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AIRESEARCH MANUFACTURING COMPANY OF ARIZONA
A DIVISION OF THE GARRETT CORPORATION
PHOENIX, ARIZONA

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BRAYTON ISOTOPE POWER SYSTEM
DESIGN INTEGRITY CHECKLIST
(BIPS-DIC)

76-311971

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By

AiResearch Manufacturing Company of Arizona

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Prepared by:

L.G. Miller

L.G. Miller, BIPS
Reliability Manager

Approved by:

J.L. McCormick

J.L. McCormick, BIPS
Program Manager

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TOTAL PAGES 10

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DESIGN INTEGRITY CHECKLIST
(BIPS-DIC)

A preliminary Failure Modes, Effects and Criticality Analysis (FMECA) for the BIPS Flight System (FS) was published as AiResearch Report 76-311709 dated January 12, 1976. The FMECA presented a thorough review of the conceptual BIPS FS to identify areas of concern and activities necessary to avoid premature failures. In order to assure that the actions recommended by the FMECA are effected in both the FS and the Ground Demonstration System (GDS), a checklist (the BIPS-DIC) was prepared for the probability of occurrence of those failure modes that rated highest in criticality ranking. This checklist was circulated as an attachment to AiResearch Coordination Memo No. BIPS-GDS-A0106 dated January 23, 1976.

The BIPS-DIC has now been revised and is published in the following pages. Addition entries have been added that reference failure modes determined to rank highest in criticality ranking according to the recently published FMECA of the BIPS-GDS (AiResearch Report No. 76-311965, dated June 1, 1976). The checklist will be updated periodically.

Confidence exists that conservative design techniques complemented by effective quality assurance and reliability programs at AiResearch, Phoenix and its subcontractors will reduce possible failure modes to extremely low probabilities.

BIPS DESIGN INTEGRITY CHECKLIST

Criticality Ranking Order Number (Note 1)	Area of Concern	Data or Action Required (From FMECA)	Planned or Required Activity		
			Definition Document	Responsible Agency	Status
1	Rupture of Mini-BRU turbine ple- num	Adequacy of plenum design is dependent upon authen- tication of C-103 creep rupture data (including contamination effects, .	Integrated Program Plan (Note 2), Sec- tions 3.3.1 through 3.3.1.5	ORNL, BCL, NASA LeRC	In process; under continu- ing review by MARSCOM. Pre- liminary results of NASA LeRC C-103 creep tests in uncontaminated environment are encouraging.
2	Rupture, cracking, fracture of HSA-HSHK	Adequacy of HSHK design is dependent upon authen- tication of C-103 creep rupture data (including contamination effects, .	Integrated Program Plan (Note 2), Sec- tions 3.3.1 through 3.3.1.5	ORNL, BCL, NASA LeRC	In process; under continuing review by MARSCOM. Prelimi- nary results of NASA LeRC C-103 creep tests in uncon- taminated environment are en- couraging.
(16)	Diffusion bonds of HSHK	Perfection of fabrication and inspection to be sat- isfactorily demonstrated.	Ultrasonic Inspection Procedure for Longi- tudinal Mode "C" Scan Inspection of HSHK Diffusion Bonds, GE, 1-20-76	NASA/GE	<ul style="list-style-type: none"> o Bonds exhibit voids un- der present autoclave conditions 15 MPa at 9 KPSI; prop. test- eters now changed (2800°F at 15 KPSI); no data available on re- sults. o NASA acceptance criteria established for bonds - no voids ultrasonic tests to be employed to determine bond quality.
(22)	Leakage of HSHK header weldments	QA inspection to detect defects	TSD	NASA/GE	<ul style="list-style-type: none"> o Leak test of joint plan- ned o Proof pressure test of loop planned o X-ray inspection or ot- her ND test will be per- formed depending on ac- cessibility constraints

Note 1: From FMECA - BIPS FS, AIRPHX 76-311709, dated January 12, 1976.

Note 2: BIPS Phase I Integrated Program Plan, AIRPHX 75-311574, dated November 20, 1975 (hereafter, "IPP").

BIPS DESIGN INTEGRITY CHECKLIST

Criticality Ranking Order Number (Note 1)	Area of Concern	Data or Action Required (From FMECA)	Planned or Required Activity		
			Definition Document	Responsible Agency	Status
(22) (Contd.)					o GE recommendation for flight system HSAs - thermal cycle welds to insure integrity.
3	Penetration of radiator seal fin surface	Measures required to assure that failure does not result from material defects or mishandling (if used as pressure vessel on the pad)	TBD	AIRPMX	Will be addressed when Task 2 is resumed in October, 1976.
(6)	Loss of, or damage to radiator emissivity coating	Proper selection of emissivity coating and method of application is extremely important. Performance effect will be determined.	TBD	AIRPMX	Will be addressed when Task 2 is resumed in October, 1976.
4	Delayed melting of HS insulation plan for SIS in ECS mode	A full scale meltdown test is expected to provide evidence to aid in determining if the ECS functions in the manner intended. Backup designs are being evaluated.	TBD	NASA/GE	In planning stage; materials on order; test scheduled to begin in August 1976.
(24)	Loss of Helium from HSIS when in ACS mode	Premature loss of Helium could result from a malfunction/failure of the auxiliary cooling valve or a premature ground command to gas venting system. Reliability tests are required to confirm reliable design.	TBD	GE/AIRPMX	Design concept not yet chosen for FS-HSA. (Design for GDS will differ from that required for FS.) Possibility of initiating start as function of HSA temperature being evaluated. GE indicates no planned action has been defined to date.

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(31)	Self-venting of adjacent layers of foil in HSCS	Close QA can assure proper coverage of zirconia on foils.	TBD	NASA/GE	GE has specified that foils have an applied density of zirconia of 0.040 mg/cm ² ±50 percent of surface. TBC purification required; sample photographed, foil weighed.
5	Cracking of brace joint between flange and side plate in BR	Prototype will be subjected to cyclic life test to determine if low cycle fatigue problem exists.	TBD	NASA AIRPA	Cyclic life test to begin in June 1976. Complete in July 1976. Test run of 100,000 to 50 thermal cycles in order to preserve prototype for use as spare for EOC tests.
(19)	Rupture of this brace joint as result of brace voids	As inspection technique should be developed to assure adequate brace joint coverage.	TBD	NASA AIRPA	TBC
7	Mini-BR turbine blade fatigue	Proper design will preclude problem. Inspection will verify the part conformance to the B/P requirements. Blade resonant frequencies will be determined by test.	AIRPM Quality Plan, QC-043	NASA AIRPM	Resonant frequency of turbine blade will be determined when test article is available in February, 1976. Turbine test rig expected to confirm performance - February 1976.
(10)	Turbine blade creep rupture	Close quality assurance inspection procedures are necessary.	AIRPM Quality Plan, QC-043	NASA/AIRPM	Turbine wheel inspection has been completed. (GDS Hardware,
6	Mini-BR compressor impeller fatigue	Inspection will verify the part conformance to the B/P requirements. Blade resonant frequencies will be determined by test.	AIRPM Quality Plan, QC-043	NASA AIRPM	Blade resonant frequencies have been measured and found to agree closely with predictions.

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Criticality, Ranking Order Number (Note 1)	Area of Concern	Data or Action Required (From FMECA)	Planned or Required Activity		
			Definition Document	Responsible Agency	Status
9	Rupture of the splinter- to-core ma- trix braze point in the MBR	Prototype will be sub- jected to cyclic life test to determine if low cycle fatigue problem exists.	TBD	NASA/AIPLA	Cyclic life test to begin in June 1976. Test may be limited to 50 thermal cycles in order to preserve proto- type for use as a spare for GDS tests.
10	Rupture of MBR pan as- sembly (ex- cessive loads result- ing from thermal growth)	BIPS integrator will per- form an interface study to assure that duct loads transmitted to the MBR do not exceed design allow- ables.	TBD	AIRPHX	System points are being de- fined with MBR design group involved.
(20)	Excessive g-loads at duct inter- faces;	BIPS FS qualification tests must substantiate that excessive g-loads are not applied during launch and other mission environments. Mission environment data is needed.	TBD	AIRPHX	FS qualification tests will be a Phase II activity. The GDS reflects FS structural design within the current limits of mission environment definition.
(21)	Pan assembly rupture due to low cy- cle fatigue	Prototype will be sub- jected to cyclic life test to determine if low cycle fatigue problem exists.	TBD	NASA/AIPLA	Cyclic life test to begin in June '76. Test may be limited to 50 thermal cycles in order to preserve prototype for use as spare for GDS tests.
11	Rupture of MBR mount assemblies	BIPS assembly procedures must assure correct in- stallation and alignment. A test is required to as- sure that mounts slide freely during thermal growth and that no galling or welding occurs because exposure to space vacuum.	TBD	AIRPHX	Assembly procedures to be prepared; test to be de- vised.

BIPS DESIGN INTEGRITY CHECKLIST

Criticality, Ranking Order Number (Note 1)	Area of Concern	Data or Action Required (From FMECA)	Planned or Required Activity		
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12	Cracking of bellows weld joints or convolutes	Correct design is essential. If double or triple plys are used, method of cleaning and purging of volume between layers must be developed.	T30	AIRPM/ Subcon- tractor	Bellows subcontractor, when selected, will be required to propose method of cleaning, purging and inspection of bellows.
14	Short circuit in alternator stator power winding output as result of failure insulation breakdown	Alternator offgassing tests and the GDS endurance test should provide confidence in the ability of the carefully selected insulating materials to withstand the high temperatures for prolonged periods.	Technical Proposal AIRPM Report, 76-011576, 12-12-76; also see IP3, Section 3.0.1.2	NASA/AIRPM	Alternator offgassing tests to be conducted by Battelle Columbus Lab under contract to AIRPM. Program initiated March 1976.
(17)	Power winding shorts to self as result of wire failure at end turns Test s.s- ceptible	Alternator offgassing tests and the GDS endurance test should provide confidence in the ability of the carefully selected insulating materials to withstand the high temperatures for prolonged periods.	Technical Proposal AIRPM Report, 76-011576, 12-12-76; also see IP3, Section 3.0.1.2	NASA AIRPM	Alternator offgassing tests to be conducted by Battelle Columbus Lab under contract to AIRPM. Program began in March 1976.
(18)	Power winding opens as result of insulation breakdown	Close control of assembly process is required to assure that winding of coil does not introduce excessive stress at end turns.	Stator assembly Drawing 1045403; Notes 3 and 12 (Insulation Tests: (1) Resistance to ground, (2) 1000 VAC Hi pot.) Also slot liner extends to prevent abrasion or cutting of the insulation	AIRPM/ AIRLA	Present design incorporates tests as noted.

BIPS DESIGN INTEGRITY CHECKLIST

Criticality Ranking Order Number (Note 1)	Area of Concern	Data or Action Required (From FMECA)	Planned or Required Activity		
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15	Leakage of working fluid as result of defective fit of Mini-BRU case joints and electrical terminal feed thrus	Close quality control is required during fabrication and assembly.	AIRPHX Quality Plan QC-043	NASA/AIRPHX	Initial development unit being evaluated.
22	Defective weld joints in HSA inlet-outlet headers	Close quality control is required during fabrication and assembly.	TBD	NASA/GE	TBD
25	Premature opening of the auxiliary cooling valve during time HSA is used in ACS mode	Premature loss of helium could result from a malfunction/failure of the auxiliary cooling valve or a premature ground command to gas venting system. Reliability tests are required to confirm reliable design.	TBD	GE	Design concept not yet chosen for FS HSA. (Design for GDS will differ from that required for FS). Possibility of initiating start as function of HSA temperature being evaluated.
26	Crack or weld failure in radiator tubes	Close quality control is required.	TBD	AIRPHX	Development effort may be initiated as part of Task 9, Phase I.
27	Penetration or fracture of a radiator tube by micrometeoroid	Proper design to meteoroid armor criteria will be performed.	TBD	AIRPHX	Will be addressed when Task 2 is resumed in October 1976.

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Criticality Ranking Order Number (Note 1)	Area of Concern	Data or Action Required (From FMECA)	Planned or Required Activity		
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28	Cracking or failure of bimetallic joint or transition section in ducting	Program is underway to evaluate several methods of joining dissimilar metals - C-100, Hastalloy-K.	IPD, Sections 3.3.3.1 and 3.3.3.5	NASA/ORNL/AIRPHX/BSL	In process; under continuing review by MAPSCOM.
29	Failure of power supply sub-module of the control system	Reliability can be achieved through conservative design, high quality redundant components, and extensive development testing.	TDS	AIRPHX	Design under development
30	Structural failure of radiator and temperature insulation	Proper design is required to preclude high localized heat loss.	AIRPHX SCW, Report 75-011-900, dated December 15, 1975	AIRPHX/BSL	Subcontractor, Thermo Electron Corporation is performing design and development of super insulation system.

BIPS DESIGN INTEGRITY CHECKLIST

Criticality Ranking Order Number (Note 3)	Area of Concern	Data or Action Required (From FMECA)	Planned or Required Activity		
			Definition Document	Responsible Agency	Status
1	Failure of emergency vacuum chamber backfill system to function	Incorporate uninterruptible power supply for Alarm and Protection System.	AIRPHX Drawing No. 306960 and Note 4.	AIRPHX	Design in process.
2	Overspeed and shutdown control fails to open or opens prematurely	Design Alarm and Protection System to minimize false alarms (signals); incorporate uninterruptible power supply.	AIRPHX Drawing No. 306960 and Note 4.	AIRPHX	Design in process.
3, 4	Failure of PHX coolant refrigeration system	Install high quality system; consider redundant units or injection of tap water as emergency measure; use high quality fail-open temperature control valve.	AIRPHX Drawing No. 306960 and Note 4.	AIRPHX	System in planning stage.
5, 6	Failure of PHX GYS emergency argon backfill system	Normally closed solenoid valve (SV-401) tentatively selected. Consider redundant valves in parallel or two normally open in series. Uninterruptible power supply required for Alarm and Protection System.	AIRPHX Drawing No. 306960 and Note 4.	AIRPHX	Design in process.
7	Leakage of high vacuum test chamber (HUTC) main chamber flange seal	High quality seal required; protect seal from damage when chamber is open.	AIRPHX Drawing No. 306960 and Note 5.	AIRPHX/ Subcontractor	To be sub-contracted.

Note 3: From FMECA-BIPS-GDS, AIRPHX 76-311965, dated June 1, 1976

Note 4: AIRPHX Report No. 76-311740, BIPS Facility Specification, dated June 15, 1976.

Note 5: AIRPHX Procurement Specification PSC-76-311703, High Vacuum Test Chamber and Pumping System, dated May 31, 1976.

BIPS DESIGN INTEGRITY CHECKLIST

Criticality Ranking Order Number (Note 3)	Area of Concern	Data or Action Required (From FMECA)	Planned or Required Activity		
			Definition Document	Responsible Agency	Status
8	HTC rough- ing pump	Cold trap required to catch backstreaming of oil; incorporate sensor to detect pump failure and close gate valves (SV-200C, D, E, and F).	AIRPMX Drawing No. 306960 and Note 5.	AIRPMX/ Subcon- tractor	To be subcontracted.
9	HTC high vacuum pump	Incorporate means to autoratically close gate valves in event of pump failure.	AIRPMX Drawing No. 306960	AIRPMX/ Subcon- tractor	To be subcontracted.
10	Working fluid man- agement sys- tem vacuum pump	Select high quality pump; incorporate cold trap or other means to preclude contaminants entering loop.	AIRPMX Drawing No. 306960	AIRPMX/ Subcon- tractor	Design in process.
11	HTC sus- taining pump system	Titanium sublimation pump tentatively selected. Un- interruptible power sup- ply is mandatory (pres- ently planned). Establish schedule for replacing titanium elements to pre- clude inadvertent shut- down of GDS.	AIRPMX Drawing No. 30-960	AIRPMX/ Subcon- tractor	To be subcontracted.