SHIPPING AND ALIGNMENT FOR THE SNS CRYOMODULE*

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Abstract

The Spallation Neutron Source (SNS) requires 32 super conducting cryomodules to raise the beam energy of the accelerator to 1.3 GeV. Thomas Jefferson National Accelerator Facility (Jefferson Lab) has been contracted to build and deliver these cryomodules. The SNS cryomodules are being assembled and tested at Jefferson Lab in Newport News , Virginia, and installed at the SNS facility in Oak Ridge, Tennessee. The cryomodules will be transported via a flatbed air ride trailer over the approximate 500-mile distance. This paper describes the alignment of the cavities and how it is preserved during the shipping and operation of the cryomodule. It includes a description of the support scheme developed to preserve the alignment during shipping and operation, and how the support scheme forms a very rigid structure with natural frequencies well above the expected 10 Hz driving frequencies during transportation. The entire cryomodule is supported by a dampened cradle, which is mounted directly onto the bed of the trailer. The transportation environment was evaluated by instrumenting a similar (CEBAF ¼) cryomodule with accelerometers during a road test of approximately 300 miles. A modal analysis of the whole system is in progress. Steps taken to minimize any transport-induced loading/deflections are discussed.

1 INTRODUCTION

The Spallation Neutron Source cryomodule must be able to withstand the shipping environment from Jefferson Lab to Oak Ridge. The initial acceleration criteria used in the design is 4g vertically, 5g axially (along beam axis) and 0.5g transversely (horizontal). This criteria is suggested in Barron's Cryogenic book [1]. All parts within the cryomodule were analyzed using this criterion as the maximum allowable static loads. Fatigue must also be taken into consideration. In order to better understand the shipping environment, a road test using an existing CEBAF ¼ cryomodule was performed. The CEBAF ¼ cryomodule cavity is aligned and supported by similar attachment rods as used in the SNS design. However, there is no spaceframe in the CEBAF design. The rods attach directly to the vacuum vessel.

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2 CRYOMODULE DESIGN

The cavity support system used on the SNS cryomodule is based on the new upgraded CEBAF cryomodule support system. There are 3 cavities in the medium β cyomodule and 4 cavities in the high β cryomodule. Each cavity is assembled into an individual helium vessel. The cavity is supported at the ends and the middle by the helium vessel. The cavity/helium vessel assembly is supported by the spaceframe via nitronic 50 rods. The rods have threaded silicon bronze end fittings and are arranged in an X-pattern. (see Figs. 1 & 2). The X-pattern is symmetric, which ensures equal loading during cooldown of the cryomodule. Nitronic 50 rods are also used to lock each helium vessel to the spaceframe in the axial direction. The attachment point on the helium vessel is as close as possible to

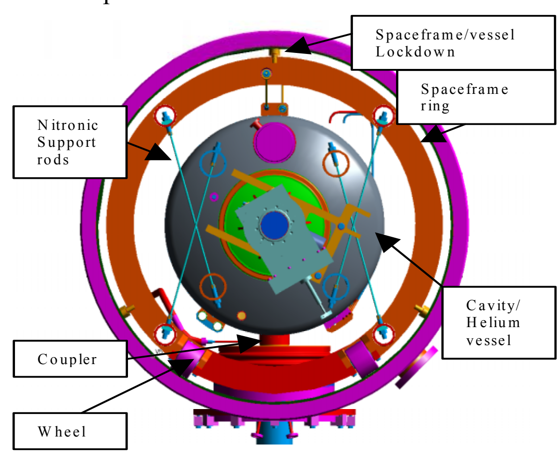

Figure 1 Medium β Cryomodule end view

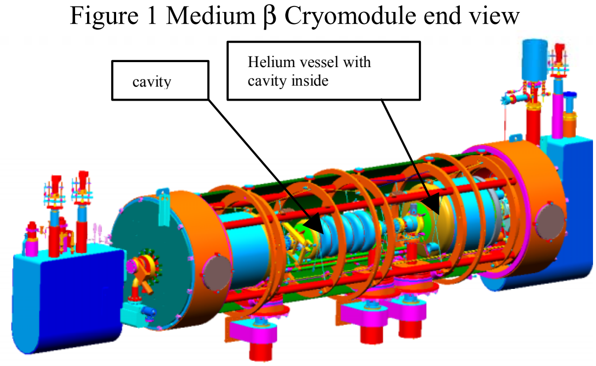

Figure 2 Medium β Cryomodule cutaway

the fundamental power couplers in order to minimize movement of the coupler during cooldown. All of the rods are pre-tensioned to approximately 600 lbs. This provides stability during shipping while stressing them below the fatigue limit. After the cavity string is aligned in the spaceframe, the asssembly is rolled into the vacuum vessel and locked down at each spaceframe ring. The spaceframe has 2 sets of wheels, which are located at the ¼ points of the cryomodule (see figure 3). The cryomodule then rests on its alignment supports, which are also located at the ¼ points. Due to the long, slender thermal path of the nitronic rods, the vacuum vessel and spaceframe maintain room temperature during operation.

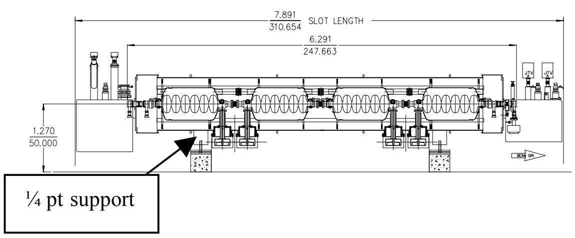

Figure 3, High β Cryomodule

3 CRYOMODULE ALIGNMENT

The alignment of the cavity string is set by indexing off of the beamline flanges at either end of each cavity. The nitronic support rods are used to move the cavity into alignment. Targets are mounted on rods, which are threaded into a precision feature on two sides of each flange (Figure 4). While the cavity string is supported by the spaceframe, each target is sighted along a line between set monuments located at both ends and both sides of the cavity string. The nitronic rods are adjusted until all the targets are within ☛0.5 mm of the line set by the monuments. After the cavity string is installed in the vacuum vessel, the alignment is verified and transferred (fiducialized) to the shell of the vacuum vessel.

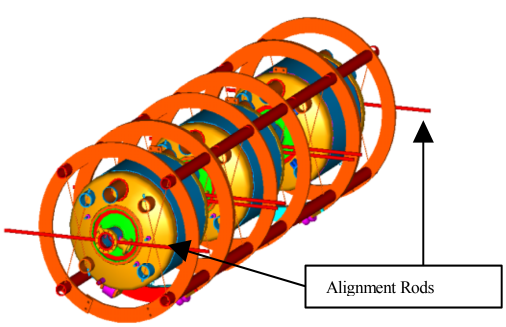

Figure 4 Cavity String Alignment

4 ANALYSIS

A simplified 3-D assembly model, which includes the cavity, helium vessel, tuner, nitronic rods and space frame, is currently being developed. This finite element model is being used to perform natural frequency and random response analyses using ABAQUS FEA (Finite Element Analysis) software. For the random response analysis, power spectral density (PSD) test data from road tests and ground vibration will be the input to the calculation. Figure 5 shows a finite element model of the medium beta cavity with the helium vessel and tuner. Preliminary results of the finite element analysis shows that the cavity natural frequencies are above the anticipated 10-to-30-Hz road vibration frequencies.

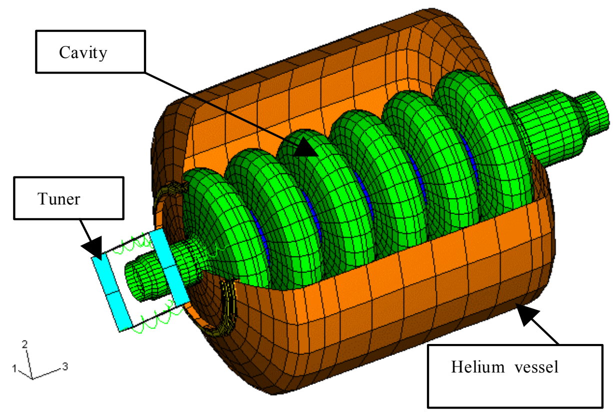

Figure 5: Medium β He vessel assembly FE model

5 THE ROAD TEST

In November 2000, a CEBAF ¼ cryomodule was mounted onto an air ride flat bed trailer. The module was cradled in a stiff frame with 1" thick hard rubber pads (see fig. 6). Since the endcans are cantilevered off the ends of the module, they were supported to the frame using hard rubber mounts. In addition, a package simulating a shipping container for the fundamental power coupler was strapped onto the back end of the flat bed. Shock and vibration data was recorded using an SV-1 saver from Dallas Instruments. Single and three axis accelerometers were placed in strategic locations on the cryomodule as well as the truck bed. Before the cryomodule was road

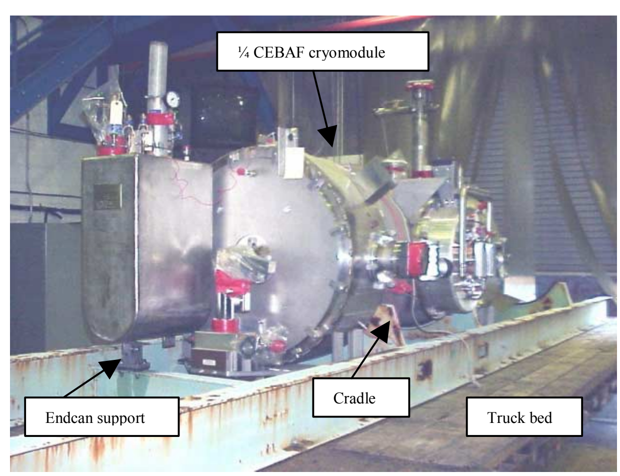

Figure 6 CEBAF ¼ Cryomodule on air ride trailer

tested, the alignment was checked and recorded. A rough check of RF characteristics (passband frequency) was conducted and the results recorded. The original measurements of the cavity RF performance (gradient, Q_0 etc.) were used as a baseline since the test cave was unavailable for more thorough testing at the time of the road test. Vacuum integrity of all the components was also verified.

6 RESULTS

The road test was completed without any major problems. The alignment, vacuum integrity and passband frequencies were all rechecked upon the return of the module from the road test. There were no measurable vacuum leaks and the passband frequencies indicated no gross change in cavity shape. The alignment check after the road test indicated a 0.3mm downward shift of one of the flanges. All other measurements were within instrument tolerances [2]. The vibration data was analyzed and the results documented [3]. The PSD curve for the cryomodule beamline is shown in figure 7. It can be seen that there are peaks in the energy distribution between 2 and 3 Hz and between 9 and 11 Hz. The peak around 10 Hz can be seen in all three axes with a maximum amplitude of 0.007 g^2/Hz axially. In the transverse direction this peak is shifted somewhat toward 14 or 15 Hz. The transverse and vertical directions show a peak in the 2-3 Hz range. The axial does not show this peak. Shock data was recorded and the maximum accelerations of the beamline were 0.9, 1.3 and 1.4 g in the vertical, axial, and transverse direction respectively. As expected, these values correspond closely to the accelerations seen at the truck bed and on the cryomodule mounting cradle. The SNS cryomodules may experience slightly different accelerations due to the difference in weight and size of the medium and high β cryomodules.

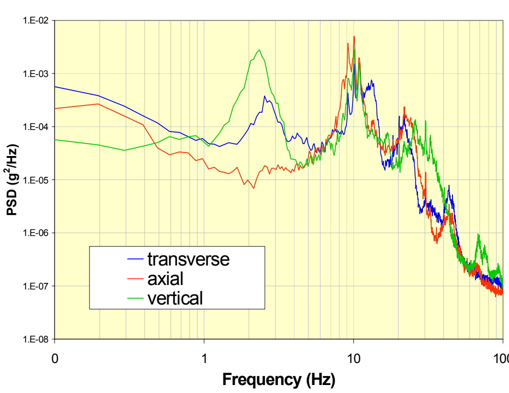

Figure 7 Road Test Vibration PSD of the Beamline

7 SUMMARY

Neither the initial road test of the CEBAF ¼ crymodule or the preliminary analysis indicate that there will be any major problems shipping the SNS cryomodules. The data recorded during road testing indicates that our design criteria may be on the conservative side. The only exception is the recorded maximum transverse acceleration of 1.4g. With our conservative margins in the axial and vertical directions, the applied 3D combination of the loads is still lower than the original criteria. An additional static analysis of each component will be done for verification. Our present design attaches the spaceframe to the vacuum vessel at each ring and supports the cavity midway within the helium vessel. This aspect of the design raises the components natural frequencies well above the 10-14 Hz driving frequencies indicated from the initial road test. The complete modal analysis of the cryomodule should be completed before year's end. Plans are in place to take the first complete medium β cryomodule on a similar road test to check the alignment, vacuum integrity and RF performance before and after shipping. The analysis and road test data will be compared.

8 References

[1] Cryogenic Systems (second edition), Randall F. Barron

[2] K. Tremblay, Jefferson Lab Alignment Group Data Transmittal, December 5, 2000

[3] P. Mutton, "CEBAF 1/4 Cryomodule Shock and Vibration Road Test",June 2001, TJNAF Internal report.