MECHANICAL ASPECTS OF THE NEW ENGLAND NULCEAR LINAC

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Summary

New England Nuclear Corporation (NEN) is building a 45-MeV proton linear accelerator, to be used for the commercial production of radiopharmaceuticals. The design goal of 5-mA average current at 60 pps and the use of permanent magnet drift tube quadrupoles will make this machine unique. In order to minimize risk, reduce costs and speed fabrication, this machine is being modeled after existing proton linacs in the U.S. and Europe.

This paper reviews some of the mechanical designs that are being used. Single stem drift tubes with a choke joint connection to the tank wall are discussed. Tank design and cooling are reviewed along with rf problems, such as loop design and transmission line cooling. Beam transport in the dome and the LEBT, along with the machine vacuum systems are discussed.

The column design and its support are presented. Conventional alignment techniques are planned and reviewed. The linac building and the schedule is presented.

Beam Transport Lines

A small beam transport system in the dome is being constructed for the 45 MeV linac. A 90° bending magnet, solenoid magnet, steering magnet and instrumentation box will be incorporated into the beam transport line. A 2000 l/sec turbo pump will operate in the dome for this beamline, with a water-cooled aperture (1/2" dia.) isolating the dome transport system vacuum from the column vacuum. A pressure of 10^{-4} Torr will be maintained in the beam transport line with the turbo in the dome, while 10^{-6} Torr will be maintained in the column. Column pumping will be provided by two 1000 l/sec ion pumps at the ground end. The insulator stack will be made with glass insulators. A 4" aperture through the insulator stack will allow for easy alignment and give adequate vacuum pumping conductance. The insulator stack and its SF_6 jacket assembly, is designed such that the insulator stack is always under compression, regardless of its orientation. The dome transport system will mount directly to the column support system to help reduce misalignment problems. (Fig. 1).

The low energy beam transport line is about 15 ft. long. Three triplets and four singlets with viewing boxes are being used in this line. A double-gap, 2-frequency buncher is being used to improve capture efficiency.

Tank

The linac tank is made from 6 flanged cylindrical sections that are aligned and bolted together at the time of installation. The overall tank length is 27.6 meters; the inner diameters vary from 1.1 to 1.02 meters and the tanks are fabricated from copper clad steel (.160" OFHC copper on .750" - 516 grade 70 steel). The clad material was 100% ultrasonically checked for voids in the copper-steel bond. Only two small voids were detected in one plate and will be repaired during tank fabrication. A short one-foot long tank section has been rolled and welded to aid in determining the amount of initial edge forming necessary for proper rolling, and the effect of the longitudinal weld shrinkage on the final section size (circumference). No copper cover weld is used to cover the longitudinal seam weld. All tanks are capable of being rolled from single sheets of clad material, so circumferential welds are not required.

The clad plates were polished at the rolling mill, but only a 50 micro-inch finish could be achieved without smearing the surface. The tank fabricator will polish the tanks after rolling and welding. "Q" measurements will be taken during this time to measure the effect of the polishing.

After welding and polishing, the tank sections will be stress relieved at 1100°F, with a reducing atmosphere maintained in them.

Copper inserts will be shrunk into the tank walls at the drift tube, post coupler and tuner locations.

Rf surface-current continuity across the bolted tank sections is provided by an oversize copper ring that is inserted between the flanges as they are drawn together (Fig. 2). Each tank section has two vacuum ports machined in it.

Tank vacuum will be provided by:

9 ion pumps - 1000 l/sec each,
2 turbomolecular pumps - 2000 l/sec, and
1 roots blower - 1000 CFH

The tank is cooled via a cooling jacket that encompasses the entire outer surface of the tank. A flow pattern through the jacket is created by welding bars that form flow channels in the jacket. Water is supplied to the tank at its mid-point (flanged connection between Sections III & IV) and is split to flow through single pass hair-pin loops. 600 gpm of temperature controlled water is available for tank cooling. 150 gpm of this water is tapped off the supply to the tank, passed through a pump to increase the pressure and is used for drift tube cooling. Post couplers, tuners and vacuum grids all having cooling capabilities and will be water cooled using tank water (Fig. 4).

The temperature control system uses a 3-way mixing valve, heater, heat exchanger and appropriate control units. The heater is used to maintain the tank at its normal operating temperature, when no rf power is being supplied to the tank.

Drift Tubes

The linac will contain 107 drift tubes, with a half drift tube in each end cover. All drift tubes contain a permanent magnet quadrupole. The use of these compact, high efficiency quadrupole magnets reduces the physical size, and thus, the cooling requirements for the drift tubes. All drift tubes are 9-cm OD. Drift tubes are supported with a single vertical stem of heavy wall (.25") OFHC copper. Tank I stems are 1-1/8" OD and tanks II through VI are 1-1/4" OD. Water-cooling and a vacuum pump-out are provided through the single stem. Tank I bodies are cooled via a copper tube that is brazed into the body. Bodies in Tanks II through VI are cooled using a series of holes and manifolds that are integral with the drift tube body.

The drift tube bodies are being fabricated from hot-forged cross-grain certified OFHC copper. Two basic body designs are used: Tank I bodies are a closed end cup with cover; Tank II through VI use a heavy wall cylinder with separate end caps.

A connector plug is brazed to the body using a silver-copper eutectic alloy. The plug allows the stem to be attached to the body by electron beam welding and at the same time it forms a part of the water manifold system in the body. Bellows are not used in the drift tube support system. The copper stem passes through the tank wall through a "choke" joint. The "choke" joints are copper inserts that are shrunk into the tank wall. The inside diameter of these inserts contain a spring-finger ring which makes contact with the drift tube stem. The contact fingers are located about one stem diameter back from the tank surface. They are positioned so as to reduce their current carrying requirements. The design allows for the necessary alignment movements without the inherent problems normally associated with the use of bellows. The vacuum seal between the tank outer surface and the stem is made with "O" rings. The containment for these "O" rings is allowed to track the stem until the drift tube is aligned and then it is fastened to the tank. This technique allows drift tubes to be aligned with no external force applied to them. (Fig. 3).

Rf and Transmission Lines

Rf power is supplied to the tank through four fixed loops located at the 1/8, 3/8, 5/8 and 7/8 points along the tank. The loops will be matched to the tank at low power, and will be water-cooled. Three power amplifiers will drive the loops through a rather complex transmission line system. 12" line is being used with an aluminum outer-conductor and a copper inner-conductor. Transmission line losses, estimated at 1% loss per 100 feet of line, require that cooling be provided. Air cooling manifolds are located at the tank vacuum windows and at the power amplifier pressure windows. These manifolds allow cooling air to enter at the tank window and pass through the entire transmission line system. Cooling air will be dried, cooled in an air/water heat exchanger and recirculated. The transmission line system is designed to be pressurizable to 45 psi if necessary.

Deionized water (5 MΩ-cm), 1050 gpm at 120 psi) is to be used for cooling the rf system. A 3 gpm deionizer is incorporated in the system to continually polish the water. This deionizer contains two mixed resin cartridges, an oxygen removal cartridge, 5 μ and 0.2 μ filters and an UV light for sterilization. Fiberglass piping is used for the rf water system.

The linac tank sections are fabricated oversize and will be tuned with mechanical slug tuners (fixed and adjustable) and an angle type tuner bar attached to the cavity wall. Post couplers will be used in this machine. End covers are not adjustable, but the half drift tubes mounted in them are located using shims, so that end gaps can be accurately adjusted.

Alignment & Schedule

Standard optical tooling instruments will be used for the linac machine alignment. Bore-sighting is planned for the initial equipment installation, with reference offset lines for future equipment realignment. A building stability check has just begun, but it is too early to draw any conclusions. The effect of the construction of the target complex, backfilling of earth shielding and a New England winter will be checked this coming year.

The status of the program today is as follows:

1. The building construction is 75% complete. Partial occupancy (rf gallery, linac tunnel and injector pit) is promised by October 1, 1979. The building is to be completed by December 1, 1979. The target complex with its support areas has not been designed as of this date. Selection of an A/E firm is in process.

2. Most major machine components - Cockcroft-Walton and dome, linac tanks, rf systems and transmission lines have been specified, designed and ordered.

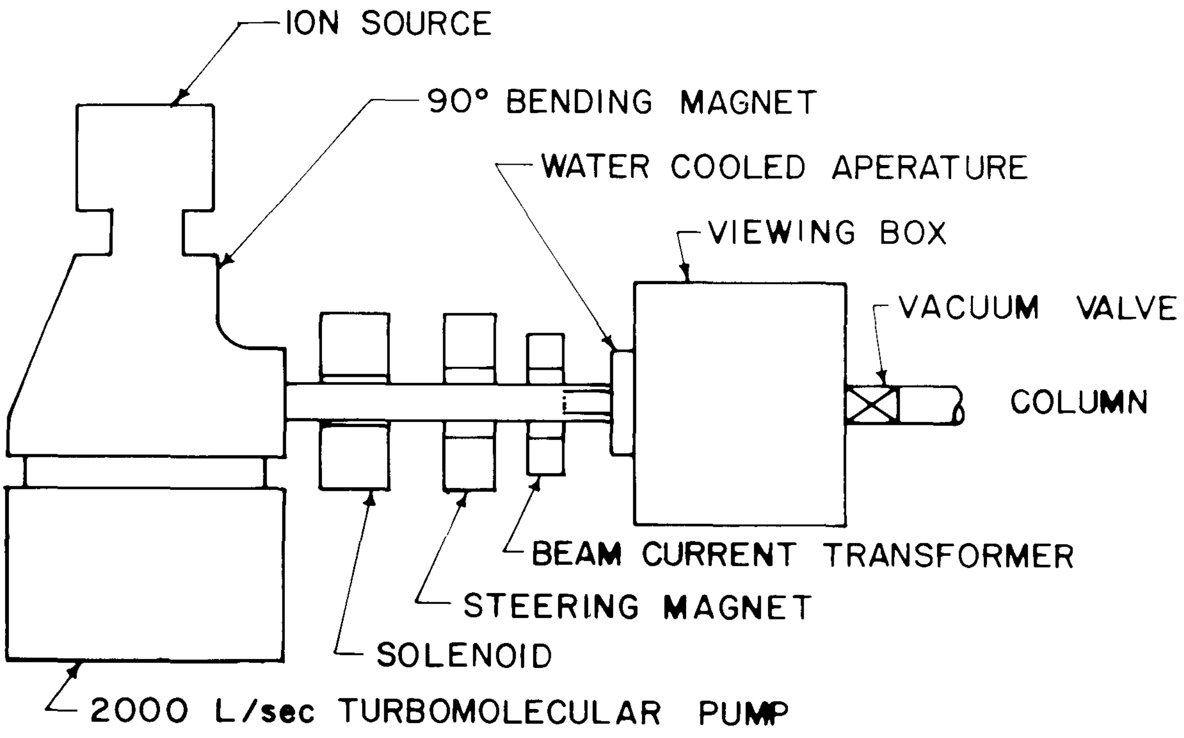
Machine turn on is scheduled for mid 1981.

Acknowledgements

The program at NEN relies very heavily on the technical support from the National Laboratories in both the United States and Europe.

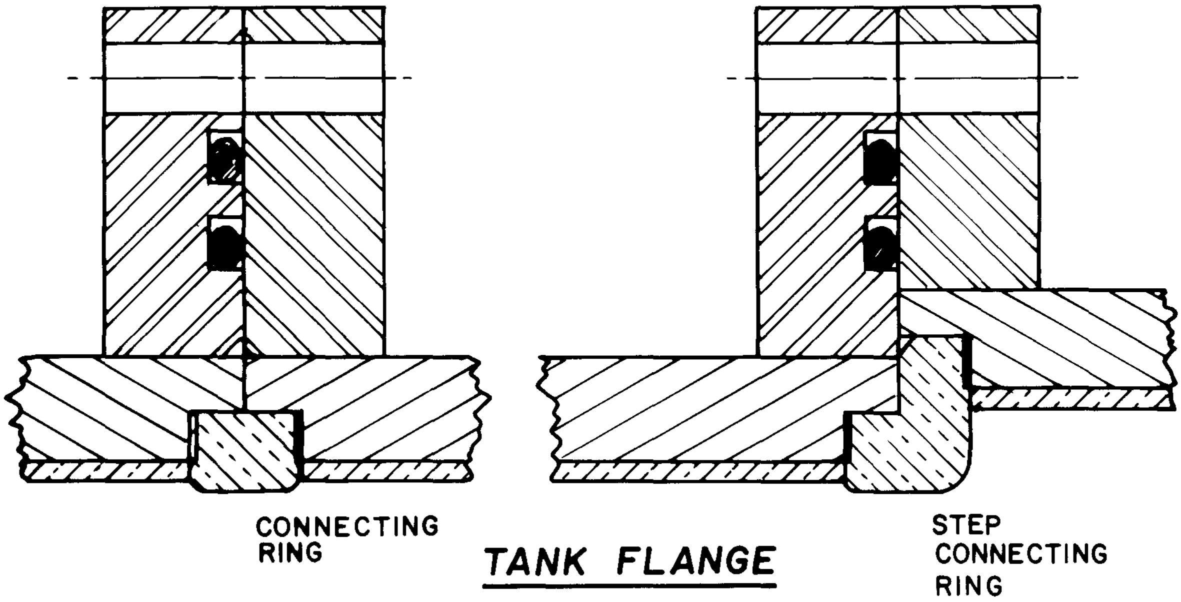
Many designs used in this machine are either a direct copy of existing designs, or are only slightly modified to meet the special needs of the NEN machine.

The program at NEN could not have proceeded to this point, and cannot be successfully completed without this technical support. The linac group at NEN is extremely grateful for this unselfish assistance and hopes to be able to someday repay its debt to the accelerator community.



BEAM TRANSPORT LINE IN DOME

Figure 1



TANK FLANGE

Figure 2

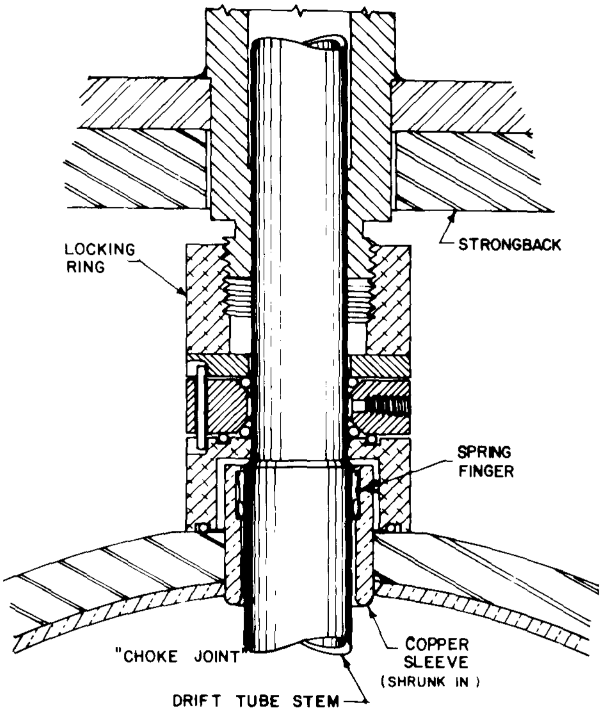
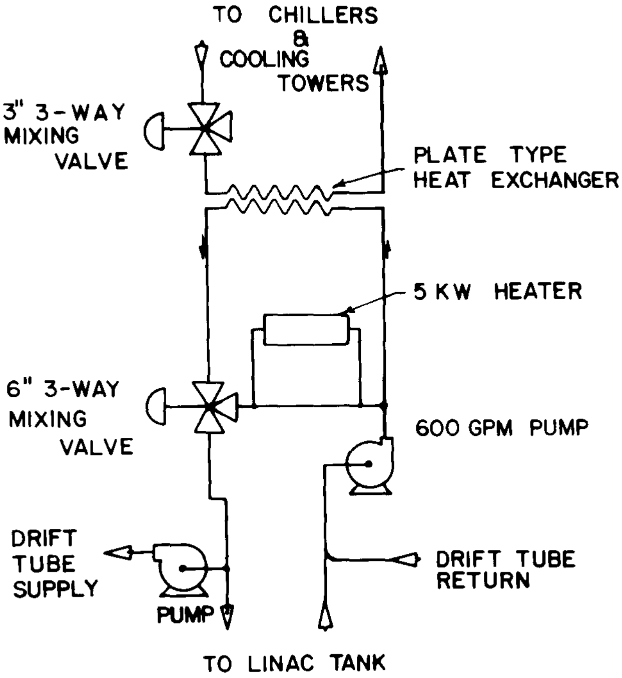


Figure 3



TANK COOLING

Figure 4