# INSTALLATION OF 100-MEV PROTON LINAC FOR PEFP*

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*Abstract*

The Proton Engineering Frontier Project (PEFP) [1] at Korea Atomic Energy Research Institute (KAERI) is developing a 100-MeV proton linac in order to supply 20-MeV and 100-MeV proton beams to users for proton beam application. The linac consists of a 50-keV injector, a 3-MeV radio frequency quadrupole (RFQ) and a 100-MeV drift tube linac (DTL). The operation of the 20-MeV part of linac at Daejeon site was finished on November 2011. It was disassembled and moved to the Gyeongju site for installation as a low energy part of the linac. We completed the fabrication and test of the accelerating structures. The installation of the proton linac started in December 2011 at the new project site. The user service is scheduled for 2013 through the beam commissioning in 2012. This work summarized the installation status of the proton linac.

## INTRODUCTION

The PEFP 100-MeV proton accelerator has two beam extraction points at 20-MeV and 100-MeV respectively. Each beam line has five target rooms for the proton beam users as shown in Figure 1.

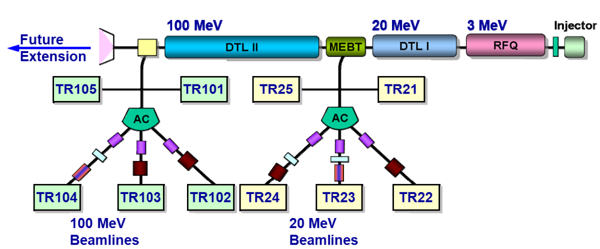


Figure 1: Schematics of PEFP accelerator and beam lines.

The accelerator and beam lines are installed in the first floor, the klystron, RCCS in second floor and the modulator in third floor. The PEFP 100-MeV proton accelerator is being installed at Gyeongju city which hosted the project. The 20-MeV accelerator was operated for five years at Daejeon site waiting for the site preparation in Gyeongju. Now it was disassembled, delivered to Gyeongju site at February 2012. And the installation of the main accelerating structure including 20-MeV and 100-MeV linac was finished in the tunnel on March 2012. The magnets of the 20-MeV beam line were installed in the experimental hall on May 2012. The alignment and test process of the linac and the beam lines will continue in parallel with the construction of the other part of the accelerator building. This brief report summarized the 20-MeV linac operation and movement, the 100-MeV linac and beam line preparation, the status of civil construction and schedule for linac commissioning.

## 20-MEV LINAC OPERATION AND MOVEMENT

The main goals of the 20-MeV accelerator operation at Daejeon site were supplying proton beams to users, studying the 20-MeV machine itself, and testing the 100-MeV accelerator components [2] waiting for the site preparation at Gyeongju.

For 5-year operation of the 20-MeV machine, the number of the irradiation samples was 1,608 and the number of users tended to increase in the period. Also the machine was upgraded with several steps including LLRF system, control system, klystron power supply, ion source and beam diagnostic system. In parallel, the machine study was done with the long-term operation test, long pulse test and high repetition rate test. In addition, the beam study was done including beam energy measurement, beam profile measurement, beam emittance measurement and beam phase measurement. The 100-MeV linac components such as linac BPM and beam line BPM were also tested in the 20-MeV linac.

The operation of the 20-MeV linac was finished at November 2011. Since then, the linac was disassembled and was moved to the Gyeongju site at February 2012. A vibration free vehicle was used for RFQ, DTL tank delivery as well as klystron delivery as shown in Figure 2.

Figure 2: 20-MeV DTL tanks on the vibration free truck for the movement to Gyeongju site.

*Work supported by by Ministry of Education, Science and Technology of the Korean government

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## PREPARATION OF THE 100-MEV LINAC AND BEAM LINE

The fabrication of the 20-MeV ~ 100-MeV DTL tanks was completed at December 2010. It consists of seven tanks and total 163 ea. drift tubes. It has hollow type electromagnet for beam focusing whereas the 20-MeV DTL has a pool-type electromagnet. The length of each tank is 6.8m. The 100-MeV DTL tank has one klystron per one DTL tank and one Resonant Frequency Control Cooling System (RCCS) for each tank.

The fabrication of two Medium Beam Energy Transport (MEBT) tanks was also completed. MEBT tanks were used as a longitudinal matching section between 20-MeV DTL and 100-MeV DTL because there is a long drift space between them for 20-MeV beam extraction. The MEBT tank is a kind of DTL tank with three gaps.

The 350MHz klystron is used as a RF amplifier for the PEFP linac. The specification of the klystron is 1.6MW peak power with 1.5ms pulse width, 60Hz repetition rate. It was modified from the TH2089F CW klystron to produce a higher peak power and reduced duty. There are total 7 klystrons are needed for 20-MeV ~ 100-MeV DTL, and all the klystrons were delivered to Gyeongju site as shown in Figure 3.

The high voltage converter modulator is used to drive the klystron. The specification of the modulator is 5.8MW peak power with 1.5ms pulse width, 60Hz repetition rate. There are two distinct features in the PEFP modulator. One is to keep the pulse voltage droop less than 1% by the adjustment of the switching frequency. The other is to limit the load arc energy less than 20J spontaneously by the internal resonant characteristics, which means that the crowbar is not necessary in the modulator. The modulator drives two or three sets of the klystrons simultaneously. Total 4 sets of modulator are necessary for whole accelerator including 3-MeV RFQ, 20-MeV DTL and 100-MeV DTL and all of them were delivered as shown in Figure 4. One of the modulators was used to drive the 20-MeV linac at Daejeon site for 3 years. The normal operation conditions was 2.8MW peak power with 1ms pulse width, 4Hz repetition rate. It was tested up to 30kW in average power.

A RCCS is used to control the resonance frequency of each DTL tank by supplying the temperature – controlled water to drift tubes. The maximum heat load is 94kW. It should cover large range of heat load from lowest heat load where only heat load from the magnet is available to high heater load where full duty RF power in addition to the magnet heat load is considered. The operating temperature range of the RCCS was designed from 21°C to 33°C to reduce the DTL tuning requirement. Within the above temperature range, the RCCS can maintain the temperature accuracy within ±0.1°C by using two sets of three-way valves. Also the RCCSs were ready to installation as shown in Figure 5.

One of the most important interfaces between machine and building was the waveguide connecting accelerator located in first floor with the klystron located second floor. The waveguide was specially designed, fabricated and tested with care and embedded inside the ceiling of the tunnel during the building construction.

There are two beam line halls, one is for the 20-MeV, the other is for 100-MeV. One of the key components of the beam line magnet is an AC magnet to distribute the proton beam into 3 target rooms pulse by pulse successively. Two sets of AC magnet were fabricated for each beam line halls. 45 degree bending magnets and 25 degree bending magnets were also fabricated. Especially, the same bending magnets and quadrupole magnets were used for both 20-MeV and 100-MeV by adjusting the operating current.

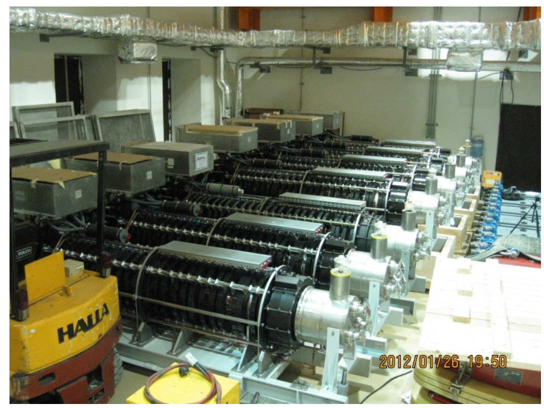


Figure 3: 7 sets of klystron ready to installation.


Figure 4: 4 sets of modulators ready to installation.


Figure 5: 11 sets of RCCSs ready to installation.




ISBN 978-3-95450-115-1

## INSTALLATION AND SCHEDULE

The 100-MeV linac was installed inside the tunnel as shown in Figure 6 after the survey of the tunnel was done and the supporting structures were prepared at March 2012. The total length from the ion source to the beam dump is 93m.The magnets of the 20-MeV beam line were also installed at May 2012 as shown in Figure 7.

Based on the construction schedule, the klystron gallery will be prepared on July 2012, the other part of the building and the conventional facilities will be finished until August 2012, respectively. Form July 2012, the RF components including klystron, RCCS and waveguides will be installed in the klystron gallery. After the modulator tests are done at September 2012, the RF test will start. The construction status of the accelerator building is shown in Figure 8.

The beam commissioning is scheduled at the end of this year. The initial goal of the beam commissioning is the beam power of 100W at the end of the 100-MeV linac. The pulse width and repetition rate are 50μsec and 1Hz with the beam energy of 100 MeV and the peak beam current of 20 mA [5, 6]. The commissioning process consists of two stages. One is for a 20MeV linac and a MEBT by using a beam stop which will be installed in MEBT. The other is for 100MeV beams by using a 1-kW beam dump installed at the end of the linac.


Figure 6: The installed 100-MeV linac in the tunnel.


Figure 7: The installed 20-MeV beam line magnets in the 20-MeV beam line hall.

Figure 8: Construction of the accelerator building at Gyeongju project site (April 26, 2012).

## CONCLUSION

The PEFP launched by the Korean government in July 2002, is developing a 100-MeV proton linac and installing the facilities at Gyeongju project site. The 20-MeV part of the linac has been successfully developed, tested and operated for 5 years at the Daejeon. After the completion of operation at November 2011, it was moved to the project site at Gyeongju. The installation of the 100-MeV linac and 20-MeV beam line magnets were finished. The construction of the accelerator building and the conventional facilities will be finished until August 2012. The RF test of the accelerator will start from September 2012. After finishing the beam commissioning which is scheduled at the end of 2012, the proton beam will be supplied to users from 2013.

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