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EXPERIENCE WITH A 51-MHz, 200-KV, ALUMINUM RF CAVITY

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Summary

A 51 MHz, 200 KV, Aluminum cavity, in vacuum, has been built, tested and set in operation on the Frascati storage ring. Problems encountered in building, vacuum sealing and conditioning are illustrated. Behaviour on the accelerator is also mentioned.

Introduction

An Aluminum RF cavity entirely under vacuum has been built and recently set into operation on the Frascati storage 1.5 GeV ring. Its frequency is 51.4 MHz, the 18th harmonic of the revolution frequency. We intend here to illustrate our experience in testing and conditioning the cavity. Although there are now many examples of vacuum cavities in this frequancy range, we think it useful to summarize here the difficulties encountered in setting into operation such kind of resonators, especially if made of Aluminum. In fact we had ourselves some difficulties in finding literature on the subject during our work.

The parameters of the cavity are shown in the following table:

$f_o = 51.4$ MHz
$Q_o = 1.5 \times 10^4$
characteristic impedance $Z_o = 100\ \Omega$
$R_{SH} = QZ_o = 1.5\ M\Omega$
voltage foreseen for operation 200 KV peak

A section of the cavity with the main dimensions is shown in Fig. 1.

Length = 1.33 m; Diameter = 1.2 m

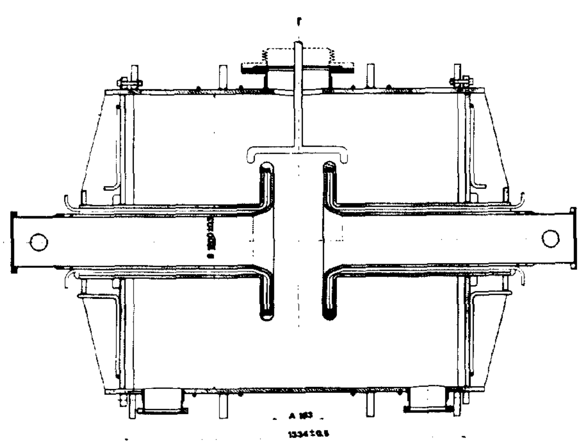

Fig. 1 - Section of the cavity.-

The design has been based on a previous experience made at SPEAR in Stanford[1]. The cavity can be opened by removing the end plates together with the reentrant electrodes.

Vacuum tightness is ensured by metal gaskets at the outer diameter of the plates. Near to the gaskets but distinct from them are situated the RF contacts, that are obtained by pressure between metallic surfaces. These contacts are therefore situated in a region of maximum circulating current. We made this choice because we wanted to use capacitive tuning by a "saddle tuner" centered across the plates (Figs. 1, 2) and to have easy access to all parts of the cavity both for welding and for trouble shooting. Uniformity of contact over such a large circumference may not be well ensured, so this solution has some drawbacks due to overheating of some zones on the circumference at high power levels.

Fig. 2 - Inside view evidencing saddle tuner and coupling loop.-

The cavity is entirely made of Aluminum; there are Aluminum stainless steel transitions to the flanges for connections to the outside. Cooling is provided by pipes welded to the surfaces, both for the outer envelope and for the reentrant electrodes. We have thus avoided direct weldings between vacuum and water, that have given leakage troubles in similar cases.

Cavity conditioning

Immediately after mechining the cavity inner surface was cleaned with acid solution (< 1% HCl + nitric) and rinsed with organic detergent (Methyl-ethyl-ketone). Vacuum was obtained by roughing with rotary fore pumps with LN_2 traps; then turbomolecular 200 lt/sec pumps to start two Ti triode pumps 400 lt/sec each (Varian). Vacuum behaviour was good. With modest outgassing at ≈ 100°C by turbomolecular pumps for 24 hrs, the pressure reached was 5×10^{-9} Torr, corresponding to a specific outgassing rate of about 2×10^{-11} Torr lt/sec cm^2. There was a strong H_2 peak, some CO and CO_2 and no significant masses above 44.

We encountered the usual difficulty in trying to feed RF into the cavity for the first time. Multipacting levels were overcome by prolonged pulsing with pulses having steep rise time and growing duration (from a few to 100 μsec and a few Hz repetition). Particularly troublesome was a high voltage level multipacting threshold at about 60 KV peak, which cannot be

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explained by discharges between the plates. These gave rise to expected levels up to about 10 KV. The high level may be due to discharges between the border of the plates and the outer cylinder.

In Fig. 3 we show a typical photo of the tail of an RF pulse in the cavity (detected by a small loop) on which can be seen the multipacting levels, evidenced by an abrupt change of the slope. When we at last after a few hours succeeded in feeding CW RF at about 20 KW power level, vacuum deteriorated to $\approx 10^{-6}$ Torr.

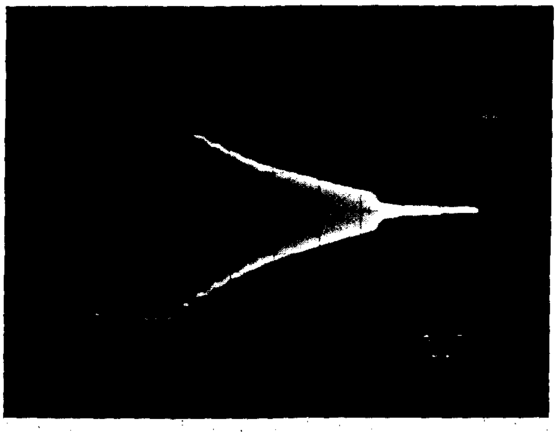

Fig. 3 - Tail of an RF pulse, evidencing multipacting levels. Vertical scale 100 KV/cm.-

After these first tests the cavity had to be reopened to improve the saddle tuner cooling. The necessary mechanical operations took several weeks to be completed. During this period the cavity surface was exposed to air and, besides being oxidized, it was probably dirtied during assembly operations.

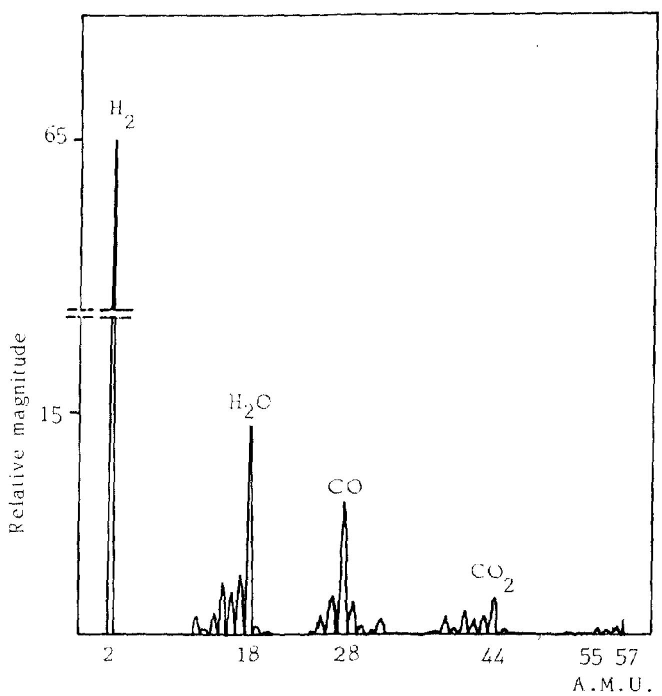

Fig. 4 - Without RF; $P = 5\times10^{-9}$ Torr.-

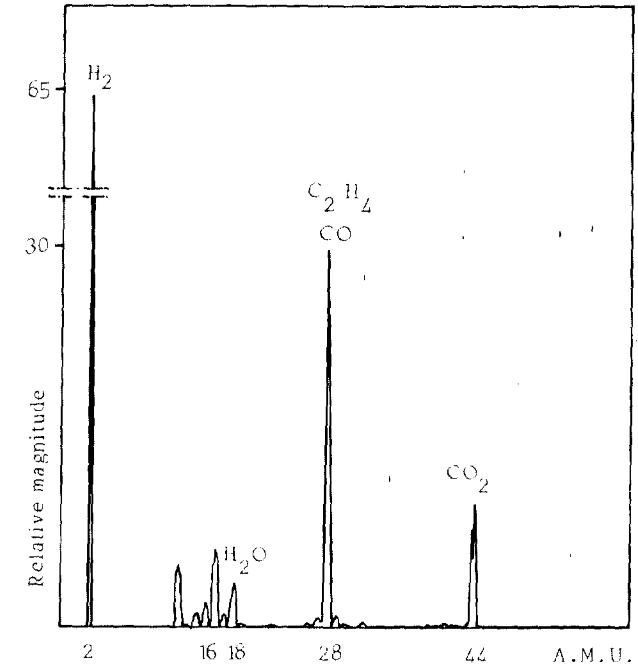

Fig. 5 - With RF; $V_p = 110$ KV; $P = 2.5 \times 10^{-7}$ Torr.-

Due to these causes, after reassembly and evacuation we were not able to feed CW RF again into it. Attempts to clean the surface with organic solvents (alcohol and acetone) were unsuccessful because of residual high mass molecules (and their fractions) from the solvents themselves. We were obliged to make a thorough cleaning all over again, with the following phases:
- No organic solvents employed; surface abrasion with fine mineral powder; rinsing with tap water; cleaning with acid solution (2% HCl, 0.6% HF); rinsing abundantly with distilled water; closing the cavity with wet surface. We used metal gaskets on the main flanges (Sn-Ag 95/5). Initial pump-down was made with rotary pumps to eliminate water; then with Zeolite pumps to reach Titanium triode pumps starting point. By outgassing for 20 hrs at 70°C we reached 5×10^{-9} Torr. We then heated again for 48 hrs at $\approx$ 140°C and reached 6×10^{-10} Torr.

In Figs. 4, 5 are spectra relative to this last situation. With RF on, Hydrogen is still the highest peak (95% taking into account the ionization coefficient).

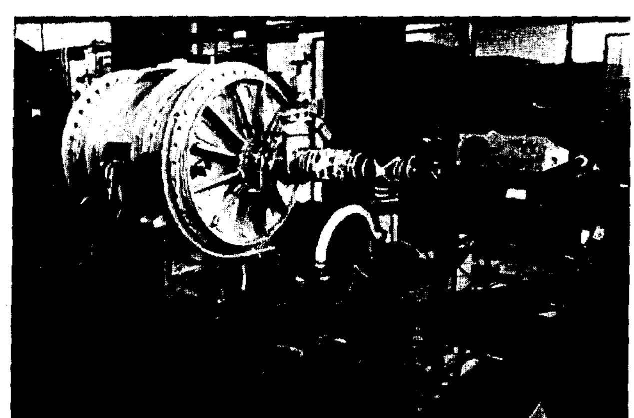

Fig. 6 - Assembled cavity during evacuation.-

Together with the expected increase of the 28 AMU peak (CO or $C_2 H_4$) there is the presence of 12 and 16 AMU peaks probably due to residual traces of solvents.

In Fig. 6 is shown the assembled cavity during evacuation. After prolonged conditioning at high RF voltage levels, the operating pressure up to 200 KV peak was about 10^{-8} Torr. Above 150 KV there is a strong emission of X rays; this threshold is in relation with the thickness of the cavity walls.

Care must be taken to screen the cavity for personnel safety.

Conclusions

The cavity has been installed on the Adone storage ring and operates satisfactorily up to 200 KV peak with a local pressure of about 10^{-8} Torr. Above this voltage the pressure rises steeply, maybe due to bad contacts on the main flanges, with local overheating, or to insufficient conditioning at high voltage level. We plan to try a different kind of metal gaskets. The behaviour with beam loading is satisfactory. Synchrotron light seems to have no relevant effect on the gap. There seem to be no dangerous upper resonance modes to influence beam stability.

References

1 - M.A. Allen: SLAC Report No. 78 - Oct. 67.
2 - H.Gerke: Das PETRA Cavity; DESY PET-77/08, Aug.77.
3 - H.Gerke: DESY M-79/28, Dec. 79.
4 - DCI Cavity, ORSAY, Private Communications.