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INITIAL OPERATION OF THE HOLIFIELD FACILITY

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Introduction

The Holifield Heavy Ion Research Facility (HHIRF) is located at Oak Ridge National Laboratory and operated, by the Physics Division, as a national user facility for research in heavy-ion science. The facility (Fig. 1) operates two accelerators: the new Pelletron electrostatic accelerator, designed to accelerate all ions at terminal potentials up to 25 million volts, and the Oak Ridge Isochronous Cyclotron (ORIC) which, in addition to its stand-alone capabilities, has been modified to serve also as a booster accelerator for ion beams from the Pelletron. In addition, a number of state-of-the-art experimental devices, a new data acquisition computer system, and special user accommodations have been implemented as part of the facility. The construction of the facility was completed officially in June of this year.

This paper reports on the present status of facility operation, observations from testing and running of the 25 MV Pelletron, experience with coupled operation of the Pelletron with the ORIC booster, and a brief summary of the experimental devices now available at the facility.

Project Chronology

A summary of important milestones during the construction of the HHIRF is given in Table I. This construction, now completed, began in 1976 and included the 25 MV electrostatic accelerator, a building addition to house the accelerator, modest additional experimental space, a building to house the gas-handling and storage system for the insulating gas, and modifications to the existing cyclotron (ORIC) to enable it to serve as a booster accelerator for the tandem.

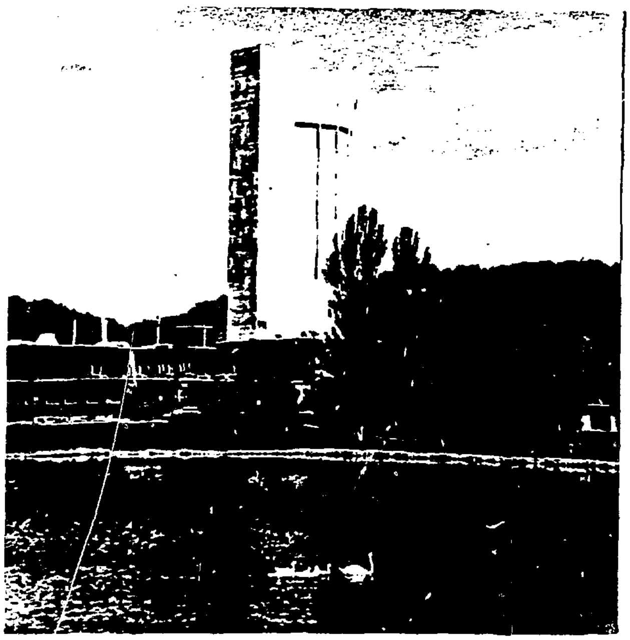

Fig. 1. View of the Holifield Facility.

TABLE I. HHIRF Project Milestone Summary

APR 1976	Start of construction
JAN 1978	Pressure vessel completed
NOV 1978	Building completed
MAY 1979	Column voltage tests performed (30 MV reached)
MAY 1980	First beam accelerated through tandem accelerator
AUG 1980	Acceptance tests with beam at 7.5 and 17.5 MV
AUG 1980	First call for experiment proposals
NOV 1980	First PAC meeting
JAN 1981	First coupled accelerator operation
FEB 1981	New data-acquisition system commissioned
MAY 1981	User building completed
JUN 1981	First operation for scheduled experiments
JUN 1982	Completion of project

A description of the Holifield Facility was presented by John Martin at the 1978 meeting of this conference series.[1] At that time, construction of the building was nearly complete and installation of the accelerator system was ready to begin. All of the goals set out in that paper have now been accomplished with the single exception of achieving operation of the electrostatic accelerator at the full design potential of 25 million volts. This point will be discussed in some detail in the next section.

The facility has now operated for approximately 11 months in support of the experimental research program: an interim period of operation from June to November of 1981 and the period since completion of the project in June of 1982. This operation for scheduled experiments has included both stand-alone operation of the tandem and a significant amount of operation in the combined accelerator mode.

The 25 MV Pelletron

We chose to have the new tandem accelerator for Oak Ridge built in a "folded" configuration, unlike the conventional linear column structure of previous large tandems. This configuration results in the physical arrangement shown schematically in Fig. 2. The pressure vessel housing the column structure is approximately 10 m in diameter and 30 m high. It is designed for operating pressures up to about 0.7 MPa (100 psig). The insulating gas used is pure SF_6.

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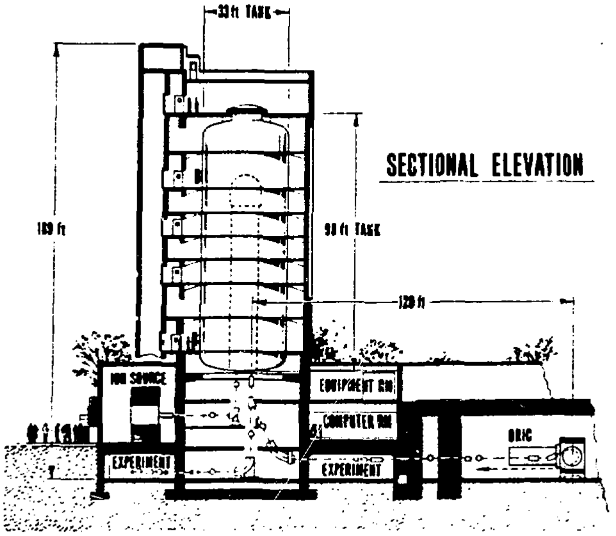

Fig. 2. Elevation section of the Holifield Facility building

The accelerator was designed and built by National Electrostatics Corporation (NEC). The column structure of the Pelletron's high voltage generator is 3.3 m in diameter and 18.9 m high, topped with a 4.8 m-high terminal shell. This column contains 27 of the standard 0.6 m, 1 MV, NEC modules. A view looking down on the completed column is shown in Fig. 3. The installation of the column structure, including charging chains and power transmission shafts but not the acceleration tubes, was completed in April, 1979.

Voltage tests on the column were performed in May, 1979. A graphical summary of the test results is shown in Fig. 4. Note that, at the higher insulating gas pressures, the maximum breakdown voltage does not appear to level off with time. Instead, the voltage exhibits a rising trend consistent with conditioning behavior. The tests at highest pressure were terminated because of uncertainties about the possibility of spark-induced damage to the column structure, the voltage holding capabilities having been adequately demonstrated.

Fig. 3. A view looking down on the high voltage terminal and column of the 25 MV Pelletron.

Examination of the column following these tests revealed markings from 42 spark "hits" rather uniformly distributed over the terminal shell and upper portions of the column. Areas of discoloration at these points ranged up to about 2 cm in diameter with some roughness of metal noticeable at the center of these spots. No evidence was observed that this roughened surface resulted in any restriking to the same spot. Our conclusion is that the basic column structure is easily capable of producing voltages and withstanding the effects of sparks to full design potential and beyond.

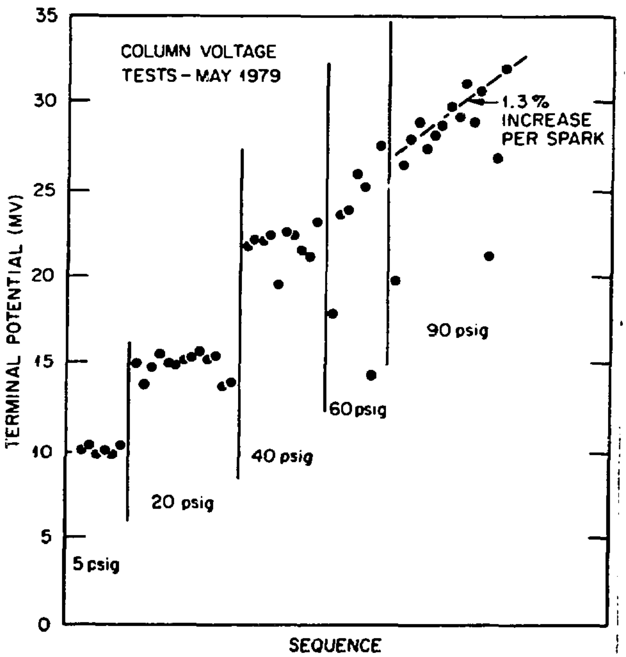

Fig. 4. Terminal voltage at breakdown as a function of spark sequence. A recent calibration indicates the voltage scale shown on this figure is too high by about 8%.

Remaining components of the accelerator system were installed in the column during the period from June to December, 1979. A number of small, but time consuming, problems delayed tests with beam until May, 1980. On May 12, a beam of oxygen ions was accelerated through the machine at a terminal potential of 15.5 MV. In July and August, 1980, system acceptance tests were performed at 7.5 MV and 17.5 MV on terminal. These tests included the demonstration of analyzed beams of 1 pμA (6 x 10^{12} part/sec) of ^{127}I ions.

Following these tests, major maintenance was performed to prepare the Pelletron for tests at full potential. As part of this maintenance, the closed corona voltage grading system supplied with the machine was replaced ith an open system. Since that time, all operation ha. been with the open system and we have no plans to reinstall the closed system. Conditioning of the accelerator was resumed in October, 1980. In December, it was discovered that eight acceleration tube sections (there are a total of 162 tube sections in the accelerator) had been damaged. This damage, in the form of electrode material deposited on the inner surface of the tube insulator, was attributed by NEC to improper spacing of the annular spark gaps at the end of the tube sections and operation at excessive tank pressures. The damaged sections were replaced and all of the end gaps were readjusted.

In January, 1981, the Pelletron was used briefly to test the booster accelerator operation of ORIC. This will be discussed in the following section. From February to April, 1981, NEC continued to work on conditioning the Pelletron to higher gradients. Maximum potentials achieved during this period were in the range of 22 MV.

In May, 1981, an agreement between NEC and ORNL provided for six month's use of the accelerator for physics experiments. During the period from June to November, 1981, ion beams were provided to some twelve experimental programs with the Pelletron operating at potentials up to 19 MV on terminal. One of the experimental programs run during this period utilized the coupled accelerator mode of operation.

In the period from November, 1981, to June of 1982, final work inside the accelerator and on the gas handling system was completed. During this period various conditioning strategies were explored. These activities included complete baking of acceleration tubes and H_2 glow discharge cleaning. None of these activities improved the voltage performance of the machine and the glow discharge cleaning probably hurt.

In June, 1982, despite failure to achieve operation at full terminal potential, it was decided to close the formal contract with NEC. The principal motivation for this action was to allow commencement of routine operation for the experimental program and to intersperse work on improving performance on a longer time scale. Beginning in June, operation for scheduled experiments resumed.

From mid-July until mid-October, the facility had a very successful operating period. The Pelletron operated for 14 weeks without a tank opening. During this period, operating voltages have been limited to about 18 MV. This limitation has been imposed by the presence, at higher voltages, of spark-induced deconditioning. In addition, 3 1/3 of the 27 1-MV column modules have been shorted due to erratic behavior.

One possible cause of the observed spark-induced deconditioning is that the annular spark gaps protecting the acceleration tubes are allowing too much of the energy produced during breakdown to be dissipated inside the tube. NEC has provided a new set of spark gaps which are designed to help alleviate this problem. On October 15, 1982, we interrupted operation for a six-week maintenance period to install and test these new spark gaps.

Operation for experiments will resume in early December. A later shutdown will be scheduled to replace defective acceleration tube sections once we have had sufficient operation to assess the effectiveness of the new spark gaps.

The range of ion species provided thus far in operation for scheduled experiments is listed in Table II. The principal ion source utilized during this period has been the ORNL version of the Aarhus negative ion source as modified by Gerald Alton.[2] One of the pleasing results of our operation to date has been the ability of this source to produce large currents of many ion species. Of particular significance was the production of a large (10 μA) beam of MgH_3^- from this source when using a MgCu alloy probe and hydrogen support gas. Microampere beams of ^{25}Mg and ^{26}Mg were obtained from a natural magnesium sample.

TABLE II. Summary of ion species provided for scheduled experiments during initial operation. Asterisks indicate those ions provided for booster operation with ORIC.

$^{9*}Be$	$^{32,34}S$
^{11}B	$^{35,37}Cl$
^{12}C	$^{48,50}Ti$
$^{16*}O$	$^{58*,60}Ni$
^{19}F	$^{116*}Cd$
$^{24,25,26}Mg$	$^{116*,120}Sn$
^{28}Si	^{197}Au

In addition to the choice of the folded configuration another break with tradition was the selection of a computer-based control system. Communication is provided through data multiplexing via CAMAC serial highways. Data is transmitted across regions of high voltage gradient by infrared digital light links. The control system employs two CPU's: an Interdata 7/32 for message switching and an 8/32 for a supervisory system. This latter system is used for logging, parameter computation, parameter set-up, etc. This system has proven to be very effective and notably reliable in operation to date.

Coupled Accelerator Operation

When the ORIC is operated as a booster accelerator for the Pelletron, the ion beam from the tandem is directed along a transfer line which leads to the rear of the enclosure for the RF resonator, as illustrated in Fig. 2. The transport of the ions beyond this point is shown in Fig. 5. An inflection magnet, located within the ORIC resonator, places the tandem-produced beam on a trajectory which is captured by the fringing field of the cyclotron magnet and brought tangent to an acceleration orbit. At this point, a special mechanism places a thin carbon foil to provide a sudden increase in the ion charge. The system is adjusted so that the ions stripped to the desired charge state are bent onto an acceleration orbit. From this point, the cyclotron accelerates the ion beam as in a conventional cyclotron.

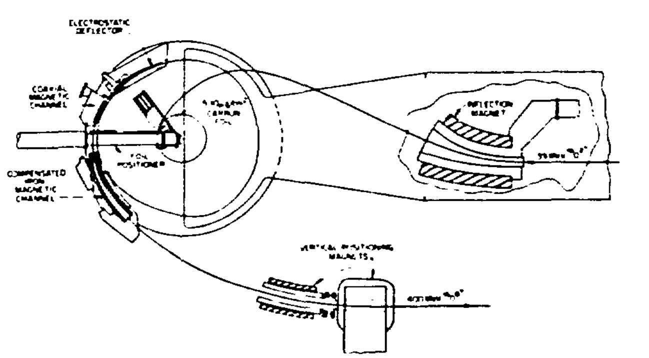

Fig. 5. The Oak Ridge Isochronous Cyclotron (ORIC) as modified for booster accelerator operation.

The conversion of ORIC to booster accelerator status required considerable reworking of the acceleration electrode, trimming capacitors, etc., to accommodate the required inflection orbits. During this period, a major program of detailed measurement of the ORIC magnetic field was accomplished. Setup of the ORIC for booster operation is done utilizing computer orbit calculations based on these measurements. To date, these have proved extremely reliable.

Initial experience with coupled accelerator operation was obtained during a series of brief tests in January, 1981. The first beam produced was a 324 MeV beam of oxygen ions. As the test proceeded, this energy was raised to 400 MeV (25 MeV/nucleon). This is the maximum energy/nucleon achievable with the ORIC booster. We were particularly pleased about the excellent energy resolution achieved ($\Delta E/E = 1/3500$). It appears that it is possible to couple the machines in such a way that the high beam quality of the tandem (particularly the brightness and energy resolution) is preserved. In subsequent operation for experiments, this high-resolution mode has not been straightforward to reproduce. We now believe that part of this difficulty is understood and will test these ideas during the next running cycle.

Operation, to date, in the coupled accelerator mode has gone very smoothly. Some 16 ion species-energy combinations have been provided for experiments in this mode. The ion species are noted in Table II.

One important feature of the coupled accelerator mode is that for many desired ion-energy combinations full voltage operation of the tandem is not required. Thus, for much of the coupled-mode program the tandem can be operated at rather relaxed voltages. The present limitations cause some loss of energy performance, but only for the heavier ions.

Experimental and User Facilities

The Holifield Facility boasts a number of unique and state-of-the-art experimental devices. These have been developed both by in-house experimental staff and in concert with members of a strong user community. A layout of the facility is shown in Fig. 6.

Included in the list of available experimental devices are two in-beam gamma-ray facilities, a 0.8-m- and a 1.6-m-diameter general purpose scattering chambers, two magnetic spectrographs (one equipped with a windowless supersonic gas jet target), a time-of-flight

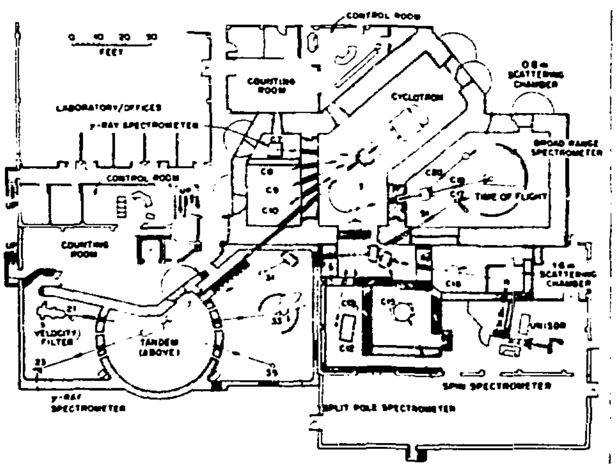

Fig. 6. Floor plan of the Holifield Facility

system equipped with a large-area detector array, and an on-line isotope separator (UNISOR).

Two of the newest experimental devices are the spin spectrometer and the velocity filter. Both of these devices were designed and built by members of the facility users organization. The spin spectrometer is a closely packed array of 72 7"-deep, equal area, NaI detectors used to make total energy and gamma-ray multiplicity measurements on an event-by-event basis. The velocity filter is a separated element electric/magnetic field device used as a beam trap to allow measurement of reaction products at zero degrees.

Such devices as the spin spectrometer place rather extreme demands on the data acquisition system. In order to handle the dimensionality required, the system is implemented in CAMAC and based on three independent CPU's. Each of these systems, including those on-line taking data, operate on a multi-tasking system which supports a number of concurrent tasks. This system has proven very effective and powerful during our initial operation for experiments.

Another aspect of operation as a user facility has been the provision of on-site accommodations for users. Accomplished with funds provided from the State of Tennessee through the University of Tennessee, from Vanderbilt University, and from the Department of Energy, a new building provides office and living areas for short-term visitors. The State of Tennessee and Oak Ridge Associated Universities have provided funds for a second building to add to this facility and provide additional office, laboratory and conference room space. This addition is scheduled for start of construction late this year.

Summary

The Holifield Facility has been completed and operation for experiments is well under way. Experience to date with operation of the 25 MV Pelletron has shown it to be a sturdy and smoothly operating accelerator. The inability to operate reliably at terminal voltages of 20 MV and above has been a disappointment but we have begun modifications aimed at the problem believed to be the source of this limitation. We are confident that with continued efforts of ORNL and NEC the machine will be brought to full potential.

Experience with booster operation of ORIC has been particularly successful and has provided a new range of ion-energy combinations for use in experiments. The long term stability of this operational mode illustrates the power and flexibility of a tandem accelerator as an injector for a cyclotron booster.

Acknowledgements

The work reported here and the success of initial operation of the Holifield Facility has been the result of the hard work of many people. I would like to acknowledge particularly the contributions of J.A. Martin, C. M. Jones, R.L. Robinson, R.S. Lord, J.A. Biggerstaff, N.F. Ziegler, S.W. Mosko, G.D. Alton, W.T. Milner, C.A. Ludemann, J.E. Mann, E.D. Hudson, E.G. Richardson, and R.C. Juras of the HHIRF staff and G.M. Klody, R.A. Rathmell, J.A. Ferry, and R. G. Herb of NEC.

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