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CHOICE OF RF CAVITY IMPEDANCES

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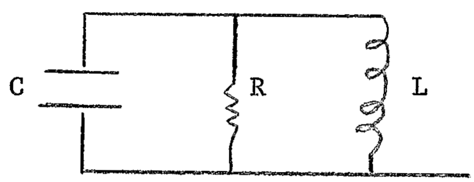
Consider the equivalent circuit of an rf cavity shown in the figure.



The circuit Q is given by $Q = R\omega c$ or in the spirit of the equivalent circuit, we use R to represent the losses in the ferrite $R = \frac{Q}{\omega c}$. Define a characteristic cavity impedance $Z_o = \sqrt{\frac{L}{c}}$, then $R = QZ_o$. The power dissipated when driving the cavity to a peak voltage V_p is then $P = \frac{V_p^2}{2QZ_o}$. To economize on power and power associated costs, cavities are normally designed with as high Q and Z_o as practical subject to constraints from tunability, etc. The beam itself is a current source which induces voltages in cavities causing various usually undesirable effects on the beam. The voltage is given by $I_f Z$ where I_f is the appropriate beam Fourier component and Z the relevant impedance. For the resonance frequency, $Z = QZ_o$. For very high frequencies, $Z = \frac{\omega_o}{\omega} Z_o$ where ω_o is the resonant frequency. Obviously, to reduce these beam induced effects, the Z_o should be kept as low as possible. At resonance, if these voltages are important Q should also be kept low. These requirements are diametrically opposite to the power considerations and clearly some compromise must be sought.

Similarly, the number of cavities enters the picture. To achieve V_t peak volts per turn with n cavities, we have

$$V_p = V_t/n$$

$$\text{Power} = n\,\frac{\left(\frac{V_t}{n}\right)^2}{2Z_oQ} \sim \frac{1}{n} \quad .$$

Note that power per cavity goes like $\frac{1}{n^2}$. The beam induced voltage per turn is n I_f Z. Thus, again, power considerations and beam induced effects suggest opposite tendencies in choosing the number of cavities.

Some recent observations on the AGS indicate four possible phenomena caused by beam induced voltages on the cavities. These are:

1) Beam induced voltage on the cavities during rf capture. It is not at all clear at the present time if this voltage is harmful but it certainly complicates the understanding of capture and no known model suggests it is useful. It would, therefore, be desirable to reduce this voltage.

2) Waveform distortion causes a bad phase space mismatch at transition. This problem is quite serious at times. It can possibly be a alleviated by nu-shift tricks, etc., but it would be desirable to reduce the source of the effect.

3) Possible coherent longitudinal instabilities during acceleration and bunched flat top. It is believed that if tuning servos track sufficiently well, this should not be a problem up to about 10^{13}. However, reduced coupling (from lower impedance) would be desirable.

4) Self bunching during flat top. This problem is quite serious during current operation. Some tricks are available such as increasing the energy spread or reducing the effective impedance by selecting the parking frequency of the cavities. These are really stop-gap solutions. A better solution would be a reduction in impedance.

It appears from these four effects that a lower cavity impedance would be desirable. Given a configuration of ferrite, the only readily adjustable parameter is the number of cavities. It would be most useful to start a program to short out the gaps on some cavities raising the power of the remaining cavities to provide adequate drive. If the number of cavities could be reduced from ten to six, the current operational problems would occur at 1/0.6 times the current intensity. Six cavities running at design rating of 10 keV/gap (which is considerably higher than present operating practice) should give adequate accelerating voltage. These cavities have been tested to 12 keV/gap.

This procedure gives an improvement of 1.6, but at some cost. The reliability will suffer from pushing the equipment to power limits. Surely, shorting bars can be devised to permit rapid (30 minute) cavity changes leaving up to four installed spares in the ring in low radiation areas. The program to arrive at six cavity operation should be designed to insure the most reliable possible operation.

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