

CONSTRUCTION OF A HIGH-POWER RF RESONANT TEST LOAD

J. Ungrin, J.C. Brown, B.G. Chidley, S.B. Hodge, G.E. McMichael, S.O. Schriber and R.B. Turner
 Accelerator Physics Branch
 Atomic Energy of Canada Limited
 Research Company
 Chalk River Nuclear Laboratories
 Chalk River, Ontario K0J 1J0

Summary

A high-power resonant load has been constructed at Chalk River as part of a program to develop high-current cw linacs. The aluminum load designed to dissipate 400 kW cw is resonant at 270 MHz to be compatible with an existing rf amplifier. It has been designed for high-power testing of accelerator components such as coupling loops, loop windows and tuners. Eleven ports have been built into the cylindrical geometry to test flexible drift-tube and post-coupler suspensions as well as several types of metal-vacuum seals. Mechanical and rf design details are discussed.

Introduction

A program is underway at the Chalk River Nuclear Laboratories (CRNL) to study high current cw linacs that could be used for breeding of fissile-fuel for nuclear power stations. Present estimates indicate that a 1 GeV proton accelerator with a 300 mA average current will be required to produce fuel at a viable cost. Detailed studies of the first 10 MeV of such an accelerator are underway at CRNL and are described elsewhere^{1,2}.

An Alvarez accelerating section will be used in the 10 MeV linac to accelerate the beam above 2 MeV and will require rf drive loops and vacuum windows individually capable of coupling cw power levels in the 500 kW range. A high power resonant load is being built at CRNL to provide a test facility for loop and rf window development as well as to test cavity components such as post-couplers, drift-tube suspensions, and tuners; all of which are subjected to much higher average power densities than are normally encountered in low-duty factor accelerators.

Basic Design Criteria

Existing rf equipment dictated a load frequency in the range 265-275 MHz and a maximum load power of ~ 400 kW. A cylindrical geometry with a diameter of 83 cm ($d = 0.766 \lambda$) was chosen corresponding to a frequency of 276.5 MHz. Cavity openings for pump ports, tuners, etc., and the addition of a drift-tube test assembly reduce the frequency to approximately the middle of the tuning range. Aluminum was selected as the shell material for fabrication reasons and a 1 m cavity length was selected as a suitable compromise between acceptable power density and compact size. A nominal 1.25 cm wall thickness is used for the cavity for vacuum and mechanical stability.

A cross-sectional view of the resonant load is shown in Fig. 1. The axis of the cylindrical load is vertical to allow easy access to numerous ports.

The bottom of the cylinder is welded to the walls while the top cover is removable to allow access to various internal test components. A Helicoflex gasket will be used to provide the vacuum and rf seal for the cavity top. Vacuum pumping is provided by a 1000 ℓ /s ion pump. Additional pumping speed may be required at high power operation and can be supplied by a titanium sublimation pump.

In addition to the rf coupling loop and vacuum pumping openings, eleven ports have been built into the cylinder walls for inserting and viewing test components as well as for sampling the rf fields.

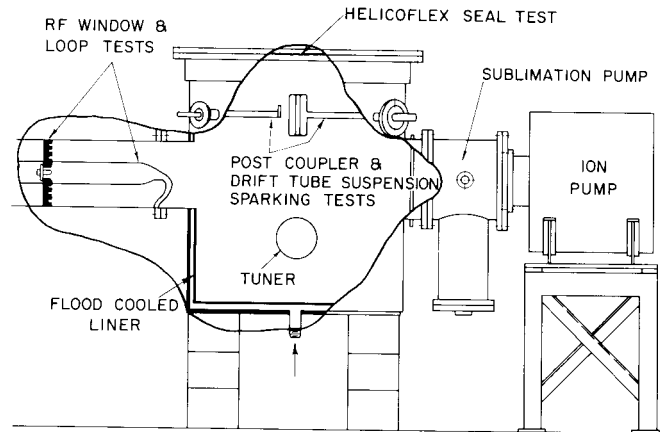


Fig. 1 Cross-sectional schematic view of resonant load.

Cooling Design

Water cooling for the resonant load has been designed to limit the maximum temperature rise to 10°C at a load power of 500 kW. At this power level the average power density is ~ 13 W/cm² on both the cylindrical walls and the end plates. About 1/3 of the cavity power is dissipated in the end plates. A philosophy of maximum wetted area has been used for the cooling scheme with only modest flow velocities.

The cylindrical walls of the rf cavity are surrounded by an outer aluminum shell that provides a 3 mm thick cooling annulus the entire length of the load. This annulus is joined to the bottom end plate. Water is fed from the centre of the tank bottom (Fig. 1) and discharges into a header at the tank flange. This cooling stream with a flow rate of 10 ℓ /s will remove ~ 83% of the load power. A separate cooling stream feeds the upper end plate.

Cooling jackets have been welded around the tuning plunger sleeves where past experience with cw accelerator operation indicates heating can occur. The vacuum pumping aperture is formed by seven ~ 17 mm diameter aluminum pipes that are welded into the pumping port parallel to the cylindrical axis and through which water is passed.

Seal Test

Electrical seals for removable cavity end plates and components such as drift-tubes have provided many problems for the operation of accelerator cavities. These problems are particularly acute for cw operation due to the high average power loss that occurs across ohmic joints. Girder suspension designs for drift-tubes such as developed at CERN³⁾ decrease or perhaps even eliminate the need for removable end plates. However, the rf contact seal problem is then transferred to one of sealing the girder-to-tank interface.

The lower end plate on the resonant load is welded to the cylinder walls with a full penetration external weld to test the possibility of this construction technique for an Alvarez end wall. The upper end plate seal is shown in Fig. 2. An 83 cm diameter, 6 mm cross-sectional diameter Helicoflex seal is used to provide both the vacuum and rf seal. The current density (6000 A/m) value across this interface will be at least as high as that expected across a girder-to-tank joint and the experiment will serve as a rigorous test of the seal. Provision has been made to copper plate the seal contact areas if required and both copper and aluminum seals have been obtained. An 'O' ring groove has been machined in the tank flange and an elastomer seal can be used as back-up should the Helicoflex seal vacuum properties degrade due to mechanical problems or high rf power.

Helicoflex seals are also being used for both the tuner and coupling loop vacuum seals. In both these cases the groove in the flanges has been designed to allow substitution of an elastomer seal. One additional test port has been specifically designed to test Helicoflex seals of various diameters and at two rf field levels by suitable location of the joint.

A simple method of joining aluminum to other metals has recently been developed for the Aladdin rf accelerator cavities⁴⁾. This method, based on an inexpensive commercially available aluminum Mott⁵⁾ gasket, will be used on the remaining nine cavity ports that are exposed to rf fields. The seals will be used to attach standard stainless steel conflat flanges to the aluminum cavity. Several techniques of depositing a copper layer on the stainless steel flange surfaces to reduce rf heating are being investigated.

Rf Drive

Power for the resonant load will be supplied from a cw amplifier using a RCA2054 VHF triode capable of delivering in excess of 400 kW. Details of the rf system are published elsewhere⁶⁾. The rf is coupled to the load via a nominal 23 cm (9 in)

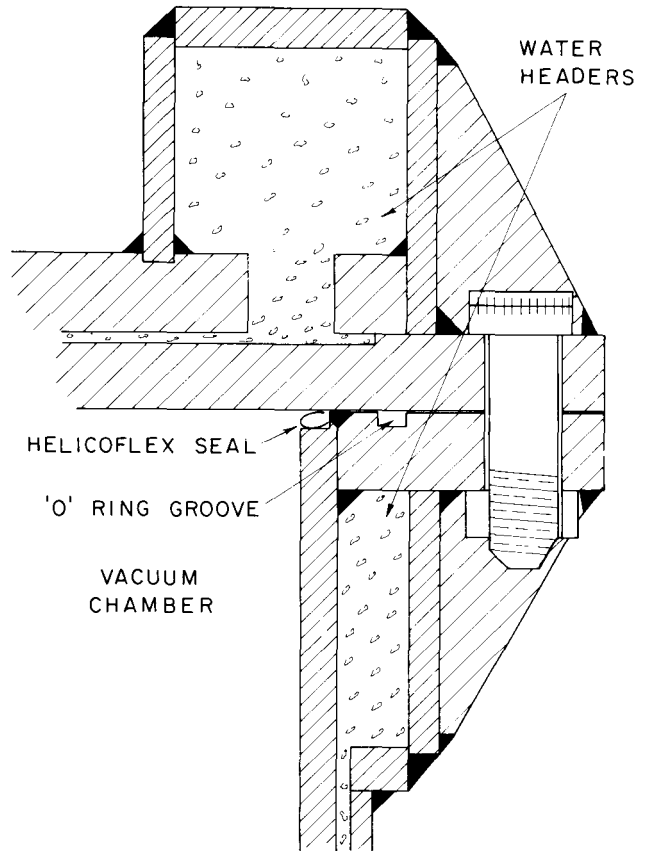


Fig. 2 End plate-to-cylinder seal.

diameter drive loop located at the midplane of the cylinder. The drive loop with vacuum window located $5/12 \lambda$ from the loop end has been designed to allow numerous loop and window tests. Details of the coupling loop are the subject of a separate paper⁷⁾ at this conference.

Tuners

Two ports capable of accommodating nominal 15 cm diameter slug tuners have been provided to allow adjustment of the load frequency and field tilt. These ports for testing tuner construction techniques are centred at 25 cm from each end plate and are arranged at a $+90^\circ$ and -90° axial orientation with respect to the drive loop.

A cross-sectional diagram of the tuner design is shown in Fig. 3. The plunger outside shell made of copper has an outside diameter that is 2 mm smaller than the sleeve inner diameter. There is sufficient thickness in the shell wall to decrease this diameter by 2 or 3 mm should multipactoring or sparking problems require. The plunger has a stroke length of 10 cm and at maximum penetration extends 8 cm into the cavity.

Experience with drift tube stems on a cw Alvarez accelerator⁸⁾ shows that major effort is required to reduce the rf currents that can reach thin walled items such as bellows. Spring contacts on finger stock can be used to short rf fields but

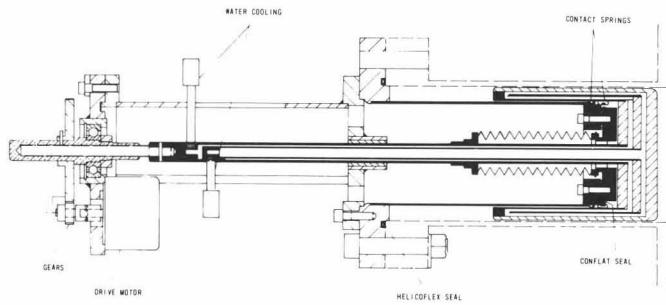


Fig. 3 Cross-sectional view of tuner.

at high duty factor a large rf field attenuation is first required. The 1 mm thick annular space between the plunger head and the cavity sleeve has a minimum length of 8 cm and should greatly reduce the rf fields beyond the plunger. A second attenuating path is provided in the opposite direction between the inside wall of the plunger and a central support tube. Both of these surfaces are made of stainless steel to spoil the Q of any inadvertent resonances that may occur in the region with rf harmonics. These two high resistivity surfaces should further attenuate the rf field. The plunger inner wall is water cooled while air cooling (not shown in the Figure) is provided for the support tube and bellows exterior. Grooves have been machined into the outside of the support tube to test two different types of contact springs.

One end of the stainless steel bellows (Fig. 3) is welded to a conflat flange which is sealed to the central support tube. A cuff attached to the other end of the bellows is welded to the central water cooling channel. The conflat flange can be unbolted from the assembly and the cuff weld can then be ground off allowing a relatively easy method of repairing or replacing the bellows.

Thermocouples (not shown) have been attached to the inside of the support sleeve to monitor the sleeve temperature. The outside of the aluminum tank port sleeve is cooled by a cooling jacket welded to the structure.

Experimental Ports

Eight additional ports exist in the rf cavity. The locations and purposes of all ports are summarized in Table I. Axial positions are referenced to the top end plate while orientation is clockwise relative to the rf drive line as viewed from the top.

A number of drift tube tests, primarily related to drift-tube stem suspension and bellows heating, are planned. A rigidly suspended 16.5 cm diameter drift-tube with a length appropriate to a 100 MeV accelerating cell has been constructed for the initial tests. Post-coupler to drift-tube coupling effects and sparking tests are other experiments planned. A viewing port has been provided to allow remote viewing of the drift-tube and post-coupler during high power operation.

Table 1

RESONANT LOAD PORTS

Distance from Top (cm)	Orientation	Diameter (cm)	Purpose
25	45°	5	Drift-tube tests
"	90°	3.8	Field probe
"	135°	5	Post-coupler tests
"	225°	6	Helicoflex tests
"	255°	3.8	Drift-tube and post-coupler viewport
"	270°	15	Tuner
"	315°	5	Spare
50	0°	25	V.F. drive loop
"	135°	3.8	Drive loop viewport
"	180°	32	Vacuum manifold
75	90°	15	Tuner
"	225°	3.8	Field probe
"	270°	3.8	Tuner viewport

Status of Construction

The cylindrical load and its end plate are 75% complete. Vacuum blanking flanges will be used on the tuner, post-coupler, and drift-tube ports for initial measurements. One tuner is now partially assembled and construction of the second will await initial test results of the first unit. The coupling loop is essentially complete and initial low power testing of the load is expected shortly.

References

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