SPECIAL DESIGN PROBLEMS AND SOLUTIONS FOR HIGH POWERED CONTINUOUS DUTY LINACS*

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Abstract

Several high powered linac designs are being considered for various purposes including radioactive waste treatment, tritium production, and neutron factories for materials studies. Since the fractional beam losses must be in the 10^{-5} to 10^{-6} range and are clearly subject to operational variables, the design engineers are forced to develop concepts which combine maintainability under radioactivity conditions, high availability, and very high reliability while dealing with the operating parameters resulting from CW operation. Several design solutions to selected problems are presented.

I. INTRODUCTION

A common feature of the new class of high powered linacs being considered for such future tasks as radioactive waste transmutation, plutonium neutralization, tritium production , etc. is the unprecedented power carried in the beam. A typical design for a 1 GeV proton linac at 200 mA implies a beam power of 200 megawatts CW! An important task in designing such a linac is to safeguard the boretube from beam impingment by configuring the machine with a large aperture ratio (ratio of boretube diameter to rms beam diameter). This involves the use of short focussing lattices to tightly contain the beam, doublet focussing, and minimizing the structural variations, such as boretube diameter or lattice length changes. A second task in designing this sort of linac is to provide a mechanical design which recognizes the major areas of potential operational difficulties such as multipactoring, RF and vacuum seal integrity, cooling channel durability and corrosion resistance as well as areas requiring relatively high maintenance so that accessibility and speed of maintenance in radioactive environments can be properly addressed.

II. THE APT POINT DESIGN AT LOS ALAMOS

Shown in Fig. 1 is a block diagram of the Los Alamos design for a high power linac. The same machine, or one closely related to it can be used for waste treatment (ATW) or conversion of plutonium (ABC). We call machines of this type AXY linacs. The linac is heavily beam loaded (79%) and will consume about 470 MVA to operate. It consists of two 100 mA H^+ injector lines feeding a funnel at 20 MeV which combines the two beams. The frequency of operation of the RFQ and DTL's in the injector lines is 350 MHz and downstream of the funnel the 200 mA beam is accelerated by RF structures operating at 700 MHz. Beyond the funnel the aperture ratio is gradually increased through the Bridge Coupled DTL (BCDTL), a new type of structure, and into the Coupled Cavity Linac (CCL). The aperture ratio through the CCL which comprises the bulk of the machine increases from 13 to 26:1. For comparison, the aperture ratio of LAMPF, the world's most powerful linac today is only 6:1.

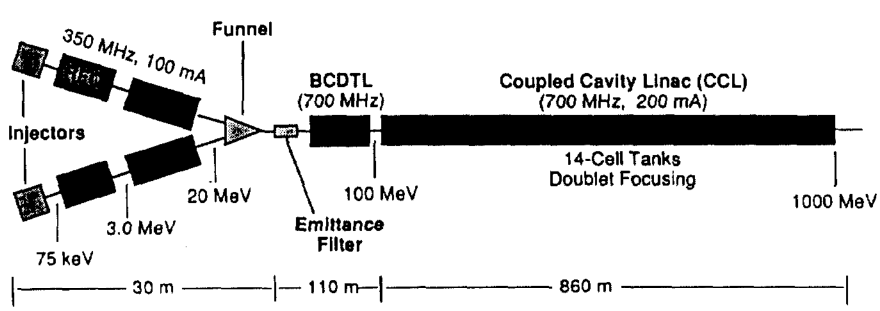

Fig. 1. High Power Linac Concept.

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III. ENGINEERING SOLUTIONS DEVELOPED IN THE APT DESIGN FOR HIGH POWERED STRUCTURES:

A) Innovative Accelerating Structures

In order to be able to use EMQ's in the DTLs, a high energy RFQ was required. A design was developed for a multi-sectioned RFQ to operate at 7 MeV (ref. 1). This 8 meter long unit actually functions as four independent 2 meter long RFQs thereby avoiding mode interference problems.

The other new structure is the BCDTL which is a multiple tank DTL with quadrupole doublet focussing in the intertank spaces much like a bridge coupled CCL. The BCDTL has large apertures at high frequency and solves many fabrication and operational problems associated with CCLs at low energy (refs. 2 & 3).

B) Radiation Hardening

Because of the potential for neutron damage to materials, essentially all the quadrupoles in the ATW point design are EMQ's with radiation resistant potting of the field coils. The technique proposed is shown in Fig. 2a-c. The coils are coated with a glass frit compound, fired to produce a glass coated surface and then potted in calcium aluminate cement (ref 4). In addition, quads are designed with demountable yokes so the coils can be removed if necessary.

Radiation hardening of the vacuum seals and knife-edge style RF seals are essential in an ATW type machine. We used the Helicoflex seal for most vacuum closures. Most of the Helicoflex beamline seals are used in conjunction with Helicoflex Quick Flanges which can be released and sealed from the aisle side of the machine with a single air drive screw. To assure high RF integrity, the RF joints throughout most of the machine are knife edges using a modified Conflat concept backed up by an independent Helicoflex seal enclosed in the same flange pair (Fig. 3).

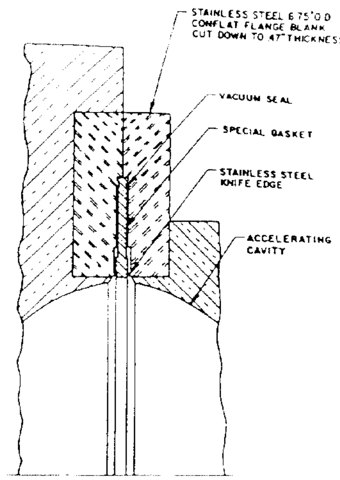

Fig. 3. Flange Design.

C) Modularization

ATW is modularized as illustrated in Fig. 4. The point design contains 403 modules of both BCDTL and CCL types requiring 366 1 MW klystrons. Modularization breaks the linac into manageable lengths for vacuum checkout and instrumentation. The modules are preassembled in the lab, aligned and checked out for vacuum, cooling and RF integrity. They are then transported to the tunnel and installed on 3-point support mounts and aligned to the tunnel alignment system. The beamline height is 1.47 meters which makes the modules convenient to work on. Most essential components are accessible from the aisle side, including the items most likely to need maintenance, i.e. the ion pumps and beamline components such as diagnostic devices located in the intertank spaces. Fig. 5 shows a typical doublet pair mounted as a module on two precision linear rails in the intertank gaps. Diagnostics, bellows, beamline vacuum valves and flanges are part of this modular

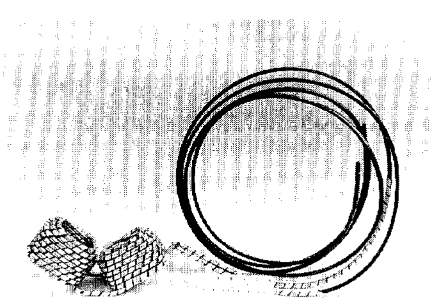

Fig. 2a. One of two copper coils that comprise a quadrupole magnet: note quadrupole complex nested winding, aluminum wrap.

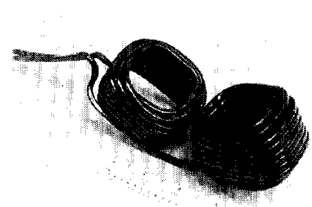

Fig. 2b. Enameled quadrupole coil.

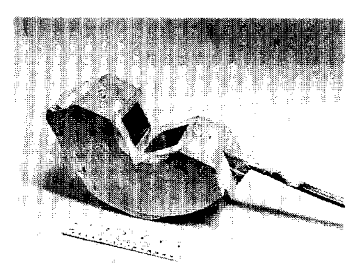

Fig. 2c. Encapsulated coil.

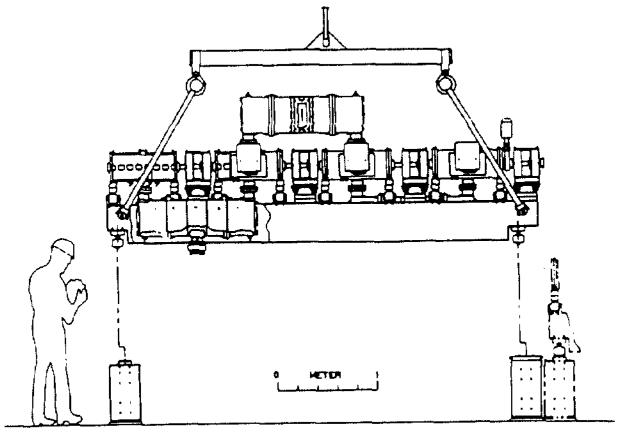

Fig. 4. Modular Linac Design.

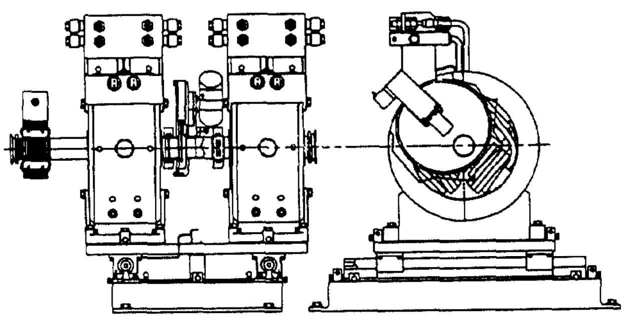

Fig. 5. Modular Doublet.

assembly. The doublet pair is critically aligned relative to the linear rails so that when the unit requires servicing it can be removed easily and mounted on a similar set of rails in the lab and then prealigned prior to re-installation on the beamline without the need for final alignment on-line.

D) Component Considerations

In the ATW point design the drift tubes were designed for changeout under potentially activated conditions by installing them on girders as shown in Fig. 6. The drift tube is "hard mounted", (sealed) by a single point RF knife edge and backed up by a silver plated Helicoflex vacuum seal. Alignment is critically set by means of a water cooled, heavy guage copper flex membrane which is stressed, yielded and work hardened in the process. This method of hard socketing is necessary to withstand CW RF heating. If the knife edge or vacuum seal were to fail, the girder could be removed from the tunnel and work done on the failed drift tube.

The APT CCL is a 700 MHz cavity system which is sized to fit into existing hydrogen brazing facilities. A major concern is the careful selection of braze alloys to avoid galvanic corrosion along the cooling channel joints. The external manifolding that supplies the cooling is also critical since it will carry radioactive water which can not leak into the tunnel. In the APT design we used high vacuum (VCR) water fittings everywhere.

E) Tunnel Considerations

The final major consideration for the designers of AXY style linacs is the beamline tunnel itself. Even

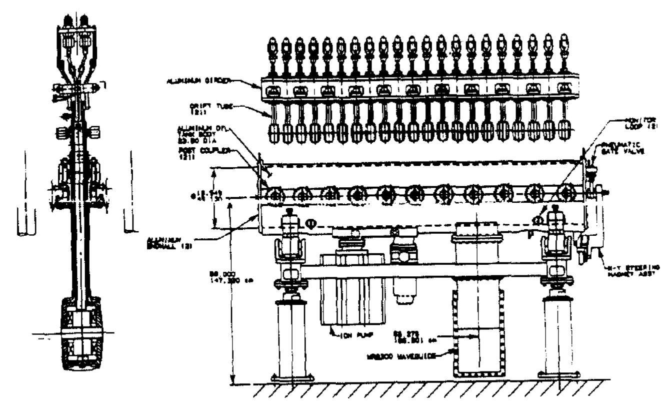

Fig. 6. Girder Mounted Drift Tubes.

though any given design will always assume hands-on maintenance as the design goal and the physics will always maximize such parameters as "aperture ratio", one must always consider future changes in personnel exposure limits, abnormal operation of the machine or degradation. . For these reasons it is wise to allow for the possibility of remote maintenance. Two major features are incorporated in our ATW point design. One is the use of radio controlled bridge cranes in the tunnel to carry surveillance booms as an adjunct to the normal workhorse function. The other feature is a tunnel spacious enough to allow a high performance remote maintenance master-slave servo-manipulator system to work. One such system is MANTIS, used at CERN.

IV. CONCLUSIONS

The point design for the Los Alamos ATW linac has been concieved to be radiation hardened in spite of its careful design for extremely low beam loss. The use of modularization, self aligning quadrupole doublets and easy aisle-side maintenance adaptable to remote servicing has been promoted in anticipation of most of the maintenance problems we can forsee.

V. REFERENCES

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