RECENT OPERATION OF THE ORELA ELECTRON LINAC AT ORNL FOR NEUTRON CROSS-SECTION RESEARCH*

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Abstract

The ORNL electron LINAC, ORELA, began operation in 1969 and has been instrumental in providing improved neutron cross section data for many isotopes over the 0.002-60 MeV energy range. The ORELA utilizes a 2-30 ns <1000 Hz pulsed gridded electron gun, a 4 section RF LINAC, and a water-cooled and moderated tantalum target to generate short neutron pulses. The short pulse lengths and long flight paths provide high neutron energy resolution. Beam energy can range up to 180 MeV and a neutron production rate of up to 10^{14} n/sec can be generated with 50 kW of beam power. Recent operation is at 8 ns, 525 Hz pulse rate and a target power of 5-10 kW. RF power for the accelerator sections are provided by four 24 MW 1300 MHz klystrons. Recent activities have included improvements to the accelerator vacuum, klystrons, interlocks and other upgrades. The current ORELA program is focused on cross-section measurements for the Nuclear Criticality Safety Program and for nuclear astrophysics. Detection and data analysis capabilities have been developed for making highly accurate measurements of neutron capture, neutron total, (n,α), and (n,fission) cross-sections simultaneously on different beam lines.

THE ORELA FACILITY

The ORELA facility was developed to provide intense short neutron pulses for high accuracy of neutron cross-section measurements. This data is utilized for neutronics modeling of nuclear power reactors, astrophysics, shielding and other applications[1].

The ORELA facility has a modulator/klystron system, an accelerator section, an electron gun, a target room and neutron detector and data acquisition systems. ORELA is setup with very long flight paths (up to 200 m) and short pulse lengths (>4 ns) to generate neutron cross-section data by using time-of-flight methods. The water-cooled and moderated tantalum target generates high intensity beams of neutrons in the eV to 60 MeV energy range. Relatively small sample size can be used. Over the past 30 years, ORELA measurements have contributed ~80% of US Evaluated Nuclear Data File (ENDF/B) evaluations [1].

Other past experimental programs on ORELA have included positron and nuclear shielding research. Proposed experimental programs have included THZ and IR FEL and Radioactive Ion Beam generation.

Accelerator

The ORELA accelerator [2] modulator and control systems were designed and built by Varian in 1968 (Varian model V7727). The accelerator active length is 16.5 m and output energy is up to 180 MeV. The average accelerating gradient is ~10 MeV/m. The accelerator is a 4 section RF LINAC. Each section is a coupled cavity TM01 transmission line operating in the 2/3 π mode and is terminated with an internal RF load. Water cooling

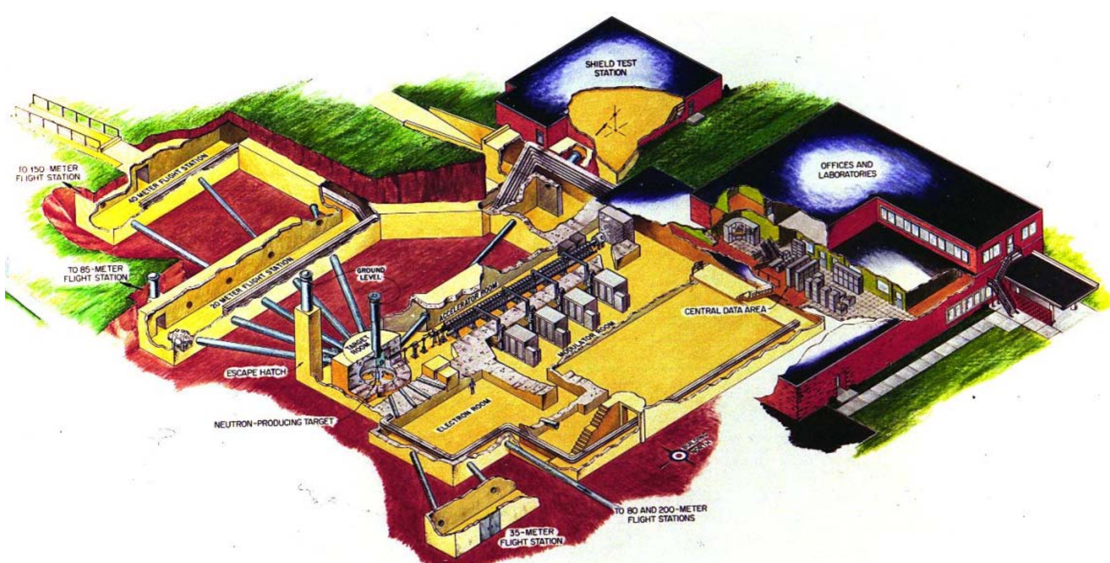

Figure 1: The ORELA electron accelerator facility.

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lines are distributed around each section. A WR650 waveguide SF6 gas cooled window is used to feed up to 24 MW microwave pulses into each section.

Two 60 l/s Vac-Ion pumps are used on each accelerator section to maintain high vacuum. All 10 Vac-Ion pumps were replaced & HV cables refurbished in the past year. A new 300 l/s turbo pump was purchased to facilitate startup of Vac-Ions.

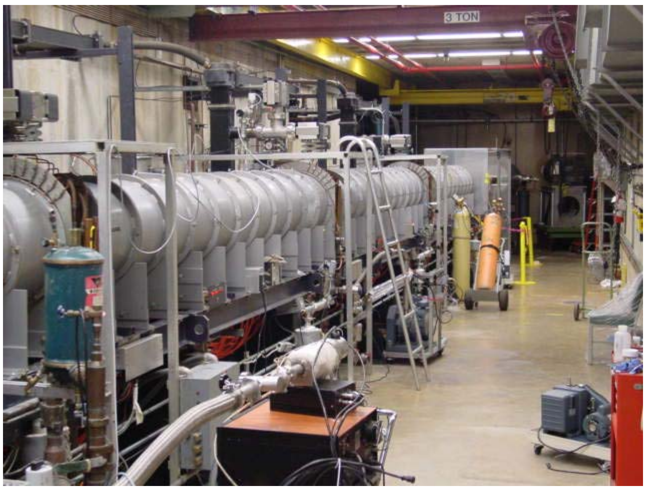

Figure 2: The ORELA Accelerator room.

Over the years, a number of vacuum issues have been a problem including small leaks from water-cooling into the accelerator vacuum. These leaks are in locations that are difficult to access and pinpoint with a leak checker but can be localized somewhat by applying vacuum or pressure to various water passages and looking at relative responses on the various vac-ion pump currents. Inspection using a borescope is helpful. For many years, additives to the water were used to provide comprehensive leak sealing of inaccessible leaks. The leak sealing material does eventually harden and block smaller water passages and leaks may become un-sealed so its use is less desirable than a more permanent fix. Two braze joints in the main water inlet of section 4 and cracks in threads of tapped water fittings on many of the outlets have been found to be the major leak points.

The water fitting threads were overcut during the original manufacturing process, which apparently lead to cracking. A differentially pumped guard vacuum was setup on outlet fittings with cracked threads by installing o-ring sealed inserts that isolate the vacuum leaks from water. This system was recently improved by replacing the aging o-rings and installing new pumps with automatic valves to prevent oil-backstreaming.

At the water inlets of one accelerator section, leaks have appeared at a SST to copper braze joint in the accelerator body. Since only two fittings in one of 4 accelerator sections have leaked, it is not clear if this was due to an original marginal braze joint, thermal expansion or excessive mechanical force used when the piping was installed. To seal the leaking joints, several types of epoxy and Vac-seal have been tried. The leak has been too large for Vac-seal to harden and the epoxies tried have eventually come loose from the cooling channel wall. A mechanical seal with a compressed rubber gasket across the braze joint has recently been developed and is still leak tight. Glyptal paint and a sleeve have also been proposed which might be immune to water exposure but likely quite difficult to remove later.

Klystron/Modulator System

Four high power klystron tubes and associated modulators provide microwave power pulses to drive the accelerator. The klystrons used are Litton model L-5081 1.3 GHz klystrons that produce up to 24 MW 2 μsec pulses with up to -250 kV, 250 A of beam power. A pulse rep rate of up to 1000 Hz can be used however 525 Hz is typical. Each klystron has a modulator unit that consists of an adjustable 0-25 kV HVDC power supply and a thyratron-driven PFN network. The thyratron/PFN system is setup with selectable pulse width and uses either a single or double thyratron depending on the pulse length. EEV CX1175 thyratrons are now used. A master oscillator, attenuator/phase shifter and TWT amplifier system provides drive power for each klystron. WR650 waveguide transmits the power to each accelerator section. Flowing SF6 gas inside the waveguide is used to cool the klystron and accelerator vacuum windows and also protect against breakdown at the windows.

Figure 3: Klystron modulator.

The klystrons themselves have been quite reliable over the years and last several 1000's of hours. A couple of tubes have been rebuilt and spares purchased. The modulator systems, especially the interlocks, cause the most down time. Water flow, airflow, and under current monitors are intermittent at times. A high-speed trip system was used in the early days but disconnected due to excessive false trips. Voltage breakdown in the thyratron drive grid bias circuit during HV turn-off is currently an issue. Occasionally at HV turn-off, a transient is coupled through the thyratron to the grid drive system that causes punch-through in the grid drive isolation transformer insulation.

Figure 4: Typical ORELA klystron.

Electron Gun System

ORELA uses a grid pulsed Pierce-type electron gun that generates a ~ 110 kV ~10 A pulsed electron beam. Grid pulses are generated by an optically-coupled thyratron driven PFN pulser. The grid drive system and high frequency cathode heater system are mounted in an SF6 filled gun tank. The pulse length can range from 2-30 ns with 8 ns and 6 A being the typical operating values. A shorter pulse is desirable for improved neutron cross-section line resolution however longer pulses give more neutron signal.

Electron gun lifetime is usually > 1000 hours depending on the accelerator vacuum quality. ORELA has a gun processing lab to refurbish electron guns. A number of recent gun failures have been attributed to pin-hole vacuum leaks in the side of the insulator ceramic. It appears that this damage is due to scattered electrons from the anode region, so an extended anode shroud was developed to protect the ceramic. EGUN modeling of the gun potential distribution and emission was performed to investigate the effect of extending the anode shroud. One gun with an extended shroud has been built and appears to perform acceptably. The gun/LEBT magnet alignment was improved to maximize coupling of electrons to the accelerator beamline and reduce anode over-heating as a potential source of dark current emission.

Improved cathode processing and emitter materials have been investigated to increase gun current. High voltage processing is used to minimize dark current, which can interfere with the neutron detector signal analysis as a noise source.

Target and Flight Paths

ORELA uses a water-cooled tantalum target that generates a “white” neutron spectrum from <2 KeV up to 60 MeV. The water cools the tantalum plates and moderates the generated neutrons. The target can handle up to 50 kW of beam power, however 4-8 kW is typical for most experiments. A cylindrical concrete bunker provides shielding for the neutron and gamma flux generated by the target.

Emanating out from the target room are 11 evacuated neutron beam flight tubes. A neutron energy filter bank precedes each flight tube to tailor the neutron spectrum. At various points along the flight tubes are end stations where neutron detectors which consist of various absorbing materials, scintillators and photomultiplier tubes. Gas converters are used with some experiments to look at alpha particles

Accelerator Operations Summary

Several operational difficulties have been overcome in the past year. The ORELA has operated more than 200 beam hours in the past 4 months. Further improvements in beam power are anticipated once more experience in tuning is gained and the system better understood. Reliability of vacuum repairs and aging modulator interlocks and controls is still a factor, however, many improvements have been made to fix these issues. Additional upgrades to the control system and the addition of a data acquisition system is planned for the coming months.

RECENT EXPERIMENTS

In the past year, a number of isotopes are being analyzed on ORELA for cross-section data. One current experiment utilizes a 99% enriched ^{41}KCl sample in the neutron beam flight path #7 in the 40-meter flight station. For this neutron capture measurement ORELA, was operating at 525 Hz, 8 n sec pulse widths and 4kW. Due to reduced electron gun emission, the 4kW power is about 60% of original specifications for these experiments so additional beam time is required.

Also underway are neutron transmission & absorption measurements of Mo-95 isotope at the 80 m flight station.

A compensated α particle measurement of Zn-64 is being performed at Flight path 11.

REFERENCES

[1] M. E. Dunn, ed., Proceedings of the Oak Ridge Electron Linear Accelerator (ORELA) Workshop ORNL/TM-2005/272

[2] N.C. Pering and T.A. Lewis, “Performance of a 140 MeV High Current Short Pulse LINAC at ORNL IEEE Trans Nuc. Sci NS-16, 316 (1969)