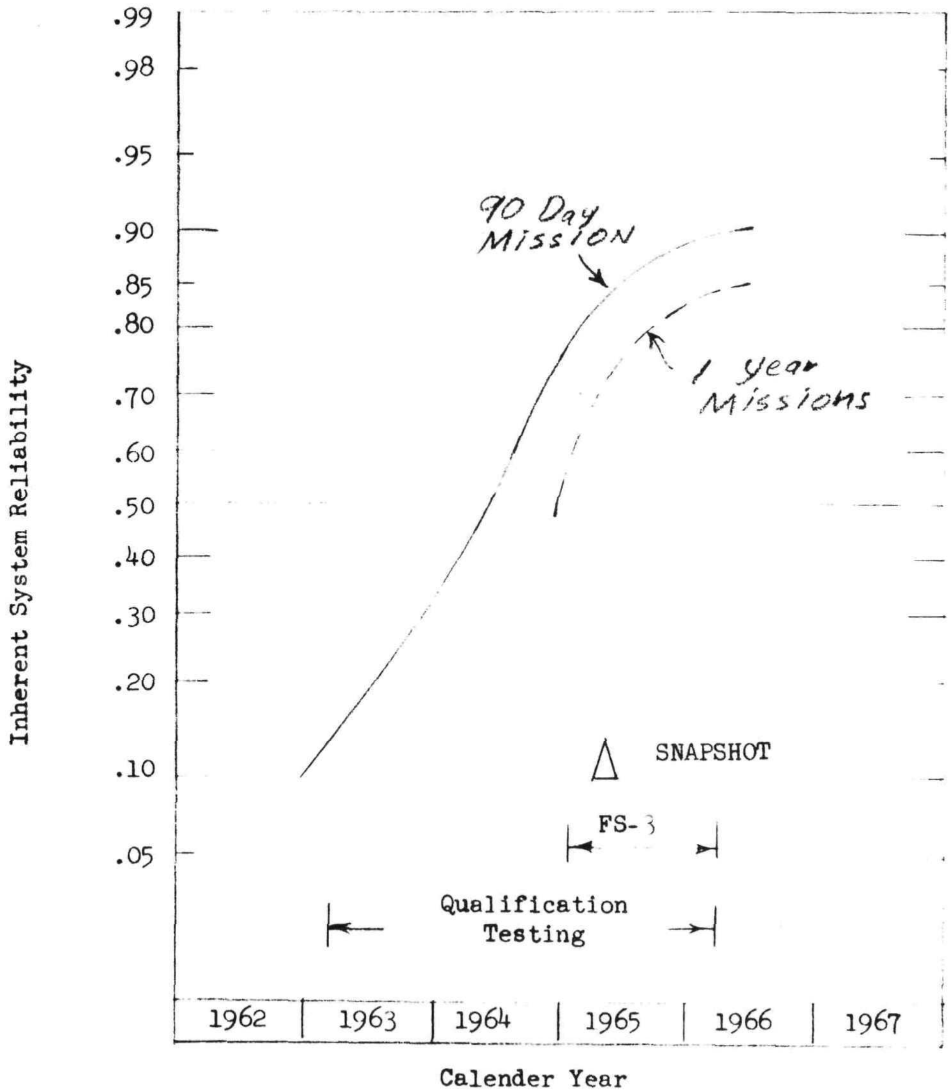
Each of the major subsystems of the SNAP 10A flight system is discussed separately, with emphasis on the qualification testing of its components. Complete references are furnished in Appendix II which identify both the item and all technical data reports of its qualification testing. The system engineer who is interested in applying these proven components to another system is urged to study the listed references and others given in the appendix to determine specific suitability.

III. SUMMARY

The SNAP 10A component qualification test program has been successfully conducted over a three-year period in conjunction with extensive development testing. In addition, the qualification and demonstration testing of both non-nuclear and complete nuclear flight systems was undertaken. During the past 1 1/2 years sufficient endurance testing has been accumulated to enable authoritative reliability predictions for operating periods of up to 1 year in orbit.

FIGURE 1

GROWTH OF SNAP 10A RELIABILITY



NOTE: Mission criteria includes the continuous delivery of 500W at 28VDC following the launch & startup in a 700 n. mi. orbit. Also included are the requirements for reflector ejection, diagnostic data, and consideration of meteoriod hazard.

The component testing has been mainly failure-free, although some components have been re-designed as a result of early failures. The qualification program has been directed at the determination of flight suitability insofar as environments and major performance objectives are concerned. The objective was to determine the suitability of each component prior to the commitment of the FS-1 and FSM-4 qualification systems and the flight systems to their respective test programs. This primary objective was met except in the case of the first expansion compensator design, which caused failure of the FS-1 during system acceptance test and necessitated its replacement with the FS-3 system.

The significant success of the ground test qualification systems and of the flight test demonstration is due in large part to the conduct of the component qualification program. Thus, significant design changes were incorporated early in the project's history, and sufficient familiarity was obtained such that very few human errors or oversights crept into the vital system test operations.

All the endurance information obtained since the FS-4 launch date, April 3, 1965, has confirmed the validity of the final component selections. The current best estimate of system reliability as derived by analysis pertinent to the 10A-FS-5 in orbit is given in Table I. If the uncertain probability of meteoroid puncture is not included, the current SNAP 10A system has a probability of .86 of surviving for 1 year mission. The reliability as a power plant, exclusive of data and shutdown functions, is very nearly 90 percent per year when meteoriods and loss of active control are tolerable.

A short summary of the extent of component qualification testing is in Table II, and indices to detailed component qualification test reports are contained in Appendix II.

IV. REACTOR AND SHIELDING SUBSYSTEM

A. Subsystem Description

The SNAP 10A reactor core has 37 elements, each element having 10 %, by weight, enriched uranium. Each element consists of a hydrided uranium-zirconium alloy wherein the hydrogen acts as the moderator. Surrounding the cylindrical core is a beryllium reflector assembly which includes four semi-cylindrical drums. Reactivity is controlled by the four semi-cylindrical drums which are rotated toward the core and alter the geometry

(Text continues on page 18)

TABLE I

BEST ESTIMATE OF THE RELIABILITY OF NPU 10FS-5

1 - PROBABILITY OF CAUSING MISSION FAILURE IF AGENA PERFORMS O.K.

SYSTEM AND MAJOR COMPONENT	LAUNCH SURVIVAL & ORBITING	PLUS STARTUP & STABIL.	PLUS ENDUR. OF: 90 Da. 500 W	PLUS ENDUR. OF: 1 Yr. ~500 W
Reactor & Shielding:				
Fuel (core)	.9996	.9991	.998	.995
Reflector Assembly (partial)	.9998	.9993	.999	.998
Radiation Shield	.9997	.9996	.999	.998
Conversion & Distribution:				
T/E Converter System	.9997	.9994	.9987	.995
Shunts, Taps, Wire	.9998	.9993	.9990	.997
Heat Transfer System:				
Pump & Battery	.9993	.998	.997	.994
Expansion Compensators (two)	.9988	.995	.985	.974
NaK Piping (include meteoroid)	.9978	.994	.985	.965
Structural System:				
Ejectable Heat Shield	.9991	.996	.996	.996
Primary Structure & Compartment	.9984	.997	.997	.997
Control System:				
Controller	.9989	.997	.994	.990
Drive Motors (two)	.9993	.997	.995	.993
Temperature Switches (four)	.9990	.997	.996	.996
Squibs & 7 Pin-pullers	.9991	.992	.992	.992
Relay Boxes	.9988	.994	.992	.990
Wire & Connectors	.9981	.995	.992	.984
Diagnostic System: (as required)	.9990	.996	.994	.989
Shutdown System: (as required)				
Delay Timers	.9998	.9996	.998	.994
EABRD & TABRD	.9995	.9990	.998	.996
Low Voltage Switches (two)	.9998	.9993	.997	.995
Total reliability inherent in NPU design:	*(.984)	.944	.905	.842

*NOTE: The probability is less than .005 that knowledge of launch-induced failures of the NPU will preclude an initiation of startup. Residual launch damage has probability of .012 of contributing to premature mission termination.

TABLE II

S-10A COMPONENT QUALIFICATION TEST SUMMARY

SUBSYSTEM Component Description	Shock Vibr. Tested / # Fail	Thermal Cycles No. Units	Thermal Cycles Total # Cycles	Thermal-Vacuum-Endurance # Units / Failed	Thermal-Vacuum-Endurance Total Hours / Longest Test	Radiation Exposure No. Units	Remarks
STRUCTURAL							
Ejectable Heat Shield 10FS1-14001-C	2/0	2	2	N/A		N/A	FSM-1, FS-1
Primary Structure 10FSM1-00-001	4/0	2	2	2/0	3,320 / 2,160		1) PSM-1A & 1B vibr. & static only 2) FSM-1, FSM-4
REACTOR & SHIELDING							
Fuel Elements 7580-18020	66/0	66	198	66/0	578,160 / 8,760		Qualification & special environmental test
	45/0	63	189	120/0	259,200 / 2,160		
Reflector Assembly 10FS-11001-B	1/0	1	10	1/0	2,160 / 2,160		DRM-1
Radiation Shield 10FSM1-13015-F	2/0	2	14	2/0	2,330 / 2,160	1 (FS-3)	DRM-1 & FSM-1
HEAT TRANSFER							
NaK Pump 10FS-81C01-D	9/0	6	60	7/0	84,625 / 17,170	1 (FS-3)	

TABLE II

S-10A COMPONENT QUALIFICATION TEST SUMMARY (Cont'd)

SUBSYSTEM / Component Description	Shock Vibr. Tested / # Fail	Thermal Cycles No. Units	Thermal Cycles Total # Cycles	Thermal-Vacuum-Endurance # Units / Failed	Thermal-Vacuum-Endurance Total Hours / Longest Test	Radiation Exposure No. Units	Remarks
HEAT TRANSFER							
Primary Battery NE10FSM1-24-008	3/0	-	-	4/0	4,320 / 1,320	1	Ampere-hours at ambient temp.
Expansion Comp. 7561-34016	4/0	4	40	4/0	34,327 / 9,051	2 (FS-3)	Assembly includes limit switches, etc.
NaK Piping 10FSM4-00-001	3/0	3	3	3/0	3,600 / 2,160	N/A	FSM-1, FS-1 & FSM-4
CONVERSION AND DISTRIBUTION							
Thermoelectric Modules 10FSM1-51022	44/0	47	470	44/10	307,838 / 18,000	120 (FS-3)	1) The demonstrated element reliability is .998 for 90 days 2) 6 failures due to utility power outages.
Converter Current Shunt 10FS-24011-D	3/0	3	30	3/0	6,480 / 2,160	1 (FS-3)	
STARTUP & CONTROL							
Controller NE10FSM1-20-004	3/0	3	30	2/0	4,320 / 2,160	1	> 1200 operating cycles

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TABLE II

S-10A COMPONENT QUALIFICATION TEST SUMMARY (Cont'd)

SUBSYSTEM	Shock Vibr.	Thermal Cycles		Thermal-Vacuum-Endurance		Radiation Exposure	Remarks
Component Description	Tested / # Fail	No. Units	Total # Cycles	# Units Failed	Total Hours / Longest Test	No. Units	
STARTUP & CONTROL							
Control Drum Actuator 10FSM1-11061	6/0	6	60	6/1	11,125 / 2,160	2	1) > 3750 operating cycles 2) Short circuit in brake winding
Reactor Temp. Control Sensor NE10FS1-24-008-C	2/0	2	20	2/0	4,320 / 2,160	1	
Reactor Temp. Control Switch NE10FS1-24-009-B	2/0	2	20	2/0	4,320 / 2,160	2	
Thermal Mech. Temp. Switch NE10FS1-24011-D	3/0	3	30	2/0	4,320 / 2,160		
Relay Box (Main & Aus.) 10FS-22002-D 10FS-22017-C	2/0	2	20	2/0	4,320 / 2,160	1 (FS-3)	Includes relays, fusistors and diodes
Squibs & Pin-Pullers NE10FS-24-015-NC	22/0	22	220	15/0	224 / 16	4	8 of these qualified on DRM-1

TABLE II

S-10A COMPONENT QUALIFICATION TEST SUMMARY (Cont'd)

SUBSYSTEM	Shock Vibr.	Thermal Cycles		Thermal-Vacuum-Endurance		Radiation Exposure	Remarks
Component Description	Tested / # Fail	No. Units	Total # Cycles	# Units Failed	Total Hours / Longest Test	No. Units	
STARTUP & CONTROL							
Ejectable Heat Shield Connectors 10FSM1-61048-B 10FSM1-20016	2/0	4	40	2/0	204 / 102		
High Temp. Wire Super Temp Pyrad 1000	4/0	3	20	2/0	2,000 / 1,000	2	
Low Temp Wire Raychem Novathene	2/0	2	20	2/0	4,320 / 2,160		Qualified as part of relay boxes.
Ball & Shaft Assy. Drum Support 10FSM1-11039-C	3/0	3	30	3/0	6,552 / 2,184		
Actuator Assy. Drum Lockout 10FSM1-11031-E	4/0	4	40	4/0	192 / 48	2	

TABLE II

S-10A COMPONENT QUALIFICATION TEST SUMMARY (Cont'd)

SUBSYSTEM Component Description	Shock Vibr. Tested / # Fail	Thermal Cycles No. Units	Thermal Cycles Total # Cycles	Thermal-Vacuum-Endurance # Units / Failed	Thermal-Vacuum-Endurance Total Hours / Longest Test	Radiation Exposure No. Units	Remarks
SAFETY SHUTDOWN							
Reflector Eject. Delay Timer NE10FS1-24-012-C	2/0	2	20	2/1	4,320 / 2,160	2	Malfunctioned first cycle after 90 days. Successfully completed > 2000 cycles after endurance test
Elect. Actuated Band Release Device 10FS-11052-NC 10FS-11049	5/0	-	-	4/0	8,640 / 2,160	2	
Temp. Actuated Band Release Device 10FSM1-11133	2/0	2	20	2/0	2,016 / 1,008		
Low Voltage Trip Device NE10FS-20-010	4/0	4	40	4/0	9,216 / 2,304	4	
DIAGNOSTIC INSTR.							
Drum Position Transducer NE10FSM1-16001-C	1/1	2	2/0	2/0	4,320 / 2,160	2	Torque exceeded 4 in-oz.

TABLE II

S-10A COMPONENT QUALIFICATION TEST SUMMARY (Cont'd)

SUBSYSTEM Component Description	Shock Vibr. Tested / # Fail	Thermal Cycles No. Units	Thermal Cycles Total # Cycles	Thermal-Vacuum-Endurance # Units / Failed	Thermal-Vacuum-Endurance Total Hours / Longest Test	Radiation Exposure No. Units	Remarks
DIAGNOSTIC INSTR.							
Drum Position Demodulator NE10FS1-24-010-B	2/0	2	20	2/0	4,320 / 2,160	2	
Reflector Limit Switch NE10FS1-24-013-NC	8/0	8	80	5/0	10,800 / 2,160	2	
Converter Impedence Isolation Inductor NE10FS-24-017	2/0	2	12	2/0	2,052 / 1,026	1	1 unit operated continually @ 17.5 amps
Converter Degradation Measurement Device NE10FS-24-013-B (and Isolation Transformer 10FS-22032)	2/0			2/0	768 / 384	1	
Gamma Flux Rad. Detector NE10FS-24-003-D	1/0			1/0	360 / 360	1	

TABLE II

S-10A COMPONENT QUALIFICATION TEST SUMMARY (Cont'd)

SUBSYSTEM Component Description	Shock Vibr. Tested / # Fail	Thermal Cycles No. Units	Thermal Cycles Total # Cycles	Thermal-Vacuum-Endurance # Units / Failed	Thermal-Vacuum-Endurance Total Hours / Longest Test	Radiation Exposure No. Units	Remarks
DIAGNOSTIC INSTR.							
Amplifier, Signal Cond. (Gamma) NE10FS-24-006-E	2/0			1/0	360 / 360	1/0	
Neutron Flux Hi Level Detector NE10FS-24-005-D	1/0	1	1	1/0	720 / 720		
(Hi Level Neutron) Power Supply NE10FS-24-002-E	1/0			1/0	360 / 360	2/2	1) No-load voltage exc. spec. limit. 2) Output volt. failure
Neutron Flux Detector Low Level NE10FS-24-004-D	1/0			1/0	720 / 720	2/0	
Neutron Flux Detector-Amplifier & Power Supply (Low Level) NE10FS-24-001-F	1/0			1/0	360 / 360	2/2	Post test analysis indicated failure in signal conditioner
Fast Neutron Integ. Flux Det. 10FS-24021	4/0	4	8	4/0	6,048 / 2,012	6/0	

TABLE II

S-10A COMPONENT QUALIFICATION TEST SUMMARY (Cont'd)

SUBSYSTEM Component Description	**Shock Vibr.** Tested / # Fail	**Thermal Cycles** No. Units	**Thermal Cycles** Total # Cycles	**Thermal-Vacuum-Endurance** # Units / Failed	**Thermal-Vacuum-Endurance** Total Hours / Longest Test	**Radiation Exposure** No. Units	**Remarks**
DIAGNOSTIC INSTR.							
RTD's & Bridge NE10FS-24-009-B 10FS-24001-B	3/0	3	30	3/0	6,480 / 2,160	3	
Thermocouple Assy. Socket-Head Cap Screw-Tip NE10FSM1-24-006-D (10FS-20068-A)	3/0	3	30	3/2	2,160 / 720	8 (FS-3)	Insulation resistant degraded in 2 unsandblasted specimens
Thermocouple Assy. NE10FSM1-24-006-D	50/0	50	50	50/2	186,000 / 2,160	25 (FS-3)	1) Qualified as part of FSM-1 & FSM-4 system tests 2) Failed during FSM-1 tests
Exp. Comp. Limit Switch 10FS-20015-NC	8/0	6	60	6/0	38,650 / 9,051	2 (FS-3)	Four units qualified as part of expans. comp. assy.
Conv. Volt. Divider 10FS-20011-C	2/0	2	2	2/0	3,240 / 2,160	1 (FS-3)	Qualified as part of FSM-1 & FSM-4 system tests

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TABLE II

S-10A COMPONENT QUALIFICATION TEST SUMMARY (Cont'd)

SUBSYSTEM Component Description	Shock Vibr. Tested # Fail	Thermal Cycles No. Units	Thermal Cycles Total # Cycles	Thermal-Vacuum-Endurance # Units Failed	Thermal-Vacuum-Endurance Total Hours / Longest Test	Radiation Exposure No. Units	Remarks
DIAGNOSTIC INSTR.							
Diff. Curr. Transductor NE7561-62-001	2/0	2	2	1/1	2,160 / 2,160	1	Shifted calib.-replaced
Exp. Comp. Position Transducer & Demodulator NE10FS-24-008	6/0	6	60	6/0	35,767 / 9,051	1	Four units qualified as part of exp. comp. assembly

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to maintain required reactivity worth. A 72 hour active control period during startup provides stabilization. During this period two control drums add reactivity to compensate for Xenon buildup and hydrogen redistribution within the elements. After the 72 hour period, long operation is assured by burnout of the samarium prepoison which compensates for reactivity losses caused by hydrogen leakage and fuel burnup.

Radiation protection of electronic components in the instrument compartment and Agena payloads requires neutron and gamma shielding. The shield was designed to limit the yearly fast neutron and gamma levels to 10^{12} nvt and 10^{7}R across a 5 ft. diameter plane, 17.5 ft. below the reactor base. Lithium hydride, cast in a stainless steel case, was used for the shielding material because it provides high neutron attenuation and withstands the operating environment. The shield used on SNAP 10 provides a neutron attenuation factor of 10,000 and a gamma attenuation factor of 10.

B. Reliability and Testing Evaluation

1. Fuel Elements

Component testing of each fuel element consisted of shock and vibration, thermal cycling and thermal endurance. Sixty-six qualification elements were tested successfully for an intergrated endurance time of 578,160 hours. In addition, 120 elements were environmentally tested including 259,200 hours of thermal vacuum endurance. In the FS-3 system test, 37 elements operated in a nuclear-thermal vacuum environment for 10,000 hours. This system test, as well as the FS-4 flight description, is included in Appendix I. When all testing is evaluated, the 37 element core, with one or two redundant elements, is estimated to be .995 reliable for one year and the average core temperature will exceed 880°F when currently available knowledge is applied to core loading.

2. Reflector Assembly

One reflector block assembly was qualification tested through shock and vibration, ten thermal cycles, and 2,160 hours of thermal vacuum endurance. Elimination of the drum drive system, EABRD, and TABRD yields an estimated reliability of .998 for one year for the remaining components.

3. Radiation Shield

Two radiation shields passed component qualification shock and vibration, 7 thermal cycles, and 90 days thermal vacuum endurance. Although no system deficiencies were noted, the number of component tests is too small to demonstrate the high inherent reliability. Therefore, the following reliability analysis goes into detail in the failure modes and reliability stress analysis:

a. Failure Modes

The purpose of the shield is to prevent radiation damage to the transistorized electronic equipment. Thus, radiation shield failure occurs when the electronic equipment receives a destructive dose. This dose is time dependent and a decrease in the radiation attenuation of the shield does not have an immediate effect. Therefore, a shield failure in flight is defined as the loss of H_2 which will cause failure of electronic equipment prior to the mission flight time.

Structural failure of the shield could have catastrophic effects on other critical components, or result in loss of hydrogen from the shield. After a structural failure of the case, H_2 leakage will commence. This leakage is dependent on the magnitude of the structural failure and the temperature of the LiH. It has been calculated that this leakage would have to be equivalent to 5% H_2, by weight, at the start of the flight to be critical. In that event, a failure will occur at the end of the 1 year mission. If the leakage exceeds the 5% equivalent the failure may occur at an earlier time. Structural failure of the shield case may be possible due to the following causes:

(1) Prelaunch - The shield could fail due to the thermal cycles to which it is subjected during system checkout, or by vibration or shock during transportation or handling. Such components, if detected, would not be launched because replacement is feasible.

(2) Launch - The shield could fail by load combinations imposed by shock, vibration, and acceleration during the launch phase. The ability of the shield to withstand launch loads has been demonstrated by seven test shields.

(3) Startup - During obrital startup the shield could fail because of thermal stresses resulting from the startup, or by meteoroid penetration. Five shields have been subjected to the startup thermal cycles, simulating all the thermal transients and stabilization. All were leak-tight.

(4) Endurance - The shield could fail during endurance operation in a space environment because of the meteoriod penetration or because of swelling of the LiH due to absorption of an excessive rediation dose. The FSM-1, FS-3, FSM-4 and FS-3 shields survived endurance without failure indications.

b. Estimated True Reliability

Because of the passive behavior of the radiation shield during system operation, the evaluation of true reliability can only be based on the integrity of the shield case to contain hydrogen as a functione of time. The test data which substantiates the performance behavior of the LiH shield material and establishes the margin of safety in case design is summarized below:

(1) Structural - The state-of-the-art failure rate for helium storage tanks is 0.07×10^{-6} failures per hour. Using an environmental factor of 900 and a launch time of 0.1 hour would result in a state-or-the-art launch reliability of 0.999994. A failure of the radiation shield is considered not to take place unless the crack area is 0.018 square inches or more. Using this fact, and the state-of-the-art value, the launch reliability can be conservatively said to exceed 0.999 even when allowance is made for mounting variations.

(2) Thermal - Information in Reference 4 and the results from numberous radiation tests on LiH, provide the most conclusive data on the performance of LiH. The SNAP 10A shield will not be subjected to radiation induced swelling as long as fully outgassed (hydroxide free) LiH is used. The result of the Baxter-Welch experiments show that, at the rate of 8×10^{12} n/cm^2 sec. and a total fast dose of 3×10^{18} nvt, no swelling or outgassing occurred. This value was obtained by applying the LITR fast-thermal ratio (1/4) to the maximum thermal dose (1.3×10^{19}) capsule. This does not take into account an estimated thermal flux depression factor of 1/10 (test bias). If both of these factors are applied, a strength equivalent SNAP 10A dose of 3.2×10^{19} is obtained. This compares favorably to the SNAP 10A fast neutron ($\sim$0.1 mev) dose rate load of 2.7×10^{11} n/cm^2 sec. and one year dose of 8.7×10^{18} nvt (fast) at the shield reactor interface. Therefore, no failure due to swelling of the LiH is anticipated, and a one year reliability of .9999 is assumed for this failure mode.

(3) Burst - One SNAP 10A shield casing was successfully pressure tested to 177% of the design limit load without bursting. The purpose of this test was to insure the integrity of the pressureized SNAP 10A shield casing. Based on a 77% margin between the maximum expected internal pressure and the actual test pressure results in a shield casing reliability $\gtrsim 0.9999$.

(4) Meteoroids - The shield meteoroid non-puncture probability has been estimated at 0.996 for 90 days and 0.984 for 1 year of operation. This, however, is the probability of a meteoroid puncture and ignores the size of the hole. The temperature of the radiation shield is assumed to be 850°F and a hole area of approximately 0.018 square inches (0.151 in. dia.) produces a non-critical loss of 5% H_2 (by weight) in 1 year. The hole size created by a meteoroid is considered to be less than twice the thickness (t) of the material for extremely small meteoroids, and is approximately equal to the meteoroid diameter for meteoroids greater than 2t in diameter. Using this criteria, the meteoroid, puncture probability can be restated as: (1) the annual probability of a meteoroid creating a 0.062 inch diameter hole (2t) is 0.011 (2) the probability of a meteoroid creating a hole somewhat larger than 0.068 inch diameter is 0.00033, and (3) the probability of being stuck by a meteoroid and creating a hole equal to or larger than .151 inch diameter is 0.000009 consistent with a capability of penetrating .140 inches of steel and the bumper.

The meteoroid non-puncture probability is one minus the probability of meteoroids causing holes equal in area to a 0.151 in. hole and is:

R_M = P(area of hole(s) $\leq$ area of .151 in. dia. hole) = 1-P (area of hole(s) $>$ area of .151 in. dia. hole). An approximation follows:

$$R_M = 1 - [P(1 \text{ hole of dia.} > .151 \text{ in.}) + P(2 \text{ holes of dia.} > .1065 \text{ in.}) + P(3 \text{ holes of dia.} > .087 \text{ in.}) + P(4 \text{ holes of dia.} > .075 \text{ in.}) + P(5 \text{ holes of dia.} > .067 \text{ in.}) + P(\geq 6 \text{ holes of dia.} > .062 \text{ in.})]$$

$$R_M = 1 - (9 \times 10^{-6} + 2 \times 10^{-10} + 8 \times 10^{-15} + 12 \times 10^{-15} + 4 \times 10^{-13} + 9 \times 10^{-7})$$

$$R_M = 1 - .00001$$

$$R_M = .99999 \text{ or } .9999 \text{ considering other combinations of holes.}$$

This probability is still extermely conservative in that it is based on the probability of the meteoroids striking the shield for 1 year, the H_2 leaking for 1 year, and the electronics being subjected to the higher dose rate for 1 year. These three are mutually exclusive, and if accounted for would increase the reliability to a considerably higher value. The probability of the meteoroid puncture causing failure in 90 days is even lower and R (meteoroid) $\geq$ .99998 for 90 days, except that a great deal of uncertainty exists in meteoroid data and theory.

(5) Total Reliability - The total true-estimated reliability is equal to the product of the above reliabilities. As the failure of the radiation shield is extremely time dependent (time to crack skin plus time for H_2 leakage plus time for electronic damage) the 90 day total estimated true reliability should exceed 0.9995. The reliability for one year is estimated to exceed .998 as a total.

V. POWER CONVERSION SUBSYSTEM

A. Subsystem Description

The power conversion system consists of "n" and "p" doped silicon-germanium (SiGe) thermoelectric material thermally coupled, but electrically isolated from the NaK heat transfer medium. These SiGe pellets are bonded to 40 parallel D-shaped stainless steel tubes arranged in a conical configuration about the NPU structure. Along any one tube or leg there are 72 SiGe thermocouples, or a total of 2,880 individual power producing elements. These pellets are electrically isolated from the hot NaK tube by thin alumina discs. The heat transport is from the NaK tube through the insulator, through the SiGe pellet, to an alumimum radiator. All materials which comprise the pellet subassemblies are brazed or otherwise metallurgically bonded to each other to ensure a sound structure, and a thermally conductive stack.

The electrical current flows through the "n" and "p" pellets which are connected alternately at their hot junctions by a copper hot strap and at the cold junction through the aluminum rediators. All 72 pellets on a tube are connected electrically in series. The series string of couples on each NaK tube is then cross-coupled electrically through the radiators with the adjacent string at every couple. These adjacent series-parallel connected legs are connected in series so that 20 leg pairs comprise the complete converter electrical network.

B. Component Functional Description

Throughout the startup and endurance phases, the converter radiator assembly must convert the heat supplied by the NaK to electricity and provide a minimum of 500 watts of power at 28.5 volts.

The T/E leg mounting hardware supports the leg assembly against the structure, and allows relative motion between the leg assembly and the structure during startup.

The interleg and intermodule connectors maintain the electrical circuit with minimum power loss. The interleg parallel connectors function only in the event of an open element, in which case they provide an alternate current path around the open element.

The current shunt and main-bus wiring provides a low resistance path between the converter and the load. The voltage taps provide a junction point between the converter legs and the wiring to the diagnostic instrumentation to allow monitoring of the leg voltages during the flight demonstration.

C. Reliability and Testing Evaluation

Thermoelectric converter module qualification test sequences and the relationship of the tests to the flight operations are as follows:

Test	Flight Operation
Steady state - 100 hrs. at 870 to 937°F	Preflight
Thermal cycle - 10 cycles; RT to 937°F	Preflight
Steady state - 100 hrs. at 870 to 937°F	Preflight
Shock and Vibration - 3 axes at 100% spec.	Laucnh
Steady state - life at 870 to 937°F	Startup and Endurance

Forty-four Type V modules have accumulated ~ 300,000 hours on life tests at 110% of design temperature. Ten module failures involving 34 elements have been experienced, six of these following utility power failure, and one following a heater failure. For a 90 day mission, element reliability can be estimated as 0.98, based on component qualification test only, if allowance is made for over-testing, but excluding the slow end-of-test shutdown which is necessary for diagnosis.

The V modules tested as part of the FSM-4, FS-3 and FS-4 contribute ~ 1.5×10^6 additional module hours. A description of the system test environments is included in Appendix I. It is impossible to determine how many elements have opened during these tests without a very costly breakdown of the available assemblies. If the most likely number is inferred to be 6 failures during the > 40 million element-hours of type V testing, the annual failure-rate is less than 1.2 per thousand elements. Calculation of the series-parallel redundancy, see Figure 2, shows that this failure-rate is equivalent to a converter reliability of .9982 for the endurance phase considering only open circuits. There is some slight probability of short-circuits as well, although none showed up during system testing. The mounting hardware, shunts and connectors were also tested without showing failure symptoms so the reliability is .992 for the entire conversion and distribution system to survive 1 year.

The relationship between the periodic estimates of reliability and the accumulation of test data can be seen in Figure 3. As successful experience was obtained from Type V elements the 90 day estimates were increased first, followed by increased annual estimates as the time of longest testing was extended. The successful development of a highly reliable converter system was a notable technical achievement due to the pre-qualification testing of Type I thru IV elements. Note that nearly all Type V test data was accumulated simultanelusly during the period of FS-3 testing, and that 70% of the 40 million element hour total was obtained from that system test alone.

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FIGURE 2

RELATION BETWEEN ELEMENT AND SYSTEM SURVIVAL
FOR
SNAP 10A CONVERTER CONFIGURATION

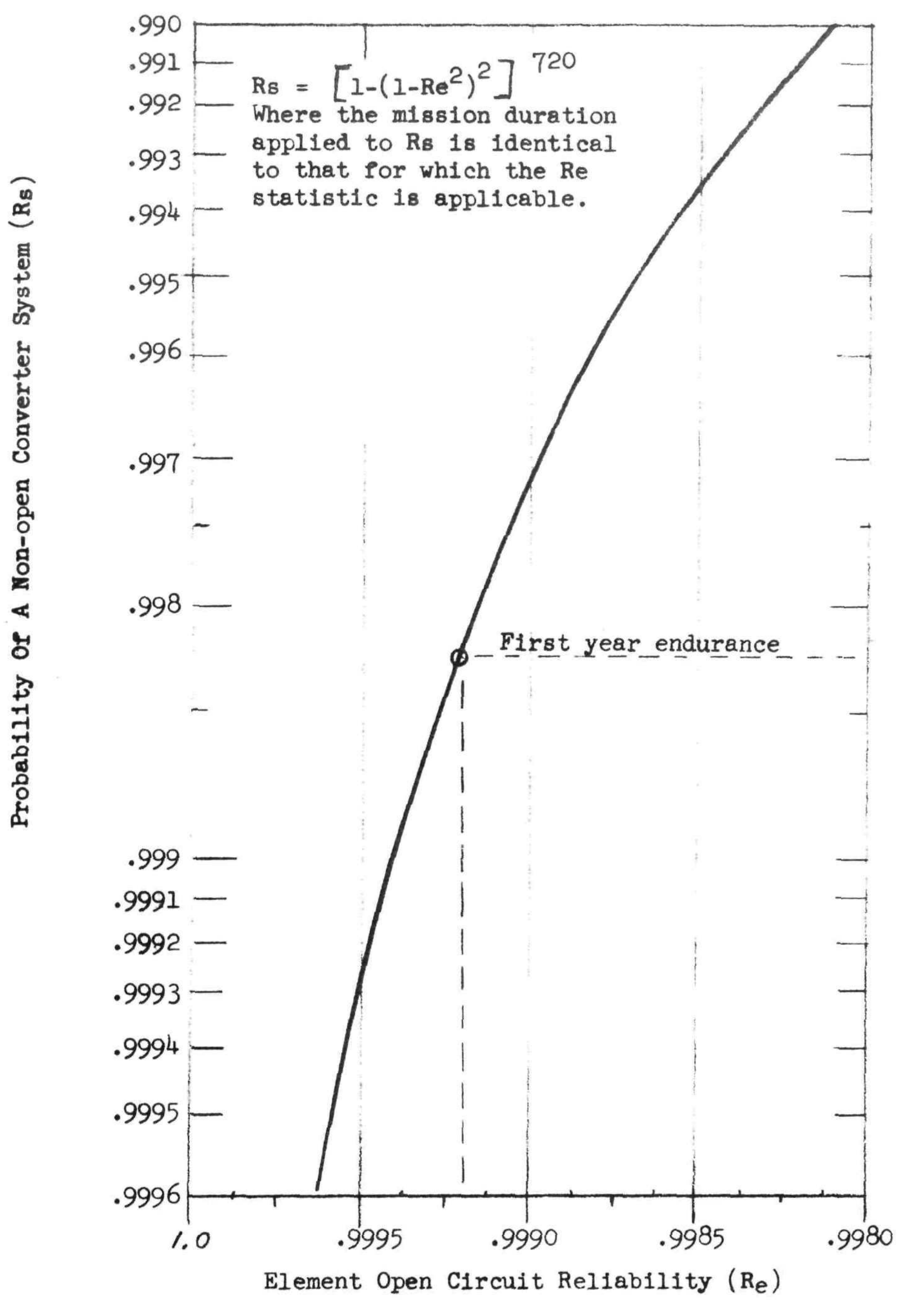


FIGURE 3a

HISTORICAL ESTIMATES OF CONVERTER RELIABILITY

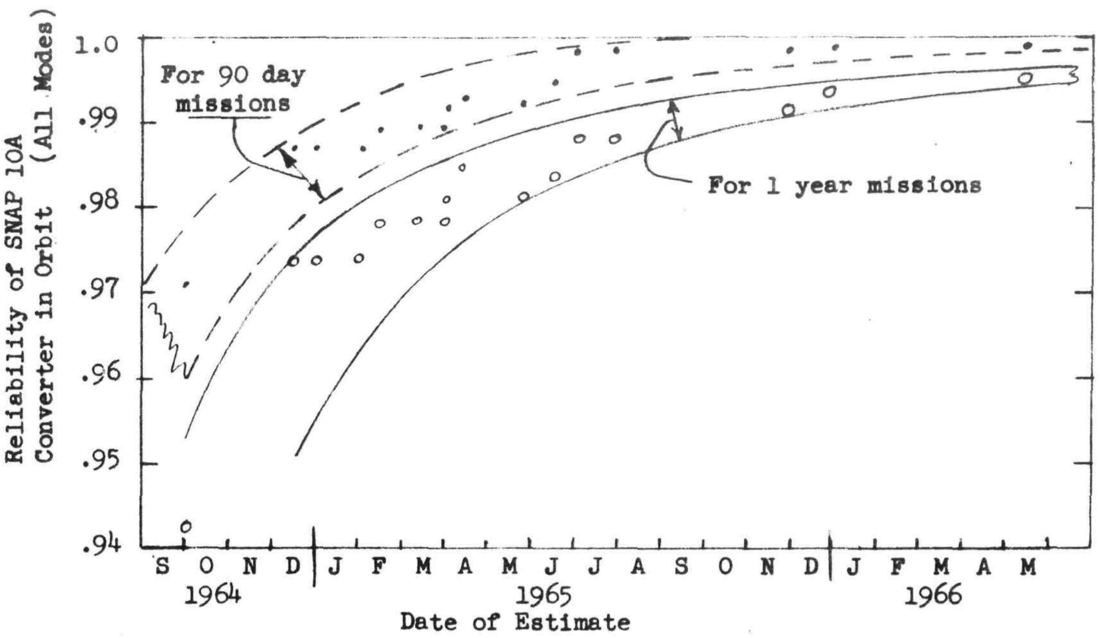
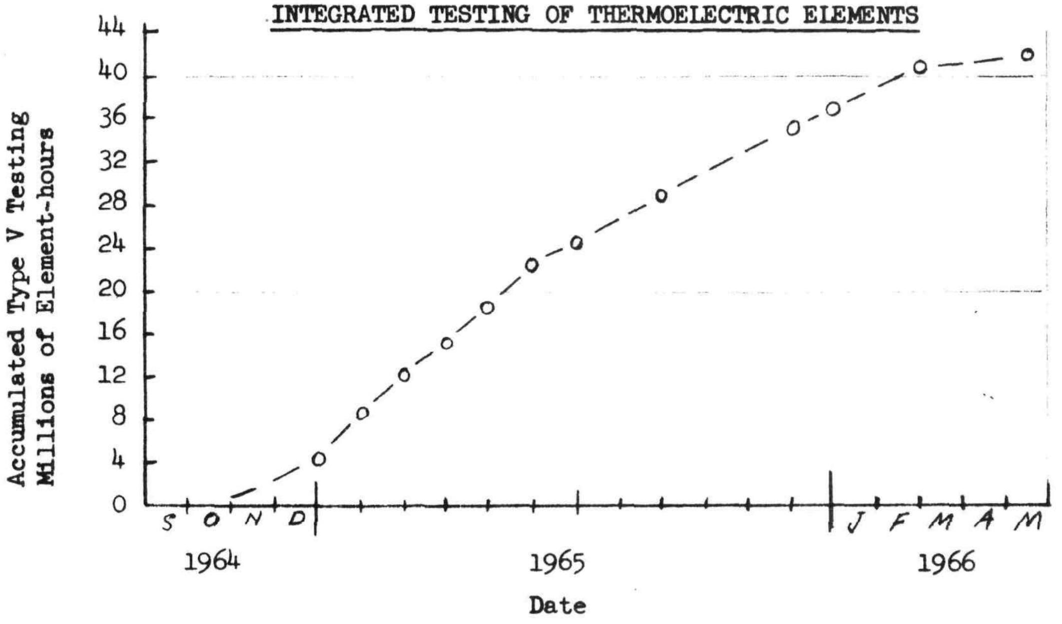


FIGURE 3b

INTEGRATED TESTING OF THERMOELECTRIC ELEMENTS



VI. HEAT TRANSFER SUBSYSTEM

A. Subsystem Description

1. Pump and Battery

The thermoelectric pump consists of a D-C conduction type of liquid metal pump powered by an integrally mounted thermoelectric generator. Electrodes are attached to the pump to permit the pump to measure flow rate and to permit the operation from a separate power source during startup. The main components are the throat, electrodes, magnet, thermoelectric elements and radiator. The following objectives reflect the flight pump qualification performance requirements.

(a) Deliver 13.2 gpm of NaK-78 at 1010°F NaK
(b) Develop a net pressure of 1.1 psi at design flow
(c) Deliver 0.48 gpm at 100°F to the system with an auxiliary power unit supplying 40 amp to the pump
(d) Have a life of 1 year with a flow of 10.5 gpm minimum at that time against the system hydraulic characteristic ($\sim$3 gpm in flight)
(e) Withstand the loads imposed by vehicle launch (shock, vibration and acceleration) and retain, at the inception of orbital operation, the minimum flow requirement.

The battery supplies 40 amp of power to the pump during the pre-reactor startup phase of operation for 24 hours maximum.

2. Expansion Compensator

The expansion compensator unit (ECU) is used on the system to (a) accommodate the net volume expansion of the NaK resulting from the temperature increase which occurs between vehicle launch and full power orbital operation, (b) provide system pressurization to ensure that neither NaK boiling nor pump cavitation occurs, and (c) maintain a void-free system. The ECU is an all metal assembly employing a welded bellow which is connected to the NaK return tube. An identical ECU is connected to each return line so that the center-of-gravity of the system remains on the NPU axis. At normal operating conditions the net volume expansion is equally distributed between two ECU's. However, in the event that the release mechanism of one compensator unit malfunctions, the other can absorb the total volume change.

In the event that a primary bellows develops a leak, the NaK will flow into the evacuated 50 cubic inch secondary container, preventing loss of NaK and maintaining an adequate system operating pressure.

The ECU bellows assembly utilizes a 13 convolution primary bellows and an 18 convolution secondary bellows, both being contained in a can assembly. The fact that two compensators are employed in the single SNAP 10A NaK loop leads to the logical failure diagram of Figure 4.

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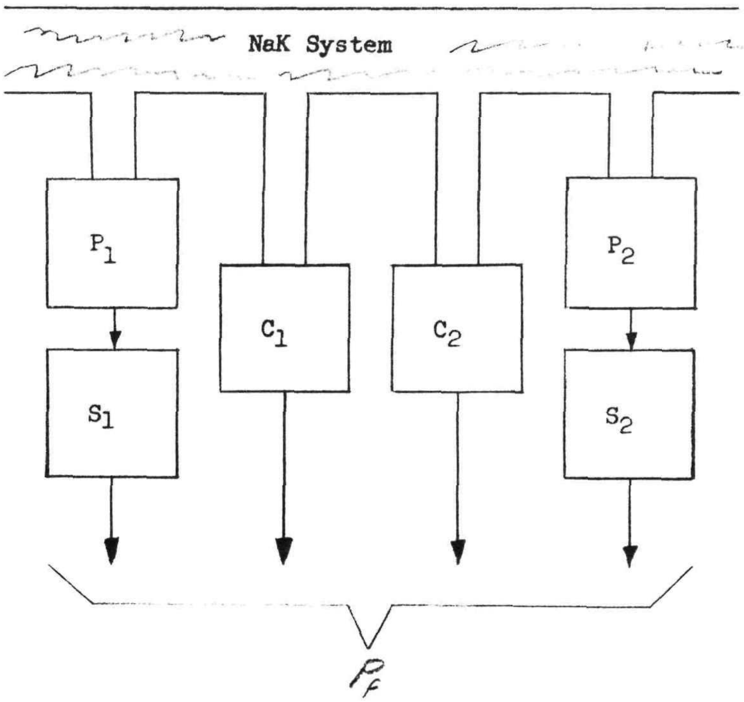
FIGURE 4

RELIABILITY OF EXPANSION COMPENSATOR SYSTEM



Probability of compensator system leakage or relaxation during first year; given a system stabilization probability $P_2 = .995$

Failure Probabilities

P = 13 convolution primary bellows
S = 18 convolution secondary bellows
C = Can leakage, spring relaxation, or hang-up

System failure probability (P_f) = $P_1 S_1 + C_1 + P_2 S_2 + C_2$

$P_f = (.09 \times .04) + .007 + (.09 \times .04) + .007 = .0212$

System success probability (R_s) = $(1 - P_f)(P_s)$

$R_s = .9788 \times .995 = .974$
for stabilization and one year operation

Note that primary bellows leakage must be accompanied by leakage of the secondary bellows of the same compensator before system leakage occurs.

3. Piping

The NaK piping system consists of pipe subassemblies, manifolds, return lines, supply lines, etc. which are welded at final assembly to the T/E leg assemblies, reactor vessel, and reactor vessel head assembly to form a complete NaK flow loop from the NaK pump outlet through the power conversion system to the reactor inlet.

The piping system must maintain containment integrity of the fluid NaK during all operational phases of the NPU. It provides flow passages for the heat transfer fluid (from the NaK pump outlet through the power conversion system to the reactor inlet) which imposes a hydraulic pressure drop compatible with pump performance and flow rate requirements of the system.

B. Reliability Testing and Evaluation

The best estimate of the reliability of this subsystem for missions of any duration can be obtained from Figure 5 by multiplication of values given for the major components. Each is discussed separately as follows:

1. Pump and Battery

Seven pumps of flight design have accumulated approximately 85,000 hours on life test without significant degradation in flow. The data can be summarized as follows:

Pump (S/N)	Time (Hours)	Temperature (°F)	Flow (lb/hr) (Initial)	Flow (lb/hr) (Final
016	17,170	1010	5450	4020
	360	1100	4360	4420
018	16,909	1010	5600	4280
	1,024	1100	4300	4420
022	9,542	1010	5270	4460
023	11,853	1100	5350	3800*
028	10,179	1010	5040	4155
031	9,389	1010	5140	4175
032	8,249	1100	5160	2390*

*These exceeded the minimum required 3900 lb/hr at the end of the specified 6000 hours even though over-tested for temperature.

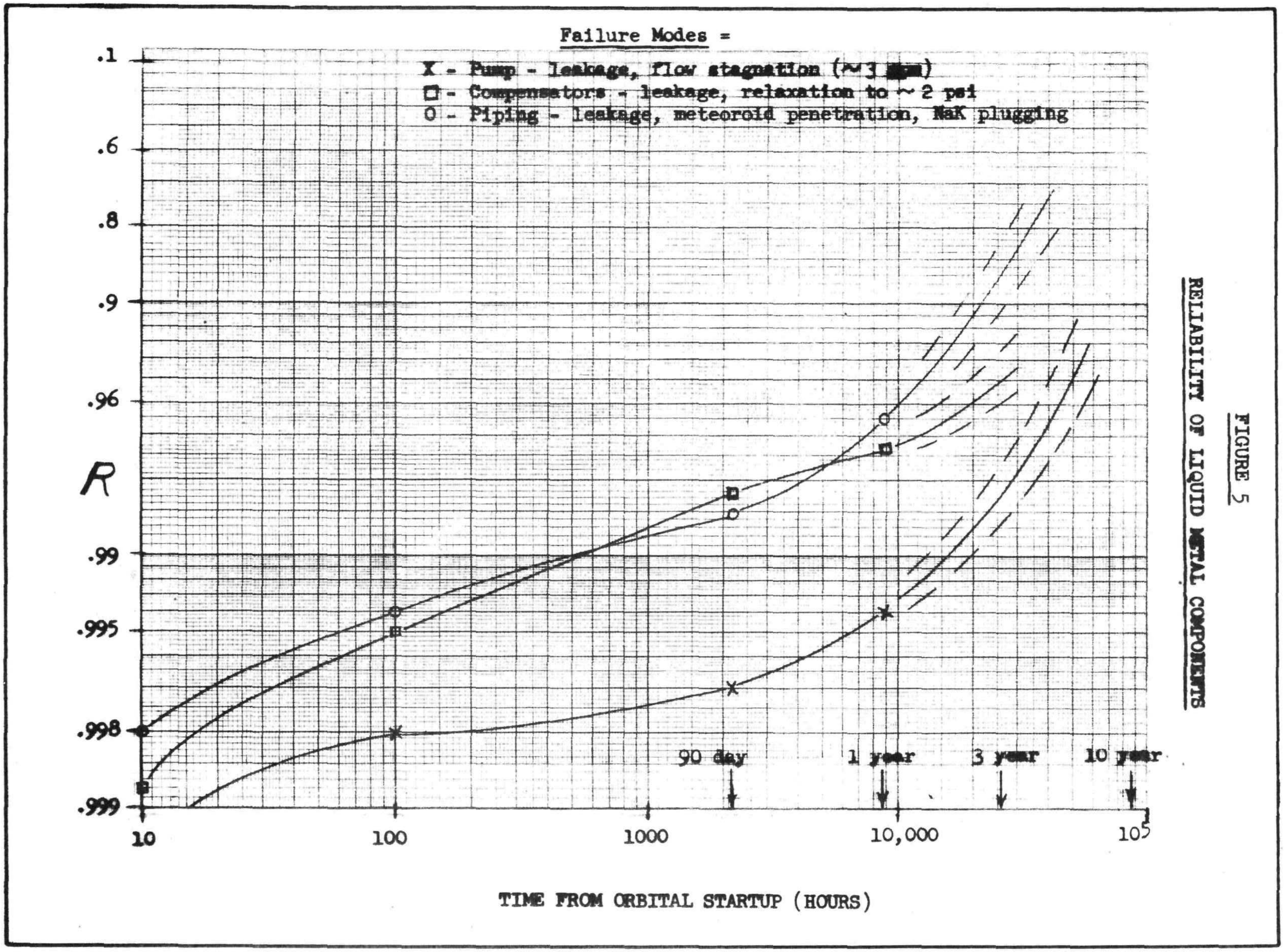


FIGURE 5

RELIABILITY OF LIQUID METAL COMPONENTS

The best estimate of pump reliability for 90-day operation, based on these life test data, is 0.975. When all development and NPU system test experience is evaluated with respect to the operational system failure level of less than 3 gpm, the reliability of the pumping system for the first year of operation is 0.994. No failures have occurred in a total of 31 similar pumps during 185,000 hours of testing to a specification much more severe than is required by the NPU system. Four batteries successfully passed qualification tests, two of these were tested by the supplier. The primary batteries have an extremely high reliability as state-of-art components for their usage up to 20 hours.

2. Expansion Compensator

Four secondary containment ECU's have completed all phases of the qualification test sequences. The goal of one year endurance was surpassed on the three units operating at design displacement of 60 cu. in. Ober 7,200 hours of testing, in addition to the specified 24 hours, has been accumulated on the unit operating at 120 cubic inches of NaK displacement. The endurance tests consisted of operation at 750°F in vacuum with the primary bellows NaK filled and the secondary containment volume evacuated.

As a consequence of the bellows failure in FS-1 acceptance testing, a tightened compensator acceptance test was instituted. Two hundred cycles of operation were required of the new dual-containment design and considerably more stringent quality control measures were initiated on the material going into bellows and can assemblies. As a result, statistical information is available on coupons from many material lots which reveals that the standard deviation of yield stress is less than 2% of the mean and that 170,000 psi is a conservative mean stress to produce a 0.2% offset. Thus, the 120,000 psi handbook value for yield is a valid 99% gauarantee level, and the design margin of safety is 0.20 over the calculated load level of 100,000 psi at 700°F. Even though yield is not equivalent to failure it can be conservatively taken so, and in the same sense the standard deviation of the yield stress can be taken as 5% of the mean when a normal distribution of stress is assumed.

From the qualification test experience and the above data it can be calculated that the reliability of each of the 13 convolutions in primary bellows is at least .9996 and this bellows inherent reliability is .9948 therefor. The secondary bellows is loaded to a stress level of only 70,000 psi, so its 18 convolution total reliability is .9997 for at least one year of service. These high inherent reliabilities for the endurance phase are not borne out by the incomplete experience to date because it is heavily weighted with the FS-1 and FS-3 failures which preceeded very important changes in design and QC procedures.

A total of 34,000 hours of qualification endurance test time has been accumulated without failure which yields a reliability estimate per ECU of 0.939 for a 90-day period. Considering the 31 bellows tested, including systems and pre-qualification, the bellows have been tested for about 175,000 hours. This corresponds to an annual reliability of ~.910 for the primary bellows, including the FS-3 failure. Based upon experience the secondary bellows is at least .96 reliable, and the vacuum-melt containment can is estimated to be .993 for the first year. When these endurance reliabilities and a value for survival of launch and startup are combined in the redundant manner shown in Figure 4, the resultant reliability for the dual compensator system is 0.974 for the first year of operation. The malfunction in FS-3 was probably a stringer because these compensators did not incorporate vacuum-melted can material.

3. Piping

The containment of the NaK piping has been demonstrated by system tests FSM-1, FSM-4 and FS-1 which provided approximately 3,600 hours of qualification test time. The FS-3 and FS-4 tests add 11,000 hours to the total, and stress analysis verifies an extremely high reliability. However, the probability of meteoroid puncture is nearly 2% so the annual reliability is estimated as .965.

VII. STRUCTURAL SUBSYSTEM

A. Subsystem Description

1. Primary

The structural subsystem consists of the primary structure, instrument compartment, and ejectable heat shield.

The primary structure is made of .020 in. titanium in the shape of a truncated cone. The shell is corrugated to form channels for the 40 NaK tubes. A torque box maintains the structural formation at each opening. Loads from the reactor and shield are transferred from the structure apex to the Agena through the shell which is mated at the interface by 8 supporting legs.

2. Instrument Compartment

The donut shaped instrument compartment, made of aluminum, is supported from the structure, within the 8 legs, so that the APU load does not affect it. Dimensionally, the compartment has a 50 in. O.D., a 26 in. I.D. and is 4 in. deep. Eight compartments, formed by webbed stiffeners, provide the structure for supporting the instrumentation and control subsystems, electrical wiring, and interface connectors.

3. Heat Shield

A honeycomb aluminum heat shield is used to minimize the system heat losses in orbit prior to thermal startup. During prelaunch, the APU is warmed, by conditioned air, to a minimum of 75°F. Since orbitual prestartup heat losses could cause NaK freezing, the heat shield acts as a thermal blanket and minimizes sun and shade transients. The shield is constructed in halves with longitudinal separation. Lower supports, at 90° from separation, allow a ratational separation of shield and breakaway connector. An overlapped band, held by a squib actuated pin puller, encircles the halves at the top. When the reactor outlet temperature reaches 275°F, the squibs are fired, the pin pulled, and the band releases. Preloaded springs provide the energy for the shield separation and trajectory. The breakaway connectors, one per shield half, carry the wiring for firing the squibs and for diagnostic thermocouples. For ease in separating, the receptacle sockets are gold plated brushes into which fold plated pins are inserted.

B. Reliability and Testing Evaluation

Two primary structures were specifically tested for qualification levels of shock and vibration and thermal cycling. Additional shock and vibration testing plus thermal-vacuum endurance runs were accomplished in system tests, as described in Appendix I. Extensive stress analysis and system development testing was conducted as noted in references 1, 2, and 3. Subsequent system testing has confirmed the high reliability values employed in Table I for this subsystem, .997 for survival of launch and startup.

Qualification testing of the instrument compartment was concurrent with the primary structure. Significant development testing and stress analysis was performed to insure that no structural failure could occur which would compromize critical components and jeopardize the mission.

The ejectable heat shield was qualification tested on two units which completed shock and vibration and thermal cycling. Endurance testing is not significant since the shield is ejected during startup. The heat shield was tested on systems FSM-1 and FSM-4 as described. in Appendix I . More than 100 ejection tests were performed in order to insure that variations in the force available were allowable in conjunction with variations in the connector friction and hinge loads. The main reason for the heat shield reliability being .996, and lower than the primary structure, is that a probability of impacting exists subsequent to ejection.

VIII. REACTOR STARTUP AND CONTROL SUBSYSTEM

A. Subsystem Description

The SNAP 10A reactor and control subsystem has been designed to provide an automatic controller sequence of events to bring the nuclear reactor to full thermal power, and to provide active temperature control during a 72 hour stabilization period. A momentary 28 VDC startup command initiates the startup sequence by energizing 12 latching relays connected in functional redundancy. A single command signal, originating in the Agena, is transmitted to the NPU on separate wires connected to the redundant banks of startup relays. Activation of these relays accomplishes three startup functions as described below.

The first startup function energizes two relays on each command wire to fire squibs for releasing retaining pins on the reactor control drum segments. The relay contacts are arranged so that either of two relays will fire squibs for releasing both coarse control drums. Full insertion of these drums is through pre-stressed springs which snap the drums in. A similar relay-squib-pin-puller arrangement is provided for releasing retaining pins on the fine control drums.

The second startup function consists of energizing 4 relays which close contacts and arm the heat shield squib bus. Once the bus is armed, heat shield ejection is dependent on a thermo-mechanical temperature switch closure firing a squib. When the squib is fired a pin is pulled which releases the heat shield retaining band allowing the spring loaded halves to eject. Parallel circuits of temperature switches, relays, and squibs are provided for redundancy.

The third function provides, by relay contact closure, electric power to the startup controller. With the reactor outlet initially at a low temperature, dual temperature sensor/switches feed the controller a corresponding low temperature input signal. Controller cyclical operation of the fine control drum stepping motors is based on a predetermined insertion rate of 1/2° drum rotation every 150 sec. When the reactor NaK coolant outlet temperature reaches the set point of 1020°F, both temperature sensor/switches close and the controller stops pulsing the motors. During the 72 hour reactor stabilization period, the controller remains energized and automatically drives the drum motors to increase reactivity when the NaK outlet temperature drops below 1010°F.

A ground command is also available to overide the remperature sensor/switch for the purpose of increasing the reactor outlet temperature. This command is a backup for use in the event of flight system performance anomalies. Following sufficient reactor stabilization, the controller electric power is switched off by ground command, and continued power operation is determined by the reactor nuclear characteristics. Provision for turning the controller power back on is afforded by a ground command should increased reactor power be required.

B. Component Functional Description

1. Relay Boxes

The main relay box and the auxiliary box contain the components necessary to distribute and supply electrical power to the operating SNAP 10A subsystems. These components are 6P-DT latching relays, 2P-DT latching relays, 2P-DT non-latching relays, relay sockets, diodes, fusistors, and interconnecting, low temperature wire.

Specific functions of the relay box components are summarized as follows:

Single, momentary commands are received from the Agena which energize latching relays in the NPU. The choice of logic function and the use of redundant contacts is dictated by the subsystem end requirements. For startup, complete redundancy is employed for energizing components and for firing squibs.

Diodes are installed across the relay coils to short-circuit the reverse current generated by the collapsing magnetic field of the de-energized relay coil. These suppression diodes substantially reduce the EMI generated by the relay box.

Fusistors, located in the main relay box, are wired in series with each of the fourteen squibs. The fusistors provide a controlled, current limiting action against squib malfunction into a short-circuit. Opening time of the flight-type fusistor is 3 seconds at a resistance of 4.5 OHMS with 28 VDC applied.

The relay sockets and interconnecting wiring have been qualified as part of the component and system qualification tests.

2. High Temperature Wire

The high temperature wire is used in all areas where the temperature ranges from 700° to 1,000°F. The wire consists of nickel clad copper, stranded conductor with fiberglass insulation and a stainless steel overbraid shield. Three layers of braided fiberglass cover the inner conductor. A layer of stainless steel braid follows with two additional layers of fiberglass over this braid. The outer fiberglass insulation is protected by a stainless steel braided shield. This wire is routed through the conical structure to the reactor/reflector area, and transmits power to the control drum stepper motors, the drum release squibs, the EABRD and related components. Signal outputs from the temperature switches, position switches, and drum position transducers are also carried on high temperature wire.

3. Controller

The controller is a solid state device operating in digital logic. Transistors are used throughout with the exception of the stepper motor output power which is switched by relays. A low temperature input signal is provided, by temperature sensor/switches, in the form of an open circuit. When power has been supplied to the controller, either by startup command or by the controller "on" command, the following sequences take place. (1) An initial time period of 50 seconds effects a delay so that short term thermal transients do not influence the reactor control - if the low temperature signal ceases during this 50 seconds, the controller resets and no further action occurs; (2) when the input signal exceeds 50 seconds, four sequenced pulses are sent to the control stepper motors, and thereafter pulses are sent every 150 seconds as long as a low temperature is sensed. The internal time base signal is generated by a transformer coupled multivibrator.

4. Drive Motors

The control drum stepper motors drive the reactor beryllium reflector drums into the dixed beryllium cavaties to increase reactivity. The motor is a synchronus stepping machine with a permanent magnet rotor and an eight pole stator with bi-filar windings. Four voltage pulses energize the motor winding sequentially to produce a shaft rotation of 6.8°. A gear reduction set with a 13.84: 1 ratio causes a drum rotation of 1/2 degree for each four-step sequence.

During non-operating periods, the motor rotor is locked in place by a spring loaded brake consisting of a disc on the shaft. A solenoid winding is electrically in series with the motor coils so the brake is released whenever the motor is being driven.

5. Temperature Switches

a. Electronic Temperature Switch

Two electronic temperature switches are used for signal conditioning of the input to the startup controller. Both switches are of similar construction, and are connected in series so that opening either switch causes controller operation.

Physically, a temperature switch consists of a platinum wire temperature sensor, located at the reactor outlet, and a signal conditioner in the instrument compartment. The sensor forms one leg of a resistance bridge which feeds a control signal to a magnetic amplifier. When the mag-amp changes state, a second mag-amp is energized. This second amplifier drives a relay which has contacts in series with the startup controller input. The operation is such that a temperature sensed below the set point of 1010°F causes the relay to be de-energized and the contacts, which are paralleled internally, open. An open circuit to the controller input initiates a drum motor stepping sequence.

b. Thermo-Mechanical Temperature Switch

The thermo-mechanical temperature switches initiate the heat shield ejection, and detect high or low temperature malfunctions. These switches are made of concentric metal tubes with a common weld at one end. These switches operate on the force generated by temperature changes on bi-metalic elements. Thus, tube materials are chosen for their difference in coefficients of thermal expansion. A suitable linkage is provided at the open ends with an adjustment screw for setting the desired contact closure temperature point. Two switches were set to close contacts at a probe temperature of 275°F. Each switch closure independently energizes a circuit for firing squibs, and thereby ejecting the heat shield. The low temperature malfunction detection switch closes contacts when the reactor outlet temperature drops to 780°F. A non-latching relay is then energized and the malfunction sequence is initiated. Similarly, for a high temperature excursion, a switch closure at 1285°F energizes the malfunction detection circuit.

6. Squibs and Pin Pullers

A pyrotechnic squib and pin puller form an actuator assembly for releasing the four control drums, both expansion compensator bellows, and the heat shield retaining band. Each of these end functions requires one pin actuation, and are redundant so that either of two squib firings initiate the action.

The actuator consists of a housing with a piston chamber, and a sliding piston and shaft which is retracted by the detonation of a squib. Two squibs are attached in a parallel redundant configuration for increased reliability. Although each squib contains two isolated bridge wires, only one such initiating circuit per squib is employed on SNAP-10A.

7. Connectors

The electrical connectors are a major link in the operating function on SNAP-10A, and their complete integrity is required for mission success. The variety of connectors used is subdivided into these four major categories:

1. High Temperature Connectors;
2. Low Temperature Connectors;
3. Ejectable Heat Shield Connectors;
4. Terminal Blocks.

High temperature connectors with stainless steel shells and Duroc D-133 insulation are used outside the instrument compartment. Applications include reactor interface, squibs, temperature switches, and expansion compensator units. Extensive environmental testing on these connectors was satisfactory, although initial problems were experienced with wire terminations.

The low temperature connectors are installed in the instrument compartment where the temperature may range from 75° to 140°F. The successful operation of these connectors was verified by component qualification tests as well as integrated system tests.

A special connector, with a low unmating force, was used on the ejectable heat shield. A plug with tapered gold-plated pins was attached to the shield half. These pins mate with brush type sockets on the receptacle which is attached to the NPU structure. This construction permits easy separation during heat shield ejection.

Terminal blocks are used in the instrument compartment for wiring tie points, power distribution, and for transitions from high temperature to low temperature wire. The terminal blocks are glass fiver filled, diallyl phthalate with 10 gold-plated brass inserts as feed-through terminals. The inserts accept a tapered, gold-plated brass pin with a crimp type wire connection. A forced fit insertion of pin into insert provides a sturdy, electrical connection which is reliable in state-of-art applications.

C. Reliability and Testing Evaluation

1. The main and auxiliary relay boxes were qualification tested as assemblies. Each box completed shock and vibration, 10 thermal cycles, and endurance testing of 90 days. This program satisfied the qualification requirements for the three types of relays, the fusistors, the diodes, and the low temperature interconnecting wiring. In addition, the following tests were completed on the separate components:

Relay Qualification Test Results

Test Type	Number Tested	Number Failures
Performance Record	51	0
Sealing	47	0
Overvoltage	47	0
Acceleration	47	0
Vibration	46	0
Shock	44	0
Low Temperature	21	0
Thermal Vacuum	21	0
Endurance	6	0
Radiation	4	0

The early radiation hardened relays used ML varnish on the coils but failures associated with these required a change to Teflon wrapped coils. Although Teflon is susceptible to radiation damage no adverse effect, within the hermetic container, is anticipated within one year. Component testing on diodes was limited to irradiation where samples were subjected to 10^{14} nv fast neutron flux and a gamma dose of 3×10^5 r. No serious degradation resulted.

Fusistors were qualification tested under shock, vibration, thermal-vacuum, and radiation environments without failure.

2. Samples of high temperature wire passed qualification level testing of shock and vibration, thermal cycling, thermal-vacuum endurance, and radiation. In addition, wire performance on system tests demonstrated 100% survival.

3. Three startup controllers were tested to qualification levels of shock and vibration and 10 thermal cycles each. Two units completed 90 days of endurance testing and a third unit was irradiated. Supplemental endurance testing was performed as follows:

Serial Number		Number of Hours	Number of Cycles
8		1,776	42,960
13		9,209	39,388
14		8,870	40,292
	TOTALS	19,855	122,640

4. The control drum actuators completed qualification tests on six units with one failure during the endurance phase. The failure resulted from a shorted winding which was deformed during assembly. Quality Control measures were adopted which prevent defects of the type observed from occurring again. Five actuators passed endurance testing successfully and two units completed radiation testing without failure.

5. Two reactor temperature control switches were subjected to shock and vibration, thermal cycling, 90-day endurance, and radiation tests. The temperature sensor, associated with the switch, completed the same tests except that only one was subjected to shock and vibration. No failures were associated with either component during the qualification tests.

Three thermo-mechanical temperature switches successfully completed shock and vibration and ten thermal cycles each. Two units were endurance tested for 90 days without failures. Successful operation during system tests added to the reliability level for demonstrated performance.

6. The squibs and pin-pullers were qualified as components as well as part of the DRM-1 assembly qualification tests. Fourteen squib and pin-puller assemblies were tested for shock and vibration and t0 thermal cycles each. Seven assemblies were endurance tested for a total of 860 hours and four were subjected to irradiation. Eight additional units completed shock and vibration, thermal cycling, and endurance during the DRM-1 tests. No failures were recorded during the test programs.

7. Qualification testing of high and low temperature connectors and terminal boards was completed as part of the FSM-1 and FSM-4 test programs. All low temperature connectors, installed on component parts, were also qualified along with that assembly's qualification tests.

The heat shield breakaway connector was qualification tested as a separate component. Two connectors were subjected to shock and vibration, and endurance testing of 102 hours each. Four units were thermal cycled ten times each. No radiation tests were performed since the connectors are unmated following reactor startup. There were no connector failures during the qualification test program.

IX. FLIGHT DIAGNOSTIC INSTRUMENTATION

A. Subsystem Description

The instrumentation on SNAP 10A provided a source of engineering design information and enabled flight system management through telemetry data evaluation and subsequent ground commands. Nine basic categories of measurements were taken as listed in Table III. Provisions were made for redundant measurements to insure a complete data profile consistent with the unique demonstration test-flight mission.

B. Reliability and Testing Evaluation

The diagnostic instrumentation was generally qualification tested on a component level. Except for the thermocouples and voltage divider, at least one of each flight type instrument was tested through shock and vibration, thermal cycles, endurance, and radiation. The structure-mounted thermocouples and the voltage divider were qualification tested as part of the FSM-1 and FSM-4 system tests.

TABLE III

ITEM	MEASUREMENT	DESCRIPTION	QUANTITY
1.	Shock & Vibration	Accelerometers along X, Y, and Z axes of reactor	3
2.	Flow	1. NaK coolant flow at reactor outlet	1
		2. NaK EM pump wall voltage	1
3.	Temperature	1. Thermocouples on reactor, piping, converter, and heat shield	33
		2. Resistance temperature detectors on pump fins, piping, and instrumentation compartment	16
4.	Nuclear	1. Reactor fast neutron leakage flux	1
		2. Instr. comp. thermal neutron flux	1
		3. Instr. comp. gamma flux	1
		4. Instr. comp. neutron dose	8
5.	Position (analog)	1. Fine control drums	2
		2. Expansion compensator bellows	2
	Position (switch)	1. Control drums full in and full out limits	8
		2. Expansion compensator bellows collapsed	2
		3. Heat shield ejected	2
		4. Reflector half position	2
		5. Reflector retaining band status	2
6.	Voltage	1. Converter leg taps	10
		2. Conterter total voltage	2
		3. Controller internal voltages	6
7.	Current	1. Converter output	1
		2. Converter leakage	1
		3. NaK pump startup battery current	1
8.	Impedence	Converter internal impedence	1
9.	Event	Relay contact event markers	14
		TOTAL	121

No serious component failures were observed during the testing period. In some cases, output degradation or a calibration shift occurred but these were not considered detrimental since satisfactory data could still be obtained. The use of redundant measurements in the system configuration ensured a high probability of obtaining data even with individual failures.

Considering the conditions under which a given instrument is required to function, the backup provisions available in this subsystem are roughly equivalent to 3:1 for reflector/drum position, 11:1 for NaK temperature, and 12:1 for converter voltage.

Table IV lists the measurements required during each mission phase for providing data for subsequent ground initiated action. The number of measurements available for each required indication shows the instrumentation redundancy. During the prelaunch and launch phase, the required indications were specified by Air Forces direction. Failure of a required indication at this time would result in a "hold" condition pending resolution by the Program Director. Instrumentation failures during prelauch would not constitute a mission failure since repairs are possible.

Because the flight-testing of FS-5 might involve the desirability of additional data points, a rigorous reliability analysis of the diagnostic system is not feasible. It is likely that no new channels need be provided, but that the success of FS-4 could lead to a net reduction of instruments. When the probability of requiring each given diagnostic function is considered in conjunction with the reliability and redundancy of each function, except those in the converter distribution system, the reliability of the subsystem is pessimistically estimated to be .989 for one year. This does not mean that the subsystem will be complete, but that it cannot be blamed for contributing to mission failure as a primary cause more often than on ~1% of the flights. These occasions would include both false or ambiguous indications and missing data because adequate failure and engineering performance data is part of the defined mission criteria.

TABLE IV

DIAGNOSTIC TELEMETRY REQUIREMENTS

Mission Phase	Measurement Type	Measurement Indication Required for Phase Success	Measurements Available	Remarks
Prelaunch and Launch	Reflector Position Switch	1	2	Loss of indication constitutes a "no go" condition at any point in the prelaunch and launch operations.
	NaK Temperature	1	5	
	NaK Flow	1	1	
	Converter Current	1	1	
	Converter Voltage	1	1	
	Drum Analog Position	2	2	
	Heat Shield Position	2	2	
	Malfunction Bus Status	1	1	
	ECU Analog Position	2	2	
Prestartup	Reflector/Band Position	1	4	A successful indication may enable saving a small proportion of otherwise doomed missions.
	NaK Flow	1	3	
Orbital	NaK Inlet/Outlet Temperature	2	21	
Orbital Startup	Fine Drum Position Switch	2	2 *	* If either switch reads full in, controller operation would be ground commanded at slow rate.
	NaK Inlet/Outlet Temperature	2	27	
	ECU Position	1	3	
	Converter Current	1	1	
	Converter Voltage	1	12	
Full Power	Reactor Inlet/Outlet Temp.	2	21	
	Converter Voltage	1	12	
	Converter Current	1	1	

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X. AUTOMATIC MALFUNCTION DETECTION AND SHUTDOWN SUBSYSTEM

A. Subsystem Description

This subsystem is a standby circuit for shutting down the SNAP 10A reactor by reflector ejection. Ejection is normally accomplished by energizing the electrically actuated band release device (EABRD), a fusible link in the reflector retaining band. When the retaining band parts, the spring loaded reflectors are free to eject.

As a backup to the EABRD, a thermally actuated band release device (TABRD) is employed to pull a holding pin in the retaining band when the reactor temperature drops below a usable limit.

Two circuits in the detection and shutdown subsystem provide an option for electrically energizing the fusible link. These options offer (1) the use of an on-board automatic malfunction detection and shutdown sequence, or (2) a ground controlled ejection command. The end functions are identical, whereas the option difference is the initiating signal origination.

The automatic malfunction detection and shutdown circuit is armed by a ground command, following the reactor stabilization period. This command energizes a latching relay which provides voltage to the detection and shutdown circuits. Once the latching relay is commanded on, there is no flight operation or action which will then de-energize the automatic shutdown sequence.

The malfunction detection circuit is activated by either of four abnormal system parameters. These are (1) loss of NaK coolant, (2) low reactor outlet temperature, (3) high reactor outlet temperature, and (4) low unregulated bus voltage. Each circuit independantly senses and monitors a critical operating limit. The first of these, loss of NaK coolant, results in a collapse of the expansion compensators bellows. As each bellows depresses, individual micro-switches are closed indicating the volume loss. With both switches closed, a common non-latching relay is energized which in turn initiates a malfunction circuit in the Agena vehicle. Circuitry in the Agena then provides for taping the system telemetry data, and for subsequent transmission to ground stations.

In the event of a system malfunction causing the reactor outlet temparature to drop, a thermo-mechanical temperature switch closes at 780°F. This switch closure energizes the same common non-latching relay, described in the NaK loss section, with the same end results. A high temperature malfunction is sensed by a similar thermo-mechanical switch which closes at a reactor outlet temperature of 1285°F.

The fourth sensing circuit combines malfunction detection and automatic reflection ejection. If the unregulated 28 VDC bus voltage, as sensed in the NPU instrument compartment, drops to 22.75 V, two low voltage sensors must close their contacts to energize a one-minute electro-mechanical timer and a non-latching relay. This double-pole relay energizes the common malfunction detection relay, described previously, and also provides a signal to switch off the Agena secondary payloads. If the low voltage condition clears within one minute, both voltage sensors and the timer automatically reset so that only a transient malfunction is detected.

The failure sequence initiates when the one-minute timer times out, indicating a continued low voltage condition. After the one minute delay, a relay is energized which sends a failure signal to the Agena for switching power to end-of-life batteries and for resetting the data acquisition tape recorder. In the NPU, a one-hour timer starts a delay period for acquiring failure data. At the end of one hour, a timer contact closure energizes a latching relay. Parallel contacts on this relay carry current to the fusible link in the reflector retaining band. After 30 seconds, at an energy of 1,800 joules, the link opens and the spring loaded reflectors are ejected.

The second circuit in the detection and shutdown subsystem allows continuous ground command option for reflector ejection. Command ejection is possible through the umbilical, prior to launch, and thereafter by radio command at any time the vehicle is in a receiving zone. The command directly energizes the ejection relay which provides power to the fusible link. This insures the capability of ejecting the reflectors should the automatic circuit malfunction. See Reference 5 for integrated ejection reliability.

B. Reliability and Testing Evaluation

The malfunction detection components do not directly affect the mission objectives, except in the event of low voltage. Therefore, the diagnostic system includes the other three functions and the following discussion is limited to the shutdown components.

1. Low Voltage Trip

Four low voltage trip devices were qualification tested through 10 thermal cycles each, shock and vibration, radiation, and 90 days each of thermal-vacuum endurance. This testing accomplished the equivalent of four complete missions without a failure. In addition, two devices on each vehicle were tested as part of the system tests, FSEM-2A, FSEM-3, FSM-4, and FS-3. Throughout all the testing, the low voltage trip device demonstrated it would function properly for the 90 day mission. The probability of these two devices either prematurely operating, or failing to operate as required is estimated to be .995 for one-year mission.

2. Delay Timer

Two reflector ejection delay timers were component-qualification tested for an equivalent of 2 normal 90-day missions. At voltages below 22 volts, the speed control did not function but this was below the system operating limits. With the voltage at 28 VDC, the timer successfully completed 2,000 timing cycles. The high test cycle performance, when compared with the flight requirements of six one-minute cycles and only a single one-hour cycle, demonstrated a high level of expected success. During radiation testing, one timer failed as a result of the type of drive lubrication used. The lubrication method was revised and no further failures were recorded. The joint probability of false actuation or failure to time out and switch is estimated to be .006 per year under the expected duty cycle distribution.

3. Electrical Band Release

Thermal-vacuum, 90-day endurance testing was completed on four EABRD's. At the end of 90 days, each device was energized and the fusible link parted. During development testing, two units were radiation tested without any detrimental effects. Five EABRD's were subject to shock and vibration testing. On one unit the heater resistance decreased greater than the allowed 10%. This EABRD was separately endurance tested for seven days and then fired successfully. The remaining 4 units completed the qualification tests. Evaluation of all development and system testing leads to the conclusion that .998 represents the EABRD reliability for 1 year.

4. Temperature Band Release

Two TABRD's successfully completed all phases of their qualification testing. Both units were subjected to shock and vibration, 10 thermal cycles each, and endurance testing for one thousand hours each. No failures were recorded during the tests. Additional stud tests demonstrated a sufficient margin of strength to preclude premature operation or failure of the component. The estimated TABRD reliability is .998 for missions of 1 year. The reflector retaining band is considered to be a part of the reflector assembly.

XI. CONCLUSIONS

The technical success of the SNAP 10A Flight Systems, as exemplified by the FS-3 and FS-4 nuclear operations, was due in large part to the component qualification testing program. Even though only a small number of each final component type was tested, the information generated was significant. Numerous design modifications were adopted after failure of components during pre-qualification tests, and system operating points were predictable with excellent accuracy.

Differences between the component designs as qualified and reported here, and those employed on the Flight Systems, were trivial and almost non-existent. Because there were numerous differences between development hardware and flight designs, an adequate engineering data reporting system was required to insure proper corrective action. Notable pre-qualification tests of components which required re-designing, were conducted on the following critical items:

1. NaK pump
2. Thermoelectric modules, Type I thru IV
3. Expansion compensator
4. Reflector ejection timer
5. Two pole, double throw relays
6. Electrically actuated band release devices
7. Converter current shunts
8. Temperature switches, electro-mechanical

Many custom designed components were successfully qualified for flight suitability under the SNAP 10A program. In addition to the entire structural and piping systems the following unique components, of Atomics International design, were qualified for use in space power plants:

1. Pin-pullers
2. Temperature actuated band releases
3. Reflector and drum-drive assemblies
4. Drum drive stepping actuators
5. Radiation shield
6. Ejectable heat shield
7. Fuel rods
8. NaK pump
9. Expansion compensator for NaK
10. Thermoelectric converter
11. Startup controller

It was not possible to conduct ground testing under exact conditions of space vacuum, non-gravity, meteoroids, magnetism and radiations. Nevertheless, sufficient calculations and design allowances were made so that no new environmental interaction was observed during the single FS-4 orbital demonstration test. No modifications are required of qualified components as a result of any testing conducted since the FS-4 launch date, although some minor system improvements can be made as a result of experience and analysis obtained in the interim.

Measurements of component and system reliability have been determined with notable accuracy from a rather small number of component and system tests. The performance during test was nearly perfect for all final flight-designed items even though the apriori confidence of meeting the February, 1962 reliability goals did not exceed 50%. It is concluded that a balanced component/system development program can be efficiently conducted with a slight degree of over-testing. A reliability stress analysis of the design margins and test data as detailed in Reference 1, when combined with an extensive system configuration study per Reference 5, can result in quantitifying the system reliability (as in Table II) adequately for purposes of project management.

Considering the total experience obtained during the SNAP 10A program, and the prior state-of-art knowledge existing for many components, the inherent reliability of the power plant design has grown to a value of nearly 90% for near-earth missions of one year duration. Even if the mission were to include meteoroid showers, elaborate data requirements, and mandatory shut down at the end of useful life, the annual reliability forecast would probably be greater than 84% unless degradation slightly below 500 watts is not allowable under any payload conditions.

By utilizing this report, designers of space systems can locate detailed component test data and evaluate the suitability of SNAP 10A qualified components for other programs.

XII. REFERENCES

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13. NAA-SR-11430, "Preliminary SNAPSHOT-1 Performance Summary", Aug. 1, 1965

14. NAA-SR-10508, "Electrical Checkout of 10FS-4 in Bldg. 013", Aug. 29, 1964

15. NAA-SR-10675, "Test Report - Acceptance SNAP 10A FS-4 Electrical Functional Test Pre-Test", Dec. 21, 1964

NOTE: Additional references to component qualification testing will be found in Appendix II, along with drawing and specification references identifying flight components.

APPENDIX I

SYSTEM TEST DESCRIPTION

I. FSM-1 QUALIFICATION TEST

The FSM-1 (Flight System Mockup-1) was the first full-scale, non-nuclear, vehicle subjected to qualification performance tests. The sequence of operations performed on FSM-1 are summarized in the following list.

1. Pre-operation checkout
2. Shock and vibration acceptance test
3. Shock and vibration qualification test
4. NaK loading
5. Thermal and simulated nuclear checkout
6. Pre-startup orbital test
7. Simulated nuclear startup test
8. Full power operation for 90 days

The pre-operational checkout was a test phase, performed at ambient environment conditions, to verify the electrical integrity of the vehicle following final assembly. Subsystem operation was checked by sending commands and thereby simulating phases of the flight. Verification of successful operation was monitored through special test points and by visual inspection.

The FSM-1 underwent shock and vibration testing at acceptance and qualification levels. Several discrepancies were noted and corrected prior to the qualification run. The most common faults occurred in wire bundling and routing where lengths of wire became frayed. Loose nuts vibrated off, fragile lead wires broke, connectors loosened, and micro-switches were cracked. All of these discrepancies were corrected by redesign for the flight system.

NaK loading consisted of forced circulation of NaK through the NPU to monitor tube plugging and coolant cleanliness. A heater in the NaK cart raised the circulating coolant remperature to 600°F while observations were maintained on the outlet temperatures of each of the 40 converter tubes. A plugging indicator in the NaK cart was periodically tested to ensure the NaK cleanliness. Following the 600°F continuous circulation, the NaK was drained and the addition of a new clean charge completed the NaK loading operation.

A thermal reference test was run for 72 hours with the temperature above 800°F for 24 hours. Data from this test established the performance of the thermoelectric converter as predicted from early component/module testing. Several trouble areas became apparent and repairs were completed prior to the 90-day full power test. A redesign of the fin thermocouples wea initiated and an improved method of gold foil wrapping was employed.

The pre-startup orbital test verified the effectiveness of the ejectable heat shield during orbit conditions of either constant sun-constant shade or sun-shade transients. Simulation of solar flux was provided by banks of radiant heaters. The test results showed that the system thermal response is not significantly affected by flow rate. The time for the system to reach thermal equilibrium is dependent on the neutron shield which represents about 2/3 of the system total heat capability.

During the simulated nuclear startup test, the NPU was subjected to the maximum thermal transient. From an initial core outlet of 130°F, the temperature was increased to 400°F in 30 minutes. In four hours the outlet temperature had reached 980°F and then stabilized at 1,000°F. As part of the startup qualification, the following actions occurred:

1. The reactor coarse and fine control drum locking pins were released by squib actuation.
2. The startup controller was energized.
3. The heat shield ejection circuits were enabled. (The heat shield itself was not installed.)
4. The coarse control drums were sprung to the full in position.
5. Stepping of the fine control drums was initiated by the controller.

Date collected during this test phase agreed well with the predicted startup transient. Corrections were made for the flight system calculations based on the measured values of the FSM-1 thermal response.

Results of the 90-day full power test provided degradation rates for the thermoelectric converter and the electromagnetic pump. This test phase also helped to qualify the structural, electrical, and piping subsystems for the thermal-vacuum endurance portion of the flight mission. A complete report of the FSM-1 system testing can be found in Reference 6.

II. FSEM-2A DEVELOPMENT TESTS

The FSEM-2A (Flight System Electrical Mockup-2A) was used to verify that the electrical power, instrumentation, and control systems will perform satisfactorily during the flight system test phases. The test program objective was to demonstrate the ability of the entire flight electrical assembly to survive acceptance tests, ground checkout, and ground handling.

Assembly of the FSEM-2A vehicle consisted of the following parts:

1. PSM-1A titanium shell
2. Reactor core mass mockup
3. Reflector assembly mockup with flight wiring harness
4. T/E pump from qualification test
5. Reactor outlet piping to support legs
6. Six converter legs
7. Radiation shield mockup
8. Expansion compensators with instrumentation
9. Ejectable heat shield connectors and bracketry

The testing convered a period of nine months. During this time the following 15 separate test pahses were completed.

1. Final assembly checkout - assembly and wiring verification checks
2. FSEM-2A/TSM-2 mating test - vehicle and test set compatibility established.
3. Reference tests - nine interspersed tests conducted to verify vehicle status between test phases
4. Life test - demonstrated ten consecutive launch and orbital sequences
5. Nose cone fit-up - verified envelope clearances with Agena nose cone
6. EMI tests - determined the conducted and radiated electromagnetic characteristics of subsystems
7. Electrical system modifications - updated modifications during test program
8. Handling and shipping - verified procedures for handling and shipping
9. Thermal vacuum tests - demonstrated operability at temperatures of 1,000°F at core outlet, 500°F at drum motors, and 120°F at the instrument compartment under a vacuum of 1 micron

10. TSM-1 checkout - established checkout procedures and operational capability between the test set and the vehicle
11. CZ isolation inductor test - verified isolation capability of the converter choke when measuring converter internal impedance
12. EABRD firing test - demonstrated operation of the electrically actuated band release device for reflector ejection
13. TSM-2A checkout - final verification of procedures and test set operation for use on the flight systems
14. Simulated squib firings - exercised squib firing relays and verified performance of squib circuits
15. VAFB launch pad checkout - established electrical checkout and handling procedures for flight launch operations.

Discrepancies which occurred during these test phases were of a minor nature. The primary gains from the test series were (1) a high level of training in checkout and handling procedures, and (2) demonstrated confidence in the ability of a flight vehicle to survive all pre-launch environments. References 7 and 8 contain a complete summary of the FSEM-2A development testing.

III. FSEM-3 INTEGRATED SYSTEM TESTS

A series of ingegrated system tests was performed with the FSEM-3 (Flight System Electrical Mockup-3) mated to the Agena FMU (Functional Mockup). The purposes of the tests were to (1) establish confidence in the electrical system operation through repetitive programming of simulated flight sequences, and (2) verification of compatability between the payloads and SNAP subsystems electrical performance during all pahses of the mission. All testing consisted of electrical functions with both vehicles at ambient environment conditions.

Each test was performed in five phases. These were (1) vehicle preconditioning, (2) simulated NPU startup sequence, recorded by Agena, (3) orbital sequence from completion of ascent through reflector ejection, (4) stimulation of thermocouples and resistance temperature sensors, and (5) a shutdown procedure.

A total of four complete test runs was successfully completed. The only malfunctions associated with the NPU were with non-critical diagnostic instrumentation. These instrument failures were (1) the gamma detector reading 20 millivolts, (2) low level neutron detector reading above full scale with no stimulation, (3) accelerometer cable open circuited, and (4) one thermocouple shorted to the sheath.

The startup controller cycled erratically during the low voltage tests, but this was for only 9 periods out of a total of 234.

In summary, the FSEM-3/FMU integrated system tests successfully demonstrated the combined systems compatibility and performance repeatability for all phases of the flight mission. See References 9 and 10 for additional data.

IV. FSM-4 NON-NUCLEAR QUALIFICATION TEST

The FSM-4 vehicle was the first flight configuration system to be qualification tested in the factory-through-flight series of environments. Major differences between this system and the earlier FSM-1 were in the thermo-electric converter, NaK pump, expansion compensators, and instrumentation. Wherever possible, FSM-4 components were the same generation as the flight system, except that a non-nuclear electric heated core was used.

In order to demonstrate the flight qualification, the following test objectives were implemented.

1. Shock and vibration testing of a NaK loaded system
2. Simulated, pre-startup orbital operation
3. Simulated orbital startup sequence with a progarmmed thermal transient
4. Thermal-vacuum endurance testing.

Since each of the above objectives consisted of various phases, a brief description of these tests, as they were conducted, follows.

Following final assembly of FSM-4, an electrical reference test was performed to validate the electrical integrity and operation of the subsystems. Loop and lead resistance checks made at this time were used as a reference for comparing data taken later in the test program.

With the system installed in a vacuum chamber at 10^{-4} mm Hg, the NaK loading was initiated. The NaK cart provided a forced flow of 3,100 lb/hr at 600°F for continuous circulation. A plugging indicator was used for monitoring NaK cleanliness. One component excepted from this test was the expansion compensator which had been removed due to an earlier system failure. A redesigned flight compensator was later installed.

The thermal reference test was performed to verify component operation at specific temperature levels up to 1,000°F. Chamber pressure was maintained at 10^{-3} torr during the 5-day test. During this time the controller and drum motors were exercised, temperature sensors were calibrated, temperature switch set-points checked, and the temperature-actuated band release device (TABRD) set. One major difficulty was experienced in that the converter isolation resistance decreased to 37 ohms. As a result of this degradation, a thorough investigation of component outgassing was conducted and it was hypothesised that degradation was due to oil back-streaming. Oxygen was added to the system and modifications to the vacuum system were made to minimize diffusion pump oil back-streaming. These actions raised the resistance to an acceptable level.

A simulated pre-startup orbital test was conducted with full size liquid nitrogen cryogenic panels maintaining a sink temperature of 160°F. Thermal profiles were programmed for constant sun, constant shade, and sun shade transients over a period of 36 hours at a vacuum of 10^{-2} torr. This test effectively qualified the system for the flight orbital period preceding the startup command.

Following the above test, flight-type expansion compensators were installed. The system was reloaded with clean NaK and an additional thermal reference test, including a transient startup, completed. The thermal reference test was run at thermal plateaus up to 1,000°F over a time of 48 hours. Periodically, oxygen was bled into the chamber to oxidize the oil film deposits in order to decrease converter current leakage.

The system, fully loaded with NaK, was next tested to acceptance levels of shock and vibration. These acceptance levels, as well as the qualification levels, are listed in Table V. Both tests were run within ±10% of the specified values. After qualification vibration testing, the vehicles was reinstalled in the vacuum chamber for additional thermal testing.

A thermal-vacuum, 90-day, endurance run was initiated with a simulated orbital startup sequence. The chamber was evacuated to 10^{-4} torr and commands sent to duplicate flight operations. Live squibs were fired to release the expansion compensators and control drums. The controller was started and the drums stepped in 42°. At this time the thermal startup simulator was energized to program a 3°F/minute transient. After the reactor outlet temperature reached 1,010°F, the system was stabilized for 72 hours, during which converter isolation resistance checks were made. Following the 72 hours, the controller was turned off and the outlet temperature was adjusted to 920°F for the endurance run.

TABLE V

VIBRATION ACCEPTANCE TEST LEVELS

Axis	Frequency Band cps	Input Level
X	5 - 8	3/8" DA
	8 - 400	1.5 G
	400 - 2000	5 G
Y & Z	6 - 8	3/8" DA
	8 - 250	1.0 G
	250 - 400	3.0 G
	400 - 2000	5.0 G

VIBRATION QUALIFICATION TEST LEVELS

Axis	Frequency Band cps	Input Level
X	6 - 9	1/2" DA
	9 - 400	2.3 G
	400 - 2000	7.5 G
Y & Z	5 - 8	1/2" DA
	8 - 250	1.7 G
	250 - 400	4.5 G
	300 - 2000	7.5 G

SHOCK QUALIFICATION TEST LEVELS, HALF-SINE

Axis	Input G	Duration	No. Req'd
X	+8	6 ms	2
	-2.5	6 ms	2
Y & Z	+5	6 ms	2
	-5	6 ms	2

The endurance phase was continued successfully for 32 days at which time a NaK leak was discovered in the upper reactor area. The system was cooled and an extensive investigation made to locate the exact leakage point. Since the leak initially could not be located, the system was taken back up to 920°F and further observations made. After an additional 23 days at temperature, the NaK leak became excessive and the system was permanently shut down. A post-test disassembly revealed the leak to be a crack in the heater-to-head weld. This weld was in the electric heater core and, therefore, did not affect any flight system design.

During the entire testing period FSM-4 was continually modified to make the vehicle identical to the flight system configuration. As a result of these modifications and the successful completion of the various tests, the flight system was qualified for all non-nuclear phases of the flight mission. Refer to Reference 11 for a more detailed description of test results.

V. FS-3 NUCLEAR QUALIFICATION TEST

The FS-3 (Flight System-3) nuclear power unit was the only vehicle to complete the entire flight qualification test program. The extensive and unique character of the full power nuclear endurance test demonstrated fully the ability of the flight system to operate successfully at the design criteria.

FS-3 conformed specifically to the flight configuration since it was the vehicle originally intended for the first flight. Due to the failure of an earlier system (FS-1), FS-3 was scheduled for nuclear qualification tests. The only modifications made were to the reflector assembly in order to meet the safety requirements of a nuclear ground test, and the use of an external controller.

The test program, designed to meet the flight requirements, consisted of the following phases.

1. Shock and vibration testing at acceptance and qualifications levels
2. Fuel loading and dry critical tests
3. NaK loading
4. Thermal acceptance
5. Full power operation with automatic startup and including power endurance.

A brief description of these test phases continues.

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The FS-3 vehicle was subjected to acceptance levels of vibration following the post-assembly electrical and physical inspection. Dummy fuel elements were substituted and cyclohexane was used in place of the NaK coolant. Following this test, the vehicle was helium leak checked and reinspected physically and electrically. Next, the qualification shock and vibration levels were completed and the vehicle inspected again. Although the qualification levels were 50% higher than the acceptance levels, both tests were completed within the specified limits. A summary of system response is presented in Table VI.

TABLE VI

	Acceptance Level Vibration			Qualification Level Vibration		
	X Axis	Y Axis	Z Axis	X Axis	Y Axis	Z Axis
First Mode Frequency (cps)	58	15	14	59	14.5	14.5
Input, G, at First Mode	0.18	0.2	0.19	0.65	0.32	0.24
Output, G, at Reactor Top	3.0	3.0	2.8	4.1	4.6	4.0
Transmissibility Ratio	16.3	15.0	15.0	6.0	14.5	16.5

Fuel loading and dry critical testing consisted of loading the core with 37 fuel-moderator elements and calibrating the two fine control drums. The loading was accomplished in 5 steps with an "approach to criticality" performed after each step. Values were determined for excess reactivity of the 37 element core, and for the reactivity of each control drum versus its rotation position. NaK was then loaded, circulated, and checked for purity.

A non-nuclear thermal acceptance test was conducted using ground test heaters to reach a NaK temperature of 870°F. Performance of the thermoelectric converter and NaK pump was verified.

Converter isolation resistance decreased as was experienced throughout other system tests. This effect was minimized later in the test by bleeding oxygen into the chamber at operating system temperatures.

Nuclear acceptance testing provided data on "wet" criticality and, by comparison with "dry" criticality, a value of NaK worth was obtained. A temperature of 600°F was maintained for 4 hours, during which pump and converter performances were analyzed and reactivity measurements were taken.

The automatic startup test consisted of a programmed reactivity insertion rate every 300 seconds which is twice the normal period. This experiment confirmed the analog study and established confidence in a normal startup at the 150 second rate. The peak outlet temperature reached was 215°F with a peak NaK flow of 0.3 lb/sec.

The full-rate (150 sec.) startup was initiated by the controller and the transient closely followed the predicted results. Peak outlet temperature was 295°F and peak NaK flow rate was 0.51 lb/sec. During the rise to full power, the temperature increased at a maximum rate of 7.3°F/min with the cut-off at an outlet temperature of 1,054°F.

During the 72-hour stabilization period, 15 drum steps were automatically inserted by the control system. The controller was then turned off and the system continued on passive control, governed by the nuclear characteristics. At controller deactivation, reactor power was 41 KW, NaK flow was 14.3 gpm, and converter electric power was 515 watts.

Performance during the 90-day qualification run was within the uncertainty band predicted for the FS-3. The average reactor temperature at the end of 90 days was 923°F, and the converter electric output was 415 watts.

Eighty-two days after first achieving full power, both expansion compensator positions indicated a compression of the bellows. The decrease in volume corresponds to that resulting from a NaK leak from the primary bellows into the secondary containment can. The system remained void free and containment integrity was maintained for the 10,000 hour endurance run.

Diagnostic instrumentation performed satisfactorily during the 90-day test. Of the 120 total channels, 57 were still functioning properly, 19 were reading off scale, 34 not programmed for readout at the time, and 10 had failed.

A scheduled shut down was initiated at the end of the 10,000 hour endurance run. Prior to this, at 9,355 hours, the control drums were stepped in for the first time since startup. This additional exercise, after a year's endurance, demonstrated the high capability of the drum drive bearings and gears and the stepper motors. At the end of 9,355 hours, the reactor outlet temperature was 971.5°F, the flow rate was 12.1 gpm, and the converter electric output was 376.5 watts.

Just before shut down at 10,000 hours, the reactor outlet was 1,054°F, flow rate was 12.6 gpm, and electric output 479 watts.

Based on the very successful completion of all the FS-3 qualification tests, the SNAP 10A system was qualified for space-nuclear operation for 10,000 hours. A final report of this testing is in preparation. Reference 12 pertains to early test results from the highly significant FS-3 test program.

VI. FS-4 FLIGHT TEST

The SNAP 10A flight test demonstration with the FS-4 vehicle culminated the efforts of designing, developing, and qualifying a nuclear reactor power system for space applications. All testing performed prior to launch provided a high demonstrated level of readiness. A companion flight system, FS-5, is available for space missions and could be expected to perform satisfactorily with a high degree of confidence.

Phases of the flight, from ascent through the endurance run, are described below. Measured flight data is compared with the levels performed during the ground test program.

During the launch and ascent phase, the structural loads were within the levels specified during acceptance and qualification tests. The following table summarizes this data. (Note: The low frequency loads were near the acceptance test levels.)

Test Data	Bending Moment (in/lb)	Shear (lb)	Remarks
Flight	171,000	1940	9.0 cps Elastic Mode
Acceptance	165,000	1950	11.0 cps Vibration Test
Qualification	239,000	2238	Static Ultimate

The first and second bending modes of the booster vehicle were excited to 50% higher than expected during liftoff. However, this did not adversely affect the FS-4 G load. A sound pressure of 137 db was recorded versus a design level of 144 db. The maximum rigid-body longitudinal acceleration was 6.6 G at booster cutoff and the lateral acceleration throughout ascent was near zero. These two levels are compared with design points of 7.5 G longitudinal and 1.0 G lateral.

In general, the flight loads were near the maximum anticipated, as demonstrated by the acceptance test levels. The qualification ultimate static loads were higher than both the flight and acceptance test levels.

During the orbital pre-startup period, FS-4 successfully met all of the environmental limits. The comparative data is shown in the following table.

Variable	Design Point	Flight Data
NaK Temp	50°F Min.	85°F Min.
Heat Shield Temp.	375°F Max.	260°F Max.
NaK Flow	0.26 gpm Min.	1.2 gpm

Orbital startup and active control covered a period of 148 hours from initiation of the startup command to turning the controller off. Prior to the startup command the vehicle was in a nominal status, and both expansion compensators released by actuation of the squib energized pin-pullers. Upon startup command, eight squibs were energized to pull four pins and to release the control drums. The spring-loaded coarse control drums went to the full-in position, and the two fine control drums were stepped in by the controller. Times to criticality, sensible heat, and full power were in excellent agreement with expected performance. Thermal response and nuclear performance indicated there were no anomalies resulting from space operation.

The controller was kept active during the stabilization period of 140 hours to automatically adjust the temperature to compensate for short term reactivity effects. Just prior to deactivation of the controller, temperature override was exercised and two additional steps inserted as a power triming operation. Following these two steps, the controller was shut off and the reactor followed the (FS-3) predicted curve for long term operation. A total of 121 diagnostic instruments were available for telemetry readout of system performance. Of these, 118 provided meaningful data throughout the flight.

After 43 days of successful, continuous operation, the FS-4 system was prematurely shut down. The accepted postulation is that shutdown occurred as a result of spurious commands initiated by a voltage malfunction associated with the launch vehicle voltage regulator. Although the premature shut down defeated the 90-day endurance test, valuable data was received on the shut down components.

Telemetry data received after the failure showed that the following actions had occurred.

1. Electrically actuated band release device had been energized

2. Reflector retaining band was separated and reflectors were ejected

3. Startup controller was pulsing, and fine control drums were full in

4. Diagnostic instrumentation, on 5V telemetry, indicated the expansion compensators were collapsed, converter output voltage was zero, and one of the series-connected, low voltage sensors was closed. The low temperature malfunction switch (785°F) was closed and event markers showed the malfunction circuits enabled and the malfunction bus energized.

This data demonstrated the operability of the startup and shutdown components after 43 days in a space nuclear environment.

The preliminary performance report of the first nuclear power plant in orbit is Reference 13. Other data and test procedures with respect to the flight designed SNAP 10 vehicles will be found in References 14, and 15. The final SNAPSHOT performance report will be published as NAA-SR-11934.

APPENDIX II QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Ejectable Heat Shield

Specification No. NE10FS1-14-001 C **Rev.**

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: (FSM-1), FSEM-2A, FSEM-3, (FS-1, FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NR 7561-19

Reports which document test results: NAA-SR-TDR 9797
NAA-SR-10997

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
6	0	4	0	hr cy		N/A		1 (a)	0
1		1 or 2		8 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. FSM-4

b.

c.

Note results and load levels of any special testing needed to qualify:

1. Heat flux from sun side to shade side

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1.

2.

Weakness remaining in final design; recommended design changes:

1. FSM-4 tests indicate significant temp. difference develops across shield under simulated space conditions. 2. Shield parting plane should be rotated 90° to prevent impact.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Primary Structure

Specification No. ______ **Rev.** ______

Drawing No. & Latest Change Letter 10FSM1-00-001

Previous drawing, spec. or change if noted in table below: ______

Circle SNAP 10A Systems which incorporated this component: (FSM-1, FSEM-2A, FSEM-3, FS-1, FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: ______

Reports which document test results: NAA-SR-Memo 10610 and system test report

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
		2 (b)	0	(b) 3200 hr / cy	0			4 (a)	0
		2		2 -				4	
		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. PSM1A & 1B, FSM-1, FSM-4 Qualified

b. FSM-1 & FSM-4 Qualified

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1.

2.

Weakness remaining in final design; recommended design changes:

1. Seal upper corrugations to prevent the venting of outgassed hydrocarbons onto converter couples

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Fuel Elements

Specification No. NE10FS1-18-001 Rev.

Drawing No. & Latest Change Letter 7580-18020

Previous drawing. spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, FSEM-2A, FSEM-3, (FS-1) FSM-4, (FS-3, FS-4) FS-5.

Qualification Test Procedure Documentation: NA-0422-008 (Type 2) NA 0421-001 NA-0422-005 (Env)

Reports which document test results: NAA-SR-Memo's 9496, 10502, 10234 NAA-SR-11547, NAA-SR-10858

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
		198 189	0 0	578,160 hr 259,200 cy	0			66 45	0 0
		193						111	
		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Submerged in water during S & V.

b.

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. Environmental tests of 120 el. 26 @ 200%, 19 @ 100% (of ref. levels)

2.

Weakness remaining in final design; recommended design changes:

1.

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Reflector Assembly

Specification No. ______ Rev. ______

Drawing No. & Latest Change Letter 10FS-11001 "B"

Previous drawing, spec. or change if noted in table below: ______

Circle SNAP 10A Systems which incorporated this component: (FSM-1, FSEM-2A), FSEM-3, (FS-1, FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA-0422-002

Reports which document test results: TDR 8521, 8872, 9674, 10234

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
		1	0	2,160 hr 2 cy	0			1	0
		10		1	1			1	
		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a.

b.

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1.

2.

Weakness remaining in final design; recommended design changes:

1.

2.

QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Shield Assembly

Specification No. NS 7580-13-001 Rev.

Drawing No. & Latest Change Letter 10FSM1-13015 "F"

Previous drawing, spec. or change if noted in table below: 10FSM1-13024(FS-3) (1)

Circle SNAP 10A Systems which incorporated this component: (FSM-1), FSEM-2A, FSEM-3, FS-1, (FSM-4), (FS-3) (1), (FS-4, FS-5)

Qualification Test Procedure Documentation: NA-0401-004

Reports which document test results: NAA-SR-Memo 10234, TDR 8870

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
		2(a)	0	2,330 hr / 0 cy	0	(b) 1	0	2 (a)	0
		2		1		1		2	
		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. DRM1 & FSM1

b. FS-3 (1)

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1.

2.

Weakness remaining in final design; recommended design changes:

1.

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Thermoelectric NaK Pump

Specification No. 10FS-81001 Rev. D

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: (FSM-1) FSEM-2A, FSEM-3, (FS-1, FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NA-0404-009

Reports which document test results: NAA-SR-Memo 11841

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
9	0	6	0	84,625 hr / cy	0	1 (a)	0	9	0
9		30		39				9	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. FS-3

b.

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. Two pumps included above exposed to accel. tests at 1100°F NaK.

2.

Weakness remaining in final design; recommended design changes:

1.

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Primary Battery

Specification No. NE10FSM1-24-008 **Rev.** B

Drawing No. & Latest Change Letter 10FS-22029

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, FSEM-2A, FSEM-3, FS-1, FSM-4, (FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NA 0403-036

Reports which document test results: NAA-SR-TDR 11156, DR 2726

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
11	0			4,320 (a) hr / cy	0	1	0	3	0
11				4		1		3	
1		1 or 2		1,000 AMP-HR	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Ampere-hours at ambient temp.

b.

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1.

2.

Weakness remaining in final design; recommended design changes:

1.

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Expansion Compensator Assembly

Specification No. 7561-34016 Rev.

Drawing No. & Latest Change Letter 7561-22003A

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, FSEM-2A, FSEM-3, FS-1, (FSM-4), (FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA 0408-011

Reports which document test results: IL, 781-13-48 Stone to Morgan 12-21-65
NAA-SR-TDR-11888, 11865, 11045, 10635, 10282

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
		40		34,327 hr / cy	0	2 (a)	0	4	0
		20		16		2		4	
		1 or(2)		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. FS-3

b.

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. 120 cu. in. on S/N 020

2.

Weakness remaining in final design; recommended design changes:

1.

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Piping, NaK

Specification No. NE10FSM4-00-001 Rev.

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: (FSM-1), FSEM-2A, FSEM-3, (FS-1, FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation:

Reports which document test results:

ENTER BELOW THE NUMBER OF COMPONENTS (or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
N/A		3 (a)	0	3,600 (a) hr / cy	0	N/A		3 (a)	0
		3		1					
		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. FSM1, FSM4 & FS-1 systems tests.

b.

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1.

2.

Weakness remaining in final design; recommended design changes:

1.

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name T/E Modules (Type V)

Specification No. 10FSM1-51022 Rev.

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, FSEM-2A, FSEM-3, FS-1, (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA 0412-002

Reports which document test results: NAA-SR-TDR 9153

Project Monthly Performance Summary

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
94	0	47	0	307,838 hr / cy	(a) 10 (b)	(c) 120	0	44	0
94		470		142		120		44	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Six failures occurred after city power loss.

b. Three failures on VP Mods, seven on VF Mods.

c. FS-3

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. Ten modules tested at 110% of design temp.

2.

Weakness remaining in final design; recommended design changes:

1. None

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Converter Current Shunt

Specification No. ______ Rev. ______

Drawing No. & Latest Change Letter 10FS-24011 "D"

Previous drawing, spec. or change if noted in table below: ______

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), (FSEM-3), (FS-1), (FSM-4), (FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: None

Reports which document test results: NAA-SR-TDR-8749

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
3	0	3	0	6,480 hr / cy	0	1(a)	0	3	0
3		30		3		1		3	
1		1 or 2		2160 hr	1 cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. FS-3

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None

2.

Weakness remaining in final design; recommended design changes:

1. None

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Reactor Startup Controller

Specification No. NE10FSM1-20-004 **Rev.** 2

Drawing No. & Latest Change Letter ____

Previous drawing, spec. or change if noted in table below: ____

Circle SNAP 10A Systems which incorporated this component: (FSM-1, FSEM-2A, FSEM-3, FS-1, FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NA-0403-018

Reports which document test results: NAA-SR-Memo-10240; NAA-SR-8639; NAA-SR-Memo-9084; NAA-SR-Memo-9120; NAA-SR-TDR-9001; NAA-SR-0412; DR's 598, 753, 557, 556, 754; Bendox TDT's 7224, 7196

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
3	0	3	0 (a)	4,320 hr 1200 cy	0 (a)	1	0	3	0
3		30		2	5	1.0		3.0	
1		1 or 2		2160 hr	270 cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Susceptibility to transient noise pulses. One additional unit successfully completed a 30-day endurance test.

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None
2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. Following a 90-day endurance run one controller was cycled to failure during a thermal endurance test. Total cycles were 42,960 or 160 times design life.

Weakness remaining in final design; recommended design changes:

1. Controller meets all requirements when adequate noise suppression devices are installed.
2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Stepper Motor Assembly Control Drum Actuator

Specification No. ______ Rev. ______

Drawing No. & Latest Change Letter 10FSM1-11061 "C"

Previous drawing, spec. or change if noted in table below: ______

Circle SNAP 10A Systems which incorporated this component: (FSM-1, FSEM-2A, FSEM-3, FS-1, FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA-0404-006

Reports which document test results: NAA-SR-9320; DR's 553, 554, 549, 550, 1400, 1401, 1402, 1414, and 1430 (NAA-SR-10750, NAA-SR-Memo-10252, NAA-SR-Memo-10717, NAA-SR-Memo-10382

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
6	0	6	0	11,125 hr / 3750 cy	1 (a)	2	0	6	0
6		60		5	14	2		6.0	
1		1 or 2		2160 hr	270 cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. A crushed bobbin had been installed, prior to encapsulation, which resulted in a short circuit in the brake winding.

b.

c.

Note results and load levels of any special testing needed to qualify:

1. Additional high vacuum-thermal testing for endurance.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. Special tests performed on two motors at accelerated stepping cycles and high current. This was followed by a regular 90 day endurance test. (NAA-SR-Memo-10382)

Weakness remaining in final design; recommended design changes:

1. None

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Reactor Temperature Control Sensors

Specification No. NE10FS1-24-008 Rev. C

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), FSEM-3, (FS-1), (FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NA-0403-028

Reports which document test results: DR's 1451, 1452, 1453, 1454 NAA-SR-10966; NAA-SR-Memo-10597; NAA-SR-11318

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
2	0	2	0	4,320 hr / cy	0	2	1(a)	2	0
		20		2		1.0		2	
		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Considered "no test" due to broken fixture.

b.

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1.

2.

Weakness remaining in final design; recommended design changes:

1.

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Reactor Temperature Control Switch

Specification No. NE10FS1-24-009 Rev. B

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, FSEM-2A, FSEM-3, (FS-1, FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA-0403-029

Reports which document test results: NAA-SR-Memo-10597; NAA-SR-Memo-9854; NAA-SR-TDR-9459; NAA-SR-11117; DR's 760, 761, 764, 765, 1455, 1456, 1464, 1465

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
4	0	2	0	4,320 hr / cy	0	2	0	2	0
4		20		2		2.0		2.0	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. None

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None

2.

Weakness remaining in final design; recommended design changes:

1. Output relay coil should not draw power during steady-state operation.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Therm. - Mechanical Temperature Switch

Specification No. NE10FS1-24011 Rev. D

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), FSEM-3, FS-1, (FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NA-0403-029

Reports which document test results: NAA-SR-TDR-9874; NAA-SR-10620; NAA-SR-11154; NAA-SR-10684

ENTER BELOW THE NUMBER OF COMPONENTS (or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
		3	0	4,320 hr cy	0			3	0
		30		2				3	
		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. None

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None

2.

Weakness remaining in final design; recommended design changes:

1. None

2.

QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Relay Box - Main & Auxiliary

Specification No. ______ Rev. ______

Drawing No. & Latest Change Letter 10FS-22002 "D"; 10FS-22017 "C"

Previous drawing, spec. or change if noted in table below: ______

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), (FSEM-3), FS-1, (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA-0403-031

Reports which document test results: NAA-SR-9402; NAA-SR-9144; NAA-SR-9879; NAA-SR-9304; NAA-SR-7963; NAA-SR-8103; NAA-SR-8824; NAA-SR-9133; NAA-SR-9144; NAA-SR-10136; NAA-SR-10286; NAA-SR-10532

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
2	0	2	0	4,320 hr / cy	0	1 (b)	0	2	0
2.0		20		2		1		2.0	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Early developmental testing failures of varnish insulated relays led to use of a non-flaking insulation.

b. FS-3

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. Each of the two types of relays were cycled in excess of 100,000 cycles with no degradation.

2.

Weakness remaining in final design; recommended design changes:

1. None

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Squibs and Pin Pullers

Specification No. NE10FS-24-015 Rev. N/C

Drawing No. & Latest Change Letter 10FSM1-11031 "E"; 10FSM1-34005 "B"; 10FS-86009

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: (FSM-1) (FSEM-2A) FSEM-3, (FS-1) (FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NA-0404-008; NA-0404-015

Reports which document test results: NAA-SR-Memo-8283; NAA-SR-TDR-8335; NAA-SR-Memo-9065; DR's 662, 663, 665, 666; NAA-SR-11336; NAA-SR-10384; NAA-SR-10955; NAA-SR-11312

ENTER BELOW THE NUMBER OF COMPONENTS (or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
50	0	22	0	224 hr 13 cy	0	4	0	22	0
50		220		16		4		22	
1		1 or 2		14 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Number tested includes 8 on DRM-1.

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. Following a ten cycle thermal-vacuum test, 64 squibs were fired for a total of 32 successful actuations.

2.

Weakness remaining in final design; recommended design changes:

1. None

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Ejectable Heat Shield Connectors

Specification No. ______ Rev. ______

Drawing No. & Latest Change Letter 10FSM1-61048 "B"; 10FSM1-20016

Previous drawing, spec. or change if noted in table below: ______

Circle SNAP 10A Systems which incorporated this component: FSM-1, FSEM-2A, FSEM-3, FS-1, (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NE10FSM1-20-016; NA-0403-010

Reports which document test results: NAA-SR-9415; NAA-SR-10176; DR's 644, 988

ENTER BELOW THE NUMBER OF COMPONENTS (or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
4	0	4	0	204 hr / cy	0			2	0
4		40		10				2	
1		1 or 2		20 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. None

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. The connectors also successfully completed all phases of the heat shield qualification test program.

2.

Weakness remaining in final design; recommended design changes:

1. None

2.

QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name High Temperature Wire

Specification No. Supertemp Pyrad 1000 Rev.

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), FSEM-3, (FS-1, FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: Pre-Qualification Testing

Reports which document test results: NAA-SR-TDR-9165; NAA-SR-10385; NAA-SR-9371; NAA-SR-10121; NAA-SR-10972

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
17,000 ft	0(a)	3	0	2,000 hr / cy	0	2	0	4	0
4		20		.93		2.0		4.0	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Acceptance tests

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. Additional test performed at 1200°F and 10^{-5} torr for 1700 hours.

2.

Weakness remaining in final design; recommended design changes:

1. None

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Low Temperature Wire

Specification No. Raychem Novathene Rev.

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), FSEM-3, FS-1, (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation:

Reports which document test results: NAA-SR-10175

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
2(a)	0	2(a)	0	4,990(b) hr / cy	0			2 (a)	0
		2		2					
		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Qualified as part of relay boxes.

b. 4,320 hours as part of relay boxes.

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None

2.

Weakness remaining in final design; recommended design changes:

1. None

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Ball & Shaft Assembly Drum Support

Specification No. ______ Rev. ______

Drawing No. & Latest Change Letter 10FSM1-11039 "C"

Previous drawing, spec. or change if noted in table below: ______

Circle SNAP 10A Systems which incorporated this component: (FSM-1,) FSEM-2A, FSEM-3, FS-1, (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA-0408-008

Reports which document test results: DR's 2114, 2115, 2116, NAA-SR-Memo-10367; 10161

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance (b)		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
		3	0	6,552 hr / cy	0 (a)			3	0
		30		3				3	
		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. 1 set, hi torque after temp lowered, 2 sets after press. increase to atmosphere.
b. Some slight deviations from spec. temp due to power loss.
c.

Note results and load levels of any special testing needed to qualify:

1.
2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. 118 hrs 90% relative humidity; 15 hrs low temperature following endurance test.
2.

Weakness remaining in final design; recommended design changes:

1.
2.

QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Actuator Assembly - Drum Lockout

Specification No. ______ **Rev.** ______

Drawing No. & Latest Change Letter 10FSM1-11031 "E"

Previous drawing, spec. or change if noted in table below: ______

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), FSEM-3, (FS-1, FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NA-0404-008

Reports which document test results: NAA-SR-TDR-8232, 8335, 9065

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
		4	0	192 hr / 4(a) cy	0	2	0	4	0
		40				2		4	
		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Squib-actuated at 250°F & 30°F following 48 hr endurance.

b.

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1.

2.

Weakness remaining in final design; recommended design changes:

1.

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Reflector Ejection Delay Timer

Specification No. NE10FS1-24-012 Rev. "C"

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A, FSEM-3, FS-1, (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA0403-019

Reports which document test results: NAA-SR-TDR-11223; NAA-SR-9246; NAA-SR-TDR-9216; NAA-SR-10506; NAA-SR-10505; NAA-SR-TDR-10779; NAA-SR-9157

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
5	0	2	0	4,320 hr 400 cy	1 (b)	2	1 (a)	2	0
5		20		2	1	2		2	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Timing malfunction was due to method of lubrication and not radiation effects.

b. Motor speed control contact caused a malfunction at low voltage. The unit then completed 2000 cycles successfully at 28 VDC.

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None

2.

Weakness remaining in final design; recommended design changes:

1. Enlarge timing tolerance so chrometric govenor may be deleted.

QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Electrically Actuated Band Release Device

Specification No. ______ Rev. ______

Drawing No. & Latest Change Letter 10FS-11052 N/C

Previous drawing, spec. or change if noted in table below: ______

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), FSEM-3, FS-1, (FSM-4), FS-3, (FS-4, FS-5.)

Qualification Test Procedure Documentation: NA 0404-011 "A"

Reports which document test results: NAA-SR-TDR-11621; NAA-SR-TDR-11360; NAA-SR-TDR-11454; NAA-SR-TDR-11620; NAA-SR-TDR-10954; DR's: 2900; 3104; 3110; 3199; 3973; 3974

ENTER BELOW THE NUMBER OF COMPONENTS (or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
5	0	0	0	8,640 hr / cy	0	2 (a)	0	5	0
5		0		4		2		5	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Radiation testing at qualification levels was successfully completed during component development tests.

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None
2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None
2.

Weakness remaining in final design; recommended design changes:

1. None
2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Temperature Actuated Band Release Device

Specification No. ______ **Rev.** ______

Drawing No. & Latest Change Letter 10FSM1-11133

Previous drawing, spec. or change if noted in table below: ______

Circle SNAP 10A Systems which incorporated this component: FSM-1, FSEM-2A, FSEM-3, FS-1, (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA 0408-009

Reports which document test results: NAA-SR-TDR-10255, 10156

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
2	0	2	0	2,016 hr / cy	0			2	0
2		20		1				2	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a.

b.

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. 25 units destructive-load tested.
2.

Weakness remaining in final design; recommended design changes:

1.

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Low-Voltage Trip Device

Specification No. NE10FS-20-010 Rev.

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A, FSEM-3), FS-1, (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation:

Reports which document test results: NAA-SR-TDR-9743

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
4	0	4	0	9,216 hr / cy	0	4	0	4	0
4		40		4		4		4	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. None

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None
2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None
2.

Weakness remaining in final design; recommended design changes:

1. None
2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Drum Position Transducer

Specification No. NE10FSM1-16-001 Rev. C

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A, FSEM-3), FS-1, (FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NA-0404-007

Reports which document test results: DR's: 527, 555, 1422, 1424, 1429, 1431

ENTER BELOW THE NUMBER OF COMPONENTS (or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
5	0	2	0	4,130 hr 2 cy	0	2	0	1	1 (a)
5		20		2		2		1	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Torque exceeded 4 in-oz but no serious difficulty. Values up to 12 in-oz have not been detrimental.

b.

c.

Note results and load levels of any special testing needed to qualify:

1. Temperature drift curves are requires for accurate position determination.
2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None
2.

Weakness remaining in final design; recommended design changes:

1. None
2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Drum Position Demodulator

Specification No. NE10FS1-24-010 **Rev.** B

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), FSEM-3, FS-1, (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA-0403-023

Reports which document test results: NAA-SR-Memo-9476; NAA-SR-Memo-9581; DR's: 1417, 1421, 1427, 1428, 1432, 1433, 1457; NAA-SR-10499; NAA-SR-TDR-10585

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
4	0	2	0	4,320 hr / cy	0	2	0(a)	2	0
4		20		2		2		2	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Following irradiation, the output decreased greater than the 1% specified.

b.

c.

Note results and load levels of any special testing needed to qualify:

1. Radiation sensitivity curves required for long term operation.
2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None
2.

Weakness remaining in final design; recommended design changes:

1. None
2.

QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Reflector Limit Switches

Specification No. NE10FS1-24-013 Rev. N/C

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, FSEM-2A, FSEM-3, (FS-1), FSM-4, (FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NA-0403-021

Reports which document test results: NAA-SR-Memo-9476; NAA-SR-Memo-9599;

Test Reports D/722-22: 201, 206, 252, 254, 256; Data Reports: 546, 508, 507, 599, 600, 601, 602, 603, 604, 605, 606, 547, 500, 501, 502, 503, 504, 505.

ENTER BELOW THE NUMBER OF COMPONENTS (or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
17	0	8	0	10,800 hr / cy	0	2	0	8	0 (a)
17		80		5		2		8	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. One momentary contact closure during vibration testing.

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None

2.

Weakness remaining in final design; recommended design changes:

1. None

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Converter Impedance Isolation Inductor

Specification No. NE10FS-24-017 **Rev.**

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, FSEM-2A, FSEM-3, FS-1, FSM-4, FS-3, (FS-4, FS-5)

Qualification Test Procedure Documentation: NA-0403-035

Reports which document test results: NAA-SR-TDR-11157

ENTER BELOW THE NUMBER OF COMPONENTS (or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
3	0	2	0	2,052 hr / cy	0	1	0	2	0
3		12		1		1		2	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. None

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None
2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None
2.

Weakness remaining in final design; recommended design changes:

1. None
2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Converter Degradation Measuring Device and Transformer

Specification No. NE10FS-24-013 Rev. B

Drawing No. & Latest Change Letter (10FS-22032)

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A, FSEM-3), FS-1, (FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NA-0403-030

Reports which document test results: NAA-SR-11155; NAA-SR-10381; NAA-SR-9234; NAA-SR-9629

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
10	0			1106 (a) hr / cy	0	1	0	2	0
10				.5		1		2	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Thermal vac. test time = 384 hrs ea.
   Ambient endur. test time = 722 hrs ea.

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None
2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None
2.

Weakness remaining in final design; recommended design changes:

1. None
2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Gamma Flux Radiation Detector

Specification No. NE10FS-24-003 Rev. D

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A, FSEM-3), FS-1, (FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NE10FS-24-003

Reports which document test results: NAA-SR-Memo-9746

Qualification Test Performed by Vendor (G.E.)

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
3	0			360 hr / cy	0	1	0	1	0
3				.17		1		1	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. None

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None

2.

Weakness remaining in final design; recommended design changes:

1. None

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name: Amplifier, Signal Conditioning (Gamma)

Specification No. NE10FS-24-006 Rev. E

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A, FSEM-3), FS-1, (FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NE10FS-24-006

Reports which document test results: NAA-SR-Memo-9746

Qualification Test Performed by Vendor (G.E.)

ENTER BELOW THE NUMBER OF COMPONENTS (or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
3	0			360 hr / cy	0	1	0	2	0
3				.17		1		2	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. None

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None

2.

Weakness remaining in final design; recommended design changes:

1. None

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Neutron Flux-Hi Level Detector

Specification No. NE10FS-24-005 Rev. D

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), (FSEM-3), FS-1, (FSM-4, FS-3, FS-4, FS-5).

Qualification Test Procedure Documentation: NE10FS-24-005

Reports which document test results: NAA-SR-TDR-11333 (Calib. only); Vendor Qual. Test data.

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
1	0	1	0	720 hr / cy	0			1	0
		1		.3				1	
		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a.

b.

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1.

2.

Weakness remaining in final design; recommended design changes:

1.

2.

QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Radiation Detector - Power Supply DC/DC (Hi-level Neutron)

Specification No. NE10FS-24-002 Rev. E

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A, FSEM-3), FS-1, (FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NE10FS-24-002

Reports which document test results: NAA-SR-Memo-10037 (Irrad. only) NAA-SR-Memo-9746 (BMI); Vendor Qual. Test data.

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
3	0			360 hr / cy	0	2	(a) 2(b)	1	0
3				.17		2		1	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. No load voltage exceeded the upper spec. limit.

b. Output voltage dropped from 490 to 23 volts during test.

c.

Note results and load levels of any special testing needed to qualify:

1. Irradiation testing, in thermal-vacuum, at 6×10^{12} nvt to 1×10^{14} nvt.
2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None
2.

Weakness remaining in final design; recommended design changes:

1. Radiation induced component damage causes premature failure.
2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Neutron Flux Detector - Low Level

Specification No. NE10FS-24-004 Rev. D

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A, FSEM-3), FS-1, (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NE10FS-24-004

Reports which document test results: NAA-SR-Memo-9746 (BMI); NAA-SR-Memo-10037 (Irrad.); NAA-SR-TDR-11333; NAA-SR-TDR-10264; Vendor Qual. Data

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
3	0			720 hr / cy	0	2	0	1	0
3				.34		2		1	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. None

b.

c.

Note results and load levels of any special testing needed to qualify:

1. Additional endurance testing to 10^{13} nvt with amplifier & power supply

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None

2.

Weakness remaining in final design; recommended design changes:

1. None

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Neutron Flux Detector - Amplifier & Power Supply (Low Level)

Specification No. NE10FS-24-001 **Rev.** F

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), (FSEM-3), FS-1, (FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NE10FS-24-001

Reports which document test results: NAA-SR-Memo-9746; NAA-SR-TDR-11333; NAA-SR-Memo-10037; NAA-SR-TDR-10264; Vendor Qual. Test Data

ENTER BELOW THE NUMBER OF COMPONENTS (or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
3	0			360 hr / cy	0	2	2 (a)	1	0
3				.17		2		1	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. System was not operating properly prior to irradiation. Post test analysis indicated a failure in the signal conditioner.

b.

c.

Note results and load levels of any special testing needed to qualify:

1. Additional endurance testing to integrated flux levels of 10^{13} nvt

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None

2.

Weakness remaining in final design; recommended design changes:

1. Amplifier failures during irradiation indicate that component hardening is required.

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Fast Neutron Integrated Flux Detector

Specification No. ____ Rev. ____

Drawing No. & Latest Change Letter 10FS-24021

Previous drawing, spec. or change if noted in table below: ____

Circle SNAP 10A Systems which incorporated this component: FSM-1, FSEM-2A, FSEM-3, FS-1, FSM-4, (FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation: NA-0405-010

Reports which document test results: NAA-SR-TDR-11152; NAA-SR-9836; NAA-SR-10125; NAA-SR-11161

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
19	0	4	0	6,048 hr / cy	0	6	0	4	0
19		8		2.8		6		4	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. None

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None

2.

Weakness remaining in final design; recommended design changes:

1. Temperature susceptibility requires that each detector be tested over its temp. range.

2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Resistance Temperature Detectors & Bridge

Specification No. NE10FS-24-009 **Rev.** B

Drawing No. & Latest Change Letter 10FS-24001 "B"

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), (FSEM-3), (FS-1), (FSM-4, FS-3, FS-4, FS-5)

Qualification Test Procedure Documentation:

Reports which document test results: NAA-SR-TDR-9768; NAA-SR-10084

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
3	0	3	0	6,480 hr / cy	0	3	0	3	0
3		30		3		3		3	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Brazing damage during installation caused calibration shift. Method of installation changed to insertion into a copper block.

b.

c.

Note results and load levels of any special testing needed to qualify:

1. Additional vibration testing in flight configuration mounting.
2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None
2.

Weakness remaining in final design; recommended design changes:

1. Variable calibration shift after exposure to temperatures over 1200°F.
2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Thermocouple Assembly, Socket-Head Cap Screw Tip

Specification No. NE10FSM1-24-006 **Rev.** D

Drawing No. & Latest Change Letter 10FS-20068 "A"

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, FSEM-2A, FSEM-3, FS-1, (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA-0403-034

Reports which document test results: NAA-SR-10472

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
		3	0	2,160 hr cy	2 (b)	8(c)	0	3	0
		30		1		8		3	
		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. High failure rate during development testing necessitated a redesign.

b. Out of tolerance degrad. in 2 un-sandblasted specimens.

c. FS-3

Note results and load levels of any special testing needed to qualify:

1. Additional endurance testing at 750°F for qualifying insulation resistance.
2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None
2.

Weakness remaining in final design; recommended design changes:

1. Decreasing insulation resistance when endurance tested in thermal vacuum.
2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Thermocouple Assembly

Specification No. NE10FSM1-24-006 **Rev.** D

Drawing No. & Latest Change Letter 10FS-20013 "F"

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), (FSEM-3), (FS-1), (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA-0403-025

Reports which document test results: DR's: 1612, 1019, 1614, 1021

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
		50	0	81,000 hr / cy	2 (b)	25(c)	0	50	0
		50		37		25		50	
		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Qualified as part of FSM-1 & FSM-4 system tests.

b. Two thermocouples failed, by open circuits, during FSM-1 testing.

c. FS-3

Note results and load levels of any special testing needed to qualify:

1. None
2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None
2.

Weakness remaining in final design; recommended design changes:

1. The basic thermocouple design is sufficient for use on all systems but strict quality control is required to prevent damage at installation.
2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Expansion Compensator Limit Switches

Specification No. ______ **Rev.** ______

Drawing No. & Latest Change Letter 10FS-20015 N/C

Previous drawing, spec. or change if noted in table below: ______

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A), FSEM-3, (FS-1), (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA-0403-026

Reports which document test results: NAA-SR-9883

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

	Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
tested / failed	8	0	60	0	38,647 hr; cy	0	2(a)	0	8	0
equiv. # missions	8		30		18		2		8	
90 day mission reqmt.	1		1 or(2)		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. FS-3

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. Qualification testing performed on 4 switches as part of experimental component assembly. Data included above.

2.

Weakness remaining in final design; recommended design changes:

1. None

2.

719-P

QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Converter Voltage Divider

Specification No. ______ **Rev.** ______

Drawing No. & Latest Change Letter 10FS-20011 "C"

Previous drawing, spec. or change if noted in table below: ______

Circle SNAP 10A Systems which incorporated this component: (FSM-1, FSEM-2A, FSEM-3, FS-1, FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA-0403-027

Reports which document test results: ______

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
2	0	2	0	3,240 (a) hr / cy	0	1(b)	0	2(a)	0
		2		1.5		1		2	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Qualified as part of FSM-1 & FSM-4 systems tests.

b. FS-3

c.

Note results and load levels of any special testing needed to qualify:

1. None
2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None
2.

Weakness remaining in final design; recommended design changes:

1. None
2.

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QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Differential Current Transductor

Specification No. NE7561-62-001 Rev.

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, FSEM-2A, FSEM-3, FS-1, FSM-4, FS-3, (FS-4, FS-5.)

Qualification Test Procedure Documentation: ST0403-NA0037

Reports which document test results: NAA-SR-TDR-11153; NAA-SR-11418

ENTER BELOW THE NUMBER OF COMPONENTS(or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
3	0	2	0	2,160 hr / cy	1 (a)	1	0	2	0
3		2		1		1		2	
1		1 or 2		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Component shifted calibration after application of 500 vdc Megger and was replaced for endurance testing.

b.

c.

Note results and load levels of any special testing needed to qualify:

1. None

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. None

2.

Weakness remaining in final design; recommended design changes:

1. Transductor should not be checked for insulation resistance, at 500 vdc, for 25 times as was done during qualification testing.

2.

QUALIFICATION TEST WORKSHEET

Flight System Material or Component

Full Name Expansion Compensator Position Transducer and Demodulator

Specification No. NE10FS-24-008 **Rev.** D

Drawing No. & Latest Change Letter

Previous drawing, spec. or change if noted in table below:

Circle SNAP 10A Systems which incorporated this component: FSM-1, (FSEM-2A,) (FSEM-3,) FS-1, (FSM-4, FS-3, FS-4, FS-5.)

Qualification Test Procedure Documentation: NA-0403-023

Reports which document test results: NAA-SR-Memo 9746 (Radiation)

Qualification test performed by vendor

ENTER BELOW THE NUMBER OF COMPONENTS (or hours, cycles):

test sequence	
tested	failed
equiv. # missions	
90 day mission reqmt.	

Mech/Elect Functions @ Room Amb.		Thermal Cycles in Vac.		Thermal-Vacuum-Endurance		Radiation (Gamma & Neutrons)		Shock, Vibration & Accel.	
6	0	60	0	35,767 hr / cy	0	1(a)	0	6	0
6		30		18		1		6	
1		1 or(2)		2160 hr	cy	one		one	

Describe all major test exceptions or failures and key-letter to table:

a. Demodulator only

b.

c.

Note results and load levels of any special testing needed to qualify:

1.

2.

Overtesting which indicates endurance or cycle reliability, or margins of strength:

1. Qualification testing performed on 4 units as part of experimental component assembly tests. Data is included above.

2.

Weakness remaining in final design; recommended design changes:

1.

2.