# FABRICATION AND TUNING OF THE SNS CCL HOT MODEL*

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*Abstract*

A full-scale powered model of the SNS CCL was completed in August 2001. The manufacturing processes and tuning procedures used in the CCL Hot Model formed the basis of the main manufacturing contract for the SNS CCL system later placed in private industry. In this paper we summarize the design basis for the CCL and the manufacturing and process steps required to fabricate and tune the Hot Model for high power testing. In particular the machining, brazing and welding steps are discussed for both the CCL Segment assembly and the powered Bridge Coupler. In addition we discuss transfer of the information and some specific modifications that were made to the basic design at the point of starting full scale manufacture in industry. One critical area to the overall success of the Hot Model was the type and specific design of the various tooling and lifting and handling fixtures utilized in the process at the various machining, brazing, welding, and tuning steps. The tooling utilized in the fabrication and tuning process is discussed in detail. The ultimate successful testing of the CCL hot model was key to development of a manufacturing plan for the CCL system.

## 1 INTRODUCTION

The Spallation Neutron Source has the goal of designing, fabricating, installing and commissioning a complete high-energy H- linac system at Oak Ridge National Laboratory to be used for the purpose of generating neutrons for materials research. The high-energy Linac spans an energy range from 2.5 MeV to 1 GeV and is composed of a room temperature section consisting of a Drift Tube Linac (DTL), and a Coupled Cavity Linac (CCL), and a Superconducting section. The CCL section is a RF Linac, operating at 805 MHz that accelerates the beam from 87 to 186 MeV and has a physical installed length of slightly over 55 meters.

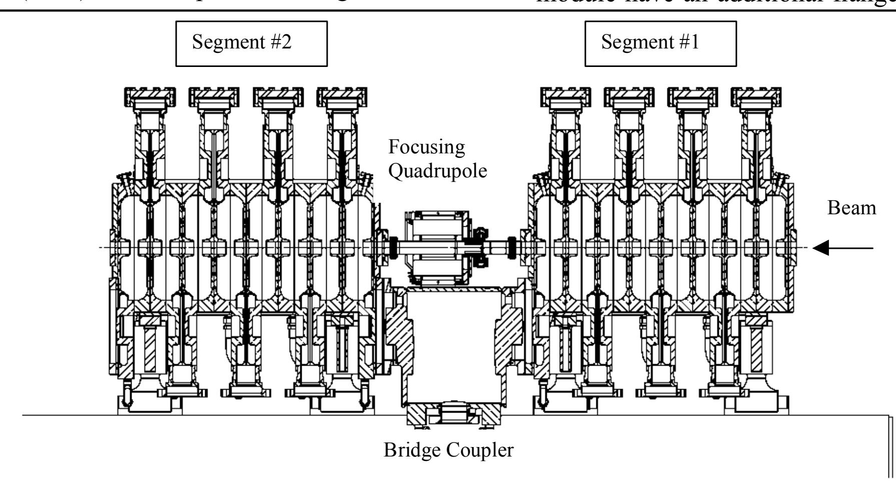


Figure 1. Cross-section view of the first two segments and first bridge coupler of the CCL

## 2 SYSTEM CONFIGURATION

The accelerator is modularized around a 5 MW RF power amplifier system. This requirement produces a CCL configuration of four modules, each containing 12 accelerator segments and 11 bridge couplers. A cross-section view of the first two segments and the first bridge coupler is shown in Figure 1. The segments are Side-Coupled Cavity accelerating structures joined by offset bridge-couplers to form a continuous RF resonator. Electromagnet quadrupoles and beam diagnostic devices also occupy the spaces between the segments. The focusing period selected is 13-Bλ in a FDFD configuration, giving 6.5-Bλ between magnet centers. Each segment occupies 4-Bλ and the remaining 2.5-Bλ is available for magnets, diagnostics, and the bridge couplers.

### *2.1 RF Cavity Configuration*

Each segment has 8 accelerating cells and 7 internal side-coupling cells. The 10 internal segments of each module have an additional flanged half-coupling cell that provides mechanical interface and power coupling with the bridge coupler. The bridge coupler has a mating end flange and cavity that forms the remaining half-coupling cell. It also has a larger powered center cell. In total each module consists of 213 cells. The module RF power is supplied through bridge couplers 3 and 9 using iris coupling into the powered center cell. This configuration

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provides even power distribution within the module and helps minimize field non-uniformities.

Several engineering and manufacturing simplifications were imposed on the RF cavity design to reduce the complexity and cost of fabrication. These include constant cell length within each segment, identical segment end coupling cells throughout the system, and constant outer corner radius on all accelerating cells. The latter feature also provides constant coupling slot geometry along the structure [1]. The bridge coupler end half-cells are also constant geometry throughout; the varying overall length with increasing beta is taken in the length of the center cell.

## 3 RF SEGMENT MANUFACTURING OVERVIEW

The CCL Hot Model segments are manufactured from simple hot rolled plate stock, machined to thickness with the cooling channels and side coupling cell cut into one surface (septum). The septum surfaces of plate pairs are vacuum-furnace brazed together to form the water cooling passages and coupling cells. The outer surfaces of the plate pairs are then machined to form the accelerating cells. The accelerating cell sides (equator planes) of the plates are stacked together to form groups of 8 accelerating cells called segments. The resonant frequency of the stacked segment is measured and adjusted by un-stacking and machining on a tuning ring inside each cell. After machining the segment is restacked and checked. When the proper tune is achieved, the stack of plates is furnace brazed together at the equator plane of each cell to form a monolithic segment having all internal cooling. After brazing fine-tuning of the segment cells is accomplished by deforming the wall of the segment in thinned “dimpling ports”. The dimpling raises the frequency of the dimpled cell slightly to achieve the final cell frequency and accelerating mode frequency desired.. The concept of a monolithic halfcell is utilized to allow incorporation of cooling water passages into the septum surfaces between cells while simultaneously eliminating the need for braze joints between the side coupling cell and the main accelerating cell. In addition this design approach allows the machinist to work with mostly wide, flat plates during the precision machining steps. The plate is easily held to the machine tool (mill or lathe) accurately and with minimal clamping force distortion.

### *3.1 Manufacturing Steps Utilized*

a) Manufacturing begins with the production of the cell blanks from hot-rolled copper plate stock. The material is high purity Oxygen Free Electronic Grade (OFE) Copper that is certified to comply with the ASTM F-68 specification of Class II or Class I. This specification controls primarily oxygen content limits (less than 5 PPM oxygen) and the wrought properties of the material.

b) The cell blanks are then finish machined on the septum side, Figure 2, to produce the coupling cell geometry and the septum cooling channels. The individual plates are called “half-cells”.

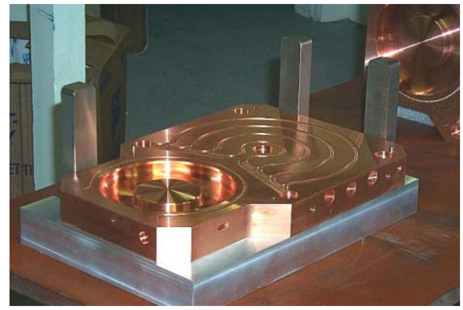

Figure 2. Septum Side Geometry

c) In the next step, the half-cells are vacuum furnace brazed together in pairs along the septum surfaces to produce “half-cell” assemblies, Figure 3. Alloy 50% Au – 50% Cu is utilized at a braze temperature of 1850 F. To this point all half-cell assemblies for each module are identical and interchangeable.

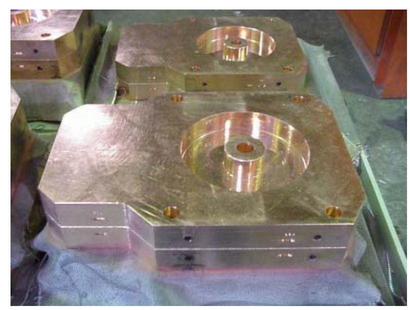

Figure 3. Septum Brazing

d) After helium leak testing, the accelerating cell sides of the plates are machined, Figure 4, to produce “finished half-cell-assemblies”. The accelerating cells are rough machined in a mill and finished on a lathe using counterweights attached to the lathe chuck for balance.

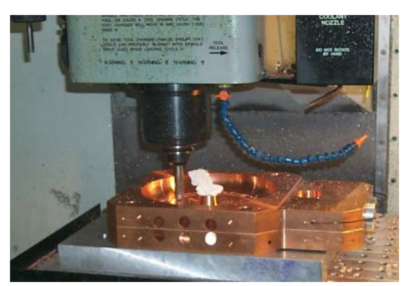

Figure 4. Accelerating cell machining

e) Following cavity finish machining the parts are again vacuum leak tested, cleaned thoroughly with a water-detergent solution and dried with clean dry nitrogen. At this point the cells belong to a specific segment and are not interchangeable between segments. The ½ accelerating cells are then frequency measured individually and then all segment cells are stacked together in a special handling fixture, Figure 5, and the collective accelerating mode frequency is measured.

Figure 5. Measuring the Segment Frequency

The offset between the individual cell frequency and the accelerating mode frequency is then determined. The difference is a result of nearest neighbor coupling between adjacent accelerating cells directly through the coupling slot. The required accelerating mode frequency is set to a value slightly below (-200kHz) the final operating mode value of 805 MHz by removing material (machining on lathe or milling machine) (Figure 4) from the tuning ring mentioned earlier. The parts are then thoroughly cleaned and stacked for vacuum furnace brazing.

f) The stacked assembly is vacuum furnace brazed using a copper-silver eutectic alloy at 1450 F, Figure 6. This braze produces a mechanically finished but not completely tuned segment assembly. It's complete with all water and vacuum fitting tube connections. The assembly is again vacuum leak tested and the final welds are made to the vacuum connection flanges.

Figure 6. Stack brazing of tuned segment assembly in the vacuum furnace

g) Following flange welding the segments are finish tuned. First the frequency of the side coupling cells must be adjusted to 805 MHz by squeezing or expanding the cell across the noses. This is done using a special wedge shaped tool to force the noses apart or by squeezing the outside with a clamp or tapping the cell nose region lightly with a hammer. When the side cells are complete the accelerating cells are adjusted in frequency (raised) by dimpling in the wall of the thin ports for each cell located on the sides of the segment. During the pre-braze tuning step the accelerating cells are intentionally set about 200 kHz low to allow room for raising the frequency at this step by dimpling. The final adjustment then must raise the frequency of the accelerating cells about 150 to 200 kHz during the dimpling process. The dimple ports are able provide a total tuning range of about +400 kHz if needed. Figure 7 shows the dimpling being done on the first Hot Model Segment located on the support stand in the test bay.

Figure 7. Tuning the Accelerating Cells

h) Following the dimpling process the segments and the bridge coupler are joined and the frequency of the group is adjusted. Particularly the frequency of the segment end cells and the end coupling cell must be done with the entire unit assembled. When this is completed an electric field measurement is made in the cells by pulling a metal bead through the gaps and recording the effect on a phase-locked loop. The field distribution must be correct or some tuning steps are repeated as required. Figure 8 shows the Hot Model assembly and a bead pull measurement.

Figure 8. Bead Pull measurement on the Hot Model

## 4 CONCLUSIONS

The manufacturing and tuning steps have been successfully demonstrated on the CCL Hot Model. The manufacturing and tuning steps as well as the specialized tooling and handling fixtures have been critical to the success of the process. These same processes have been incorporated into the contract and work procedures for the construction of the full-scale CCL accelerator.