DESIGN CONSIDERATIONS FOR A DEVELOPMENTAL HIGH POWER COUPLING LOOP TO DRIVE A RESONANT LOAD

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Summary

An rf drive loop has been designed for a 400 kW, 100% duty factor (cw), 270 MHz resonant cavity load. Operating experience with a high power cw Alvarez linac at Chalk River has resulted in the evolution of design features that reduce multipactoring, field emission and rf arc track damage. The design provides means for the development of coaxial vacuum windows, the evaluation of loop conductor shapes and the investigation of rf arc propagation phenomena.

Introduction

The Alvarez accelerating structure for the high current proton linac, ZEBRA, currently under study at CRNL[1,2], will require components capable of operating at much higher average power than is found in present low duty factor accelerators. A 400 kW 100% duty factor (cw) 270 MHz resonant load[3] is being constructed at CRNL as a test facility for the development of drift tube linac components such as tuners, post couplers, drift tube suspensions and drive loops.

A cross-sectional view of the resonant load drive loop design is shown in Fig. 1. The coupling loop is located within the tank vacuum in preference to placing it behind a domed window as the latter is susceptible to failure from multipactoring and ion bombardment damage. Multipactoring, often encountered along the evacuated portion of the drive line, can be controlled. The coaxial window geometry is simple and relatively inexpensive to replace.

The transmission line is designed for 50 ohm constant impedance, including the window which is compensated for the dielectric constant of the window material. To avoid transition discontinuities and to simplify cooling, the radial dimensions were selected to match the 230 mm (9-3/16" commercial) rigid copper rf feedline.

The tank side of the window is located 5/12 λ from the position of the detuned short - i.e., from the detuned electric field node - as determined from electric field probe measurements on a 1:1 scale model of the drive line and resonant load. With this configuration any tank detuning will cause the loop impedance to fall but the voltage at the window remains relatively large, above the higher order mode multipactoring voltage levels.

Structural Features

The loop assembly is made of interchangeable sections for convenience in the development of high power windows and the evaluation of various loop shapes.

A teflon rf window, based on a design that operates successfully at 150 kW cw on an Alvarez linac, will be used for initial tests. The window supporting section can be removed to test designs using other materials, such as ceramics, that would require different vacuum sealing methods and different diameters for impedance compensation. The tapered transition section was made relatively short and free of sharp corners or gaps that might initiate multipactoring or arc discharges. The end of the loop conductor that normally is connected to the outer conductor shell, has been fastened to a ring clamped in the outer conductor assembly to provide both electrical and vacuum connections. This arrangement allows both ends to be freed readily for replacement.

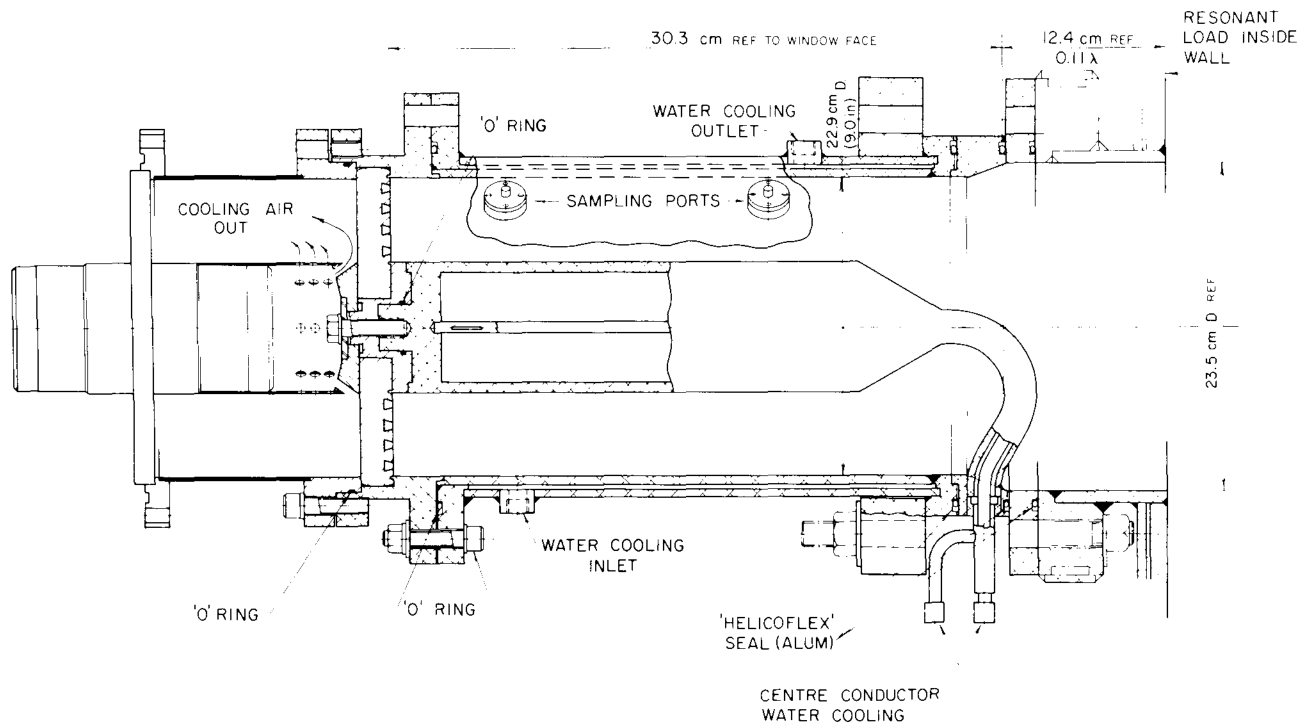
Loop coupling may be adjusted either by trimming a spacer or by rotating the loop. In the latter method, the centre conductor cooling line interferes with the tank port flange bolts restricting loop positions. However, by using a slightly rotated orientation of the flange bolt holes, almost any required loop angle may be obtained by positioning the cooling tube between a suitable pair of bolt holes on either side of the maximum position.

Aluminum was chosen as the construction material for ease of fabrication and to avoid incompatibility of the cooling water chemistries of copper and aluminium. Only the air-cooled rf feedline adaptor section is made of copper and brass.

Vacuum Seals

Because the loop and drive line are within the vacuum, the seals must have low outgassing rates and very small leakage to reduce the incidence of rf breakdown. Helicoflex seals are used in the outer conductor and port flange joints, but they do not provide an rf conduction path. Instead a short section of the joint surfaces next to the conducting wall forms a pressure contact. As a backup measure the Helicoflex seal grooves have been designed to allow substitution of an elastomer seal.

The vacuum seal to the teflon window is made by clamping the 24.4 mm thick disc at its inner and outer circumference against a knife edge fixed on the vacuum side. The knife edge nose is rounded to ensure cold flow around the sealing surface, allowing the joint to be remade several times.



COUPLING LOOP FOR A HIGH POWER RESONANT LOAD

FIGURE 1

Cooling

Both the centre and outer conductors are flood cooled with water to remove heat from transmission losses, most of which occur in the centre conductor assembly. A water flow rate of 0.1 ℓ/s, large enough to maintain a small temperature rise, was chosen to ensure reliable low flow protection.

The 230 mm rigid copper drive line is air cooled at a flow rate of about 24 ℓ/s. Window cooling is provided by directing part of the air flow leaving the centre conductor onto the window surface.

Experience with Rf Breakdown, Multipactoring and Ion Sputtering

In our early Alvarez linac designs, the drive loop supporting flange was located 100 mm from the end of the loop, resulting in a long annular gap between the loop body and the port wall. Some rf field was necessarily coupled into this gap, and in the presence of local high pressure, could initiate arcing. Figure 2 is a photograph of the end of a loop that was damaged when a leak developed at the flange joint. Such discharges may transfer to the open end of the loop and propagate towards the window. The gap may be shielded by spring contacts, although they must be designed to handle substantial currents.

At our drive levels, the voltage on the 50 ohm 15.2 cm copper drive line was well below the onset of half cycle multipactoring, but higher order multipactoring was considered possible above 15 kW[4]. In fact multipactoring occurred at 35 kW. The resultant ion bombardment and sputtering caused conductor erosion, the deposition of a conducting copper layer on the window, and eventual track etching on the window surface. The net result was intolerable reflected power.

However, by strapping a layer of bar magnets around the periphery of the outer conductor to obtain an axial field of 5-10 mT, the electron path geometry was altered sufficiently to suppress multipactoring and allow the power to be increased gradually during conditioning. The magnetic field modified the path of any rf discharge so that the resultant outer conductor erosion was reduced. After many events, the conductor surface marking, as seen in Fig. 3, consisted of many light spiral tracks which, upon disassembly, proved relatively easy to remove.

Damage to the window was also reduced substantially. Instead of several deep tracks across the teflon window face, the entire surface was coated, lighter in the central region and much heavier with some charring near the outer edges.

Fig. 2 Surface pitting from rf sparking between loop and port walls.

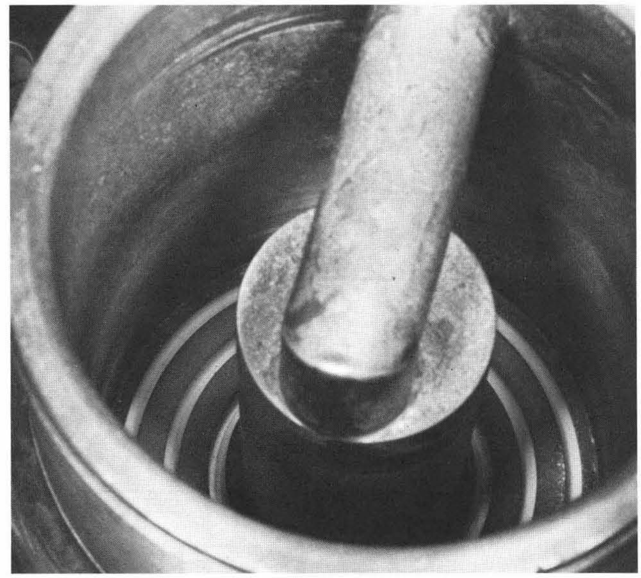


Fig. 3 Alvarez linac loop after ion bombardment damage.

As a further modification, a series of four equally spaced grooves 8 mm wide by 6.4 mm deep were machined into the vacuum face to inhibit the formation of a conducting path across the face by sputtered copper deposits. Figure 3 is a photograph of an Alvarez linac loop showing the wall and window surfaces damaged during high power operation.

Although the window surface is heavily coated and charred near the edges, the groove sidewalls and bottom are almost untouched. With the window in this condition, the mismatch seen by the source is relatively small, i.e., VSWR $\leq$ 1.5.

Conclusions

Improved loop performance has been achieved by:

- eliminating the narrow re-entrant gap between the loop and port wall
- shaping the centre conductor taper to avoid sharp edges and shaping the loop conductor to avoid a shallow crevice at the wall
- using a grooved teflon window
- immersing the evacuated section of the loop in a solenoidal magnetic field produced by bar magnets
- incorporating ports in the outer wall for installing field or light sensing probes to monitor arc propogation phenomena.

Development work is continuing.

Acknowledgements

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References

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