ORIC OPERATION AND DEVELOPMENT

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The primary mission of the Oak Ridge Isochronous Cyclotron (ORIC) is to serve as a driver for the production of radioactive ion beams (RIBs). ORIC provides high intensity proton, deuteron, and alpha particle beams to a target-ion source assembly that is located on the RIB injector platform. The reaction in the target produces radioactive atoms that are then ionized and injected into the tandem. ORIC has operated for approximately 1200 hours during the period for light ion beam development and radioactive beam production.

During the period, ORIC subsystems have been upgraded by means of both capital equipment funds and a four-year Accelerator Improvement Project (AIP) which began in FY 1996. Machine improvements have included numerous power supply replacements and control system conversions to the HRIBF Vista/programmable logic controller (PLC) based system for higher reliability and ease of maintenance. Details of all machine development are provided in this section by ORIC subsystem.

1. Light Ion Beam Production

The ORIC beam development program has had significant advancements during the two-year period in providing proton, deuteron, and alpha beams to the RIB injector target-ion source. Most recently, emphasis has been placed on deuterons for ^{17}F development. Beam development has centered on increasing extraction efficiencies to minimize beam loss and machine activation, maximizing beam intensities transported to the RIB target, and expanding the range of available energies. Progress to date is tabulated in Table 1.

Table 1. Maximum Values of ORIC Beam Parameters Obtained to Date

	Extracted Beam Energy (MeV)	Extracted Beam Intensity (μA)	Extraction Efficiency (%)
Protons	43	10	85
Deuterons	49	12	75
Alphas	75	1.6	33

In particular, the turn structure of the deuteron beam was analyzed in the central region. A 0.25"-diameter tantalum bar phase clipper was mounted to the adjustable track assembly on the front of the dee opposite the puller electrode track to clip unextractable beam and thus increase extraction efficiency. Movement of the clipper through the first four turns of the beam demonstrated that phase clipping on the low side of either turns three or four improved extraction efficiency to around 85%. At higher intensities, the clipping effect was less pronounced and efficiencies were around 55%. The bar also serves as an effective means of limiting beam intensity from a larger-aperture source, thus providing a wider dynamic intensity range.

Machine startup and reliability have greatly improved, largely due to funding of the ORIC AIP. Startup time has typically been reduced from one shift to two or three hours. Diagnosis of problems requires considerably less time due to modernization of the control system and improved diagnostics.

The beam development program will continue to emphasize optimizing accelerator parameters for additional beam energies, attaining higher intensities, and increasing the extraction efficiency. With recent advancements and near-term planned improvements, ORIC appears to be positioned to reliably operate for many years to come.

2. Beamline Subsystem Development

A Hall Probe readout system has been installed on the ORIC beam lines. The probes were installed in beam switching magnet BSM_1_1 and vertical dipole BMV_9_1, both of which are used to transport beam to the RIB target ion source. The probes are utilized to provide magnet field level readings to the operations staff during tuning and beam transport, reducing the dependence on precise coil current measurements. Additionally, a probe was installed in the 153° beam-analyzing magnet (BAM_2_1) to aid measurement of beam energies.

Power supply replacements have included a new 320A supply for vertical bending magnet BMV_1_2 where the beam exits ORIC, and a small unit for neutralization of BSM_1_1 when beam is transported to BAM_2_1.

3. Extraction Subsystem Development

The lower channel power leads have been redesigned to facilitate fabrication and installation. The power leads are essentially three pairs of water-cooled welding cables. The coolant is contained in a flexible metal bellows that isolates the coolant from the vacuum system and yet allows for the range of motion required to extract beam through the lower channel. The leads are required to carry up to 3000 A dc.

Spare components have been developed for the coaxial magnetic channel and the lower magnetic channel. ORIC operation with high-current light-ion beams causes high levels of activation on extraction system components. For this reason, it is not be feasible to repair a failed coax or lower channel until the radioactivity has decayed so it is extremely important to have spare components ready for installation. A coax assembly consists of a coaxial magnet channel body and a coax insert and, typically, failures occur on the coax insert. An existing coax body was retrofitted with mounting hardware to match the current coax insert design. A spare lower channel had been fabricated during the period of heavy ion operation and minor modifications have been made to the channel for use in the light ion program. Additionally, the coil coolant circuit electrical insulators were redesigned using PEEK (polyetheretherketone) as the base material. These insulators isolate the water-cooled coils from ground while passing the coolant from the coolant system to the coils. The insulators were previously fabricated from nylon. In contrast to nylon, PEEK has excellent dimensional stability, low out-gassing, low water absorption, high strength and relatively high radiation resistance. A temperature sensor system is also being developed for readout of coil and coolant temperatures in the coax and lower channel to provide temperature information to the control system for display and for implementing thermal interlocks.

ORIC's coaxial magnetic extraction channel is powered by a 50V, 6000A dc low-ripple power supply. The power supply which had been in service since 1968 had become quite problematic in recent years and parts were difficult to obtain, resulting in excessive unscheduled maintenance. Consequently, a new unit built by Alpha Scientific replaced the supply. The new supply is SCR regulated and controlled by a HRIBF control system-compatible PLC. It was located closer to the load than the previous supply, eliminating approximately 150 feet of water-cooled copper bus.

4. Ion Source Subsystem Development

At the end of the previous reporting period, a new ion source head assembly had been designed. The design has worked quite well. The cathode replacement interval is now approximately 300 hours, considerably longer than with the preceding source. Additionally, gas-handling system improvements have resulted in a cleaner, more efficient system with less gas required for both striking and sustaining the source arc.

Source aperture plates with holes ranging from 0.010" to 0.030" are utilized in the source chimney depending on the desired beam current. It was determined that for improved horizontal centering of the beam exiting ORIC that the apertures should be offset 0.020" to the west side of the machine.

5. Magnets and Coils Subsystem Development

Orbit shaping in ORIC is accomplished by a set of 10 concentric trimming coils mounted to the main magnet pole faces. During FY97, trimming coil T9 failed with an internal water leak. Combined with the 1986 loss of T10 and the 1988 loss of one-third of T8, operation of ORIC became more difficult. However, calculations indicated that most beams could be isochronized even with these coil losses, and that proved to be the case with skilled operator tuning. However, loss of another coil in the almost 40-year-old assemblies could result in a lengthy shutdown period. Thus, it was determined that a new set of trimming coils should be fabricated. Original drawings were reviewed, design changes were made, and a new set of drawings produced. A contract was awarded to Everson Electric Company to fabricate a set of two coil assemblies and delivery is expected early in FY1999. Installation of a full set of trimming coils would restore the original flexibility in tuning a wide range of beams. The coil fabrication process is shown in Fig. 1.

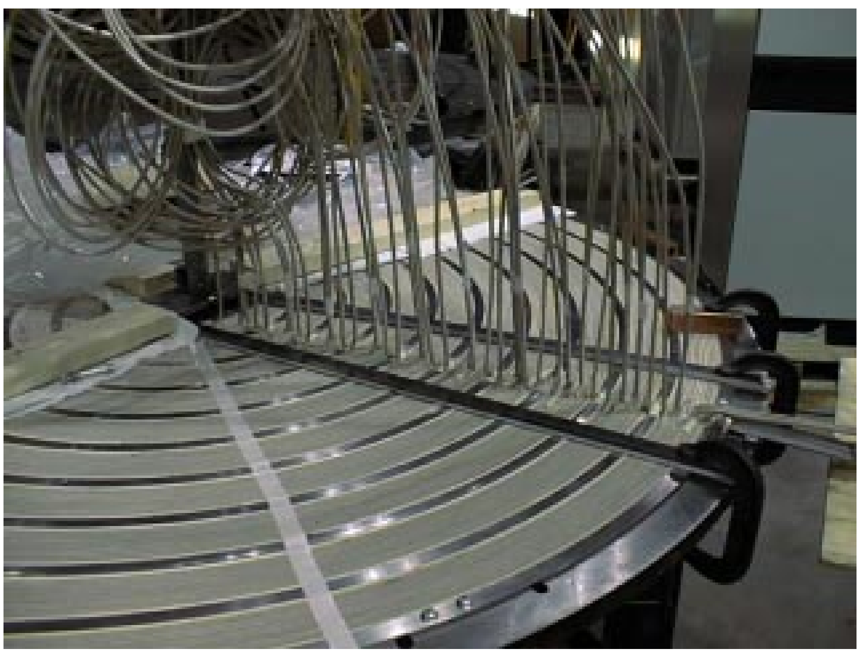

Fig. 1. Replacement trim coils for the ORIC in the fabrication process.

A program to replace all trimming coil power supplies is also underway. Specifications were prepared and an order was placed for four of the ten units. Orders for the remaining units are planned for next year. The new power supplies will be sized in three groups in order to permit interchangeability.

The aluminum conductors of the main cyclotron magnet were given a passivation treatment by circulating a potassium dichromate solution for a period of several days to protect the water passages of the conductors from corrosion. Originally, this treatment was done annually, however, in recent years the treatments have been limited to less frequent scheduling by environmental restrictions. During treatment, about 5 lb. of reagent is used in about 400 liters of solution. Following treatment, the reagent is removed from the water by a mixed resin bed deionizer whose resin must then be disposed of as RCRA waste.

Circulating beam in ORIC may be offset from the median plane by introduction of a slight main magnet coil current imbalance imposed by a small auxiliary main field power supply. The in-house built unit with hard-wired controls was replaced by a new switch-mode power supply interfaced to the control system that permits finer adjustment.

6. Radiofrequency Subsystem Development

All associated dc power supplies for the RF system power amplifier were replaced with new equipment. Most notably a new 600 kW power amplifier (PA) anode power supply was specified, purchased, and installed. The new unit features an SCR voltage regulator/current limiter, vacuum-impregnated-epoxy transformer coil windings, silicon rectifier stacks, an ignitron crowbar, and a PLC control interface. Performance and reliability of the new anode power supply following a period of debugging have been excellent.

Other power supplies including units for the PA screen, the PA grid bias, and the PA cathode heater were also upgraded. These units all have voltage/current regulation and PLC interfacing. The four ENI A-300 broadband power amplifiers in the RF system's driver amplifier stage were replaced with four new units. The former units had been in service for nearly 20 years and replacement transistors were no longer available. The newer models have better output transistors and improved heat transfer design.

In addition to these changes, the ORIC RF controls were converted to Vista/PLC operation. All flow protection circuits are now individually wired to the PLC for easy monitoring and power supply interlocking, replacing numerous relays. Each RF power supply is controlled from a graphical display screen with strip-chart monitoring capability, full interlock displays, and 15-bit control resolution. The A-300 power levels are now monitored via a bar graph display, and the shorting plane controls were also upgraded to Vista/PLC control.

7. Utilities Subsystem Development

Funding was requested and approved for a pollution prevention project for the cyclotron and related equipment. The project involves the replacement of seven oil-filled mechanical pumps with seven oil-free dry scroll pumps thereby eliminating the costs associated with disposing of mechanical pump oil, cleaning supplies and solvents. The project also funds the conversion of two diffusion pumped helium leak detectors to turbomolecular-based units coupled with oil free backing pumps.

The ORIC trim coils, harmonic coils, and valley coils utilize more than 80 coolant circuits. Each circuit has a flow switch that provides coolant flow protection. The flow switches had become somewhat unreliable resulting in the expenditure of several man-hours of effort to set the switches each time ORIC was started, and concern that the flow protection was not effective. Flow measurements were taken for each coolant loop. Each switch was removed from the system, completely rebuilt with the flow orifice sized according to the manufacturer’s recommendation, and individually tested using a flow meter prior to installation.

The RF system flow circuits were upgraded to allow individual circuit flow protection for each power supply. This required the replacement of approximately 10 flow switches and their relocation to a common area making maintenance and troubleshooting much easier.

ORIC's original 20" south diffusion pump was replaced due to a crack in the pump body in the boiler area which was virtually inaccessible. Due to the crack and poor performance history of the pump, a replacement pump was purchased and installed. The new pump is a standard design unit from Varian that has superior performance and maintainability compared to the original pump.

ORIC's hardwired vacuum control system was converted to the Vista/PLC-based system. Control of all system valves and diffusion pump heaters is now accomplished through Vista. Interlocks were revised and implemented in the PLC code and all interlocks are displayed individually on graphics windows. The system is entirely self-protecting.