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STATUS REPORT ON THE OAK RIDGE 25 MV TANDEM ACCELERATOR*

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Introduction

A new heavy-ion accelerator facility [1,2] is nearing completion at the Oak Ridge National Laboratory. This paper presents a brief description of the scope and status of this project and a discussion of some aspects of the first operational experience with the 25 MV tandem accelerator which is being provided by the National Electrostatics Corporation (NEC) as a major component of the first phase of the facility.

Project Scope and Schedule

Construction of this facility will proceed in at least two phases. Phase I, which is now under way, consists of a new 25 MV tandem accelerator, improvements to and modifications of the existing Oak Ridge Isochronous Cyclotron (ORIC) [3], and a building addition to house the tandem accelerator. After completion of Phase I, it will be possible to operate the two accelerators independently and also in a coupled mode [4,5,6] in which beams from the tandem accelerator are injected into the ORIC for further acceleration. In Phase II [7], it is proposed to modify the ORIC by addition of superconducting main field coils to increase its K value ($K = ME/q^2$) from the present value of 100 to a value of about 300.

Since the tandem accelerator has been described previously [1,2,8,9,10], only highlights will be noted here. The accelerator, which is insulated with pure SF_6 at pressures up to about 0.7 MPa (gauge), has been designed to operate at terminal potentials of up to 25 MV with analyzed beam intensities up to 1 pμA (0.62 x 10^{13} particles/sec). The accelerator pressure vessel, which is approximately 30 m high and 10 m in diameter, houses a column structure 18.9 m long (excluding the high voltage terminal) of which 16.5 m is insulated. As shown in Figure 1, the accelerator has a vertical, folded configuration. The column structure is equipped with five dead sections with vacuum pumps and electron traps in each dead section. In addition to the terminal magnet, which provides excellent charge state separation, the column structure is equipped with three quadrupole lenses, three sets of steerers, and a "second" stripper located in the upper major dead section. The accelerator uses a CAMAC-based digital control system in which virtually all control and monitoring information is transmitted on five bit-serial highways. A photograph of the column structure is shown in Figure 2.

A brief chronology of schedule milestones relevant to the tandem accelerator is shown in Table 1. As can be seen, work started on the accelerator system in May 1975 and beam was successfully transmitted through the entire system in May 1980. The remainder of the paper will be devoted to brief discussions of the SF_6 handling system, column voltage tests, initial operation with beam, and the current status of the accelerator.

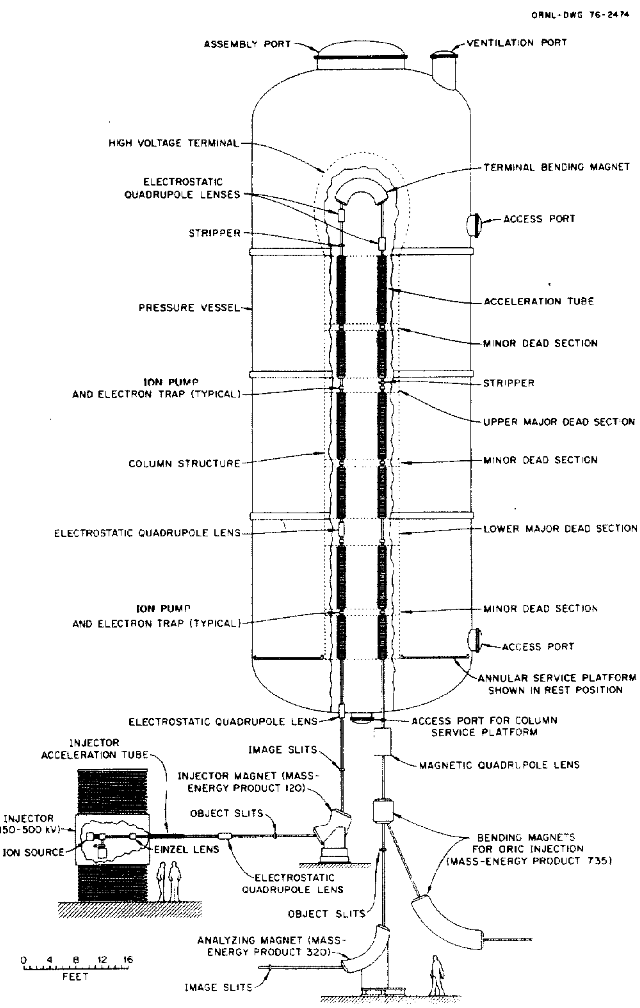

Fig. 1. A simplified schematic drawing of the Oak Ridge 25 MV tandem accelerator.

SF_6 Handling System

Essentially conventional SF_6 transfer, storage, and recirculation systems have been provided for the accelerator. The SF_6 inventory is stored in the liquid phase in three vessels. Oil-free reciprocating compressors, Kinney vacuum pumps, and a steam-heated vaporizer are used to transfer SF_6 to and from the storage and accelerator vessels. The system is controlled from a central point by a hard-wired control system which utilizes components typically used in chemical process systems.

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Table 1. Heavy Ion Facility Milestones

November 1974	Project authorized by Congress
May 1975	Contract signed with NEC
April 1976	Building construction started
January 1978	Installation and testing of pressure vessel complete
September 1978	Injector and column structure tested in air under computer control (in Madison)
October 1978	SF_6 shipment complete - 128,000 kg on hand
December 1978	Building completed
April 1979	Column installation completed (with chains and shafts)
April 1979	SF_6 transfer system commissioned
May 1979	Column voltage tests (without acceleration tubes)
February 1980	Column complete (with acceleration tubes) - ready for beam tests
May 1980	First successful transmission of beam through entire system (Oxygen 6+ at 15.5 MV)
July, August 1980	Acceptance tests at 7.5 MV and 17.5 MV successfully performed
January 1981	First successful coupled operation of tandem accelerator and ORIC (Extracted beam of 401 MeV $^{16}O^{8+}$)

The transfer system was commissioned in April 1979 and used for the first time to pressurize the accelerator vessel to full pressure in May 1979. Since that time, 22 complete transfers (storage to accelerator to storage) have been accomplished without major incident or SF_6 loss. The present estimated transfer times under optimum conditions are storage to accelerator (0.55 MPa (gauge)): 13 1/4 hours and accelerator (0.55 MPa (gauge)) to storage: 11 1/4 hours.

Column Voltage Tests

Tests of the voltage holding capability of the column structure before installation of acceleration tubes were performed by NEC in May 1979. In these tests, which have been described in detail in Reference 10, the accelerator was filled with SF_6 to a set of test pressures ranging between 0.034 MPa (gauge) and 0.62 MPa (gauge). At each test pressure, a set of measurements was made in which the terminal potential was slowly increased until a spark occurred, thus giving a distribution in breakdown voltage for each test pressure. The absolute calibration for the voltage scale of these measurements was established from previous calibrations (in other NEC accelerators) of current vs. gradient in the corona voltage grading system and is estimated to be accurate to ± 5%. At the highest pressure, 0.62 MPa (gauge), the breakdown voltage ranged from 26.4 to 32.0 MV with an average value of 28.8 MV.

At the two higher pressures, 0.41 and 0.62 MPa, there is good evidence for a conditioning phenomena in the sense that breakdown voltage tends to increase with breakdown number. For the highest pressure, for which we have 13 data points, this increase averages about 1.3% per breakdown and does not appear to change over the 13 breakdowns. That is, the breakdown voltage does not appear to level off with breakdown number for the number of breakdowns observed. For this reason, we believe that the breakdown voltages observed at 0.62 MPa represent a conservative measure of the ultimate voltage holding capability of the column structure.

Examination of the column structure after these tests revealed 42 spark hits. The largest of these were characterized by a discoloration of 1 to 2 cm in diameter with some melting in the center and roughness of the order of 0.25 mm. There was no evidence of any other physical damage to the column structure and no evidence that sparks tended to occur at a previous spark site. Specifically, we see no reason to suppose that the surface roughness associated with a spark hit will pose a functional problem. The distribution of spark hits was approximately uniform over the surface of the high voltage terminal and upper column although there was some preference for upper terminal surfaces with compound curvature.

Initial Operation with Beam

In the interval June-December 1979, NEC installed the acceleration tubes, terminal magnet, and other column components such as pumps, lenses, etc., and in January 1980, NEC began the process of commissioning the column in preparation for beam and voltage tests. The interval between January 1980 and May 1980 was characterized by several non-fundamental but time-consuming problems which delayed the successful transmission of beam completely through the accelerator until May 12, 1980. In this first test, an analyzed beam of 60 pnA of $^{16}O^{6+}$ was accelerated at a terminal potential of 15.5 MV. Subsequent milestones for operation with beam are summarized in Table 2.

The first task to be performed after initial operation of the accelerator with beam was a preliminary calibration of the analyzing magnet over the mass-energy product range 29 to 110 using ^{16}O beams of various charge states at a terminal potential of 9.2 MV. An absolute calibration was obtained as part of this series with a 27.4 MeV $^{16}O^{2+}$ beam using the nuclear reaction $^{12}C(^{16}O, \alpha,)^{24}Mg$.*

Table 2. Milestones for Operation with Beam

May 1980:

First complete transmission of beam through accelerator system - $^{16}O^{6+}$ at 15.5 MV.

June 1980:

Absolute calibration of analyzing magnet with the reaction $^{12}C(^{16}O, \alpha,)^{24}Mg$.*

July 1980:

First system acceptance test

$^{127}I^{10+}$, 7.5 MV, foil stripper, 10 pnA for 10 min.

August 1980:

System acceptance tests

$^{127}I^{4+}$, 7.5 MV, gas stripper, 1 pμA for 60 min, 9.1 transmission factor.

$^{127}I^{6+}$, 17.5 MV, gas stripper, 1 pμA for 60 min, 8.9 transmission factor.

$^{127}I^{13+}$, 17.5 MV, foil stripper, 10 pnA for 10 min.

January 1981:

First successful coupled operation of tandem accelerator and ORIC [6].

injected beam: 38 MeV $^{16}O^{2+}$
extracted beam: 401 MeV $^{16}O^{8+}$.

The initial magnet calibration was then followed by performance of the acceptance tests summarized in Table 2. In this table, "transmission factor" is defined as the ratio of injected beam, as measured at the injector magnet image slits, to the accelerated beam, as measured at the analyzing magnet image slits. These acceptance tests constitute the complete set of system acceptance tests required for terminal potentials of 7.5 and 17 MV. During the 7.5 MV gas stripper tests, various charge state ^{127}I beams were also used to perform a preliminary calibration of the analyzing magnet over the mass-energy product range 106 to 302.

A more recent milestone, the first coupled operation of the tandem accelerator and ORIC, is described in detail in Reference 6. For these tests, the tandem accelerator provided bunched beams of typically 0.4 pμA of $^{16}O^{2+}$ at energies in the range 36 to 40 MeV. Typical bunch widths for these initial tests are estimated to be 1 to 1.5 nsec.

We have been pleased to note that initial operation of the accelerator with beam, and more specifically, adjustment of the terminal and analyzing magnets in conjunction with the terminal potential has been straightforward. In cases where the terminal gas stripper has been employed, the overall transmission from injector magnet image slits to analyzing magnet image slits, when corrected for the charge state fraction characteristic of the terminal stripping process, typically exceeds 50%. The most significant loss in transmission appears to occur in the low-energy acceleration tube—for reasons which are not yet clear.

Current Status

In the interval September-October 1980 the accelerator vessel was open for a major maintenance period in which a number of tasks were performed. These included careful baking of the acceleration tubes and replacement of the closed corona voltage grading system with a new open system similar to that used in the Canberra 14UD accelerator [11].

The interval from mid-October to early December 1980 was devoted to initial conditioning of the acceleration tubes in groups of four and five 61 cm sections. (Only minimal conditioning was required for the earlier acceptance tests with beam.) After review of the results of this work, NEC decided to readjust selected acceleration tube spark gaps, a task which was completed in early January 1981.

The interval from mid-January to the present (mid-March 1981) has been devoted to the ORIC injection tests described above and to further conditioning of the acceleration tubes, again, mostly in groups of four to nine sections. At the present time, all sections have been conditioned to a gradient of at least 0.9 MV/section and the accelerator has been operated as a whole for brief periods at terminal potentials up to about 22 MV. This conditioning period is expected to end in early April, after which a series of beam tests at terminal potentials above 20 MV is planned.

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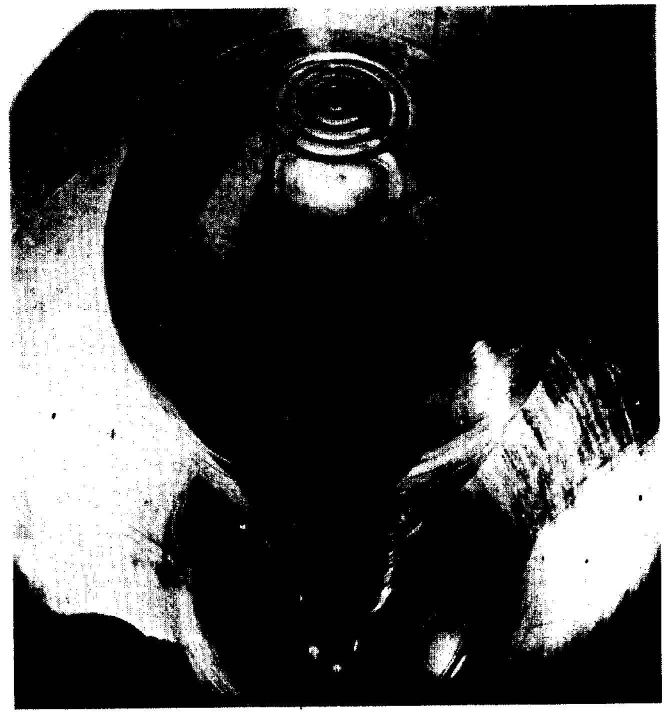

Fig. 2. A view of the completed column structure from above.

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