THERMAL PREFORMANCE OF A′ CRYOUNIT

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ABSTRACT

CEBAF, an electron accelerator under construction in Virginia, has 338 superconducting RF cavities contained in 42 1/4 cryomodules. Four cryounits which house eight RF cavities and a set of end caps make up a cryomodule. The thermal performance of a prototypical cryounit and end cap set is presented.

INTRODUCTION

The upgraded cryounit was retested on A′ to verify the improvement to the static heat leak as well as the assembly time as seen on an earlier assembly and test. Changes to the mechanical design were; an increase in the vacuum tank diameter to provide more clearance for the multi-layer insulation (MLI); larger diameter thermal shield to provide increased clearance for the helium containment vessel; a second warm magnetic shield; improved supports; welded bridging components to facilitate assembly; new Reemay Dacron spacer material; and improved installation procedures on MLI insulation. There were minimal changes in the assembly technique to a previous cryounit. There was, however, a concentrated effort to enhance the thermal performance of the end caps (cryogenic inlet and outlet) and the transfer lines by improving the MLI insulation installation and assembly clearances.

DISCUSSION

Cooldown commenced on the afternoon of April 22 with bo the shield and the primary system refrigerators in operation. After approximately ten (10) hours the shield was at 160 K. This works out to a 15 K per hour cooling rate. The rate could be accelerated in the future. The primary system cooldown lagged the shield circuit somewhat and could be accelerated considerably. The rate of cooldown was nearly 15 K per hour but still needs to be improved by a factor of two. The cooldown rate for the primary and secondary system are shown on figures 1 and 2.

Static heat loads were measured throughout the testing period and as expected decreased with time which is indicative of the thermal time constant of the MLI system. On an earlier test, a definitive heat load was not possible because of the inadequacy of the temperature instrumentation. Basically, the diodes were attached to the outside of the inner process piping and surrounded by the multi-layer insulation. On A′ this problem was corrected by immersing the sensor in the fluid and as expected this yielded much better results.

Although the bulk shield temperature design is 45 K, the shield was run at 35 K. Based upon this somewhat lower bulk temperature the shield load was typically 93 W. This subsequently improved later in the test to typically 86 W. Data from an earlier test indicated about 70+ W. This was not surprising since the heat stations on the end cans were moved somewhat too close to intercept the subatmospheric transfer line bayonet. The experimental data indicates a 16

W heat load for the cryounit 45 K shield. The design criteria for the cryounit shield is 16 W. However, the remaining 70 W measured in the end caps is higher than the end caps shield criteria of 36 W. Because of the reduced bulk temperature, the measured heat load should be reduced by 5%. The increased shield load on the "L" shaped end cans is correctible and it is anticipated that this will be improved with the new end cans incorporating design changes such as smaller bayonets. The bridging component diameter fit tightly on the vacuum tank flange. This slight interference made insulation installation more difficult than with an earlier assembly and contributed to the higher shield load. The error bar on these measurements are typically ±20% on mass flow and at least ±10% on enthalpy.

The primary system saw a marked improvement in temperature instrumentation over earlier tests. The measurements assume that the flow from the transfer line contains pure liquid with no flashing losses. Based upon this assumption the heat load includes the losses attributable to the supply transfer line, the supply and return end cans, the cryounit, and the return transfer line. Data taken during the run at 4 K indicate a primary heat load of 16 W ±.5 for the above assumptions. For the case where the JT valve is closed this load decreases to 6 W. This is the design heat load for the cryounit (1.9 W) plus end cans (4 W) corrected for this condition. Heat loads at 2 K were more difficult to measure due to the subatmospheric flow measurements but were not noticeably higher than at 4 K. Where possible the JT valve was secured and this enabled one to use the decrease in liquid level to cross check these heat load values. Corrections were made for changes in liquid level drop off but this does not materially affect the conclusion that the cryounit end cap combination meets the design heat load. Table 1-3 summarizes representative heat load data.

Calibration of dynamic heat load was made on a number of occasions by turning on the internal cryounit heater to a known wattage and measuring the change in mass flow or drop off in liquid level. The right (LE5-4) cavity was tested at relatively low power levels dissipating between 4-5 W. This equates to a Q nearly identical to that obtained in the vertical dewar tests. The left cavity (TBW-6) exhibited multipacting above a gradient of 3 MV/m. By staying just below this threshold the cavity dissipated approximately 15 W. This Q was also nearly identical to Q's measured in the vertical dewar tests. The left cavity was retested and RF power dissipation for this series of tests yielded slightly lower values (7 W) than the previous test but in agreement with the lower RF power levels.

CONCLUSION

Measured heat loads for the A′ cryounit and end cans are at design values for the primary system, 6 W; but high for the secondary cryounit end can combination, 80+ W. The source of the high heat load in the end cans is understood and expected. These high heat loads were addressed and corrected during an end cap redesign which was part of reconfiguring the CEBAF cryogenic distribution system from generally series to parallel flow. Transfer lines and instrumentation were much improved and permitted reliable temperature measurements. Cooldown rates were not excessive and dynamic Q measurements were completed and agreed with earlier vertical dewar tests. Test was successful in that a considerable amount of objectives were obtained.

<u>Table 1</u>

CRYOMODULE HEAT LEAK BUDGET

WATTS AT GIVEN TEMPERATURE

STATIC	2K	45K
RADIATIVE	0.98	18.6
INPUT WAVEGUIDE	5.04	32.8
SUPPORTS	0.41	11.3
TUNER	0.2	.8
INSTRUMENTATION	0.9	1.8
JT VALVE	0.25	2.5
RELIEF LINES	0.25	3.0
BORE TUBE	0.48	6.9
50 K U TUBE	-	3.4
2.2 K U TUBE	1.31	3.2
2.0 K U TUBE	2.25	5.1
UNALLOCATED	0.83	12.3
	12.90 W	101.6 W

DYNAMIC	2K	45K
RF RESIDUAL	34.72	-
BCS	9.12	-
INPUT WAVEGUIDE	2.16	21.60
HOM LOSSES	2.00	-
	48.00 W	21.60 W

STATIC		
CRYOUNIT W/TL & END CANS	7.25 W	52.6 W

Table 2

RESULTS OF THERMAL

PERFORMANCE TEST

(CORRECTED FOR BULK TEMPERATURE) SECONDARY HEAT LOAD

STATIC	MEASURED	DESIGN
CRYOUNIT	15.2/16 W	16 W
END CANS	66.5/70 W	36 W
TOTAL	81.7/86 W	52 W

Table 3

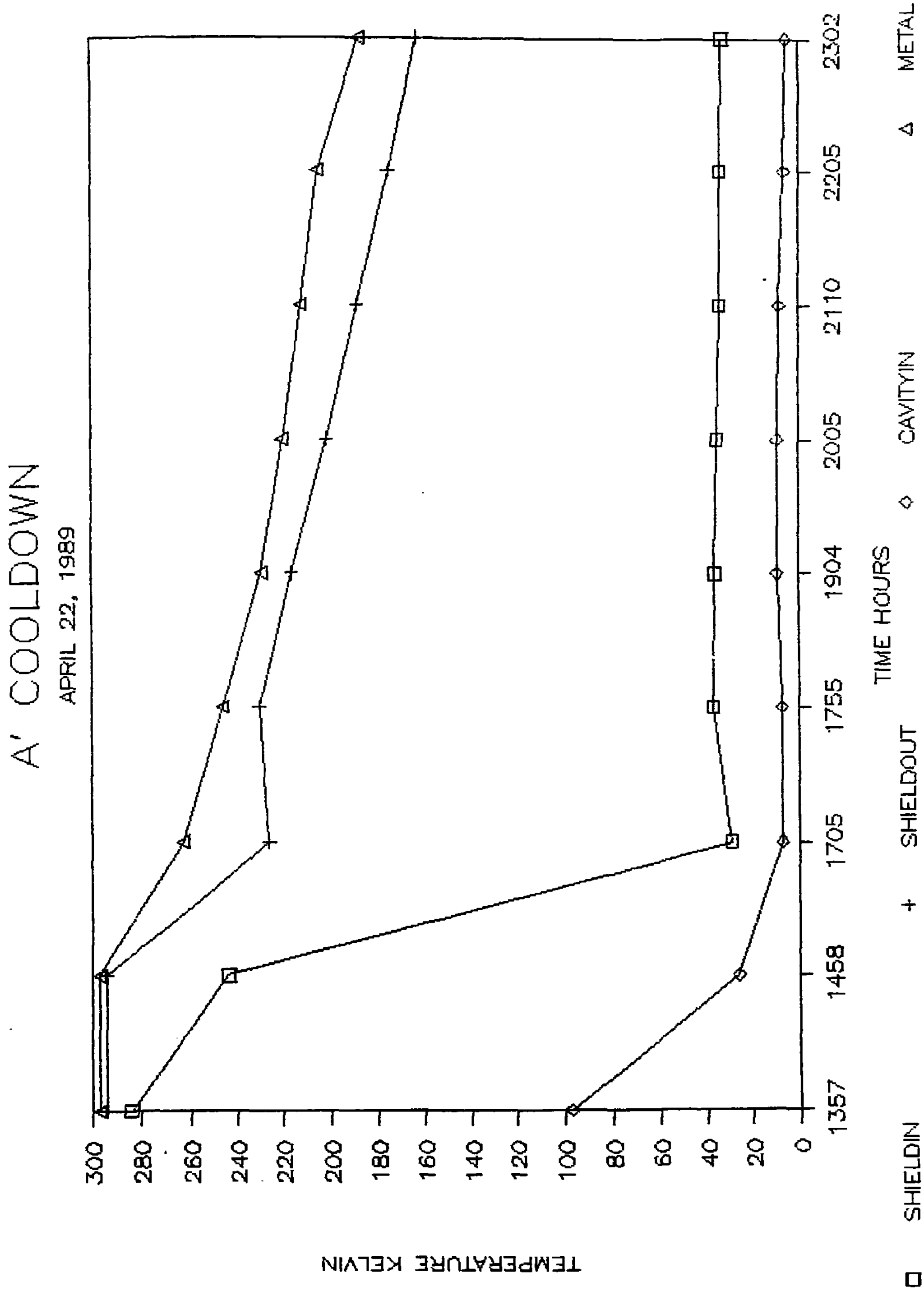
RESULTS OF THERMAL

PERFORMANCE TEST

(CORRECTED FOR JT + TRANSFER LINE) PRIMARY HEAT LOAD

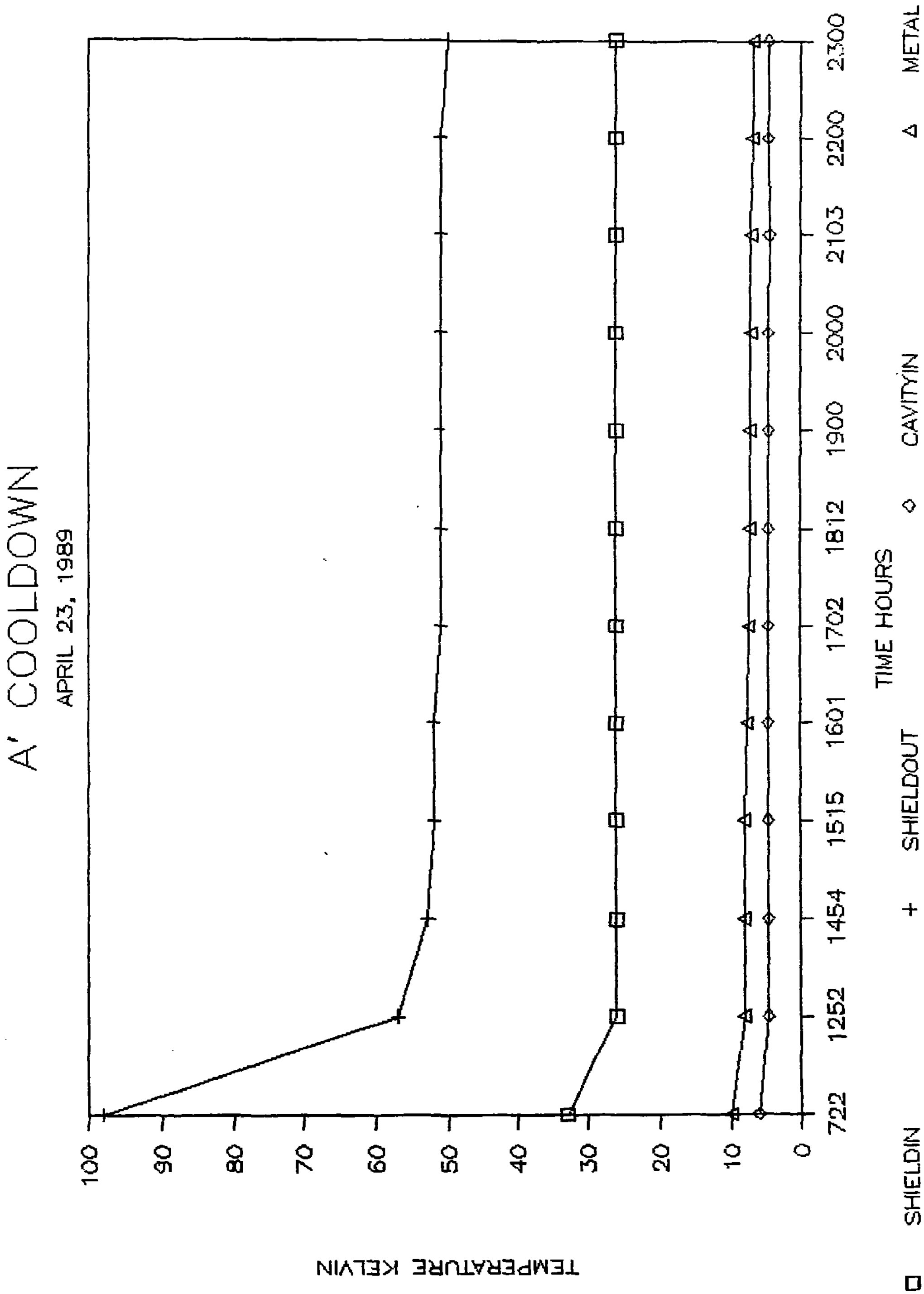
STATIC	MEASURED	DESIGN
CRYOUNIT	1.9 W	2.1 W
END CANS	4.0 (1.25) W	5.4 W
TOTAL	7.2 W	7.5 W

FIGURE 1

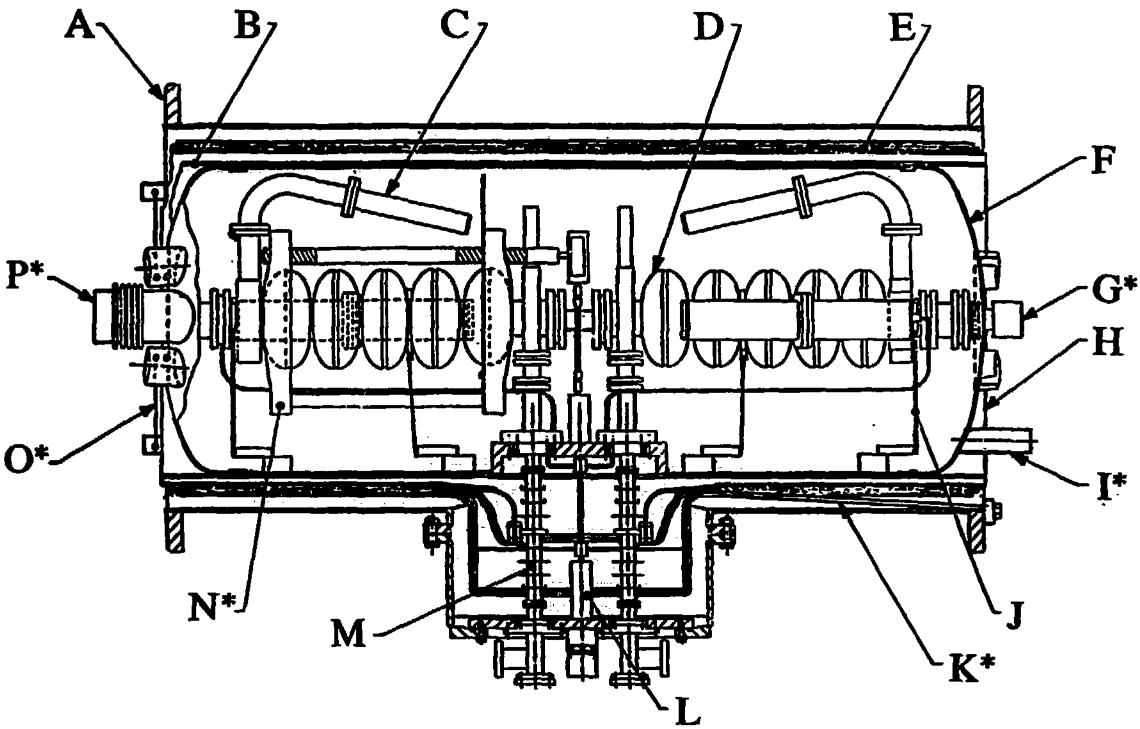


A' COOLDOWN
APRIL 22, 1989
TEMPERATURE KELVIN
TIME HOURS
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
1357
1458
1705
1755
1904
2005
2110
2205
2302
SHIELDIN
SHIELDOUT
CAVITYIN
METAL

FIGURE 2


A' COOLDOWN
APRIL 23, 1989
TEMPERATURE KELVIN
100
90
80
70
60
50
40
30
20
10
0
722
1252
1454
1515
1601
1702
1812
1900
2000
2103
2200
2300
TIME HOURS
SHIELDIN
SHIELDOUT
CAVITYIN
METAL

TOP VIEW OF CRYOUNIT CEBAF



A. Vacuum Shell Flange
B. Magnetic Shield and Inner Superinsulation
C. HOM Load
D. Cavity
E. Shield Superinsulation
F. Helium Vessel
G. Flange Surface on Isolation Valve
H. 40 to 50 K Radiation Shield
I. Shield Helium Supply Line
J. Outboard Cavity Support
K. Axial Support
L. Rotary Feedthrough
M. Fundamental Power Waveguide
N. Tuning Mechanism
O. Helium Vessel Support Rod
P. 2 K Helium Return

*Asterisked items shown only once to simplify illustration.