MECHANICAL DESIGN OF THE DRIFT-TUBE LINAC (DTL) FOR THE SPALLATION NEUTRON SOURCE *

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Abstract

The Spallation Neutron Source (SNS) utilizes a linac to accelerate H^- ions to 1 GeV at an average beam power of 1.4 MW. The linac consists of four RF structures: a 2.5-MeV RFQ, an 87-MeV DTL, a 186-MeV CCL, and a 1-GeV SRF linac. The DTL is divided into six RF structures, each powered by a 2.5-MW klystron. Design and fabrication of the DTL has been completed, and LANL has aligned and tuned the first structure (Tank #3) to be installed at ORNL. The description of the design and fabrication process, including machining and copper plating of the tank sections, machining and welding of the drift tubes. Also, design and fabrication of the post couplers, slug tuners, endwalls, Iris waveguide, and support structure is discussed. In addition, the assembly and alignment of the RF components using the Leica Laser Tracker System Coordinate Measuring Machine are also discussed.

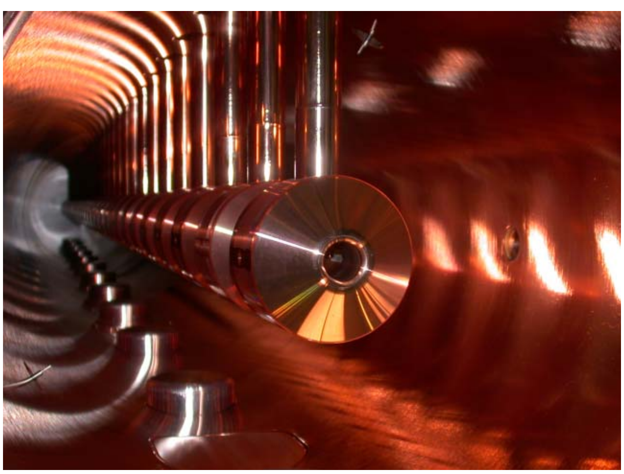

Figure 1: Photo of Drift tubes inside DTL tank 3

INTRODUCTION

The 402.5-MHz DTL is based on the Transverse magnetic (TM) Alverez design. Cells are of length $\beta\lambda$ and the transverse focusing period is $6\beta\lambda$ in length. Focusing is accomplished with permanent magnet quadrupoles (PMQs) positioned within specific drift tubes. The focusing lattice is Focus-Focus-Empty-Defocus-Defocus-Empty, (FFODDO). The magnets are internal to the drift tube bodies and are orientated (clocked) in either of two positions to produce the focusing or defocusing field. Empty drift tubes do not contain a magnet and are left as solid copper. Some empty drift tubes will incorporate electromagnet dipoles (EMDs) for beam steering or beam position monitoring (BPM) diagnostics. The EMD drift tubes are usually at the end of each DTL tank while the BPM drift tubes are at the beginning. The DTL will have post couplers to stabilize and adjust the longitudinal field distribution along the tank. Slug tuners will be used to provide static frequency adjustment to RF cavity.

DTL RF STRUCTURE

The DTL RF structure includes drift tubes tanks, endwalls, slug tuners, post couplers, and the waveguide iris assemblies. See figure 2 for a general layout of a DTL tank 3.

DTL Tank

The primary DTL structure is the tank or RF cavity. The tank is a vacuum vessel that provides a RF envelope and a mechanically stable platform for the array of drift-tube assemblies, post couplers, and slug tuners. The tank also provides support and interfaces to other beam-line components such as the RF system, the cooling system and the vacuum pumping system. Each tank incorporates coolant passages to flow temperature controlled water used to adjust the electro-magnetic resonant frequency of the DTL. Varying the temperature will change the dimensional characteristics of the DTL which will change its capacitance and inductance, thus changing the electro-magnetic resonant frequency.

For ease of fabrication and assembly each DTL tank assembly consist of 2 or 3 sections bolted together to form one long assembly. Each tank section is approximately 7 feet long and is fabricated from medium carbon forged (per ASTM A266 [1]) steel. Component penetrations, fastener holes, vacuum seal grooves, RF seal grooves, coolant channels, and interface surfaces are all integrally machined into each tank section. This eliminates the need for welding on any additional components to the tank section. Eliminating welding on the tank sections increases the material uniformity and reduces plating and other fabrication risks.

Steel was chosen over other potential materials such as aluminum, stainless steel, and copper because of lower material and fabrication costs.

Tank Plating

Each DTL tank section was Copper plated to increase the electrical conductivity of the tank RF surfaces. The Tank sections were plated at Gesellschaft für Schwerionenfschung (GSI) in Darmstadt Germany using

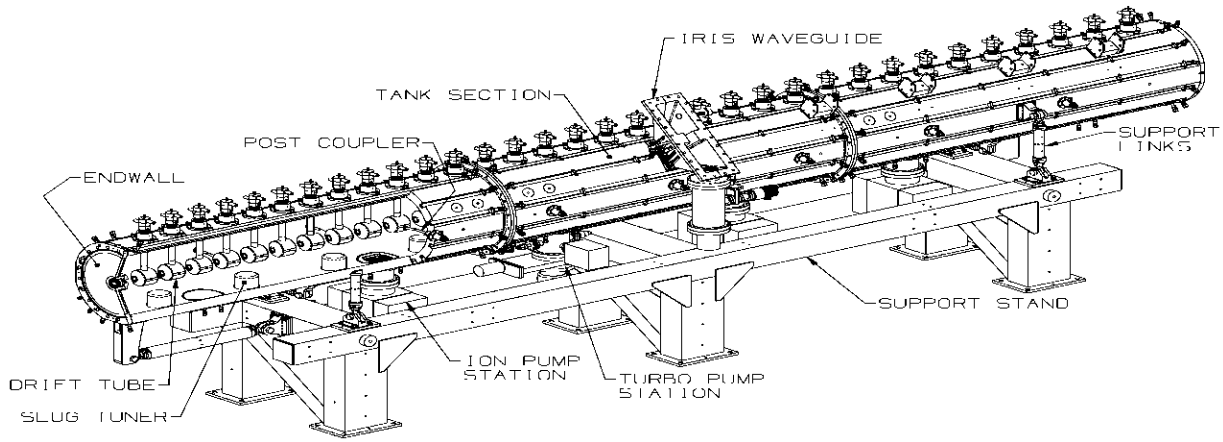

Figure 2: Partial cut-away isometric view of DTL tank 3

GSI's standard plating process for accelerator components. Their process provides a high-conductivity, ductility, high-brightness and a relatively good hardness for a plated surface. GSI was chosen because of their vast experience in copper plating accelerator components and the relatively short time they require to plate a tank section. Including preparation, each tank section was plated in approximately 2 days.

The plating process is proprietary to GSI however it is similar to the Udylite Bright Acid Copper (UBAC) bath process used on prior accelerator tanks such as the Ramp Gradient DTL and the Accelerator Test Stand (ATS) at LANL.

Drift Tubes

Each drift tube assembly is comprised of a body and stem, see figure 3. The body is made up of oxygen free electronic grade copper (OFE) parts and electron beam (EB) welded together. The stem is fabricated from concentric stainless steel tubing and is welded to the drift tube body. OFE copper was chosen for the body material because of its high electrical and thermal conductivity. The stem is constructed of stainless steel due to its strength and modulus properties. The Stainless steel stem exterior is Copper plated using the UBAC plating process. Due to high RF heating each Drift tube will be water-cooled. Drift tube fabrication methods and issues are discussed in [2].

Most Drift tubes will house a 16 segment Samarium Cobalt (SM_2CO_{17}) Permanent Magnet Quadrupole (PMQ). The PMQ's provide transverse beam focusing with a gradient of 3.70 kG/cm.

Some Drift tubes will house an Electro-Magnet Dipole (EMD) required for transverse beam steering. Each DTL tank assembly will have 2 sets of the "x" and "y" EMD steering magnets. Two Drift tubes downstream of the EMD Drift tubes will house a Beam Position Monitor (BPM), which will provide beam location feedback.

Post Couplers

Post couplers are used to provide longitudinal electric field adjustment and stability. Post couplers are located in every DTL tank along the horizontal axis. They are alternately spaced from one side to the other. On tanks 1 thru 3 the post couplers are located at every other drift tubes. In tanks 4 thru 6, post couplers are located at every drift tube position. Post couplers are constructed of OFE copper and are EB welded together. Each post coupler is water-cooled and requires a unique stem length and a rotational orientation on the tank wall.

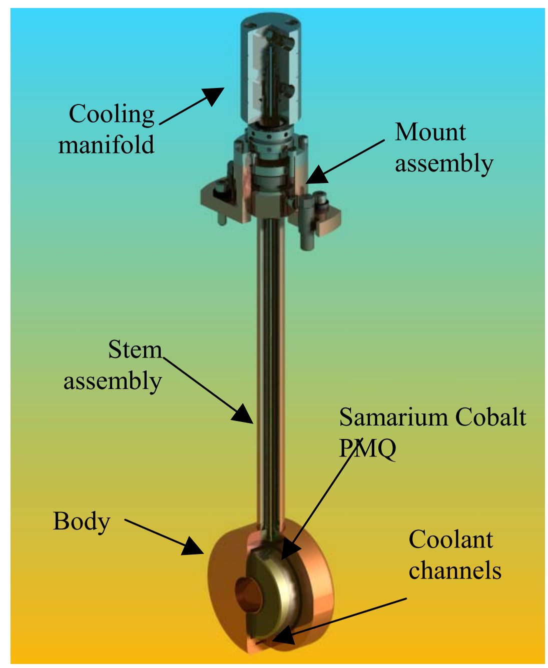

Figure 3: Cut away view of a typical Drift tube

Slug Tuners

Slug tuners provide static frequency adjustment to the RF cavity. Each DTL tank incorporates 12 tuners approximately equally spaced. Each slug tuner is constructed of OFE copper components and furnace brazed. The tuning range for each tuner is approximately 110 kHz to 440 kHz for a flush to a 3"cavitiy penetration respectively. The penetration length was determined during low power testing on the DTL cold model.

Endwalls

Endwalls are bolted-on components that enclose each end of the DTL tank assembly. A PMQ may be installed in the half of drift tube body protruding from the endwall internal surface. The endwalls are fabricated from OFE copper parts and furnace brazed together. In some location the endwalls provide enclosures for diagnostic equipment such as a current monitor (toriod). Each endwall is water cooled to compensate for high RF heating.

Iris Waveguide

The Iris waveguide provides RF coupling to the tank cavity from the waveguide. The Iris interfaces to the air-filled waveguide thru a 402.5 MHz window. The Iris waveguide is a brazed assembly using Dispersion Strengthen (DS) copper GlidCop® AL-15 material. The DS copper was chosen because of its high strength and high thermal conductivity properties. The high strength is required due to the structural loading caused by gravity and possible seismic activity.

ALIGNMENT

Accurate transverse magnetic alignment of each drift tube PMQ is essential for proper beam focusing and beam dynamitics. Typical transverse magnetic alignment between drift tubes is ±0.005 inches (± 0.13 mm). To achieve this alignment requirement a two-step process is used, drift tube fiducialization followed by drift tube alignment. Both processes utilize the Lecia laser tracker system coordinate measure machine, LTD 500.

Drift Tube Fiducialization

A pulsed taut wire system is used to locate the transverse magnetic center of the PMQ located within the drift tube. The Lecia laser tracker system will be used to measure and record the magnetic center of the PMQ relative to references (fiducials) located on the outside of each drift tube.

A short rectangular pulse accelerates the wire transversely at the PMQ by an amount proportional to the displacement of the wire from the magnetic center. The transverse wave propagates along the wire to sensors where they are measured. The PMQ is translated transversely using x-y translation stages until the signal measured in the wire is minimized. Displacing the PMQ by know amounts using translations stages gives an accurate calibration of signal size versus misalignment. When the wire is located at the magnetic center of the PMQ the laser tracker system will be used to measure the transverse location of the wire magnetic center to the external features (fiducials). This process is also used to fiducialize the DTL endwalls that have PMQ's installed.

Drift Tube Alignment

After the drift tube fiducialization is completed each drift tube is installed into the DTL tank assembly. Using the fiducialization data each drift tube is aligned to a common axis. This axis is the beamline axis. The axis is established using the magnetic centers of the upstream endwall PMQ and the downstream endwall PMQ. If either endwall does not have a PMQ installed the geometric center of the endwall bore tube is used. The Lecia laser tracker system coordinate measure machine aides in the construction of the alignment axis as well as the drift tube alignment.

DTL SUPPORT STRUCTURE

The DTL support structure provides support for the DTL tanks and sub-systems including the vacuum system and the water-cooling system. Each DTL tank assembly is supported by a kinematic support link system connected to a welded steel frame. The support system is designed to provide each drift tube with a structural dynamic stability of less than 200 μ-inch transverse RMS. The support structure also provides seismic restraint for the DTL tank assemblies.

REFERENCES

[1] ASTM A 266/A266M –99, "Standard specification for carbon steel forgings for pressure vessel components".

[2] W. Fox, "Manufacturing issues related to the fabrication of the SNS DTL drift tubes and how they were resolved", PAC2003, May 2003.