OPERATION OF PLS 2-GeV LINAC*

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The PLS 2-GeV electron linac at the Pohang Accelerator Laboratory (PAL) has been constructed as a full energy injector to the storage ring of the Pohang Light Source (PLS) project. The 150-m long linac uses 11 klystrons of 80-MW maximum output power driven by 200-MW modulators. There are 42 constant gradient acceleration sections and 6 quadrupole triplets. By December 10, 1993, we completed the linac installation with the beam analyzing station and the beam transport line to the beam dump of 30-m long. We completed the machine commissioning by June 30, 1994. Since September 1, 1994, it provides 2-GeV beams to the PLS storage ring for its commissioning, which is also completed by December 24, 1994 with 300-mA stored current. In this paper, we present the operational experience of the PLS 2-GeV linac.

I. INTRODUCTION

The Pohang Accelerator Laboratory (PAL) has recently completed the 2-GeV synchrotron radiation source named the Pohang Light Source (PLS). The PLS will serve as a low-emittance light source for various research such as basic science, applied science, and industrial and medical applications. There is a 2-GeV linear accelerator as a full energy injector to the storage ring. This linac is consisted of eleven klystrons and modulators, and ten SLAC-type pulse compressors on the ground floor and 42 accelerating columns, six quadrupole triplets, and various components in the tunnel which is placed 6-m below the ground level.

Installation work started on July 1, 1992 has been completed by December 10, 1993. This includes the first section of the beam transport line (BTL) to the beam dumps and the beam analyzing station #3 (BAS3) in order to measure the beam energy and the other physical parameters.

The commissioning started on January 7, 1994. On March 9, 1994, we achieved the 1.5-GeV beam without using SLEDs. Exactly two month later, the 2-GeV beam was obtained, and it was declared that the 2-GeV linac commissioning was successfully completed [1].

During the summer maintenance period, the remaining BTL work was completed. From September 1, 1994, the beam injection to the storage ring (SR) was started. On the first day, the beam arrived in front of the Lambertson septum magnet in the storage ring. During the commissioning period for the storage ring, the linac provides about 600 mA of beams continuously. At present, we are operating the 2-GeV linac 24 hours a day from Monday morning to Friday morning with two shift teams per day.

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II. GENERAL DESCRIPTION

The nominal beam energy of the PLS linac is 2-GeV with the operating frequency of 2,856 MHz. There are 42 SLAC-type accelerating columns and 11 klystrons including those for the preinjector. Total length of the linac is 150-m long with an extra length of 15 m before the switching magnet. Therefore, the required accelerating gradient of the main linac is at least 15.8 MV/m. When we consider one or two klystrons as standby, it requires an accelerating gradient of 17.8 and 19.8 MV/m, respectively. In order to achieve this accelerating gradient, we adopted high-power klystrons of 80-MW and SLED-type pulse compressors. In addition, we required the RF pulse length at least 4 μs for a higher energy gain factor from SLED cavities. Major parameters for the PLS linac are summarized in Table 1.

Table 1: Major parameters of PLS 2-GeV Linac

Beam Energy	2 GeV
Accelerating Gradient	15.5 MV/m (min.)
Energy Spread	+/- 0.3% or less
Machine Length	150 m
RF Frequency	2,856 MHz
Repetition Rate	60 Hz (max.)
E-gun	> 2 A / 1, 2, or 40 ns
Emittance (theory)	75 π nm-rad at 2-GeV
Klystron Output Power	80 MW max.
No. of Klystrons	11 (=1+10)
No. of Pulse Compressors	10
No. of Accelerating Columns	42 (=2+40)
No. of Quadrupole Triplets	6
No. of Support/Girder	22
Beam Exit	100 MeV, 1 GeV, 2 GeV

The linac building has three levels; the tunnel in 6-m below the ground floor for accelerating columns and other components, the ground floor for the klystron gallery, and upper floor for utilities including air-conditioning and air handling units. The air temperature and the humidity of the klystron galley are maintained within the range of 23 - 25°C and 55% or less throughout the year, respectively. During the machine operation, there is no air exchange in the tunnel to avoid any contamination due to ozone or radioactive dust in the klystron gallery. There is 3-m thick concrete shielding between the tunnel ceiling and the klystron gallery. There are three beam switch yards at 100-MeV, 1-GeV, and 2-GeV locations for the beam extraction to other facilities. Currently, two locations at 100-MeV and 2-GeV are operational.

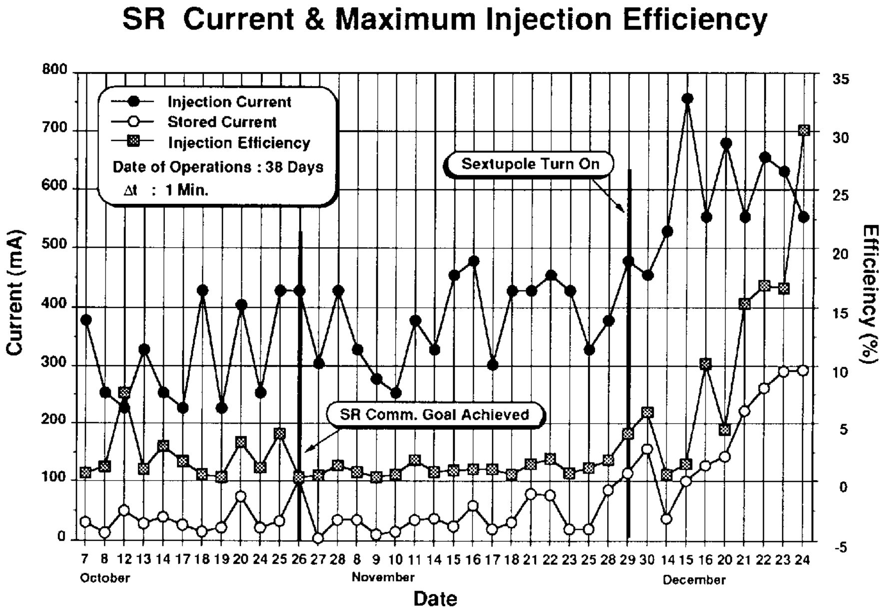

Fig. 1: Beam current and the injection efficiency during the period of October - December, 1994.

Main and auxiliary cooling stations are also annexed in the linac building. Both stations supply cooling water of temperature controlled at 45+/- 0.2ºC and non-controlled at 32 +/- 1ºC. The auxiliary station had been used for the preinjector initially and is now serving the test laboratory. The linac substation contains various transformers of total 8-MVA with three different groundings.

III. NORMAL OPERATION

A. First Period: August 1994

After successful commissioning of the linac completed by the end of June, 1994, we had an annual preventive maintenance period. We had intensive maintenance work for the main cooling system. We also improved the preinjector cooling and vacuum systems which had been constructed for training our staff in 1992. We removed all the vacuum manifold system and installed distributed pumping system the same as regular sections. Other two module had experienced vacuum vents for visual inspections. On the other hand, we opened the beam tunnel so that the staff could complete the remaining installation work for the BTL to the storage ring. When we resumed the RF conditioning, it had taken about two weeks to recover the stable operation condition One notes that it was a special case, because the vacuum system of the preinjector was replaced completely. Through the machine operation on August 17 and 18, we were able to obtain beams of 2.23 GeV with a total RF power of 600 MW. The accelerating efficiency with a given RF power is improved due mainly to the fine adjustment of the RF phase by the computer control. During this period, the linac was operated with self-generated trigger signals of 30 Hz.

B. Second Period: September to December, 1995

Just before the commissioning of the storage ring started, we changed the triggers for the e-gun, the modulators, and other microwave related equipment from self-generated signals to signals synchronized with the RF system of the storage ring. Since the SR injection system is operated at 10 Hz, we reduce the e-gun trigger to the same repetition rate. However, we keep the modulator operation at 30 Hz in order to have stable operations. Currently, the e-gun and the driving RF source such as the solid state amplifier are operated at 10 Hz while all modulators are operated at 30 Hz.

Before the beam injection to the storage ring, the BTL commissioning took place on September 1, 1994. We sent the 2-GeV beam successfully to the SR injection point within 2 hours. From the following day, we supplied 1.4-GeV beams to the storage ring for the storage ring commissioning. The reason to reduce the beam energy to 1.4 GeV was that the injection kicker could provide a full aperture kick at that energy. For 2-GeV beam injection, the storage ring uses correctors imbedded at nearby bending magnets to obtain an extra-kick. The first circulation of the beam at the storage ring was made on September 8, 1994, and the beam was stored for the first time on September 13, 1994. The history of linac operations are summarized in Fig. 1 during October - December period. It shows clearly that the beam current from the linac increased as we achieved experiences for the linac operation. The stored beam and the injection efficiency were also increased drastically. The beam energy was changed from 1.4 GeV to 2 GeV on October 24, 1994. During the brief shutdown period in the beginning of November for the storage ring maintenance, we operated the linac to achieve maximum possible beam energy which was 2.34 GeV on November 7, 1994. It is still the best energy we have obtained. There was another brief shutdown due to the completion ceremony which held on December 7, 1994. The commissioning was resumed from December 11, and we achieved the maximum stored beam current of 300 mA on December 24, 1994. On the same day, we declared the completion of the SR commissioning.

C: Third Period: January to April, 1995

The first three months of 1995 was allocated to replace various diagnostic instruments installed temporarily. And the intensive work for the vacuum cleaning and survey/alignments in the storage ring were also performed. During this period, we replaced the e-gun pulser system which could provide 2 ns pulse only. The new pulser system can provide 1, 2, or 40 ns pulsed beams. About 40 % of the electron beams generated from the e-gun is delivered to the storage ring. In February and March, we trained all the linac division members as machine operators.

Normal operation for the linac started from April 1, 1995. At present, we operate the linac 24 hours a day from Monday morning to Friday morning. A team of two-member serves a operation shift and there are two shift teams per day.

Up to now, we have no significant failures in the linac operations. The operation hours for eleven klystrons are over 120,000 hours as shown in FIg. 2. As of the end of April 1995, the cumulative beam operation time for the linac is about 1,100 hours.

V. FUTURE PLAN AND SUMMARY

The PLS project is the first attempt in Korea for constructing a major accelerator facility. In addition, the 2-GeV injector linac is the third largest electron linac in the world. The prime mission for providing beams to the storage ring requires a few minutes for each injection, and ultimately, it will happen once or twice in a day. Therefore, we planned to use electron beams of various energies to promote other branches of basic and applied sciences.

First, we propose to add a "pulse stretcher" ring for nuclear physics experiments in the other side of the storage ring where there is enough space already prepared [2]. Secondly, there is a plan to build a compact storage ring for commercial use by Samsung Heavy Industries [3]. The PAL will help to design an injector linac and a compact ring, and our experiences will be great help for them to construct the compact ring.

The PLS 2-GeV linac has been successfully commissioned in June 1994 as scheduled, and its performance exceeds the design values. We have demonstrated that it is a viable option as a full energy injector to the storage rings up to this energy in the construction cost. Through the PLS project, we have established a technology base for particle accelerators and trained young scientists and engineers in Korea. We are mostly benefited from exchanges of personnel and information with other established laboratories through institutional collaborations. We expect to use our experiences for advanced accelerator R&D programs and for new projects.

VI. ACKNOWLEDGMENTS

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VII. REFERENCE

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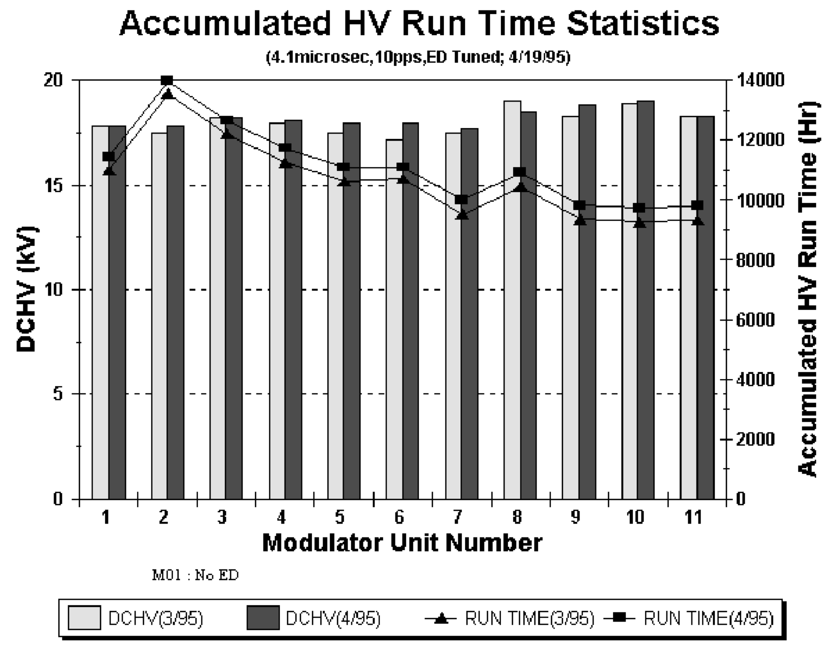

Fig. 2: Cumulative operation times for eleven klystrons.