DESIGN OF MECHANICAL STRUCTURE AND CRYOSTAT FOR IASW SUPERCONDUCTING WIGGLER AT NSRRC

H. H. Chen#, C. S. Hwang, C. H. Chang , J. C. Jan, F. Y. Lin, M. H. Huang, T. C. Fan.
NSRRC, 101 Hsin-Ann Road, Hsinchu Science Park, Hsinchu 30077, Taiwan, R.O.C.

Abstract

An in-achromatic superconducting wiggler (IASW) was successfully constructed and installed at the Taiwan Light Source (TLS) in January 2006. The cryostat with a 30 L liquid nitrogen aluminum reservoir shielding surrounds the helium vessel, which comprises the cold mass and 100 L liquid helium. The helium vessel is suspended by eight suspension links, which are thermally intercepted at 80 K and can be adjusted by applying tension, such that the center of the cold mass does not move during cooled to 4.2 K. A three-layered stainless tube was designed to prevent the transfer port from freezing and the steam- electricity separation system is designed to supply electricity and return the helium gas to prevent freezing of the power feedthrough.

INTRODUCTION

A 16-pole superconducting wiggler (IASW) with a period of 6.1 cm and field strength of 3.1 T was constructed and installed between the first and second bending magnets of a TBA arc section of the TLS storage ring, and an auto filling system for liquid helium and nitrogen was used. The cryogenic system of the magnet includes the 4.2 K cool mass and a 78 K liquid nitrogen vessel, which are separated by the vacuum gap in the 300 K vacuum vessel and 30 layers of super insulation. The service tower provides the transfer port for the power inlet, the electrical equipment, the gas return, the pressure gauge and other components. Figure 1 show the structure of the cryogenic system. A three- layered stainless tube was designed to prevent the transfer port from freezing and a vacuum cylinder was used to cover the seal fitting to prevent the transfer port from freezing. The current lead was welded with an Nb_3Sn bar and soaked with the liquid helium to prevent burn-out of the superconducting wire during filling with liquid helium. The steam - electricity separation system was designed to include a power inlet and to return the helium gas to prevent the power feedthrough from freezing. The stress and strain or thermal effects are calculated by finite element analysis. This work presents designs of the main components of the cryostat, the head load and the mechanical stress analysis.

#cff@nsrrc.org.tw

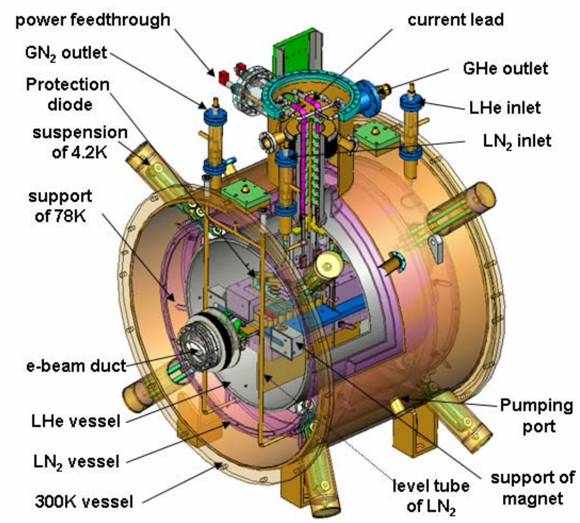

Figure 1: Structure of Superconducting magnet.

STRUCTURE OF THE CRYOSTAT

Main Components

The cool mass with the magnet assembly and the stainless steel vessel is suspended by eight suspension links. The magnet that is supported inside the end-plate of the vessel to an accuracy of within ±0.1 mm. The alignment marks on the other side of the end plate are referenced to 300 K. The 4.2 K duct with dimensions of 117 mm x 19 mm x 500 mm was inserted into the gap of the magnet and welded to the end plate to produce the helium vessel, and the vessel was reducing the diameter by 1.8 mm, when the temperature cooled to 4.2 K[1], as show in Fig. 2.

The aluminum vessel with liquid nitrogen shielding surrounds the helium vessel. The SS/AL bimetal with a 3/8" hole is welded to the transfer tube and six pieces of the FRP plate with dimensions of 5 mm x 10 mm x 90 mm and sharp point are used to support with the 300 K vessel, as show in Fig. 1.

The 300K vacuum vessel and the service tower are welded to a thin wall pipe and a bellows on the helium vessel, which heat load is about 0.42 W, as show in Fig. 3; the two of the vacuum chambers are thus separated. The service tower provides the transfer port for the power supply, the electrical equipment, the gas return, the pressure gauge and other components. The 300 K vessel provides the inlet port, the pumping port and the safety valve.

The e-beam vacuum duct separates the electron beam from the cryogenic system of the magnet. It is thermally

 1-4244-0917-9/07/$25.00

intersected by two copper plates that are connected to the liquid nitrogen vessel, and is calculated to optimize the operating temperature of the duct at between 100 K and 120 K is similar to the SW6 superconducting wiggler of the NSRRC[2][3], as show in Fig. 4.

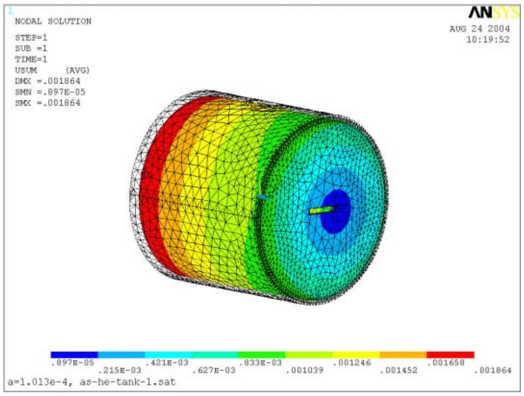

Figure 2: Reducing the diameter by 1.8 mm, when the helium vessel cooled to 4.2 K.

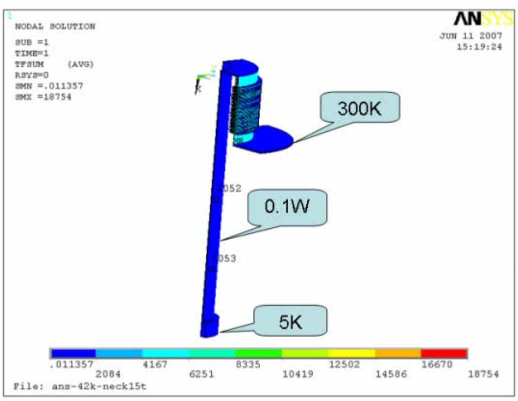

Figure 3: Heat flux of the service tower.

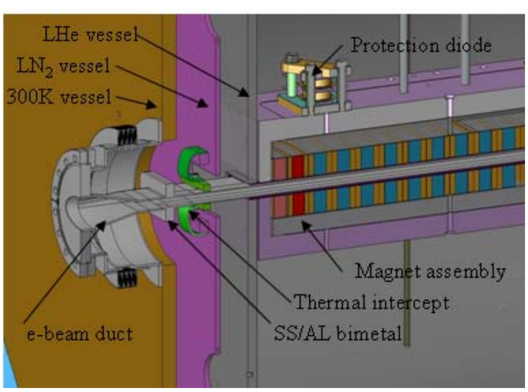

Figure 4: E-beam duct in the cryostat.

Suspension Link

The helium vessel is suspended by eight suspension links, and the suspensions are made of unidirectional fibreglass. They have a racetrack shape, an Elastic modulus of 1820 kg/mm, Yield strength of 50 kg/mm^2, and an ultimate tensile force of 12400 kg. They thus allow the helium vessel to contract at 4.2 K reducing the diameter by 1.8 mm. The biradial arrangement of the links prevents the center of the helium vessel from moving during cooling. It can be adjusted by suitable the tension from the eight vacuum cylinders. However, the weak point of this design is not the fiberglass, but the rod-end, which only allows a tensile load of 2700 kg before following Hooks Law, so the total extension of all links is 1.5 mm, which is safe.

The links were thermally intercepted by liquid nitrogen (80 K). Figure 5 shows the design of the suspensions and the heat flux distribution. The total (eight suspensions) conduction heat load at LHe is about 0.51 W and that at LN_2 is about 1.84 W, and from the 300K vessel is about 2.36 W.

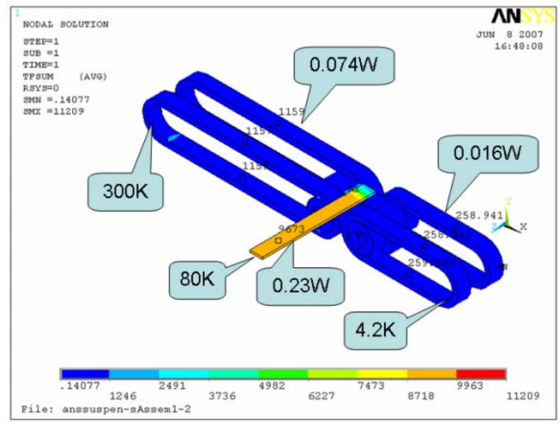

Figure 5: Heat flux of the suspension.

Transfer Ports

A three layered stainless tube was designed and a vacuum cylinder was used to cover the VCR seal fitting to prevent the transfer port from freezing during filling with liquid nitrogen or liquid helium. The thermal conductivity was calculated; Figure 6 shows the temperature distribution and presents the structure of the transfer port.

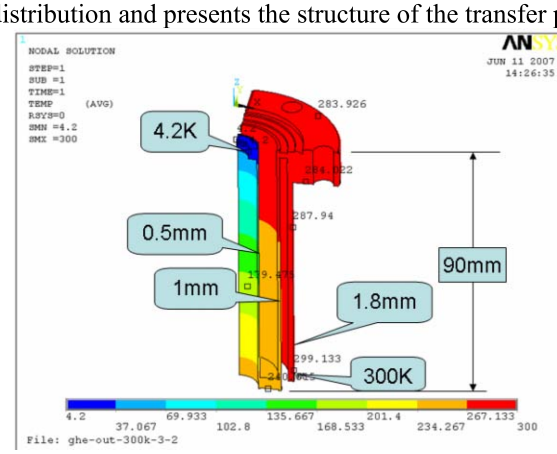

Figure 6: Temperature distribution and presents the structure of the transfer port.

Inlet for Liquid Helium

The helium vessel has two holes for the inlet of liquid helium. One is at the bottom of the vessel, and is used to allow in the liquid nitrogen to pre-cool the vessel, and then purge out with the gaseous helium when the magnet

1-4244-0917-9/07/$25.00 ©2007 IEEE

is cooled in the laboratory. The other hole is on the top of the vessel, it is used as an inlet from above to below when the liquid helium is to be stored. The transfer tube is designed with an S- shape to tolerate the shrinkage strain caused by cooling. Figure 7 presents the design of the inlet tube.

Figure 7: Designs of the LHe inlet tube.

Steam-electricity Separation System

A pair of vapor-cooled copper current leads was used to supply 265A from the power feedthrough. The cryogenic-ceramic breaks were welded to through the helium steam to form of a Y-pipe, as shown in Fig.8. The flexible OFHC was calculated to control the transmission of the heat load between the power feedthrough and the current lead. Top of the current lead was cooled by the steam of helium at 50 K during quenching or re-filling with the liquid helium, the power feedthrough was also prevented from freezing, and the helium steam was returned to the compressor of the cryogenic system.

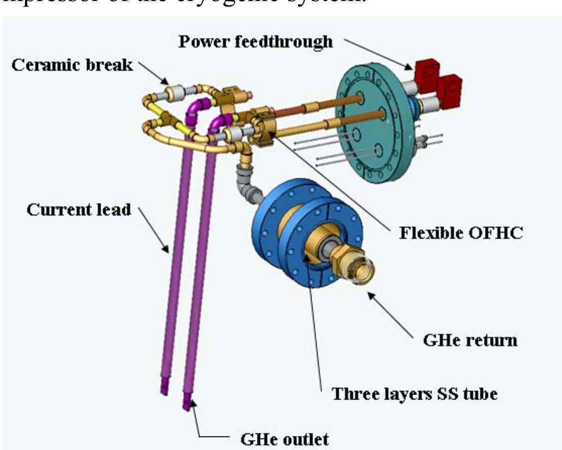

Figure 8: Steam-electricity separation system for GHe return.

Prevention of Wire Burn-out

NbTi superconducting wire with a diameter of 0.64mm was used to form the coil. It was welded to the current lead that had triple the diameter, but it burned out at where it is not immersed in LHe, during re-filling with LHe or magnet quenching. The Nb_3Sn bar was welded to immerse in the LHe to the 75% level in the helium vessel, as shown in Fig.9. The measured temperature of the end of current lead was from 6 K to 12 K. When the level of LHe is less than 75% the system is re-filled. And the magnet is quenched; the temperature of the top of the NB_3Sn bar then increase to 33 K, and the current loop is safe.

The quenching-protection circuit is designed for quenching the superconducting coil. It has six pairs of the R620 cold diodes, and software is used to watch the coil voltage and temperature [3].

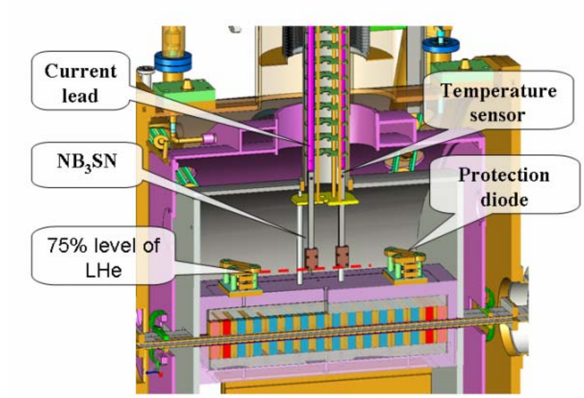

Figure 9: Nb_3Sn bar was welded to immerse in the LHe to the 75% level in the helium vessel.

CONCLUSIONS

The cryostat has 4.2 K liquid helium vessel, a 78 K liquid nitrogen vessel, and a 300 K vacuum vessel; the suspensions are biradial supports of the cool mass, which prevent motion of the center of the helium vessel during cooling. Vapor-cooled copper current leads are used to supply a current of 265 A. The steam- electricity separation system for electricity supply and the helium gas returns prevent the power feedthrough from freezing. The Nb_3Sn bar was soaked in liquid helium to prevent burn-out of the superconducting wire during filling with liquid helium. Quenching-protection diodes and software protection are used to protect the coil; safety valve and burst disk are used to protect the cryostat.

The magnet works well, and two of the same superconducting wigglers will be installed in the future.

REFERENCES

[1] C. H. Chang, et al. "Preliminary Test Results Concerning the "Within-Achromat" Superconducting Wiggler at NSRRC", IEEE Trans. On Applied Superconductivity, vol.16, no.2, pp.1862-1864, MT19.

[2] H. H. Chen, et al. "Analysis of Heat Load in a Superconducting Wiggler with a Semi-cold UHV Beam Duct", IEEE Trans. On Applied Superconductivity, vol.16, no.2, pp.1320-1323, MT19.

[3] C. S. Hwang, et al. "Superconducting Wiggler with Semi-cold Beam Duct at Taiwan Light Source", Nuclear Instruments and Methods in Physics Research. A 556 (2006) 607-615.

 1-4244-0917-9/07/$25.00 ©2007 IEEE