DEVELOPMENT OF A HIGH-POWER RF CAVITY FOR THE PEP-II B FACTORY*

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We describe the development and fabrication of the first high-power RF cavity for PEP-II. Design choices and fabrication technologies for the first cavity and subsequent production cavities are described. Conditioning and high-power testing of the first and subsequent cavities are discussed, as well as integration of the cavity into modular RF systems for both high-energy and low-energy rings. Plans for installation of the cavity raft assemblies in the RF sections of the PEP tunnel are also considered.

I. INTRODUCTION

The RF system for the PEP-II asymmetric B factory [1] requires a number of accelerating cavities to replenish the energy lost by the beams as they circulate in the high- and low-energy storage rings. We chose to use single-cell normal conducting cavities, see figure 1, designed to operate up to a maximum wall dissipation of 150 kW, which corresponds to a gap voltage of about 1 MV. The cavities are designed to have maximum shunt impedance for the accelerating mode, while the higher-order modes (HOMs) are strongly damped to minimize the overall machine impedance.

We are close to completion of the first high-power RF cavity for PEP-II and the lessons learned in its manufacture have been incorporated into the plans for the production run of cavities.

II. DESIGN

The RF design of the cavity and the thermal analysis have been described previously [2,3,4]. Implementation of the cooling scheme requires the complex pattern of water channels to be constructed in close proximity to the RF surface, while avoiding any potential leak paths between water and vacuum. This is achieved by cutting the channels into the outside of the shell that forms the cavity body and the outside of the various port subassemblies, while not crossing any brazed or welded joints. The individual channels are then covered, on the body by electroforming and on the ports by brazing, and individual inlets and outlets are connected in series or parallel as appropriate.

The finished, interior surface must be suitable for future cleaning and/or surface treatments. Therefore, the design must avoid leaving any cracks, voids or crevices on the inside surfaces that could trap cleaning solvents and produce virtual leaks. For this reason the major structural joints of the cavity are made by deep penetration electron-beam welding, with the arrangement that the final machined RF surface is sufficiently far from any regions of porosity associated with the root of the weld. Where this is not possible, for example final joints made after the RF surface is finished, the surface region is re-melted with a cosmetic weld to leave a smooth and void-free surface.

Flanges are added by TIG welding to stainless steel inserts brazed into the port subassemblies.

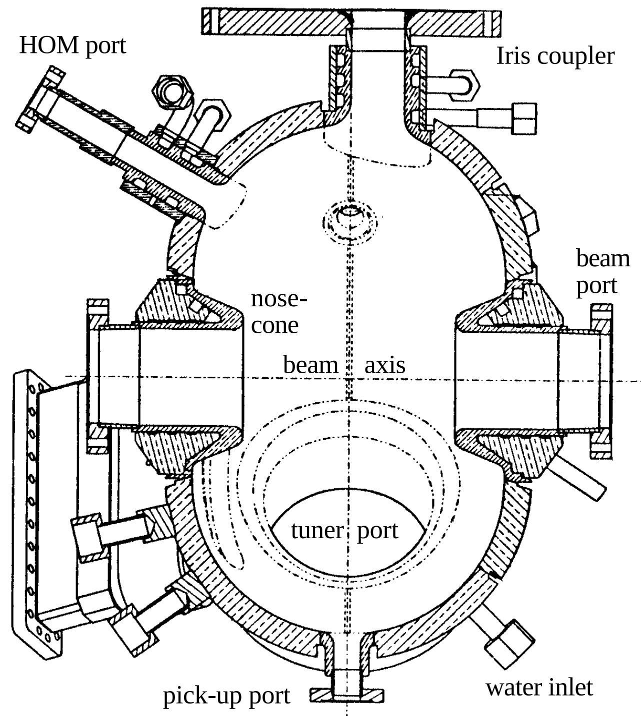

Figure 1: Horizontal cross section through the PEP-II high-power cavity showing the coupler, HOM port, beam ports and small pick-up port.

III. FABRICATION

The basic cavity body is made from two bowls, cold-formed from OFE copper plate, which are electron-beam

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welded together at the equator. The body cooling channels are cut into the outside of this shell by CNC multi-axis milling and then filled with wax, activated, and covered with electroformed copper, figure 2. The bowl is then turned to the nominal outside dimension and re-installed in the milling machine where the water fitting holes are prepared. The cooling channels are flushed of the wax and then pressure tested. The openings for the HOM and equatorial ports are then machined into the cavity body and the assembly is leak checked.

The ports are machined from OFE copper billet, with cooling channels cut in the outside. The port parts, flange extensions and cooling channel covers are brazed together and leak checked prior to machining the joint which mates with the cavity body.

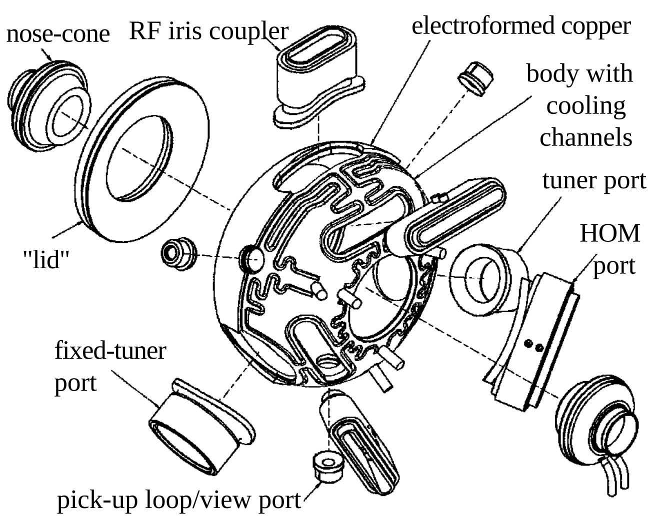

Figure 2: Assembly of high-power cavity showing body cooling channels on one half (exposed), equatorial and HOM port inserts, nose-cones and "lid" section.

The equatorial and HOM ports are clamped in place, tack welded and then joined to the body by electron-beam welding. The HOM port joints, which are accessible through the large "lid" opening on one side of the cavity, are welded from the inside, figure 3, while the equatorial ports are welded from the outside, figure 4.

Once the ports are welded in place, the interior is machined to achieve the finished RF surface, which is also facilitated by the large lid opening. This is an interrupted cut in places where the tool passes over the port openings. With care a surface finish better than 24 micro-inches is attainable with conventional turning using tungsten carbide cutting tools. After surface finishing of the body, the cavity is tuned by machining the nose-cone sections. These are clamped in place while the frequency is measured and then removed for machining. Dummy tuner plungers are inserted during tuning and the temperature and dielectric constant of the purging gas are taken into account. Frequency changes due to vacuum forces and weld shrinkage will also be accounted for in production versions. These effects will be measured in the first cavity and corrected for when machining the real fixed tuner.

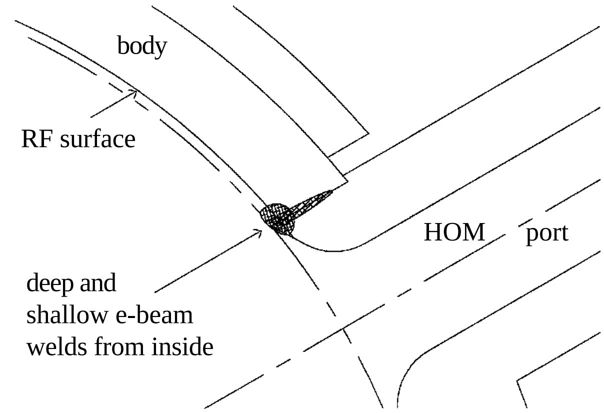

Figure 3: HOM port electron beam welds. Deep weld and shallow re-melt are both made from the inside; the RF surface is cut afterwards.

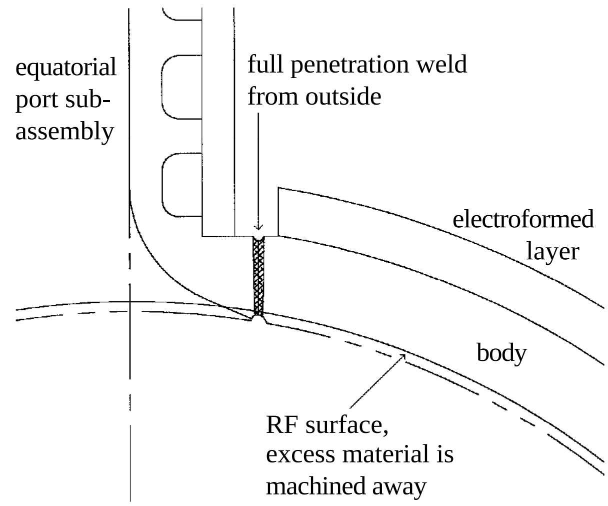

Figure 4: Equatorial port electron beam weld joint. Weld is full penetration from the outside, about 2 mm is removed from the inside during final machining.

The HOM-side nose cone and a larger "lid" containing the other nose cone are then electron-beam welded in place, the main structural welds being done from the outside with cosmetic welds done on the inside through the beam-port openings, figure 5.

After inspection and final cleaning the flanges are TIG welded in place and the cavities are mounted in a support raft, figure 6, plumbed and prepared for high-power testing.

IV. TESTING

It is intended to test all cavities as complete assemblies, with windows, couplers and HOM loads attached, before installation in the tunnel. The cavities will be fitted with fixed and movable tuners, pick-up loops etc., and placed in the test bunker. The cavities will be RF conditioned starting with a low-power, low-duty cycle pulsed mode and working up to full power and CW operation, while monitoring cavity vacuum and window performance. The first cavity will be tested this summer using the existing 500 kW test stand.

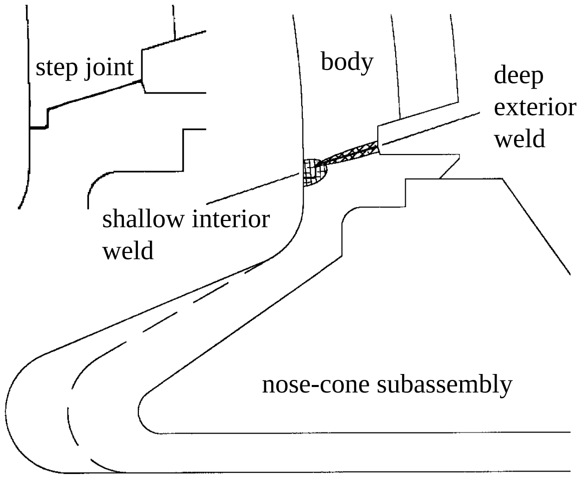

Figure 5: Electron-beam weld joint between cavity body and nose-cone subassembly. Main weld is done from the outside and crack is sealed by shallow interior weld. The step in the joint makes for positive alignment.

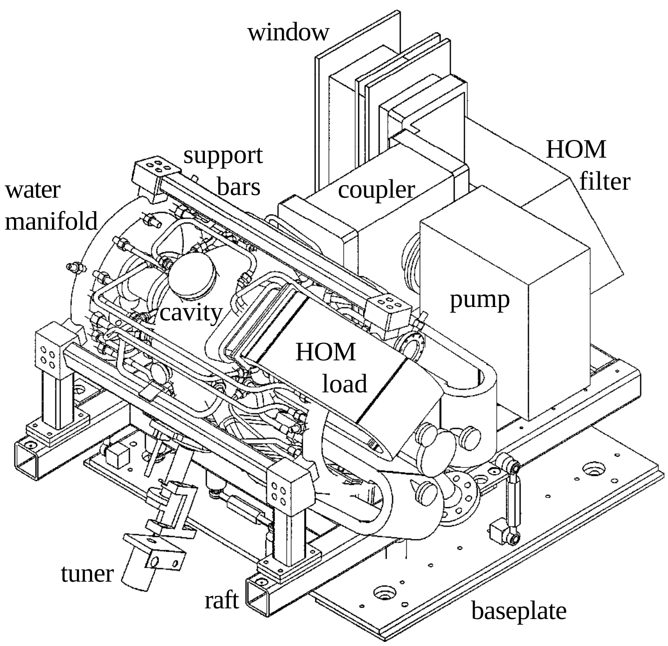

Figure 6: Cavity, coupler, window, tuner, pump and HOM loads mounted on raft for installation

V. INSTALLATION

The tested RF cavity raft assemblies will be delivered to the tunnel in a clean condition and installed in the straight-section vacuum beam-line. The waveguide will be connected to the klystron gallery and the water manifolds on the raft will be joined to the supply and return lines by flexible hoses. All electrical and control cables to the raft will be joined locally to simplify installation and maintenance. In the high-energy ring each klystron will power four cavities while in the low-energy ring, which has higher current, each station will power only two cavities [5]. Cavities will be pre-surveyed to datum points on the raft superstructure so that alignment in the tunnel, using adjustable struts under each raft, can be accomplished with the more easily accessible raft datum points.

VI. PRODUCTION

Cold-forming of the bowls from plate minimizes material waste while the cost of the dies can be amortized over the production run. Lack of heat in the process minimizes migration of oxygen through the copper, while work hardening improves the machinability of the material. The CNC machining is cost-effective for large-scale production because the investment in tooling and programming is similarly amortized over a large number of cavities. In production, the parts will be processed in batches to make the most efficient use of the machine set-up for each manufacturing step. Alternative means of covering the port cooling channels may be entertained for the production run of cavities because of the relatively high cost of machining the components to the tolerances required for reliable brazing.

VII. CONCLUSIONS

Fabrication of the first high-power cavity has provided many lessons which have been incorporated in the plans for the production cavities. Process development, particularly in the areas of electroforming and deep-penetration electron-beam welding of copper have given us confidence that we have a reliable and repeatable fabrication method.

VIII. ACKNOWLEDGMENTS

This paper describes the work of a large group of people, too numerous to credit individually, who have contributed to the design, fabrication and testing phases of the cavity project.

IX. REFERENCES

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