

Design of a Tuner and Adjustable RF Coupler for a CW 2856 MHz RF Cavity*

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ABSTRACT

A tuning plunger and an adjustable RF coupler have been designed at AECL's Chalk River Laboratories for a CW 2856 MHz RF cavity for the MIT-Bates South Hall Ring. The tuner provides a frequency range of 1.1 MHz with a frequency resolution of less than 0.5 kHz. The high-power RF drive coupler uses iris coupling and a set of coupling factor (β) adjustment posts to provide fixed β -values from 1 to 10. This paper describes the RF design, mechanical design and performance of these units.

INTRODUCTION

The 2856 MHz RF cavity required by the MIT-Bates South Hall Ring, and described elsewhere,¹ places heavy demands on the cavity's tuning and RF coupling systems. The high average dissipated power, up to 10 kW CW, and a wide range of beam-loading conditions, covering both pulse-stretcher and storage modes of operation, require tuning and coupling systems with a wide range of capability. Reference design requirements for the tuner and RF coupling system are given in Table 1 and Table 2, respectively.

Table 1: SHR Cavity Tuner Specifications

Cavity Frequency	2856.000 MHz
Frequency Range	± 200 kHz
Tuning angle precision	$\pm 0.5^\circ$

TUNER DESIGN

The tuning range specification of 200 kHz covers the expected range of cavity detuning required for beam-loading compensation. However, additional tuning is required to compensate for an approximate 350 kHz frequency shift from thermal expansion of the cavity body at 10 kW dissipated power, and for a frequency shift of up to 200 kHz caused by changes in the RF coupling factor. Consequently, the tuner

Table 2: SHR Cavity RF Coupling Specifications

Design power	> 20 kW
Input line	WR284 waveguide
Input coupling VSWR	< 1.8:1
Coupling factor, β	Adjustable up to 10 in fixed steps

design has over 1000 kHz tuning range about 2856 MHz.

A cross-section of the cavity in the tuner plane is shown in Figure 1. The 12.7 mm diameter tuner plunger is centered in a 15.9 mm diameter hole in the cavity wall. The plunger surface facing the cavity centre is restricted from any position closer to the centre than the cavity wall. This constraint reduces the maximum frequency shift possible, but also reduces the RF dissipation on the plunger. The measured frequency range with this tuner is shown in Figure 2.

The tuning plunger is water cooled using internal coaxial cooling lines, where the water flows down inside the outer wall of the plunger and returns up the centre. Provision has also been made for a small-diameter line to the high-vacuum region inside the tuner. This can be used to provide additional

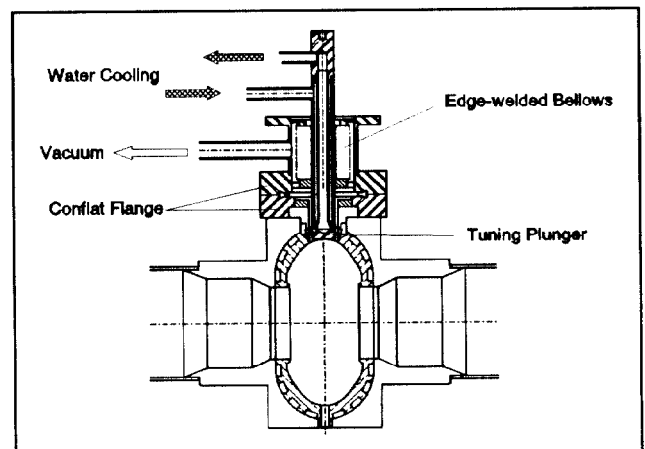


Figure 1: Cross-section of Cavity and Tuner

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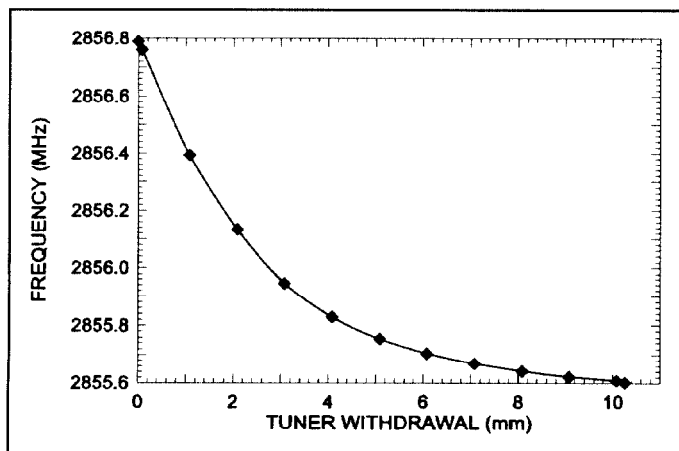


Figure 2: SHR Cavity frequency as a function of tuner withdrawal from a position flush with cavity wall.

pumping in this area if out-gassing is a problem during initial testing. No sliding RF contacts are used between the tuning plunger and the hole walls in the cavity.

At the tuner position nearest the cavity wall, the frequency gradient is almost 400 kHz/mm. When the RF coupling factor, β , is 1 (critical coupling), the frequency shift required to produce a tuning angle change of 0.5° is less than 1.5 kHz or, equivalently, a tuner position shift of less than $3 \mu\text{m}$. A standard, commercial linear actuator, a VP30-10 Stepping Motor Driven Actuator, from Klinger Instruments, operates the bellows. It provides 10 mm of linear travel in $1.0 \mu\text{m}$ steps. This provides a tuning angle precision of better than $\pm 0.2^\circ$ for all β . A shaft encoder monitors the actuator position, with limit switches and origin reference included in the actuator.

RF COUPLER DESIGN

Initially, inductive RF input coupling was considered. Typically, this uses a drive loop at the end of a coaxial line. The coupling factor, β , could be adjusted by rotating the drive loop at the cavity wall. However, the size of drive loop and coaxial line suitable for an S-band cavity would be too small to handle over 20 kW CW RF power. The RF losses in the small line would cause excessive RF dissipation that cannot easily be cooled.

Upon further examination, an RF coupling design based on aperture coupling was considered much more reasonable. Aperture coupling is often used on S-band accelerator structures, but usually with a single, fixed coupling factor. The design strategy was then to find an aperture coupling design with $\beta=10$, and provide a method for reducing the coupling without excessive shifts in the fundamental (TM_{010} -mode) frequency. An adjustable capacitive post, located in the drive waveguide at the first minima in the standing electric field pattern, was selected to adjust the coupling.

A cold model to test this technique was fabricated with two different electric field tapers in the waveguide before the

coupling aperture. The $\lambda/4$ taper produced a coupling factor over 7.0, and the longer, $\lambda/2$ taper produced a coupling factor of 9.5. In both cases, critical coupling, $\beta=1$, could be achieved using a metal post penetrating across the guide approximately $\lambda/4$ away from the iris. An alumina post was also tested. In this case, a substantial range of β was possible, but critical coupling could not be achieved. The maximum change in cavity frequency produced by the post was less than 250 kHz. The improvement in the coupling with the longer taper is caused by the better match between the different waveguide heights produced by the longer taper.

The final RF coupler design is shown in Figure 3. A $3\lambda/4$ taper, made from three separate linear $\lambda/4$ sections approximating an exponential taper, was selected to provide the match between the WR-284 waveguide and the 5 mm high coupling aperture in the cavity. The long taper is essential because of the large reduction in waveguide height required. Calculations of the matching section indicate that the VSWR through the taper is less than 1.2. The 5 mm aperture height is necessary to minimize the perturbation on the cavity cooling channels. This height is sufficiently small to fit between the main outer cooling channels at the mid-section of the cavity. The coupling is only weakly dependent on this height. The aperture also extends 5 mm along the RF propagation direction, again to provide sufficient space for the cooling

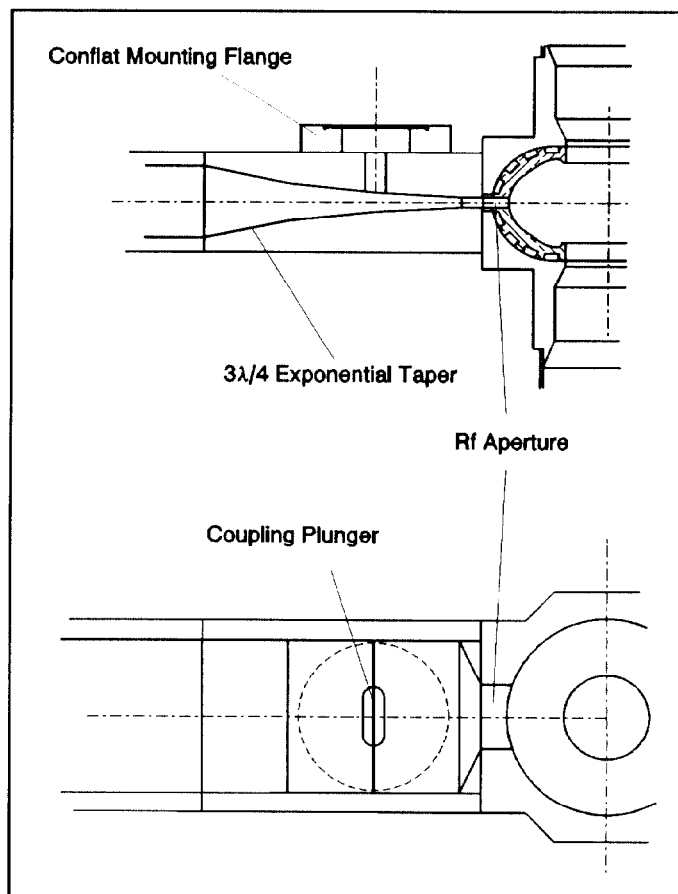


Figure 3: RF Input Waveguide and Aperture-Coupler

channels. Computations have shown that the coupling is not strongly dependent on this thickness, either, provided the thickness is much less than λ .

The post shape and position were selected to provide the full range of coupling required while minimizing the cavity frequency shift produced by changes in the coupling. A set of water-cooled posts was manufactured with varying lengths to cover the full range of β , each brazed to separate 2 3/4" Conflat flanges. The coupling factor can be changed simply by changing posts. Figure 4 shows the effect of coupling post length on the coupling factor and cavity frequency.

CONCLUSION

A tuner and RF coupler for a high-power, 2856 MHz RF cavity have been designed and fabricated at AECL's Chalk River Laboratories for the MIT-Bates South Hall Ring. The tuner is designed to handle high-power dissipation and provide the frequency precision necessary for accurate control of the cavity detuning angle. The RF coupler provides a range of β from 1 to 10 using a set of fixed capacitive posts, positioned to minimize the cavity frequency perturbation. The entire cavity system, including the tuner and RF coupler, is presently at MIT-Bates awaiting final testing and installation.

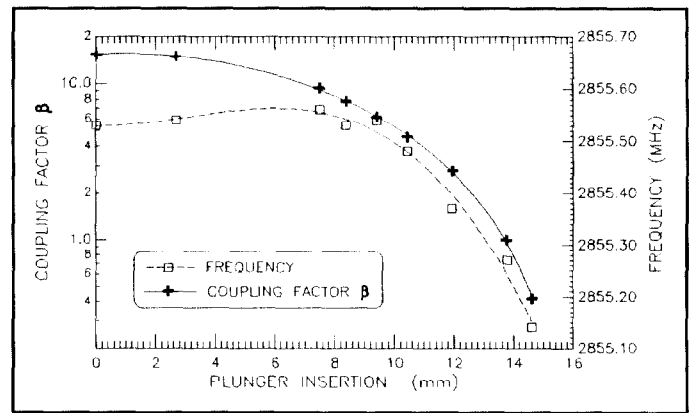


Figure 4: Effect of post length on coupling factor and cavity frequency.

REFERENCES

1. M.S. de Jong, et al., "A 2856 MHz RF Cavity for the MIT-Bates South Hall Ring," in the proceedings of this conference.