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A COMPACT RF SYSTEM FOR A 30-INCH AVF CYCLOTRON

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This paper describes the RF system for the 30-inch AVF cyclotron developed by The Cyclotron Corporation.[1] A discussion of the design considerations and a summary of the performance achieved are included. Several unique design features are discussed.

The 30-inch AVF cyclotron requires a high energy gain per turn and an adjustable frequency RF system. Such features as convenience, economy, and compactness were also major considerations for a system that is to be marketed commercially. In order to determine what type of accelerating structure would best meet these requirements, three alternatives were considered. Two small dees operating on the third harmonic of the ion rotation frequency were first investigated. The high energy gain per turn with low power available from such a system appeared, however, to be more than counterbalanced by the accuracy which would be required of the magnetic field profile. First harmonic operation was deemed particularly important since we planned to accelerate well beyond $\nu_r = 1$ into the non-isochronous portion of the field.

A single 180° dee was considered next. The primary advantage of this system would have been increased room for the extraction system. Its major disadvantage is, of course, the lower energy gain per turn since the peak RF voltage is determined by the minimum dee-to-ground clearance.

The system finally chosen was two 120° dees with a dee-to-ground clearance of ½ inch. This system supports dee voltages of 40 kV, which makes possible maximum voltage gains of 135 kV per turn. This provides a comfortable margin over the nominal operating level of 100 kV per turn. The complete measured specifications for this system are tabulated in Table I.

TABLE I

Hill Gap	4"
Valley Gap	2"
Dee Aperture	.8"
Minimum Dee-to-Ground	.5"
Maximum Dee Voltage	40 kV
dc Input for 40 kV on Dee	26 kW
Frequency Range	12.5 - 25 Mc/s
Frequency Stability	± 200 c/s
Dee Radius	14.5"
Resonator Size	60" x 10" x 33"

Having chosen a dee structure, a resonator was designed to achieve the desired frequency range. Important considerations in the resonator design were economy of RF power and compactness. The design selected is illustrated in Fig. 1. Rather than use a complete liner, the cyclotron hill iron was copper plated, which leaves the full valley gap under approximately half of the dee area. This reduces dee capacity, permitting a higher maximum frequency as well as lower RF power. The dee stems pass through two vacuum insulators into the vertical resonator chamber. The frequency is adjusted by connecting the dee stems by straps of different impedance and length. Thus, for 25 Mc operation, a short, low-impedance strap is used and for 12.5 Mc operation, a long, high-impedance strap is used. Adjusting the frequency of the resonator is easily accomplished by opening the back of the resonator and changing straps. The resonator box is constructed of one-inch-thick plywood and lined with copper sheet. This copper lining, as well as the dee stems and connecting straps, is water-cooled.

Since the resonant structure is a foreshortened half-wave line, it has a voltage node at its midpoint. This voltage node is a convenient point to introduce a dc bias onto the entire dee structure. One important benefit from this bias is that it provides a clearing field to sweep out ions that might otherwise damage the insulators. The most important aspect of the bias, however, is that it shifts the multipacting voltage to a point where the oscillator can start.[2]

In the interest of economy, ease of operation, and maintenance, a power oscillator was selected as the source of RF power. The grounded grid circuit employed is illustrated in Fig. 2. In this circuit, the anode and cathode circuits of the power triode are isolated by the grid structure and the internal construction of the oscillator box. Both the anode and cathode circuits are coupled to the resonant dee structure by resonant coupling loops.[3] These loops are located in the resonator such that there is very little mutual coupling between them. Thus, feedback required for oscillation is obtained from currents circulating in the resonant dee structure which is strongly coupled to both loops. This type of circuit produces a very stable oscillator which excites only resonator modes. Even when accelerating 15 kW of beam power, the oscillator is stable. The oscillator requires tuning only when gross changes in frequency are made. This tuning only involves adjusting the capacitors which foreshorten the anode and cathode loops.

The anode loop is a foreshortened quarter-wave line, while the cathode loop is a foreshortened half-wave line. This arrangement, dictated by the coupling geometry, is particularly fortuitous in that the phase shift inherent in each of these resonant coupling circuits are in opposite directions and tend to cancel. The oscillator tube is a Machlett 6424 which has an anode rating of 20 kW and a maximum RF output of 30 kW. The net RF output during normal operation of this circuit does not exceed 20 kW. The oscillator tube is protected by a crowbar circuit which resets automatically. Besides protecting the tube, this circuit provides a useful means of "baking in" the RF structure.

The over-all power requirements and frequency response of the RF system were predicted using a two-dimensional analysis.[4] The measured results agreed almost exactly with respect to frequency and required about 10 per cent more power than predicted. There is no measured or theoretical evidence that the 90° bend in the plane of the RF system causes a large increase in the RF power.

An automatic frequency control circuit maintains the RF frequency of the RF system constant to within ± one part in 10^5. This is accomplished with a stable tuned frequency discriminator whose amplified output drives a Schmitt trigger. The resonator frequency is then adjusted by means of a panel in the resonator box which is driven by a stepping motor.

About a year of operating experience with the RF system reported here has proved it to be reliable and easy to operate. This system is now standard on The Cyclotron Corporation's Model CS-15 cyclotron.

Acknowledgment

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References

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Abstract

A high degree of stability, simplicity, and compactness has been achieved with the RF system in operation on a new 30-inch AVF cyclotron. The over-all size of this RF system has been reduced by bending the resonator from the horizontal to the vertical plane so that the RF system extends only 24 inches beyond the cyclotron coils. The resonant structure is a half-wave line terminated in two 120-degree dees. The dee capacity has been reduced by copper plating the cyclotron hill iron, which leaves the full valley gap under a large portion of the dees. The RF frequency, which is the same as the ion rotation frequency, is quickly and easily adjusted from 12.5 to 25 Mc by changing straps in the resonator which is in air. The system is powered by a grounded grid oscillator which uses a single triode. A dee-to-ground voltage of 35 kV at 25 Mc is routinely obtained with 30 kW of dc input to the oscillator. The minimum dee-to-ground gap is ½ inch. Other features of the system include biasing of the entire RF structure to prevent multipacting and a .01 per cent frequency regulation system.

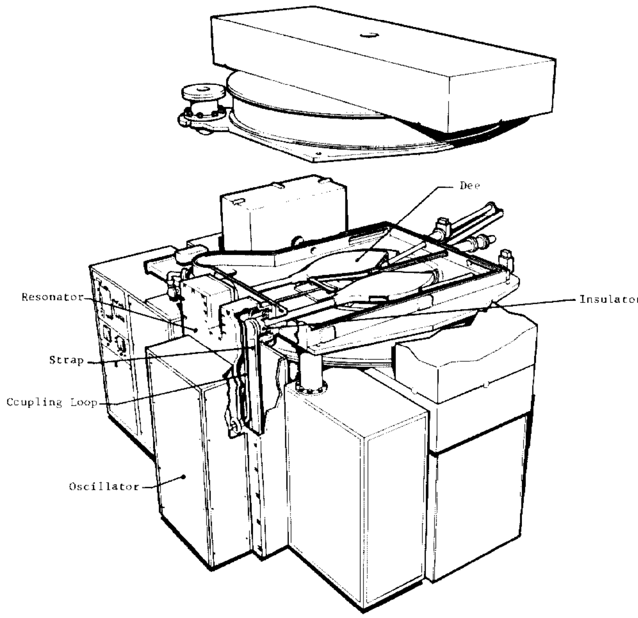

Fig. 1. General RF System Layout.

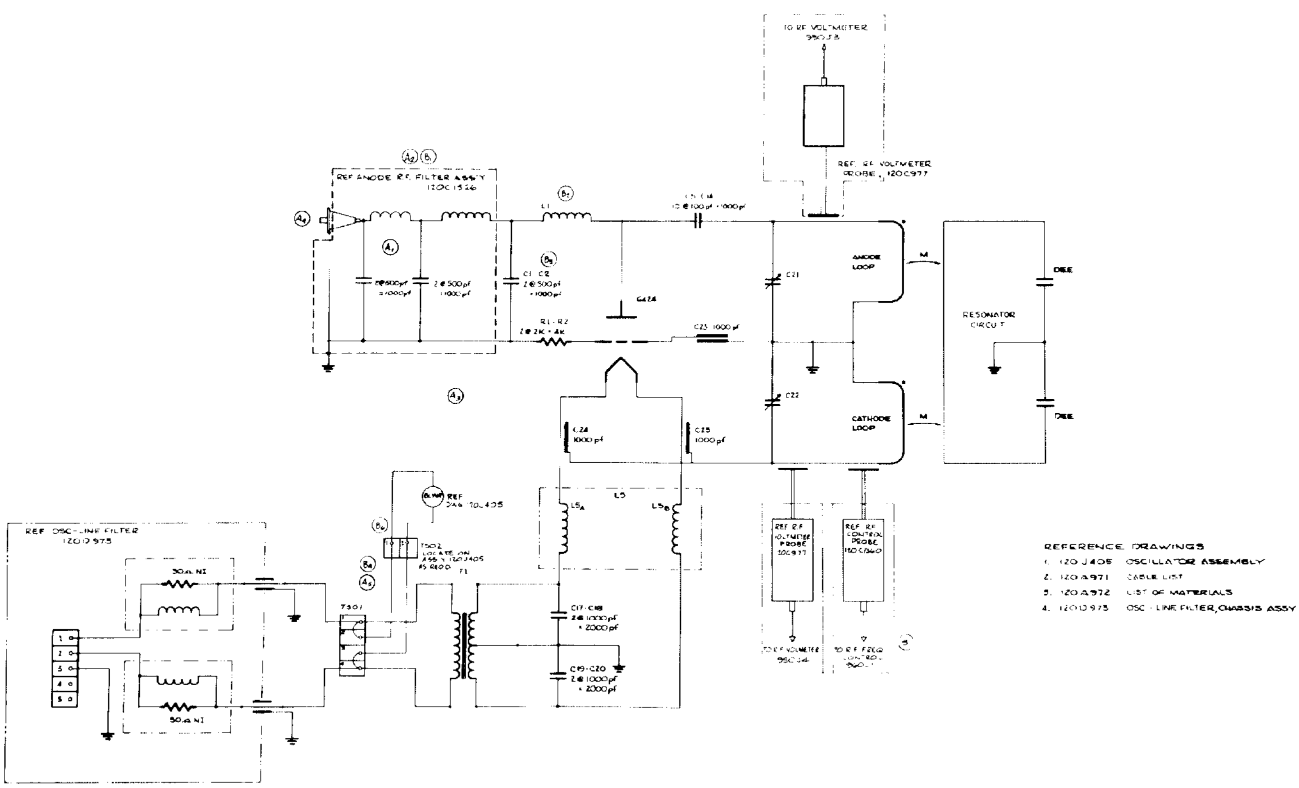

Fig. 2. RF System Schematic.