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# Current Status of Ion Source System Development for 35 MeV Cyclotron

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## 1. Introduction

A new 35 MeV cyclotron is now currently being designed for radioisotope production and fundamental researches. The 35 MeV cyclotron implementation can face the uncertainty of the construction due to technical difficulties and the complexity of the accelerator devices. Therefore, the prior verification of the cyclotron system should be performed before the construction of the cyclotron facilities. Especially, the ion source system is critical part of the cyclotron system. Now, we are developing the new ion source system for the 35 MeV cyclotron. In this research, we describe the current status of the ion source system development for 35 MeV cyclotron. First, we are currently developing the ion source system for the 35 MeV cyclotron. The new ion source control system will be used for the verification of the new 35 MeV cyclotron development.

## 2. Methods and Results

### *2.1 35 MeV Cyclotron Ion Source System Overview*

The ion source system creates the negative hydrogen (H-) ion and then extracts the H- ion to transport to the low energy beam transport (LEBT). The ion source system consists of multi-cusp ion source, electric power unit, cooling system, vacuum system, and the control system. Figure 1 shows the 35 MeV new ion source system specification.

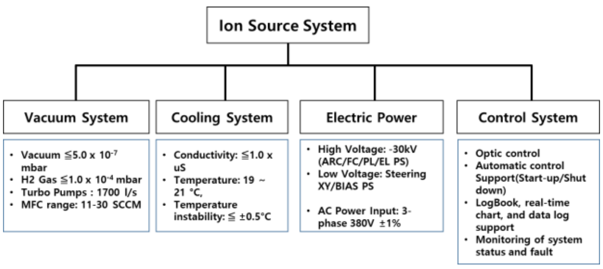


Fig. 1. 35 MeV Cyclotron Ion Source System. The ion source system consists of multi-cusp ion source, electric power unit, cooling system, vacuum system, and control system.

The ion source system creates the negative hydrogen (H-) ion and then extracts the H- ion into the injection system in order to transport the H- ion into the center of the main chamber. The ion source consists of ion plasma chamber, extraction lens, vacuum box, and steering magnets. The electrical power system, which provides the power for H- ion beam extraction, is consists of low voltage section and high voltage section. The low voltage section includes the bias power supply (PS) and the ion source steering magnet PS. The high voltage section provides the ion source such as ARC, filament, plasma, and extraction lens. The vacuum system maintains stably the vacuum status of the ion source. The vacuum system is divided into high vacuum and low vacuum parts, and two turbo molecular pump (TMPs) and mechanical pumps (MPs) are used for maintaining the vacuum status of the ion source. The ion source cooling system performs the removal of the ion source heat by supplying the deionized water to the ion source. The control system controls the power supplies, ion source devices to operate the ion source system remotely.

### *2.2 Ion Source Hardware*

We adopted D-Pace Multi-cusp type ion source for the cyclotron ion source. Figure 2 shows Multi-cusp ion source. The TRIUMF style ion source has 15 mA H- beam current and can be run at 30 KeV as required on a 35 MeV Cyclotron. The detailed specification is described in Table 1.

Fig. 2. D-pace filament powered negative ion source [1].

We adopted D-Pace filament powered negative ion source for the construction of the ion source system. Figure 2 shows multi-cusp ion source [1]. The D-Pace ion source has 15 mA H- beam current and can be run at 30KeV as required on a 35MeV cyclotron. The emittance is about 100 *mm•mrad*. The ion source utilizes three electrodes for injecting the H- ion created from the ion plasma.

Based on the ion source, we designed the power electric system for the ion source. The ion source power is composed of high voltage power supplies, low voltage power supplies, ion source, and isolation transformer. As shown in Fig. 3, the power supplies are divided into the high voltage section and the low voltage section. The high voltage is about negative 30kV and the power supplies at the high voltage section provide the power with the ion source devices.

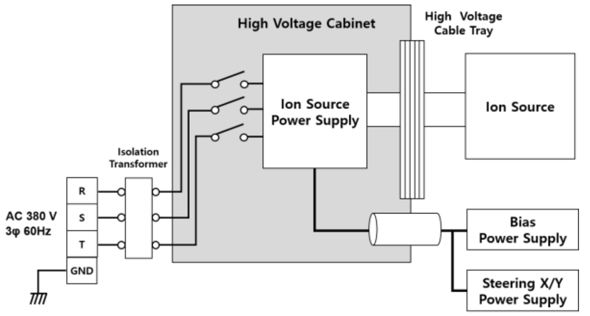


Fig. 3. Power Electrical System of Ion Source. The power system is composed high voltage section and low voltage section.

The high voltage power supplies are ARC power supply (PS), filament PS, plasma PS, and extraction PS. The ARC PS provides the current for creating the arc in the ion source chamber. The filament PS supplies the high current for heating the filament in the chamber. The plasma PS controls the H- ion source creation and the extraction PS controls the acceleration and the focus of the H- ion. The low voltage power supplies are bias PS and steering PS. The bias PS and the steering magnet PS provide the ion source with output power at the low voltage section. The isolation transformer is used for isolating the AC input power from the high voltage region.

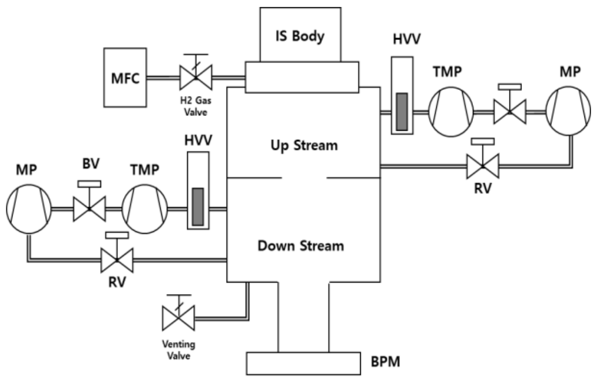


Fig. 4. 35 MeV Cyclotron vacuum system. The vacuum system consists of ion source (IS) body, upstream part, and downstream part.

Figure 4 shows the ion source vacuum system. The ion source vacuum system consists of ion source (IS) chamber body, vacuum upstream part, and vacuum downstream part. The hydrogen ($H_2$) gas is inserted into the ion chamber through the mass flow controller (MFC). the differential vacuum required in the H- ion source vacuum box is adopted. The ion source vacuum box is divided into two parts of upstream and downstream parts. Two turbo molecular pumps (TMPs) and mechanical pumps (MPs) are used for the vacuum system. The high vacuum valves (HVVs) are used to seal the TMPs from the ion chamber. The ionization gauges are used to measure the vacuum pressure in the up/downstream side of the vacuum box.

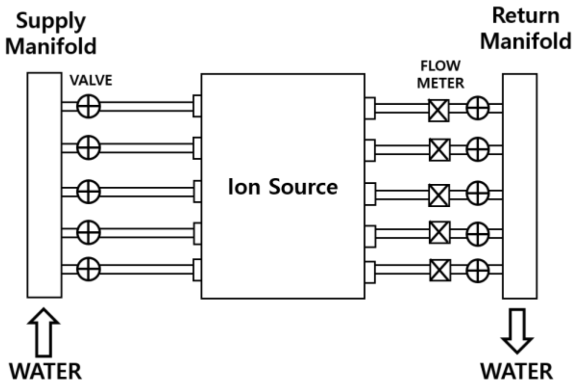


Fig. 5. Cyclotron ion source cooling system. The cooling system performs the removal of the heat generated from the ion source.

The ion source cooling system performs the removal of the heat generated from the ion source. Figure 5 shows the cyclotron ion source cooling system. The deionized water is used for cooling the ion source and the distributing pipe system supplies the water into the ion source. Typically, 20℃ de-ionized water is supplied through a supply manifold to the ion source parts such as back plate, body, plasma and extraction parts, filaments, x-y steering magnets, and TMPs. The water temperature rises when the water is returned from the ion source parts.

### *2.3 Ion Source Control System*

We developed the EPICS beamline control system for the RFT-30 cyclotron. To control the various systems in the ion source, we developed the ion source control system based on the experimental physics and industrial computer (EPICS) [3]. The figure 6 shows the EPICS ion source control system. The EPICS control system consists of EPICS IOC server, CSS Client OPI, and ion source devices. The EPIC IOC server controls the power supplies and other devices of the ion source. The client user interface is based on the control system studio (CSS) and the client program can change the process variables (PVs) of the IOC server. The ion source devices are composed of the ion source power supplies and the PLC controller.

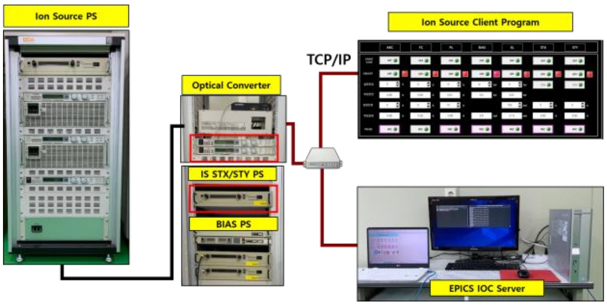

Fig. 6. Ion Source Control System Overview. The EPICS control system consists of EPICS IOC server, CSS Client OPI, and ion source PS devices.

The EPICS base, ASYN, STREAM programs are installed at the EPICS IOC Server [3,4]. The EPICS IOC server is used for the PLC control and the power supply control. As shown in Fig. 6, the power supplies are connected to the serial device server and ASYN driver and StreamDevice module are used for the control of power supplies. The vacuum gauges are read the EPICS IOC program and used in the operational interlocks. For the PLC client control program, we constructed the client operator interface (OPI) by using the control system studio (CSS) [5]. The CSS based client program can control the ion source devices using the process variable(PV) of the OPI.

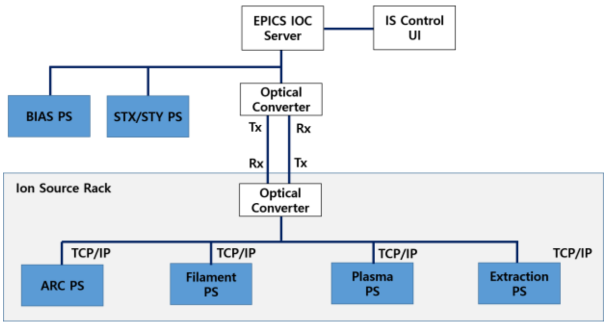

Fig. 7. Ion Source PS Control Overview. The ion source has two separate regions such as low voltage region and high voltage region.

We designed the optical communication based control system for the ion source PS control. Figure 7 shows the ion source power supplies control overview. In order to control the IS power supply, we have developed the EPICS control program. The ion source has two separate regions such as low voltage region and high voltage region. The communication failure between two regions may cause serious problems and breakdowns of the devices. To solve this problem, we utilized the optical communication between two regions. The power supplies at the high voltage section is connected to the optical converter and the optical converter at the low voltage section is into the EPICs IOC server. The optical converter can prevent the control problems caused by the potential difference between the high voltage and low voltage sections.

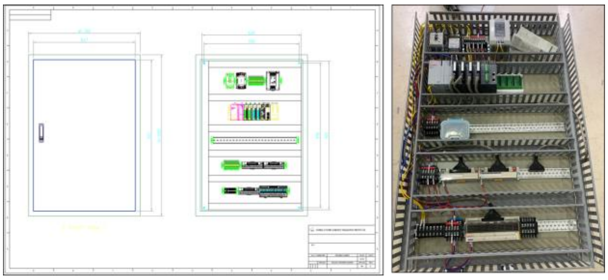
Fig. 8. RFT-30 PLC control hardware. The PLC hardware is used for the ion source vacuum control.

Figure 8 shows the PLC control hardware of the ion source. We utilized the LS series PLC, which is widely used in the industrial fields [6]. The PLC hardware is used for the ion source control of vacuum and cooling devices. A new EPICS device support for the PLC is based on EPICS Modbus module, which allows for a simple integration of LS PLC into EPICs control system [7]. The PLC with analog input modules and digital input/output (I/O) modules are used for implementing the operational logic for the pumps, valves, and safety interlocks.

## 3. Conclusions

An ion source system is now currently being designed for the cyclotron. The new ion source system will be used for the verification of the new 35 MeV cyclotron development. The prior verification of the cyclotron system can reduce the uncertainty of the development due to technical difficulties and complexity of the cyclotron system.

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