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ALTERNATE HSA
DESIGN
REQUIREMENTS

31-2366

March 8, 1977

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TABLE OF CONTENTS

	Page
1.0 INTRODUCTION	1
2.0 TECHNICAL APPROACH	3
3.0 PROGRAM PLAN	5
3.1 Task 1 - Design Requirements	5
3.2 Configuration Study	8

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1.0 INTRODUCTION

This report, submitted by the AiResearch Manufacturing Company of Arizona, a Division of The Garrett Corporation, summarizes the requirements definition and a small amount of conceptual layout work which was performed for ERDA. This work was done to provide assistance to the NASA in conjunction with a program to develop advanced HSA designs for use in the Brayton Isotope Power Systems (BIPS). The information generated by this task has helped to maintain consistency and continuity between the ERDA systems development program and the NASA technology and component development program.

2.0 TECHNICAL APPROACH

The primary goal of the NASA study will be to generate alternate approaches which manifest integration of the HSA Auxiliary Cooling System (ACS), Emergency Cooling System (ECS), Shuttle Heat Dump Subsystem, and Thermal Insulation System to improve the HSA performance. The intent of the study will be to generate candidate designs which minimize thermal loss penalties by a combination of smaller total insulated area and a reduction of the number and/or lengths of joints. Methods to improve the HSA thermal performance will be explored, and techniques to integrate the various HSA cooling systems to minimize the weight penalty of the total system were also to be investigated. The following paragraphs define the basic objectives and technical guidelines.

Multifoil insulation, with up to 110 foils, is the primary insulating material. In the case of the superalloy design, fibrous insulations can be considered for support regions (e.g., preload screw) to minimize structural losses. The point of departure for the insulation and structural design is the current HSA design.

Efforts to minimize the Multi-Hundred Watt (MHW) view-factor of the insulation during the normal operating mode will be candidates for investigation, due to the heat loss penalty. Further investigation of methods to thermally isolate the MHW from the HSA outer can will be conducted. This task will be facilitated by more complete information on shock, vibration, and acceleration loads than existed at the time of the original HSA design.

The outside support structure will conform to the current GDS and Flight System (FS) structural design as closely as possible. Constraints on the structural design which should be observed during the study are:

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- (a) The alternate HSA designs will interface at the four mount points currently defined in AiResearch Drawings L3621585, "Lower Support Structure," and L3621586, "Support Structure."
- (b) The inlet and outlet duct centerline location and stub duct length will remain as currently defined in AiResearch Drawing 241000, "System Assembly, BIPS-GDS."

3.0 PROGRAM PLAN

The recommended preliminary design study of the AHSA will consist of six tasks as shown in Figure 1. This report covers only the work funded by ERDA which was definition of Design Requirements and a preliminary review of characteristics of configurations which appear to have desirable attributes. This information was provided to NASA to aid in preparation of a program plan for a study program to be funded by NASA later this year.

3.1 Design Requirements

The primary design materials for the AHSA should include a superalloy and the Columbium alloy C-103. Both materials will be evaluated in the same configurations.

The following considerations will be made:

(a) Pressure Drop Trade-Off

The baseline design is the 2 HSA configuration.

The design $\Delta P/P = 0.003$

The pressure drop tradeoff is

$$-1650 \times \Delta(\Delta P/P) = \Delta \text{Weight (lb) for this condition.}$$

The HSA pressure drop is not specified.

(b) Candidate Materials

Candidate materials for the AHSA study are:

- (1) Superalloy having a seven-year life at approximately 100 psia and 1450°F maximum metal temperature
- (2) C-103 having a seven-year life at 70 psia and 1600°F exit gas temperature

PRELIMINARY DESIGN SCHEDULE - ALTERNATE HSA

FIGURE 1

(c) Heat Exchanger Design Margin

This will consist of designing for 50°F greater than maximum hot spot temperature for the seven-year life

(d) Film Temperature Drop

Efforts will be conducted to minimize film temperature drop for maximum cycle efficiency. Tradeoff for turbine inlet temperature is:

<u>Turbine Inlet Temperature (T6)</u>	<u>Lb/Degree</u>
1300°F	-1.0
1400°F	-0.5
1600°F	-0.1

That is, if 1 lb can be saved in a 1300° two (2) HSA system, T6 can drop to 1299°F.

(e) Size And Weight (must address 1, 2, and 3 HSA cases)

The physical requirements include the overall HSA weight and envelope restrictions. The nature of the AHSA interface with the system will be ascertained.

(f) ACS (Auxiliary Cooling System)

Requirements will be established for the AHSA should system idle after isotope loading be necessary.

(g) ECS (Emergency Cooling System)

Characteristics will be established to preclude destruction of the AHSA should a working fluid flow malfunction arise.

(h) Shuttle Heat Dump Interfacing

(i) Insulation

Insulation concepts (with AIRPHX/TECO support) with trade-off of weight and performance (minimum heat loss) will be reviewed and selected for the AHSA candidates. Insulation properties as shown by TECO at the PDR will be used.

$$\phi = \frac{1.06 \times 10^{-12} (T_{\text{hot}}^4 - T_{\text{sink}}^4)}{0.778N + (1.11 \times 10^{-2})N^2}$$

where

ϕ = Heat flux perpendicular to foils watt/cm²
 T_{hot} = Hot face temperature, °K
 T_{sink} = Sink temperature facing last foil, °K
 N = Number of foils

(j) Dynamic Environment

Effects of shock, vibration and acceleration loads during launch and separation will be investigated to ensure sufficient margins commensurate with the seven-year lifetime. Section 4.9 of the PDR document presents the detail.

(k) Cost/Development Risk

- (l) Fabricability, Inspectability and Reliability
- (m) Cycle Conditions

The candidate design is a 2HSA system with a weight goal of 81 lb. The cycle performance data is presented in the CCD, No. 75-311274C, (Figure I-1) and in the PDR Document (Figure 2.1-2).

For the superalloy system, the HSHX will be designed to accept a flow rate range of 0.23 to 0.27 lb/sec with a pressure level of 62 to 72 psia and a temperature rise of 278°F to 303°F. The data are presented in this manner because the turbine inlet temperature is unknown.

- (n) Accessibility

The HSA configuration need not permit access to the heat source via the aft or working fluid exit end of the assembly.

3.2 Configuration Study

The Heat Source Heat Exchanger (HSHX) configurations, which were investigated in this study, are the single helically coiled tube configuration (similar to that of Fairchild Space and Electronics Company Report FSEC-ESC-217-76/76) and the multiple parallel tubular configuration. In this last approach, a relatively large number of small tubes channel working fluid around the periphery of the heat source.

Two multiple tubular exchanger arrangements have been examined in a cursory manner. The bank of tubes may, after leaving the toroidal header, be bent to a helical contour such that the tubes adjacent to the heat source are in contact, minimizing radiation through the tube bank. Alternatively, the tubes may be routed parallel to the HSHX longitudinal axis, spaced sufficiently to allow joining to the headers; in this case, a cylindrical enclosure would be brazed to the tube bank outer diameter to intercept radiation. The latter approach may provide superior heat transfer performance, when the cavity effect of the inter-tube spacing on radiation heat transfer is properly evaluated. A literature search has been conducted to determine recent progress in cavity radiation analysis.

Both configurations investigated are based primarily on the use of tubular elements, employ welded joints as the means of joining working fluid passages, and will require relatively common manufacturing techniques. Thus, either configuration is considered to offer lower cost/development risk than the present HSHX concept.

Based on preliminary analyses, the advantage in HSHX size and weight lies with the multiple tubular unit. Typical envelope and weight values are tabulated below for arrangements satisfying the cycle pressure loss goal:

	Size, in.	Weight, lb
Multi-tube (approx. 75 helically wrapped 0.25 in. O.D. tubes)	10.0 dia X 18	10
Single helical tube (1.89 in. O.D.)	12.0 dia X 17	22

In establishing more detailed layouts of the chosen HSHX configurations, the functional, life, and design margin requirements would be satisfied such that HSA weight and thermal loss is minimized. Multi-foil insulation has been employed, with loss data based on

TECO's correlation. While support of the forward end of the heat source is similar to the existing approach, it is planned to integrate the working fluid exit header with the aft heat source support. This should reduce losses and simplify both HSHX and heat source installation. Re-examination of the multi-foil support structure is also contemplated.

Adequate approaches to the auxiliary cooling (ACS), emergency cooling (ECS), and shuttle heat dump modes appear to be available.

The ACS cooling requirement is intended to be satisfied by pressurizing the HSA with helium gas, shorting the multi-foil insulation such that the heat flux may be removed by cooling of the HSA outer wall. The same approach is also applicable to the shuttle heat dump mode; here, cooling passages may be provided on the HSA outer wall to allow heat rejection to a shuttle heat transport loop.

Current investigations of multi-foil meltdown indicate that this approach would provide a reliable means of satisfying the ECS cooling function.

In all of the above areas, very detailed modeling of the entire HSA will be needed to finalize multi-foil layer number selection. Such effort is a part of prototype HSA development and will not be attempted in the present study. The preliminary layout of the multiple tube HSHX design is shown in Figure 2. The single helical tube as it might be used in the GDS, without evaluation of launch loads, is shown in Figure 3.

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MULTIPLE TUBE HSHX

FIGURE 2

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SINGLE HELICAL TUBE

FIGURE 3