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PRELIMINARY EVALUATION OF THE MINI-BRU TURBINE PLENUM IN SUPERALLOY AND THE CURRENTLY AVAILABLE HEAT EXCHANGER FOR THE BIPS WORKHORSE SYSTEM				PROCESSING				
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REFERENCES AND SPECIAL INFORMATION

Attachments: Figures 1 through 4,
Tables 1 and 2

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MASTER

The Mini-BRU turbine plenum and nozzle assembly in superalloy and the currently available L.A. heat exchanger have been examined for the BIPS workhorse system. Waspaloy can be used as the material of construction for the plenum and nozzle assembly. The L.A. heat exchanger can be utilized in the workhorse system with recommended modification.

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PRELIMINARY EVALUATION OF THE MINI-BRU
TURBINE PLENUM IN SUPERALLOY AND THE
CURRENTLY AVAILABLE HEAT EXCHANGER FOR
THE BIPS WORKHORSE SYSTEM

76-311903

May 11, 1976

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INTRODUCTION

The Mini-BRU turbine plenum fabricated in superalloy, and the currently available L.A. heat exchanger (P/N X979185), have been examined under the following two operating conditions for the BIPS workhorse system.

<u>Pressure</u> (psia)	<u>Max. Plenum Metal Temp. (°F)</u>	<u>Hours</u>
100	1600	5
50	1400	50

Waspaloy is chosen as the first candidate material for the Mini-BRU turbine plenum and nozzle assembly. The original plenum configuration of CB-103 was modified to cope with the high thermal expansion coefficients and high Young's Modulus of Waspaloy. No detailed creep relaxation analysis was carried out in this report due to the relatively short operating hours.

CONCLUSION

- (1) Based on the estimated metal temperature and material data, the modified turbine plenum in Waspaloy is satisfactory from a stress standpoint for either of the two operating conditions.

- (2) With recommended modification, the currently available heat exchanger can be operated in the workhorse system at either of the two operating conditions.

RECOMMENDATIONS

- (1) The turbine plenum and nozzle assembly should be fabricated according to the modified configuration as shown in Figure 1.
- (2) The plenum skin and nozzle assembly should be fabricated in Waspaloy (A). Creep properties for Waspaloy sheet and forgings are shown in Figures 2 and 3 for heat treat (A) condition.
- (3) The plenum should be fabricated from 0.06 inch sheet.
- (4) The turbine shroud should have uniform thickness instead of being stiffened as in the CB-103 configuration.
- (5) That the turbine nozzle be welded to the shroud in a manner similar to the CB-103 configuration.
- (6) That the L.A. heat exchanger be utilized without electrodes in the top three and bottom three tubes as shown in Figure 4.
- (7) Two 0.063 inch HS-188 plates should be E-beam welded to the top and bottom corrugated sheets of the heat exchanger as shown in Figure 4.

DISCUSSION

- (1) Turbine Plenum in Superalloy for the Workhorse System

When superalloy such as Waspaloy is used as the material of construction for the turbine plenum, thermal stress plays an important

role. In order to provide enough flexibility to minimize the thermal stress, the plenum is modified as shown in Figure 1. The turbine plenum and nozzle assembly were analyzed for two different plenum skin thicknesses. Reducing the skin thickness will generally increase the pressure stress and decrease the thermal stress. The net effect is dependent upon the metal temperature and actual thickness used for the plenum. Table I summarizes the stress level in the vane. Table II summarizes the general stress levels in the turbine plenum and its supporting structure. The stress level associated with the 1400°F max. skin temperature and 50 psia are generally lower than the stress levels associated with the 1600°F max. skin temperature and 100 psia pressure. However, the two different skin thicknesses do not significantly change the nozzle stress level, but has a significant effect upon the plenum hoop stress. For the 1600°F operating condition, since the design life is only 5 hours, the elastic stress distribution is all that is needed to be considered. For the 1400°F operating condition, the design life is 50 hours. Creep strength is the criterion. The creep strength of Waspaloy is shown in Figures 2 and 3. In either operating condition, there are no calculated stresses that exceed the material yield strength at temperature or the 0.5 percent creep strength for 50 hours. (The 0.5 percent creep strength is used since 1 percent creep data is not available for sheet.)

(2) The Existing L.A. HSHX for the Workhorse System

This piece of hardware, as shown in Figure 4, was originally designed for very low pressure. If utilized in the workhorse system, the pressure will be much higher. The tube temperature was estimated to be 1750°F and the supporting plate to be 1600°F. As a result of the thermal gradient, high thermal stresses exist at the juncture where the three top and bottom tubes are welded to the two side plates. The central tubes are less critical because of the side plate flexibility. Since this HSHX produce more heat than is needed for the workhorse system, it is recommended not to insert the electrodes in the

top and bottom three tubes as indicated in Figure 4. The top and bottom plates (0.063 inch flat plate and 0.036 inch corrugated sheet) are subjected to much higher pressure in the workhorse system than it was original designed for. The maximum bending stress at the ends is 39,600 psi under 50 psia, exceeding the yield strength of Hastelloy X at 1400°F. This bending strength can be reduced to a level of 11,360 psi if reinforced with a 0.063 inch HS-188 plate E-beam welded to the corrugated sheets as shown in Figure 4. The added stiffness is also adequate for the 1600°F and 100 psia operating condition for five hours life.

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MODIFIED TURBINE PLENUM CONFIGURATION IN WASPALLOY

FIGURE 1

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FIGURE 2

T.H. 11-4-72 (5)

FIGURE 4

TABLE 1

STRESS LEVELS IN THE VANE ATTACHMENT (REFERENCE FIGURE 1)

Point	R(inch)	1600°F 100 psia				1400°F 50 psia			
		0.04 Inch Plenum		0.06 Inch Plenum		0.04 Inch Plenum		0.06 Inch Plenum	
		Bending Stress (psi)	Shear (psi)	Bending Stress (psi)	Shear (psi)	Bending Stress (psi)	Shear (psi)	Bending Stress (psi)	Shear (psi)
(L.E.) 487	1.876	-2,100	8,700	-3,500	8,100	-5,200	8,700	-6,500	8,100
486	1.804	900	-3,200	1,100	-3,400	800	-1,200	900	-1,400
485	1.75	100	-3,000	0	-2,300	600	-400	400	-800
484	1.70	4,400	14,500	4,400	14,100	3,900	13,500	3,900	13,100
483	1.65	3,800	11,800	4,000	11,500	3,200	10,900	3,500	10,400
482	1.60	4,500	15,700	5,000	15,400	4,300	14,100	4,900	13,700
481	1.55	3,500	14,800	4,600	14,700	4,600	13,500	6,000	13,300
480	1.50	1,300	11,300	3,300	11,600	3,500	14,400	6,100	10,600
(T.E.) 479	1.483	1,100	10,200	4,300	10,800	3,000	8,800	6,900	9,400

NOTE: (1) Stress levels reflect pressure and temperature

(2) Yielding strength of Waspaloy at 1600°F = 75 ksi (typ.)

(3) 0.5 percent creep strength of Waspaloy sheet at 1400°F and 50 hour = 51 ksi (typ.) Ref. Figure 2

(4) 0.5 percent creep strength of Waspaloy forging at 1400°F and 50 hours = 47 ksi (typ.) Ref. Figure 3

(5) Stresses shown are for a 40°F margin on temperature

TABLE 2
STRESS LEVELS IN PLENUM

	1600°F Max. Skin Temp.; 100 psia					1400°F Max. Skin Temp.; 50 psia				
		0.06 Inch Plenum		0.04 Inch Plenum			0.04 Inch Plenum		0.06 Inch Plenum	
Point	Temp. (°F)	Bending Stress (psi)	Hoop Stress (psi)	Bending Stress (psi)	Hoop Stress (psi)	Temp. (°F)	Bending Stress (psi)	Hoop Stress (psi)	Bending Stress (psi)	Hoop Stress (psi)
A	1,600	-8,200	-8,700	-3,700	-5,700	1,400	-4,200	-7,100	-8,100	-9,200
B	1,600	200	5,000	1,400	7,000	1,400	600	3,500	0	2,800
C	1,600	3,300	3,700	3,100	4,700	1,400	1,900	2,700	2,700	2,600
D	1,550	-5,900	-13,500	-5,300	-12,300	1,350	-5,200	-14,500	-5,700	-15,500
E	1,440	4,300	-900	1,200	-3,500	1,240	1,900	-1,800	3,200	-500
F	1,400	1,200	-1,800	2,600	-1,500	1,200	-300	-1,400	-1,300	-1,500
G	512	-65,000	-44,800	-65,000	-44,800	512	-59,200	-40,500	-59,200	-38,800
H	1,422	-51,200	-3,600	-52,900	-3,500	1,272	-20,700	4,700	-19,300	4,600
I	1,470	26,900	19,300	25,300	18,400	1,270	19,700	16,900	21,500	17,900

- NOTE: (1) See Figure 1 for point locations
(2) Stress levels reflect pressure and temperature
(3) The 0.2 percent yield strength of Waspaloy at 1600°F is 75,000 psi
(4) The 0.5 percent creep strength of Waspaloy at 1400°F and 50 hrs. is 51,000 psi
(5) Stresses shown are for a 40°F margin on temperature