UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BERKELEY, CALIFORNIA

UCRL-3365

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Berkeley, California

Contract No. W-7405-eng-48

LINEAR ACCELERATOR FOR HEAVY IONS

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March 27, 1956

Printed for the U. S. Atomic Energy Commission

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A source of high-energy high-intensity heavy ions has long been desired as a tool for physics, chemistry, and biology. Heavy ions are presently being accelerated in the 60-inch cyclotron; however, the energy spread is large and external beam currents are relatively low.

A joint undertaking now in progress is the construction of two heavy-ion linear accelerators, one at the University of California Radiation Laboratory and the other at Yale University. It is hoped to produce ions of masses up to that of neon with energies of 10 Mev per nucleon. The huge accelerator will consist of two 70-Mc resonant cavities of the Alvarez type yielding a beam pulse of about two milliseconds' duration. Ions are formed by a high-voltage arc in the ion source that sparks approximately ten times a second. They then are fed into the accelerator by an injector mechanism, go through a prestripper which effects the first increase in energy, through a stripper that removes electrons from them and thus increases their positive charge, and through a poststripper that adds the final increment of energy.

Injector Mechanism

The ions are separated by an analyzing magnet before entering the injector. Ions are then injected into the beam axis by a 500 kv Cockcroft-Walton accelerator.

Prestripper

After leaving the ion source and injector mechanism, the ions will enter the prestripper cavity with an energy of 0.07 Mev per nucleon. This cavity is to be 15 feet long and 124 inches in diameter, and will have thirty-seven 8-inch-diameter drift tubes. The purpose of this cavity is to give more energy to the ions prior to their entering the stripper where still more electrons are to be removed. Owing to the high fields required in this cavity, quadrupole focusing cannot be used; grid focusing will therefore be utilized here. A full-wave transmission line will couple rf power from the poststripper cavity.

Stripper

Situated between the two main cavities, the prestripper and poststripper, is the stripper--a device on which much research and money were expended. Experiments with oxygen and neon ions accelerated in the 4-Mev Van de Graaff indicate that a foil of a few $\mu g/cm^2$ is required for stripping the ions in that machine. A beam of such intensity as this accelerator provides would tear the foil apart in such a short time as to make it impractical for use here. Stripping can be accomplished, however, by passing the beam through a gas. The required small amount of gas can be obtained either with a differential pumping system or with a jet of vapor that flows transverse to the beam. This machine will use the latter method, passing the beam through a jet of mercury vapor.

Poststripper

The major portion of the final energy is to be picked up in the poststripper, a cavity 108 inches in diameter and 90 feet long, of copper-clad steel construction. It will have 68 drift tubes, 20 inches in diameter, each with a quadrupole strong-focusing magnet inside the copper shell. The bore will be 2 inches in the first drift tube of the poststripper, and will increase to 3.5 inches at the target end to allow for expansion of the beam resulting from any misalignment of the magnets. Alignment of these quadrupole focusing magnets is obviously very critical and must be held to very close tolerances.

Quadrupole focusing offers two advantages in this particular type of accelerator. (The first advantage is in fact a necessity.) The current in the beam is so small that it would be undesirable to use grid focusing, for most of the beam would be lost to the grid, leaving little or nothing at the target. This leaves strong focusing available, a relatively new idea in accelerator focusing. A strong-focusing magnet is an assembly of four magnetic (or electrostatic) poles forming a symmetrical hyperbolic field. The beam passing through a magnet is compressed in one plane and expanded in the plane perpendicular to it. The next magnet is just the reverse. The beam, passing through these magnetic fields, goes through a series of focusing and defocusing movements and is finally brought to a point focus at the target.

Strong focusing also offers an advantage in focusing simultaneously particles that are in various states of ionization.

The incentive in terms of research objectives for the design and construction of a heavy-ion accelerator was largely provided by Gregory Breit of Yale University and Glenn T. Seaborg of the University of California.

This work was done under the auspices of the U. S. Atomic Energy Commission.