An Economical Solution for a High Quality 500 MHz RF Cavity for the SRS Booster Synchrotron.

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Abstract

Various construction techniques were investigated for the manufacture of a high quality 500 MHz RF cavity for the 600 MeV SRS booster synchrotron. The paper describes the adopted economical solution, which employed a temperature sequence of vacuum brazing for the copper-copper and copper-stainless steel components together with TIG welding for stainless steel bonding.

1.INTRODUCTION

For a number of reasons it was decided to construct a spare RF cavity for the SRS booster synchrotron. The RF system requirements for the booster synchrotron are modest, so the cavity could be simple. However, it was decided to use the opportunity to investigate various construction techniques with a view to produce an economic cavity capable of dissipating 40 kW.

2. SPECIFICATION

Radiation loss/turn at 600 MeV	4.5 keV
Maximum energy gain/turn	2 keV
Maximum beam current	20 mA
Maximum cavity coupling factor, β	2.5:1
RF frequency	500 MHz
RF power available	150 W
This implies the following,	
RF power to the beam at 600 MeV	90 W
Minimum power dissipated in the cavity	60 W
If allow effective voltage of 20 kV, then	
Transit time corrected shunt impedance	3.33 MΩ

3. CONSTRUCTION TECHNIQUES

3.1 De mountable Cavity

A modified pill-box copper cavity with re-entrant nose cones constructed with de mountable body, end plates, and nose cones bolted together using knife edge type seals for vacuum joints was considered and rejected because of the unreliability of the joints making both good RF and vacuum connections.

3.2 De mountable Cavity with Ceramic Vacuum Tube

A similar de mountable cavity as above but with a vacuum tight ceramic tube was considered. Figure 1 shows the E field concentrated in the ceramic, reducing the component on the axis, and therefore the shunt impedance. This design is used in klystron cavities where the shunt impedance is of less concern, but for an accelerating cavity the shunt impedance of 1.35 MΩ for this design is insufficient.

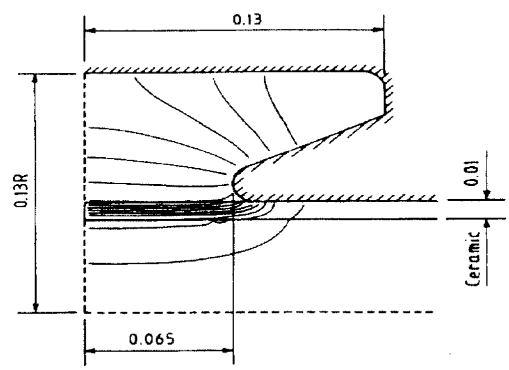

Figure 1 Field configuration of cavity with ceramic tube

3.3 Stainless Steel Cavity

The E field of a welded stainless steel "simple" re-entrant cavity is shown in figure 2. URMELT calculates a shunt impedance of 1.25 MΩ, and since the resistance of stainless steel at 500 MHz is a factor of 2.4 greater than that of copper, an input power of 144 watts would be required to obtain the required nominal voltage.

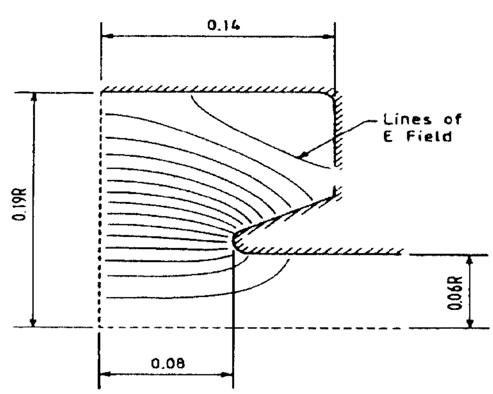

Figure 2 Two dimensional cavity design

3.4 Copper Plated Stainless Steel Cavity

A cavity as in section 3.3 could be constructed, and after extensive RF testing could be copper plated. This scheme was rejected for this exercise because of the time needed to develop techniques to overcome the difficulty in achieving good adhesion of the copper to the stainless steel and the uniform plating over the whole of the internal surface of the cavity. Experience from other laboratories has shown that under various conditions delamination of the copper could occur. Magnetron sputtering of the copper was considered, but investigation of this technique was deferred to a later date.

3.5 A Vacuum Brazed Copper Cavity.

A vacuum brazed copper cavity could meet all the requirements. An optimised three dimensional MAFIA [2] model is shown in figure 3, the boundaries are irregular due to the rectangular mesh.

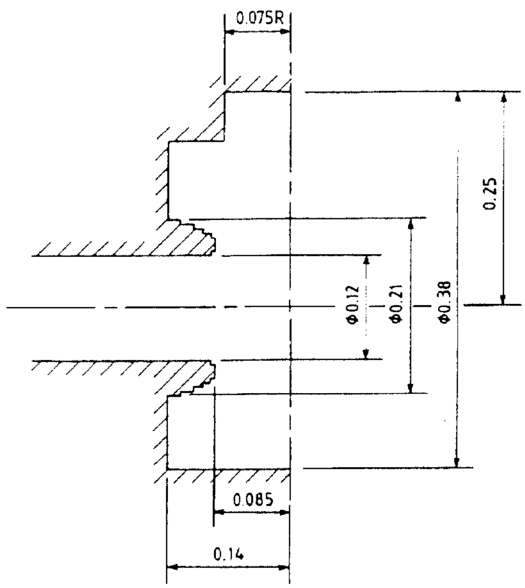

Figure 3 Three dimensional cavity design

This model included the coupling aperture, but not the probe port as this would only cause a small perturbation. The predicted parameters were as below.

Resonant frequency	500 MHz
Shunt impedance	3.3 MΩ
Unloaded Q	30600

4. MECHANICAL DESIGN.

The cavity was manufactured from OFHC copper, to BS 3839, forgings and 304L stainless steel for the flanges. The contract was let to Vacuum Generators, Telford, and AEA Technology, Culham were the sub-contractors for the vacuum brazing. Figure 4 is a sectional view of how the finished cavity should look.

The manufacture used a step brazing technique, where the brazing took place in 3 stages at 3 different temperatures, ensuring that the initial brazes do not liquefy during subsequent braze stages. Table 1 details the braze details.

A dull nickel (100% nickel - no additives or impurities) coating was required on all the stainless steel components in the braze areas. This coating inhibits the diffusion of chromium to the surface of the steel, promoting good wetting of the filler material during the flux free brazing. The coating has to undergo a 900°C blister test to ensure that peeling, blistering, cratering, exfoliation or loss of bond strength does not occur during the brazing process. The coating is 6μm ±2μm thick.

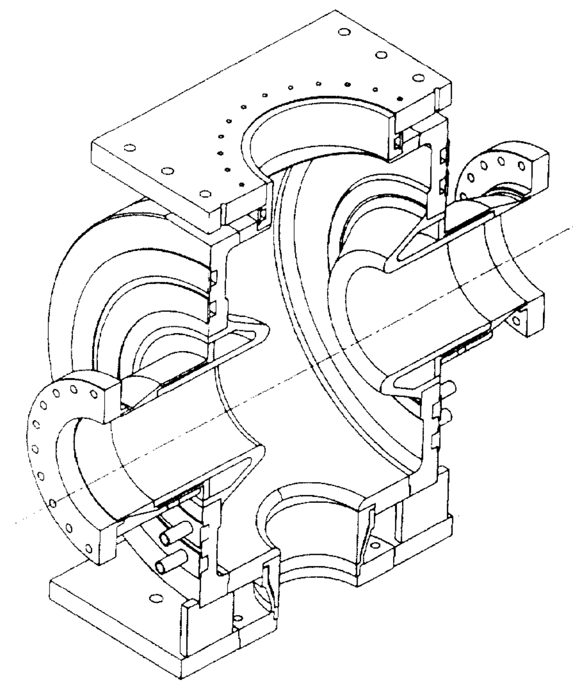

Figure 4 Sectional view of finished cavity.

1st Stage Braze

Temperature	930°C
Braze Material	PD4 - Pallabraze 880
	15% palladium: silver: copper fluxless
Used on	Initial sub-assemblies, ports, etc.

2nd Stage Braze

Temperature	860°C
Braze Material	PD4 - Pallabraze 840
	10% palladium: silver: copper fluxless
Used on	End plate assemblies.

3rd Stage Braze

Temperature	820-830°C
Braze Material	PD4 - Pallabraze 810
	5% palladium: silver: copper fluxless
Used on	End plates to body

Table 1 Brazing Procedure

Before the 3rd stage braze the end plates were clamped to the body for RF testing and frequency tuning.(See section 5)

After completion of the brazing stages the stainless steel flanges were TIG welded to the cavity.

5. RF TUNING

RF measurements before the final braze gave the surprising result of the RF frequency being approximately 9.5 MHz high. Close examination of all the detailed drawings and computer readouts showed that a simple translation error in the positioning of the nose cones had occurred. Modelling the actual cavity with MAFIA produced a result within the expected error of less than 2 MHz.

Use of the computer code URMEL-T predicted that by reducing the overall length of the cavity body by 31mm, i.e. bringing the nose cones nearer to each other (increasing the capacitance), the cavity could be made to resonate at the required frequency. However this would make the overall length of the cavity fall outside the allowable limits on length. A second method is to cut an annulus in each end plate (increasing the inductance). Both the depth and the diameter of the annulus was limited by the thickness of the end plate, position of the cooling water channels, and the position of the nose cones. In the end a combination of both techniques was used. Figure 5 is a graphs showing the change in resonant frequency as a function of distance between nose cones and size of annulus cut in the end plates.

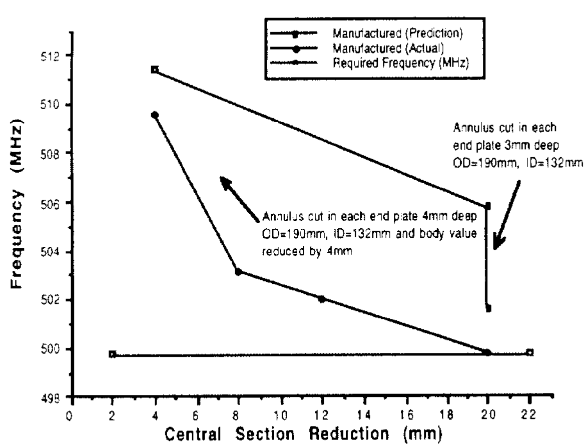

Figure 5 Resonant Frequency as a function of distance between nose cones.

The mechanical tuning was relatively simple as the end plates and cavity body had not been braze together at this stage. A resonant frequency of 499.7 MHz was achieved by reducing the overall length of the cavity body by 20mm, and cutting an annulus of 4mm deep with an outer radius of 190mm and an inner radius of 132mm in each end plate.

6. RF MEASUREMENTS

The RF parameters of the finished cavity were measured using the new low power test rig. [3]

Resonant Frequency	499.5 MHz
Shunt Impedance	3.0 MΩ
Unloaded Q	26,500

7.CONCLUSIONS

This technique has proved useful in producing an economical cavity with the required parameters. The stepped brazing technique has proved successful, and the ability to. easily and quickly mechanically tune the cavity before the final braze proved important.

Copper plating of stainless steel cavities, using magnetron spluttering is now being investigated.

8 ACKNOWLEDGEMENTS

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