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LINAC Section 3 and 4 Replacement at the Canadian Light Source

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Introduction

The Canadian Light Source Inc. (CLSI), opened in 2004 and located in Saskatoon, Saskatchewan, Canada, is a third-generation synchrotron light source facility with a 2.9 GeV storage ring. CLSI was built based on the Saskatchewan Accelerator Laboratory (SAL) with its LINAC. The SAL LINAC was built in 1960s and refurbished to operate at 250 MeV in 2002. It was also designed at an average beam power up to 46KW. To be used by CLS, the LINAC was modified for operation at pulse power levels of 25 MW with the current 100 mA. The modified LINAC consists of an electron gun and section 0 to 6, Energy Compression System (ECS) and Section 7.

The LINAC has kept a steady performance throughout the years, along with many repairs and replacements – most of which are preventative. The original Varian type accelerating Sections are planned to be replaced gradually by SLAC type Sections. Section 3 and 4 are two of the original 3 Varian type sections left in CLS - with over 55 years of service, they were accumulating vacuum leak problems from time to time. The replacement of Section 3 and 4 was completed in 2020. The mechanical consideration of the Section 3 and 4 replacement mainly includes upgrading supporting structures, designing Waveguides, modifying LCW systems, getting solution to move the sections around in the LINAC tunnel, etc.

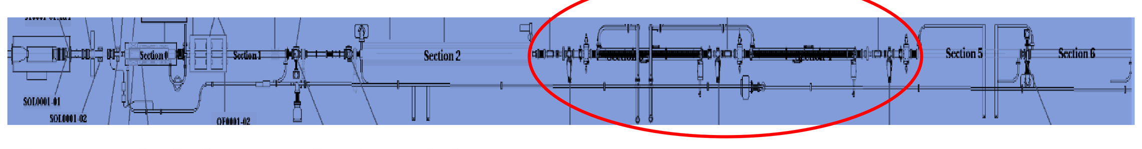


Figure 1 CLS Gun and Sections 0-6

Background

CLS has encountered gun failure in 2018, and the repairing of the device took quite a long time. The old Varian Section was discontinued and no spare could be available. We have been experiencing some vacuum leaks from the old Sections over time. It is a huge risk to run the old Varian Sections that were built at the same time as the electron gun. The old Varian Sections in CLS had been planned to be replaced gradually.

The goal this time was to replace the Section 3 and 4 and add more components together with the new Sections in between Section 2 and 5. New added components include Ion pumps, View Screens, Vacuum Valves, Steer Magnets, FCT's , CCG's, TCG's and BPM's. As well, RF Loads were replaced and Waveguides were redesigned.

Figure 2 Overview of the new installation

Old Varian Section vs. new SLAC Section

The old Varian Section in CLS weighs around 2 tons; its outside diameter is close to 400mm and the total length is around 5 meters. Solenoids are located surrounding outside of the Varian Section and need separate cooling.

The new SLAC Sections are quite small compare to the old Varian ones: each weighs around 400 kg, the contour diameter is about 145mm, and the length is around 3.1 meters. No solenoids on the SLAC Sections.

Figure 3a An old Varian Section

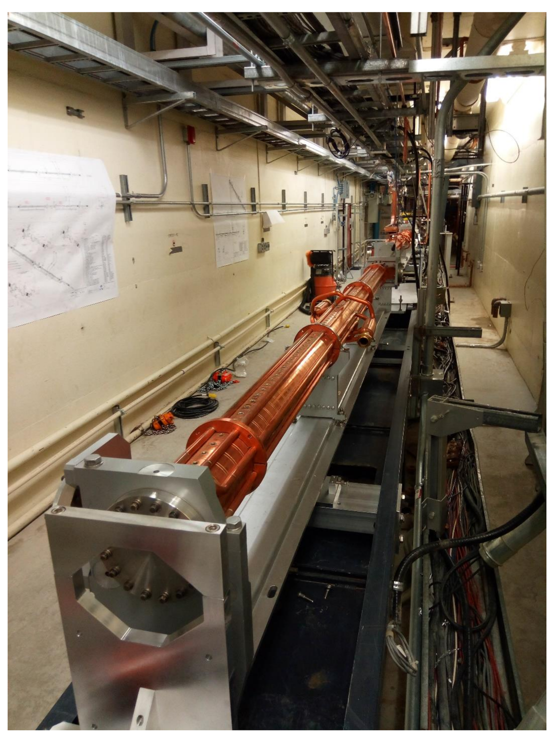


Figure 3b A new SLAC Section

Design of new Structures

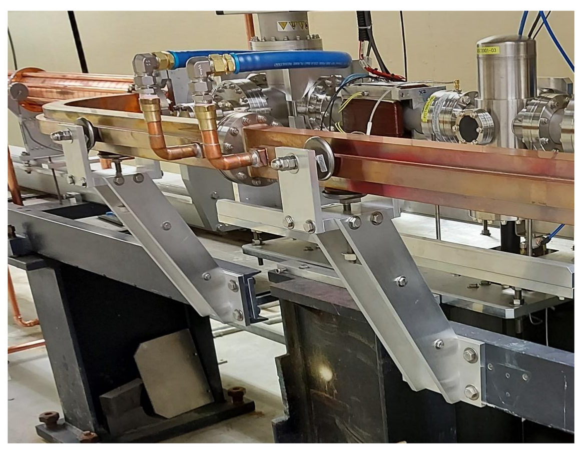
Three types of structures (Figure 4a-c) were added to meet the supporting requirements:

- Structure Assemblies to support the groups of new components
- Adjustable from all directions
- Bolted connections
- Side reinforcements

Figure 4a

- Structure assemblies to support the new Sections
- Adjustable from all directions
- Bolted connections

Figure 4b



- Structure assemblies to support the new Waveguides
- Adjustable from all directions
- Bolted connections

Figure 4c

FEA assisting design of new Components' Supporting Assemblies

Three different new structure assemblies were designed to carry the three groups of new components added between Section 2 and 5 (Figure 4a).

To meet the original beam height, it is critical to support all of the new equipment without any deflections caused by any source such as heat, unbalanced weight and misalignment. Ansys analysis was performed to optimize the design of the new added supporting structures by comparing the results of the stresses and the deflections of the different designs. Deflections on the base plates of all the fully loaded new structures were optimized to minimal.

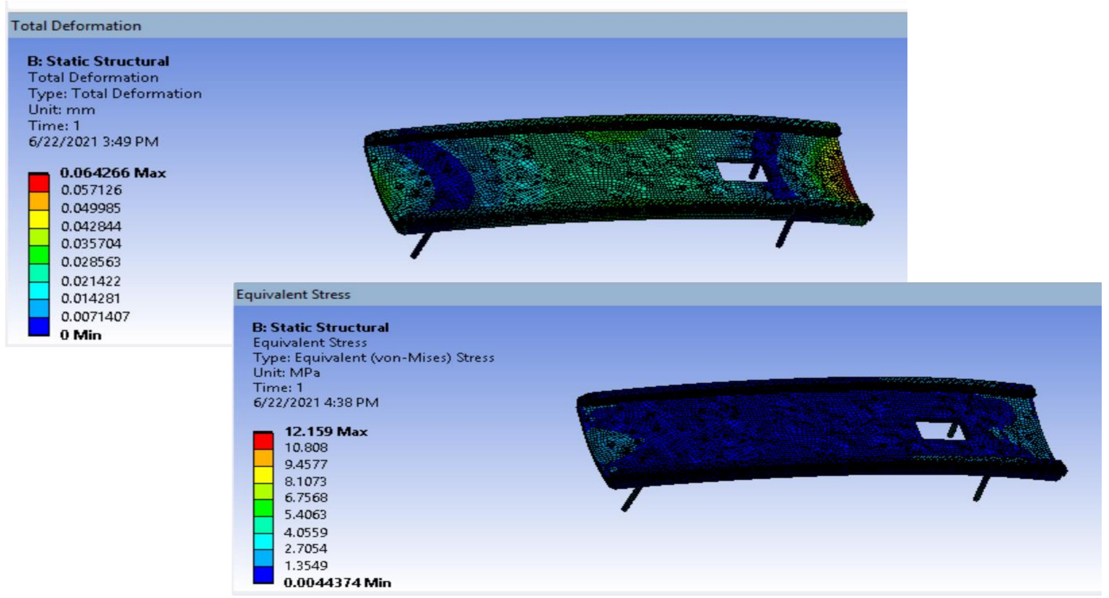


Figure 5 Typical FEA simulation of a Components' supporting assembly

Repurposing the existing supports

With the new components added in between the new shorter sections, the weight distribution is not even on the reused girders. New supporting structures should be designed to be capable of maintaining the expected beam position by considering possible adjustments from all directions.

Force distribution on each girder has been carefully analyzed and proper reinforcements were applied to limit deflections. FEA simulations has been performed to help prove the estimations.

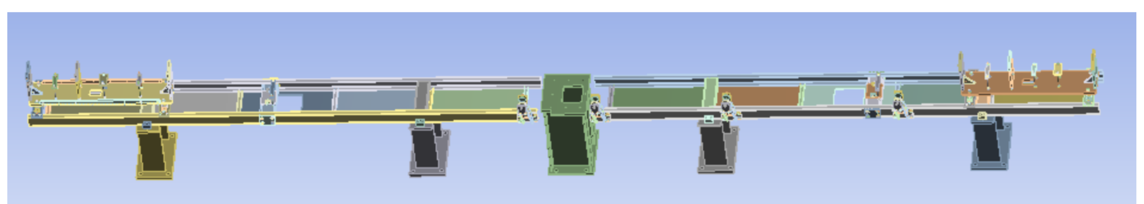


Figure 6 Overview of the existing supports

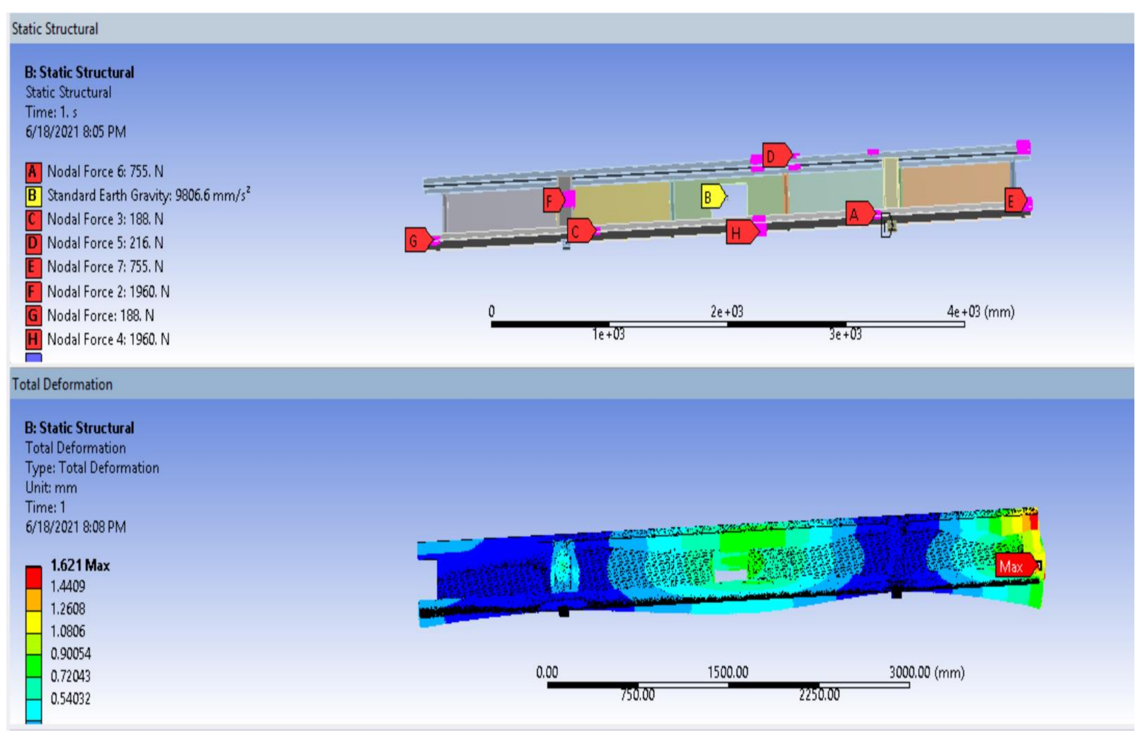


Figure 7 FEA simulation for one girder

Design of Waveguides

The existing CLS LINAC Section 3 and 4 Waveguides were installed in the 1960s. With years of operation, dust and stains have accumulated throughout the full length of the Waveguides (Figure 8a-b). In addition, the placements of the RF inputs/ outputs on the new LINAC Section 3 and 4 were opposite from the old Sections. Thus, the waveguides had to be replaced with the Sections.

Figure 8a Stain at the WG bend

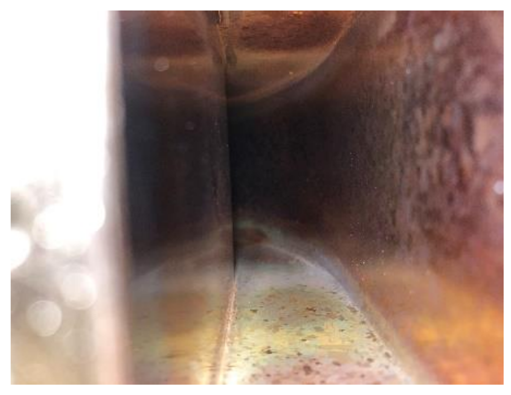


Figure 8b Stain at the WG bottom

Figure 9a Old Waveguides

Figure 9b New Waveguides

The two new Waveguides route from the ceiling of the LINAC tunnel down to the RF inputs of the new Section 3 and 4. Multiple identical Waveguide segments were adapted for easy installation and utmost interchangeability.

The positions of the new Waveguides were constrained by the locations of the tie-in flanges which were not movable and were precisely surveyed (Figure 10). Any deviation caused by the manufacturing processes of the Waveguide segments could lead to unacceptable results.

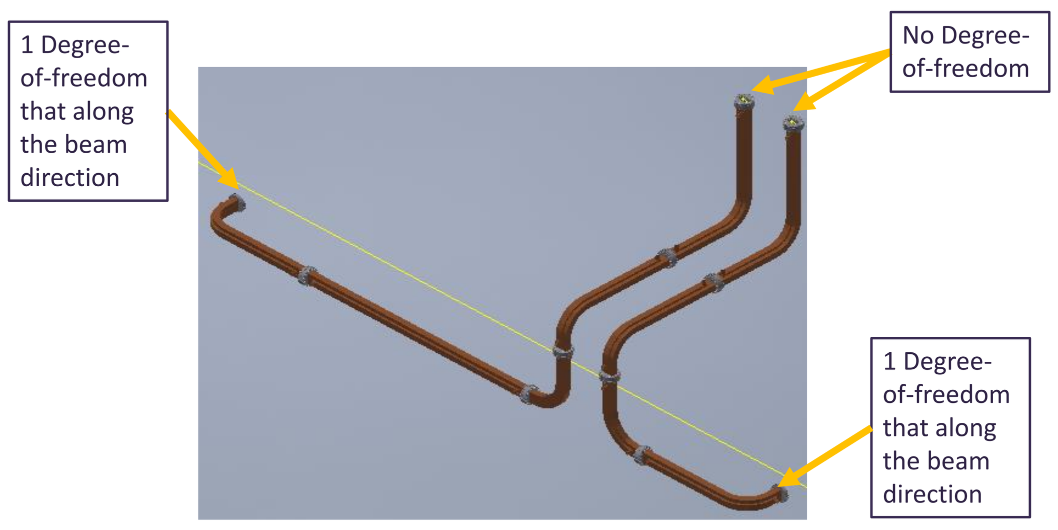


Figure 10 Constraints of the new Waveguides

Modification of LCW Systems

Each of the old Varian Sections has separated cooling systems for solenoids and Section/RF Load. Thus the pump of the Low Energy LCW system (which supplies cooling LCW to the solenoids) was resized.

Section 3 LCW system and Section 4 LCW system were modified and optimized to cool each Section and its RF Load in series instead of parallel. Auto and manual Vents were installed to eliminate air clogging in each system.

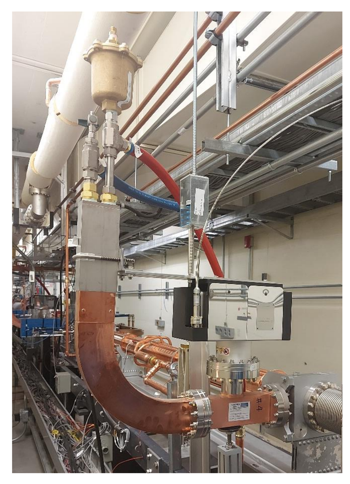


Figure 11 Vents installed on top of the RF Load

Figure 12 Disassembled old Sections

Moving the Sections around inside the LINAC Tunnel

The space in the LINAC tunnel was carefully measured. Special tools were designed to support the old Sections during its moving and storage. By using the special tools and the heavy-duty scissor lifts, the old and new Sections were able to be successfully moved around in the tunnel.

Conclusion and Future work

The Section 3 and 4 replacement was engineered and executed in 2019-2020. We have been observing good performance of the LINAC ever since. We look forward to the continued beam quality improvements this will bring.

In the future, we are going to replace the RF Loads of Section 5 and 6, and Section 2 will be the last Varian Section to be replaced.

Acknowledgements

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