UPGRADE OF THE AGS H$^-$ LINAC*

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Abstract

The AGS linac presently accelerates 25 mA of H$^-$ to 200 MeV at a 5 Hz rep-rate and 500 μs pulse width. The Booster takes 4 pulses every 3.8 seconds, and the remaining pulses are used for isotope production. We are in the process of upgrading the linac to increase the average current delivered for isotope production by more than a factor of two, while at the same time expecting to decrease linac downtime. Various aspects of this upgrade are discussed, including the upgrade of the control system, new high power transmission line, transport line vacuum, and rf power supply system upgrades.

Introduction

The AGS 200 MeV linac typically operates at 25 mA, 5 Hz, and 500 μs beam pulse width. This year, four pulses were delivered to the Booster (every $\approx$3.8 seconds) at a 7.5 Hz rep-rate, while the remaining pulses went to the Brookhaven Linac Isotope Producer (BLIP) [1], at a 5 Hz rep rate. The linac typically operates $\approx$ 6 months per year, with an availability of $\approx$ 95%.

The linac first began operation in 1970. Over the years, some systems have been upgraded (from H$^+$ to H$^-$ operation, Cockcroft-Walton replaced by an RFQ, polarized H$^-$ added, vacuum system improvements, etc.), but it is a credit to the original builders of this linac that many of the original systems are still in use, almost 25 years later. (It is incredible that most of the original linac control system is still being used). Upgrades to several major areas of the linac are now in progress, some funded through AGS Department Accelerator Improvement Projects, but most funded as part of an upgrade to the BLIP facility, through the DOE OHER.

All beam pulses not needed by the AGS Booster are deflected by a pulsed dipole in the 200 MeV transport line and sent to the BLIP facility. This facility produces radionuclides and radiopharmaceuticals for the pharmaceutical and medical communities, as well as supporting a research program to search for more effective diagnostic and therapeutic agents. To meet increased demands for isotopes, the average linac current will be increased by more than a factor of two, to 146 μA, by the end of 1995. The increases in the various parameter are shown in Table I.

TABLE I

	Present	Upgrade
Beam Current	25 mA	30 mA
Repetition Rate	5 Hz	7.5 Hz
Beam Width	500 μs	650 μs
RF Width	650 μs	850 μs
Average Current	62 μA	146 μA

In addition, some aspects of the upgrade are aimed at improving reliability. In the following, the various system improvements will be described.

Linac Control System

Controls for the ion source and low energy beam transport lines to the linac were modernized approximately 5 years ago, during the RFQ preinjector upgrade. The rest of the linac operates with a 25 year old control system, in which reference voltages are derived from motor-driven potentiometers, which can be set via computer. While "robust", this system lacks the flexibility of modern control systems, and the computers used are no longer supported. These systems will be upgraded using RHIC-style VME controls. In this system, equipment distributed throughout the linac is connected via a local serial field bus to an intelligent front end (VME based). The VME crates are connected to a commercial network (Ethernet). Workstations on this network provide the user interface.

The control system allows multiple sets of user parameters to be stored at the front end, and a given set can be loaded on command from a coded timeline.

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This allows one to switch each device back and forth among up to seven different setpoints on a pulse by pulse basis. (For example, allowing pulses going to the Booster to have a different tune from pulses going to BLIP).

Devices to be put on the new control system include the 286 drift tube quadrupoles, 38 quads and dipoles in the 200 MeV transport lines, the phase and amplitude settings for the 9 rf stations, vacuum gauge readbacks, valve status, and ion pump status/reset. In total, we will be installing ≈ 400 channels of analog IO/digital status. In addition, all existing instrumentation will be interfaced to the new control system, and the timing system will be modernized.

Another aspect of the control system upgrade is to convert all the rf system control logic from the original '70 vintage TTL logic printed circuit board arrays, to programmable logic controllers (PLC's). As a prototype, the rf systems for the two RFQ's and four bunchers (H^- and polarized H^- lines), have been operating with PLC controls for one year, with extremely high reliability. In this system, two Allen Bradley PLC 5/20 controllers are located within the local system racks, along with all remote I/O racks and three Panel View switch screens. A personal computer in the linac control room, operating Control View, has the capability to monitor, log, and control all rf system statuses. We are now designing the PLC system to replace the control logic in the nine high power rf systems. This PLC system will replace an additional 81 12" chassis of hardwired discrete TTL circuit boards.

High Power Coaxial Transmission Line

Up to 6 MW peak power is fed from each of the nine rf amplifiers to the nine accelerating cavities via 12" coaxial transmission line. There is a 3 db power split, and power is fed in at two places on each cavity. The total length of transmission line for the nine systems is ≈ 350 m, with over 500 rf joints. The linac began initial operation in 1970 at the design rep-rate of 10 Hz, but with a beam pulse width of only ≈ 100 μs. In 1976, the rep-rate was reduced to 5 Hz, motivated in large part by failures in the 12" coaxial transmission line. It was found that transmission line failures were reduced significantly at 5 Hz, even though the pulse width was increased to keep the average beam current constant. With our desire to increase the repetition rate to 7.5 Hz, the transmission line reliability had to be readdressed.

Some choices were made in the design of the original line aimed at keeping costs down, and the fact that the linac has operated for 25 years with this coax serves to justify those choices, but there are obvious areas where the design can be improved. Our main failures occur due to sparking at the connectors joining sections of center conductor. The connector rf contact is a single spring ring, designed to make contact ≈ 6 mm from the edge of the center conductor. Slight misalignments over the long lengths of coax can cause this spring ring to fail to make good rf contact. In addition, all center conductor in our system is made of aluminum, again leading to poorer rf contact. Finally, the system is unpressurized.

We have decided to replace all transmission line for the nine rf systems with commercially available 12" rigid coax. This transmission line will have EIA-type center connectors and flanges. The center conductor will be copper, and the entire system will be pressurized with dry air to 15 psi, with a 2 scfd bleed at each feedloop. We will replace the full system, including the 3 db power splitters, waster loads, breakaway and telescoping sections, and reflectometers. The vendor has been selected, and all installation is scheduled for the summer of 1995.

200 MeV Transport Vacuum

Over the years, linac vacuum failures had begun to increase due to aging of components. In 1992, improvements were made to the linac tank vacuum, including the installation of new intertank valves, rebuilding all ion pumps, and installing all new vacuum gauging. The tanks now typically operate in the 10^{-8} Torr range. In the past two years the vacuum system for the ≈ 25 m of transport line from the end of the linac to a point past where the beam enters the Booster transport line was replaced, in order to replace all viton o-rings with metal seals (conflat flanges). This included new y-chambers, diagnostic boxes, all new electrical feedthroughs, etc. In addition, new ion pumps were installed, and extra pumping added.

The BLIP transport line vacuum is now the last section to be modernized. This 25 m section has been the most troublesome, since it gets most of the linac beam, and tails in the energy distribution coming, for example, from turnon transients, result in beam losses after the bend into this line. While radiation levels are high at various points throughout this line, they are particularly high at the end of the line, where the beam passes through two stainless steel windows while entering the BLIP target area. (Levels, several days after shutting beam off, are still several R/hr at various locations in this beam line). Therefore, viton o-rings quickly become hardened. A portion of this beam line will be replaced this year, and the remainder in the summer of 1995. All o-rings will be eliminated, replaced by conflat flanges. New ion pumps will be installed, and one additional turbo pump and two additional ion pumps added in the line.

7835 Anode Capacitor Bank Charging Supply

The Burle 7835 triode is the high power tube used in our linac. The 40 μF capacitor bank for the anode modulator is charged by a 60 kV, 2 A power supply, which typically operates at $\leq$ 35 kV. Each supply sits in 550 gallon oil tank outside of the linac building, making them difficult to maintain. In addition, there is in total $\approx$ 600 m of high voltage cable required to connect the nine supplies to the cap banks. With the higher average rf power required as part of this upgrade, a charging current above 2 A will be required. We will therefore replace these supplies with oil-free (or minimal insulating fluid) units, which will be placed in the linac equipment gallery next to each cap bank. This eliminates the long runs of high voltage cable, and makes maintenance of the supplies easier. The new supplies will be 50 kV, 3 A units, and must be easily upgradeable to 5 A. Installation of the new supplies should begin during the summer of 1995.

Low Level RF

The present linac low level rf systems are 18 years old, and such low level control can now clearly be done much simpler and better with modern technology. Improved transient response will help reduce beam loss during pulse turnon/off. We expect system reliability to improve. The design of this low level rf system by the AGS RF Group is beginning.

Intertank Beam Position Monitors

We were fortunate to have received from FNAL some stripline beam position monitors [2], which had been installed between those DTL tanks which were removed as part of their linac upgrade. These position monitors will be installed in six of our eight intertank spaces during the present shutdown period. We will then be able to implement either the delta-t or phase scan technique for more accurate setting the tank phases and amplitudes.

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