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2 kWe Solar Dynamic Ground Test Demonstration Project

Volume II: Design Report

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SOLAR DYNAMIC GROUND TEST DEMONSTRATOR (SDGTD)
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1. INTRODUCTION

Critical Design Reviews (CDRs) were held on the Solar Dynamic Ground Test Demonstrator (SDGTD) Program in accordance with the following schedule:

Review	Date	Location
Radiator	26 Feb 93	Loral Vought
Concentrator	13-14 Apr 93	Harris
Receiver, Recuperator, Cooler	12-14 May 93	Aerospace Systems & Equipment
Data Acquisition & Control, Power Conversion & Control, Parasitic Load Radiator, Electric Load Simulator (NASA)	25-27 May 93	Fluid Systems
Turbo Alternator Compressor, System Integration, Buildup Assy Platform (NASA), Solar Simulator (NASA Update), Liquid Utilities Pallet	2-4 June 93	NASA LeRC

This CDR summary report will provide the following information for each of the system components and the system integration:

1. A bibliography of design/design review documentation,
2. A summary of the major discussion issues from each design review,
3. A definition of the component and system detail designs along with the bottom line from the supporting analysis,
4. Status and key results from pertinent development activities on-going in the CDR time period,
5. A brief description of planned testing, and
6. A discussion of issues still open at the completion of CDR.

This report was prepared by the companies responsible for the individual reviews and compiled by Fluid Systems. In reading through this document, the reader will detect different writing and presentation styles. Fluid Systems has not attempted to "wordsmith" this document to provide a consistent style or tone. We did not feel that this was a worthwhile expenditure of program resources and we wanted the writers to communicate directly with the reader.

Appendix 1 to this report contains a listing and status (as of 28 June 1993) of all the action items generated during all SDGTD CDRs. The reader should remember that the SDGTD program is being conducted in an open communication forum, and program participants are encouraged to ask questions or request information. Team members are allowed and encouraged to participate in the reviews on an equal basis. No request for information, as long as it is within the work scope, is refused, so many action items are generated.

2. SYSTEM INTEGRATION

2.1 Design Document Listing

The following list of documents was generated by Rocketdyne and Fluid Systems to support the system integration design activities and the system integration CDR:

Document Number	Document Title
213000001 ISSUE 3	SYSTEM LAYOUT
213000002 ISSUE 4	PIPING & INSTR. DIAGRAM
213000014 ISSUE 2	EI&C (CABLING) DIAGRAM
213000016 ISSUE 2	ICD, PCS
213000017 ISSUE 4	INSTRUMENT LIST
213000019 ISSUE 1	WIRE LIST
213000020 ISSUE 1	CONNECTOR LIST
213010116 ISSUE 2	ICD, CONCENTRATOR
213010117 ISSUE 2	ICD, RECEIVER
213010118 ISSUE 2	ICD, RADIATOR
213010119 ISSUE 2	ICD, PLR
213010120 ISSUE 2	ICD, PCCU
213010132 ISSUE 1	ICD, LUP
213SRR00002	HAZARD ANALYSIS
213TP000002 ISSUE 2	TEST PLAN, SYSTEM
213TPS000001 ISSUE 3	TEST PLAN - SUMMARY
N10115 ISSUE 5	SPECIFICATION, SYSTEM
N10116 ISSUE 2	SPECIFICATION, CONCENTRATOR
N10117 ISSUE 2	SPECIFICATION, RECEIVER
N10118 ISSUE 2	SPECIFICATION, RADIATOR
N10119 ISSUE 2	SPECIFICATION, PLR
N10120 ISSUE 2	SPECIFICATION, PCCU
N10121 ISSUE 2	SPECIFICATION, DACS
N10132 ISSUE 1	SPECIFICATION, LUP
UNNUMBERED	CDR DESIGN REPORT
UNNUMBERED	CDR VIEWGRAPHS
41-11460(2)	THERMODYNAMIC CYCLE STATEPOINTS
41-12000	SYSTEM STARTING PROFILES
41-12065	SYSTEM THERMODYNAMIC CONTROL METHODS
41-12072	SYSTEM VERIFICATION TEST PROFILE
41-12119	SYSTEM THERMO. DATA FOR CDR

The 41-XXXXX documents are published by Fluid Systems. All others in this listing are Rocketdyne's.

2.2 Design Review Minutes

The System Critical Design Review was held at NASA LeRC on Thursday, June 3, 1993. The presentation topics covered during the system review were:

Topic	Presented by
Requirements	C. Kudija (Rocketdyne)
Changes Since PDR	C. Kudija
System Design Documents	C. Kudija
Instrumentation & Cabling	R. Kozik (Rocketdyne)
System Analysis	
- Component Alignment	C. Kudija
- System Efficiency	C. Kudija
- Thermodynamic Cycle Analysis	T. Mock (Fluid Systems)
Safety	C. Kudija
System Test Plans	L. Mason (NASA)

The system CDR began with a review of the system specification and the changes in the specification which have occurred since PDR. No major issues were generated during this discussion. The integrated system design and the associated design changes since PDR were reviewed next. Again, no major issues were identified and the overall system integration approach was accepted. The component specifications and Interface Control Drawings were summarized but not reviewed in detail. No major issues were generated by either NASA or the component subcontractors. These documents are to be released to configuration management control by Rocketdyne after incorporation of CDR review comments. The subcontractors and NASA were encouraged to give these documents one final review prior to placing under configuration management control.

The instrumentation list, cabling schematics, and wire list were reviewed next. A significant amount of work has gone into organizing the numerous electrical/electronic signals contained within the SDGTD, and it was evident in the completeness of these documents. Several issues arose in this presentation. The first involves apparent discrepancies between the DACS detail designs presented at the DACS CDR and the system cabling requirements. Fluid systems indicated that the detail design of the DACS was based upon system documents two issues back and that they were aware of the discrepancies. Several specific action items were taken to require Steve Siems and Bob Kozik to insure that these discrepancies were resolved. The second issue involves the grounding scheme to insure that ground loops do not get into the instrumentation. Fluid Systems indicated that the design of thermocouple modules within the DACS provided ground isolation and that inadvertent grounds in the instrumentation would not result in ground loops which provide erroneous signals. Had the DACS and the system instrumentation design been based on "grounded" thermocouples this would not have been the case and ground loops would be a concern. Nonetheless, an action item was taken to review this issue.

Following the presentation on instrumentation and cabling, system analysis presentations were given. The first involved the allocations to insure adequate optical alignment. The approach of providing installation adjustability rather than tolerance allocation was presented and accepted. However, the transient effects of receiver, BAP, and concentrator motions have not been cumulatively evaluated. Additional work is required to bring all the alignment tolerances and thermo-elastic distortion effects together. An action item was taken to complete this task. Some of the transient thermal analyses are very complex and have not been completed for the final component designs selected.

The overall system efficiency from light in to user electric power out was presented. The system goal is 15 percent. Current analysis indicates 16.1 percent. The losses were reviewed from the light source to the concentrator.

The thermodynamic cycle analysis was presented next. The maximum insolation orbital conditions were defined. System startup transients were provided. A methodology of conducting the system verification test was presented, in stepwise fashion, brought the system up slowly from a low-temperature, low-power condition to full-power design conditions. This test approach was well received. The shutdown transient generated some interesting discussions and a steak dinner bet between NASA and Fluid Systems (even more important than an action item). This discussion involved the amount of electrical power which can be generated if solar tracking is lost at the sunrise condition (normally the lowest energy state). Lee Mason of NASA suggested that testing should be done to quantify the amount of available electrical energy available over a wide range of shutdown conditions. Fluid Systems countered with a proposal to test several conditions to calibrate the analytical model and use the model to generate the maps. A steak dinner bet was placed between Lee Mason and Bob Macosko of NASA and Dennis Alexander and Ted Mock of Fluid Systems: Fluid Systems will conduct system testing to include no more than three shutdown conditions, after which NASA will select a shutdown condition and Fluid Systems will predict within 5.0 percent the actual (by test) available electrical energy.

Methods of thermodynamic control were also presented. Constant speed operation over a range of speeds was presented. The specifics of these analyses are contained in Section 2.4 of this summary report.

The results of the component and system hazards analysis were presented. No hazards were identified which, with planned action, would result in unacceptable safety conditions. Leakage of n-heptane into the gas loop via a failed gas cooler was discussed and an action item taken to resolve the issue.

The system test plans, both contractor and NASA phases, were discussed. The time required to conduct the contractor system verification testing was reduced and made more aggressive based on the incorporation of the Fluid Systems hot-loop testing which occurs prior to delivery of the PCS. This approach was accepted. The NASA testing is still in the preliminary stages of planning. A four-phase (most important issues first) approach was identified. Team members were encouraged to review the NASA test plans, especially in the area of risk identification.

Generated action items (see Appendix 1) were reviewed, accepted, assigned, and due date established.

2.3 System Integration Design Summary

The SDGTD system layout is shown in Figure 2-1. The system integration concepts provide optical coupling of the solar simulator, the concentrator and the receiver. Physical integration primarily involves integration of components to the tank. Figure 2-1 shows that significant component-to-component physical integration is not desired or required. This maximizes the ease by which components can be changed out to evaluate different design concepts without requiring complex integration activities. Changes in the system design since PDR include the following:

a. The solar simulator position was revised to eliminate a potential interference with the 10-foot diameter valve housing on the west end of the tank.

b. The BAP, concentrator, receiver, and PCS were repositioned in the tank (shifted approximately three feet west) in response to the solar simulator position change.

c. The liquid utilities pallet was located below the radiators to contain the liquid loop components and to restrain the movement of the hanging radiator panels.

d. The PCCU was moved from the BAP to the tank floor to simplify mounting and potential interferences.

e. The BAP was changed to a single-level structure rather than a bilevel structure. A removable pallet for the receiver/PCS was identified to provide for the movement of the receiver/PCS to allow temporary incorporation of a flux measurement target.

f. Not shown on the system layout but of major significance was the establishment of the detailed electrical interface conditions including the tank pass-through concepts. Detailed cabling schematics, connector and wire lists were generated to control the detail design of numerous control and instrumentation cables.

Current System Design

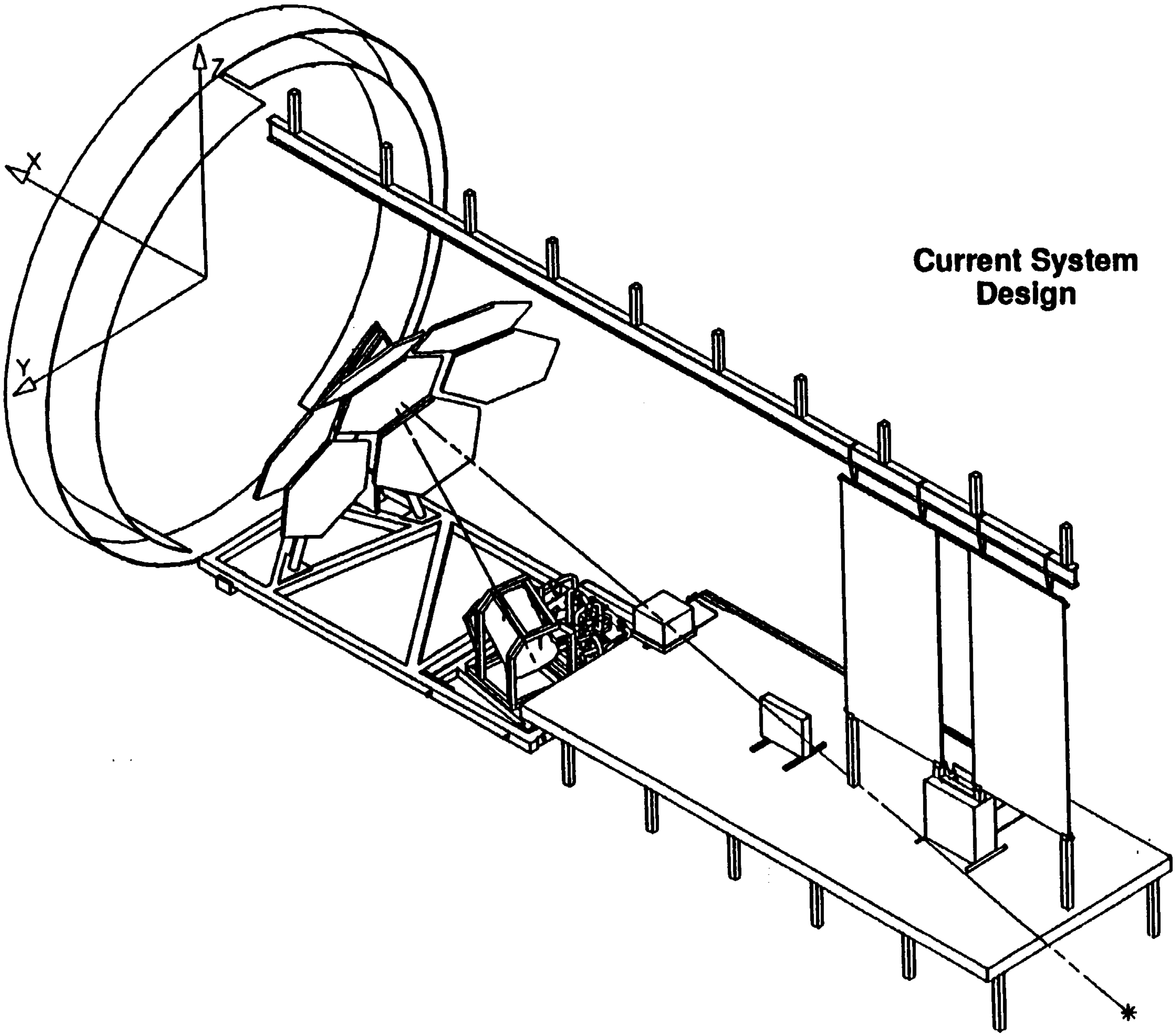


Figure 2-1. System Layout

2.4 System Performance Analysis

The maximum insolation cycle statepoints for sunrise and sunset conditions are shown in Table 2-1. The schematic for interpreting the statepoint table is shown in Figure 2-2.

Starting transients have been defined for three different scenarios:

* Normal start from orbital soak conditions (360°R)

* Normal start for Tank 6 ambient conditions (520°R) with conditioned radiator

* Potential first start transient for the system in Tank 6 which is intended to keep receiver temperatures down

The system is started by acquiring the sun (or turning on the solar simulator in the tank) and storing energy in the receiver. The Brayton system needs approximately 1250°R turbine inlet temperature to become self sustaining. It is necessary, therefore, to raise the energy level of the receiver to a level sufficient to produce the necessary turbine inlet temperature. However, the solar flux distribution within the receiver, as deposited by the concentrator, is not uniform. Without gas flow in the receiver, canisters heat up very unevenly. Overheating of hot spot canisters is possible if the sun is acquired for too long without operating the Brayton system. Brayton system operation removes energy from the receiver as well as redistributes (smoothes) the energy with the receiver. Once started, the system needs approximately 3 orbits to achieve a balanced thermal operation. Balanced operation means that the sunrise conditions of orbit n + 1 are virtually identical to sunrise conditions of the previous orbit n. The characteristics of the normal Tank 6 start from ambient conditions is given in Table 2-2.

The baseline control method for orbital operation is to set a TAC speed and maintain it throughout the orbit. As the receiver warms up during the insolated period of the orbit more and more power is produced. During the eclipse period the system cools down and less and less power is generated. This methodology is referred to as the constant speed approach, which results in a variation in available power during the orbit. This characteristic is shown in Figures 2-3 and 2-4, which show temperature and power variation during a typical (maximum insolation) orbit.

Table 2-1. System Statepoints at Sunset and Sunrise

Temperatures in °R, Pressures in psia

QIN APERTURE, KWT	12.545	
CYCLE VARIABLE	SUNSET	SUNRISE
COMP INLET P1	67.632	65.748
COMP INLET T1	463.7	461.7
COMP DISCH P2	109.95	106.93
COMP DISCH T2	596.4	593.9
ALT HX DISCH P3	109.88	106.86
ALT HX DISCH T3	616.7	612.5
RECUP DISCH P4	109.21	106.21
RECUP DISCH T4	1575.0	1475.2
RCVR INLET P5	109.15	106.16
RCVR INLET T5	1573.0	1473.7
RCVR DISCH P6A	107.51	104.62
RCVR DISCH T6A	1878.7	1752.5
TURB INLET P6	107.37	104.48
TURB INLET T6	1874.1	1749.0
TURB DISCH P8	68.904	66.999
TURB DISCH T8	1627.3	1518.3
RECUP INLET P9	68.873	66.970
RECUP INLET T9	1600.5	1495.4
RECUP DISCH P10	68.307	66.427
RECUP DICSH T10	662.8	654.0
COOLER INLET P11	68.278	66.397
COOLER INLET T11	662.8	654.0
COOLER DISCH P12	67.641	65.757
COOLER DISCH T12	463.7	461.7
COMP PR	1.6257	1.6263
TURB PR/COMP PR	.95848	.95885
COMP IN FLOW, #/SEC	.39199	.39063
TURB IN FLOW, #/SEC	.38341	.38207
COOLANT FLOW, #/SEC	.04853	.04853
COOLANT TLIQAVG	539.5	539.5
COOLANT CP, BTU/#°F	.53925	.53925
COOLANT DELTA T	176.5	170.1
CLR INLET TLIQ	452.1	450.7
CLR DISCH TLIQ	628.6	620.8
TSINK	375.0	375.0
JOUR BRG LOSS, KW	.05484	.05418
THRST BRG LOSS, KW	.13972	.13804
ALT WIND LOSS, KW	.09021	.08817
ALT EM EFF	.90832	.91111
GROSS ALT INPUT, KW	2.3212	1.9443
ALT OUTPUT, KWE(AC)	2.1084	1.7715

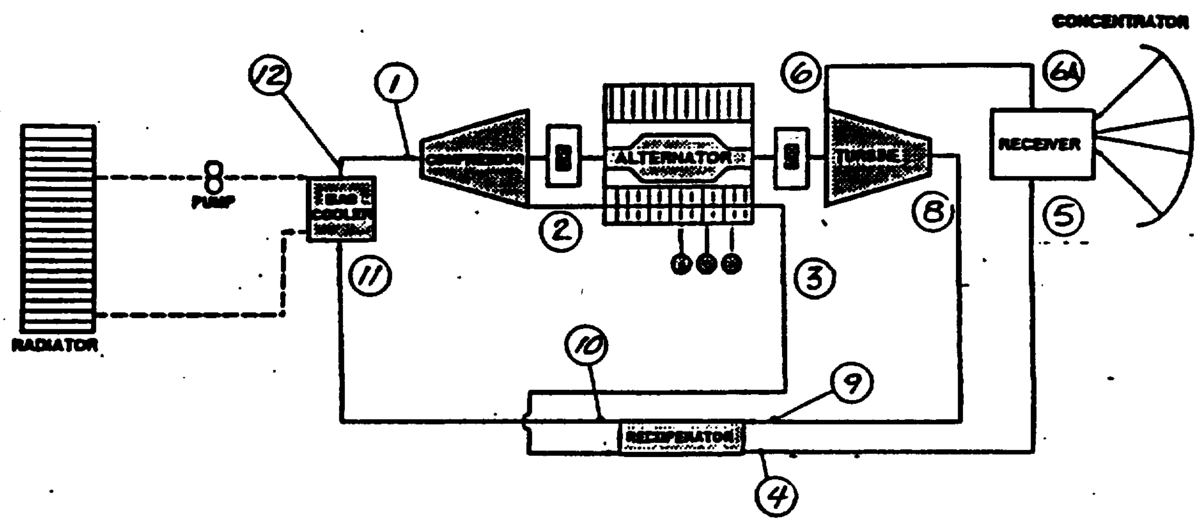


Figure 2-2. SDGTD Cycle Station Locations

The selection of the speed setpoint has a significant effect on the operation of the system, predominantly the receiver. If at low speed the receiver becomes overheated and the salt stays at or above the melt temperature, very little variation in electrical power out is observed from sunset to sunrise. This occurs because most of the salt within the receiver is remains molten staying at or slightly above the melt temperature of the salt. Conversely, operation at too high a speed results in overcooling of the receiver. The canisters of salt within the receiver tend to operate at or below the salt melt temperature. In this case large swings in electrical power are observed between sunrise and sunset. Neither of these conditions is desirable. Figure 2-5 shows the electrical power produced at sunrise and sunset during a max insolation orbit as speed is reset from 47,000 rpm to 55,000 rpm. The aerodynamic design point for the compressor and turbine are 52,000 rpm. The turbine inlet temperature variations for sunset and sunrise over the same speed range are shown in Figure 2-6. Remember that the salt melt temperature is 1873°R when studying Figure 2-6 and you get an appreciation for what is happening. The same conditions would exist if the cycle gas inventory was changed at constant speed. A low-level inventory would produce results similar to operation at low speed. In short, the receiver responds to flowrate, which is produced by a combination of gas inventory (pressure) and TAC speed.

Operation in low earth orbit would result in a wide range of orbital conditions. Varying orbital conditions result in a range of orbit times and insolation periods. The characteristics described in the above paragraph, for the cases we have analyzed so far, remain reasonably consistent. The values of temperature and power vary but the trends are consistent. Figure 2-7 shows the ratio of sunrise to sunset electrical power (max orbit power/min orbit power) as a function of speed setpoint for a maximum insolation orbit operating at 100 percent gas inventory. Note the dip or bucket in the curve near 52,000 rpm. The area to the right this bucket is the desirable operating range. We believe that algorithms can be developed to locate this condition by measuring output power alone. No complex and unreliable temperature measuring instrumentation is required for system operation and control.

Table 2-2. System Nominal Cold Startup Scenario for Startup in Tank 6

- RECEIVER AND RECUPERATOR AT 520°R
- TSINK = 375°R AT START INITIATION
- COOLANT HEATER MAINTAINING RADIATOR INLET TEMPERATURE TO 620°R
- COOLER AT AVERAGE TEMP OF 450°R
- COOLANT FLOW RATE CONSTANT AT 174.7 LB/HR
- GAS CYCLE INVENTORY AT BASELINE VALUE
- THEN:

ORBIT NO.	TIME, MIN	SPEED SET POINT, RPM	PNET, KWE	ACTION TAKEN OR OCCURRED (Q RCVR = BTU)
1	0 50.00 ~50.33 50.67 66	0 47000 47000 47000 47000	0 0 0 0.285 1.459	SUNRISE (Q = 17924) TURN STARTER ON STARTER OFF SELF SUSTAINING SUNSET (Q = 56388)
2	0 66	47000 47000	0.747 1.658	SUNRISE (Q = 47592) SUNSET (Q = 65652)
3	0 ~41.1 66	50500 50500 50500	1.513 1.939 1.955	SUNRISE (Q = 54569) RECUPERATOR HEATUP COMPLETED SUNSET (Q = 68613)
4	0 1.4 66	52000 52000 52000	1.778 1.732 2.062	SUNRISE (Q = 55517) COOLANT HEATER OFF SUNSET (Q = 68926)
5	0 66	52000 52000	1.721 2.060	SUNRISE (Q = 55245) SUNSET (Q = 68734)
6	0	52000	1.695	SUNRISE (Q = 55077)

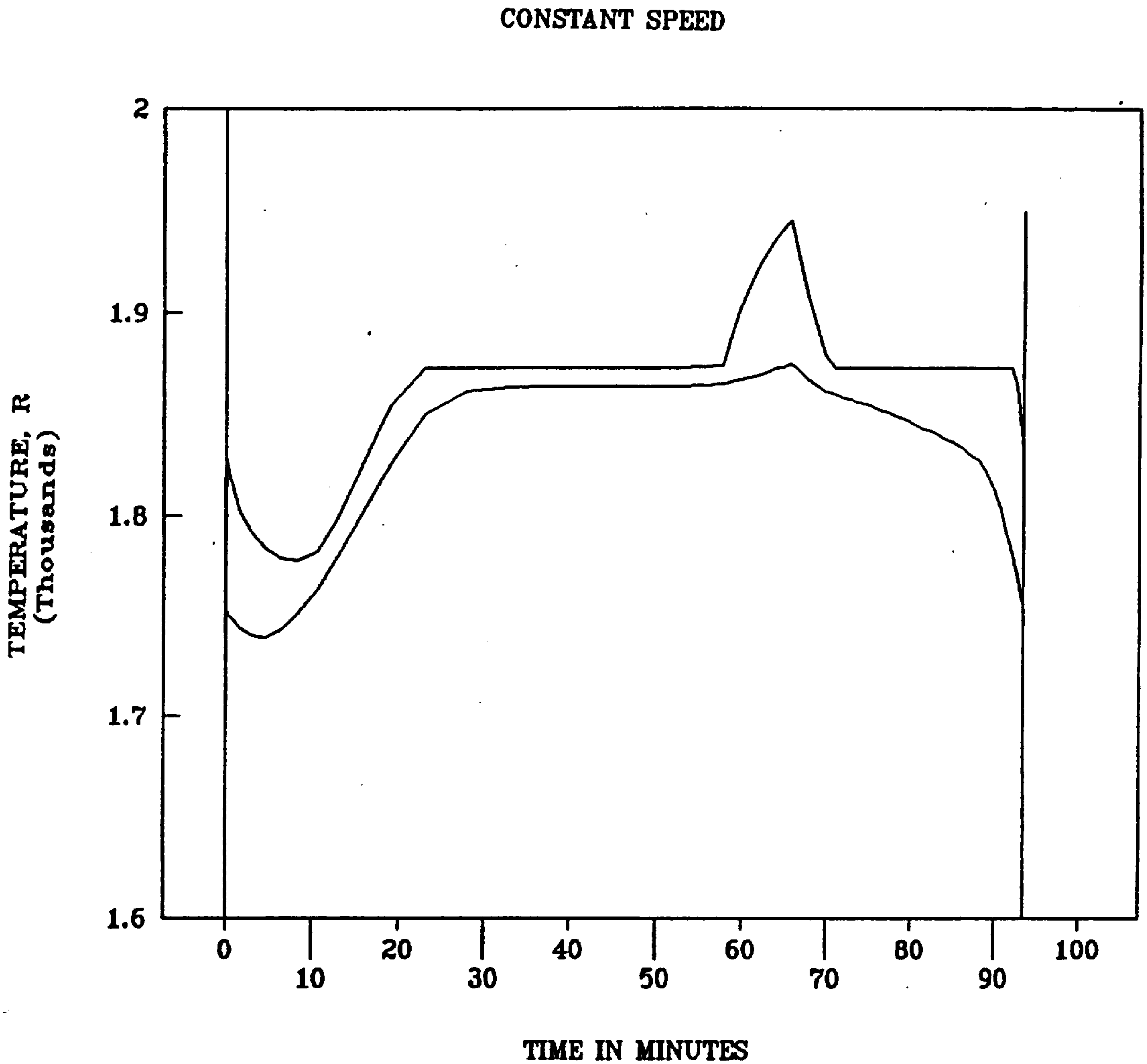


Figure 2-3. TCAN and TIT Versus Orbit Time

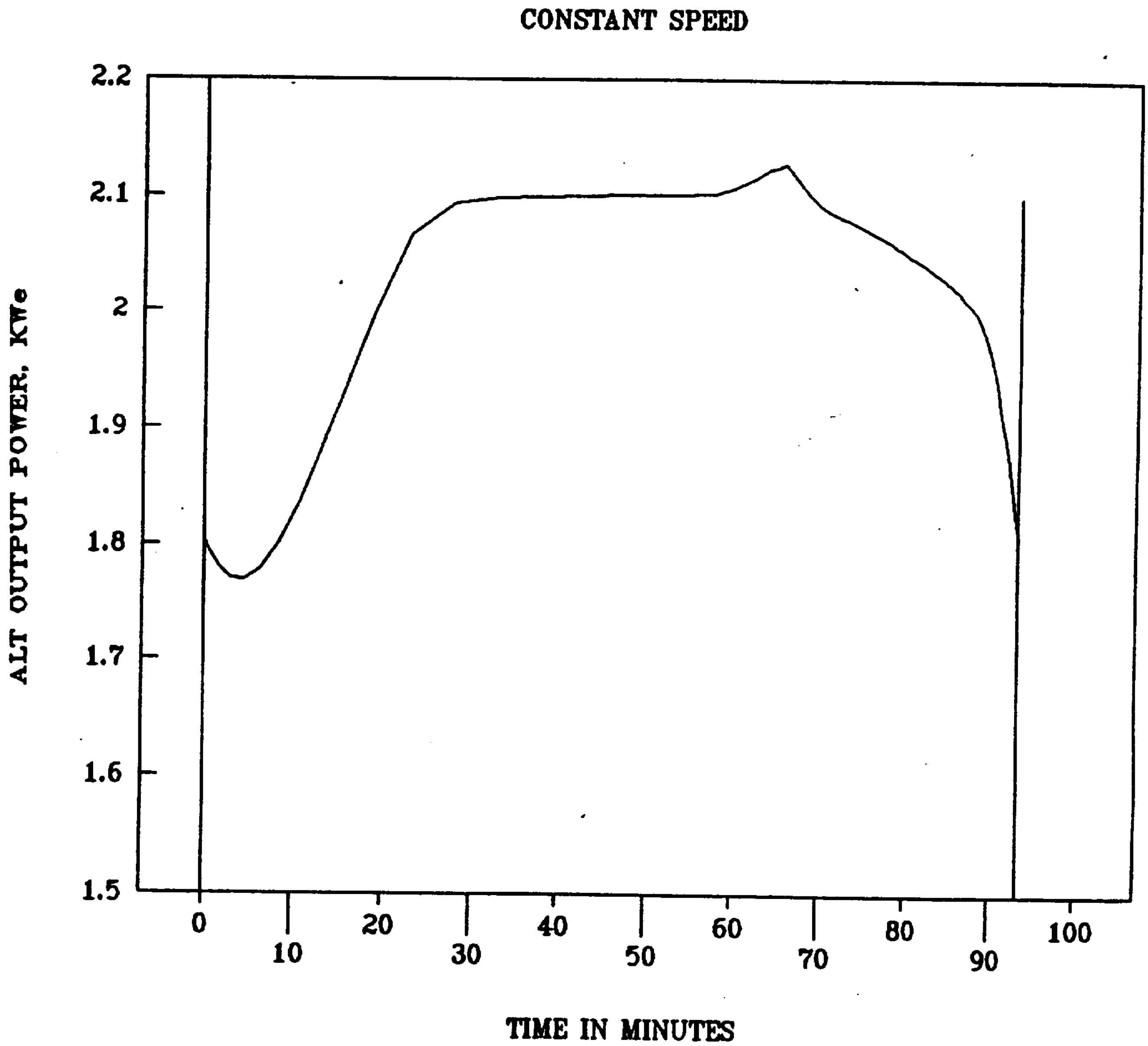


Figure 2-4. KWe Versus Orbit Time

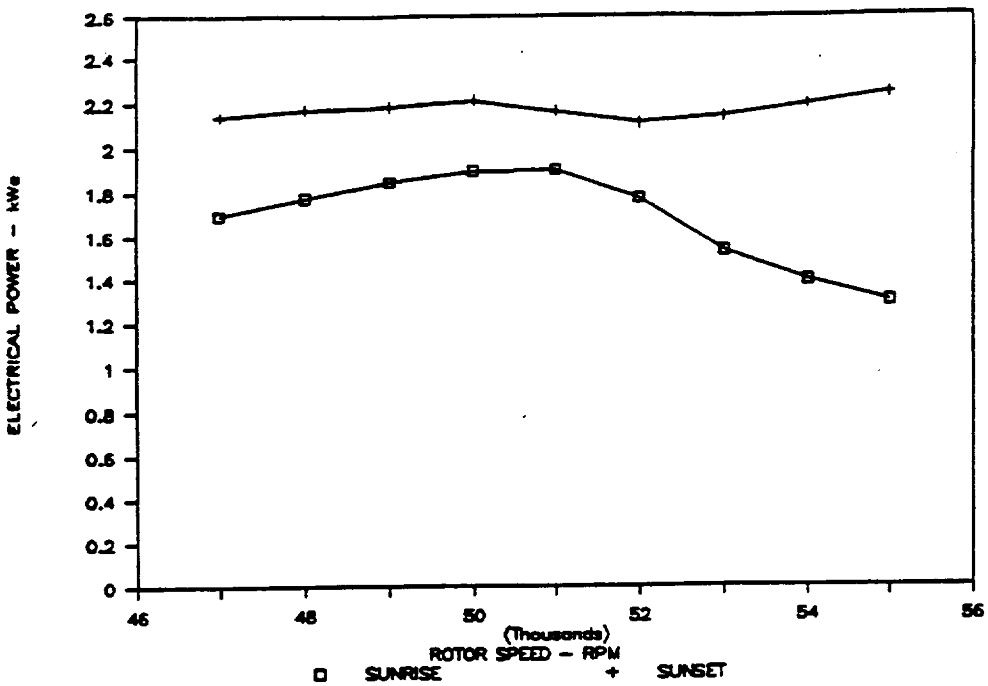


Figure 2-5. Net Output Power for Sunrise and Sunset Versus Shaft Speed Setpoint

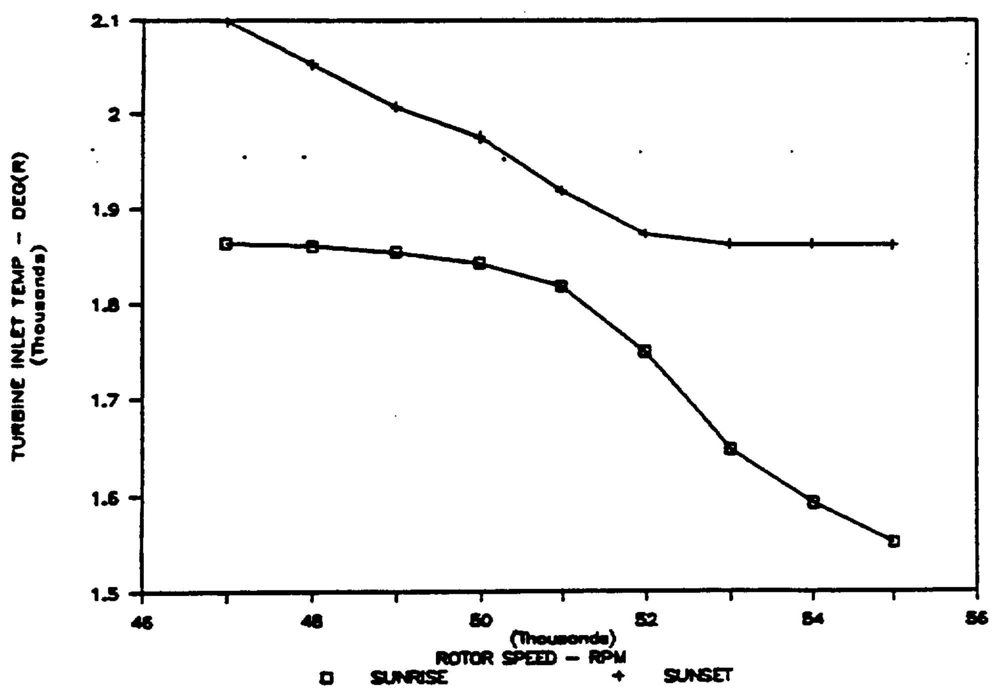


Figure 2-6. Turbine Inlet Temperature for Sunrise and Sunset Versus Shaft Speed Setpoint

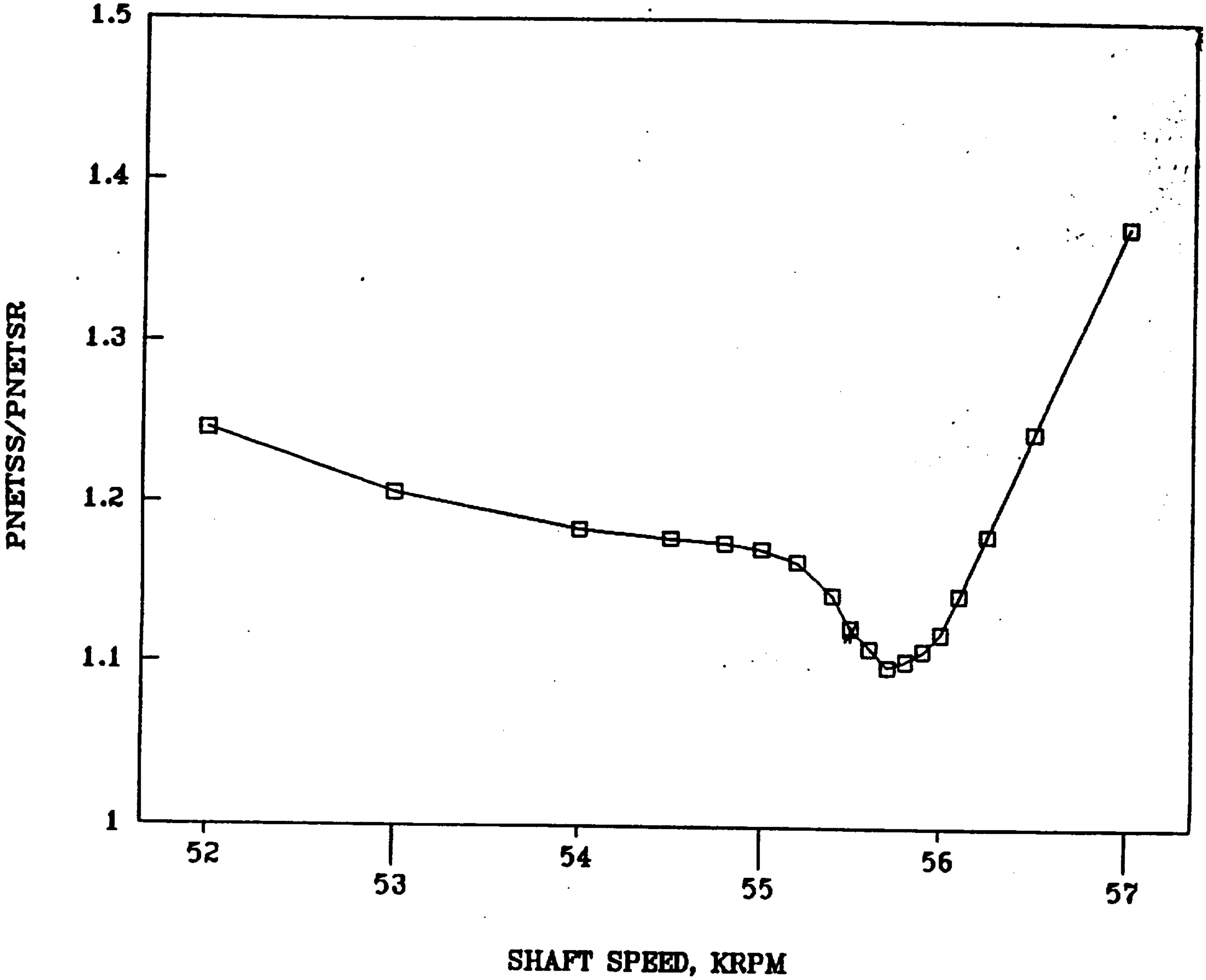


Figure 2-7. PNETSS/PNETSR Versus KRPM

2.5 System Safety

Hazards analyses were conducted using NHB100.1 as a guide. Hazard risk is measured by assessing the probability and the consequences of events occurring. The value system for assessing severity (consequence) is:

Class I — Catastrophic, may cause death or major system destruction

Class II — Critical, may cause severe injury, severe occupational illness, or major property damage

Class III — Marginal, may cause minor occupational illness or property damage

Class IV — Negligible, probably would not affect personal safety or health but is a violation of specific criteria.

The value system used to assess probability is:

Estimate A Likely to occur immediately

Estimate B Probably will occur in time

Estimate C May occur in time

Estimate D Unlikely to occur

Combining the probability and the consequences is accomplished with the table shown in Table 2-3 to obtain an overall safety Risk Assessment Code. Hazards with Risk Assessments Code of 1 or 2 are considered undesirable and require action to reduce risk. Each contractor has accomplished an assessment of their components, and Rocketdyne has assessed the system and compiled an overall program compendium of risk items to identify hazards which require corrective action. Table 2-4 provides a compilation of the number of hazards identified by Risk Assessment Code.

Table 2-3. Risk Assessment Code

		Probability Estimate			
		A	B	C	D
Severity class	I	1	1	2	3
	II	1	2	3	4
	III	2	3	4	5
	IV	3	4	5	6

Table 2-4. Summary of Hazards by RAC

RAC	Number Before Correction Action	Number After Corrective Action
1	0	0
2	12	0
3	26	18
4	40	42
5	12	20
6	2	6

2.6 System Test Plan

The initial draft of an integrated system test plan summary has been developed by NASA Lewis. This document is currently incorporated as an appendix to Rocketdyne's Test Plan Summary (213TPS000001). The integrated system test plan summary describes the tests that will follow the System Verification Tests performed in Tank 6 by the contractor team.

Three primary goals are to be accomplished through the integrated system testing. First, the tests should demonstrate the technology readiness of an integrated solar dynamic power system for ultimate use in space. Second, the tests should provide data that will allow evaluation of the various NASA and contractor design codes used to predict system and component performance. Finally, the test program should provide a means to acquire system operating experience for the NASA/contractor team and provide greater insight into the control methodologies needed to operate solar dynamic systems for eventual space missions.

The integrated system tests are organized into four separate phases. Phase A is the Demonstration Test Phase. During this phase of testing, a representative cold soak startup will be followed by a series of orbit cycling cases culminating in operation of the SDGTD at its reference design conditions (maximum insolation orbit). The stability of the system during random and/or sudden variations in user load will be demonstrated. Additionally, Phase A will demonstrate the system's capacity to provide power via receiver thermal energy reserves during a simulated loss of solar energy. All of these tests will be performed using constant speed control.

Phase B is the Off Design/Perturbation Test Phase. The purpose of this test series is to evaluate the system's ability to respond to operational perturbations and return to a stable and safe operating condition. TAC set speed variations will be investigated to determine the number of orbits needed to return to balanced orbital conditions and to verify analytical predictions. This data will also be used to prepare control algorithms for peaking power and constant power control tests to be performed during this phase. Phase B will also evaluate the system's sensitivity to slight off-pointing of the concentrator with respect to the receiver. This test phase will conclude with a series of steady-state (continuous light input), low-power, off-design tests to investigate system performance over a range of shaft speeds, turbine inlet temperatures, compressor inlet temperatures, and gas flow rates.

Phase C is the Automatic Control Test Phase. Using information gained during the first two test phases, Phase C will investigate automatic control strategies for a range of different operational modes. Algorithms will be developed and tested that will direct the system to automatically compensate for orbital variations and potential component degradation. In addition, automatic control methodologies will be implemented for startup, shutdown, and hot restart sequences. This test phase will culminate in a complete preprogrammed mission simulation where the system will be expected to respond automatically to a series of control perturbations.

The final test phase currently defined in the program is Phase D, the Fault Management Test Phase. During this test phase, the electrical protection system will be evaluated for its ability to keep the system on-line and operational following various faults that could occur during a typical mission scenario. The possible electrical faults that will be evaluated include a momentary electrical overload, load type switch (from constant power to constant impedance or constant current), and a load-side short circuit. A summary describing the estimated number of orbit cycles, startup/shutdowns, operational hours, and total days for each of the test phases is provided in Table 2-5. These estimates reflect the test program as it is envisioned today. As turnkey approaches and following the lessons learned during the contractor verification tests, this program will undoubtedly be refined.

In order to facilitate a timely completion of the integrated system test program, the system will be operated 24 hours a day, 7 days a week. However, rest periods and/or vacuum breaks have be designated at logical intervals in the test schedule to allow replacement of lamps in the solar simulator, inspection of components, recalibration of instrumentation, and preparation for upcoming tests. The integrated system test program is expected to begin in spring 1995 and be complete in about 6 weeks. A preliminary schedule is provided in Figure 2-8.

Table 2-5. Operational Summary

TEST PHASE	ORBIT CYCLES	STARTUP/ SHUTDOWNS	OPER. HOURS	TOTAL DAYS
A - DEMONSTRATION	80	2	120	20
B - PERTURBATION	106	1	279(1)	19
C - AUTO CONTROL	80	4	120	6
D - FAULT MGMT	16	1	24	1
TOTAL	282	8	543	46

(1) INCLUDES UP TO 120 HRS OF STEADY STATE (NON ORBIT CYCLING) TESTING

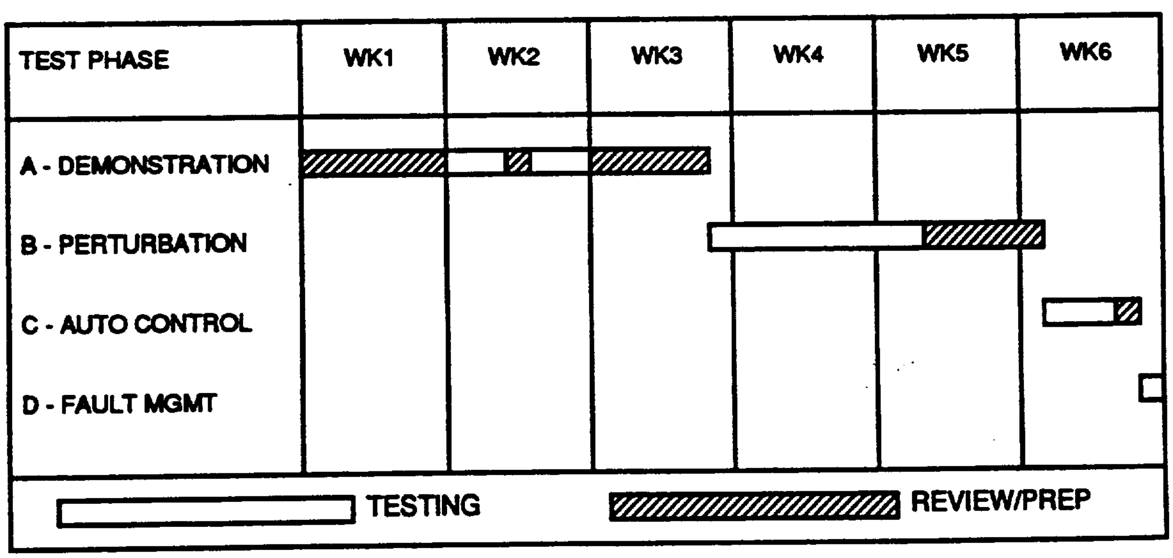


Figure 2-8. Test Schedule

2.7 Open Issues

Thirteen action items were accepted at System CDR. Several of these can be regarded as "issues" as opposed to "request for information." The system integration issues which require resolution are:

a. Significant differences between the latest Cabling ICDs and the DACS detail drawings have been identified. This is believed to be a result of generating DACS drawings from cabling information which was known to be preliminary. The DACS details were planned to be revised when the cabling information was released. Rocketdyne and Fluid Systems need to get together to insure that this transpires.

b. The quantitative understanding of how the receiver beam moves relative to the aperture is still not complete. This requires completion of analytical transient thermal analysis at NASA and ASE. When the analysis is completed the motions and alignment allocations need to be compiled to identify the total mismatch permissible. Biasing schemes need to be developed to align the system cold so that operating alignment is achieved. The magnitude of the motion is controlled by concentrator motion, which has a cold-to-hot transient of 0.50 inch. Other motions are considerably less.

DESIGN DOCUMENT LIST

1. "Solar Dynamic Ground Test Demonstration Weight Status", LV Document 3-47300/3DIR-005 dated 5 February 1993. Releases preliminary weights based on the drawings provided by design.

2. "SDGTD - Radiator Panel Sizing Thermal Analysis", LV Document 3-47300/2DIR-542 dated 22 November 1992. Releases panel sizing and thermal performance results of the radiator panels.

3. DRD No. PA-01 Safety Program Plan, LV Report No. 3-47300/3R-005 dated 10 February 1993.

4. DRD No. PA-01 System Safety Subsystem Hazard Analysis, LV Report No. 3-47300/3R-002 dated 10 February 1993.

5. "Stress Analysis of Solar Dynamic Ground Test Panel", LV Document 3-47300/3DIR-006 dated 9 February 1993. Document panel strength for CDR.

6. Drawings released. See drawing tree Figure 3.1.

DESIGN REVIEW MINUTES

The Critical Design Review for the Waste Heat Radiator was conducted at Loral Vought Systems, Dallas, Texas on 26 February 1993. The content, sequence, and presenters were as indicated in Figure 3.2. Attendees included the SDGTD team members and representatives from NASA-Lewis.

Radiator requirements were presented in the form several vugraphs and a detailed Compliance Matrix which had been pre-coordinated with Rocketdyne. The discussion included the design changes which have occurred since the Preliminary Design Review (PDR) which was held in November at the Allied Signal Garrett facility in Tempe, Arizona. The addition of the second fluid loop into the design was one of the major changes in this chart. It was stated that the an error had occurred at PDR in that this second fluid loop had not been included in the design although it had been intended from inception. The other changes were more of a cosmetic nature. A review of the Compliance Matrix for the Design Requirements Specification for the SDGTD Radiator resulted in discussion of the following topics:

1. the secondary fluid FC-75 was considered a more hazardous fluid than n-Heptane,

2. whether the WHR can withstand the 100 startup cycles,

3. whether the new radiator ICD's had been released,

4. the vibrational analysis of the WHR in the Tank 6 facility due to chamber vibrational environments not performed

A thermal performance summary was presented next which stated the thermal performance design conditions as stated in Allied Signal's SD GTD cycle statepoint analysis. The WHR design recommendation was presented which was followed by the radiator detailed design, beginning with a summary of the materials and processes that will be used in the manufacture of the radiator panels. The drawing tree was presented which showed all drawings had been released with the exception of the Radiator Panel Support Rod drawing. Discussion on the drawings involved the panel brackets motion restraint mechanism particularly where the location of the bolt holes will be and if it could be moved for added design margins and the impact of relocating the bolt holes. It was noted that the spacing between the bottom of the hanging radiator panel and the restraining bracket was about 0.6 of an inch, discussion involved whether this was enough to allow for thermal growth of the panel. On the radiator system assembly chart, a comment was made that the Allied Signal supplied interconnect tube would be a flexible tube. Discussion on the support rod panel retention involved what type of straps might be used, the end fittings of the support rod, placement of the support straps in relation to the support structure of the overhead I-beam. The concern was that these did not interfere with each other. It was noted that a support rod coupling was included in the design to allow installation ease of the panels into Tank 6 facility.

A summary of the thermal analytical methodology was presented followed by pictorial charts of the thermal model setup.

The radiator transient analysis was presented which summarized the cold start and hot restart step functions used in the analysis. A chart showing the time response of these step functions was shown. A comment was made as to the freezing temperature of the n-Heptane fluid which is much colder than the cold start temperature used in the analysis.

The stress and weights analysis presentation was shown with a discussion as to the requirements for safety of margins.

A summary of stability criteria was presented followed by the stability analysis for FC-75 fluid and n-Heptane fluid.

The presentation on the safety plan showed that the safety plan and hazard analysis reports have been released. A review of the system safety hazard classification was presented followed by the final hazard analysis and safety data.

The manufacturing plan was presented showing that the engineering drawings had been released, tool design was reworking the bond molds, permission was being asked to use space station tooling, a sample weld had been made on an extrusion and manifold assembly, and schedules were being worked for release of shop orders. A manufacturing build and flow plan was presented showing the manufacturing flow process.

A total of five RIDS were written, one of which was later withdrawn by the author. Of the remaining four, two were assigned to Loral Vought, one to Rocketdyne and one to NASA.

DESIGN AND ANALYSIS SUMMARY

The Waste Heat Radiator (WHR) panel sizing and performance analysis were finalized with the release of Fluid Systems's thermodynamic performance update of the Closed Brayton Cycle (CBC) engine. The radiator panels are designed to meet the thermal performance requirements of the Solar Dynamic Ground Test Demonstration (SDGTD) program as reflected in Rocketdyne Specification N10118 "Design Requirements Specification for the 2 kWe SD GTD Waste Heat Radiator". The n-Heptane working fluid enter the radiators from the gas cooler at a nominal inlet temperature of 186 °F and returns the fluid to the gas cooler at a temperature of 4 °F. The flow rate is 172.4 lb/hr and the radiator effective sink temperature is -70 °F.

The WHR system has two radiator panels each measuring approximately 70 inches by 144 inches with the panels connected in a series flow configuration. The panels will be hung vertically from the ceiling beam of NASA-Lewis's Tank 6 facility with the inlet and outlet ports of the WHR system located between the radiator panels. Figure 3.3 shows the WHR installation in the Tank 6 facility.

The panels are constructed of aluminum extrusion flow tubes evenly spaced across the width of the panel and aluminum honeycomb placed between the flow tubes. The flow tubes are aligned so that the fluid flows along the length of the panel. This flow tube/honeycomb structure is sandwiched between two 0.010 inch aluminum face sheets. At the ends of the panel are manifold tubes which the extrusion flow tubes are welded to. There are 22 tubes in each panel with only 11 tubes welded to the manifold tube. The remaining flow tubes are inactive and are included to simulate the thermal mass of a redundant flow loop as is the case in Space Station Freedom's radiators. A drawing of the panel construction is shown in Figure 3.4. The radiator panels are coated with Chemglaze A276 thermal control coating.

The radiator panels were designed at steady state nominal operating conditions. A transient analysis was performed to determine the response of the panels from a cold start and a hot restart condition. Results show that the WHR fluid outlet temperature will reach nominal operating condition in about 20 minutes for both cases.

Structural analyses were conducted to determine the stresses that would be incurred due to ground handling loading, pressure loading of the manifold and extrusion flow tubes, and hoist support loads in the attachment fittings of the panels. Analysis shows high safety margins in each of these cases. No special support structure will be required during handling of the panels.

The dry weight of the two WHR panels is 183.2 lbs. The two major components of the panels is the extrusion flow tubes and the aluminum facesheets which make up about 50% of the weight.

An alternate fluid for n-Heptane is FC-75. Fluid stability analyses were performed on both fluids using the flow conditions and thermal environment of the n-Heptane system. Analysis shows that there is no fluid instability with the n-Heptane fluid; however, there is a potential of flow instability with FC-75 when used at the n-Heptane design conditions.

A Safety Program Plan and a Subsystem Hazard Analysis document were submitted on 10 February 1993. The hazard identified was a leakage of n-Heptane. Risk assessment of this hazard identifies no unacceptable conditions that would preclude continuing the ground test program.

TEST PLANS

Acceptance testing of the WHR panels will be done at Loral Vought's Thermal Mechanical Test Laboratory. The tests to be performed on each panel will be a proof pressure test, a leak test, a fluid pressure drop test, a thermal imaging test using a heated fluid flowing through the panels, and a thermocouple instrumentation checkout test. The latter three tests will involved using the CFE Liquid Utility Pallet with n-Heptane fluid. Preliminary test plans were released prior to SDGTD PDR and are in process of being finalized.

Preliminary test plans for component testing and systems integration tests at NASA-Lewis Tank 6 facility were released prior to SDGTD PDR. The test plans are in process of being updated.

OPEN ISSUSES

None.

AGENDA

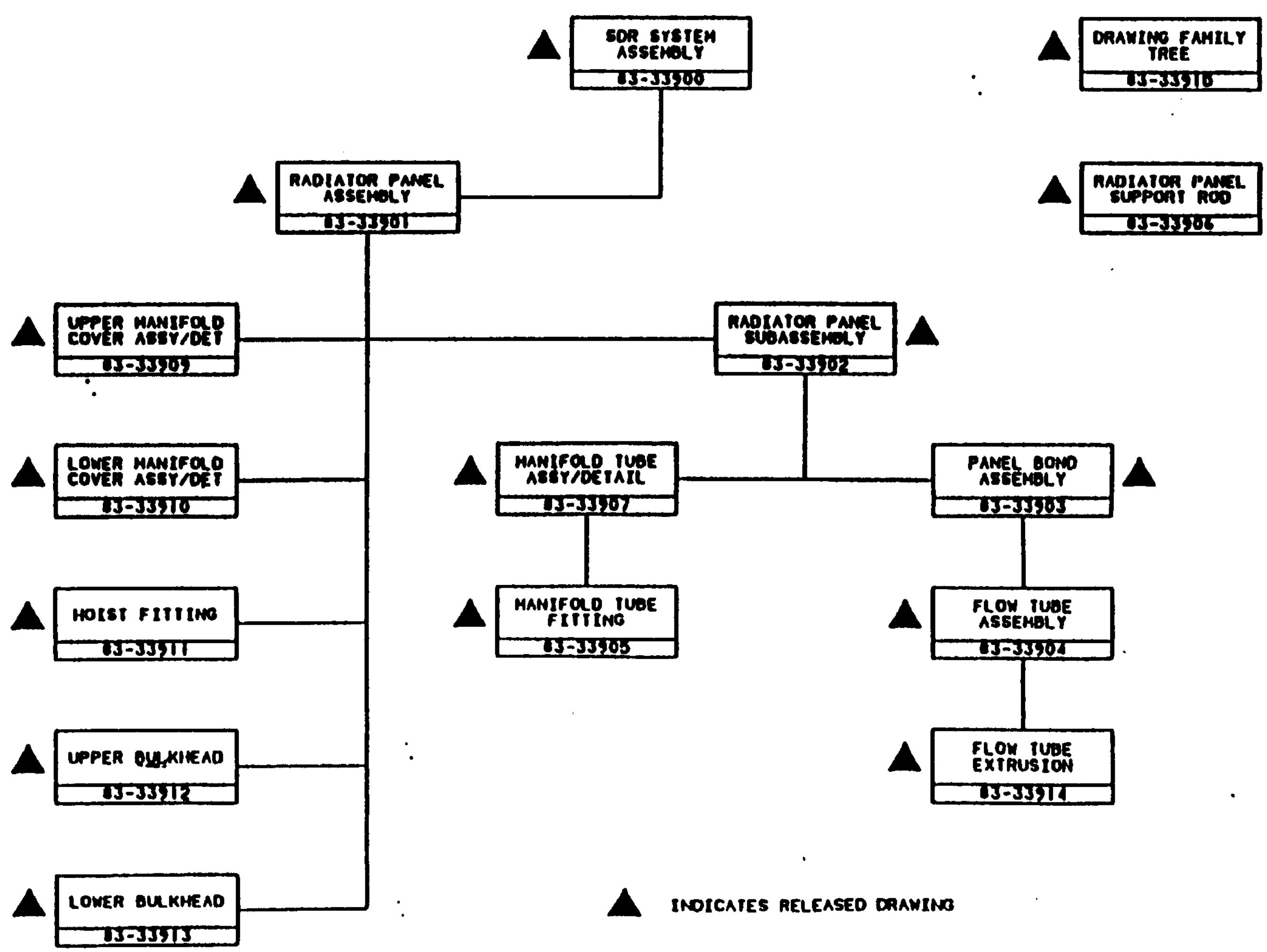
SOLAR DYNAMIC GROUND TEST DEMONSTRATION

WELCOME/INTRODUCTIONS	8:30 – 8:40	
OVERVIEW OF SYSTEM	8:40 – 8:50	MIKE FLEMING
RADIATOR REQUIREMENTS	8:50 – 9:10	ROBERT FLORES
RADIATOR DESIGN		
DESIGN DETAILS	9:10 – 10:40	CHARLIE HOFFMAN
BREAK	10:40 – 10:55	
SUPPORTING ANALYSIS	10:55 – 11:15	ROBERT FLORES
SAFETY PLAN	11:15 – 11:30	JIM ROGERS
TESTING	11:30 – 11:45	ROBERT FLORES
LUNCH	11:45 – 1:00	
MANUFACTURING/TOOLING	1:00 – 1:10	TOM GILCHRIST
QUALITY PROGRAM	1:10 – 1:30	MARVIN NEIL
MATERIALS PURCHASING STATUS	1:30 – 1:40	DON LOSER
FACILITY TOUR	1:40 – 3:00	TOM GILCHRIST
ACTION ITEM REVIEW	3:00 – 4:00	ALL

FIGURE 3.1

FIGURE 3.2

SDR DRAWING FAMILY TREE



RADIATOR PANEL TEST SET-UP

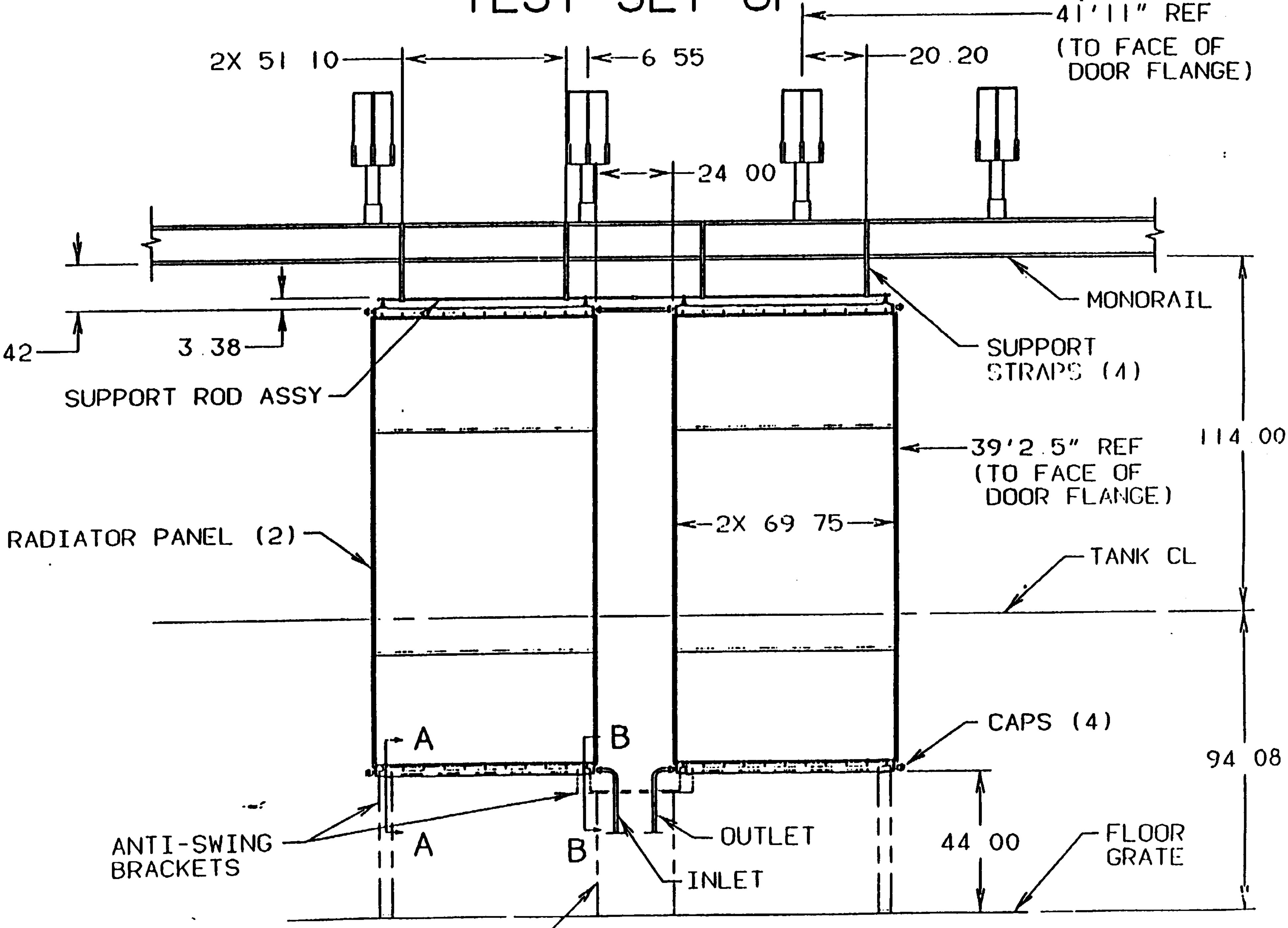


FIGURE 3.3

PANEL BOND ASSEMBLY

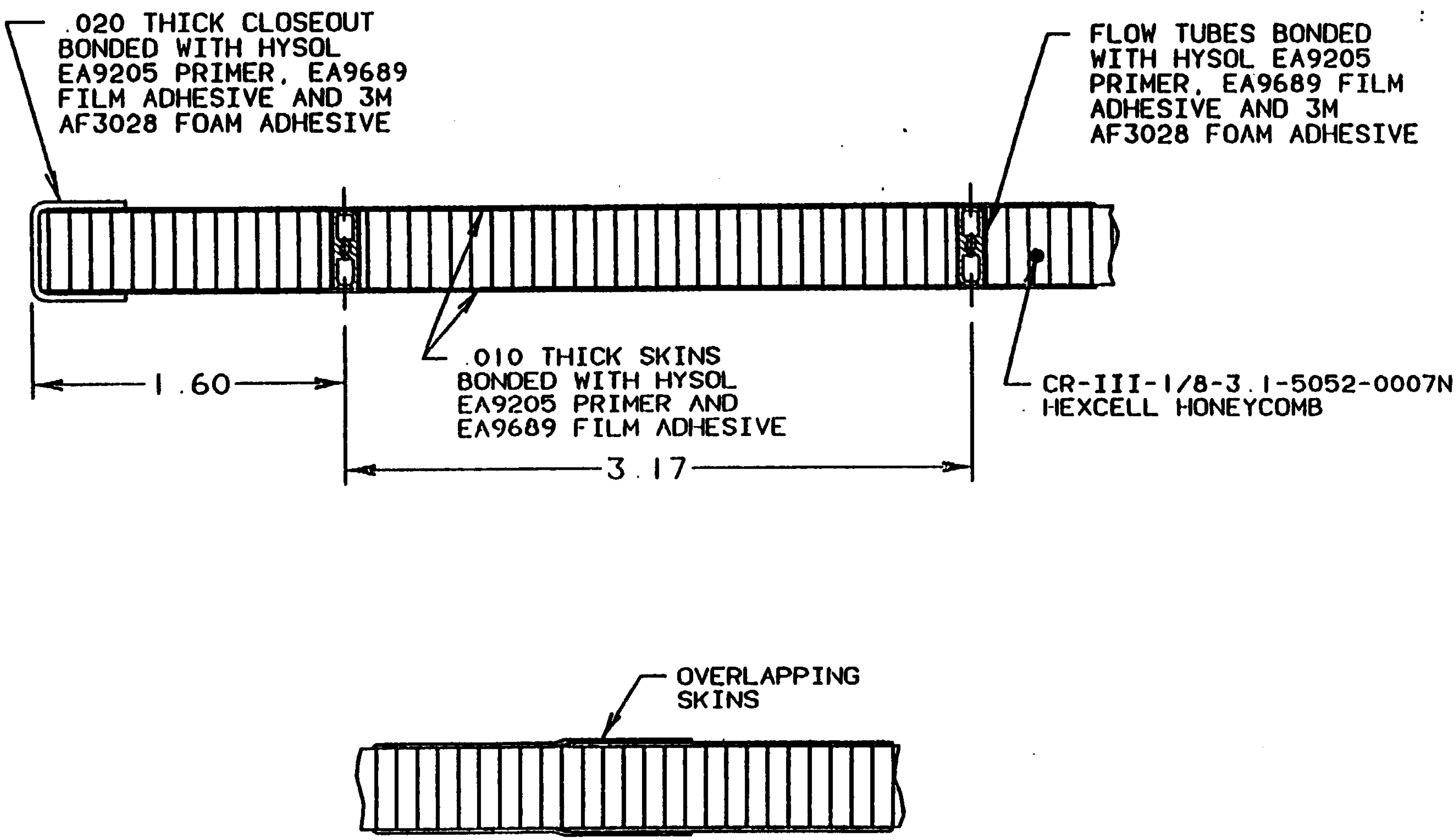


FIGURE 3.4

4. Concentrator

4.1 Concentrator Design Document List

Document Number	Document Title	Scheduled Signoff	Actual Signoff
2001423	Reflective Facet SOW		
7000493	Reflective Facet Assy Spec		10/15/92
7000494	Facet Dev. & ATP		10/15/92
	Rev A		03/15/93
7000495	Concentrator ATP		10/15/92
	Rev A		03/15/93
7000496	Flux Distr. Test Plan		10/15/92
	Rev A		03/10/93
7000498	Facet Alignment Plan		03/10/93
7000499	Hex P/L Verification		09/18/92
	Rev A		01/25/93
7000500	Support Str. P/L Plan		02/18/93
7000502	Spares List (LS-01)		10/16/92
7000503	Manufacturing Plan		1/31/93
7000504	Flux Distr. STE C/O Plan	4/30/93	

4.2 Concentrator CDR Minutes

The SDGTD Concentrator Critical Design Review was held in Palm Bay, Florida on 13-14 April 1993.

Dr. Bill Tankersley, Director of Business Development for Harris GASD Space Systems Product Line made a few welcoming remarks before the review began. The review began with an overview by Paul Jensen. George Borell followed with the requirements/performance matrix, deviations and waivers, ICD Status, action item status and risk assessment/mitigation. NASA stated that they would try to push ahead vibration testing of the tank as much as possible to address vibration load risks.

Paul Schertz, of Solar Kinetics Inc., then presented the facet development summary and status. NASA indicated that an 85% reflectance value is extremely important.

Scott Streetman (Harris) presented the Design of the Concentrator. NASA was concerned about using an insert in the aluminum corner fitting. An insert had yielded the parent material in a corner fitting in NASA's concentrator mock-up. Harris said all components had positive stress margins. Other discussions were on fitting threads and how to prevent a loose fit, cold welding/Brinelling of ball/socket joints. Action items were written on these subjects. There was concern about cuffing the web of the old SCAD latches and strikers. Upon discussion the group agreed it was satisfactory. There was concern over the assembly sequence of the concentrator - the last hexes are up high. No action items resulted however. The concern over facet size and fitting location did result in a action item to minimize chance of interference.

Dave Bahnman presented the Design of the Support Structure. NASA cannot meet previous agreements (January TIM in Cleveland) on BAP hole tolerances, so an action item was written to resolve this. Harris agreed to give Rocketdyne the mass of the concentrator and support structure on a monthly basis.

Susan Smith presented the Structural Analysis of the concentrator and support structure. The static and thermal load analysis presentations and conclusions were straight forward. The shock load analysis raised concern because of the large negative margins in support structure parts. The validity of the shock load requirement must be readdressed later (it is requirement for analysis only, not a design requirement). Facet distortion analysis was presented. The results were included in the optical analysis, to be discussed later.

Jay Campbell started the second day of the design review with the Thermal Analysis presentation. All assumptions, techniques, and conclusions were acceptable.

Jay continued with the Optical Design. An analysis that includes (a small amount of) receiver shadowing of the concentrator needs to be performed. He also agreed to perform a transient analysis, instead of just steady state hot and cold. The combination of error/uncertainties in the analysis was discussed. The presented numbers for flux peaks and tube-to-tube variations are probably intolerable by the receiver. A Monte Carlo combining technique could be used, but requires considerable time and effort. The idea was tabled for now, and a deferred action item was written.

Jeff Dupper presented the test plans and special test equipment preliminary design. There was discussion about the number of thermal cycles the facets should be tested to, though no definite conclusion was reached. Jay presented the decision-making process for selecting a laser method over a light bulb method.

Kent Jefferies, NASA, presented a chart concurring with decision while asserting that methods were both technically satisfactory. Jeff also answered two outstanding ar s action items regarding flux measurement accuracy. Several actions resulted regarding instrumentation locations, cabling, etc.

Action items were reviewed, assigned and agreed to (this was done at this time because some people had to leave to board planes). Action items are listed in Appendix 1.

Paul Jensen then presented the Manufacturing Overview. He also presented the Hazard Analysis. The format for the Hazard Analysis was not per the latest request, Harris agreed to change. And Harris also agreed to add hazards for the shock load and for vibration loads.

A side session was held on Product Assurance.

A CDR package was compiled that incorporated change pages and fixed typographical errors, etc. Reproducible copies will be provided to NASA, Fluid Systems and Rocketdyne.

4.3 Design Description

The Concentrator design is shown in Figure 4-1. This design has matured in the months since PDR in several important ways:

1. The shape of the Concentrator was redesigned immediately after PDR due to a change in solar simulator shape and distance. The simulator changes resulted in a concentrator design more sensitive to off-nominal performance issues.

2. The concentrator hex panel corner fitting design was adapted to enable operation a low temperatures. The basic corner fitting design was taken from the SCAD concentrator, which was only designed for room temperature operation. The corner fittings now include a shouldered bolt which ties together the shear plate, hex beam, and corner fitting. This design eliminates structural requirements on the epoxy bond at the corner, thus minimizing required test and analysis. This design is shown in Figure 4-2.

3. The support structure design was matured and has been adapted to the interface with the BAP. The support structure has significant adjustment capability at the expense of a robust load carrying capability. This is appropriate for a ground-based engineering experiment.

4. Thermal analysis at PDR indicated that facets and corner fittings would operate at the extremes of the acceptable range during testing. Analysis also identified the sensitivity of concentrator performance to support structure temperature excursions. Four thermal design solutions have been implemented to control these conditions:

   a. The cold wall section nearest the concentrator has been turned off. This reduces the temperatures of the facets and corner fittings.

   b. A high emissivity coating (tape) has been added to the rear surface of the facets to provide better radiation heat transfer from the facet to the tank end cap, which is quite warm.

   c. The shouldered bolts described above were added to provide positive load-carrying ability at cold temperature.

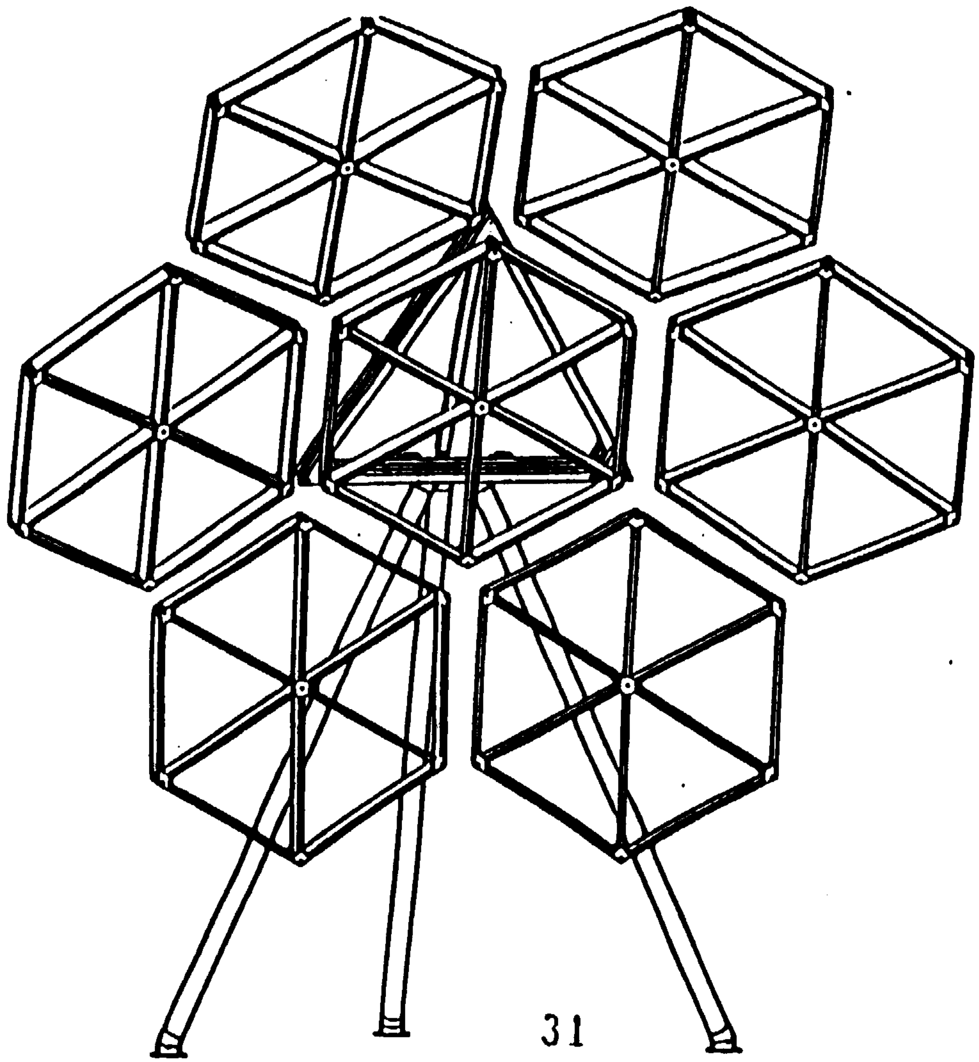


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Figure 4-1. SDGTD Design

HEX PANEL CORNER JOINT
DETAIL VIEW

- INTEGRITY OF CORNER JOINT IS INSURED BY MECHANICAL FASTENERS
- BEARING BLOCK REACTS BENDING MOMENT IN BEAMS
- TITANIUM SPACER IS NECESSARY TO AVOID FRACTURE OF BEAMS WHEN HOT

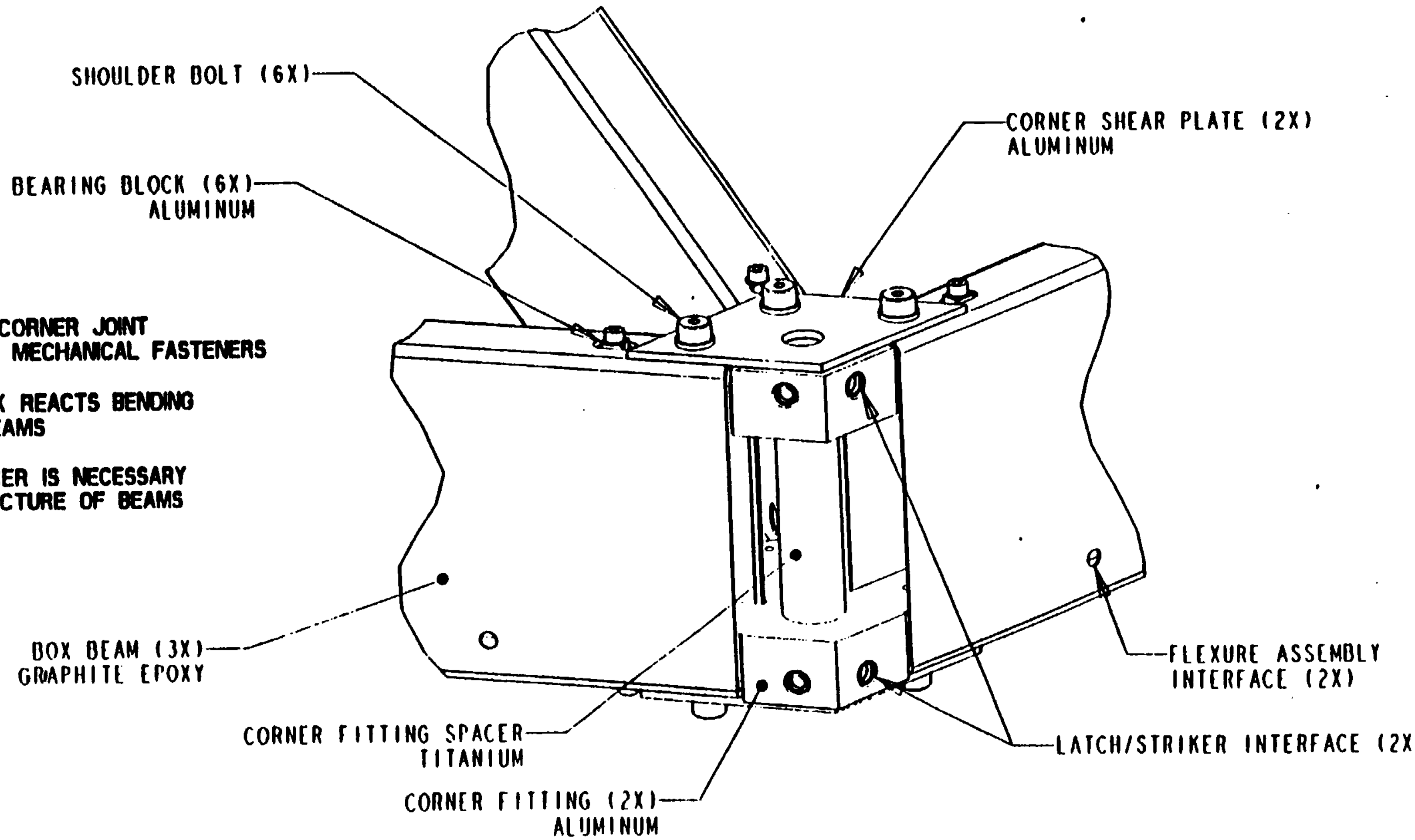

Figure 4-2. Hex Panel Corner Joint Page #40

d. White paint was added to the support structure to minimize absorbed heat flux and to reduce temperature excursions.

5. Structural analysis of the concentrator and support structure was conducted to evaluate combined thermal and 1 g loads and vertical and lateral handling loads. The concentrator and support structure have positive margins for all combined thermal and 1 g loads as well as handling loads. Factors of safety of 1.5 to 2.5 were used in these margin calculations depending on the nature of the specific item.

6. Optical analysis has identified new off-nominal performance values based on the PDR solar simulator and CDR concentrator shape. The off-nominal cases show slightly higher peak fluxes (approximately 30 sources), significantly higher tube-to-tube variations (±40 percent) and marginally higher aperture plate spillover.

4.4 Facet Fabrication Development Status

The following is the status of SDGTD Facet Development as of Harris' CDR, 13 April 93:

The basic design of the aluminum honeycomb facet has been established. It will be front and rear aluminum sheets with an aluminum honeycomb between. The front sheet will have a layer of polymide levelizer and a layer of vacuum deposited aluminum for the reflective surface. The interface drawing has been released and contains overall and insert dimensions and tolerances. The radii of curvature are firm at 18 facets of 200 inches and 24 facets of 247 inches.

Development work has centered around achieving acceptable specular reflectivity: greater than 85% at a 15 mrad aperture and a goal of greater than 85% at a 7 mrad aperture. The parameters affecting specularity include the levelizer "smoothness" and the print through of the honeycomb core.

The adhesive selected (at 13 April) to bond core to facesheets was EA9396 (without filler). This results in acceptable print through.

An SKI proprietary levelizer is being used. Specular Reflectivity of 86% at 15 mrad but only 75% at 7 mrad has been achieved. The next step is to investigate oxide

removal methods from the aluminum, try a 20 mil thick front facesheet, and after cure temperatures and times.

Two tool tasks are complete: sheet forming and spin coater. The others are either in design or assembly: punch and trim, material prep, and assembly tooling.

The PDR for the facets is planned for late June.

4.5 Test Plan

Test planning continued between PDR and CDR. The following test plans were updated:

1. Support Structure Verification - a test conducted to verify the support structure is capable of withstanding the expected loads due to the combination of thermal and weight conditions. A proof load of 2X will be applied to the support structure. Support structure stiffness will also be verified. In addition, interface and instrumentation features and operation will be verified.

2. Hex Proofload Test - a test to verify hex panel assembly and bonding workmanship.

3. Facet Development and Acceptance Testing - planned to be conducted to verify the facet radius of curvature, slope error, hemispherical reflectivity and specular reflectivity. In addition, changes in radius of curvature and slope error will be evaluated under exposure to vacuum and temperature conditions.

4. Facet Alignment Technique Verification - planned to be conducted to demonstrate the facets can be aligned to meet the requirements determined by system analysis using the identified procedures, equipment, and software. The testing will also verify that the process is repeatable.

5. Flux Distribution Testing - planned to measure the concentrator incident flux distribution on the walls of the receiver when the concentrator is exposed to the solar simulator and the Tank 6 thermal/vacuum environment. As a result of suggestions at PDR, the selected test approach uses direct flux measurement at receiver canister locations rather than indirect aperture measurements that require optical codes to calculate canister flux.

4.6 Open Issues

The following are the major open issues for the SDGTD Concentrator as of its CDR on 13 April 1993:

1. The outgassing of the facet levelizer and facet adhesive slightly exceed Hi-Rel space requirements. Waivers must be submitted.

2. The desired facet reflectivity has not been demonstrated at a 7 mrad cone angle. Levelizer application and facesheet type need to be addressed. [Update: Levelizer a.nd 20 mil front facesheet have been selected.]

3. The off-nominal (worst case) flux distribution may exceed the desires of AlliedSignal ASE.

4. The flux sensor for the Flux Distribution Test has not been selected. Candidates include a pyroheliometer and solar cells. [Update: Solar cells have been selected as the sensor]

5. The thermal control paint for the support structure has not been finalized requirements have been established. [Update: White chemglaze has been selected as the paint for the support structure.]

6. Thermal control treatment for facets has not been finalized.

5. HEAT EXCHANGERS

5.1 DESIGN DOCUMENTS LIST

The following documents were prepared and transmitted to Fluid Systems to support the CDR:

(a) December 1992

(1) Acceleration schedule

(2) Quality assurance plan review (Memo 29317-57200-639)

(3) Recuperator refurbishment plan (Document 92-65708)

(4) SE-02, comments on interface control drawings (Memo 39317-57200-005)

(b) January 1993

(1) Single tube test plan (Document 93-65811)

(2) Receiver layout

(3) Long-lead materials on order

(4) Special test equipment (STE) on order for single tube test (Memo 39314-72399-006)

(5) Accelerated expenditure planning

(6) Customer-directed changes (cooler, foil bearings)

(c) February 1993

(1) Program management review charts (Loral Vought, Dallas, Texas)

(d) March 1993

(1) Product assurance plan comments (PA-01) (Memo 39314-72399-023)

(2) An industrial safety letter (PA-01) (Memo 39312-72399-023)

(3) An update to the recommended spares list (LS-01) (Memo 39314-72399-021)

(4) Drawings (MA-05) for the canister, canister assembly, and single-tube test assembly (Memo 39314-72399-018)

(5) A drawing tree (MA-05) (Memo 39314-72399-018)

(6) P and ID drawing comments

(e) April 1993

(1) Receiver spares list, CDR update (LS-01)

(2) Test plan, cooler, CDR update (SE-03) (Document 93-66142)

(3) Test plan, receiver, CDR update (SE-03) (Document 93-66141)

(4) Hazard analysis (PA-01) (Document 93-66189, Rev. 1)

(5) Receiver detail drawing package (MA-05)

(6) Refurbishment and acceptance test report for recuperator (HW-01, E-01) (Document 93-66138)

(7) Review documentation

- CDR agenda (Memo 39314-72399-024)
- CDR package (Document 93-66172)
- CDR charts (Document 93-66201, Rev. 1, May 12-14, 1993)

(8) Receiver specification review

(9) Foil bearing drawings and acceptance test data

- Drawings 2207317, 2207311, 2207312
- Memo 39308-48705-005

(f) May 1993

(1) Critical design review (CDR) was held on May 12 through 14, 1993 in Los Angeles. A document summarizing the CDR meeting minutes and action items was issued (39314-72399-042).

5.2 DESIGN REVIEW MINUTES

The CDR meeting minutes and action items were submitted to Fluid Systems via Memorandum 39314-72399-042. Major discussions held during the presentation at CDR included the following.

5.2.1 Analysis

Incident flux distribution: The off-nominal flux distribution analysis (canister and tube to tube) was not officially part of the CDR, but was included as a splinter session following the CDR.

Receiver startup: A discussion regarding startup preference was held. It was suggested that the startup procedures be changed to delay turning on the engine until the second orbit. Fluid Systems took the action item to run the system model for both cases for NASA and ASE to review.

Pallet motions: The pallet motions were discussed. There was some confusion regarding the coordinates.

5.2.2 Design

Materials concerns: Several questions were raised regarding materials, i.e. monoball lubricant, silicon carbide cloth for inner liner, and outgassing of materials. Action items were generated to address the concerns.

Interfacing: An action item was generated to define a dimensioning scheme for aligning the ducting between the receiver and the PCS.

5.2.3 Fabrication

Emissivity: An emissivity discussion was held regarding the coating for the full-size receiver. A matrix was created to compare the three possibilities. ASE took the action to issue and execute an emissivity plan.*

Single tube test: A discussion was held regarding disposition of the single tube after testing. NASA will direct ASE after the test.

5.3 RECEIVER DESIGN SUMMARY

The receiver design (shown in Figures 1 and 2) comprises a cylindrical receiver cavity, the walls of which are lined with a series of tubes running the length of the cavity. The receiver incorporates integral thermal storage, using a eutectic mixture of lithium fluoride and calcium difluoride as the thermal storage solid-to-liquid phase change material (PCM). This thermal storage is required in order to enable power production when the solar simulator is off (equivalent to an eclipse period for a typical low-earth orbit). The eutectic has a melting point of 1413°F.

The working fluid flows through a finned annular region in the tubes. The PCM is contained in a series of hermetically sealed metal containment canisters. The canisters are stacked and brazed to the working fluid tube.

The receiver cavity walls consist of a metallic shell with an inner ceramic cloth liner. The shell is externally insulated.

The receiver configuration combines three functional components—the heat receiver, the heat source heat exchanger, and the thermal storage device—into a single unit. The working fluid from the recuperator flows to a toroidal manifold at the aperture end of the receiver. The manifold distributes the fluid to the individual tubes. The flow is collected in the outlet manifold and sent to the turbine.

* Please note that an emissivity plan was prepared and submitted by June 2, 1993. The plan was executed, which resulted in a decision to incorporate alumina-titania surface treatment as the emissivity coating for the full-size receiver.

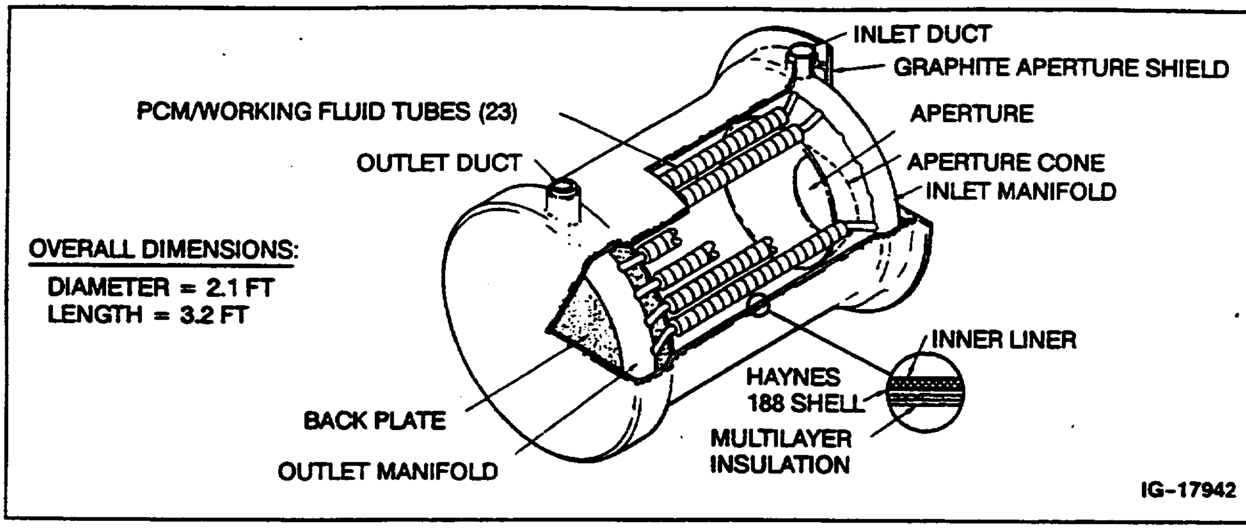

Figure 1. SDGTD Receiver

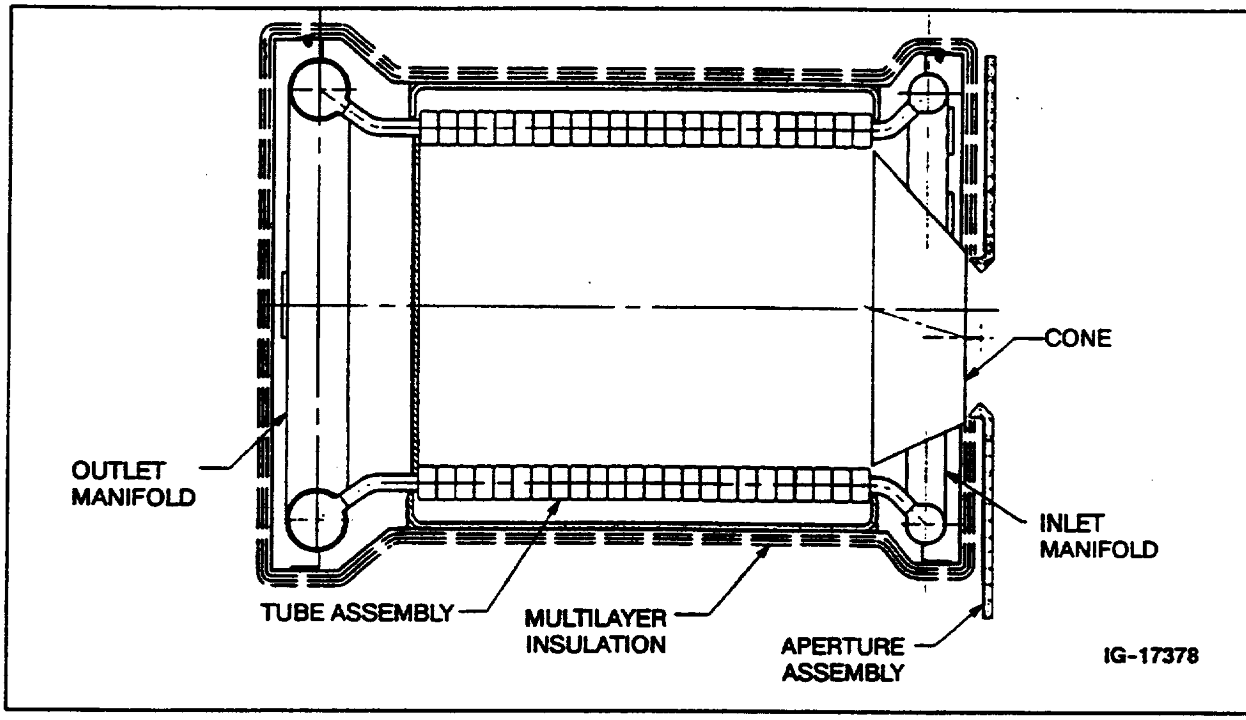

Figure 2. Receiver Section View

During simulated sunlight periods, heat is transferred through the PCM to the CBC working fluid. The PCM is also melted and heated by the solar flux. During eclipse periods, the PCM transfers heat to the CBC working fluid and is frozen and cooled.

As indicated in Figures 1 and 2, the receiver comprises 23 tubes, with 24 containment canisters per tube. The canister size, tube diameters, and material are identical to the Freedom configuration, which has undergone extensive design, fabrication, and testing efforts at AlliedSignal. Significant test efforts have also been performed by NASA Lewis Research Center.

The receiver weight breakdown is presented in Table 1.

TABLE 1

RECEIVER WEIGHT SUMMARY

Component	Weight, lb
Phase change material	53
Working fluid tubes	44
Containment canisters	109
Manifolds and ducts	62
Outer shell assembly	109
Tie rods, mounts, supports, and brackets	25
Aperture assembly	38
Total receiver	440
Support frame	230
Total receiver and frame	670

The receiver gas circuit, outer shell assembly, and aperture assembly are each independently mounted to a support frame, using tie rods, as shown in Fig. 3. The approach minimizes weight-induced and thermally-induced stresses by off-loading weight from the gas circuit and allowing thermal growth.

The following paragraphs contain descriptions of the various components of the receiver.

5.3.1 Containment Canister

The containment canisters are individual compartments that contain the PCM. The canister material is the cobalt-base superalloy Haynes 188. The canisters are sealed by vacuum electron beam welding after filling with the PCM through a small fill-hole. The canisters have a 1.78-in. OD and a 0.94- in. ID, and are 1.00 in. long. The sidewall and outer wall thickness is 0.060 in. The inner wall thickness is 0.032 in. A fabricated containment canister is shown in Figure 4.

The canisters are stacked and brazed to the working fluid tube as shown in Figure 5. The canisters are not brazed to each other, but are separated by amorphous silica spacers.

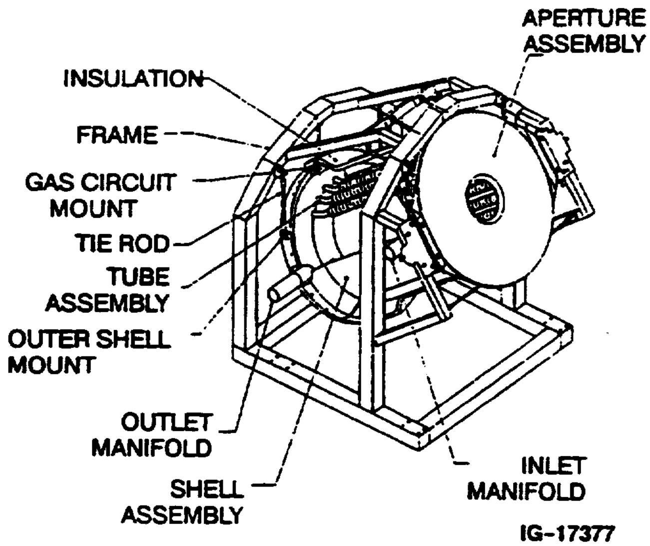

Figure 3. Receiver Assembly Overview

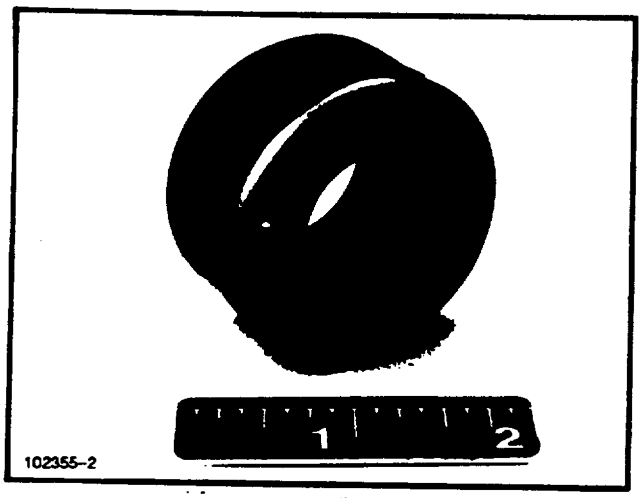

Figure 4. Containment Canister

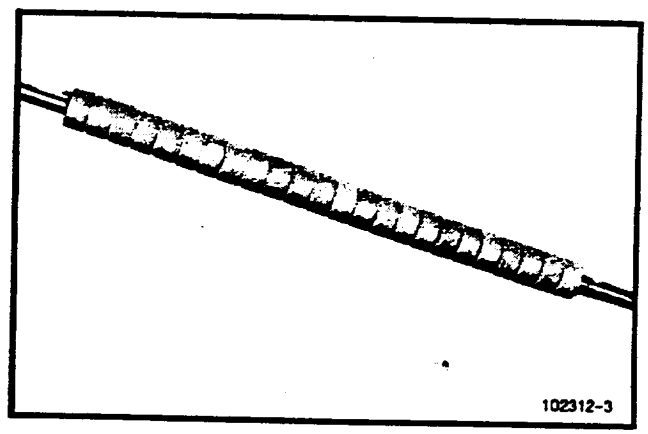

Figure 5. Canisters Brazed to Working Fluid Tube

The use of individual containment canisters for the PCM is a key attribute of the receiver design. This configuration affords a readily fabricable and highly reliable design. Failure of a canister would affect only that individual canister, and have minimal impact on receiver operation. The compartmentalization also reduces the chance of failure by localizing the void formation upon freezing (due to the lower density of the liquid as compared to the solid), minimizing the likelihood of high stress buildup.

The thick-walled canisters are very durable and afford adequate resistance to long-term space exposure considerations such as sublimation and atomic oxygen attack. In addition, the canister sidewalls provide adequate heat transfer paths, thus obviating the need for PCM thermal conductivity enhancement.

The canisters are designed to avoid thermal ratcheting. Heat is added at the outer surface and removed at the inner surface. This allows for void formation at the hot face during freezing, such that liquid formed during melting can expand into the void.

5.3.2 Gas Circuit

The gas circuit consists of the 23 working fluid tubes and the manifolds. The entire gas circuit is made of Haynes 188. The tubes are approximately 2.3 ft long and have a 0.875-in. OD and a 0.035-in. wall thickness. Fluid flows through the tubes via a finned annular region, as shown in Figures 6 and 7. The center of the tube is blocked to increase the flow velocity. The fin, which is 0.006 in. thick, is brazed to the tube inner wall and the outer wall of the centerbody blockage. The fins form twenty flow passages. To prevent fluid channeling in the event of a poor braze between the fins and the tube wall, the fins are installed in 3-in.-long sections. Adjacent sections are slightly offset, allowing flow redistribution.

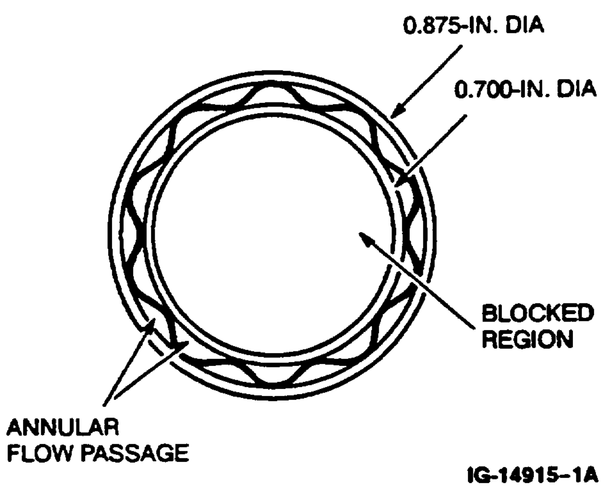

Figure 6. Tube Cross Section

Figure 7. Finned Tube

The fins act to decrease the hydraulic radius of the flow passages. This results in an increased heat transfer coefficient for the constant Nusselt number flow regime. Along with the increase in heat transfer surface, a significant enhancement in heat transfer rate is afforded by the configuration.

As shown in Figure 2, both the inlet and outlet ends of each tube are bent. The bending accommodates differential tube-to-tube thermal expansion and reduces thermal stresses. The differential thermal expansion is due to the circumferentially asymmetric incident flux arising from the offset parabolic concentrator. There are no fins in the bent tube ends.

The tubes are connected to toroidal manifolds. The manifold holes are ported to aid in welding and reduce the difference in wall thickness between the tubes and the manifolds (see Figure 8). Tube spacing is 2.6 in. center to center. The inlet manifold has a major diameter of 23 in., a minor diameter of 2.0 in., and a wall thickness of

0.05 in. The outlet manifold has a major diameter of 23 in., a minor diameter of 3 in., and a wall thickness of 0.20 in. The large difference in manifold wall thickness is driven by stress considerations. It is desirable to reduce the outlet manifold stress at the expense of the inlet manifold stress, since the high temperature at the outlet end results in creep damage. The inlet end temperatures are below the creep threshold for Haynes 188.

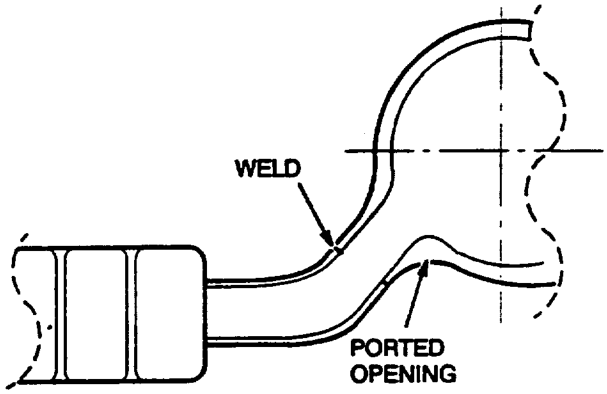

Figure 8. Tube/Manifold Details

The gas circuit is supported through the manifolds to the external support frame through a series of tie rods, as shown in Figure 9. There are five tie rods on the inlet manifold and one on the outlet manifold. This arrangement is designed to relieve the more critical outlet manifold as much as possible. The tie rods incorporate spherical rod ends to allow for rotation while restricting motion in the tie rod axial direction.

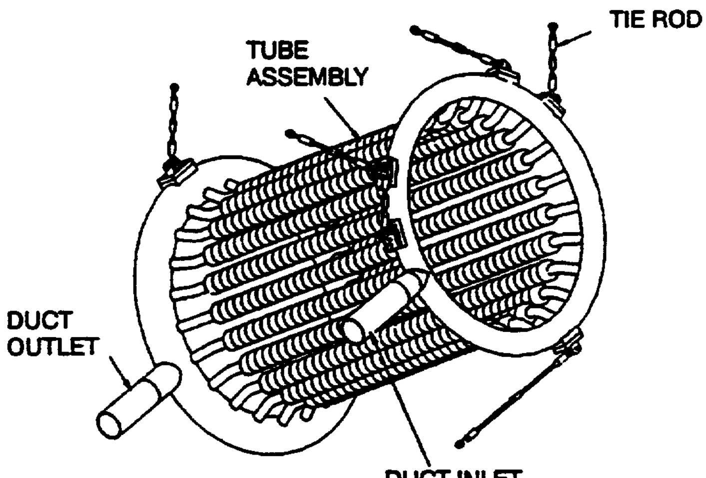

Figure 9. Receiver Gas Circuit

The mounting configuration provides restraint of motion to six degrees of freedom. This results in a statically determinant structure and allows for thermal growth with essentially no additional thermal stresses imposed on the gas circuit by the mounts.

5.3.3 Outer Shell Assembly

The outer shell assembly comprises an inner liner, a metallic shell (including an aperture cone), and external insulation. The assembly is shown in Figure 10 (without insulation for clarity). The inner liner, which defines the cavity walls, consists of layers of silicon carbide cloth stitched together, with silicon carbide fiber in between the layers. The liner assembly sections are attached to the metallic shell with wire fasteners, as shown in Figure 11.

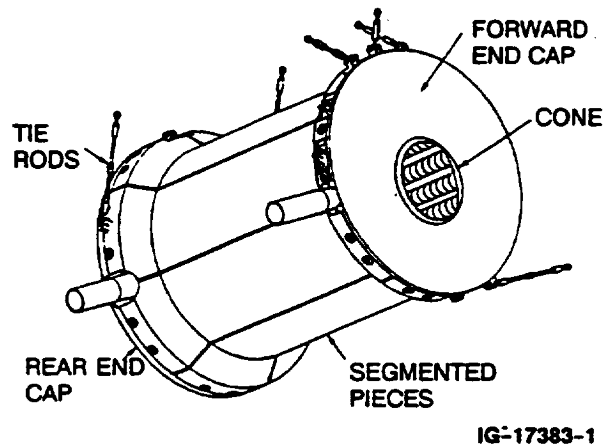

Figure 10. Receiver Outer Shell Assembly

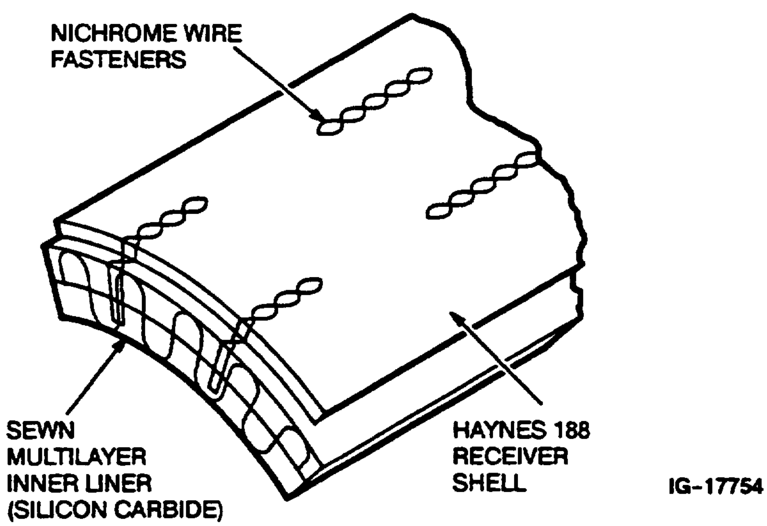

Figure 11. Inner Liner Attachment

Since there is a reasonably large gap between tubes, some of the radiation entering the receiver through the aperture will impinge directly on the walls. The walls act to reradiate the incoming flux to the back side of the tubes and aid in providing a relatively uniform flux circumferentially around the tubes.

The outer shell consists of eight segmented cylindrical pieces attached to end caps. The outer shell provides the support structure for the inner liner, a mandrel for the outer insulation, and an attachment structure for the aperture cone. The configuration is shown in Figure 12. The aperture cone is configured to represent the envelope of the incoming light rays from the concentrator, while protecting the manifold from cavity reradiation (see Figure 2). The outer shell, end caps, and aperture cone are made of Haynes 188.

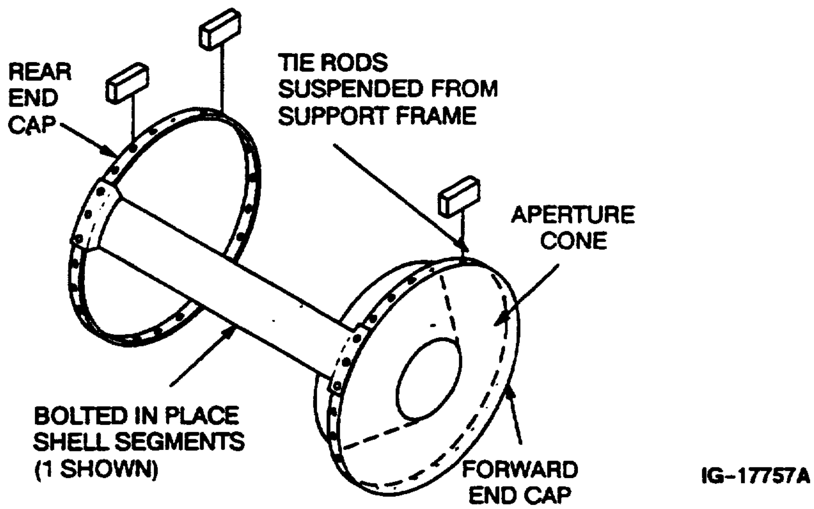

Figure 12. Outer Shell Assembly

The outer shell assembly is attached to the support frame with six tie rods, four on the forward (aperture) end and two on the rear end. The outer shell mounting, which is totally independent of the gas circuit mounting, provides for a statically determinant structure, with six degrees of freedom restrained, allowing for thermal growth with essentially no additional thermal stress imposed on the assembly by the mounts.

The receiver insulation comprises high-temperature multilayer insulation (MLI) wrapped around the outer shell. The MLI consists of alternating layers of metallic foil and amorphous silica cloth. Forty foil layers are used—30 layers of nickel and 10 layers of aluminum. The total insulation thickness is 0.75 in.

5.3.4 Mounts/Tie Rods

As previously discussed, tie rods with spherical rod ends are used to transfer receiver loads to the support frame. The gas circuit and outer shell are independently supported. As shown in Figure 13, the tie rods with spherical rod ends are attached to the structure through a clevis mount, mount base, and pin. The clevis mounts are oriented on the mount base such that no bending moments are induced in the mounts.

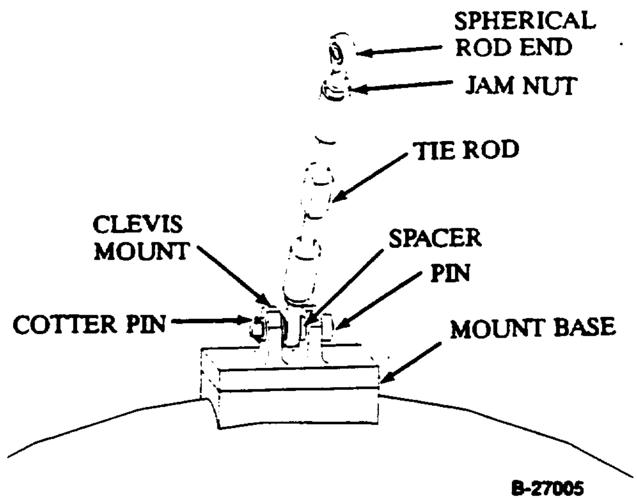

Figure 13. Mount Configuration

The mount structure and tie rods are Haynes 188 with the exception of the spherical rod ends, which are Haynes 25.

5.3.5 Aperture Assembly

The receiver aperture accepts the simulated solar flux from the concentrator. The aperture is 7 in. in dia. The centerline of the aperture is offset 1.5 in. from the centerline of the receiver to better match the asymmetric flux from the offset parabolic concentrator. The aperture position is defined by the aperture assembly, which must accept the steady-state spillage from the concentrator as well as any transient flux during simulated sun acquisition. The aperture assembly is shown in Figure 14.

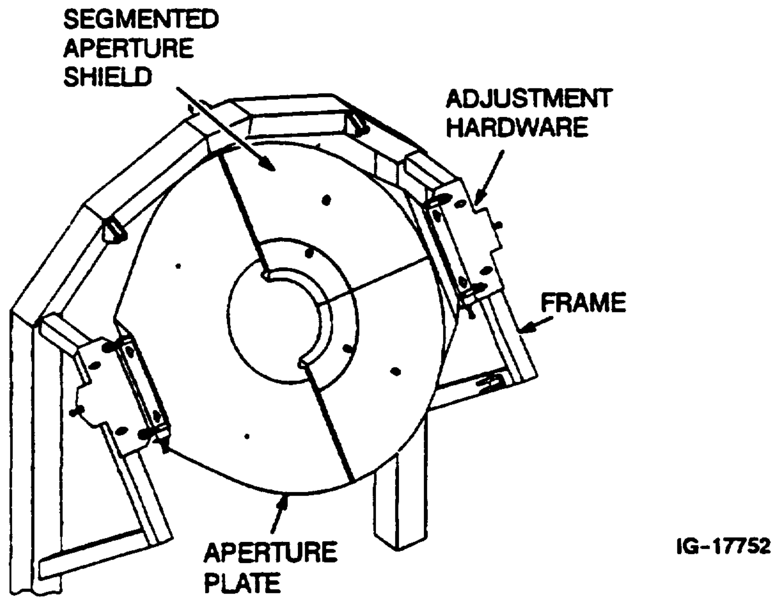

Figure 14. Receiver Aperture Assembly

The aperture assembly comprises an aperture plate and an attached aperture shield. The aperture plate is a circular disk of A-286 stainless steel, 30 in. in dia, 0.063 in. thick, with an 11-in.-dia hole in the center. The aperture shield, which protects the aperture plate from flux spillage, is made of 0.5-in.-thick high-purity graphite (UCAR grade ATJ, manufactured by Union Carbide) divided into eight overlapping segments. The aperture shield has a 30-in. OD and a 7-in. ID. Graphite was selected because of its very favorable properties, including high temperature capability, high heat capacity, excellent thermal conductivity, and excellent thermal shock resistance (due to a low coefficient of expansion and a low modulus of elasticity). The segmenting of the graphite will further improve the thermal shock resistance.

The graphite segments are slotted and attached to the aperture plate using A-286 fasteners. The arrangement forms a loose connection to enable unrestricted thermal growth.

The aperture plate is attached to the frame structure through slotted mount brackets. The mounting hardware is designed to restrain six degrees of freedom, providing a statically determinant structure, allowing for thermal growth with essentially no additional thermal stress imposed on the plate by the mounts. The mounting hardware has adjustment features that can be used to locate the aperture with respect to the frame. The aperture assembly mounting is independent of the gas circuit and outer shell mounting.

5.3.6 Frame Support Structure

The frame structure, which supports the receiver, is shown in Figure 15 (see also Figure 3). The gas circuit, outer shell assembly, and aperture assembly are independently mounted to the frame. The frame is made of 3-in. square stainless steel tubing. The mounts are welded to the frame.

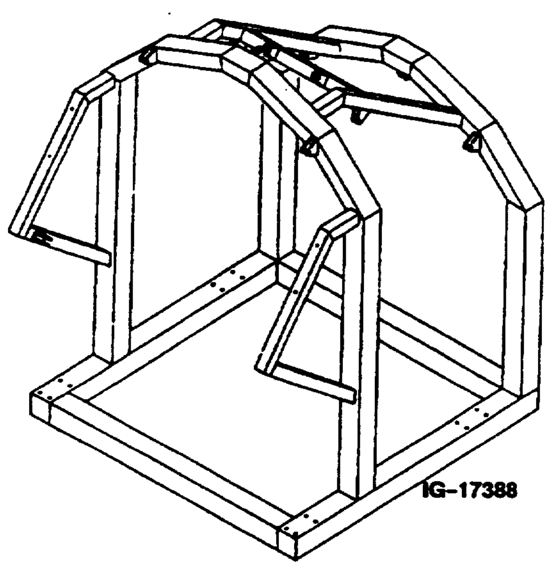

Figure 15. Receiver Frame

5.4 RECEIVER ANALYSIS SUMMARY

The major accomplishment presented at the PDR was the canister life analysis. The maximum total creep strain for 1000 hours of orbital operation was demonstrated to be comfortably under the allowable creep rupture ductility. The major objective for the CDR is to show adequate life for the gas loop (tube and manifold assembly). Results are also presented for analyses performed to confirm the structural integrity of the outer shell, aperture plate, mounting system, and power conversion subsystem (PCS) interface.

5.4.1 Design Conditions

Gas loop and outer shell temperatures were predicted based on the incident flux distribution presented at the ASE preliminary design review. This particular distribution is referred to as the nominal flux distribution and is identified as Harris Corporation file ELL68.C1, 9/18/92. The total power into the aperture was adjusted to 12.725 kw. One exception was the analysis of the aperture, which utilized a higher-flux off-nominal condition.

Receiver design code SOLREC-TSD, which is used to predict temperatures throughout the receiver, was not rerun to account for the effect of a 1.5-in. offset aperture, a change that occurred after the PDR. The effect on the gas loop temperatures as a result of the offset aperture is believed to be negligible.

5.4.2 Structural Models

The following approach was taken to determine the stress at critical areas within the gas loop. Global finite element models were constructed using the ANSYS computer code. These models represented entire receiver components using a relatively coarse grid. At critical junctions, detailed zoom-in models were constructed using ANSYS and CAEDS computer codes and a fine grid. Results from the global models were used to set the boundary conditions for the zoom-in models.

5.4.2.1 Manifold/Tube Structural Model

The model, shown in Figure 16, comprises 1350 elements with 28 elements for each tube. The tube elements include the significant stiffness effect of the attached canisters and internal fins. The tube ends are bent to take up thermal expansion and reduce thermal stresses. There are no internal fins in the tube bends.

5.4.2.2 Gas Circuit Support System

The selected mounting scheme is to use a statically determinant system with six degrees of freedom restraint. The primary benefit of this approach is that essentially no additional stresses are imposed on the structure due to thermal growth. The model, shown on Figure 17, uses links with rod end bearings to connect manifold lugs to lugs in the support structure.

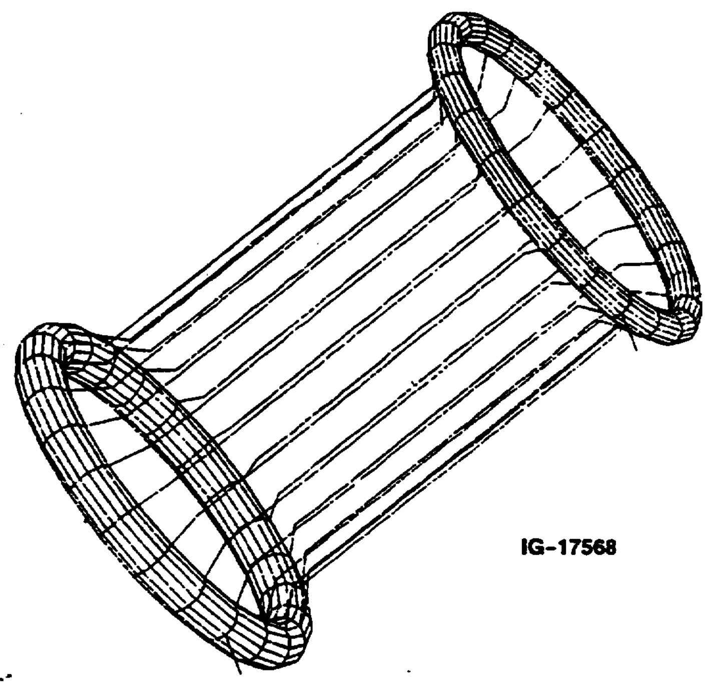

Figure 16. Gas Circuit Structural Model with Attached Ducts

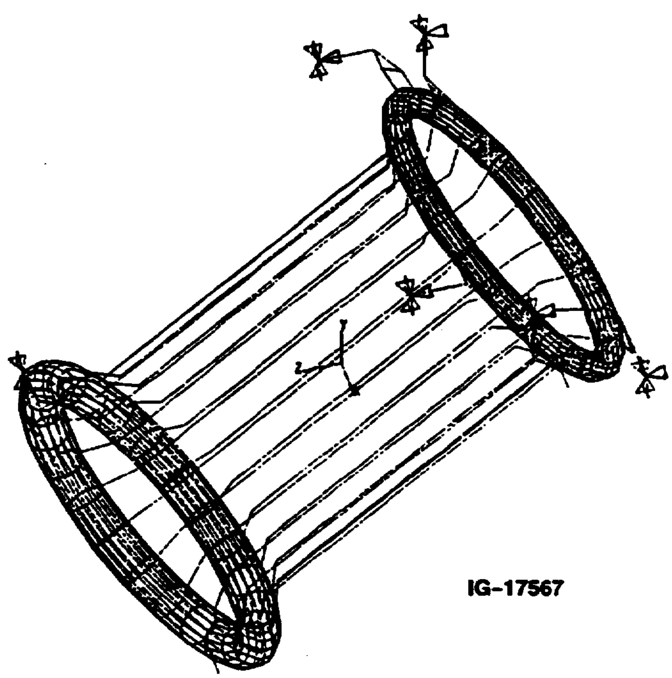

Figure 17. Gas Circuit Structural Model with Support System

Five links are used on the inlet manifold with a single link at the outlet manifold. The stresses imposed in the manifolds through the lugs act primarily on the inlet manifold. This arrangement minimizes potential creep problems because the inlet manifold temperature is below the creep threshold for Haynes 188.

5.4.2.3 Receiver-to-PCS Interface

The attachment of the PCS ducting system to the receiver ducts can produce significant thermal and weight stresses. The fastest and most accurate way to analyze the interface loads and moments is to integrate the receiver model with the Fluid Systems PCS model. This was accomplished, and the overall model is shown in Figure 18.

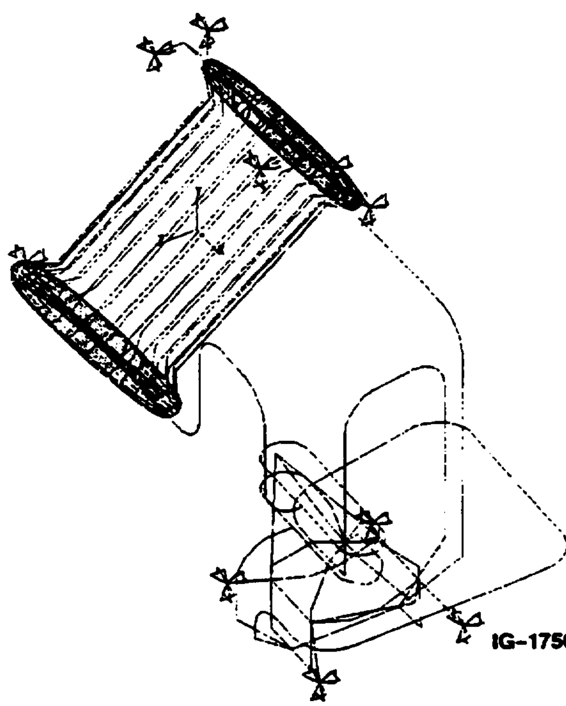

Figure 18. Combined Gas Circuit and Ducting System Structural Model

5.4.2.4 Receiver Outer Structure

The outer structure comprises the outer shell, inner liner, aperture cone, and the multilayer insulation. Initially, the outer structure was supported by the gas loop, but the resultant stresses in the manifolds were determined to be excessive. It was decided to use a separate mounting system independent of the gas loop and to use a similar six degrees of freedom restrained system. The final outer shell and aperture cone structural model is shown on Figure 19.

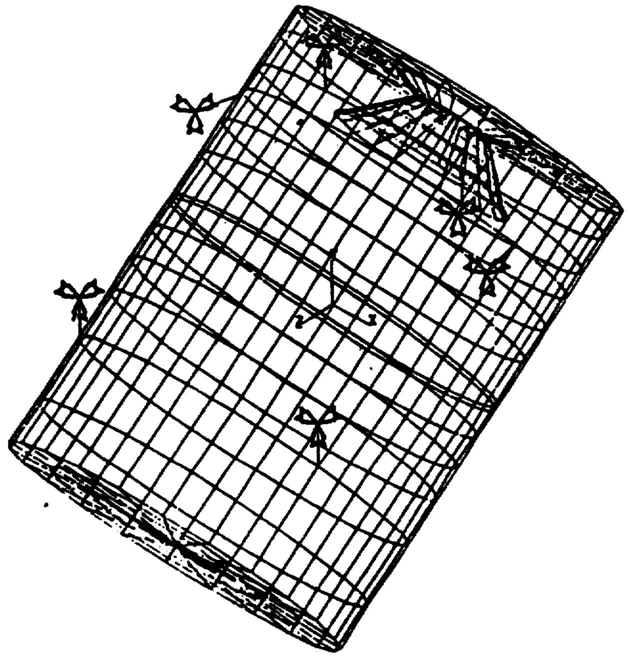

Figure 19. Outer Shell and Aperture Cone Structural Model

5.4.2.5 Zoom-In Models

Four detailed zoom-in models were created to study critical junction areas where discontinuities in shape and wall thickness occur, such as the tube-to-manifold and the duct-to-manifold transitions. An example of a local model is shown in Figure 20.

5.4.3 Gas Loop Stresses for Orbital Conditions

Three types of stresses were considered: pressure, self-weight, and thermal. Maximum stresses were always observed at the junctions. For self-weight and thermal stresses, the junction loads were obtained from the global model and applied to the zoom-in models. The zoom-in models were used to establish pressure stresses. Weight stresses can be combined with pressure stresses by adding component stress values and converting to von Mises stresses.

Thermal stresses result primarily from differential growth between tubes caused by different average tube temperatures—a result of asymmetric incident flux. Temperature inputs to the global model were identical to those calculated for PDR (see para. 5.4.1). Stresses were predicted at 80 min into the orbit, a time at which the tube-to-adjacent-tube temperature difference reaches a maximum difference (37°F).

The gas loop stresses are summarized in Table 2.

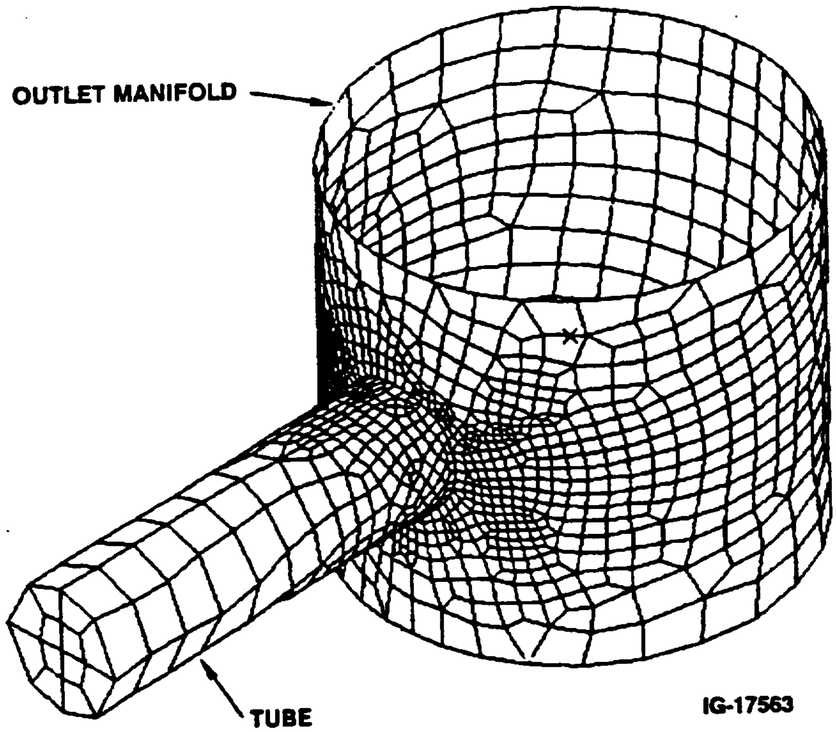

Figure 20. Local Model for Tube-to-outlet Manifold Junction

TABLE 2

GAS LOOP VON MISES STRESS SUMMARY

Junction	Location	Tube Number	Weight Stress, psi	Pressure Stress, psi	Combined Stress, psi*	Thermal Stress, psi
Outlet Manifold-to-Tube	Manifold	18**	3163	3093	5024	3424
	Tube		7973	2921	8996	8680
Outlet Manifold-to-Duct	Manifold	–	109	4388	4402	220
	Duct		326	5150	5149	518
Inlet Manifold-to-Tube	Manifold	18	9004	8641	17420	15695
	Tube		9697	9040	18583	16226
Inlet Manifold-to-Duct	manifold	–	2249	7439	9189	1469
	Duct		957	6058	6407	586

*Weight and pressure combined

**Maximum adjacent tube-to-tube average temperature difference between tubes 18 and 19

The tube-to-manifold and duct-to-manifold stresses are determined using the zoom-in models. By comparing junction stresses obtained from the global model with zoom-in model results, stress intensification factors (SIF's) were computed. These SIF's were used to advantage to convert nominal thermal stresses from a global analysis into actual junction thermal stresses for the system startup analysis as discussed in para. 5.4.4.

5.4.3.1 Gas Loop Predicted Life

Stresses in the gas loop are always below yield, and therefore, no plastic strain damage will exist. The minimum fatigue allowable strength for Haynes 188 is not known. It was considered reasonable, therefore, to assume that the fatigue strength is the same as the material minimum yield strength.

Tube creep strain at the outlet manifold-to-tube junction is the life-limiting strain. The tube creep strain for pressure- plus weight-induced stress for 1000 hr of operating time at 1400°F is 0.15 percent.

Tube creep strain for temperature-induced stress for 1000 hr is 0.4 percent. This is a conservative result because stress relaxation is neglected, and maximum initial stress is assumed to remain constant over the entire orbit.

Total tube creep strain is 0.55 percent, which is less than the conservatively assumed allowable of 2.0 percent. Creep rupture elongation for Haynes 188, based on data obtained by NASA-LeRC, is about 20 percent at 1450° to 1550°F. To limit excessive deformations in the gas loop, the maximum creep strain was limited to 2 percent.

Orbital fatigue life was examined using the inlet manifold-to-tube junction as the life-limiting structure. Based on a Goodman diagram for Haynes 188 at 1100°F, the computed margin of safety was 0.68, which yields essentially infinite life.

5.4.4 Gas Loop Stresses for Startup Conditions

Startup comprises static heating for one sun period, followed by an engine startup cycle which is essentially complete in 30 sec, after which the engine is self-sustaining.

Manifold and tube end temperatures were determined as a function of time using an outlet manifold thermal model presented at the PDR. Based on these predicted temperatures, gas circuit stresses were determined at sunset of the first orbit, the time at which the maximum tube-to-adjacent-tube temperature difference occurred. The weight- and pressure-induced stresses are similar to those determined for the orbital case.

The nominal thermal stresses at the tube-to-outlet manifold junction were obtained from the global model stress analysis. These stresses were then modified using the SIF's previously developed (para. 5.4.3). Thermal stresses at the tube-to-inlet-manifold junction were obtained from the zoom-in model analysis. A thermal stress summary is presented in Table 3. The weight- plus pressure-induced stresses are summarized in Table 4.

TABLE 3 THERMAL STRESS SUMMARY					
Junction	Location	Temperature, °F	Nominal Stress, ksi	SIF	Actual Stress, ksi
Tube-to-Outlet	Manifold	-46	5.7	1.73	9.86
Manifold	Tube		12.3	2.48	30.59
Tube-to-Inlet	Manifold	171			30.5
Manifold	Tube				29.2

TABLE 4 WEIGHT- PLUS PRESSURE-INDUCED STRESSES			
Junction	Location	Temperature, °F	Actual Stress, ksi
Tube-to-Outlet	Manifold	-46	5.0
Manifold	Tube		9.0
Tube-to-Inlet	Manifold	171	17.4
Manifold	Tube		18.6

5.4.4.1 Life Prediction for Startup Conditions

No specific data for the minimum fatigue strength for Haynes 188 are available. It is reasonable to assume, therefore, that the fatigue strength is equivalent to the yield strength. A Goodman diagram was constructed using the weight- plus pressure-induced stress as the mean stress and the temperature-induced stress as the alternating stress.

At the critical outlet and inlet manifold-to-tube junctions, the computed margin of safety was +0.63 for the outlet and +0.22 for the inlet. Thus, the fatigue life is essentially infinite. No creep is predicted. The gas circuit will comfortably meet the required 100 startups.

5.4.5 Tube/Fin Shear Lag

A separate finite element ANSYS model was created to analyze the stresses in the transition region where the finned annular flow section abruptly changes to a full diameter plain tube section. The predicted stresses in both tubes and fins were below the yield strength of Haynes 188 at the operating temperature.

5.4.6 Outer Shell Stresses

The outer structure is not connected to the gas circuit and only needs to support itself. The global model was found to be sufficient to predict stresses with reasonable accuracy. Thermally induced stresses were based on typical temperature distributions. All of the predicted stresses were found to be of moderate magnitude and will present no structural problems.

5.4.7 Mount Analysis

The gas loop is mounted using five mounts on the inlet manifold and one on the outlet manifold. No reaction loads are present in the mounts due to differential thermal growth (no thermal restraints). The axial thermal growth is essentially toward the outlet side. The mounts are oriented such that no bending is induced in the mounts. The mount loads are determined from the global model with a maximum load due to self weight of 100 lb.

A detail model of the manifold, mount base, and clevis was constructed. Results indicated low stresses in the inlet and outlet manifolds. The stresses are well below the endurance limit, yield strength, and creep threshold at 1400°F.

Allowable loads were determined for the link and rod end bearing assembly and were found to be much greater than the applied load of 100 lb. Creep strain in the hot end (outlet manifold support) link pin was determined to be 0.1 percent, which is well below the allowable limit of 2 percent.

The outer shell mounting scheme is similar to that used for the gas loop. The maximum lug load due to self-weight is less than 100 lb, and the maximum temperature is less than 1400°F. Therefore, the outer shell lugs are qualified by similarity to the gas loop lugs.

Low stresses and high-temperature materials ensure that the mounts will comfortably meet the required 1000-hr life.

5.4.7.1 Tie Rod Heat Losses

Six tie rods support the gas loop, and another six tie rods independently support the outer structure. Each tie rod is approximately 8 in. long and 0.25 in. in diameter. These tie rods break through the insulation and present a heat leak path which could be significant.

A thermal model of the tie rod was generated, and the predicted heat leak was 16.3 w per rod, 196 w total. The majority of the loss, 75 percent, was by radiation, and the remaining 25 percent was by conduction. The nominal receiver surface heat loss is set at 560 w, so the loss through the tie rods is significant.

The heat leak can be substantially reduced by insulating the rods. The conductive heat leak for 100 percent efficient insulation will be 28 w total. With practical insulation, the expected heat leak will be 60 w total, which is a reasonable portion of the overall receiver heat loss budget.

5.4.8 Receiver-to-PCS Interface

Allowance must be made for mismatches between the receiver inlet and outlet tubes and the PCS interconnecting ducts. The analysis also has to consider the impact of pallet motions, because these motions affect the spacing between the receiver and the PCS.

An analysis was conducted using the integrated receiver/PCS global finite element model. The mismatches were taken as the tolerances currently shown on the receiver interface drawing. Local stresses were determined using the SIF's previously established. The resultant stresses on the inlet and outlet manifolds at the critical locations were found to be moderate at the maximum mismatch condition. A Goodman diagram was constructed, and the margin of safety was found to be +0.42, indicating infinite life.

5.4.9 Aperture Assembly

The aperture assembly comprises an aperture plate and an attached aperture shield. The assembly is mounted to the frame structure. Graphite (UCAR ATJ) segments, 0.5 in. thick, form the shield. Graphite is used because of its high heat capacity, excellent thermal conductivity, high-temperature capability, and excellent thermal shock resistance. The plate, which supports the graphite segments, is made from 0.063-in.-thick A-286 stainless steel. A-286 was selected because it has a higher strength than Haynes 188 at moderate temperatures. The graphite segments are joined to the plate using A-286 bolts. Oversize slots in the graphite provide for differential thermal expansion.

To ensure the adequacy of this configuration, a finite element model was constructed and was used for both thermal and stress analysis. A special off-nominal flux case was used to examine the effect of a maximum flux condition. This case is identified by Harris Corp. as case B dated 3-4-93. Two steady-state conditions were analyzed: (1) as-received flux (pointed flux) and (2) as-received flux with aperture center moved +0.23-in. (off-pointed flux).

Special attention was given to the thermal stresses caused by (1) the temperature distribution in the graphite and the aperture plate, (2) mounting restraints at the aperture plate, and (3) restraint at the graphite/aperture interface.

Results of the analysis demonstrated that the aperture plate margin of safety is 0.93 for pointed flux and 0.50 for off-pointed flux based on the endurance limit. The aperture shield stress is low compared to the material characteristic strength. The stress was sufficiently low that the use of a statistical approach to determine the probability of survival of the graphite components was not required.

The aperture assembly can comfortably meet the required 1000-hr life requirement.

5.5 RECEIVER MANUFACTURING DEVELOPMENT STATUS

5.5.1 Canister Development

The canisters that contain the thermal energy storage (TES) salt are formed from Haynes 188 sheet stock. Each canister comprises two formed sections which are trimmed and electron-beam (EB) welded prior to filling with the salt. The forming process was selected over previous machining of bar stock because of a substantial cost advantage.

The canister forming is accomplished by a multistage progressive die set that converts the 0.063-in. sheet stock into a cup section. Selective trim of the formed cups results in the left- and right-hand details which, when joined by EB weld, form the completed canisters.

5.5.1.1 Weld Process

Following canister forming, the two canister halves are girth welded together by automated EB. The weld development included investigation into weld location, weld joint preparation (straight vs angled), gun angle, weld speed, and EB power. The final canister girth weld location and preparation are shown in Drawing 2305601.

Girth weld microstructure and wall alignment across the girth weld and canister wall thinning were evaluated through cross-sectional examination and found to be acceptable (Material Analysis MA 07574).

For the plug weld of the filling hole, ASE experimented with a "straight hat" plug and a "tapered" plug. The tapered hole was not sensitive to weld shrinkage and produced welds free of cracks, and was therefore selected.

5.5.1.2 Salt Fill

To ensure precise salt volume within each canister, ASE has developed a fill/melt/fill/melt process that ensures accuracy and repeatability. In this process, each canister is weighed prior to filling. Powder salt is introduced through a 0.121-in.-dia hole on the canister side wall. The canister is then melted in a vacuum furnace and reweighed. A final powder refill and remelt is performed to obtain a final salt weight of 41.8 gm (MA 07444).

5.5.1.3 Brazing

The braze development program encompasses two problem statements, each of which comprises a full development effort. The first effort addresses braze attachment of the salt-filled canisters to the gas loop tube. The second effort addresses the need for heat transfer enhancement of the gas loop tube by the addition of brazed, extended heat transfer surfaces interior to the gas loop tube.

The 23 gas loop tubes consist of brazed assemblies each containing 24 TES canisters, an outer gas containment tube, gas-side fins, and an inner gas containment tube. The gas-side fins are prebrazed to the gas containment tubes using MBF 30B

Metglas braze alloy (MA 07468). The salt canisters are then brazed to the tube assembly using AMS 4787 Nioro braze alloy. Both braze processes are performed in a vacuum furnace.

5.5.1.4 Inspection

The canisters will be inspected at various stages of manufacture. The initial inspection will consist of a dimensional check of the canisters from the die set. This will be done on a first article basis because all subsequent canisters will be a "product of the tool." Subsequent to machining and welding, a visual inspection, dimensional (height) verification, and weld x-ray verification will take place. After this testing, the canisters will be laser marked with a permanent identification which will allow traceability through future operations.

To verify the weld integrity of the canisters, ASE has developed a real-time x-ray technique that detects flaws as small as 0.005 in. This nondestructive inspection of the canister girth welds, along with static x-ray of the plug weld, will be used to inspect all canisters. The x-ray inspection will supplement the final acceptance test for each canister which consists of thermal cycling and helium leak test.

Tube-to-fin and tube-to-canister braze joints will be inspected using a static x-ray process.

As the acceptance test of the canister, each filled assembly will be subjected to a structural integrity verification and a helium leakage test.

Canisters will be temperature cycled five times to the highest temperature anticipated during the life of the canister. This temperature, 1840°F, is encountered during braze. As a safety margin, the canisters will be cycled from 1300°F (well below the salt melt temperature) to 1850°F (just above the braze temperature). Following temperature cycling, the unit will be visually inspected for deformation and salt leakage.

The final check will be a helium gas penetration test wherein the canisters are subjected to a differential pressure of 25 psi to induce helium into the canisters through any defects.

A subsequent helium leak check using high vacuum to extract any induced helium will be conducted to segregate sound from unsound units.

5.5.2 Single Tube Fabrication

A single tube containing 24 canisters has been fabricated for thermal cycling testing. This tube is similar to the full-size receiver tube in all respects except for the bent sections at the manifold attachment points, which were eliminated to accommodate the test rig. All details for this tube were manufactured to preliminary engineering-controlled prints and manufacturing operations and tooling (MOT) instructions. Deviations from these documents required to proceed with the fabrication without affecting schedule have been documented and will be incorporated in the final release documents.

5.5.3 Single Tube Test

In order to verify the structural integrity of the receiver critical areas, a thermal cycle test will be performed on a single tube assembly. This test will involve approximately 1200 simulated thermal cycles over a 2000-hr period. The metal temperature of the various critical canisters will be recorded during the entire test period to detect any evidence of loss of structural integrity. The details of the test plan are described in ASE Document 93-65811.

The single tube will be encased in a shell which contains various electric radiant heaters, and wrapped with MLI.

The tube and shell assembly will be placed inside a vacuum tank to simulate the SDGTD operating condition. Before the actual durability test, the tube assembly will be calibrated for steady-state heat losses at various canister wall temperature values. Cycle testing will begin in early June. At the conclusion of the test, the single tube and canisters will be inspected for any structural failure.

5.6 CANISTER COATING DEVELOPMENT STATUS

ASE, in conjunction with NASA Lewis, has experimented with various canister surface treatments to obtain an emissivity of 0.8 or greater (MA 07504).

Grit-blasting of the Haynes 188 material using silicon carbide, along with high-temperature oxidation (1600°F for 24 hr) produces such emissivity. Long-term exposure (~5000 hr) to high-temperature vacuum conditions, especially when temperature cycled, suggests that some spalling of the oxidized layer may occur. Additional treatment of the oxide layer using physical vapor deposition (PVD) of a substance like silica could minimize the spalling action.

Subsequent to the CDR, an action item memorandum (39314-72399-037) describing the surface emittance action plan was issued and sent to Fluid Systems and NASA. This action plan describes in detail the following:

(a) Full receiver canister surface coating selection criteria

(b) Alumina-titania coating of the additional samples and their testing and evaluations

(c) Resolutions of the CDR action items 20 and 21

From the emissivity results available to date, the alumina-titania coating appears to be the most promising coating for the full-up receiver. To further evaluate this coating, the following test samples were prepared with 0.001-in. thick alumina-titania coating:

(a) A tube brazed with three salt-filled canisters

(b) Three individual salt-filled canisters

(c) Five test coupons, 1 in. in diameter

The brazed tube, a canister, and two coupons are currently going through thermal cycling from 1500° to 300°F, under vacuum. The coating on the individual canister and the canisters on the assembled tube will be evaluated for spalling specifically at the rounded edges.

Also a coupon and a canister will be sectioned to evaluate the effect of depositing alumina-titania coating on a flat coupon vs rounded canister.

It was determined based on discussions with the vendor that the coating can be applied at either the individual canister level or the assembled tube level. The cost and duration for providing this coating at either manufacturing step are identical. The 0.020-in.-thick insulation between the canisters, on the assembled tube, disintegrates due to abrasive effect from grit blasting and the alumina-titania powder impingement. A protective ring or other means of protecting this insulation should be provided during the coating process to eliminate this problem for coating at the tube level.

A canister prepared with grit-blast, oxidation, and silica coating is also undergoing the thermal cycling test along with the alumina-titania samples. This is the back-up coating to the alumina-titania coating.

5.7 TEST PLANS

Test plan updates were submitted to Fluid Systems as part of the CDR data submittal. The submittals consisted of the following:

(a) Cooler test plan (Document 93-66142): The purpose of the cooler testing is to verify the design integrity of the government-furnished units as received by ASE. The acceptance testing will consist of a visual inspection, a proof pressure test, and a leak test. The testing is scheduled for June 1993. Following testing, the testing data sheets will be submitted to Fluid Systems for review. Upon approval, the units will be shipped to Fluid Systems.

(b) Receiver test plan (Document 93-66141): The purpose of the receiver testing is to verify the design integrity of the unit. The test objectives of the receiver testing include: 1) demonstrate structural integrity of the solar receiver by proof testing, 2) demonstrate gas containment integrity by helium leak checking, and 3) document the flow characteristics by subjecting the unit to a dynamic flow test and plotting unit pressure drop with respect to gas flow rate. The testing is scheduled for January 1994.

Test procedures for the single tube test were submitted to Fluid Systems and NASA for their approval. Also an engineering discussion responding to NASA's comments on the single tube test plan was issued to Fluid Systems and NASA. The single tube test setup is currently undergoing the checkout and shakedown process. Cycle testing will begin in early June.

5.8 RECUPERATOR

5.8.1 Analysis

The performance of the recuperator, predicted by computer using experimental data, has been assessed. The predicted performance at the given state points is 0.01 to 0.35 percent lower than the required cold-side effectiveness. However, the predicted port-to-port pressure loss is 18.6 to 61.3 percent less than the allowed values. Surface temperature profiles are available. It is recommended that the Colburn modulus degradation approach should be used in the system performance program. A memorandum report summarizing the computer-predicted performance study is available (39305-57652-01).

ASE reviewed the recuperator start transient curve prepared by Fluid Systems. The SDGTD start transient conditions are more benign than the design conditions of the original MBR. ASE issued a memo (attachment to 39314-72399-038) concurring with Fluid Systems that the MBR SN D-1 recuperator should be able to withstand the 100 start cycles required for the SDGTD.

5.8.2 Refurbishment

ASE has received from Fluid Systems two recuperators, PN 190930-1 (SN R001 and D002). Unit SN D001 has successfully completed a helium leak check and, therefore, is considered a good candidate for refurbishment. The second recuperator, R001, was returned to Fluid Systems.

Recuperator SN D-1 was proof pressure tested at 259 psig on the high-pressure side and 176 psig on the low-pressure side. No visible deformation was found. After the proof pressure test, the unit internal and external leakage was measured at 1.67 x 10^{-3} and 4.41 x 10^{-9} std cc/sec of helium at a 15-psig pressure differential. Pressure decay using air at an initial pressure of 30 psi was also conducted on this unit. The pressure dropped to 25.61 psi after 64 hr.

The refurbished recuperator was then cleaned to the AlliedSignal cleanliness specification (C-38). A recuperator refurbishment and assessment test report was submitted (Document 93-66138). Upon approval from the customer, the refurbished and cleaned recuperator will be shipped to Fluid Systems.

5.9 COOLER

ASE performed cost/risk tradeoff studies to investigate using two existing coolers fabricated for the prototype flight cryocooler (PFC) program in lieu of a custom designed and fabricated cooler. The decision was made to use the existing coolers.

Four existing PFC units identified by ASE PN 2340374 were stored at Kirtland Air Force Base in Albuquerque, New Mexico. These four units were obtained by the National Aeronautics and Space Administration (NASA) Lewis Research Center (LeRC), through stock transfer from Phillips Laboratory/Kirtland Air Force Base and provided to ASE as government-furnished equipment.

In accordance with *Supplemental Provisions for Analysis, Design, Fabrication, and Test of the Solar Ground Test Demonstration (SDGTD) Gas Cooler* (Document 41-11818(1)), the effort for WBS CDBF will be limited to the following tasks:

(a) CDBFA 0100—Analysis: Provide performance algorithms on the PFC aftercoolers for incorporation into the Fluid Systems SDGTD system model.

(b) CDBFA 0500—Project Liaison: As required, in support of the generation of performance algorithms for submittal to Fluid Systems.

(c) CDBFB 0300—Acceptance Test: This includes the following three tasks:

  (1) Visual inspection of GFE aftercoolers

  (2) Pressure test to ensure structural integrity in accordance with original ATP

  (3) Leak check to ensure pressure boundary integrity in accordance with original ATP

(d) CDBFB 0400—Project Liaison: As required, in support of acceptance testing

The coolers are currently located in the ASE space laboratory being prepared for test. The weight of each cooler is 19 lb. Cooler testing will begin in June.

5.10 OPEN ISSUES

(a) Emissivity treatment of canisters: Analysis showed that with typical Haynes 188 surface emissivity, the canister surface temperature during operation could climb to a a level that would adversely reduce creep life. To minimize this potential life reduction, a goal was set to obtain an emissivity value of 0.8, minimum. This new technology effort required considerable engineering evaluation, culminating in the incorporation of a alumina-titania surface treatment. (This action item has been closed subsequent to CDR.)

(b) Shipping/handling requirements: ASE must design and fabricate a support structure and a shipping container for the receiver.

(c) Plug for aperture: A tool for aperture alignment must be designed and fabricated.

(d) Frame coating: ASE is investigating the possibility of coating the frame to increase reflectivity.

(e) Instrumentation: ASE is designing the thermocouple instrumentation routing to be compatible with the MLI installation.

(f) Off-nominal flux distribution: In accordance with a Fluid Systems request, ASE provided a cost and manpower requirement for improved tube-to-tube stress analysis activities.

(g) Interface analyses: In accordance with ASE's statement of work (Document 41-11484), para 3.2.2, "System Interface Definition," ASE will work with Fluid Systems and the system integrator to develop receiver interfaces. Design layouts will be generated to allow definition of physical and electrical interfaces. Layouts will be incorporated into the interface control drawing. This statement has been now been expanded by the customer to include the following tasks:

    (1) ASE has the design responsibility to provide a receiver support structure which locates the aperture at the specified location within the specified tolerance to the pallet datum.

    (2) ASE is required to provide analysis of the applied loads at the pallet interfaces, relative motion between the installed aperture position and the operating position, the allowable forces and moments, and the installed-to-operating displacements at the duct interfaces.

    (3) ASE must account for the contribution of the receiver support structure, the PCS support structure, and the pallet pad motions on the relative displacements of the aperture and duct flanges.

    To obtain all of this detailed information, it was necessary to develop a combined PCS/receiver/pallet finite element model which provides an integrated result of interface stresses and displacements. Several iterations were required to obtain a solution that produced, an acceptable stress on the receiver ducts and was within the capabilities of an existing set of PCS bellows. To ensure that the model is fully representative, ASE is working directly with NASA to obtain the correct pallet displacements and the mounting frame temperature distributions. The customer has requested that this model be documented and controlled so that it may properly serve as an interface definition.

(h) Single tube test disposition: NASA will direct ASE after completion of the test.

(i) Monoball lubricants: ASE is investigating monoball lubricants for use in the tie rods.

(j) Insulation installation: ASE must provide more detailed information to ADD to define insulation requirements.

6. Power Conditioning and Control Unit (PCCU)

6.1 Design Document List

The following is a bibliography of all documents used to support the PCCU CDR:

41-11764-5	Solar Dynamic Ground Test Demonstration, Preliminary Design Review, "Electrons"
41-12044	Software Development Plan for the Power Conditioning and Control Unit Software of the Solar Dynamic Ground Test Demonstrator
41-12083	Software Requirements Specification for the Power Conditioning and Control Unit Software of the Solar Dynamic Ground Test Demonstrator
41-12084	Software Design Document for the Power Conditioning and Control Unit Software of the Solar Dynamic Ground Test Demonstrator
41-12094	Software Test Plan for the Power Conditioning and Control Unit Software of the Solar Dynamic Ground Test Demonstrator
41-12097	Test Plan for the Power Conditioning and Control Unit of the Solar Dynamic Ground Test Demonstrator
41-12105	Solar Dynamic Ground Test Demonstrator (SDGTD) Power Conditioning and Control Unit (PCCU) Critical Design Review (CDR) Package Report
41-12158	Power Conditioning and Control Unit (PCCU), Critical Design Review (CDR View Graphs)

Fluid Systems Drawings

3793461	Drawing Tree, GTD PCCU

6.2 Design Review Minutes

The PCCU CDR was held on Wednesday, May 26, 1993.

On Tuesday, May 25, 1993, the operation of the PCCU breadboard, the SIPS, and the air-turbine-driven TAC, connected in various system configurations, was demonstrated to NASA in the Fluids Systems Space Laboratory.

The following major design elements were presented at the PCCU CDR:

Requirements

A compliance matrix of PCCU requirements, as documented in Rocketdyne Specification N10120, was presented. Exceptions taken to the requirements were as follows:

- The PCCU length will be 25 inches instead of 24 inches.
- Communication from the PCCU to the SIPS is via the DACS and is not a direct connection to the SIPS as implied by the requirements.
- No special test connector will be provided on the PCCU. Sufficient test points already exist at connectors J109 and J110.

NASA requested that the full set of output power quality requirements be incorporated into Rocketdyne Specification N10120 and that external references to the Space Station Power Quality requirements be deleted. An action item was assigned to resolve this (PCCU Action Item 8).

Schematic Review

Design highlights of the PCCU card file, including the address and data bus configuration, and schematic diagrams of the following printed wiring board and chassis assemblies were presented in detail:

- Central Processing Unit
- Start Inverter Module
- Speed/PLR Control Module
- Voltage Regulator Module
- PCCU Heat Sink Chassis
- Field Control Module
- PLR Driver Assembly

NASA requested that full documentation of all Field Programmable Gate Arrays (FPGAs), EPROMs, and Programmable Array Logic (PAL) be provided when the equipment is turned over to them. Fluid Systems agreed to provide the requested data (PCCU Action Item 5).

PCCU Software

The PCCU software requirements and design were presented, including the following topics:

- A description of the SDGTD PCCU Software Documentation to be generated during development of the PCCU:

  Software Development Plan
  Software Requirements Specification
  Software Design Document
  Software Test Plan

- A block diagram of the system states and modes, including the conditions required to cause transition between the various states.

- The CSCI architecture.

- The system state and CSC table.

- Interrupt frame timing.

- PCCU/DACS serial communication protocol, timing, and queue structure.

- The memory map.

NASA expressed concern that once a long message was begun from the PCCU to the DACS, the PCCU could not terminate the message in favor of transmitting a higher priority message (e.g., emergency shutdown due to overspeed). So much time may required to finish the long message as to prevent expedient action by the DACS. An action item was assigned to investigate this (PCCU Action Item 3).

The need for constant speed motoring of the TAC was discussed. Analysis shows that in the cold-start condition it will be necessary to motor the TAC at constant speed for some time before the TAC will become self-sustaining. Based on this requirement, it was agreed to incorporate a constant-speed motoring CSCI in the PCCU software (PCCU Action Item 7).

Mechanical Design

The PCCU mechanical design was presented. The following major topics were discussed in detail:

- PCCU Top Assembly

- Card File Construction

- Printed Wiring Board Construction and Component Heat Sinking
- PCCU Heat Sink Chassis, including the PLR Driver Printed Wiring Assembly, Current Measuring Shunts, the Single Point Ground, Field Control Circuit Board, and Output Filter

There was some discussion concerning the size of the PCCU for the Ground Test Demonstrator versus the size of an actual flight unit. The point was made that for the GTD system maximum use of the allowable envelope was made to allow modularization of the major sub-assemblies and to allow spare area in the heat sink assembly and card file for growth. In an actual flight system, packaging would be considerably more efficient, resulting in a smaller package.

Breadboard Test Results

The following test data obtained prior to the NASA visit was presented:

- TAC Field Current required as a function of speed, output voltage, and output power
- Ripple Voltage Spectral Content; Requirement and Actual Data
- Induction Start Data, including Torque developed as a function of SIPS frequency, voltage, and current, with field windings open and terminated with a 16-ohm resistor.

A summary of the tests performed for the NASA representatives the day before the PCCU CDR was presented. These tests included:

- Induction and Synchronous Motoring
- PCCU Speed Control and Voltage Regulator operation using the SIPS to simulate the TAC
- PCCU closed loop speed control and voltage regulator operation using an air-turbine-driven TAC as the power source
- Measurement of TAC three-hase power quality when operating into a three-phase resistive load.

No significant discussion resulted from this portion of the presentation.

Test Plan

The PCCU Test Plan, as detailed in Fluid Systems Report 41-12097, was presented. No significant discussion resulted.

Spares

A list of recommended spares to support the PCCU was presented. One spare for each Printed Wiring Assembly in the PCCU will be provided. The list was accepted.

6.3 Design Summary

6.3.1 Electrical Design

PCCU Card file - The PCCU card file contains four printed wiring modules, one empty card slot with test points, and one empty card slot for expansion. Printed wiring assemblies contained in the card file are as follows:

- Central Processing Unit
- Start Inverter Module
- Speed/PLR Control Module
- Voltage Regulator Module

An extender card will be provided for accessing test points in the card file and for troubleshooting the above circuit cards.

Signals between the PCCU card file and PCCU heat sink travel via connector J1 on the card file and P1 on the heat sink.

The power supply input to the card file from the heat sink (±15 Vdc and +5 Vdc) is via J6 on the card file and P6 on the heat sink.

A 16-bit data bus, a 4-bit address bus, and 3 circuit card "select" lines provide communication from the CPU module to the other 3 modules. The wire list for the card file is contained in Drawing 3793444.

Central Processing Unit (CPU) - The following features highlight the design of the CPU module:

- 80C196KB-12 Intel microcomputer
- 44,928 bytes of EPROM
- 8K RAM
- 230 bytes of on-chip RAM
- 12 MHz clock
- 19.2K baud serial port
- 16-bit bidirectional data bus
- 16-bit receive-only port
- 8-bit address port
- 4 analog input channels (not used)

Three external card select signals are generated in PALs on the CPU module and are used in conjunction with the address bus to provide read and write signals to the other three modules. The schematic diagram of the CPU module can be found on Drawing 3793426.

<u>Start Inverter Module</u> - The following features highlight the design of the Start Inverter module:

- The frequency reference (400 Hz) for the induction start mode is located on this module and is switched on and off under control of the CPU module.
- Circuitry required to disconnect the TAC field windings from their power sources during the induction start mode is located in this module.
- Signal conditioning circuitry capable of amplifying and filtering the signals from three independent TAC monopoles exists in the module. Any one of the three signals can be used to detect TAC rotor position once the TAC is rotating at sufficient speed to generate the required signals.
- A multiplexer in this module under control of the CPU module selects the monopole signal to be used for a start attempt. If a monopole fails, the DACS can command the CPU to select a different monopole for the next start attempt.
- Automatic gain control circuitry and peak detection circuits keep the amplitude of the major peaks from the monopole signal constant as the TAC accelerates. Comparitor circuits detect zero crossings of the monopole signal and can detect the reduced pulse height of the minor peaks as the notched compressor blades in the TAC pass under the monopole. Digital processing circuitry in the FPGA generates an index pulse required by the SIPS to keep the driving three-phase power input synchronized with the TAC rotor position.
- A frequency multiplier (phase locked loop) is included to multiply the frequency signal from the selected monopole pickup (26 pulses per revolution) by 16 to produces pulses at the rate of 416 pulses per revolution, resulting in a TAC rotor position detection resolution of better than one pulse per degree of revolution.
- The analog output from the phase locked loop is converted to a digital word (12 bits) via the A to D converter on the voltage regulator module and is read by the CPU to determine speed during the start cycle.
- In operation, the CPU commands the DACS to enable the SIPS and commands the start inverter module to output the 400 Hz induction start frequency to the SIPS. When the start inverter module has successfully detected the notches in the TAC compressor wheel, it signals the CPU, and the CPU commands

the start inverter module to switch the frequency reference signal from the fixed 400 Hz input to the frequency required to maintain synchronism with the TAC rotor. This frequency signal maintains the correct frequency and phase relationship of the phase A power signal from the SIPS. The SIPS automatically takes care of phases B and C. When the start inverter phase locked loop analog signal indicates the TAC is above starter cut-off speed, the CPU commands the start inverter to terminate the start.

The schematic diagram of the start inverter module can be found on Drawing 3793434.

<u>Speed/PLR Control Module</u> - The following features highlight the design of the Speed/PLR Control module:

- The Speed/PLR Control module uses alternator phase A, B, or C, optically coupled to the module for noise immunity, to detect TAC rotor speed.

- The Speed/PLR Control module determines the average period of the phase selected. The CPU commands the number of cycles to be timed (30 cycles at 52,000 RPM) and adjusts this command as a function of speed to maintain speed resolution at approximately 2 RPM. A 1.5 MHz counter frequency is used by the Speed/PLR Control module to determine the period.

- The Speed/PLR Control module provides control logic to turn 21 PLR heater elements on or off as commanded by the CPU. One of seven of these elements is capable of being operated in an analog fashion for fine PLR control. The percent on of this element is also commanded by the CPU.

The schematic diagram of the Speed/PLR Control module can be found on Drawing 3793433.

<u>Voltage Regulator Module</u> - The following features highlight the design of the Voltage Regulator module:

- The Voltage Regulator module provides three low-level (0 to 50 mV) and three high-level (up to 120 Vdc) signal conditioners.

- An eight-to-one analog multiplexer selects one of the signals for conversion to digital via a 12-bit A to D converter.

- The CPU commands which analog channel is to be converted and reads the results of the conversion.

- The Voltage Regulator module provides drive circuitry required to pulse width modulate (PWM) one set of fields of the TAC powered by the 120 Vdc output voltage of the PCCU. The percent

PWM is commanded by the CPU.

The schematic diagram of the Voltage Regulator module can be found on Drawing 3793438.

<u>PCCU Heat Sink Chassis</u> - The following features highlight the design of the PCCU Heat Sink Chassis:

- Three instrumentation current transformers provide TAC three-phase output current information to the DACS.

- Three power current transformers, connected in a Y configuration, provide direct current proportional to TAC output current to one pair of TAC field coils.

- A three-phase, full-wave bridge rectifier converts the three-phase AC output of the TAC to 120 Vdc.

- A power filter consisting of a 100 uH inductor and a 50 uF capacitor filters the output ripple.

- Six 50 mV shunts provide current instrumentation for the following currents:

  Total DC Output Current
  PLR Current
  User Load Current
  Auxiliary Load Current
  Field A Current
  Field B Current

- A 120 Vdc to ±15 and +5 Vdc converter power supply provides power to logic and conditioning circuits in the card file.

- Power field effect transistors drive the 21 PLR heater elements in the PLR and pulse width modulate the 120 Vdc output voltage to the second pair of TAC field coils.

The schematic diagram of the PCCU Heat Sink Chassis can be found on Drawing 3793408.

6.3.2 Software Requirements

The software requirements for the following operating modes were presented:

- Power Up Mode
- Monitor Mode
- Idle Mode
- Start Mode
- Run Mode
- Shutdown Mode
- Health Monitoring

Power Up Mode - Upon Power Up, the software will calculate ROM and RAM checksums twice. If a failure occurs, the software is to go into an idle state (not the Idle Mode described below), where it will essentially do nothing. This mode will be detected by the DACS and the cause of the problem investigated.

Assuming the PCCU passes its checksums, the next steps are to initialize variables, disable the user load, and proceed to monitor mode.

Monitor Mode - Monitor mode is used by the software to determine what the TAC is going to do next. Since Power Up may occur due to recovery from a momentary power interrupt, it is possible that the TAC may be spinning upon Power Up. Monitor mode enables the software to observe the speed of the TAC and determine if the next operating mode should be Idle Mode, Run Mode, or if it should remain in monitor mode until the TAC decides if it is going to accelerate or decelerate.

If the PCCU determines TAC speed is zero, it will proceed to Idle Mode. If the PCCU determines TAC speed is greater than some minimum speed (called Run Cutoff), it will proceed to Run Mode and take control of the TAC speed and voltage. If the TAC is between zero and Run Cutoff, the PCCU will remain in this mode observing TAC speed until its speed exceeds Run Cutoff or drops to zero, or until the PCCU is commanded by the DACS to transition to another mode (Shutdown or Start).

Idle Mode - (This mode should not be confused with the Idle State described above for the case where the PCCU fails its checksum upon Power Up.)

In Idle Mode, the PCCU responds to DACS commands via the serial link. When so commanded, the PCCU proceeds to the Start Mode.

Start Mode: Induction Mode - Upon entering Start Mode, the PCCU checks TAC speed. If TAC speed is greater than Run Cutoff, it proceeds to Run Mode.

If a Position Valid signal from the Start Inverter Module is true, the PCCU transitions to Synchronous Start Mode. The Position Valid signal is generated by the Start Inverter Module when the TAC is spinning fast enough so that the signals from the monopole pickups on the TAC are providing a coherent signal to the Start Inverter Module, including the amplitude variations required to indicate to the Start Inverter Module when two compressor blades with notches are passing under the monopoles. These notched blades and their associated reduced amplitude monopole signals provide TAC rotor position information required by the Start Inverter Module to operate in the Synchronous Start Mode.

If neither of the above conditions is true (the typical case), the PCCU commands the DACS to enable the SIPS and provides a 400 Hz command to the SIPS to initiate the Induction Start. A software timer is started.

When the Position Valid signal becomes true, the PCCU proceeds to the Synchronous Start Mode. If more than TBD seconds elapse before a Position Valid signal is received, the PCCU terminates the start, goes to Monitor Mode, and signals the DACS of a Start failure.

Start Mode: Synchronous Mode - The PCCU remains in the Synchronous Start Mode until TAC speed is greater than Run Cutoff, or until commanded by the DACS to terminate the start.

While in the Synchronous Start Mode, the PCCU commands the SIPS via the DACS to adjust its output voltage as a function of speed in accordance with a lookup table in the PCCU.

The PCCU provides a synchronizing signal to the SIPS to cause the Phase A output of the SIPS to be n synchronized with a TAC rotor position pulse generated by the Start Inverter Module. This pulse is produced twice per revolution of the TAC shaft. SIPS Phases B and C follow automatically.

Run Mode - While in the Run Mode, the PCCU provides Speed Control, PLR Control, and Voltage Regulator Control as follows:

Run Mode: Speed Control - The Speed Control executes in a 50 millisecond frame time. Period data from the TAC three-phase output frequency is provided to the CPU Module by the Speed/PLR Control Module.

The CPU Module reads the period data, converts it to speed, and determines the speed error.

Speed is controlled by varying the total electrical load on the system. The Speed Control issues the total electrical load command to the PLR Control (discussed below). The total electrical load command consists of two parts: the proportional command and the integral command.

The proportional command, in watts, is the product of speed error in RPM and the proportional gain in watts per RPM.

The integral command, in watts, is the product of speed error in RPM, the integral gain in watts per RPM per second, and the sampling interval in seconds, plus the previously calculated integral command.

The total load command is the sum of the proportional command and the integral command.

Run Mode: PLR Control - The PLR Control maintains the total electrical load on the system at the value commanded by the Speed Control by varying the Parasitic Load. It operates in a one millisecond frame time. Output voltage and current are converted to 12-bit digital values by the Voltage Regulator Module and read by the CPU Module.

New load commands are sent to the PLR Control every 50 milliseconds. In the time between new load commands, the PLR Control monitors the total load on the system, consisting of user load, auxiliary load, and PLR load, and adjusts the PLR load each millisecond to keep total load equal to the last load command.

Load commands to the PLR, generated in the PLR Control, are formatted to minimize transients to the total load on the system when transmitted to the PLR. If the load correction is small, the correction is made in a set of seven fine-control resistors in the PLR. If the change is greater than that which can be handled by the fine resistors, higher power resistors are switched, selecting from among the bank of seven 125 watt resistors, if possible or, if necessary, from among the bank of seven 500-watt resistors. Lookup tables in the PLR Control are used to aid in the selection of resistors to be turned on or off.

Run Mode: Voltage Regulator Control - The Voltage Regulator Control maintains output voltage at a level commanded by the DACS, nominally 120 Vdc.

The output voltage at the PCCU terminals is converted to a 12-bit digital value by the Voltage Regulator Module and read by the CPU Module.

Actual output voltage is controlled by varying the Pulse Width Modulation duty cycle command to a TAC field current driver on the Voltage Regulator Module. The total PWM command, referred to as duty cycle, consists of two parts: the proportional command and the integral command.

The proportional command, in percent, is the product of voltage error in volts and the proportional gain in percent per volt.

The integral command, in percent, is the product of voltage error in volts, the integral gain in percent per volt per second, and the sampling interval in seconds, plus the previously calculated integral command.

The total duty cycle is the sum of the proportional command and the integral command.

Shutdown Mode - This mode is commanded by the DACS. When so commanded, the PCCU assumes a decreasing speed command as a function of time. The time rate of decrease is commanded by the DACS.

Health Monitoring - The following actions are taken by the PCCU in response to various faults:

- System Short Circuit: If the PCCU determines that higher than normal field current is required to maintain the output voltage at its commanded level, it will signal the DACS, via the serial link, to shut down the system.
- Overvoltage: If output voltage is greater than 125 volts for 10 milliseconds, the PCCU will disconnect field drive from the TAC fields and will signal the DACS to shut down the system.
- User Overload: If the commanded power to the PLR drops to a level less than that required to maintain speed control, the PCCU will command the DACS, via the serial bus, to drop the user load. If no response is observed by the PCCU in 500 milliseconds, the PCCU will send a hardware signal on a dedicated pair of wires to the DACS that will cause a hardware dropout of the user load.
- Overspeed: If an overspeed condition is detected by the PCCU, the PCCU will signal the DACS, via the serial bus, to shut down.

6.3.3 Software Design

The following key points highlight the design of the PCCU software.

Software Documentation - The following features highlight the software documentation to be generated during the PCCU development:

- Software Development Plan: Describes the general software development process, provides the software development schedule, and lists key activities and deliverable documentation.

- Software Requirements Specification: Describes the functional requirements of the software, includes special algorithms and timing requirements, and describes the hardware interfaces.

- Software Design Document: Describes how the requirements will be implemented, the structure of the software modules and data, and any internal interfaces.

- Software Test Plan: Describes how the software will be tested, including a brief description of the tests and the test objectives.

<u>System Modes</u> - The PCCU software operating modes, and the criteria for transitioning between them, follow.

- Modes:

  Power Up
  Monitor
  Idle
  Start
  Run
  Shutdown

- Power Up to Monitor Mode -

  Automatic upon successful completion of Power Up.

- Monitor to Idle Mode -

  TAC speed less than Monitor Cutoff.

- Monitor to Start Mode -

  DACS start command received.

- Monitor to Run Mode -

  TAC speed greater than Run Cutoff.

- Monitor to Shutdown Mode -

  DACS shutdown command received.

- Idle to Start Mode

  DACS start command received.

- Start to Monitor Mode -

  Start mode failure or DACS terminate start command received.

- Start to Run Mode -

  TAC speed greater than Run Cutoff.

- Start to Shutdown Mode -

  DACS shutdown command received.

- Run to Monitor Mode -

  TAC speed less than Run Cutoff.

- Run to Shutdown Mode -

  DACS shutdown command received.

- Run to Start Mode -

  DACS start command received.

- Shutdown to Idle Mode -

  TAC speed less than Monitor Cutoff.

- Shutdown to Start Mode -

  DACS start command received.

CSCI Architecture - The following describes the PCCU CSCI Architecture:

- Power Up (CSC00)

  ROM Checksum (CSU0000)
  RAM Checksum (CSU0001)
  Initialize (CSU0002)

- Monitor (CSC01)

- Start Control (CSC02)

  Begin Start (CSU0200)
  Induction Start (CSU0201)
  Synchronous Start (CSU0202)
  Terminate Start (CSU0203)

- Speed Control (CSC03)

- PLR Control (CSC04)

- Voltage Regulator (CSC05)

- Health Monitoring (CSC06)

  Low-speed Health Monitoring (CSU0600)
  High-speed Health Monitoring (CSU0601)

- DACS Communication (CSC07)

  Data Report (CSU0700)
  Command Read (CSU0701)
  Queue Manager (CSU0702)
  UART Handler (CSU0703)

<u>Mode/CSC Relationships</u> - The following describes which CSCs operate in which modes:

- Power Up Mode

  Power Up CSC

- Monitor Mode

  DACS Communication CSC
  Health Monitoring CSC
  Monitor CSC

- Idle Mode

  DACS Communication CSC
  Health Monitoring CSC

- Start Mode

  DACS Communication CSC
  Health Monitoring CSC
  Start Control CSC

- Run Mode

  DACS Communication CSC
  Health Monitoring CSC
  Speed Control CSC
  PLR Control CSC
  Voltage Regulator CSC

- Shutdown Mode

  DACS Communication CSC
  Health Monitoring CSC
  Speed Control CSC
  PLR Control CSC
  Voltage Regulator CSC

Shutdown CSC

DACS Communication - The following describes the message format of messages sent between the PCCU and the DACS in the order sent:

- Start Message Character

  AA

- Message Number

  8-Bit, Unsigned

- Message Length

  Total Number of Bytes in Message

- Command

- Data

  0 or More Data Bytes

- Checksum

  Unsigned 8-Bit Checksum

6.3.4 Hardware Design

Top Assembly

The PCCU consists of two major assemblies: the PCCU Heat Sink Chassis Assembly (3793421) and the Card File Assembly (3793454). These two assemblies are mounted to an N-heptane cooled base plate/heat sink in the final application.

Card File Assembly

The card file contains card slots for 6 printed wiring assemblies. These slots are used to house 4 printed wiring modules and an extender card. There is one spare slot. One of the card slots provides access to test points on the backplane.

The card file contains zero insertion force (ZIF) card guides. The ZIF guides are unlocked with a screwdriver. When the cards are fully inserted in their connectors, the ZIF guides are locked, causing the guides to firmly grip the edges of the card heat sink (see "Printed Wiring Assemblies" below for a description of the heat sink). Heat from the card is conducted from the card heat sink, through the ZIF card guides to the walls of the card file chassis, and to the cold base plate below.

Printed Wiring Assemblies

The printed wiring assemblies are of standard construction except that a thin aluminum plate will be installed between the top surface of the PC board and the components on the board. The plate will be bonded to the top surface of the board. At present, it is not anticipated that the components on the board will need to be bonded to the plate. The plate is there to conduct heat from the PC board to the walls of the card file chassis. Heat from the components will be conducted to the PC board material and then to the plate via the component leads.

PCCU Heat Sink Chassis

The PCCU Heat Sink Chassis contains the higher power components and the significant heat producers of the PCCU circuitry. Components and subassemblies contained in the PCCU Heat Sink Assembly are listed in Section 6.3.1 under the Heat Sink Chassis discussion.

Power dissipating components in the heat sink are mounted either directly to the bottom plate of the heat sink or to structure in the heat sink that is in intimate contact with the bottom plate. The bottom plate is bolted to the cold plate in the final application.

6.4 Breadboard Development Status

The PCCU breadboard has been fabricated and was demonstrated to NASA at the CDR. Special test software designed to show specific features of the PCCU hardware was run for this demonstration. The PCCU breadboard will now be used as a vehicle for software integration and performance verification of the PCCU.

6.5 Test Plan

PCCU test plans for the following assemblies are detailed in Fluid Systems Report 41-12097, "Test Plan for the Power Conditioning and Control Unit of the Solar Dynamic Ground Test Demonstrator."

Printed Wiring Assembly (PWA) Acceptance Tests - All PWAs will be acceptance tested to an approved acceptance test procedure. Tests will be conducted using general purpose test plans and special purpose test equipment to provide and monitor signals to and from the PWA under test.

PCCU Design Verification Tests - This will be a one-time test to prove the design of the PCCU. A fully instrumented PCCU will be installed in a vacuum chamber and operated under conditions as near as possible to those in Tank 6 at NASA Lewis. Temperatures and PCCU functional characteristics will be monitored during the test.

Tests that cannot practically be performed in a small vacuum tank (i.e., operation with an actual TAC) will be conducted in air ambient.

PCCU Acceptance Test - This test will be performed prior to accepting the PCCU for operation in the NASA vacuum tank. This test will be sufficient to show that all facets of the PCCU are performing to minimum standards for operation in the tank. Generally, after the PCCU has been repaired or modified, this test, modified as required to account for any changes to the PCCU, will be the final proof test prior to installation and operation in the tank.

6.6 Open Issues

No significant open issues remain.

7. Parasitic Load Radiator (PLR)

7.1 Design Document List

41-11764-5	Solar Dynamic Ground Test Demonstration, Preliminary Design Review, "Electrons"
41-12096	Test Plan for the Parasitic Load Radiator Used on the Solar Dynamic Ground Test Demonstrator
41-12106	Solar Dynamic Ground Test Demonstrator (SDGTD) Parasitic Load Radiator (PLR) Critical Design Review (CDR) Package Report
41-12167	Parasitic Load Radiator (PLR), Critical Design Review (CDR View Graphs)

7.2 Design Review Minutes

The PLR CDR was held on Wednesday, May 26, 1993. The following topics were presented and discussed:

- PLR Requirements
- Design Description
- PLR Analyses
- Breadboard Test Hardware
- PLR Test Plan
- PLR Spares

Issues raised appear below.

Requirements

A compliance matrix of PLR requirements, as documented in Rocketdyne Specification N10119, was presented. Exceptions taken to the requirements were as follows:

- Paragraph 3.5.2 of the spec requires that a mating connector be provided with the PLR. Instead of a mating connector, the cable assembly that connects the PLR to the PCCU will be provided.

Design Description

The Design Description discussion included a summary of the changes made to the PLR since the PDR. A description of each of the seven radiator plates was provided, along with the details of the heater elements to be used in each plate. The area of each radiator plate has been increased to provide a more conservative design (lower operating temperature). All seven radiator plate assemblies will be identical to each other, each containing a 500-, a 125-, and a 60-

watt heater element.

PLR Analyses

The PLR Analyses included a prediction of a radiator plate temperature versus total power dissipated by heater elements in the plate and calculated maximum allowable watt densities of heater elements in plates operating at various temperatures. The maximum allowable watt densities were compared to the actual watt densities of the various heater elements to show the conservatism of the design.

Included in the PLR Analyses section was a discussion of the combinations of heater elements and plates to be turned on to satisfy various total power requirements while spreading the load across as many plates as possible to produce minimum heating of any one plate. The software algorithm to be used to calculate which 500-, 125-, and 60-watt heater elements to be turned on for any possible total load was presented.

Breadboard Test Hardware

Progress on the breadboard test hardware was presented. Two radiator plates had been fabricated for breadboard testing. One of the plates had been etched in a ferric chloride bath and sand blasted and was ready for the oxidation process in 2100 °F air.

PLR Test Plan

The PLR test plan as described in Fluid Systems Document 41-12096 was presented.

PLR Spares

The list of spare parts to be provided with the PLR was presented. The CDR material was accepted by those present with no significant issues raised.

7.3 Design Summary

The following summarizes the electrical and thermal design of the PLR.

7.3.1 Electrical Design

The PLR consists of 21 electrical heater elements installed in 7 radiator plates. Each radiator plate contains one 500-, one 125-, and one 60-watt element. These elements are rated at 2000 watts at 240 volts, 500 watts at 240 volts, and 240 watts at 240 volts respectively by the vendor. Because they will all operate at 120 volts dc in this application, all elements operate at 25 percent of their nominal power rating.

The 500- and 125-watt elements are operated in either the on or off state. The 60-watt elements operate in the on, off, or linear state. That is, the transistors in the PCCU driving these elements operate in the linear region, giving essentially analog control over 420 watts (7 times 60 watts) of parasitic load power. For small changes in PLR power and to correct for changes in power due to heater elements heating up, this bank of fine trim resistors will be used.

When the PLR fine bank runs out of control range (all on or all off), a gross change will be required. For this case, the PCCU calculates the amount of power to be dissipated in the bank of 500- and 125-watt elements as follows:

Total coarse (500 watt) and trim (125 watt) power =
INTEGER[(PLR COMMAND - 147.5)/125]*125

The power to be dissipated in the fine bank will be the difference between the total commanded PLR power and the power calculated for the coarse and trim banks.

By using these equations, the fine bank always comes out approximately in the middle of its range (148 to 272 watts) after a gross change. This allows the PCCU to correct the dissipated power due to resistor tolerances and hot and cold resistors simply by adjusting the fine bank up or down.

After calculating the total power to be dissipated in the coarse and trim banks, the specific 500- and 125-watt resistors to be turned on are determined by reference to a lookup table in the PCCU software. The combination to be turned on results in minimum power dissipation per plate. For example, if the required coarse power is 625 watts, five 125 watt elements, one in each plate, will be turned on instead of one 500 watt element and one 125 watt element. When 500- and 125-watt elements both need to be on, elements from different plates are used.

By using the above approach, the maximum power dissipated in any one plate is 560 watts.

7.3.2 Thermal Analysis

The results of an analysis to determine plate temperature while dissipating various power levels were presented . This analysis showed that when dissipating 560 watts, the maximum possible dissipation per plate, plate temperature will be approximately 820 °F.

Results were presented of an analysis to determine maximum allowable heater element surface power density, in watts per square inch, when operating in plates at various temperatures so that the surface temperature of the element will not exceed the maximum allowable as specified by the vendor. The maximum allowable surface temperature specified by the vendor for these heater elements is 1500 °F.

This analysis showed that at a plate temperature of 820 °F, the maximum allowable surface power density is approximately 28 watts per square inch. Calculated power densities of the three heater elements used in this application are as follows:

500 watts	22 watts per square inch
125 watts	6 watts per square inch
60 watts	8 watts per square inch

The worst case heater element is operating at 79 percent of its rated watt density.

7.4 Test Plan

PLR test plans for the following assemblies are detailed in Fluid Systems Document 41-12096, "Test Plan for the Parasitic Load Radiator Used on the Solar Dynamic Ground Test Demonstrator."

Radiator Plate Design Verification Test - This test will be performed on a single prototype radiator plate.

The radiator plate will be loaded with three special PLR heater elements. These heater elements are similar to the heater elements to be used in the PLR assembly except they have been instrumented with thermocouples to provide the sheath temperature of the element.

The loaded plate will be installed in a vacuum chamber and energized at 500, 560, and 685 watts. Plate and heater sheath temperatures will be monitored and compared to acceptable limits.

Radiator Plate Acceptance Test - This test will be performed on all radiator plates prior to installation in the complete PLR Assembly. The test itself is identical to the Radiator Plate Design Verification Test described above.

PLR Assembly Acceptance Test - This test shall be performed on the PLR Assembly prior to installation in the vacuum tank.

The insulation resistance and dielectric strength of all mutually insulated components shall be tested and verified to be within acceptable limits. The resistance of each heater element will be measured both hot and cold to verify resistance is within an acceptable range.

The PLR Assembly will be installed in a vacuum tank and energized at rated power. Plate temperatures, the connector temperature, and the mounting base temperature will be monitored.

7.6 Open Issues

There are no significant open issues remaining.

8. Data Acquisition & Control System (DACS)

8.1 Design Document List

The following is a bibliography of all documents used to support the DACS CDR:

41-11764-5	Solar Dynamic Ground Test Demonstration, Preliminary Design Review, "Electrons"
41-12071	Software Requirements Specification for the Data Acquisition and Control Subsystem (DACS) Software of the Solar Dynamic Ground Test Demonstrator
41-12092	Software Design Document for the Data Acquisition and Control Subsystem (DACS) Software of the Solar Dynamic Ground Test Demonstrator
41-12093	Software Test Plan for the Solar Dynamic Ground Test Demonstrator Data Acquisition and Control Subsystem Software
41-12102	Solar Dynamic Ground Test Demonstrator Data Acquisition and Control Subsystem Critical Design Review Package Report
41-12139	Data Acquisition and Control Subsystem (DACS), Critical Design Review (CDR View Graphs)
41-12088	Uncertainty Analysis for the Data Acquisition and Control Subsystem (DACS) of the Solar Dynamic Ground Test Demonstrator

Fluid Systems Drawings

P16M-01-028	SDGTD - DACS: Equipment Tree

8.2 Design Review Minutes

The DACS CDR was held at AlliedSignal Fluid Systems on Tuesday, May 25, 1993. The following major design elements were presented at the PCCU CDR:

Requirements

A compliance matrix of DACS requirements, as documented in Rocketdyne Specification N10121, was presented. Exceptions taken to the requirements were as follows:

- The Liquid Loop Heater control setpoint will be adjustable from the CRC, the PID will be tuned during initial setup and will not be tunable from the CRC. Likewise, the Pressure Transmitter Heater Unit controllers setpoint will be adjustable from the CRC and the PID will be initially tuned at setup and will require no further tuning from the CRC.

- There is no longer a requirement for remote positioning of the Concentrator.

- The pressure, speed and temperature accuracies attainable by the DACS are not to specification. The specification for speed has been changed. It was found that this parameter monitors the state of health of the TAC and as such does not need to be as stringent. The temperature specification was changed to read "% of Range" instead of "% of Full Scale." The discrepancy with the Radiator and Receiver differential pressures are state of health measurements and the inaccuracies can be tolerated.

There was some discussion concerning the following:

- Due to the inaccuracy of the signal conditioning for TAC speed signal, the raw signal would be routed to the CRC Output Patch Panel and critical measurements would be made with a counter/timer instrument.

Functional Description

During the functional description of the DACS the following items were discussed and presented in detail:

- National Instruments' SCXI platform versus the Programmable Logic Controller (PLC) platform

- Modular approach for both data acquisition and control of the SCXI system

- Block diagram of the DACS

- Data acquisition parameters for strain, accumulator volume potentiometer, pressure transmitters, thermocouples, pyroheliometers and flowmeter

- PCCU voltage, current and speed data acquisition, display and output interfaces

- TAC displacement probe data acquisition and output interfacing

- Solar Simulator Subsystem reserved interface cabling and signal conditioning in the DACS

- Block diagram and schematics of the control functions provided by the DACS

- Alternate power provided by the DACS to the PCCU, the liquid loop pumps and the shutdown valves.

There was some discussion concerning the following:

- The grounding scheme between the PCCU and the DACS would need to be clearly defined (PDR Action Item 60).

- The time necessary for the DACS to process a watchdog signal input and issue the appropriate command. Reference the User Load Relay and the TAC speed signal to shutdown valve command response.

Layout and Design Definition

The layout of the DACS Control Room Console (CRC) and Instrumentation Console (IC) were presented. The following topics were discussed in detail:

- CRC and IC top assembly

- Analog Instrumentation Panel (P16M-13-114) front panel topography

- SCXI signal conditioning chassis's input card configuration.

There was some discussion concerning the following:

- Names assigned to the signals in the wire listing will be included on the front panels along with those signals' descriptive name (DACS Action Item 8).

Uncertainty Analysis

The major topics discussed were:

- Definition and description of the terms used in the uncertainty analysis

- An explanation of the tabular form used in the analysis

- Summary of the measurement parameter analysis results.

There was some discussion of the following:

- An accuracy requirement for the pyroheliometers has not been issued. The requirement needs to be issued to determine if the uncertainty of the measurement is acceptable (DACS Action Item 12).

DACS Software Test Results

The prototype testing of the Labview platform to be used in the DACS was presented. The following topics were discussed in detail:

- Objectives of the testing
- Test equipment setup
- Testing results
- Conclusions.

No significant discussion resulted.

DACS Software

The following topics were presented concerning the DACS software:

- A review of the system hardware, including computers, interfaces, data acquisition and control
- Software requirements for human engineering, interface, operational, data acquisition and storage, diagnostic, safety and quality control
- Software design concerning the DOS and Windows platform, architecture, operational modes, storage and operating sequences.

There was discussion of the following:

- The type of actions that would be taken during alarm conditions
- How security will be handled
- Redundant data storage; the low-speed data acquisition file should be stored in real time on two separate computers to provide data protection
- What type of warnings will be given before the data disks run out of storage space
- Concerns about locking out the system startup if the ELS is not active.
- Whether the DACS display will indicate that the solar

shutter is open

- Whether there is enough CPU time available to linearize the thermocouples

- What will allow the operator to control the gas charge valves.

DACS Test Plan

The software development cycle, testing process and major functions to be tested were explained in detail. No significant discussion resulted.

Spares

The spares provided in the DACS and its expansion capability were presented. It was shown that the requirements for a minimum of 10 percent installed spare I/O as delivered and the capability to expand I/O by an additional 20 percent were met. No significant discussion resulted.

Fabrication and Schedule

The schedule presented was as follows:

- Instrumentation Console and Control Room Console fabrication from 6/14/93 to 8/31/93

- Software code generation and testing from 6/1/93 to 11/1/93

- Hot Loop testing from 11/1/93 to 2/1/93

- Power Control Subsystem testing from 7/1/94 to mid-October 1994

- System testing at NASA, LeRC from 11/1/94 to 9/1/95.

No significant discussion resulted.

8.3 Design Summary

8.3.1 Hardware Design

The DACS is comprised of two separate consoles, the Instrumentation Console (IC) and the Control Room Console (CRC).

The IC is comprised of the following:

486/66 MHz computer (ICPC)
Monitor, 19" with Touch Screen (M1)
National Instruments SCXI chassis (SCXI1-4)
IC Patch Panel A (P16N-01-176)
IC Patch Panel B (P16N-01-177)
SDGTD Heater Control: LCL, BAP & LCL Pressure Transducers (P16M-04-018)
SDGTD-Liquid Coolant Pump Controllers (P16M-04-017)
IC-SCXI/CRC Signal Conditioning Buffer (P16M-13-115)
Displacement Probe Signal Conditioning
Power Supplies

The ICPC is populated with three National Instruments data acquisition boards (one 12 bit high speed and two 16 bit low speed) for sampling the multiplexed signals from the data acquisition boards. The ICPC also contains a National Instruments digital I/O board, a National Instruments analog output board, an RS 422 communications board, two IEEE 488 boards and a VGA video driver board. The software is DOS 5.0, Microsoft Windows 3.1 and National Instruments Labview for Windows. The man/machine interface is a 19" monitor with a touch screen.

The signal conditioning, gas charge and shutdown valve switching, and PCCU alternate and accessory power switching are contained in the four National Instruments SCXI chassis. The chassis house the individual modules for signal conditioning and control. The IC Patch Panels A and B are the connector mounting panels for I/O interfacing.

The Liquid Control Loop (LCL) heater, the BAP and LCL pressure transducer heaters are controlled by individual PID controllers housed in the P16M-04-018 Fluid Systems unit. The analog setpoints for the individual controllers are provided by the analog I/O in the ICPC.

The LCL pumps (both primary and secondary) are speed controlled by individual PID controllers housed in the Fluid Systems P16M-04-017 unit. The power, setpoints and enable signals to these controllers are controlled by the SCXI chassis. The P16M-04-017 unit also contains the dc-dc Converter for accessory power to the Shutdown Valves.

SDGTD high voltage signals, signals which present a high Common Mode voltage at the signal conditioning and signals with multiple destinations are conditioned in the Fluid Systems P16M-13-115 unit.

The IC also houses the displacement probe conditioning manufactured by Capacitec and interfaces those conditioned signals to the CRC.

The +115 Vdc power supply which provides alternate power for the PCCU, Shutdown Valves and the LCL Pumps is contained in the IC. Two +40 Vdc power supplies are in a single chassis mounted in the IC. One +40 Vdc power supply provides both pull-in power for the Shutdown Valves and actuation power for the Gas Charge Valve. The second +40 Vdc supply provides power for the pressure transmitter excitation.

The CRC is comprised of the following:

486/66 MHz computer (CRCPC1-4)
Monitor, 19" with Touch Screen (M1-4)
Laser Printer (PRNT1)
Tape Drive (TD1)
Analog Instrumentation Panel (P16M-13-114)
CRC Input Patch Panel (P16N-01-174)
CRC Output Patch Panel (P16N-01-175)

The CRCPC1-4 computers are using DOS 5.0, Microsoft Windows 3.1 and National Instruments Labview for Windows. They are linked to each other, the printer, the tape drive, the IC, the Electronic Load Subassembly (ELS) and the Solar Simulator Subassembly (SSS) using the IEEE 488 interface bus. The software will be configured such that the machine that the Test Operator logs in on will become the system control machine. All the commands to the SDGTD will be issued from this machine only while the Test Operator is logged in. All other machines will only be capable of displaying system data acquisition and control parameters. All the machines will be capable of data output to the printer at all times.

The Fluid Systems P16M-13-115 unit contains the SDGTD manual Emergency Shutdown switch and six digital panel readouts for selected parameters to be monitored in case of a DACS failure.

The CRC Input Patch Panel is the connector mounting panel for I/O interfacing. The CRC Output Patch Panel contains monitor points for connection of test equipment for real-time monitoring of key parameters.

8.3.2.2 Software Design

Following are key points in the design of the DACS software.

Software Documentation

- Software Requirements Specification: Describes the functional requirements of the software, timing requirements, and the hardware interfaces.
- Software Design Document: Describes how the requirements will be implemented, the structure of the software modules and data, and any internal interfaces.
- Software Test Plan: Describes how the software will be tested, including a brief description of the tests and the test objectives during development of the software.

System Modes - Following are the various operating modes of the DACS software and the criteria for transitioning between them:

MODES

- Monitor
- Active
- Recording
- Calibration
- Backup
- Start
- Shutdown
- Emergency stop
- Display
- Control

- MONITOR

  Monitors all man/machine interfaces for input. The system is not scanning for any data input nor recording information. The prerecorded data files, however, can be accessed by the users.

- ACTIVE

  Scans the data acquisition channels, communicating with the PCCU, SIPS, ELSS and SSS.

- RECORDING

  Can be activated only in the ACTIVE state. The system is recording the acquired data in this state.

- CALIBRATION

  Can run only when the system is in the MONITOR state. In this state the data channels can be displayed with the calibration data. It will allow the operator to change calibration values and perform a two-step calibration.

- BACKUP

  Can be operated during the RECORDING, ACTIVE and MONITOR states. It allows the backup CSC to backup the data files on the ICPC.

- START

  Performs the standard startup sequence.

- SHUTDOWN

  Performs the standard shutdown sequence.

- EMERGENCY STOP

  Opens the shutdown valves, records the shutdown, closes the high-speed data acquisition file, informs the PCCU of the shutdown and alarms the operator of the problems.

- DISPLAY

  Displays the data requested by the operator.

- CONTROL

  When activated, displays pertinent information and accepts control commands from the operator.

<u>CSCI Architecture</u> - The following describes the DACS CSCI architecture:

ICPC:

IEEE 488 Transceiver Module for the SIPS
SIPS Interpreter and Control Module
RS 422 Transceiver Module for the PCCU
PCCU Interpreter and Control Module
High Speed Data Acquisition Module
Low Speed Data Acquisition Module
Control Output Module
Data Linearization Conversion and Control Module
Alarm Processor Module
Alarm Condition Editor

Calibration Data Editor Module
High Speed Data Recorder Module
Low Speed Data Recorder Module
Data File Indexer Module
IEEE 488 Transceiver Module for the DACS, ELS and SSS
Man/Machine Interface Module for the ICPC
Access Control and Editor Module for the ICPC
Control Interpreter Module for the ICPC
Backup Module for the ICPC

TCPC & DDPC:

IEEE 488 Transceiver Module for the DACS, ELS and SSS
Backup Program Module for the TCPC
Control Interpreter Module for the TCPC
Access Control and Editor Module for the TCPC
Man/Machine Interface Module for the TCPC
Orbital Summary Module

<u>Mode/CSC Relationships</u> - The following describes which CSCs operate in which modes:

- MONITOR

  Alarm Condition Editor
  Calibration Data Editor Module
  Data File Indexer Module
  IEEE 488 Transceiver Module for the DACS, ELS and SSS
  Man/Machine Interface Module for the ICPC
  Access Control and Editor Module for the ICPC
  Control Interpreter Module for the ICPC
  Backup Module for the ICPC
  IEEE 488 Transceiver Module for the DACS, ELS and SSS
  Backup Program Module for the TCPC
  Control Interpreter Module for the TCPC
  Access Control and Editor Module for the TCPC
  Man/Machine Interface Module for the TCPC
  Orbital Summary Module

- ACTIVE

  IEEE 488 Transceiver Module for the SIPS
  SIPS Interpreter and Control Module
  RS 422 Transceiver Module for the PCCU
  PCCU Interpreter and Control Module
  High Speed Data Acquisition Module
  Low Speed Data Acquisition Module
  Control Output Module
  Data Linearization Conversion and Control Module
  Alarm Processor Module
  Data File Indexer Module

IEEE 488 Transceiver Module for the DACS, ELS and SSS
Control Interpreter Module for the ICPC
Backup Module for the ICPC
IEEE 488 Transceiver Module for the DACS, ELS and SSS
Backup Program Module for the TCPC
Control Interpreter Module for the TCPC
Man/Machine Interface Module for the TCPC
Orbital Summary Module

- RECORDING

IEEE 488 Transceiver Module for the SIPS
SIPS Interpreter and Control Module
RS 422 Transceiver Module for the PCCU
PCCU Interpreter and Control Module
High Speed Data Acquisition Module
Low Speed Data Acquisition Module
Control Output Module
Data Linearization Conversion and Control Module
Alarm Processor Module
High Speed Data Recorder Module
Low Speed Data Recorder Module
Data File Indexer Module
IEEE 488 Transceiver Module for the DACS, ELS and SSS
Control Interpreter Module for the ICPC
Backup Module for the ICPC
IEEE 488 Transceiver Module for the DACS, ELS and SSS
Backup Program Module for the TCPC
Control Interpreter Module for the TCPC
Man/Machine Interface Module for the TCPC
Orbital Summary Module

- CALIBRATION

High Speed Data Acquisition Module
Low Speed Data Acquisition Module
Control Output Module
Data Linearization Conversion and Control Module
Calibration Data Editor Module
Man/Machine Interface Module for the ICPC
Man/Machine Interface Module for the TCPC

- BACKUP

IEEE 488 Transceiver Module for the DACS, ELS and SSS
Man/Machine Interface Module for the ICPC
Backup Module for the ICPC
IEEE 488 Transceiver Module for the DACS, ELS and SSS
Backup Program Module for the TCPC
Control Interpreter Module for the TCPC
Man/Machine Interface Module for the TCPC

- START

  IEEE 488 Transceiver Module for the SIPS
  SIPS Interpreter and Control Module
  RS 422 Transceiver Module for the PCCU
  PCCU Interpreter and Control Module
  High Speed Data Acquisition Module
  Low Speed Data Acquisition Module
  Control Output Module
  Data Linearization Conversion and Control Module
  Alarm Processor Module
  Alarm Condition Editor
  Calibration Data Editor Module
  High Speed Data Recorder Module
  Low Speed Data Recorder Module
  Data File Indexer Module
  IEEE 488 Transceiver Module for the DACS, ELS and SSS
  Man/Machine Interface Module for the ICPC
  Access Control and Editor Module for the ICPC
  Control Interpreter Module for the ICPC
  Backup Module for the ICPC
  IEEE 488 Transceiver Module for the DACS, ELS and SSS
  Backup Program Module for the TCPC
  Control Interpreter Module for the TCPC
  Access Control and Editor Module for the TCPC
  Man/Machine Interface Module for the TCPC
  Orbital Summary Module

- SHUTDOWN

  IEEE 488 Transceiver Module for the SIPS
  SIPS Interpreter and Control Module
  RS 422 Transceiver Module for the PCCU
  PCCU Interpreter and Control Module
  High Speed Data Acquisition Module
  Low Speed Data Acquisition Module
  Control Output Module
  Data Linearization Conversion and Control Module
  Calibration Data Editor Module
  High Speed Data Recorder Module
  Low Speed Data Recorder Module
  Data File Indexer Module
  IEEE 488 Transceiver Module for the DACS, ELS and SSS
  Control Interpreter Module for the ICPC
  IEEE 488 Transceiver Module for the DACS, ELS and SSS
  Control Interpreter Module for the TCPC
  Man/Machine Interface Module for the TCPC
  Orbital Summary Module

- EMERGENCY STOP

  IEEE 488 Transceiver Module for the SIPS
  SIPS Interpreter and Control Module
  RS 422 Transceiver Module for the PCCU
  PCCU Interpreter and Control Module
  High Speed Data Acquisition Module
  Low Speed Data Acquisition Module
  Control Output Module
  Data Linearization Conversion and Control Module
  Alarm Processor Module
  High Speed Data Recorder Module
  Low Speed Data Recorder Module
  IEEE 488 Transceiver Module for the DACS, ELS and SSS
  Man/Machine Interface Module for the ICPC
  Control Interpreter Module for the ICPC
  Backup Module for the ICPC
  IEEE 488 Transceiver Module for the DACS, ELS and SSS
  Control Interpreter Module for the TCPC
  Man/Machine Interface Module for the TCPC

- DISPLAY

  IEEE 488 Transceiver Module for the SIPS
  SIPS Interpreter and Control Module
  RS 422 Transceiver Module for the PCCU
  PCCU Interpreter and Control Module
  High Speed Data Acquisition Module
  Low Speed Data Acquisition Module
  Control Output Module
  Data Linearization Conversion and Control Module
  Alarm Processor Module
  Alarm Condition Editor
  Calibration Data Editor Module
  High Speed Data Recorder Module
  Low Speed Data Recorder Module
  Data File Indexer Module
  IEEE 488 Transceiver Module for the DACS, ELS and SSS
  Access Control and Editor Module for the ICPC
  Control Interpreter Module for the ICPC
  Backup Module for the ICPC
  IEEE 488 Transceiver Module for the DACS, ELS and SSS
  Backup Program Module for the TCPC
  Control Interpreter Module for the TCPC
  Access Control and Editor Module for the TCPC
  Man/Machine Interface Module for the TCPC
  Orbital Summary Module

- CONTROL

  IEEE 488 Transceiver Module for the SIPS
  SIPS Interpreter and Control Module
  RS 422 Transceiver Module for the PCCU
  PCCU Interpreter and Control Module
  High Speed Data Acquisition Module
  Low Speed Data Acquisition Module
  Control Output Module
  Data Linearization Conversion and Control Module
  Alarm Processor Module
  Alarm Condition Editor
  Calibration Data Editor Module
  High Speed Data Recorder Module
  Low Speed Data Recorder Module
  IEEE 488 Transceiver Module for the DACS, ELS and SSS
  Access Control and Editor Module for the ICPC
  Control Interpreter Module for the ICPC
  Backup Module for the ICPC
  IEEE 488 Transceiver Module for the DACS, ELS and SSS
  Backup Program Module for the TCPC
  Control Interpreter Module for the TCPC
  Access Control and Editor Module for the TCPC
  Man/Machine Interface Module for the TCPC
  Orbital Summary Module

<u>Communication</u> - The DACS will communicate with the following:

- ELS IEEE 488
- SSS IEEE 488
- SIP IEEE 488
- PCCU RS 422

8.5 Open Issues

There are no significant open issues remaining.

9. Electric Load Simulator (ELS)

The ELS system provides a computer-controlled electronic load to test the 2.1 kWe SDGTD Program. The load consists of a single electrically isolated load module with a minimum load capacity of 4 kW. The system is upgradable to four load modules for a total of 16 kW.

The load modules are purely resistive dc loads controlled from a local panel (manual control) or remotely by a controller through an IEEE 488 bus from a PC/AT 286/386/486. The controller can operate any single load module from zero to 100 percent of its rated dissipation by local or remote programming. The controller shall be capable of commanding at least four independent load modules. The local control panel shall provide for manual data entry and local readout of the load status and program steps and is disabled when in remote operation. Displays and status checking are not disabled in local or remote mode. If configured in the local mode, the PC will remotely monitor the status of the load system operation.

In remote operation the controller can command the load modules to follow a load profile. The load profile shall consist of step or smooth ramp changes, without unwarranted discontinuities in loading, between programmed load settings at programmed execution rates.

The load module controller being purchased has built-in capabilities for modulation of the load power/current/resistance. Because arbitrary waveform capability does not exist in the controller, the following specifications for waveform generation apply only to the controller's capability, which may not be used by Labview. These specifications for the controller's own waveforms are:

SQUARE WAVE GENERATOR

Frequency Range	16 Hz - 10 kHz
Time Resolution	2 us
Accuracy	4 us
Duty Cycle Range	3 - 97% (1.0 kHz max)
Dwell Time Range	35 - 65, 500 us
Dwell Time Resolution	2 us
Dwell Time Accuracy	4 us

WAVEFORM GENERATOR

Programmable Slew Rate (10-90%)	20mA/us-20A/us
Dwell Time Range	35 -65, 500 us
Dwell Time Resolution	2 us
Dwell Time Accuracy	4 us

A separate commercial Arbitrary Waveform Generator will be added to the equipment rack for the purpose of supplying computer controllable arbitrary waveform modulation of the load. A coaxial cable connection from the arbitrary waveform generator to the load module will supply the load module with modulation when needed. This arbitrary waveform generator will be resident on the same IEEE 488 bus (as isolated from the computer) with the load module controller.

The programmed load can be modulated by an external input from an arbitrary analog signal. The external modulation input accepts a 0 - 10 Volt input and provides load command modulation in the given regulating mode over a sinusoidal frequency range of dc to 5 kHz full scale, with a 3 DB bandwidth. The external modulation input is usable to 20 kHz (sinusoidal) at reduced amplitude. Each load module has an independent external modulation input.

The controller shall provide for control of load module operation in constant current, constant power, and constant resistance. Each load mode shall operate in the mode commanded by the controller and shall not require a change in the load power level in order to change from one mode to another. The programming range, accuracy, resolution and rate of change of load shall be as follows:

CONSTANT CURRENT MODE

Range	0 - 200 A
Accuracy	0.1% FS ± 50 mA
Resolution	50 mA

CONSTANT RESISTANCE MODE

Range	0.10 - 100.0 ohms
Accuracy	1% FS ± 0.025 ohms
Resolution	0.025 ohms

CONSTANT POWER MODE

Range	40.0 - 4000 W
Accuracy	0.5% FS ± 1.0 W
Resolution	1.0 W

RATE OF CHANGE OF LOAD

Step Change/Slew Rate	100 us max to 90% change
Ramp Rate	100 us to 100 minutes
Accuracy	± 10% of setting
Resolution	± 10% of setting
Monotonicity	Spiking shall be less than or equal to the resolution of the mode in use.

The ELS system provides load power, voltage and current data over the communication bus upon request at a minimum rate of 1 Hz. The readback data specifications are:

POWER

Range	0 - 4000 W
Resolution	1.0 W
Accuracy	0.5% FS ± 1.0 mW

VOLTAGE

Range	0 - 200 V
Resolution	50 mV
Accuracy	0.2% FS ± 50 mV

CURRENT

Range	0 - 200 A
Resolution	50 mA
Accuracy	0.2% FS ± 50 mA

The ELS provides overvoltage, overcurrent, overpower and overtemperature protection. Voltage, current and power limits are programmable from 0 - 117% of its maximum input level. Upon an over condition, the fault status is reported over the communication bus and the load will program its input current to zero and open its input relay. Overtemperature protection is provided by two thermostats that monitor the heat sink temperature. If the temperature exceeds safe limits, the load will be turned off and an alarm will be given. The programmable protection limits are:

CURRENT LIMIT

Range	0 - 220 A
Resolution	0.88 A
Accuracy	1% FS ± 0.88 A

POWER

Range	0 - 4500 W
Resolution	18.0 W
Accuracy	1% FS ± 18.0 W

VOLTAGE

Range	0 - 220 V
Resolution	0.88 V
Accuracy	1% FS ± 0.88 V

TEMPERATURE

Over/Under Setpoint	Alarm at ±1% Deviation
Overtemperature	Fixed at 85 degrees C

The load modules have a fail-safe feature in case command power is lost. In the event of a failure, load power of each load module shall automatically ramp down to the leakage current rating of less than 1 mA within 15 seconds. A reset command from the local panel or remote communication bus will give the same results.

The ELS can simulate a short circuit at its input by programming itself to a constant current value that can not be satisfied by its control loop. All protection limits remain in effect during the application of a short circuit. Turning the short circuit on does not affect the programmed setting and load input will return to its previously programmed values when the short is turned off.

The ELS system provides remote sensing at the load modules, which is useful when measuring unit under test output voltage.

10. Turboalternator-Compressor (TAC)

The purpose of this report is to document the design status of the Power Conversion Subsystem (PCS) Turboalternator-Compressor (TAC) at the time of the Critical Design Review (CDR). This report presents the evidence to satisfy the requirements of the TAC refurbishment CDR milestone.

The TAC, Figure 10-1, that will be used in the SDGTD PCS will be refurbished from the Brayton Isotope Power System (BIPS) program of the mid-1970s. This TAC designated the Mini-BRU was optimized for use in a closed Brayton cycle power conversion system with an isotope heat source. The design working fluid was HeXe 83.8 as in the SDGTD.

SDGTD program assets include two Mini-BRUs, one of which will be refurbished for use in the SDGTD PCS. One of the Mini-BRU units successfully completed a 1000-hour endurance test in 1978; the other has not been run other than an acceptance test on compressed air.

10.1 DESIGN DOCUMENT LIST

The following list of documents was generated by Fluid Systems to document the Turboalternator-Compressor (TAC) design activities leading up to and including CDR:

Document Number	Document Title
3793297	Turboalternator-Compressor Drawing Tree
41-12095	TAC Test Plan
41-12103	TAC CDR Design Integration Report
41-12181	TAC CDR Viewgraphs
42-MR-8602	Mini-BRU vs V-22 Foil Journal Bearing Comparison
42-MR-9766	SDGTD Turbine Inlet Plenum
42-MR-9842	New Seal Plate Configuration for the Compressor on the SDGTD
42-MR-9896	SDGTD TAC Thermal Analysis

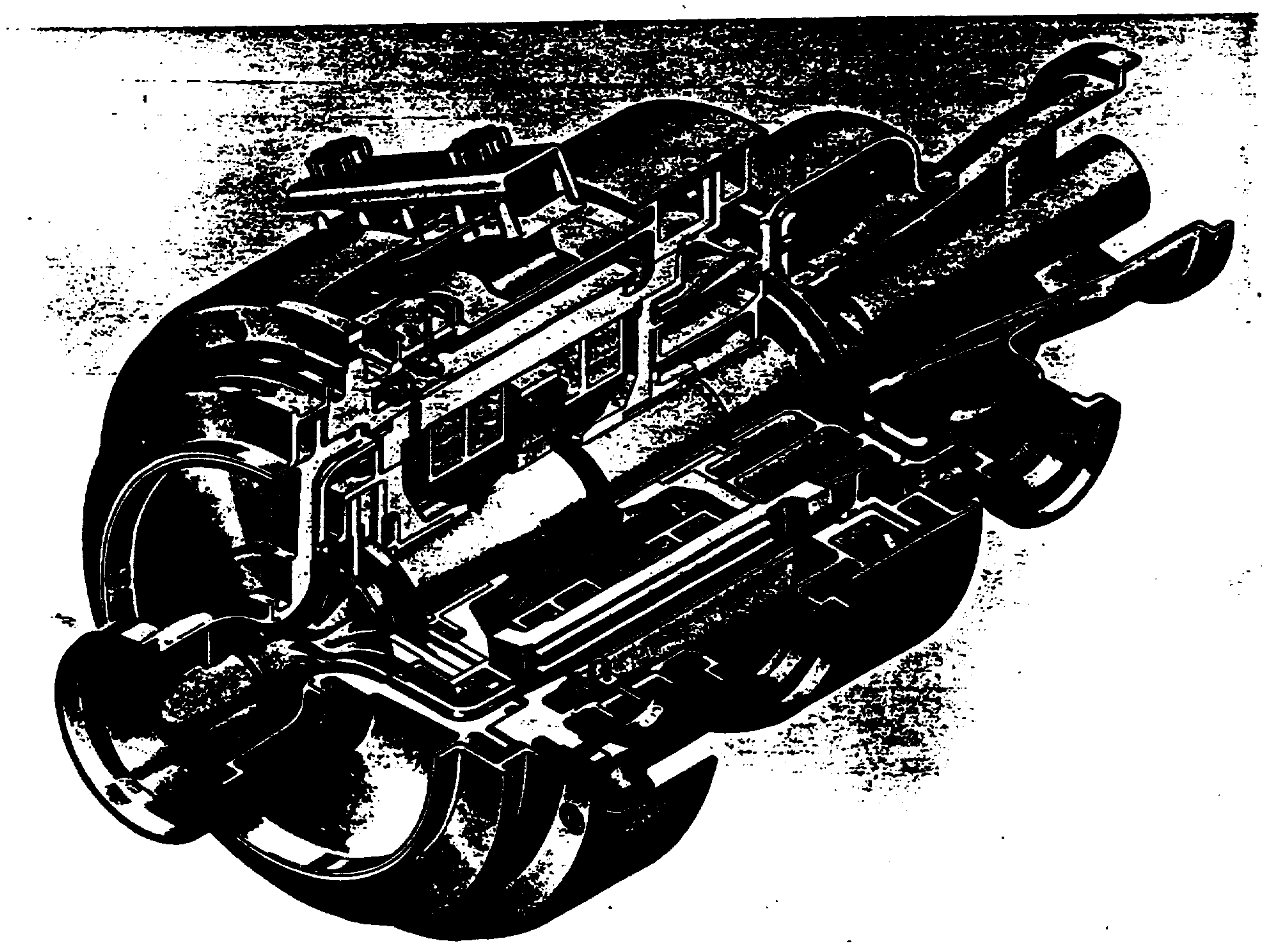

Figure 10-1. Turboalternator-Compressor

10.2 DESIGN REVIEW MINUTES

The TAC Critical Design Review was held at NASA LeRC on Wednesday, June 2, 1993. Topics covered during the review were as follows:

- INTRODUCTION
- TAC OPERATING CONDITIONS
- TAC DESIGN CHANGES
- TAC VERIFICATION AND TEST PLAN
- TAC RISK ASSESSMENT
- TAC HARDWARE ASSESSMENT
- TAC REFURBISHMENT PLAN
- TAC SPARES

10.3 DESIGN AND ANALYSIS SUMMARY

10.3.1 TAC Nominal Operating Conditions

Table 10-1 gives the key TAC operating parameters for various BIPS and SDGTD system operating conditions.

Table 10-1. TAC Nominal Operating Conditions

CONDITION	CASE 0	CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	CASE 6
OPERATING CONDITION	OPEN LOOP	0.5 CAPSULES	1 CAPSULE	2 CAPSULE	3 CAPSULE	WHL	SDGTD
ALTERNATOR OUTPUT POWER, kWe	VARIOUS	0.35	0.696	1.509	2.162	1.3	2.0
TURBINE INLET TEMPERATURE, R	AMBIENT	2060*	2060*	2060*	2060*	1855	1843
COMP DISCH PRESSURE, PSIA	N/A	20.6	33.2	67.8	106	66.7	110
COMP FLOW RATE, LB/SEC	N/A	0.071	0.117	0.235	0.357	0.255	0.396
ROTOR SPEED, KRPM	52	52	52	52	52	52	52
LIFE	N/A	10 YEARS	10 YEARS	10 YEARS	10 YEARS	1000 HOURS	1000 HOURS
STARTS	N/A	1000	1000	1000	1000	40 ACTUAL	600

*COLUMBIUM TURBINE PLENUM

Case 0 is operation of the TAC open loop with ambient temperature compressed air. This case is applicable to the Alternator Test Rig testing and the TAC Acceptance Test.

Cases 1 through 4 are the nominal design conditions for the BIPS. The number of capsules refers to the isotope heat source module quantity. The design turbine inlet temperature (TIT) is 2060 °R for these cases to take advantage of the isotope temperature capability. This elevated TIT gave higher cycle efficiency but necessitated a refractory metal (columbium) turbine plenum design to meet the creep life requirements of a flight unit. The Mini-BRU was never operated at any of these conditions.

Case 5 is the Workhorse Loop (WHL) test case at 1.3 kWe. The WHL was a laboratory test loop which used an electric heat source and a refrigerated heat sink. The Mini-BRU operated closed loop in the WHL at these conditions for 1000 hours. The Mini-BRU was never operated at full power in the WHL.

Case 6 is the SDGTD operating point. This point is a 2 kWe output condition with a lower TIT and higher pressure than the BIPS full power Case 4. This SDGTD full-power operating condition for the TAC was derived from Fluid Systems document 41-11460, "SDGTD State Point Analysis."

The TAC design is identical to the Mini-BRU except for two areas: additional pressure and displacement instrumentation and a new foil journal bearing design. A new assembly drawing and several new detailed drawings are required to implement the design changes. The TAC assembly (Part 3703271-1) calls out mostly parts common to the Mini-BRU; however, several new and reworked parts were necessary to make the above design changes. These new detail drawings are indicated on the drawing tree and are submitted as part of the CDR design package under separate cover.

10.3.2 INSTRUMENTATION

One conclusion drawn at the end of the BIPS program was that additional TAC instrumentation was required. The Mini-BRU was a compact flight design and did not incorporate much instrumentation even in the ground/workhorse loop test configuration. For the SDGTD TAC, the Mini-BRU will be modified to incorporate more instrumentation to provide additional information for analytical verification, fault diagnosis, and health monitoring.

Four capacitance (cap) displacement probes were added. Capacitance probes are used for their accuracy and stability up to high temperatures. Two radial cap probes, Part 3793273-1, monitor radial shaft motion at the thrust rotor OD. These probes are an important tool used to monitor rotor stability. Two axial cap probes, Part 3793272-1, sense the axial position of the compressor backface. The purpose of these probes is to indicate axial shaft position from which a determination of rotor thrust can be made.

Additional pressure taps and thermocouples were added to provide more complete information on the unit's thermal environment.

10.3.3 FOIL BEARINGS

The foil bearing system for the Mini-BRU was well characterized during the BIPS program. Following completion of the BIPS foil bearing development program in which two journal bearing failures occurred, the bearings successfully operated in the WHL for 1000 hours.

Foil bearing designs have greatly improved since the Mini-BRU was designed in the 1970s. Current designs have several advantages over the Mini-BRU design:

- 150 percent greater load capacity.
- Improved damping characteristics.
- Higher temperature capability (500 °F steady state compared to 400 °F).

These improvements come from the addition of backing springs, improved coatings and improved manufacturing techniques. The backing springs optimize the supporting pressure field in the gas film thickness for increased load capacity. Backing springs also improve damping by introducing additional coulomb frictions between the foil and carrier. The improved damping is especially desirable because of a foil bearing supported rotor's susceptibility to subsynchronous instabilities. A high temperature proprietary coating called PBGF (polyimide-bonded-graphite-fluoride) gives an additional 100° F temperature margin over Teflon-S.

During the hardware assessment it was determined that no bearing sets of the original WHL configuration were available. Therefore, even if the Mini-BRU bearings were used in the SDGTD TAC, new bearings would have to be fabricated. In addition, some additional hot development testing would still need to be done on these bearings because the 1000-hour bearing configuration is not known. The actual bearings that ran 1000 hours are not available, and configuration changes made during that testing were not fully incorporated into the drawings. In particular, the 1000-hour bearing sway space is in question.

The Mini-BRU bearing is a research design with no production tooling and would have to be hand made. The production fabrication process yields tighter tolerance parts with greater repeatability and is therefore more desirable than hand made foil bearings. A production bearing would ensure NASA's ability to obtain spare bearing parts for any follow-on testing to the SDGTD program.

A production journal bearing from the V-22 Osprey environmental control unit was identified as fitting the TAC envelope. This bearing was designed in 1988 and has the advantages described above. It was selected for the baseline journal bearing and will be subjected to the verification process detailed below for use in the SDGTD TAC.

Table 10-2 compares of the design parameters for the Mini-BRU and V-22 bearings.

Table 10-2. Foil Journal Bearing Design Parameters

	MINI-BRU BEARING	V-22 BEARING
NUMBER OF FOILS	EIGHT	FIVE
TYPE OF FOIL	P	T
BACKING SPRINGS	NO	YES
COATING	TEFLON-S	PBGF
MATERIAL	302 S.S.	INCO X-750
FOIL WIDTH	0.9 in	0.95 in
SHAFT DIAMETER	1.038 in	1.038 in
SWAY SPACE	9 mils	6 mils
SPRING RATE	1000-1200 lb/in	1000-1200 lb/in
BREAKAWAY TORQUE	13 in-lb	11 in-lb
POWER LOSS (OP PT)	30 watts	30 watts
DAMPING COEF	approx 0.2	0.41-0.65
LOAD CAPACITY	11 lb	30 lb
STEADY STATE TEMPERATURE LIMIT	400 °F	500 °F
TRANSIENT TEMPERATURE LIMIT	450 °F	550 °F
AXIAL FLOW AREA	0.034 in^2	0.018 in^2

Incorporation of the V-22 journal bearings simply requires new bearing retainers, Parts 3793275-2 and 3793276-2. The retainer design was modified to accept the five-foil bearing and to set the new sway space.

The Mini-BRU journal bearing retainer incorporated a Teflon-coated steel bumper ring, Part 3604343-2, which did not allow the shaft to fully compress the journal bearings in the radial direction. This bumper ring allowed 0.0035 in. of radial motion before the shaft would contact it. This feature was used with the Mini-BRU bearings because of their tendency to allow relatively large amplitude subsynchronous shaft orbits at operating speed. Because of the superior damping of the V-22 bearing these bumpers were not needed and were eliminated from the design.

The new turbine journal bearing retainer is different from the

Mini-BRU retainer in that the cooling slots on the ID of the retainer were eliminated. Although the V-22 bearing has less flow area due to smaller sway space, thermal analyses discussed later in this report predict bearing temperatures below limits. This design change will be verified by testing.

There is no production thrust bearing that will fit the current Mini-BRU envelope. Installing the V-22 thrust bearing would require modification of the TAC but could be done. This bearing has a much greater load capacity than the Mini-BRU thrust bearing and is being procured as a backup in case additional thrust capacity is required. The 1000-hour thrust bearing configuration is not in question, and five sets have been newly fabricated to support the SDGTD program.

10.4 COMPONENT PERFORMANCE

The TAC performance parameters are verified for SDGTD operating conditions as follows.

10.4.1 COMPRESSOR AND TURBINE PERFORMANCE

BIPS analysis and testing thoroughly mapped compressor and turbine performance over a large range of conditions including the SDGTD design point. This data is documented in NASA CR-159441, "Final Report Analysis, Design, Fabrication and Testing of the Mini-Brayton Rotating Unit." No further analysis is necessary. The BIPS maps are being used for SDGTD performance analysis. The deliverable TAC will demonstrate compressor and turbine performance in the PCS Hot Loop Test.

10.4.2 ALTERNATOR PERFORMANCE

BIPS analysis and testing thoroughly mapped alternator generating and motoring characteristics. This work is reported in Fluid Systems Reports 75-311211, "Final Report, Mini-Brayton Alternator Design" and 31-2316, "Test Report, Mini-Brayton Alternator Performance and Motor Characteristics." No further analysis is required.

The only alternator testing required is that necessary to support the PCCU and SIPS development. This will be accomplished with the Alternator Test Rig. The deliverable TAC will demonstrate alternator performance in the TAC Acceptance Test and the PCS Hot Loop Test.

10.4.3 FOIL BEARING PERFORMANCE

The Mini-BRU foil thrust and journal bearings were designed to operate at design conditions specified in Table 10-1, Cases 1 through 4. These bearings were demonstrated for a 1000-hour test in the WHL at Table 10-1, Case 5.

The SDGTD will use the Mini-BRU thrust bearing design, but a new journal bearing design will be installed. The new journal bearing will be a production unit from the Boeing/Bell V-22 Osprey Environmental Control Unit. In order to get an early idea of the performance advantages of the V-22 bearing some comparable open cycle Alternator Test Rig data was taken for the Mini-BRU and the V-22 supported rotor system. This data is evaluated in Fluid Systems Report 42-MR-8602. This evaluation supports the design change to the V-22 bearing.

Final verification of the foil bearing performance will be obtained by the PCS Hot Loop Test. The bearing performance parameters will be verified as follows.

10.4.3.1 Power Loss

A BIPS analysis calculated bearing power loss for the Mini-BRU; results are given in Table 10-3. The SDGTD operating conditions are very close to the BIPS 3 HSA condition, Table 10-1, Case 4. The thrust bearing prediction is valid for SDGTD. However, a new journal bearing prediction was made based on the design change to the V-22 bearing.

Table 10-3. Foil Bearing Loss SDGTD Design Conditions

BEARING	POWER LOSS, W
Mini-BRU THRUST BEARING, TOTAL BOTH SIDES	80
Mini-BRU JOURNAL BEARING	38
V-22 THRUST BEARING, TOTAL BOTH SIDES	190
V-22 JOURNAL BEARING	30

These power loss predictions cannot be verified by direct measurements in the PCS Hot Loop Test. However, TAC pressure and temperature instrumentation will provide data for input to the TAC thermal and secondary flow models. Because bearing temperatures are sensitive to bearing power loss, power loss predictions will be validated indirectly by evaluating test data with the aid of the analytical models. Note that the V-22 journal bearing has a lower predicted power loss than the Mini-BRU journal bearing.

10.4.3.2 Load Capacity

The load capacities of the Mini-BRU and V-22 bearings are given in Table 10-4.

Table 10-4. Foil Bearing Load Capacity SDGTD Design Conditions

BEARING	LOAD CAPACITY, LB
Mini-BRU THRUST BEARING	30
Mini-BRU JOURNAL BEARING	11
V-22 THRUST BEARING	80
V-22 JOURNAL BEARING	30

Because of the improved design, the V-22 bearings have significantly higher load capacities. The load capacities of the above bearings have been demonstrated in air on various test rigs. No further verification analysis or testing for bearing load capacity is necessary.

10.4.3.3 Spring Rate

Bearing spring rates were designed to minimize preload, breakaway torque, power loss and control rotor deflections to acceptable values. The thrust and journal bearing spring rates were verified by test. Representative load-deflection curves for the Mini-BRU and V-22 journal bearings are given in Figure 10-2. The Mini-BRU thrust bearing load-deflection curve is given in Figure 10-3. The Mini-BRU journal bearing will allow more radial deflection due to its larger sway space. Hysteresis exhibited by the curves is due to foil overlap exacerbated by the use of a nonrotating static test rig.

The V-22 journal bearing spring rate is comparable to the Mini-BRU journal bearing. The journal bearing spring rate is the average slop of the curve as it crosses the null deflection axis. Both bearings give spring rates 1000 to 1200 lb/in. The V-22 bearing's performance in the TAC will be verified by open cycle Alternator Test Rig testing and by the PCS Hot Loop Test.

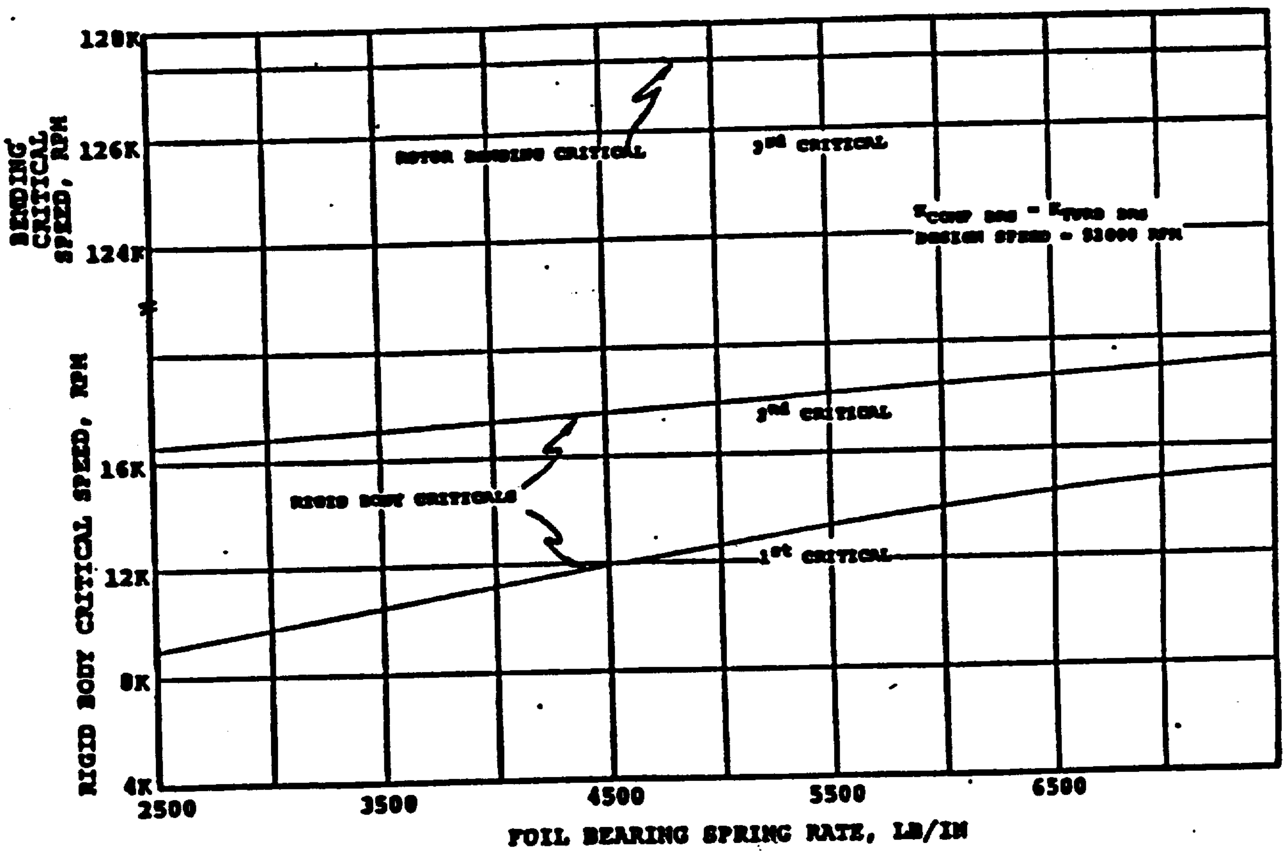

Figure 10-2.   Critical Speed

ONO SOKKI FFT ANALYZER CF-900 series
1kHz A: AC/ 10V B: AC/ 50V S.SUM 16/16 DUAL 1k

AVERAGE SP SUM

PWR SPECTRUM ChA

	1	867.5Hz	-21.23dBV
1st CRIT.	②	137.5 (8250 rpm)	-43.22
	3	842.5	-48.85
	4	927.5	-51.50
	5	852.5	-51.98
	6	102.5	-52.46
	7	895.0	-52.25
	8	887.5	-52.83
2nd CRIT.	⑨	192.5 (11550rpm)	-53.23
	10	905.0	-53.32

MASS MEM
BL: 1
R: 0

WINDOW
HANNING

OVERLAP
MAX

Cn DELAY
OF 0/64

TRIGGER
ChA
SLOPE: +
LEVEL:
0.0%

POSITION
-0F 8/64

UNIT
X: Hz
Y: PK

COH BLNK
OFF

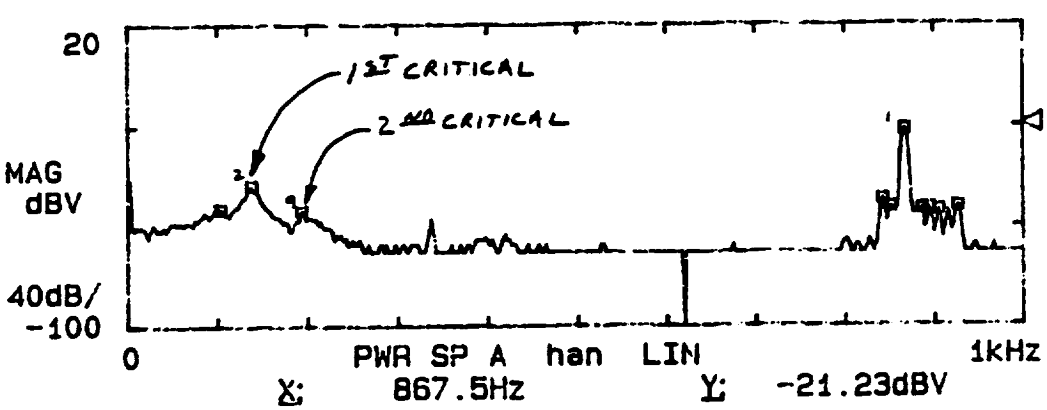

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Figure 10-3. Radial Runout FFT, Alternator Test Rig with V-22 Journal Bearings

10.4.3.4 Breakaway Torque

Maximum locked rotor torque capability of the alternator is 4 in-lb. The breakaway torque of the rotor is a result of the foil bearing preload. The bearings were designed for minimum power loss and breakaway torque. The maximum total breakaway torque verified for the SDGTD TAC bearing set (V-22 journal and Mini-BRU thrust) is 2.1 in-lb. This gives a 100 percent start margin. Verification will be done in Alternator Test Rig testing and the PCS Hot Loop Test.

10.5 ROTORDYNAMICS

A rotordynamics analysis was performed for the Mini-BRU rotor during the BIPS program, the results of which are reported in NASA CR-159441, "Final Report, Analysis, Design, Fabrication, and Testing of the Mini-Brayton Rotating Unit." This analysis assumed a higher journal bearing spring rate (3500 vs. 1000 lb/in), which affects the first two critical speeds and bearing loadings. However, the effects of the lower spring rates can be easily evaluated for the SDGTD TAC. The WHL 1000-hour test ran successfully on 1000 lb/in journal bearings, but no runout data was taken to validate margins. Because radial runout probes have been added to the SDGTD TAC, the rotordynamics will be verified with open cycle Alternator Test Rig testing and the PCS Hot Loop Test.

10.5.1 CRITICAL SPEED

The three Mini-BRU critical speeds, first and second rigid body, and first bending, were calculated for various journal bearing spring rates. As seen in Figure 10-4, however, the lowest spring rate analyzed is 2500 lb/in.

Operation at or near critical speeds will result in excessive bearing loading. The TAC operating speed is between the second and third critical speeds. The TAC can be safely operated in a speed range between 25 percent above the second critical and 40 percent of the third. The first and second rigid body criticals are dependent on spring rate. These critical speeds were not calculated for the 1000 lb/in bearings, but as can be seen from Figure 10-5, they will be lower with the lower spring rates. Figure 10-6 is an FFT of a radial shaft motion signal from the Alternator Test Rig mounted on the new V-22 bearings. The first and second critical response frequencies show up at 8250 rpm and 11,550 rpm respectively. Because the Alternator Test Rig rotor was designed to match the TAC rotor weight, center of gravity and moment of inertia, these measured values should be very close to those of the TAC. The critical speeds of the deliverable TAC will be verified in the TAC Acceptance Test. By the above criteria, steady state operation of the TAC should be above a minimum of 15,000 rpm. The third critical is not dependent on mount stiffness and will be unchanged from 125,700 rpm. This gives a 142 percent margin from the operating speed of 52,00 rpm. This meets the minimum required 40 percent margin.

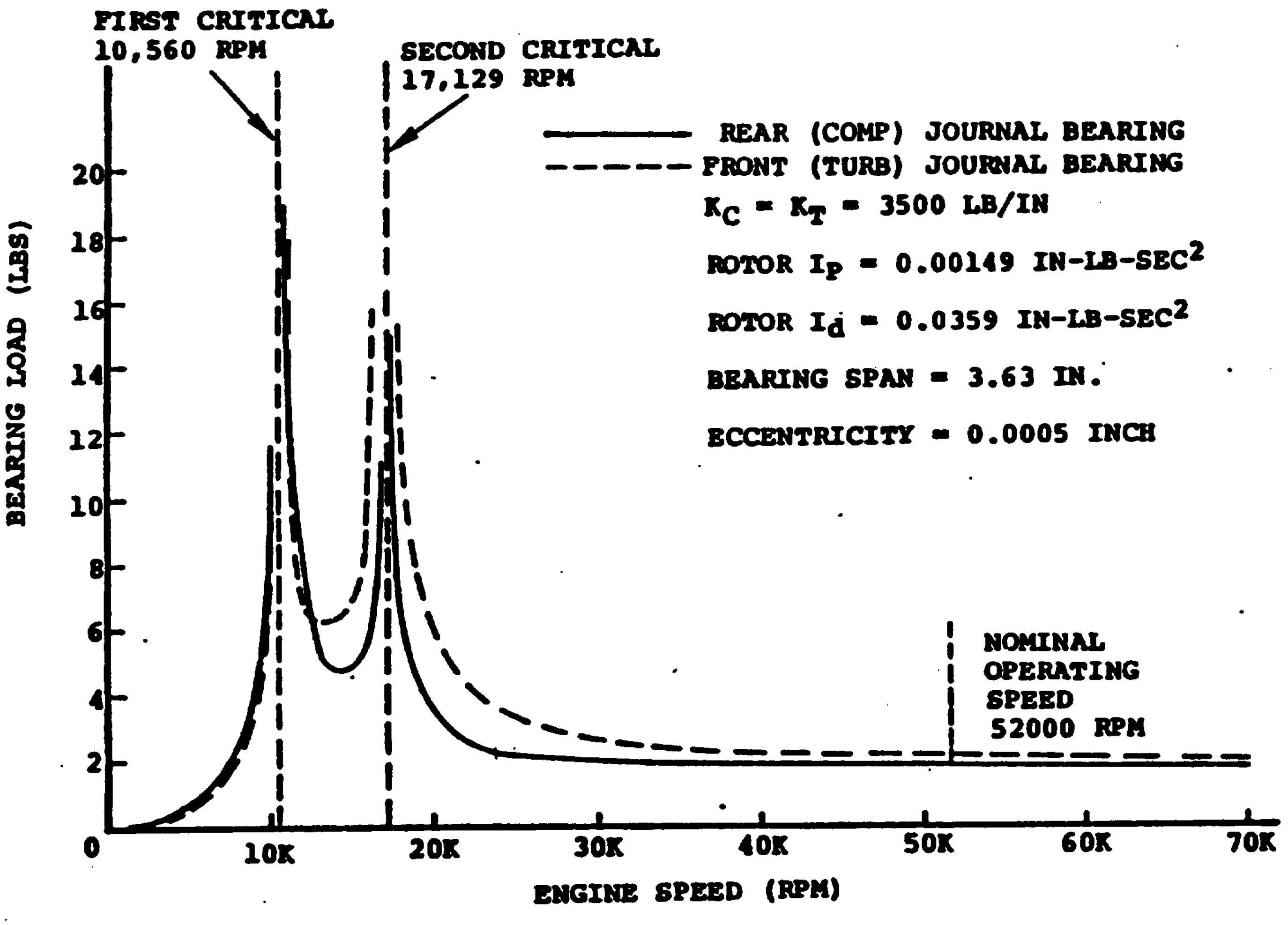


Figure 10-4. "Absolute" Bearing Loads for the Mini-BRU Rotor/Bearing System

- 1000-1200 lb/in THROUGH NULL POINT

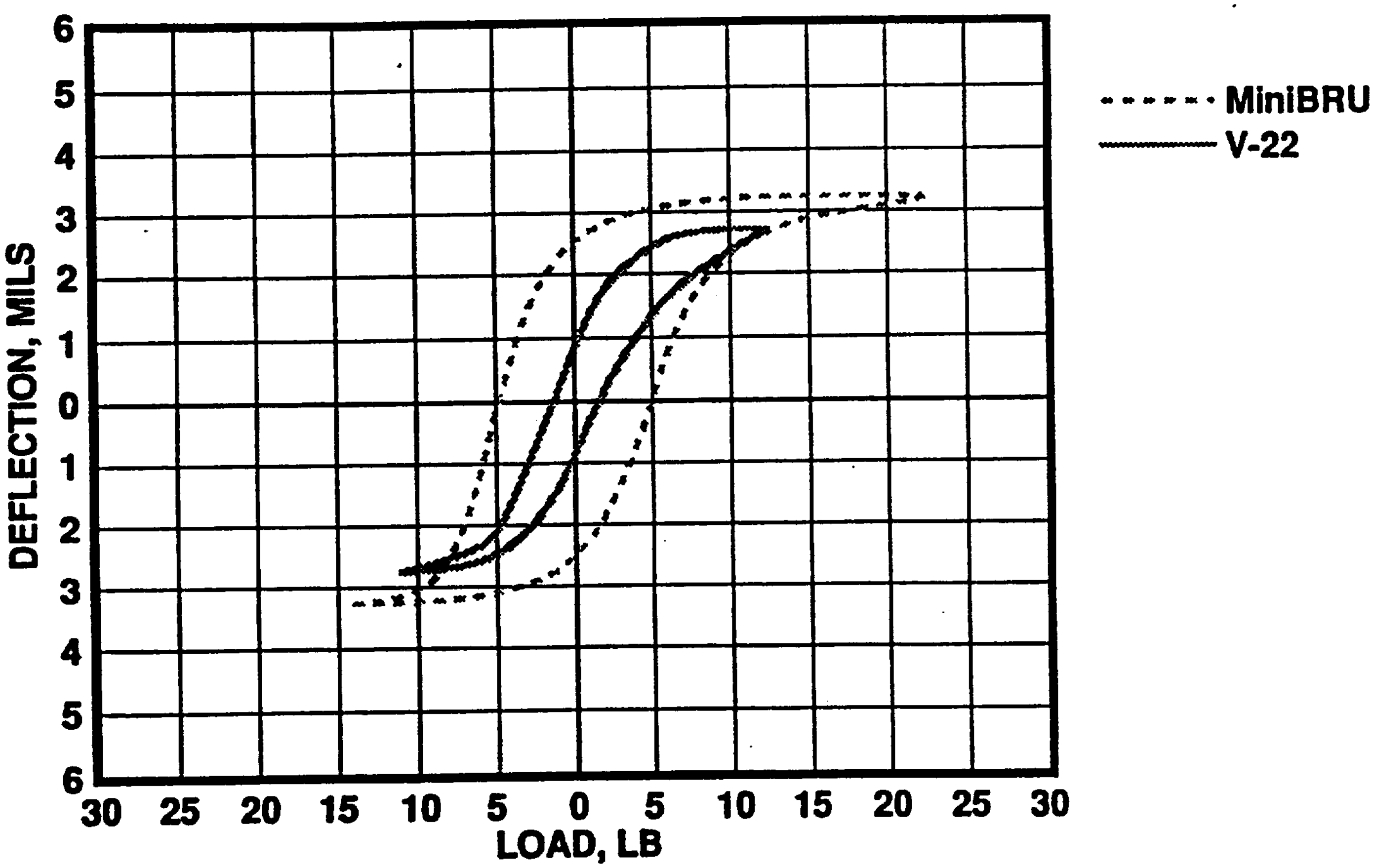


Figure 10-5. Foil Bearing Performance: Journal Bearing Spring Rate

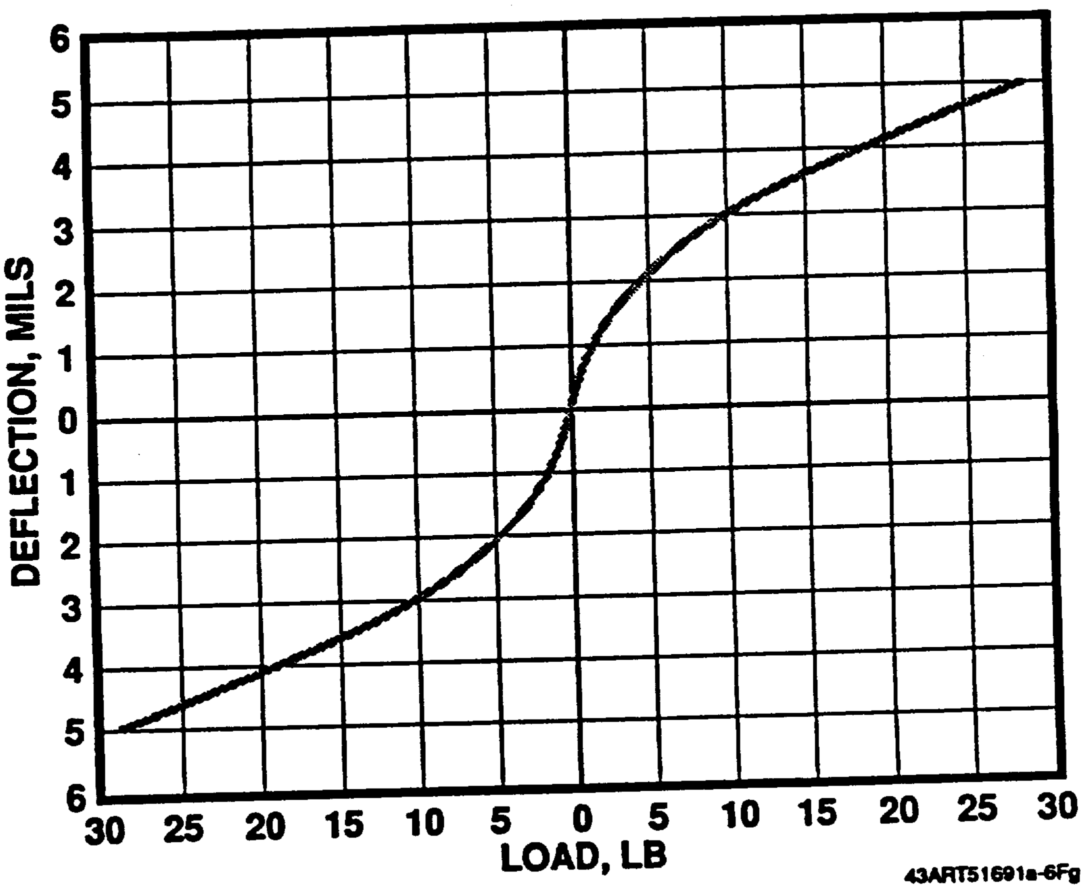


Figure 10-6. Foil Bearing Performance: Thrust Bearing Spring Rate

10.5.2 JOURNAL BEARING LOADING

The absolute dynamic bearing loads calculated with 0.0005 inch eccentricity (corresponding to a rotor unbalance of 0.020 oz-in) and 3500 lb/in journal bearing are given in Figure 10-6. Steady state bearing loading at operating speed is 2 lb. This is a conservative calculation since the rotor unbalance will typically be less than 0.010 oz-in and bearing spring rates are 1000 lb/in.

The low spring rate combined with the high bending critical result in low dynamic bearing loads near the operating speed. These loads must be superimposed on any steady state unidirectional loads to obtain total bearing loading. Because there are no maneuver loads and the TAC is operated vertically, there are no unidirectional loads in the SDGTD TAC.

With journal bearing load capacity of 30 lb, design margin is sufficiently high. Verification of dynamic bearing loading will be through rotor radial runout data from the open cycle Alternator Test Rig and the PCS Hot Loop Test.

10.5.3 ROTOR STABILITY

The TAC rotor is considered stable when the total peak-to-peak radial runout is 1 mil or less at a steady state condition. Shaft runout can exceed 1 mil, even up to the physical limit, for shock or other transients as long as the rotor orbit returns to 1 mil or less when the transient excitation is removed. The physical limit is complete compression of the journal bearings, which is when the deflection equals the sway space. There are no seal or other radial clearances more limiting than the journal bearing sway space. The V-22 bearing sway space is 6 mils diametral.

The foil bearing supported rotor will respond to unbalance loading at the once-per-revolution synchronous frequency. Lower frequency excitations produce a subsynchronous rotor response at the first and second critical frequencies.

The unbalance loading is a direct result of rotor balance. Foil bearing spring rate has a negligible effect on this synchronous runout, the amplitude will be equal to shaft eccentricity. Precision balancing of the rotor will limit the amplitude of this response to values less than 0.5 mils peak-to-peak. This response is analytically predictable and directly proportional to the amount of unbalance in the rotor.

Subsynchronous rotor responses are the result of excitations that are very difficult to predict. Excitation forces are nonlinear and primarily result from clearance and flow effects of the aerodynamic components. Nonlinear orbit analysis to predict the effects of these excitations is very expensive and must be validated with extensive testing. The accepted design approach to subsynchronous stability is to design the bearing from experience and test the rotor system at design operating conditions.

Subsynchronous stability increases with bearing spring rate and damping. The upper limits to spring rate are breakaway torque/power loss and thermal overload. Coulomb damping in the bearing is provided by friction between bearing components.

The Mini-BRU journal bearing was demonstrated to be stable in the open cycle test rigs. There was also a vibration criterion for the Mini-BRU Acceptance Test that demonstrated stability at no-load while driven with compressed air. Both of these tests would have accurately shown the rotor synchronous response. The concern in verifying that the SDGTD TAC will be stable is that neither of these conditions accurately replicates the aerodynamic excitations which give rise to subsynchronous instability at the WHL or SDGTD operating conditions. In fact, because the WHL test did not incorporate shaft runout probes, the stability of the rotor at this condition is not known. One could presume that 1000 hours of successful operation indicates a stable rotor system. The important question, however, is how much margin of stability exists at WHL conditions, and is it enough for the rotor to remain stable at the higher power conditions of the SDGTD testing where aerodynamic excitations are greater?

As a result, two actions were taken to assure and validate rotor stability at the SDGTD design conditions: the bearing design was upgraded to one with significantly more damping and shaft runout instrumentation was added to the TAC. Rotor stability will be verified in the open cycle Alternator Test Rig, the TAC Acceptance Test and in the PCS Hot Loop Test.

10.5.4 ROTOR THRUST

Preliminary BIPS aerodynamic analysis indicated that the Mini-BRU net thrust load would vary between 2 and 10 pounds as a function of pressure and power level. Net thrust values are calculated as the difference between the large opposing thrust loads of the compressor and turbine, so a low percentage error gives a large absolute error in net thrust. In consideration of the Mini-BRU objective of designing a bearing system with minimum power losses, it was decided to size the thrust bearing on the basis of the calculated 10-lb aerodynamic thrust load. In the event that subsequent testing revealed higher net thrust loads, the plan was to scallop the turbine wheel to balance the thrust within the capability limits of the original thrust bearing design.

The initial sizing of the Mini-BRU thrust bearing based on the above criteria resulted in a bearing design of 1.75 in. OD and 1.09 in. ID that provided a bearing area of 1.47 in. As stated above, this bearing has a maximum load capacity of 30 lb.

More detailed BIPS thrust predictions were performed later in the BIPS program. This work gave a net thrust of 29 lb towards the turbine for full power conditions. This prediction is out of the 2 to 10 lb design range and right at the load capacity of the bearing.

Although the unit ran successfully at WHL conditions (Case 5 in Table 10-1), no instrumentation was installed to measure shaft axial deflections. The direction of net thrust can be deduced from the temperature data as being towards the turbine because the turbine thrust bearing ran hotter than the compressor thrust bearing. However, the actual thrust condition at this case was not determined.

A new SDGTD thrust calculation was made and is found in Fluid Systems Report 41-MR-9896. Thrust loads were calculated at the three conditions summarized in Table 10-5.

Table 10-5. SDGTD Calculated Thrust Loads

OPERATING CASE FROM TABLE 10-1	CALCULATED NET THRUST, LB*
BIPS 3 CAPSULE, CASE 4	29
WHL, CASE 5	52
SDGTD OP POINT, CASE 6	28

* DIRECTION OF NET THRUST IN EACH CASE IS TOWARDS THE TURBINE

The analysis predicts that at the SDGTD operating point the thrust bearing will be operating at its load capacity with no margin and that at lower power conditions it may exceed its load capacity. This is the reason for the addition of the axial shaft position cap probes. The shaft axial deflection data derived from this instrumentation will be essential in determining the actual thrust condition at relevant operating conditions.

If thrust loads are indeed too high, this will be discovered in the PCS Hot Loop Test. At that point, either the thrust load will be reduced by scalloping the turbine or modifications will be made to the TAC to install the V-22 thrust bearing. Either of these options will require several months to implement.

Because turbine backface pressure is higher than the pressure at the bladed face, scalloping the turbine would increase the turbine thrust towards the compressor and reduces net thrust. Scalloping would also require modification of the turbine backshroud to maintain optimum backface clearances.

The V-22 thrust bearing is being procured as a backup. This bearing has an 80-lb load capacity but much greater power loss and breakaway torque. It also requires some modifications to the TAC rotor and structure.

10.6 STRESS AND THERMAL CONDITIONS

10.6.1 TAC TEMPERATURES

Thermal management of the TAC is a critical part of the design process. TAC internal temperatures must remain below maximum values at the operating points. Verification is accomplished by a detailed thermal analysis followed by the instrumented PCS Hot Loop Test. The analysis is documented in Fluid Systems Report 42-MR-9896.

The thermal analysis predicts temperatures higher than those measured in the WHL test but lower than the limits. This analysis will be validated at SDGTD operating conditions in the PCS Hot Loop Test.

10.6.2 TURBINE PLENUM CREEP LIFE

The turbine plenum creep limit is 1 percent strain over 1000 hours. Average SDGTD TIT for the 1000 hours is 1410 °F. Turbine plenum creep life is verified by similarity to completed BIPS analysis. The BIPS analysis was conducted for a lower temperature but for a longer time. The similarity analysis detailed in Fluid Systems Report 42-MR-9766 shows that the Hastelloy-X turbine plenum has adequate creep design margin for SDGTD use.

10.6.3 FLANGE LOADS

Maximum flange loadings for the turbine exit and inlet and for compressor exit and inlet are determined from BIPS analysis. The calculated loads and margins induced from PCS ducting are given in the PCS design integration report, 41-12104. No further analysis is necessary to determine maximum loads.

10.6.4 TURBINE WHEEL STRESS

No additional SDGTD turbine wheel stress analysis is required. The BIPS turbine wheel, Part 3604335-1, stress analysis reported in NASA CR-159441, "Final Report, Analysis, Design, Fabrication and Testing of the Mini-Brayton Rotating Unit," is sufficient for the SDGTD TAC verification. The turbine has a predicted burst margin of 3.53, a 0.1 percent creep life of 848 years, an LCF life greater than 1 million start cycles, and sufficient blade vibration margin.

10.6.5 COMPRESSOR IMPELLER STRESS

No additional SDGTD compressor impeller stress analysis is required. The BIPS compressor impeller, Part 3605372-1, stress analysis reported in NASA CR-159441, "Final Report, Analysis, Design, Fabrication and Testing of the Mini-Brayton Rotating Unit," is sufficient for the SDGTD TAC verification. The compressor has a burst margin of 3.83 and sufficient blade vibration margin.

10.6.6 TURBINE BACKSHROUD STRESS

No SDGTD analysis is required on the turbine backshroud, Part 3605822-1. Because of its large thermal gradient, this item was analyzed for the Mini-BRU for stress and deflection. The results indicated sufficient margin and are found in NASA CR-159441, "Final Report, Analysis, Design, Fabrication and Testing of the Mini-Brayton Rotating Unit."

10.6.7 COMPRESSOR BACKSHROUD STRESS

The compressor backshroud, Part 3793283-1, was redesigned from the Mini-BRU, Part 3604348-1. The function of this part is to seal the compressor backface from the bearing cavity. The modifications were made to allow mounting of the axial cap probes. An inner ring was added which incorporates two threaded holes to position the probe to sense the distance to the compressor backface. This shortens the length of the spring seal, thereby increasing stiffness and stress if not modified. The analysis supporting the new configuration is presented in Fluid Systems Report 42-MR-9842.

10.6.8 CLEARANCE CONTROL

Clearances between rotating and static parts in the TAC are critical. Critical clearances to be analyzed are compressor, turbine, seal, and foil bearing. No rubs are allowed during steady state operation or transients. Compressor and turbine face clearances also need to be evaluated to assure required hot values will result from cold build values. Also, the sway space of the journal bearings is a critical flow area that may change with different operating temperatures.

Thermal deflections will be predicted using similarity to BIPS analysis and new analyses where required. Analysis indicates that no clearance problems from differential thermal expansion will occur.

10.7 MATERIALS SELECTION

Material selections for the Mini-BRU were validated by analysis and testing in the BIPS program. New materials added to the TAC from SDGTD design changes are given in Table 10-6.

Table 10-6. SDGTD TAC New Materials

DESCRIPTION	MATERIAL	FUNCTION	BASIS
Cap Probe Dielectric	Ablestick 6203FF Epoxy	Electrical insulator in probe tip.	High temperature capability (600 °F).
Set Screw Tip	Vespel SP-1	Lock cap probes in place without marring threads.	Low hardness and temperature capability.
Foil Bearing Coating	Polyimide-Bonded-Graphite-Fluoride (PBGF)	Reduce friction during startup and shutdown.	High temperature capability and low friction durability.
Journal Bearing Foil	Inconel X-750	Radial shaft support	Past operational experience.

10.8 HARDWARE ASSESSMENT

An important asset of the SDGTD program is the existing hardware from the BIPS program. The BIPS hardware was delivered to Fluid Systems as government furnished property in July 1992. An assessment of the condition of this equipment is summarized in Fluid Systems Report 41-12010, "Hardware Assessment and Refurbishment Report," contract data item HW-01, submitted under separate cover.

Two Mini-BRUs were delivered. Serial D-001 was run for the famous 1000-hour WHL test, while Serial D-002 has no operational time other than the cold acceptance test. The assessment of the component parts of each TAC produced no discriminators for elimination of either TAC from consideration from SDGTD use. The program plan calls for one TAC to be reworked and refurbished. The component parts of the other will be refurbished as required to meet the spares requirements, but the second TAC will not be reworked or assembled.

The BIPS program had three interchangeable turbine plenum designs. Each design was fabricated from a different material: columbium, Waspaloy, and Hastelloy-X. The columbium plenum was designed and fabricated for use at a TIT of 1600 °F. However, it was never used. The Waspaloy plenum was used for the 1000-hour test. However, it developed a leak at a pressure tap braze. The Hastelloy-X plenum was never tested at temperature. Both Waspaloy and Hastelloy-X are nickel based superalloys with similar material properties. Both have been shown acceptable at 1400 °F.

The only Waspaloy plenum on hand is the one that ran 1000 hours. To use this unit again would require some rework to repair the leak, fill unused instrumentation ports and rebuild ground flanges. Because several spare Hastelloy-X plenums are on hand, it will be used in the

SDGTD TAC.

10.9 TAC REFURBISHMENT PLAN

Figure 10-7 shows the TAC Refurbishment Plan. This plan is divided into six phases. Time frame for each phase is noted on Figure 10-7.

10.9.1 HARDWARE RECEIPT

SDGTD program assets include all of the BIPS hardware that was stored at BIPS program termination in 1978. This hardware was extricated from long-term storage and evaluated by NASA and Fluid Systems engineers prior to being shipped from Plumbrook. Much of the BIPS hardware was not applicable to the SDGTD program and was returned to storage. Mini-BRU, Workhorse Loop, test rig components and all tooling were shipped to Fluid Systems for possible use in the SDGTD program.

Hardware received at Fluid Systems was entered into inventory and is being handled in accordance with the government furnished property plan section of the contract.

10.9.2 HARDWARE ASSESSMENT

The hardware was assessed by various types of nondestructive inspections and tests. The results of the assessment are found in Fluid Systems Report 41-12010, "Hardware Assessment and Refurbishment Report."

10.9.3 TAC REFURBISHMENT

To support the design changes discussed earlier in this report and to replace parts damaged in storage, several new parts must be fabricated. A listing of these parts is found in Figure 10-7. Several existing parts must be reworked to accommodate the additional instrumentation. A listing of these parts is also found in Figure 10-7. All of the referenced drawings for new and reworked parts are submitted as part of the CDR design package under separate cover.

Parts that must be repaired because of deterioration or damage during the BIPS program or subsequent storage are detailed item by item on the Out-of-Tolerance Sheets in the Hardware Assessment and Refurbishment Report.

The TAC parts will be cleaned as required in accordance with Fluid Systems specification GPS3008-1, "Cleaning, Critical Components." The parts will be instrumented as required by Drawing 3793269. The TAC will then be assembled in accordance with Fluid Systems Report 41-12140, "Turboalternator-Compressor Engineering Assembly Instructions." As of CDR this document has not been released.

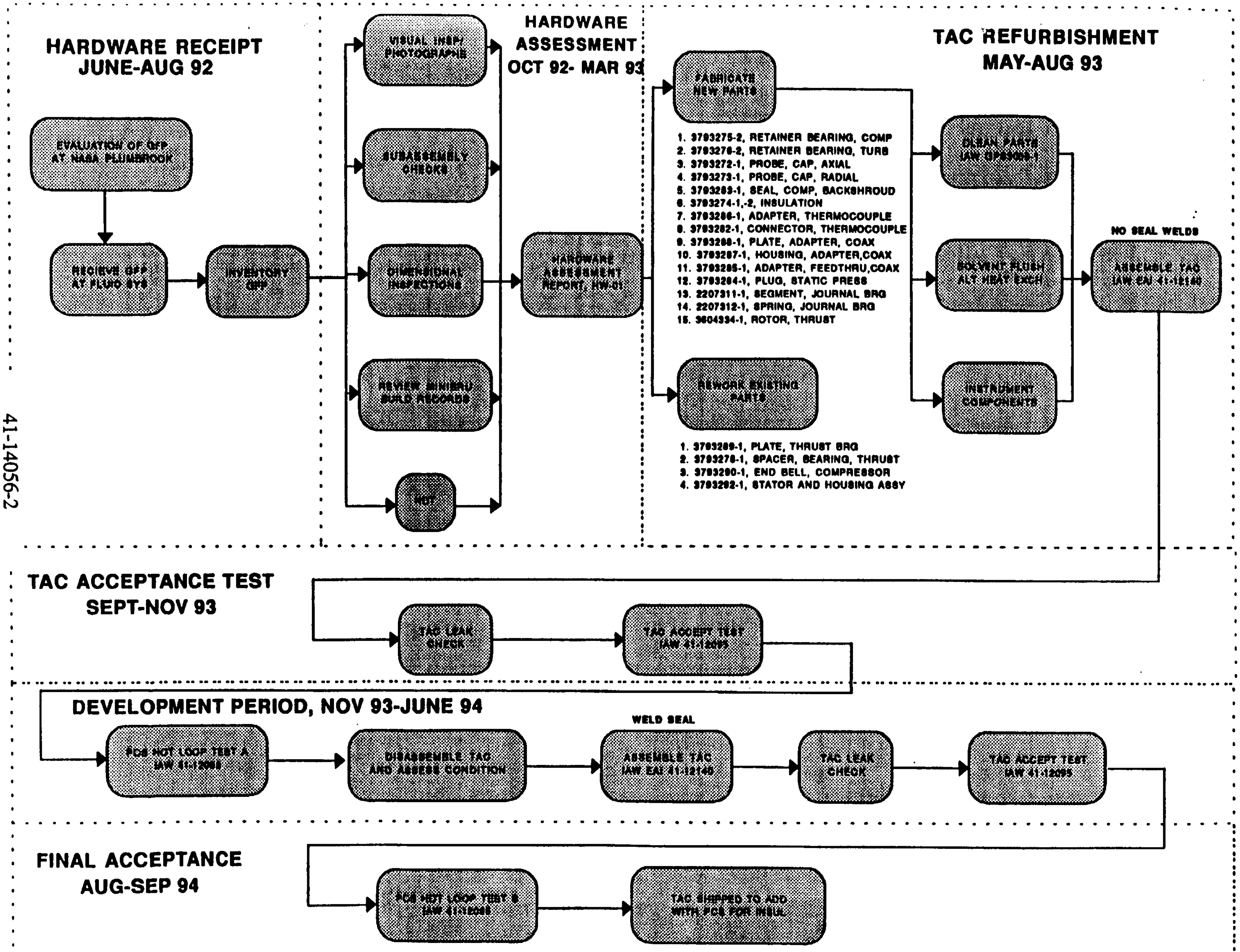


Figure 10-7. TAC Refurbishment Plan

TAC Serial D-001 will be reworked and refurbished for the SDGTD PCS. This TAC will be rebuilt with the design changes herein. The turbine will use an unused Hastelloy-X plenum instead of the damaged Waspaloy one. Aerodynamic performance of the Mini-BRU will be replicated as closely as possible by using the same compressor impeller and diffuser and turbine rotor. The Hardware Assessment and Refurbishment Report indicates the extent of repair required for each component part as well as parts which must be replaced.

10.9.4 TAC ACCEPTANCE TEST

The TAC will be leak checked and acceptance tested prior to assembly into the PCS for the Hot Loop Test. The TAC Acceptance Test will be conducted in accordance with Fluid Systems Report 41-12095.

10.9.5 DEVELOPMENT PERIOD

The TAC will be verified to operate satisfactorily at all applicable SDGTD operating conditions in the PCS Hot Loop Testing. The TAC will not be weld sealed going into this test. The primary TAC performance unknowns going into this test are the bearing thermal and rotordynamic performance. If any design changes are found necessary as the result of this testing, sufficient time exists in this development period to accomplish the change and conduct subsequent verification testing.

Following Hot Loop Testing the TAC will be disassembled and its condition assessed. It will then be resubjected to acceptance testing prior to reinstallation into the PCS.

10.9.6 FINAL ACCEPTANCE

Prior to final shipment the TAC will be weld sealed and reinstalled into the PCS. A hot acceptance test will be run and the entire PCS assembly will be shipped to Aerospace Design and Development for the installation of multilayer insulation. From ADD the PCS will be delivered to NASA Lewis.

10.10 TEST PLAN

10.10.1 ALTERNATOR TEST RIG TESTING

Refer to Fluid Systems Report 41-11982, "Alternator Test Rig Engineering Assembly Instructions," for a technical description and a discussion of the purpose of each rig configuration. The Alternator Test Rig is currently operational at Fluid Systems.

In most cases this cold testing on compressed air will not absolutely verify a parameter for the SDGTD condition. However, valuable information can be gained in this incremental step towards full-up hot loop testing.

10.10.2 TAC ACCEPTANCE TEST

The TAC acceptance test is also run open loop with ambient temperature compressed air. This test differs from the rig testing in that the test unit is the deliverable TAC. A helium leak check is also conducted as part of the acceptance test. Refer to Fluid Systems Report 41-12095, "Turboalternator-Compressor Acceptance Test Plan," for a description of the test configuration and purpose.

Although in most cases this cold testing will not absolutely verify a parameter for the SDGTD condition, valuable information can be gained in this incremental step towards full-up hot testing.

10.10.3 PCS HOT LOOP TEST

The PCS Hot Loop Test will replicate the SDGTD operating conditions for the PCS including flows and temperatures. An electric heater coupled with the PCS will generate design TIT. Refer to Fluid Systems Reports 41-12098 and 41-12099, "Power Conversion Subsystem Hot Loop Test Plans A and B," for a description of the test configuration and purpose.

This test will verify all TAC parameters, except for life and cycles, at SDGTD operating conditions.

11. POWER CONVERSION SUBSYSTEM (PCS)

11.1 Design Documents Listing

41-12104 Power Conversion Subsystem (PCS) CDR Design Integration Report

41-12098 Hot Loop Test Plan, Part A

41-12099 Hot Loop Test Plan, Part B

11.2 Design Review Minutes

The PCS Critical Design Review was held on Friday, June 4, 1993 at NASA LeRC. The presentation topics covered during the design reviews were:

Requirements
Configuration
Mechanical Interface
Working Fluid Containment
Ducting Pressure Loss
Flowmeter Design
Analysis
Instrumentation
Recuperator Life
Hot Loop Test

The structural analysis section was presented by Bob Armstrong, the remaining topics by Pete Amundsen. The topics were presented sequentially as listed. The presentation contained the following information:

11.3 REQUIREMENTS

The PCS integrates and supports the PCS components to:

Maintain acceptable subsystem pressure losses

Maintain acceptable external and internal interface loads and deflections

Provide subsystem instrumentation

Maintain working fluid boundary integrity

The PCS is composed primarily of GFE from the BIPS WHL Program, and unlike other major SDGTD components or subsystems, does not have a formalized design specification. The design process for the PCS requires an integration activity to first define subsystem requirements prior to the mechanical integration of the existing GFE components. The following PCS requirements were derived from multiple sources as defined below.

Performance:	Pressure loss in accordance with maximum insolation orbit, Table X in 41-11460(2)
Mechanical Interface:	PCS component loads and deflections from original component analyses and specifications
	Pallet interface per ICD 213000016
Life:	Operating life
Instrumentation:	In accordance with 213000017
Working Fluid Containment:	10^{-1} ssc/s helium (1% inventory per day)
Outgassing:	Compliance with MSFC Handbook 527

11.4 CONFIGURATION

The resultant PCS configuration--shown in top, side, and end views as Figures 11-1, 11-2, and 11-3 respectively--maximizes the use of GFE. The drawing tree for the PCS, Part 3793295, depicts the new drawings in bold type. The configuration is similar to the mock up configuration presented at PDR in that much of the WHL support structure, superfluous to the SDGTD activity, has been eliminated to facilitate integration with the receiver and minimize shadowing. As this structure provided blow-off load retention for the non-pressure-compensated turbine discharge bellows, a three-link bellows restraint grounded to the TAC housing was designed. The significant departures from the mockup configuration are the series arrangement of the gas coolers and that the plane of the U shape of the turbine inlet duct was rotated from the horizontal to the vertical plane. The former change was dictated by the system performance analysis and the latter by the global PCS/receiver thermal/stress model which will be discussed in the analysis section.

Three new ducting assemblies, the turbine inlet duct, the receiver inlet duct, and the cold ducting from the low-pressure recuperator discharge to the compressor inlet are required in the SDGTD PCS. The resultant ducting configuration incorporates existing WHL bellows. A common male/female welded flange arrangement is used in all of the elements of the cold duct and the required 90-degree bends between the coolers are made with a common detail.

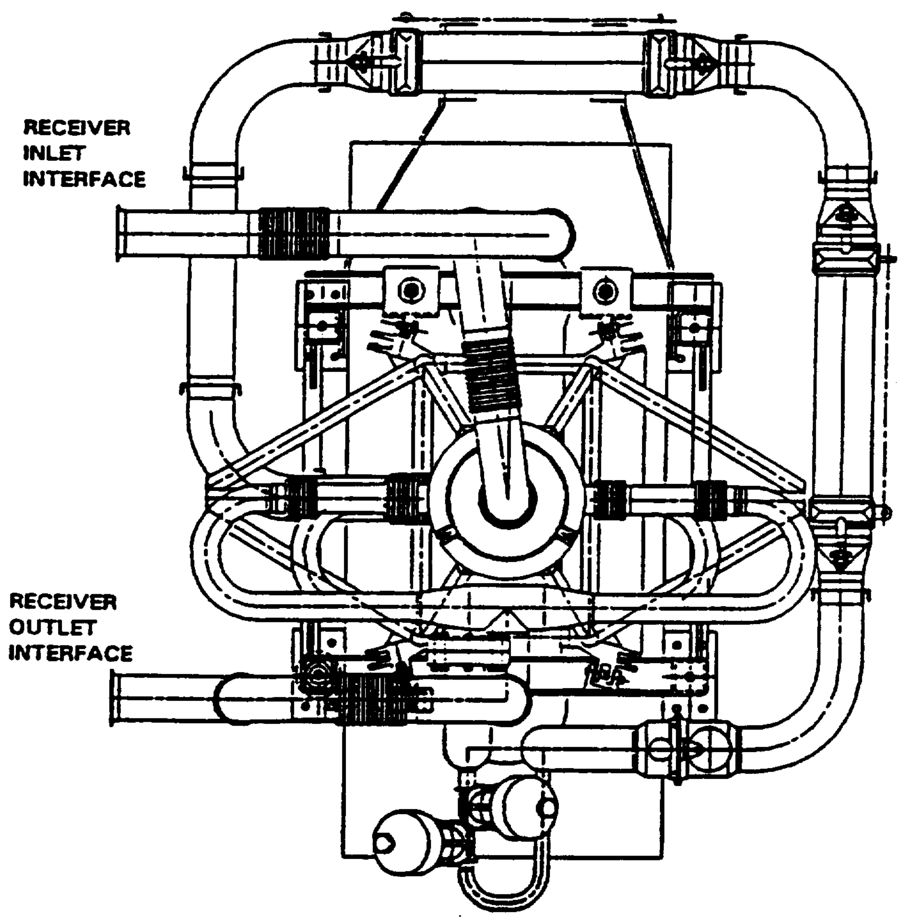


Figure 11-1. PCS: Top View

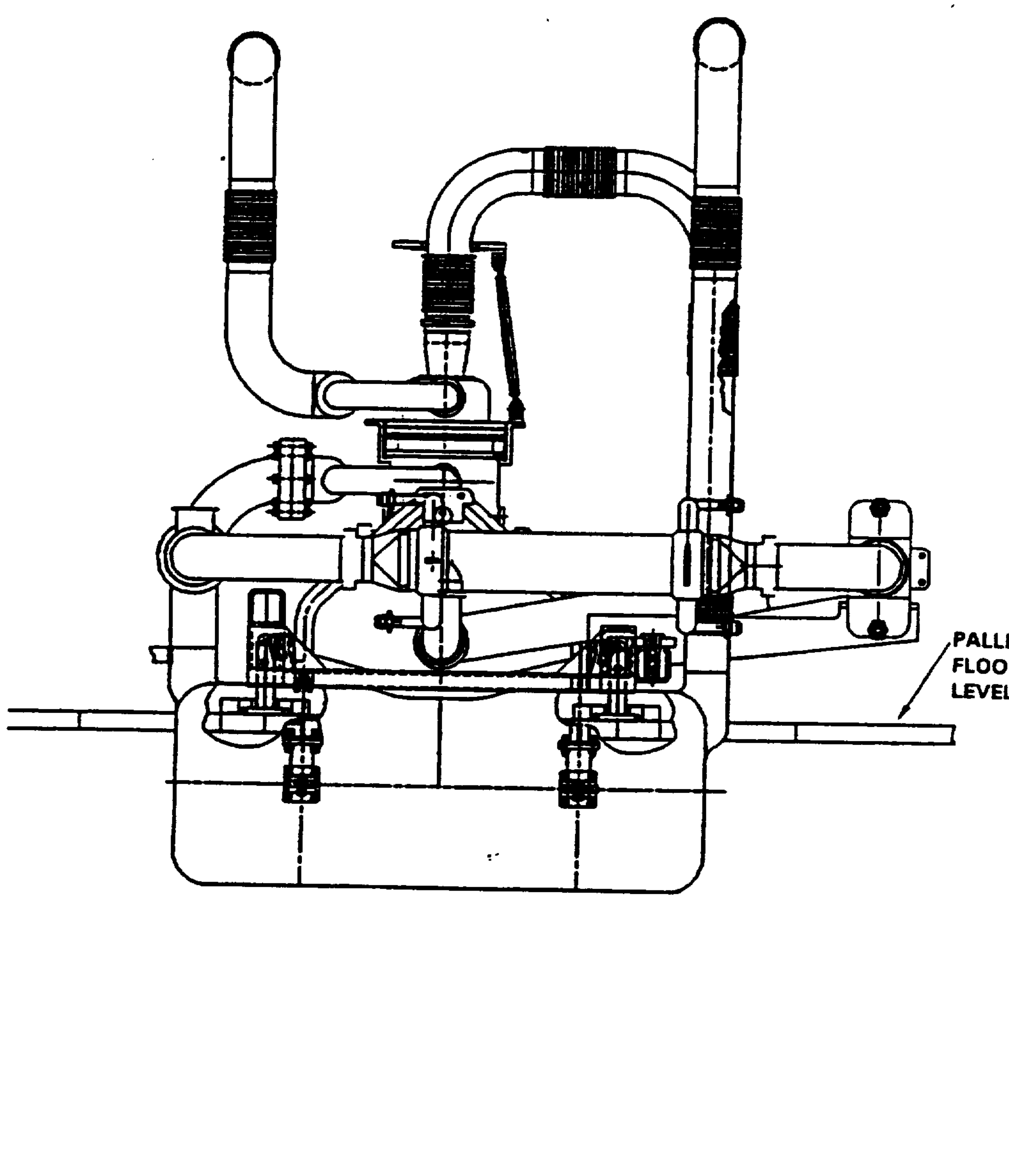


Figure 11-2. PCS: Side View

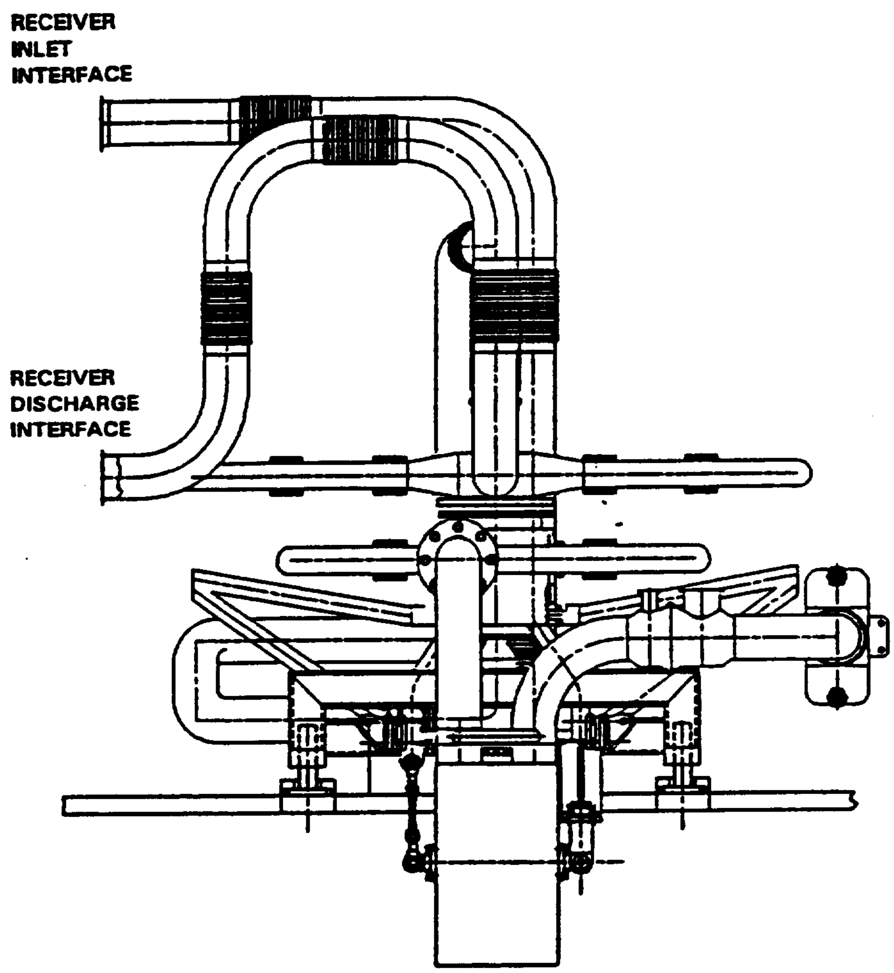


Figure 11-3. PCS: End View

11.6 MECHANICAL INTERFACE

The critical mechanical interface for the PCS and the receiver is the receiver discharge/turbine inlet duct which operates at 1400 °F. In order to minimize interface induced loads in the duct, receiver discharge manifold, and the TAC plenum, the turbine inlet duct flange will be aligned at pallet installation to the receiver outlet flange to 0 orthogonal tolerance. The mount structure for the PCS provides for ±0.25 inch adjustment of the PCS relative to the pallet datum in three orthogonal axes. The recommended installed true position of the receiver outlet flange relative to the pallet datum would require a maximum of ±0.125 inch adjustment capability. The receiver inlet duct interface (which operates at 1100 °F) will then be subjected to the actual tolerance mismatch between the inlet and the out ducts. The major action item for the PCS CDR is to validate the installed tolerance allocations at the duct interfaces against both manufacturing and resultant stress allowables.

11.7 WORKING FLUID CONTAINMENT

The WHL demonstrated a leak rate of 10^{-4} scc/s of helium as compared to the SDGTD requirement of 10^{-1} scc/s. Review of the WHL leak testing indicated that the major leak resulted from a damage pressure tap on the TAC plenum which resisted repair efforts. For the SDGTD, the plenum will be replaced and the pressure instrumentation installed in the downstream duct. Although the existing O-rings in the WHL have not been eliminated, the new ducting for the SDGTD has welded flanges, either cup type or radial burn down.

11.8 ANALYSIS

11.8.1 DUCTING PRESSURE LOSS

A ducting pressure loss analysis was conducted using the detail duct drawings and compared to the allocations from Table X, 41-11460(2). The calculated pressure drops for the new ducting meet the allocations with the exception of the turbine inlet duct, which exceeded its allocation by 0.1 psid, not significant in terms of measured system performance.

11.8.2 FLOWMETER DESIGN

The existing WHL in-line flow measuring section was too long for SDGTD packaging and did not produce an adequate delta p required by the SDGTD instrumentation accuracy requirements. A new flow section has been designed to match the signal requirements of the transducer. Because of the limited length for the measuring section, pressure recovery is poor, resulting in a pressure drop that could approach 1 psid. The flow section will not be used during full power performance demonstrations, being replaced for those demonstrations with an interchangeable straight section.

11.8.3 DUCT ANALYSIS

A finite element ANSYS model of the PCS was created. Maximum insolation sunset pressure and temperature conditions, component weight, support displacements, and interface mismatch displacements were imposed on the model. Initial running of the model indicated that PCS component mechanical load and deflection allowables could be met for the PDR configuration with the exception of the burndown flanges, which required minor flange thickness increases. This model was combined with the receiver ANSYS model to provide a global model so that interface reactions could be more adequately addressed. As a result of this global model it was determined that the horizontal leg of the turbine inlet duct was impacting the creep life of the receiver outlet manifold. Rotating the duct section to the vertical minimized the overhanging moment.

11.8.4 INSTRUMENTATION

Instrumentation capability in compliance with 213000017 has been provided either by using existing instrumentation in the existing hardware or by providing WHL type bosses in the new ducting as required. Receiver inlet pressure and delta p will be measured on the PCS side of the receiver inlet and outlet duct flanges. Redundant capability and alternate instrumentation capability has been provided as shown in Figures 11-4 and 11-5.

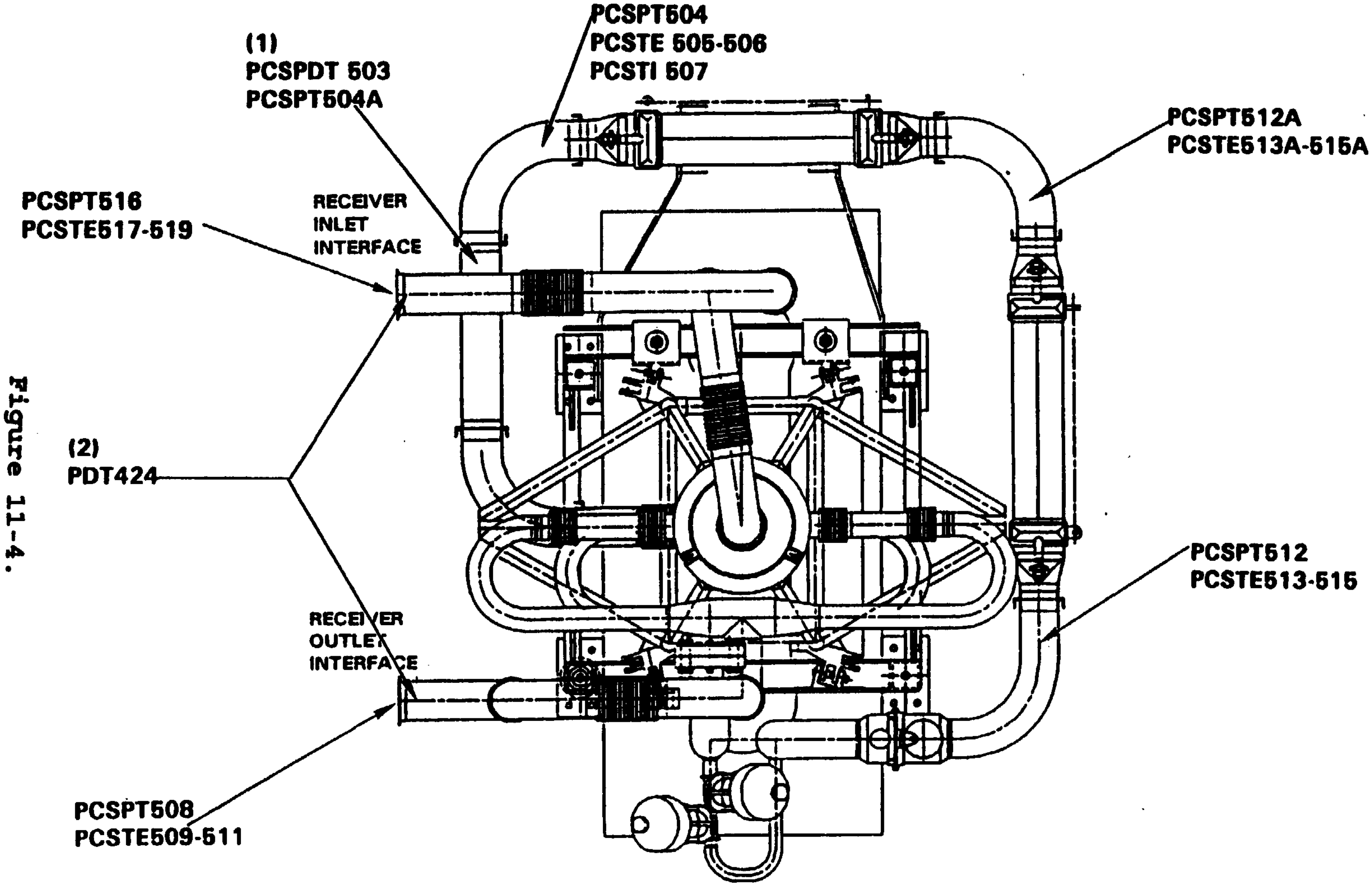
11.8.5 RECUPERATOR LIFE

The GFE recuperator for the SDGTD incurred approximately 44 starts during the WHL program. The WHL recuperator had a predicted minimum life (based on internal leakage criteria and minimum material properties) of 220 cycles. The fatigue life is driven by the thermal gradient in the recuperator in the first 30 seconds after the start. Comparison of the temperature profiles in the recuperator (see Figure 11-6) indicated that both the WHL and SDGTD profiles are much more benign than the profile used to obtain the 220-hour minimum life number. It was therefore concluded that the recuperator will demonstrate in excess of 100 WHL cold starts without incurring significant internal leakage.

11.9 TEST PLAN

Figure 11-7 is a flow chart showing the component/subsystem test sequence up to delivery at Tank 6. The Hot Loop Test has been expanded to include a B phase in July or August 1994. This test replaces the electronic subsystem test originally scheduled; now the electronic components can be tested with an operating TAC rather than the TAC simulator. The MLI will now be installed in September or October on the assembled PCS instead of insulation of components as was originally proposed. The steam/working fluid heat exchanger proposed at PDR has been replaced with an electric heater based on the BCD configuration. Although the electric heater is more expensive to fabricate than the

PCS Instrumentation is Installed in Ducts with Common (WHL) Instrumentation Configuration - 2TC Bosses and 3 Static Ports Per Station, Except as Noted



(1) 4 MANIFOLD STATIC PORTS, EACH

(2) 3 MANIFOLD STATIC PORTS EACH DUCT

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Figure 11-4.

Existing (Refurbished) WHL Instrumentation is Used in 3 Locations

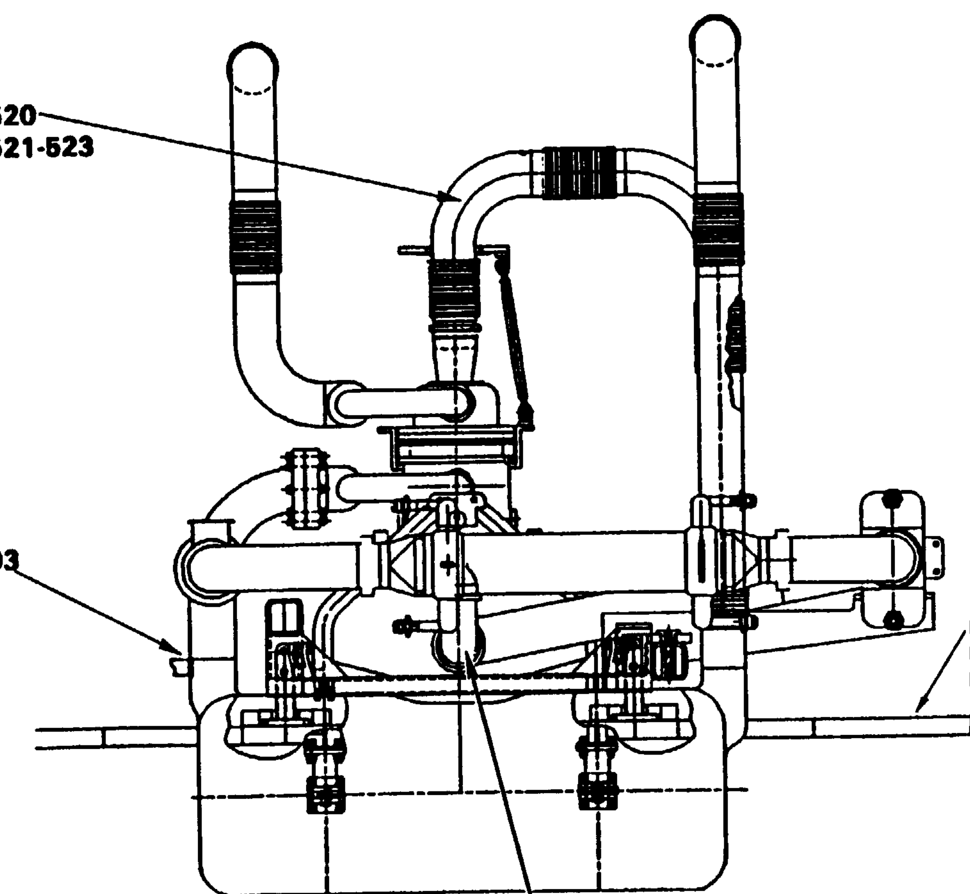

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Figure 11-5.

The WHL and SDGTD Start Profiles Are More Benign Than Run 600

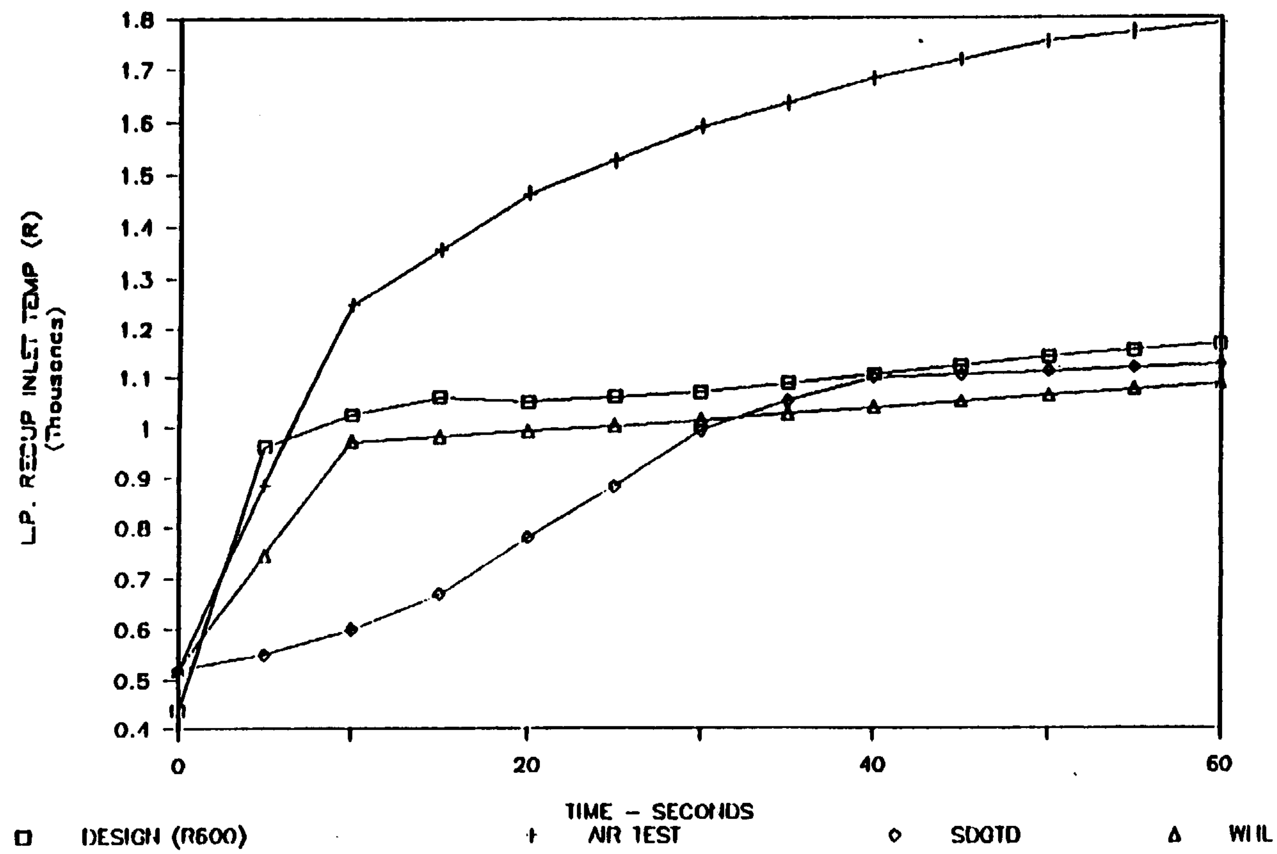

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Figure 11-6.

The Hot Loop Test Series Verifies Component/Subsystem Integrated Operation

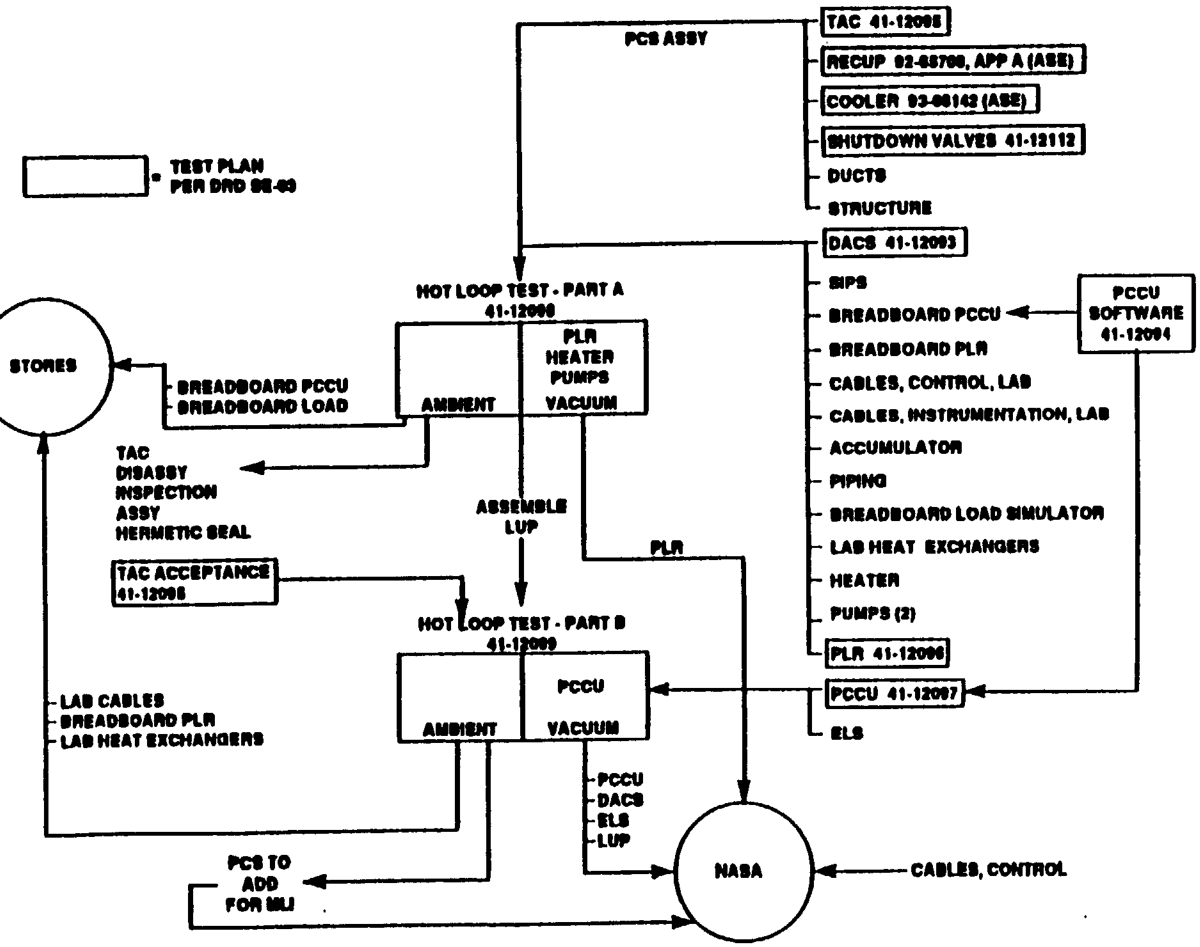

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Figure 11-7.

steam heat exchanger, testing cost reductions more than offset the procurement costs.

12. LIQUID UTILITIES PALLET (LUP)

12.1 Design Document Listing

41-12127 Liquid Utilities Pallet CDR Design Integration Report

12.2 Design Review Minutes

The LUP Critical Design Review was held on Friday, June 4, 1993 at NASA LeRC. The presentation topics covered during the design reviews were:

Requirements
Configuration
Instrumentation
Liquid Loop Heater
Accumulator
Liquid Loop Pumps

The topics were presented in the order listed by Pete Amundsen. The presentation is summarized below.

12.3 DESCRIPTION

The LUP is a compartmentalized test support unit which provides for coolant auxiliary heating, density change accommodation, motive flow, and pressure, temperature, and flow measurement. The LUP provides the lower support for the radiators and is the instrumentation patch panel for radiator and LUP instrumentation. The LUP subsystem is comprised of the following components:

* Accumulator
* Two Pump/Motor Assemblies
* Liquid Loop Heater
* Environmental Heater (wiring capability supplied)
* Mounting Base Assembly
* Flowmeter
* Check valves and hoses

12.4 REQUIREMENTS

The following are the primary functional LUP requirements:

Environment: Vacuum 10^{-5} to 10^{-7} torr

Coolant Leakage: None permitted

Coolant: N-heptane

Coolant Temperature Range: 420 to 670 °R

Over the operating envelope defined for the SDGTD, maximum liquid (N-heptane) coolant temperature of 645 °R and flow of 0.051 lb/sec occurs at the inlet to the radiator at sunset at 1.3 kWe continuous power per Table 2, Report 41-11685. The minimum temperature and flow conditions of 451 °R and 0.048 lb/sec, respectively, occur at the maximum insolation orbit at sunrise per Table X, Report 41-11460(2). The wet LUP components were designed to provide an operational cushion of 25 °R, minimum. Maximum specified pump flow requirement (0.051 lb/sec) is 28.5 gph.

Coolant Flow Rate: 20 to 32 gpm

Coolant Pressure Range: 25 minimum to 99 psia maximum

Maximum system vapor pressure for N-heptane at 670 °R is 20.3 psia, which occurs at the radiator inlet.

Coolant Density Ratio: 0.98 to 1.043

The coolant density ratio is a function of component volumes, fill temperature and operating temperature distribution. At the 1.3 kWe continuous power conditions, assuming that the fill is accomplished at stabilized 520 °R and system volume of 462.6 cubic inches, the liquid volume increases to 474.4 cubic inches, a factor of 1.025. With a 30 cubic inch capacity accumulator and with the fill accomplished to 10 cubic inches of accumulator volume the system has a density ratio range from 0.978 to 1.043.

Liquid Loop Heater Power Requirements: 4.9 kW

This value is the heat rejected to the coolant at the maximum insolation orbit sunset condition as defined in Table XI, Report 41-11460(2)

Liquid Loop Pressure Drop: 20 psid

The following pressure drops have been allocated to the liquid loop components (reference document for supplied components):

Accumulator	2 psid
Liquid Loop Heater	2 psid
Flowmeter	0.2 psid (manufacturer's data)
Check valves	0.5 psid
PCCU Cold Plate	1 psid
Gas Coolers	0.1 psid (41-12119)
Radiator	10 psid (Loral CDR)
Hose	3 psid

Outgassing:

Vacuum stability in compliance with MSFC Handbook 527 or vacuum exposed materials exclusively of A rated materials form the MAPTIS database.

12.5 CONFIGURATION

The block diagram for the LUP is shown as Figure 12-1. Individual component designs are discussed in the following sections.

12.6 Major Component Definition

INSTRUMENTATION

The pressure transducers contained in the LUP need to be maintained between -10 and +120 °F while operating to maintain instrument accuracy. Each transducer produces approximately 1.5 watts when operating. NASA was asked to provide thermal environment assessments at the LUP (and PCS). The LUP (and system wiring) can provide thermostatically controlled heaters if required.

LIQUID LOOP HEATER, PART 3793334

The liquid loop heater was designed to provide both redundant heating element capability and heating element replacement without breaking into the liquid loop. The unit was designed to provide the capability for 8900 watts input into the liquid at maximum loop delta temperature against a requirement of 4900 watts at maximum insolation sunset liquid delta temperature. The heater body and heating element interface are similar to those of the PLR. A thermal analysis, assuming pure to establish temperature heater body temperature, was conducted. The resultant stress analysis of the heater body indicates a cyclic life of 33,800 cycles and a margin of safety at proof pressure of 9.8. (see Appendix 1 of Fluid Systems Report 41-12127)

ACCUMULATOR, PART 3793337

The design and resultant acceptance requirements identified above have been flowed directly to the accumulator vendor via notes 6 and 7 of Drawing 3793337 provided under DRD MA-05. The specific design features of the accumulator include a flow-through design which keeps the accumulator at fluid temperature, eliminating the need for a separate heater. A liquid volume sensor has been included in the design to simplify coolant fill verification and operational performance.

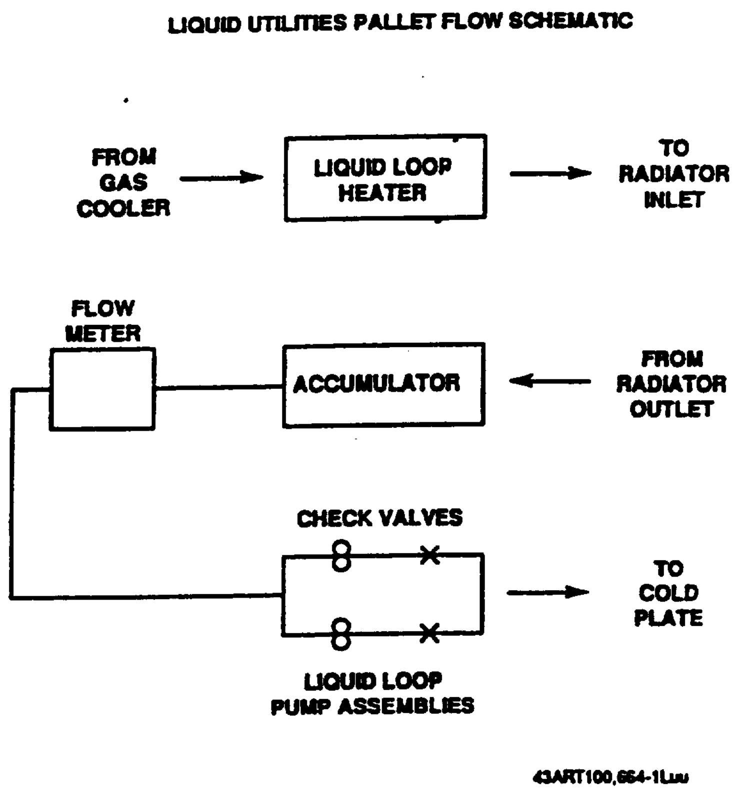


Figure 12-1. LUP Block Diagram

Pump/Motor Assembly, Part 3793335

Liquid coolant pump power is chargeable against system efficiency. A survey of available pump/motor combinations did not identify a commercial unit which met SDGTD criteria for a hard-vacuum, minimal-power application. Tuthill Pump Company offers magnetic-coupling-driven gear pump heads in the proper flow pressure class but not with vacuum-rated motors. Two Tuthill pump heads with 24 volt, 1 amp brush type dc motors were procured and flow tested on N-heptane down to 410 °R to verify pump head performance. The results show compliance with the system flow requirement.

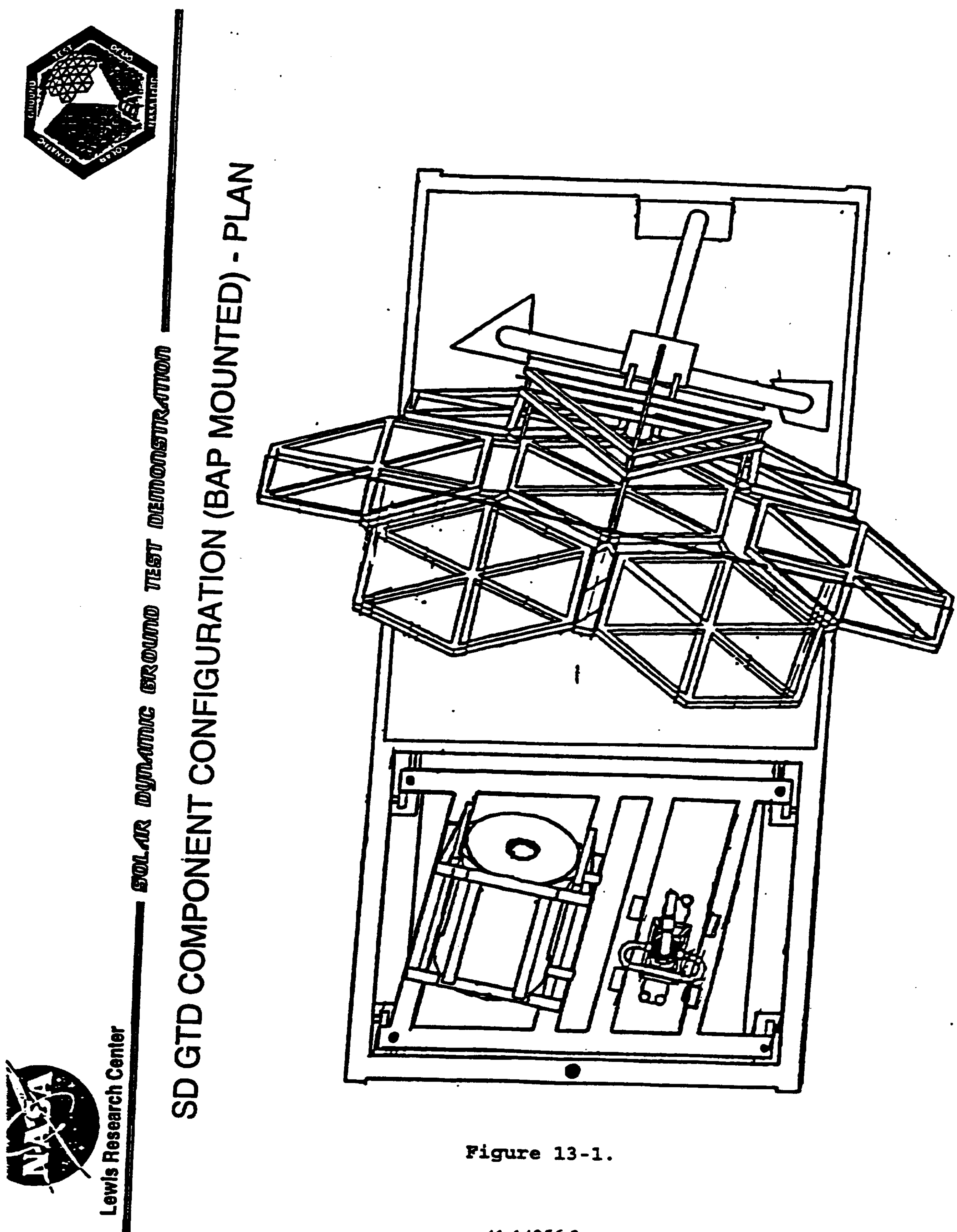
A vacuum-rated variation of an existing RBEH -01200 Inland Motor brushless dc motor was specified, Part 3793338, and the design requirements and acceptance criteria for the motors flowed down to the supplier through Notes 8 and 9 of the motor drawing. The motor has significant speed and torque margin for the application. Analysis by the supplier indicates that efficiency demonstrated by the originally supplied nonvacuum-rated motor can be demonstrated. A pump/motor adapter, Part 3793339, was designed to mate the pump and motor using a modified magnetic coupling, Part 3793340. Dick Shaltens questioned the applicability of the pump O-rings in a vacuum environment. The delta pressure across the O-rings is in the same direction whether in an ambient or vacuum environment and the pumps will be tested in vacuum as part of the hot loop testing.

13. **NASA Tank 6 Facility Integration Review: Build - Assembly Platform (BAP) and Test Configuration Support**

An overview of the design for the BAP and Test Configuration Structural Support hardware was given by the Engineering Directorate. A portion of the presentation was dedicated to a review of the design details of the BAP and Pallet hardware configuration and their behavior within the Tank 6 vacuum facility. The remainder of the materials presented were directed at general information as to status of supporting activities currently in progress.

Design requirements and configuration were reviewed. Plan and elevation views of the SDGTD components mounted on the BAP are shown in Figures 13-1 and 13-2. Design features for adjustability of component position and relative alignment were presented. The respective ranges of adjustability were summarized and discussed. The features allow for 3-axis positioning of the PCS/Receiver sub-pallet to align the Receiver to the optical path of the energy coming off the Concentrator. Preliminary stresses and deflections were presented for the BAP and PCS/Receiver Pallet. More analysis is needed, particularly in the area of thermal distortions and resulting displacements of the SDGTD system components for the various thermal conditions which they will be subjected to during testing. Stresses were also presented for the structural support hardware that interfaces between the BAP and the Tank 6 facility. The method of lubrication in vacuum and material preparation/application procedures for adjustable (positioning) features and other features with relative motion was presented. The procedures are outlined in Figure 13-3. Methods and procedures planned for assuring the manufacture of clean interfacing hardware for the vacuum service were presented. Highlights of the procedures are summarized in Figure 13-4. Status of the related facility test specific support hardware was presented: Assembly Bridge (SDGTD program assembly area outside of Vacuum Tank 6), Movable Platform (test observation area), and Modular Rail System (for transfer of the SDGTD component platform from the assembly area to the test position within Tank 6). Near term items are summarized in Figure 13-5. All of the above will be completed well in advance of SDGTD need.

From the above subject matter related to design/analysis of the BAP, PCS/Receiver Pallet, and test specific interfacing hardware, three areas of concern were generated by the SDGTD team for further review: 1) discrepancies in component ICD (interface control drawing) dimensions and some corresponding mounting features on the PCS/Receiver Pallet were detected - NASA will review all ICDs and correct to the latest ICD, 2) deformation of Teflon material (employed at the BAP West End Support to reduce friction) - NASA will review, and 3) review of West End Support Structure analysis for the limiting case of infinite friction at the above Teflon sliding plane (due to an uncertainty in the value of coefficient of friction that will exist between stainless steel/Teflon at vacuum) - NASA will review.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SD GTD COMPONENT CONFIGURATION (BAP MOUNTED) - PLAN
SOLAR DYNAMIC GROUND TEST DEMONSTRATION

Figure 13-1.

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SOLAR DYNAMIC GROUND TEST DEMONSTRATION

SD GTD COMPONENT CONFIGURATION (BAP MOUNTED) - ELEVATION

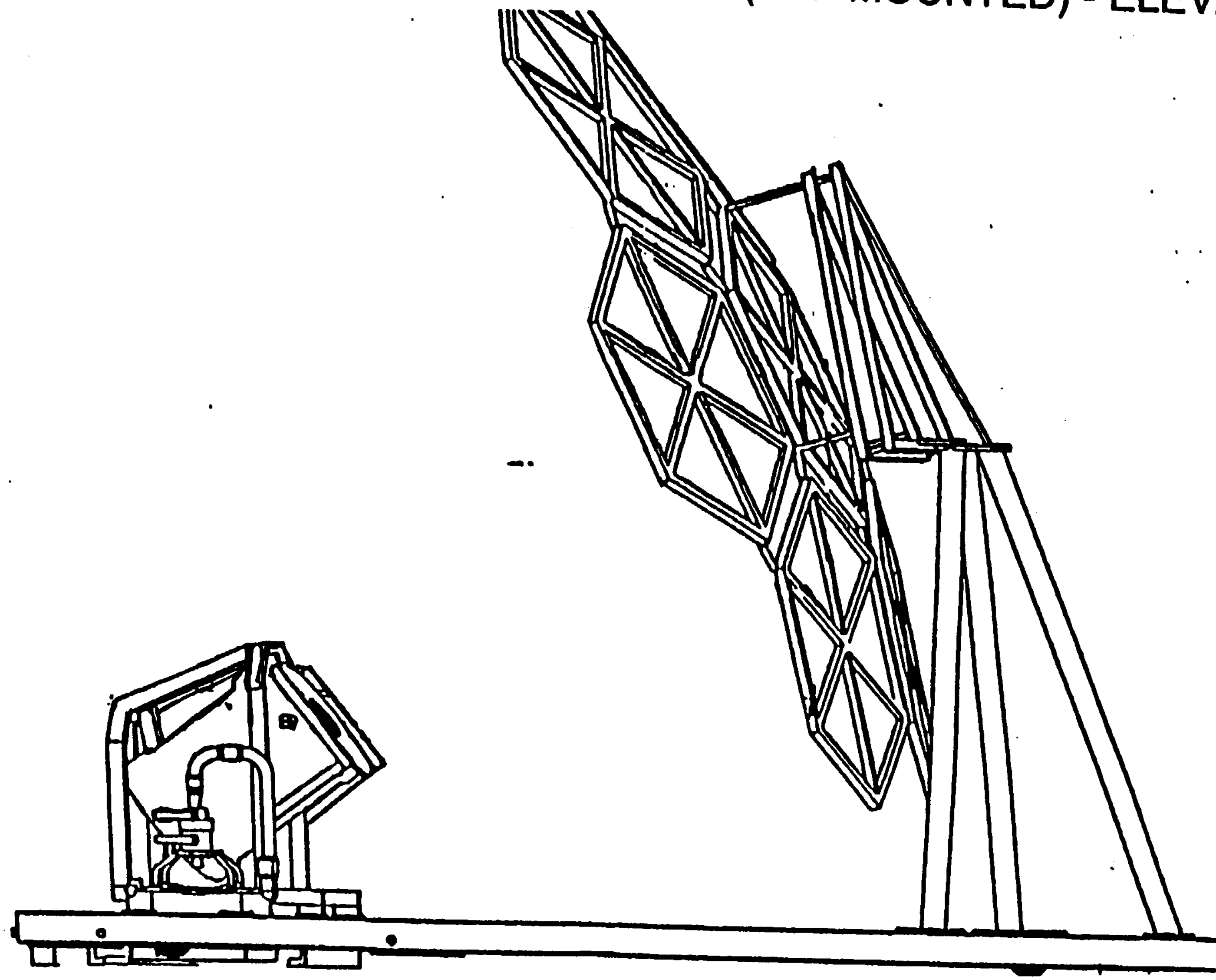

Figure 13-2.

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LUBRICATION

SOLAR DYNAMIC GROUND TEST DEMONSTRATION

BONDED LUBRICANT NOTE FOR ALL MOVING PARTS: THREADED PARTS, WHEEL AXLES, AND SLIDING SURFACES

- INSTRUCTIONS:
  - Vapor degrease per MIL-T-81533.
  - Sand blast using 120 mesh clean dry media.
  - Passivate surface per QQ-P-35, Type II for 20 minutes @ 120-130F.
  - Rinse part with clean water (<200 ppm solids) and air dry. (Do not touch pretreated surfaces with bare hands.)
  - Apply Molykote no. 3400A bonded lubricant, Dow Corning Corporation, Midland MI 48640 or equal meeting MIL-L-46010B. per manufacturers instructions at 0.0005" thkns.
  - Air dry for 1/2 hour minimum prior to oven curing.
  - Oven cure @ 400F for 1 hour (for optimal performance).

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Figure 13-3.

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BAP/PALLET FABRICATION CLEANLINESS CONTROL

SOLAR DYNAMIC GROUND TEST DEMONSTRATION

- MATERIALS WILL BE PREMACHINED TO PREFIT WELDMENT AND CLEANED PRIOR TO FINAL WELDING ASSEMBLY AT ALL SURFACES
- WELDING WILL BE PERFORMED EXCLUSIVELY WITH INERT COVER GAS
- ALL TUBE TO TUBE CONNECTIONS HAVE COMMUNICATING PASSAGES FOR "BACKUP" WELDING COVER GAS AND FINAL CLEANING OF CONTAMINANTS
- THERMAL STRESS RELIEF OF TUBULAR WELDMENTS WILL BE PERFORMED IN INERT GAS FURNACE
- ALL WELDED JOINTS ARE DESIGNED TO BE CLEANABLE WITHOUT TRAPPED CONTAMINANTS AFTER FINAL MACHINING
- ALL ACCESSIBLE SURFACES OF THE MACHINED WELDMENT WILL BE "IMPROVED" VIA MECHANICAL ENHANCEMENTS TO REDUCE OUTGASSING

Figure 13-4.

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DESIGN AND FABRICATION STATUS

SOLAR DYNAMIC GROUND TEST DEMONSTRATION

- PALLET DESIGNS ARE COMPLETE AND FABRICATION HAS BEEN INITIATED
- BAP DESIGN IS NEARING COMPLETION AND FABRICATION HAS BEEN INITIATED
- BAP SUPPORTS (TEST CONFIGURATION) DESIGN IS NEARING COMPLETION AND FABRICATION WILL BE INITIATED SHORTLY (9/93)
- FOUNDATION DESIGN FOR THE MODULAR RAIL SYSTEM IS IN PROGRESS AND INSTALLATION WILL BE INITIATED UPON DESIGN COMPLETION (8/93)
- MODULAR RAIL SYSTEM DESIGN IS NEARING COMPLETION AND FABRICATION WILL BE INITIATED THEREAFTER (10/93)

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Figure 13-5.

Appendix 1

CRITICAL DESIGN REVIEW ACTION ITEM STATUS

SOLAR DYNAMIC GROUND TEST DEMONSTRATOR
CRITICAL DESIGN REVIEW (CDR) ACTION ITEMS

ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
** ACTION ITEMS FROM REVIEW ON - BAP					
BAP 1	ALEXANDER	NASA	07/01/93	COLUMN SUPPORT AT PALLET END OF TANK IS NOT DETERMINANT DUE TO FRICTIONAL CONTACT. LOADS/STRESSES DEVELOPED ARE THEREFORE A FUNCTION OF ASSUMED COEFF.	ASSUME COLUMN IS RIGIDLY ATTACHED TO BAP AND ASCERTAIN STRESS LEVELS ON COLUMN AND SUPPORTS. THIS IS THE WORST CASE AND IF THIS IS OK ANY FRICTION CASE IS ALSO OK.
BAP 2	KUDIJA	NASA	07/01/93	T.E. AND COMPRESSION SET EFFECTS HAVE NOT BEEN ACCOUNTED FOR FOR THE TEFLON PAD SUPPORTS	ACCOUNT FOR THESE EFFECTS IN TERMS OF BAP MOTION AND ROTATION
BAP 3	KUDIJA	NASA	06/17/93	PCS ICD DOES NOT MATCH PRELIMINARY BAP DRAWING AT LEAST FOR THE RECEIVER AND PCS PAD DIMENSIONS	COMPARE EXISTING BAP DRAWING TO CONCENTRATOR, RECEIVER AND PCS ICDs AND INSURE THAT THEY ARE IDENTICAL AND IF NOT REVISE BAP DRAWING
BAP 4	ALEXANDER	NASA	/ /	PLEASE REVIEW CONC, RECEIVER, AND PCS ICDS TO DETERMINE THAT BAP INTERFACES MIRROR THESE DOCUMENTS	(DUPLICATE OF BAP-3)
** ACTION ITEMS FROM REVIEW ON - CONC					
CONC 0	BAHNMAN	HARRIS	/ /	THE QUESTION OF RISK ASSOCIATED WITH THE 20G SHOCK CASE IS SOMEWHAT DEPENDANT UPON THE CLEARANCE BETWEEN THE CONCENTRATOR AND INTERIOR BUILDING STRUCTURE AS WELL AS THE OPEN END CAP	DETERMINE THE EXPECTED CLEARANCE OF THE CONCENTRATOR WHEN MOVED BETWEEN THE INTERIOR STRUCTURE AND END CAP. DETERMINE IF IT IS PREFERABLE TO JOCKEY THE BAP (IE MOVE THE BAP WEST INCREMENTALLY) TO PERMIT MOVING THE END UP OUT OT THE WAY AND INCREASE CLR.

SOLAR DYNAMIC GROUND TEST DEMONSTRATOR
CRITICAL DESIGN REVIEW (CDR) ACTION ITEMS

ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
CONC 0	RICHTER	HARRIS	/ /		CONSIDER REMOVING THE DELTA FRAME PRIOR TO MOVING THE BAP
CONC 0	STRUMPT	HARRIS	/ /	OFF NOMINAL FLUX DISTRIBUTIONS ARE WORST CASES AND NOT LIKELY TO EXIST	DEVELOP STATISTICAL APPROACH TO DETERMINE A MORE REASONABLE OFF NOMINAL FLUX DISTRIBUTION
CONC 27	SHALTENS	HARRIS	04/30/93	SURFACE FINISH OF BALL JOINTS IN SUPPORT STRUCTURE APPEAR TO BE APPROX 16-32 RMS. IS THIS FINE FINISH APPROPRIATE FOR USE WITH SOLID LUBRICANTS IN A VACUUM	REVIEW SURFACE FINISH REQUIREMENT FOR APPLICATION AND SOLID LUBRICANT
CONC 28	STEVENS	HARRIS	04/30/93	CLARIFY LOCATION TOLERANCE OF CONCENTRATOR TRIPOD/BAP INTERFACE IN THE TANK COORD SYSTEM	IDENTIFY THE ALLOCATION OF THE .5" TOTAL IN X AXIS THAT IS ALLOTTED BAP POSITION WITH THE TANK AND THE PORTION FOR FABRICATION OF BAP (HOLE LOCATION). WHAT PORTION OF THE ABOVE POS TOL IS ASSOCIATED WITH CONC TO SOL SIM (EXCLUDING CONC. TO RECEIVER)
CONC 29	KUDIJA	HARRIS	04/28/93	THE CONC SUPPORT LEG NUT PLATE DESIGN IS NOT YET MATURE ENOUGH FOR THE ICD. THE OPTIMUM SOLUTION BETWEEN BAP MFG, SITE INSTALLATION, AND PRECISION DISMOUNT/REMOUNT IS NOT DEFINED	DEFINE SUPPORT LEG ATTACHMENT APPROACH IN SUFFICIENT DETAIL FOR THE ICD

SOLAR DYNAMIC GROUND TEST DEMONSTRATOR
CRITICAL DESIGN REVIEW (CDR) ACTION ITEMS

ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
CONC 30	KUDIJA	HARRIS	04/30/93	ICD DOES NOT SHOW RADIOMETER COOLANT LINES	HARRIS TO PROVIDE LATCH INSERT ORIENTATION AND CABLE LENGTH BASED ON HARRIS RECOMMENDED ROUTING/MOUNTING DESIGN TO RD AND NASA LEWIS
CONC 31	KUDIJA	NASA	04/30/93	ICD DOES NOT SHOW RADIOMETER COOLANT LINES	NASA TO DEFINE POSITION AND WEIGHT OF RADIOMETER AND PHOTODIODES TO RD AND HARRIS
CONC 32	SHALTENS	HARRIS	04/30/93	GENERAL CONCERN AND CONFUSION ON OUTGASSING OF FACETS	WHAT IS RELATIONSHIP OF (1) INDIVIDUAL COMPONENT OUTGASSING REQM'TS AND (2) END ARTICLE (FACET) WHICH IS BASICALLY A COMPOSITE FOR USE IN VACUUM SYSTEM. WHICH COMPONENT OR END ARTICLE SPEC GOVERNS
CONC 33	STEVENS	HARRIS	04/23/93	HEX PANEL CORNER/HUB FITTING TO TITANIUM SPACER LH/RH THREADED CONNECTIONS: THREADED CONNECTIONS MAY BE LOOSE SINCE THEY DO NOT TIGHTEN UP. DOES THIS ADVERSELY EFFECT THE STRIKER/LATCH HOUSING ATTACHMENT	LOOK AT CONTROLLING THREAD CLASS OR LIQUID SHIM PRODUCT TO FILL THREAD CLEARANCE
CONC 34	SHALTENS	HARRIS	04/30/93	CONFUSION EXISTS ON REFLECTIVITY MEASUREMENTS. WHAT DO THEY MEAN AND HOW WILL THEY BE USED. IS THE RESULT OF THE SOLAR AVERAGED SPECULAR REFLECTIVITY WHAT WE WANT TO REPORT.	RESOLVE METHOD OF MEASUREMENT AND REPORTING OF FACET REFLECTIVITY NUMBER. WE NEED AGREEMENT. NEED AGREEMENT ON WAVELENGTH, CONE ANGLE, INSTRUMENT LIMITATIONS AND ETC.

SOLAR DYNAMIC GROUND TEST DEMONSTRATOR
CRITICAL DESIGN REVIEW (CDR) ACTION ITEMS

ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
CONC 35	RICHTER	HARRIS	04/30/93	OUTGASSING	IS EP-3 SPACE QUALIFIABLE?
CONC 36	BEACH	HARRIS	05/07/93	STEADY STATE THERMAL ANALYSI BIASES "HOT CASE" RESULTS HIGH, AS COMPARED WITH TRANSIENT (MORE REALISTIC) ANALYSIS. THERMAL CONTROL APPROACH(S) FOR HOT CASE SHULD BE BASED ON TRANSIENT PEAK TEMPERATURES.	RUN TRANSIENT THERMAL ANALYSIS TO DETERMINE "ORBITAL" MAX/MIN TEMPERATURES FOR HARRIS HARDWARE. USE MAX INSOL ORBIT TIMES
CONC 37	JEFFERIES	HARRIS	/ /	1)SPACING BETWEEN FACET AND HEX BEAM OF 1/8" IS SAME AS SCAD AND SOME INTERFERENCE OCCURRED....2)THERMAL GROWTH OF ALUM FACET RELEATIVE TO HEX BEAM COULD INCREASE THIS INTERFERENCE. 3) STIFFNESS ASSUMPTION OF STANDOFFS COULD AFFECT THIS CLEARANCE.	RECONSIDER SPACING OF FACETS TO HEX BEAM
CONC 38	JEFFERIES	HARRIS	04/30/93	SAME AS A/I 37	RECONSIDER DIFFERENCE BETWEEN FACET CAPTURE FITTING DIAMETER AND STANDOFF BASE DIAMETER
CONC 39	KUDIJA	ROCKET	04/30/93	N10116 CONCENTRATOR SPEC CALLS OUT 200 KW/SQM FOR APERTURE SHIELD LIMIT. UNITS SHOULD REFLECT THE ACTUAL REQUIREMENT WIHC IS IMPOSED ON A SQ IN BASIS NOT TO EXCEED 2000F ADIABATIC	UPDATE N10116 TO READ 127 WATTS/SQ.IN

SOLAR DYNAMIC GROUND TEST DEMONSTRATOR
CRITICAL DESIGN REVIEW (CDR) ACTION ITEMS

ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
CONC 40	KUDIJA	ROCKET	04/30/93	N10116 CONC SPEC BACKWALL FLUX HAS NOT BEEN FULLY COORDINATED	COORDINATE AN EFFORT TO DEFINE THE BACKWALL FLUX REQUIREMENT AND MODIFY SPEC.
CONC 41	RICHTER	HARRIS	05/07/93	CAN HARRIS USE A CALORIMETER SPECIFIED FOR VACUUM USE TO MEASURE TOTAL FLUX INTO THE RECEIVER	IDENTIFY AVAILABILITY AT GARRETT, HARRIS, LORAL
CONC 42	RICHTER	HARRIS	05/07/93	THERE IS CONCERN THAT WHEN USING THE LASER METHOD FOR FACET POINTING, THAT IF THE LASER IS POINTED AT A DEFECT SIGHT ON THE FACET (CAUSING SCATTER) THIS WILL THROW OFF THE POINTING FOR THAT FACET	IMPLEMENT A CRITERIA THAT EXCLUDES GROSS MIS-POINTS OR INCREASE THE NUMBER OF MEASUREMENTS FOR THE SOFTWARE
CONC 43	ALEXANDER	HARRIS	05/07/93	TANK WIRING AND PASS THROUGHS ARE BEING DESIGNED AND FABRICATED NOW. WE DON'T HAVE ADEQUATE INFORMATION ON FLUX TEST UNIT	PROVIDE A WIRING SCHEMATIC FOR THE FLUX TEST TARGET INCLUDING INSTRUMENTATION, POWER, AND CONTROL SIGNALS. INDICATE AMOUNT OF CURRENT ANTICIPATED ON EACH WIRE.
CONC 44	BEACH	HARRIS	05/07/93	FLUX DISTRIBUTION TEST WILL HAVE DIFFERENT FLUX ON BAP THAN DURING SYSTEM TESTS. POTENTIAL FOR BAP DISTORTION IS UNKNOWN	TRANSMIT INCIDENT FLUXES ON BAP TO LERC FOR ASSESSMENT OF BAP DISTORTION

SOLAR DYNAMIC GROUND TEST DEMONSTRATOR
CRITICAL DESIGN REVIEW (CDR) ACTION ITEMS

ACT. ITEM NO.		SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
** ACTION ITEMS FROM REVIEW ON - DACS						
DACS	1	SIEMS	ROCKET	/ /	THE SIGNAL FROM THE PUMP CONTROLLER LOCATED IN THE INSTR CONSOLE FOR THE ACCESSORY CURRENT IS NOT CONTAINED ON THE WIRE LIST (OR THE INSTRUMENT LIST).	RECOMMEND ROCKETDYNE ASSIGN NAME TO THIS SIGNAL AND ADD TO THE WIRE LIST. (DUE NEXT ISSUE OF DOCUMENTS)
DACS	2	LINDAMOOD	GFSD	06/03/93		ON DRAWING P16M-13-115 SHEET 14, BOARD SCHEMATIC, I THINK THE CENTEROF OP AMPS SHOULD BE LABELED U7,U8,U9 INSTEAD OF U7,U7,U7
DACS	3	SIEMS	GFSD	/ /	THE ANALOG INSTRUMENTATION PANEL OF THE CRC HAS GENERAL NAMES OVER THE ANALOG METERS ONLY.	ADD THE INSTRUMENT LIST I.D. NUMBERS ABOVE THE GENERIC NAMES ON THE FRONT PANEL (NOTE: THIS ACTION ITEM IS A SUBSET OF DACS-8 AND IS THEREFORE DELETED)
DACS	4	WILLIAMS	GFSD	06/30/93		HARDWARE SPARES SHOULD ALSO BE ACCOMPANIED BY DIAGNOSTIC SOFTWARE (NATIONAL INSTRUMENT, ETC.) SO NASA CAN FIGURE OUT IF HARDWARE IS SICK RATHER THAN USING LABVIEW TO TEST HARDWARE.
DACS	5	WILLIAMS	GFSD	/ /		CAN SIPS BE COMMANDED TO START THE TAC IF THE TAC IS ALREADY RUNNING (THIS COULD HAPPEN IF THE TACH IS COMMANDED TO SHUTDOWN AND THEN THE OPERATOR CHANGES HIS MIND)

SOLAR DYNAMIC GROUND TEST DEMONSTRATOR
CRITICAL DESIGN REVIEW (CDR) ACTION ITEMS

ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
DACS 6	WILLIAMS	GFSD	06/03/93	SOME CONCERN ABOUT ALARMS. CAN CONTINUING ALARM ACKNOWLEDGEMENT KEEP THE OPERATOR FROM HAVING TIME TO GET THE SYSTEM (SOFTWARE BUTTONS, ETC.) UNDER CONTROL?	ASFS SHOULD DEVELOP A SERIES OF SCENARIOS BASED ON FAULT TREE ANALYSIS TO SEE WHAT THE SEQUENCE AND ACTIONS SHOULD BE. IN SOME CASES THIS MAY REQUIRE A MANUAL FOR TEST CONTROL, LISTINGS OF STEPS TO TAKE TO TROUBLESHOOT OR SHUT DOWN SYSTEM IN EMERGENCY
DACS 7	WILLIAMS	GFSD	/ /	1.) LACK OF CONCENTRATOR POSITION CONTROL AND 2.) GAS CHARGE VALVE ON SYSTEM SCREEEN	1.) REVIEW AT SYSTEM CDR AND 2.) VERIFY IF A NEW ITEM, IF IT IS, DISCUSS CONCERNS WITH NASA GTD RESPONSIBLE ENGINEERS
DACS 8	WILLIAMS	GFSD	06/05/93		ALL PATCH PANELS, CONTROL PANELS, DOCUMENTATION AND ETC SHOULD INCLUE LEGENDS FOR TAG NOs SO THAT SIGNAL TRACING IS MUCH EASIER. (DRAWINGS AND PHYSICAL PANEL SILKSCREENS)
DACS 9	WILLIAMS	GFSD	08/01/93	WILL THERE BE ANY PROBLEMS WITH THERMIONIC EMISSION FROM THE HOT RECEIVER CAVITY INTO THE VACUUM OF THE TANK. THIS COULD CAUSE WIRE AND COMPONENTS AT HIGH + CHARGE TO COLLECT ELECTRONS. THIS COULD CAUSE ELECTRON FLOWS TO OTHER COMPONENTS IN THE TANK...	DETERMINE IF THE PROBLEM COULD HAPPEN AND IF SO PERHAPS BUILD AN ELECTRON GRID TO KEEP ELECTRONS TRAPPED IN THE CAVITY.

SOLAR DYNAMIC GROUND TEST DEMONSTRATOR
CRITICAL DESIGN REVIEW (CDR) ACTION ITEMS

ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
DACS 10	WILLIAMS	HARRIS	/ /		NEED TO HAVE DEFINITION OF THE TYPES, OUTPUTS, AND NUMBER OF PYROHELIOMETERS IN THE CONCENTRATOR. ANY NONLINEARITY?
DACS 11	STEVE	GFSD	07/01/93		WHAT IS THE GROUNDING SCHEME FOR GROUNDED AND OR UNGROUNDED THERMOCOUPLES IN RESPECT WITH DATA COLLECTION IN INSTRUMENT CONSOLE. NEED TO PROVIDE A SINGLE POINT GROUND TO PREVENT GROUND LOOPS.
DACS 12	GAYDOS	HARRIS	06/15/93		PRESENTLY, THESE IS NOT A REQUIREMENT FOR PYROHELIOMETER ACCURACY. THE CURRENT PYROHELIOMETERS HAVE AN ERROR WHICH SEEMS HIGH. SINCE THE LIGHT INTENSITY IS IMPORTANT IS THIS ERROR ACCEPTABLE.
DACS 13	KANKAM	GFSD	/ /	ONLY ONE PC CONTAINS THE LOW SPEED DATA	DEVISE APPROACH TO PREVENT LOSS OF TEST DATA IF HARD DISK CONTAINING DATA CRASHES. (DUE NEXT SRD RELEASE)
DACS 14	RICHARDS	GFSD	/ /		CHECK AVAILABLE DISK STORAGE SPACE AND ISSUE ALARM IF LOW. (COORDINATE WITH A/I DACS-13) DUE AT NEXT SRD RELEASE

SOLAR DYNAMIC GROUND TEST DEMONSTRATOR
CRITICAL DESIGN REVIEW (CDR) ACTION ITEMS

ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
DACS 15	RICHARDS	GFSD	/ /	CURRENT APPROACH LOCKS OUT THE SYSTEM FROM STARTING IF THE ELS IS NOT CONNECTED	REVISE TO NOTIFY OPERATOR THAT THE DACS IS "OFF LINE" BUT ALLOW SYSTEM TO START. (NEXT SRD RELEASE)
DACS 16	RICHARDS	GFSD	/ /	CURRENT ALARM APPROACH HAS A HIGH AND LOW LEVEL ALARMS WITH CAUTION AND CRITICAL SET POINTS. EXCEEDING CRITICAL LEVELS RESULTS IN SYSTEM SHUTDOWN.	REVISE APPROACH TO PROVIDE SELECTABLE SHUTDOWN ON EITHER LOW OR HIGHCRITICAL VALUES. DUE NEXT SRD RELEASE
DACS 17	ALEXANDER	GFSD	/ /	THE SYSTEM SCREEN DOES NOT IDENFITY THAT THE SOLAR SIMULATOR SHUTTER IS OPEN/CLOSED	CHANGE COLOR OF CONCENTRATOR ICON TO SHOW SHUTTER OPEN/CLOSED STATUS. RECOMMEND GRAY=SHUTTER CLOSED AND WHITE=SHUTTER OPEN. DUE NEXT SRD RELEASE
DACS 18	WILLIAMS	GFSD	06/15/93		SEND 14 SETS OF COLOR SCREENS TO NASA AND COMPONENT COMPANIES ASAP FOR REVIEW AND MARKUP
DACS 19	WILLIAMS	GFSD	/ /		IS THERE A POSSIBILITY OF THERMIONIC EMISSION FROM THE RECEIVER. NOTE THAT THIS ACTION ITEM IS A DUPLICATE OF DACS-9 AND IS DELETED
DACS 20	WILLIAMS	GFSD	07/01/93		HOW MUCH TIME WILL BE REQUIRED TO LINEARIZE THE THERMOCOUPLES

SOLAR DYNAMIC GROUND TEST DEMONSTRATOR
CRITICAL DESIGN REVIEW (CDR) ACTION ITEMS

ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
DACS 21	ALEXANDER	GFSD	06/15/93	SPEED ACCURACY DOES NOT MEET SPEC REQUIREMENTS	HOW WILL THIS BE RECONCILED?
DACS 22	MACOSKO	GFSD	/ /	ON PG 3 OF THE DACS PRESENTATION DOCUMENT THE CONTROL OF THE GAS CHARGE VALVE IS INDICATED AS A DACS FUNCTION. ON PG 81, SYSTEM CONTROL, THE CHARGE VALVE OPERATION IS NOT SHOWN	ADD CHARGE VALVE ACTUATION TO THE SYSTEM CONTROL SCREEN. NEXT SRD RELEASE
DACS 23	MOHR	GFSD	07/01/93		SHOULD THERE BE A SERARATE AND REDUNDANT OVERSPEED SHUTDOWN (E.G. LAB OVERSPEED) IN CASE OF OVERSPEED THAT OCCURS IF THERE IS A COMPUTER PROBLEM
DACS 24	MOHR	GFSD	06/15/93		41-12139 PAGE 38. 120 VAC WIRING MAY WANT TO USE TWISTED PAIR FOR AC WIRING FOR RADIATED FIELD IMMUNIZATION
DACS 25	MOHR	GFSD	/ /		VALVES THAT ARE HELD OPEN BY DACS - WHAT HAPPENS IF POWER TO VALVES IN INTERRUPTED? FAIL SAFE? CAN THERE BE A FAILURE MODE WHERE POWER STAYS ON TO VALVES WHEN IT IS DESIRED TO CUT POWER TO VALVES?

SOLAR DYNAMIC GROUND TEST DEMONSTRATOR
CRITICAL DESIGN REVIEW (CDR) ACTION ITEMS

ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
DACS 26	MOHR	GFSD	06/15/93		WILL SLEW RATE OF 3-B MODULE BE ADEQUATE TO PROVIDE OVERSPEED INFORMATION? MAY WANT TO SPLIT SPEED SIGNAL INTO A MORE ACCURATE 0-40 KHZ RANGE AND A LESS ACCURATE, FASTER RESPONSE 0-90 KHZ RANGE
DACS 27	MOHR	GFSD	08/01/93		P16M-13-115 - MAY WANT TO KEEP R7,8,9,10,11, AND R12 CLOSE TO P.C. BOARD EDGE CONNECTOR. USE A LOT OF GROUND PLANE IN/AROUND/BETWEEN INCOMING SIGNALS
DACS 28	TOLBERT	GFSD	/ /	THE REVIEW BOOKLET CONTAINS MANY CIRCUIT DRAWINGS WHICH ARE NOT LEGIBLE	FOR THE PRESETATION PACKET "DACS" THE DRAWING NUMBERS SHOULD BE INCLUDED SO THAT WE CAN CROSS REFERENCE LEDGIBLE DRAWINGS
DACS 29	ALEXANDER	GFSD	/ /	IF VALVES STICK CLOSED SYSTEM OVERSPEED PROTECTION DOESN'T WORK.	HAVE DACS COMMAND FULL PLR AND FULL ELS LOADS ON EMERGENCY STOP ACTIVATION. (DUE AT NEXT SRD RELEASE)
DACS 30	ALEXANDER	GFSD	07/01/93	DEFINE REQUIRED SHUTDOWNS. SHUTDOWN(S) TIMING MAY BE INADEQUATE TO PREVENT DAMAGE TO HARDWARE	PROVIDE TIMELINES FOR SHUTDOWNS WHICH IDENTIFY COMMUNICATION, VALVE ACTIVATION, DELAYS ETC TO DETERMINE IF PLANNED APPROACH ACTS FAST ENOUGH.

SOLAR DYNAMIC GROUND TEST DEMONSTRATOR
CRITICAL DESIGN REVIEW (CDR) ACTION ITEMS

ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
DACS 31	WILLIAMS	GFSD	07/01/93	AFTER A MESSAGE IS RECEIVED FROM PCCU, HOW LONG (LATENCY TIME IN LABVIEW, ETC.) IS IT TO TRANSMIT A MESSAGE TO SIPS OR ELS. THIS IS IMPORTANT FOR SIPS OR ELS DISCONNECT	ASFS TO DETERMINE MINIMUM LATENCY PERIODS AND WEIGH THESE AGAINST SYSTEM REQUIREMENTS. FURTHER DISCUSSION SEEMED TO SUGGEST THAT SOFTWARE SHOULD NOT BE USED IN THE ELS DISCONNECT LOOP.
** ACTION ITEMS FROM REVIEW ON - ELS					
ELS 1	GAYDOS	NASA	08/15/93	THE TEST PLANS AND PROCEDURES FOR LERC CHECKOUT OF THE ELS SHOULD BE REVIEWED BY ALLIED FOR CONCURRENCE AND COMMENTS.	NASA TO SEND PROCEDURES TO ASFS
ELS 2	GAYDOS	NASA	06/15/93	THE ACCURACY SPEC SEEM HIGH. SPECIFICALLY, THE CURRENT MODE IS LISTED AS +/- 2% OF RATED OVER THE FULL RANGE AND THE POWER MODE IS +/- 5% OF RATED OVER THE FULL RANGE. FOR THE POWER MODE, THIS WOULD EQUATE TO +/- 200W OVER THE FULL RANGE.	WHAT ARE THE ACTUAL ACCURACIES?
ELS 3	POST	NASA	08/15/93	DOES THE ELS HAVE THE CAPABILITY OF AUTOMATICALLY PREVENTING OVERLOADS OF THE SYSTEM?	INCORPORATE ELS COMMAND "FILTERING" IN THE ELS OR DEVICE COMANDING THE ELS

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ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
ELS 4	SIEMS	NASA	06/15/93	NASA NEEDS TO DEFINE OR CLARIFY AMOUNT OF "BUS" ISOLATION REQUIRED BY ELS COMPUTER	PROVIDE DIAGRAM
** ACTION ITEMS FROM REVIEW ON - HEAT					
HEAT 1		ROCKET	06/02/93		CLARIFY SPEC REGARDING NUMBER OF COLD STARTS (12 STARTS FROM 360R THE REST FROM 70F??)
HEAT 2		ASE	06/02/93		PROVIDE SCHEDULE FOR COMPLIANCE WITH "IN PROCESS" SPEC REQUIREMENTS
HEAT 3		ROCKET	05/14/93		ROCKETDYNE TO PROVIDE FRAME TEMPERATURE DISTRIBUTION IN ORDER TO PERFORM THERMAL STRESS ANALYSIS OF RECEIVER FRAME
HEAT 4		ASE	06/02/93		ASE TO PERFORM HOT CANISTER TO COLD INSIDE TUBE THERMAL ANALYSIS (TRANSIENT)
HEAT 5		GFSD	06/02/93		ANALYZE ALTERNATE STARTUP (AT SECOND START UP PERIOD) PROCEDURE AND EFFECT ON RECEIVER. WHICH START UP DOES RECEIVER PREFER

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ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
HEAT 6		ASE	/ /		INVESTIGATE MONOBALL GALLING. RISK
HEAT 7		ASE	07/01/93		PROVIDE DISPLACEMENT VECTOR FOR APERTURE SHIELD RELATIVE TO PALLET FOR COLD TO HOT CONDITIONS
HEAT 8		ASE	06/02/93		EVALUATE NEED FOR VACUUM COMPATIBLE LUBRICANT ON MONOBALL (TO AVOID GALLING)
HEAT 9		ADD	07/15/93		A.D.D. TO INVESTIGATE INSULATION PERFORMANCE IMPACT OF NON-ISOTHERMAL SHELL
HEAT 10		ASE	06/02/93		CHECK STABILITY IN VACUUM (VAPOR PRESSURE) OF SILICON CARBIDE CLOTH PLANNED TO BE USED FOR RECEIVER INNER LINER
HEAT 11		ASE	/ /		INVESTIGATE POTENTIAL FOR FRETTING/WEAR OF MONBALL DUE TO GTD/TANK/SHIPPING INDUCED VIBRATION
HEAT 12		ASE	06/02/93		PROVIDE LAYOUT SHOWING AMOUNT OF CLEARANCE BETWEEN APERTURE CONE AND LIGHT IN COLD CONDITION AND THE DEFINITION OF THE AMOUNT OF MOTION OF THE CONE COLD TO HOT. DOES THE CONE HIT THE LIGHT

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ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
HEAT 13		ASE	06/02/93		PROVIDE MATERIALS MATRIX FOR OUTGASSING REQUIREMENTS
HEAT 14		ASE	/ /		PERFORM COLD, HOT, AND TRANSIENT THERMAL AND THERMAL DISTORTION ANALYSIS OF RECEIVER SUPPORT FRAME AND APERTURE PLAT AND SHELL. REPORT MOVEMENT IN TANK COORD SYSTEM
HEAT 15		ASE	/ /		PERFORM APERTURE PLATE THERMAL ANALYSIS (AND THERMAL STRESS IF NECESSARY) USING MLI CONDUCTIVE PROPERTIES AND CONTACT CONDUCTANCE BASED ON SURFACE FINISH AND CONTACT PRESSURES
HEAT 16		ASE	/ /		SUMMARIZE THERMAL ANALYSIS MODEL, MATERIAL PROPERTIES USED PLUS THEIR SOURCE AND UNCERTAINITY HEAT TRANSFER PROPERTIES PLUS THEIR SOURCE AND UNCERTAINTY. SHOW ANS SUMMARIZE SENSITIVITIES TO INDICATE WHAT KEY ITEMS ARE
HEAT 17		ASE	/ /		LIST MEANINGFULL TESTS/INVESTIGATIONS TO BE ACCOMPLISHED ON SINGLE TUBE AFTER COMPLETION OF SINGLE TUBE TEST

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ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
HEAT 18		ASE	/ /		VIBRATION TEST SILICON CARBIDE INNER LINING
HEAT 19		GFSD	/ /		HEAT LEAK ASSESSMENT ON SYSTEM OF INSTRUMENTATION PASS-THROUGHS
HEAT 20		ASE	05/20/93		DETERMINE WAYS TO MEASURE EMISSIVITY OF CANISTER CURVED SURFACES, IF NOT FEASIBLE WHAT KIND OF MEASUREMENTS CAN APPROXIMATE SUCH VALUES. DETERMINE IF ABSOLUTE MEASUREMENT IMPORTANT AS CHANGE IN EMISSIVITY AFTER COMPLETION OF TEST. (PROVIDE PLAN)
HEAT 21		ASE	05/20/93		DETERMINE OPTIONS FOR SURFACE TREATMENT OF CANISTERS WHEN CANISTERS ARE ALREADY BRAZED ONTO TUBES (GENERATE PLAN)
HEAT 22		ASE	05/26/93		THE PCS IS ALIGNED TO CRITICAL OUTLET DUCT. DIMENSION OUTLET DUCT DIRECTLY TO PAD TO WITHIN .0125 TRUE POSITION. DIMENSION INLET DUCT TO OUTLET DUCT TO WITHIN .09 TRUE POSITION.

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ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
** ACTION ITEMS FROM REVIEW ON - LUP					
LUP 1	KUDIJA	ROCKET	/ /	THE PLACEMENT OF THE COMPONENTS ON THE LUP AS IDENTIFIED BY ASFS DOES NOT MATCH THE P&ID AND THE LUP ICD. SPECIFICALLY THE FLOWMETER IS LOCATED DOWNSTREAM OF THE PUMPS ON THE P&ID. ASFS WOULD LIKE TO MOVE FLOWMETER UPSTREAM OF PUMPS TO ELIMINATE PULSES	REVISE ICD AND P&ID (DUE NEXT REVISION)
** ACTION ITEMS FROM REVIEW ON - PCCU					
PCCU 1	WILLIAMS	ROCKET	10/01/93	HAVE OUTGASSING AND THERMAL AND VACUUM ENVIRONMENTAL ISSUES BEEN COVERED.	WORK WITH TIM GAYTOS AT NASA TO DOUBLE CHECK COMPONENTS
PCCU 3	WILLIAMS	GFSD	/ /	HIGH PRIORITY COMMANDS ON RS-422 BUS CANNOT BE TRANSMITTED UNTIL LOW PRIORITY COMMAND (OR DATA) IS FINISHED BEING SENT TO DACS. SHOULD THE LONG MESSAGES FROM PCCU TO DACS BE BROKEN IN PIECES WHICH CAN HAVE A HI PRIORITY MESSAGE STUCK IN BETWEEN?	ASFS TO DETERMINE MAXIMUM ALLOWABLE DELAYS ON HI PRIORITY COMMUNICATIONS TO SEE IF LONG MESSAGES MUST BE ???? WITH NUMBERED FRAMES FOR REASSEMBLY LATER (COORDINATE WITH RELATED AI IN DACS)
PCCU 4	WILLIAMS	NASA	/ /	AFTER NASA TAKES OVER THE SYSTEM, WE NEED A WAY TO CONTRACTUALLY (OR OTHERWISE) GET REPAIRS DONE ON CIRCUIT BOARDS IN PCCU OR ELSEWHERE WHERE THE KNOWLEDGE OF THE OPERATION OF THE BOARDS IS RETAINED BY ASFS. NOT INCLUDING N.I. OR P.C. HARDWARE)	THIS IS A PROBLEM FOR NASA CONTRACTING OFFICER AND PROGRAM MANAGEMENT

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ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
PCCU 5	WILLIAMS	GFSD	/ /	IF NASA IS TO TAKE OVER THE OPERATION OF THE SYSTEM AFTER ACCEPTANCE TESTS, THEN WE NEED TO BE SUPPLIED WITH MORE THOROUGH DOCUMENTATION OF PCCU HARWARE THEORY OF OPERATION, FIRWARE THEORY, FIRWMARE LISTINGS, FIELD PROGRAMMABLE GATE ARRAY SCHEMATICS ETC.	DEVELOP COMPLETE THEORY OF OPERATION DOCUMENTS, SUPPLY COMPLETE LISTINGS OF FIRMWARE/SOFTWARE AND SOURCE CODE AND FPGA SCHEMATICS/CODES.
PCCU 6	KANKAM	GFSD	06/11/93	THE 3 PHASE POWER QUALITY TEST WAS SUCCUESSFULLY OBSERVED. HARMONIC MEASUREMENT WAS MADE OF ALTERNATOR VL-N WHEN DIRECTLY CONNECTED TO 3 PHASE RES. LOAD. GREATER DISTORTION IS EXPECTED IN THE PHASE CURRENTS WHICH CAN CAUSE MALFUNCTION OF INSTRUMENTS.	FUTURE TESTS AT ASFS SHOULD INCORPORATE APPROPRIATE INSTRUMENTATION TO MEASURE THE LEVEL OF HARMONIC DISTORTION IN THE CURRENT.
PCCU 7	KANKAM	GFSD	/ /	PRESENT SOFTWARE ALGORITHM DOES NOT INCORPORATE TAC MOTORING AT CONSTANT SPEED. THIS IS AN UNDESIRABLE RESTRICTION ON THE SYSTEM OPERATION. THE LIKELIHOOD TO OPERATE IN THE ABOVE MODE IS REAL.	THE PCCU SOFTWARE SHOULD INCLUDE TAC MOTORING AT CONSTANT SPEED IN ADDITION TO ITS PRESENT CAPABILITIES. (NEXT SRD RELEASE)

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ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
PCCU 8	KANKAM	ROCKET	06/15/93	IT WAS AGREED AT PDR THAT POWER QUALITY REQUIREMENTS WOULD INCLUDE A SUMMARY TABLE IN THE OFFICIAL DOCUMENTS. NONE OF THE DOCUMENTS SUPPLIED SO FAR HAVE THIS TABLE.	INCLUDE A POWER QUALITY REQUIRMENTS TABLE IN THE APPROPRIATE SPECS. THE CONTENT OF THE TABLE WAS AGREED AT PDR, SHOULD BE DISCUSSED WITH NASA PRIOR TO INCLUSION.
PCCU 9	PEMBERTON	GFSD	/ /	CAN THE PCCU AND DACS RS422 DATA PACKET SYNC BE LOST? IF SO, WILL IT RE-SYNC?	INCORPORATE A DATA PACKET TIME OUT (NEXT RELEASE OF DACS AND PCCU SRD)
PCCU 10	STEVE	ROCKET	06/15/93		ARE THERE ANY REQUIREMENTS FOR CONTROL OF INTERNAL TANK LIGHTING DURING DARK PHASE (SHUTTER CLOSED), OTHER THAN MANUAL CONTROL
** ACTION ITEMS FROM REVIEW ON - PCS					
PCS 1	ARMSTRONG	GFSD	06/15/93	WELD DUCT FLANGE ANALYSIS NEEDS REDOING. THE FLANGE THICKNESS AND FIXITY HAS CHANGES SINCE ORIGINAL ANALYSIS. TURBINE EXIT BYBASS BELLOWS STRUTS NEEDS TO BE MODIFIED TO INCLUDE EFFECT OF OFFSET AT UPPER FLANGE.	UPDATE ANALYSIS.
PCS 2	WILLIAMS	GFSD	07/01/93	SEMICONDUCTORS AND OTHER ELECTRONICS HAVE BOTH AN OPERATING TEMPERATURE RANGE AND A STORAGE TEMPERATURE RANGE. DURING VARIOUS TESTS, BOTH IN AND OUT OF TANK 6, THESE RANGES MUST NOT BE EXCEEDED.	EXAMINE/WRITE TEST PLANS FOR POSSIBLE ACCIDENTAL OVERHEATING OR UNDERCOOLING. THIS ACTION AFFECTS PCCU, RADIOMETERS, LUP, PUMPMOTORS, AND ETC.

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ACT. ITEM NO.		SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
PCS	3	BEACH	NASA	06/17/93	NEED TO DETERMINE IF AUXILLIARY HEATING IS NEEDED TO MAINTAIN PRESSURE TRANSDUCER TEMPERATURES (-10 TO + 130F) (P51 OF PCS/LUP DESIGN REVIEW PACKAGE)	PROVIDE THERMAL BOUNDRY CONDITION FOR BOXES CONTAINING PRESSURE TRANSDUCERS
PCS	4	MACOSKO	ROCKET	06/17/93	NEED TO RESOLVE ISSUE OF GAS CHARGE LINE LOCATION AND INSTALLATION OF TAP BETWEEN THE BYPASS VALVES TO BE USED FOR ON LINE ADJUSTING OF THE GAS INVENTORY. THERE ARE A NUMBER OF REASONS FOR CONSIDERING A TAP BETWEEN VALVES.	A DISCUSSION IS NEEDED BETWEEN INTERESTED PARTIES (ROCKETDYNE, NASA, FLUID SYSTEMS) TO CONSIDER PROS AND CONS
PCS	5	KUDIJA	GFSD	07/01/93	THE STRESS MODEL MAY NOT MODEL THE TURBINE EXHAUST DUCT BELLOWS UNIBALL STRUT STIFFENERS FOR SOME MODES.	CHECK THE STRUT/FLANGE MODES AND UPDATE MODEL IF NECESSARY.
PCS	6	KUDIJA	GFSD	06/15/93	HAST X SHEET DATA WAS USED FOR BELLOWS AND DUCT ALLOWABLES. IT WAS NOT KNOWN IF AN ALLOWANCE WAS MADE FOR COLD WORK OF THE MATERIAL IN MAKING THE DUCTS.	CHECK TO SEE IF COLD WORKED MATERIAL HAS A DIFFERENT ALLOWABLE.

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ACT. ITEM NO.		SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
PCS	7	KUDIJA	GFSD	06/17/93	CONTROL OF THE RECEIVER/PCS DUCT INTERFACE IS ACHIEVED BY AN UNDOCUMENTED AGREE STIFFNESS MODEL AND DUCT END DIMENSIONAL TOLERANCE.	PROVIDE DOCUMENTATION OF THIS AGREEMENT SO THAT IT MAY BE REFERENCED IN SPECIFICATIONS.
PCS	8	KUDIJA	GFSD	/ /	YOU DID EXACTLY WHAT THE ICD SAID. 213000016 WAS WRONG. ICD DIDN'T IDENTIFY TWO PORTS SHOWN ON P&ID	FIX THE ICD AND INCORP GAS CHARGE PORTS ON PCS. (THIS IS A DUPLICATION OF PCS-4)
PCS	9	AMUNDSEN	ROCKET	06/28/93	THE LOCATION OF THE PCS INSTRUMENTATION PATCH PANEL INTERSECTS THE REVISED DUCT FROM THE RECEIVER TO THE TAC.	COORDINATE A NEW PCS PATCH PANEL LOCATION WITH FLUID SYSTEMS (ACTION ITEM DUEDATE) AND REVISE THE PCS ICD APPROPRIATELY.
** ACTION ITEMS FROM REVIEW ON - RAD						
RAD	1	PERRONE	NASA	03/05/93	DOES THE SYSTEM SPEC/COMPONENT SPECS HAVE THE CORRECT MARGINS FOR THE THERMAL FLUID SYSTEM WITH REGARDS TO PERSONNEL SAFETY/TANK 6 REQUIREMENTS UNDER PRESSURE CONDITIONS	REVIEW SPECS/NASA REQUIREMENTS (IE SYSTEM, RADIATOR, LUP)
RAD	2	BANKAITIS		/ /	UNCLEAR IF MARGIN OF SAFETY MEETS LERC SAFETY REQUIREMENT	NASA TO LOOK AT MARGIN OF SAFETY REQUIREMENT A REQUEST CHANGE TO SPECS IF NECESSARY

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ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
RAD 3	KUDIJA	LORAL	06/01/93	NOT CLEAR THAT STRAP RETAINER LOCATIONS DO NOT INTERFER WITH I-BEAM SUPPORTS	CHECK THIS ALIGNMENT
RAD 4		ROCKET	04/30/93	VIBRATION REQUIREMENT FLOWDOWN FROM SYSTEM SPEC IS INAPPROPRIATE.	DELETE RADIATOR VIBRATION ENVIRONMENT REQUIREMENT
RAD 5	KUDIJA	LORAL	03/31/93	THERMAL EXPANSION ALLOWANCE ALONG PANEL LENGTH HAVE NOT BEEN CHECKED	CHECK THERMAL EXPANSION ALLOWANCES
** ACTION ITEMS FROM REVIEW ON - SYST					
SYST 1	KOZIK	GFSD	06/17/93	DACS DWG P16M-20-038 INTERFACE WIRING NOT CONSISTENT WITH ROCKETDYNEWIRE LIST	COORDINATION MEETING BETWEEN SIEMS AND KOZIK REQUIRED TO RESOLVE ISSUES
SYST 2	KOZIK	GFSD	06/17/93	DACS DWG P16M-15-033. 1) START INV. IEEE488 SIGNALS NOT SHOWN GOING TO I.C. PATCH PANEL. 2) SIGNALS BETWEEN I.C. & C.R.C NOT CLEAR AS TO WHICH PATCH PANEL SIGNALS LEAVE I.C. 3) PATCH PANEL TO/FROM LOAD SIM & SOLAR SIMULATOR NOT SHOWN	COORDINATION MEETING BETWEEN KOZIK AND SIEMS REQUIRED TO RESOLVE ISSUES.
SYST 3	KOZIK	GFSD	06/17/93	DWG P16N-01-177. 1)CONNECTOR P/N NOT CONSISTENT WITH CONNECTOR LIST (REF ITEMS 5&6). 2) SEVERAL CONNECTORS MISSING 3) PANEL CONNECTORS CUTOUTS IN ERROR FOR CONNECTOR SHELL SIZES. 4) PER CONVERSATION WITH SIEMS, CONNECTOR J3117 TO BE COAX.	COORDINATION MEETING REQUIRED BETWEEN SIEMS AND KOZIK TO RESOLVE DIFFERENCES.

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ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
SYST 4	KOZIK	GFSD	06/17/93	DACS DWG P16N-01-175 SHT 2. 1)CONNECTOR ID NOT CONSISTENT WITH INTERCABLING DIAGRAM. 2)CONNECTOR P/N NOT CONSISTENT W/CONNECTOR LIST. 3)IEEE-488 CONNECTOR MISSING (REF J5029)	COORDINATION MEETING BETWEEN SIEMS AND KOZIK REQUIRED TO RESOLVE ISSUES
SYST 5	KOZIK	GFSD	06/17/93	DACS DWG P16N-01-176. 1)CONNECTOR P/N IN ERROR (REF ITEMS 2,3,4). 2)THERMOCOUPLE MATERIAL CONTACTS(SOCKETS) NOT SPECIFIED ON DWG. 3)PANEL CONNECTOR CUTOUTS IN ERROR FOR CONNECTOR SHELL SIZE.	COORDINATION MEETING BETWEEN SIEMS AND KOZIK REQUIRED TO RESOLVE ISSUES.
SYST 6	MASON	GFSD	08/30/93		RESOVLE UNCERTAINTY CONCERNING IF AND HOW A REMOTE CONCENTRATOR ACTUATION SYSTEM WILL BE EMPLOYED.
SYST 7	MASON	ROCKET	/ /	SYSTEM SPEC PARAGRAPH 3.2.1.1 NET AVAILABLE POWER GOAL OF 1.8 kWe SHOULD BE STATED AS "NET ORBITAL AVERAGE AVAILABLE POWER"	REVISE SPEC AT NEXT UPDATE
SYST 8	MASON	NASA	/ /	WITHDRAWN	NONE
SYST 9	MASON	ROCKET	06/15/93		HAS THE PROBABILITY OF N-HEPTANE LEAKING TO THE GAS IN THE GAS COOLERS BEEN ADDRESSED

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ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
SYST 10	JEFFERIES	GFSD	06/30/93	IN SHOWING SYSTEM OPERATION, TED MOCK DESCRIBED SHUTDOWN IN WHICH SYSTEM CONTINUED TO OPERATE AT FULL RPM FOR OVER ONE HOUR AFTER ECLIPSE WITH NO INSOLATION. IS IT POSSIBLE TO SURVIVE A FULL ORBIT WITH CONCENTRATOR COMPLETELY MISPOINTED?	INVESTIGATE MODE OF OPERATION (I.E. DECREASED POWER/SPEED) TO ENABLE SURVIVING MISPOINTING FOR A FULL ORBIT.
SYST 11	JENSEN	NASA	06/30/93	THE RECEIVER COULD GET QUITE COLD WHILE SITTING OFF TO THE SIDE DURING THE FLUX DISTRIBUTION TEST FOR THE CONCENTRATOR	PERFORM A THERMAL ANAYSIS TO DETERMINE THE COLD TEMPERATURE AND VERIFY THAT IT IS WITH THE CAPABILITY OF THE RECEIVER.
SYST 12	JENSEN	NASA	09/30/93	MOVING THE RECIEVER INSIDE THE TANK REQUIRES A CRANE. DURING THE FLUX DISTRIBUTION TEST THE RECEIVER MUST BE MOVED OFF TO THE SIDE	DETERMINE WHERE THE RECEIVER WILL BE PLACED DURING FLUX DISTRIBUTIONTEST AND HOW IT IS TO BE PLACED THERE.
SYST 13	CAMPBELL	ROCKET	07/21/93	T.E. DEPARTURES AND UNCERTAINTIES FOR TANK, BAP, AND RECEIVER ARE UNKOWN AT THIS TIME. METHODOLOGY FOR ACCOUNTING FOR ALL ERROR CONTRIBUTORS IS UNCERTAIN.	DEFINE PLAN FOR ACCOUNTING FOR ALL ERRORS AFFECTING SPOT LOCATION ON APERTURE. PLAN SHOULD INCLUDE BUDGETS AND DEFINE HOW SPECS ARE TO BE INTERPRETTED

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ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
SYST 14	CAMPBELL	ROCKET	06/30/93	GIVEN WARYING INDICES OF REFRACTION ON EITHER SIDE OF THE TANK WINDOW, IF THE WINDOW IS NOT NORMAL TO THE CHIEF RAY, THEN RTHE APPARANT SOURCE LOCATION WILL NOT MATCH THE PHYSICAL LOCATION AS MEASURED WITH THEODELITES	DETERMINE MAGNITUDE OF SUCH AN EFFECT AND IF SIGNIFICANT PROPOSE REQUIREMENTS AND METHODOLOGY FOR MEASURING EFFECT
SYST 15	AMUNDSEN	ROCKET	/ /	PAPER TRAIL AND RESPONSIBILITIES FOR REQUIRED THERMAL DISTORTION ANALYSIS HAS NOT BEEN ESTABLISHED OR AT LEAST IS NOT VISIBLE TO THIS WRITER.	PROVIDE A DOCUMENT REFERENCING ALL ANALYSIS DEFINING AMBIENT TO HOT DELTAS IN ALL COMPONENTS IN THE TANK INSTALLATION LOAD PATH. (DUPLICATE OF SYST A/I 13)
SYST 16	BEACH	ROCKET	/ /	OVERALL ALIGNMENT SCHEME FOR SDGTD SYSTEM IN TANK 6 IS NOT MATURE	DEVELOP ALIGNMENT PROCEDURE FOR SYSTEM. PROCEDURE WILL INCLUDE BIASES FOR PREDICTED DISTORTIONS RSULTING FROM T.E. DISTORTION, TANK MOVEMENTS AND ETC. (DUPLICATE OF SYST A/I 13)
** ACTION ITEMS FROM REVIEW ON - TAC					
TAC 1	ALEXANDER	GFSD	07/01/93	STRESS AND TEMPERATURE ON TURBINE BACKSHROUD APPEAR HIGH	CALCULATE THE CREEP ON THE BACKSHROUD IN 1000 HOURS OF SDGTD TESTING.

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ACT. ITEM NO.	SUBMITTED BY	ASSIGN TO	DUEDATE	CONCERN	REQUESTED ACTION
TAC 2	PERRONE	GFSD	06/15/93	THE EPOXY POTTING MATERIAL FOR THE BEARING T/Cs MAY EXCEED 500F	VERIFY MAX TEMP CAPABILTIY OF EPOXY POTTING MATERIAL
TAC 3	MASON	ROCKET	06/30/93	ADDITIONAL WIRING AND FEEDTHROUGHS FOR THE ACCELEROMETER/VIBRATION MEASUREMENT DEVICE	EVALUATE NEED/FEASIBILITY FOR VIBRATION MEASUREMENT OF TAC. ADD TO WIRE AND INSTRUMENTATION LIST IF NEED WARRANTED.

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13. ABSTRACT (*Maximum 200 words*)

Critical Design Reviews (CDRs) were held on the Solar Dynamic Ground Test Demonstrator (SDGTD). This CDR summary report will provide the following information for each of the system components and the system integration:
1. A bibliography of design/design review documentation,
2. A summary of the major discussion issues from issues from each design review,
3. A definition of the component and system detail designs along with the bottom line from the supporting analysis,
4. Status and key results from pertinent development activities on-going in the CDR time period,
5. A brief description of planned testing, and
6. A discussion of issues still open at the completion of CDR.

Appendix 1 to this report contains a listing and status (as of 28 June 1993) of all the action items generated during all SDGTD CDRs. The reader should remember that the SDGTD program is being conducted in an open communication forum, and program participants are encouraged to ask questions or request information. Team members are allowed and encouraged to participate in the reviews on an equal basis. No request for information, as long as it is within the work scope, is refused, so many action items are generated.

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