KEK PS INJECTOR LINAC UPGRADING

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Abstract: An Alvarez linac is being built to increase the injection energy of the booster synchrotron from 20 MeV to 40 MeV. Its drift tubes are equipped with quadrupole permanent magnets. It has post couplers and still inherits the two feed system. Two TH 516 RF high power amplifiers, which have excited the 20 MeV linac, are modified so that one excites the old linac and the other the new one. 40 MeV H^- beams will be supplied to the booster in November of 1985.

Introduction

An additional Alvarez linac is being built to upgrade the injection energy of the 500 MeV booster synchrotron from 20 MeV to 40 MeV [1,2,3]. As the space-charge limited current of the synchrotron is proportional to $\beta^2\gamma^3$ of the injected protons, two times higher beam intensity is expected by this project. Furthermore, it is apparently beneficial for both polarized and ordinary H^- charge-exchange injection which will be normal operating mode of the 12 GeV proton synchrotron complex at KEK in very near future. Energy loss or multiple scattering caused by passing through a stripping foil determines how many turns can be effectively accepted by the booster. An energy loss of 2.8 keV due to a 120 μg/cm^2 thick carbon foil decreases to 1.6 keV by the upgrading. Multiple scattering might be more serious than the energy loss above mentioned for the 20 MeV beams and it will reduce to about a half when the proton energy increases to 40 MeV. Thus, combining the charge-exchange injection with the linac upgrading, higher beam intensity of the booster can be attained with lower beam loss at the injection into it.

Linac Cavity

Main design parameters of the new linac are shown in Table 1. It consists of four sectional tanks as shown in Fig. 1, which are separated at the center of the accelerating gaps. Each tank is fablicated by copper plating on a 3 cm thick steel cylinder. The technique of thick and smooth plating was developed for the operating 20 MeV linac. The tanks are plated by 0.5 mm thick instead of previous 1 mm in following two steps in a pyrophosphoric acid bath: 0.45 mm thick plating in 13 hours, cutting heavily plated copper near edges and 0.05 mm thick plating again. Many ports for drift tubes, post couplers, frequency tuners, RF couplers, vacuum pumps, monitors and viewing windows are made of stainless steel SUS 304 and welded to the tank wall before the copper plating. Almost all flanges have coaxial double grooves for elastomer and/or metal O rings, which enable to confirm vacuum sealing of the O rings quickly and separately by connecting a helium leak detector to spaces between the two O rings. To test vacuum leak of welding, the tank is evacuated by a 450 ℓ/S turbomolecular pump. All ports are sealed with dummy flanges and Viton O rings. It is covered with a helium bag. After about 30 minutes, a peak of m/e = 4 was detected by a quadrupole mass filter. It increases gradually

Table 1

Main parameters of new linac

Energy	20.60 - 40.46 MeV
Frequency	201.070 MHz
Tank	Steel, copper plated
Length	12.84 m
Inside diameter	0.90 m
Number of cells	35
Drift tube	Stainless steel, copper plated
Length	23.32 - 28.79 cm
Outer diameter	16 cm
Bore diameter	3 cm
Stem diameter	3.6 cm
Quadrupole magnet	Permanent (ALNICO-9)
Aperture	3.4 cm
Length	16 cm
Outer diameter	13.5 cm
Field gradient	2.0 - 2.05 kG/cm
Synchronous phase	- 30°
Average axial field	2.1 MV/m
Shunt impedance	70.33 - 68.71 MΩ/m
Transit time factor	0.8699 - 0.8143
Effective shunt impedance	53.22 - 45.56 MΩ/m
RF	
Excitation power	1.078 MW
Coupling	Loop, two feeds
Stabilizer	Post couplers
Post diameter	3.0 cm
Vacuum system	
Main pump	Ion pump (1000 ℓ/S × 7)
Roughing pump	Turbomolecular pump (500 ℓ/S × 1)

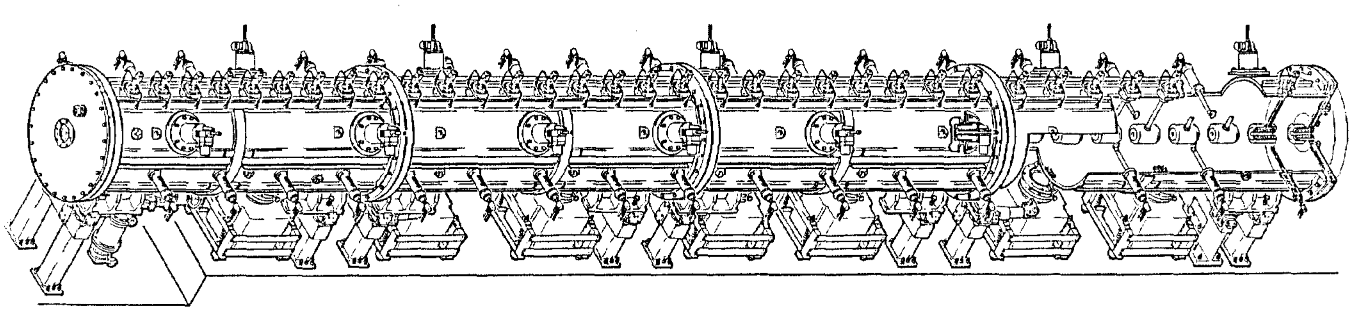

Fig. 1 New linac accelerates protons or H^- ions from 20 MeV to 40 MeV.

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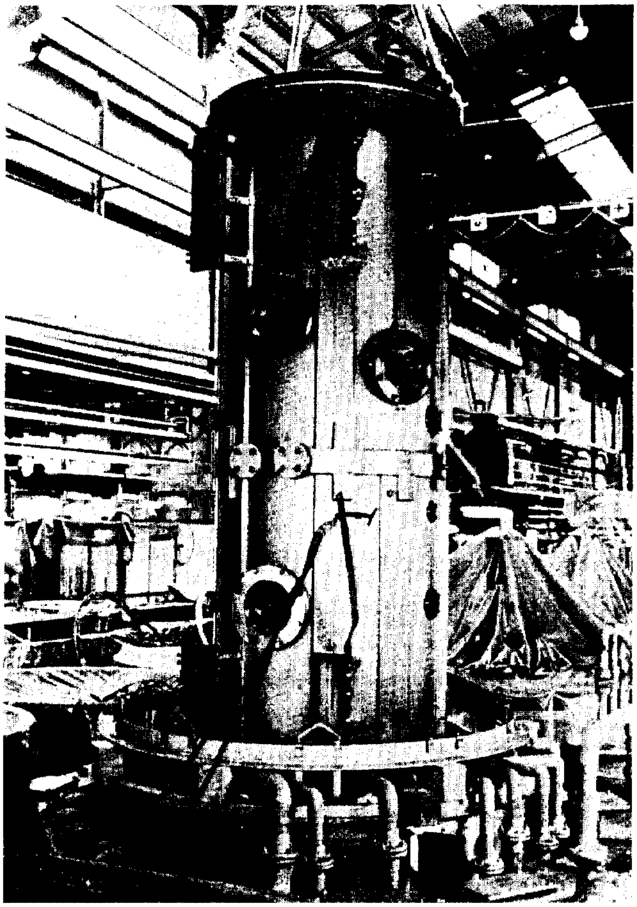


Fig. 2 A tank on the copper plating bath.

after removal of the bag and remaines for long time, so it is helium diffusing through the O rings and not an indication of any leak.

Fourteen cylindrical frequency tuners are distributed along the linac cavity. Two of them are in a feedback loop and tune the resonant frequency to that of the 20 MeV linac continuously. They have conventional choke structure so that the RF current which passes through contactors is to be greatly reduced to ensure long term stable operation. Other tuners are 12.5 cm in diameter and have stroke of ± 9 cm corresponding to shift of the resonant frequency of ± 15 kHz each. They are manipulated by hand and fixed before acceleration of particles.

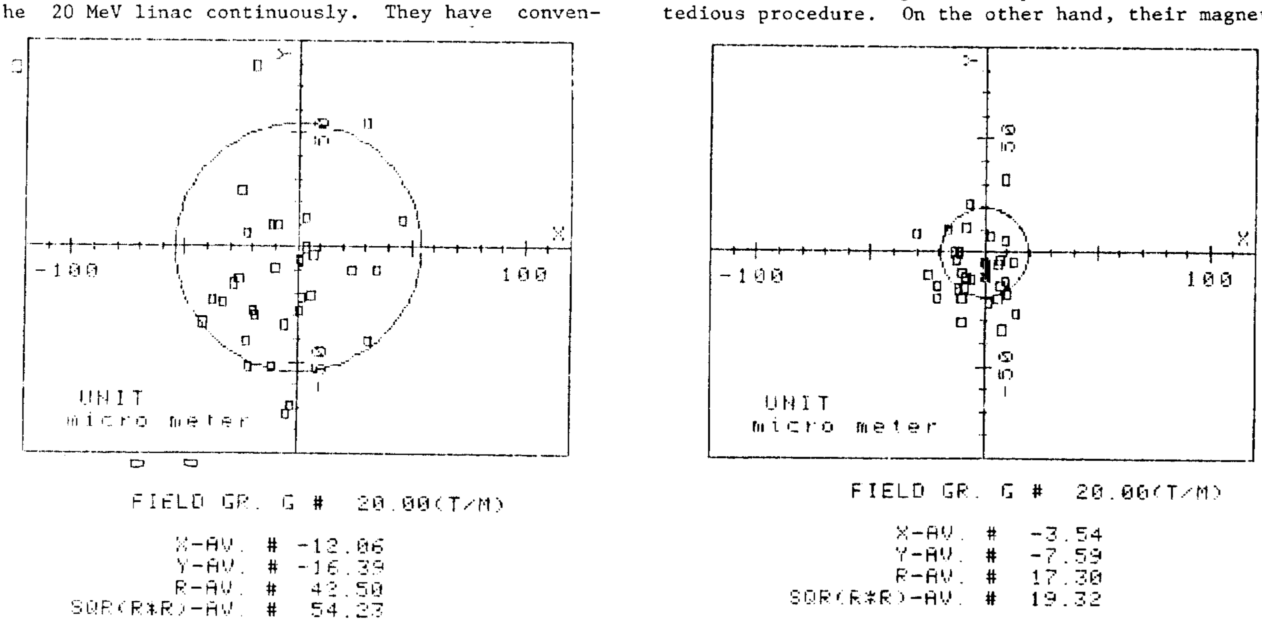
A 400 MHz model cavity of 15 cells was made to settle design of post couplers with tabs. Their characteristics were well analyzed by the equivalent circuit [4]. It was found that the accelerating field was completely disturbed when the posts were withrawn a little bit from the stabilizing positions. Then the post couplers of the 201 MHz cavity are made to be able to move along and around their axes without breaking vacuum.

The new linac cavity is supported by flexible structure as the old one to prevent damages caused by earthquakes. It can move horizontally and is fixed by springs together with oil dampers. Its resonant frequency is designed to be 2 Hz, which may be lower than the earthquake frequencies here.

To measure polarization of protons at 20 MeV, the new cavity is separated by 2.5 m from the old one. A toroidal current monitor, a profile monitor and a bunch monitor are also to be installed. Beams are regulated by four quadrupole electromagnets, which can be utilized to measure transverse emittances with the profile monitor.

Drift Tubes

Drift tubes are equipped with ALNICO-9 quadrupole permanent magnets which have windings for magnetization and demagnetization [2], so they look like ordinary quadrupole electromagnets. Pole pieces and yorks of the magnets are made of low carbon steel, and small blocks of ALNICO are assembled and set between them. Although rare-earth magnets have larger BH products than those of the ALNICO magnets, they can not be magnetized and demagnetized after put into the drift tubes. Electron beam welding (EBW) is a suitable method for assembling the drift tubes and it was successfully applied to the drift tubes of the 20 MeV linac. However, the magnetic field should be reduced to several gauss or less at welding area. The ALNICO magnets can be demagnetized by a normal but somewhat tedious procedure. On the other hand, their magnetiz-



(a) (b)

Fig. 3 Deviations of the dipole minima from the axes of quadrupole permanent magnets. Before (a) and after (b) correction by shims.

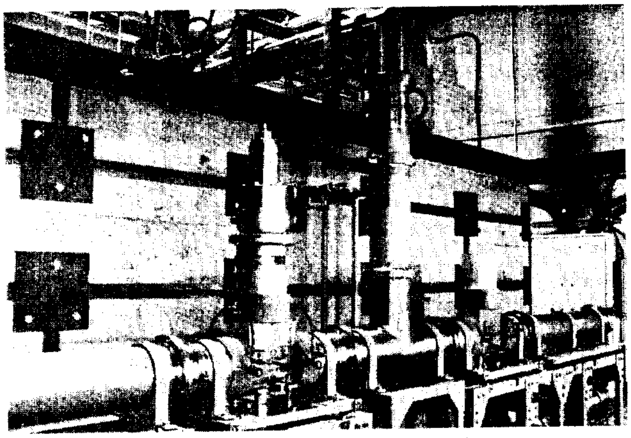


Fig. 4 Output power of the second TH 516 amplifier is devided by a Tee splitter (center) and fed to the new linac cavity through circulators. High power dummy loads are removed and the left circulator is terminated by a reducer with a matched load.

ation is much simpler, at first the magnets are fully magnetized, then they are partially demagnetized to the design field. The fields can be adjusted in 10 % of the design value without appreciable shifting of the magnetic axes.

Inhomogeneity in magnetic property of four legs causes deviation of the dipole minimum from the geometrical axis of the quadrupole magnet. Distribution of the deviation is shown in Fig. 3. The circle shows the RMS deviation. Ten quadrupole magnets out of thirty six had big deviations and they were sent back to the company to rearrange pieces of the ALNICO magnets. Then twenty magnets were carefully shimmed so that the deviations of Fig. 3(a) became those of Fig. 3(b), which are smaller than a tolerance of alignment of the drift tubes in the linac tank.

RF System

Conversion from protons to H^- ions changes beam structure from short and high intensity to long and low intensity, typically 5 μS and 130 mA to 60 μS and 15 mA. No extemely intensive beam loading compensation of the accelerating RF is needed. So far two Thomson-CSF TH 516 amplifiers were used to excite the single linac cavity by the two feed system. Its excitation power was 1 MW, whereas the beam power was 2.6 MW for a 130 mA beam and the total power amounted to 3.6 MW. The beam power decreases to 0.3 MW for a 15 mA beam and the total power becomes 1.3 MW. Although the pulse width is stretched, 1.3 MW can be fed by a TH 516 amplifier without critical tuning. Thus the RF high power system is modified: one TH 516 high power system excites the old 20 MeV linac and the other new one. The two feed system has advantages not only improving the accelerating field distribution but also lightening burdens to a circulator and an RF window. The output RF power of the first TH 516 amplifier is divided by a simple T-shaped power splitter with two 70.7 Ohm quater-wavelength sections. Each divided power is fed to the 20 MeV linac through a circulator and a hybrid phase shifter. The output power of the second amplifier is guided to another Tee splitter near the new linac by a 15 m long WX-203D coaxial line with five elbows. After devided, each power is fed to the new linac through a circulator. Both lengths from the splitter to the RF couplers of the linac cavity are carefully made to be equal to eliminate a hybrid phase shifter. When the circulators are replaced by WX-203D coaxial lines and dummy loads are attached instead of the RF couplers, the phase difference between two dummy loads is 1 ∿ 3° for 201.25 ± 2 MHz. When the circulators are put in due places, the phase difference is 1° for the same frequency range. VSWR of the high power line following the second amplifier is 1.15 at the design frequency as shown in Fig. 5, although that of the first one is less than 1.07.

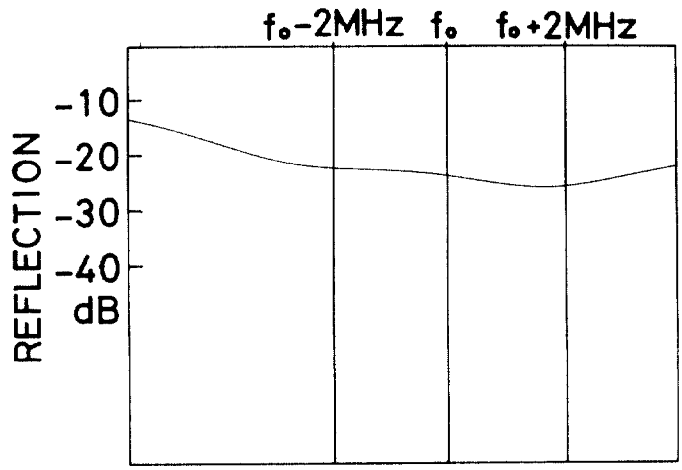


Fig. 5 Reflection of WX-203D coaxial line following the second TH 516 high power amplifier. Dummy loads are attached for both RF couplers of two feed system to the new linac cavity. f_0 = 201.25 MHz.

After June of 1985, H^- ions will be accelerated by the 20 MeV linac under the operating mode as mentioned above. The new linac will be installed by the end of October of 1985.

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