# RF SYSTEM FOR KOMAC RFQ*

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*Abstract*

The 1 MW, 350 MHz RF system for KOMAC (Korea Multipurpose Accelerator Complex) Test Facility (KTF) RFQ has been installed and is being tested at KAERI (Korea Atomic Energy Research Institute). The main components of the RF system are 350 MHz, 1 MW CW klystron, 1 MW circulator, RF window, various W/G components, LLRF system, 100 kV, 20 A high voltage power supply for the klystron and 2 MW cooling system. In this paper, the installation and test results of the RF system and its components are presented.

## 1 INTRODUCTION

As a first stage of the KOMAC project whose final goal is to develop a 1 GeV, 20 mA proton accelerator, the KTF has been developed at KAERI. The KTF consists of 50 keV proton injector [1], 3 MeV 350 MHz RFQ [2] and 20 MeV, 700 MHz CCDTL [3].

Two types of RFQ have been developed. The one is 0.45 MeV RFQ whose purpose is to check the basic RFQ technologies such as tuning, beam matching and so on, the other is 3 MeV main RFQ which was fabricated and vacuum tight checked already. The required RF power for 0.45 MeV RFQ is 110 kW CW and for 3 MeV is 417 kW CW respectively. The 1 MW, 350 MHz RF system has been developed to deliver a RF power to the RFQ. The high power RF system consists of klystron, circulator, RF window, various waveguide components, klystron power supplies and cooling system. Recently all components of the RF system were prepared and are being tested. The status of the KTF RFQ RF system is shown in Figure 1.

Figure 1: KTF RFQ RF system

## 2 RF COMPONENTS DESCRIPTIONS

### *2.1 Klystron*

The KTF RFQ RF system utilizes a 1 MW CW klystron at 350 MHz. The klystron was manufactured by THALES Electron Devices and is shown in Figure 2. The klystron has a triode type electron gun to control the beam current and is capable of dissipating the full beam power (1800 kW). It could deliver RF power up to 1.1 MW into the load of a VSWR 1.2:1 at 350 MHz during the acceptance test at THALES Electron Devices last year. It is now installed at KAERI KTF site and being high power tested. In order to protect personnel from X-ray, additional 2 mm thick lead shield - besides the lead shielding in the collector zone - around the klystron was installed.

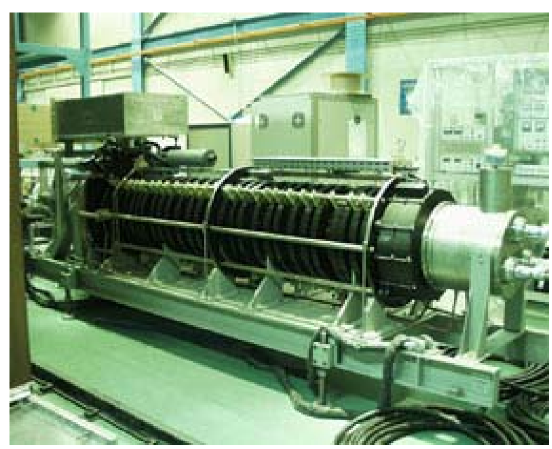

Figure 2: 1 MW 350 MHz Klystron

### *2.2 Klystron Power Supplies*

The specifications of the high voltage power supplies for the KTF klystron are 100 kV, 20 A with the conditions that the voltage peak to peak ripple and the voltage regulation are less than 1 %, and energy deposition in the klystron at the tube arc is less than 20 J. The power supply that meets the above conditions has been designed,

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manufactured and tested by KAERI. The schematic circuit diagram of the power supplies that includes high voltage power supply, modulating anode power supply and heater power supply is shown in Figure 3. The main components of the high voltage power supply are IVR (Induction Voltage Regulator), transformer & rectifier tank for 12 pulses rectification, L-C filter, and ignitron (NL-1489 ; National) crowbar. Voltage dividing resistors and a tetrode tube (TH5188 ; Thomson-csf) were used to provide variable high voltage to modulating anode of the klystron. The variable voltage modulating anode power supply gives the flexibility of klystron operation.

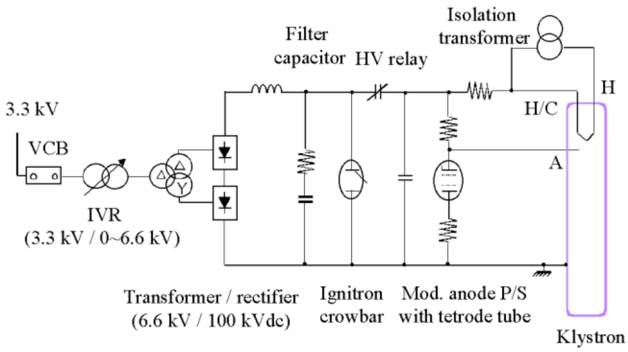


Figure 3: Circuit diagram of high voltage power supply

## 2.3 Circulator

A 350 MHz Y-junction type circulator, which can deliver 1.3 MW CW RF power for forward direction and permit 1.3 MW reverse power at any phase, was used. The circulator has been manufactured by Advanced Ferrite Technology (AFT). It uses temperature compensating system to compensate the temperature dependent ferrite saturation magnetization. It was installed at KTF site as shown in Figure 4.

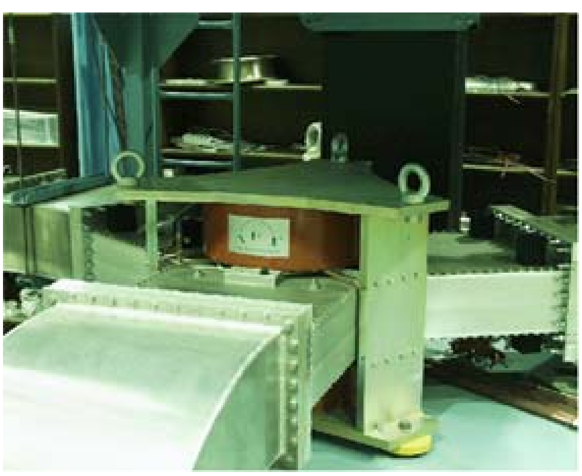

Figure 4: 1.3 MW, 350 MHz Y-junction circulator

## 2.4 Waveguide Components

The WR2300 waveguide components, which were manufactured by Dielectric communications, have been used. It consists of straight, E-plane, H-plane sweep bend, flexible section, and full height to half height step transition. In addition to those purchased from Dielectric, waveguide components were manufactured in a domestic company. Those include E-plane, H-plane mitre bend, harmonic filter and are being tested.

## 2.5 RF Dummy Load

A 1 MW at 350 MHz RF dummy load manufactured by Dielectric communications was used. It is about 4 m long and uses water and ethylene glycol mixture (volume ratio - 50 : 50) as a coolant. In the KTF RFQ RF system, the RF dummy load is used as a dummy load not only for klystron full power test but also for absorbing reflected RF power from RFQ through circulator.

## 2.6 RF Window

A RF window manufactured by THALES Electron Devices was used. It uses half height WR2300 waveguide flange at both sides, and can transmit RF power of 750 kW CW at 350 MHz on a load with a VSWR ≤ 1.3 : 1. The RF window will be installed with the RFQ input coupler, which is a coaxial loop coupler with half height WR2300 waveguide to coaxial transition.

## 2.7 Cooling System

A 2 MW DI water cooling system for KTF RFQ and RF system was prepared already as shown in Figure 5. The required cooling loops for RF system are circulator, RF load, RF window cooling loops and body, cavity, collector cooling loops for klystron. Because the coolant of the RF load is a mixture of water and ethylene glycol, a separate cooling loop for RF load with storage tank, pump and heat exchanger was installed. Also pump for pressurization was installed in klystron body cooling loop, because the pressure of the DI water cooling loop was too low to supply enough flow to that cooling loop.

Figure 5: 2 MW DI water cooling system

## 2.8 LLRF (Low Level RF)

The LLRF consists of a 350MHz signal generator, a 160W solid state amplifier, amplitude/phase control loops, and RF interlocks. The designed field stability in the RFQ cavity is within ± 1% amplitude and ±1.4° phase using feedback control loops in the LLRF. For frequency control, another tuner controller module was used. The RF interlock signals comes from excessive reflected RF power, circulator arcs and window arcs.

## 3 TEST RESULTS

The klystron power supplies were tested. At first, electrical breakdown at the high voltage cable was occurred. After the cable was replaced, the high voltage test up to 95 kV showed no problems. A crowbar test using ignitron was carried out. Wire test using 0.3 mm diameter and 200 mm long copper wire to confirm that the energy deposition in the klystron at the tube arc is within the limit value showed that the dissipation energy at the load was less that 20 J. Interlocks for the high voltage power supply and LLRF were installed and RF tests have been carried out. In RF tests, parts of waveguide section that connected circulator with RFQ were removed and shorting plate was installed at the end of the open section. In these test scheme, klystron and circulator can be tested simultaneously, because the RF power flows from klystron to shorting plate through circulator, then reflects from shorting plate, and finally is absorbed in dummy load through the circulator. Using these test schemes, the high power RF system was tested up to 100 kW CW RF power. RF power was measured by calorimetric method with RF dummy load and simultaneously by power meter with directional coupler. Two data showed good agreement within 5%.

## 4 CONCLUSIONS AND FUTURE WORKS

The RF system for KTF RFQ has been developed. Each components and overall system are being tested. The high power RF system was tested up to 100 kW CW RF power.

During the test, two problems were found out. First, there were RF leakages between the waveguide joint. After disassembling and investigating the waveguide joint, it was found out that there were some poor machined parts in the waveguide flange that was made by domestic company. Second, there was RF power reflection from the dummy load that is very sensitive to coolant temperature, the reason of which is not clearly known yet.

After the correction of the above problems, this RF system will supply the RF power of 100kW level for RF window and low energy RFQ test. With the completion of the low energy RFQ experiment, it will be used as RF system of 500kW level for the 3MeV RFQ experiment, that is the original role of this RF system.

## 5 ACKNOWLEDGEMENT

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