books

On linacs, their design and operation

Linear Accelerators

P. M. Lapostolle, A. L. Septier, *eds.*
1204 pp. American Elsevier
(North-Holland), New York,
1970. $61.00

Reviewed by Wolfgang Panofsky

When Luis Alvarez proposed his first proton linear accelerator at Berkeley he argued that the cost of linear accelerators scales linearly with length and therefore with energy, while that of the then-known circular accelerators scaled with the cube of the energy. Therefore, linear accelerators should be the eventual leaders in the race towards high energies. Alvarez's prophesy was not fulfilled, because new inventions such as phase stability and strong focusing changed the scale factors pertaining to circular accelerators and the scaling laws themselves. Nevertheless, linear accelerators have proven to be unique in their ability to meet many needs as tools in high-energy and nuclear physics, other than that of reaching the highest possible energies for proton accelerators. This book is a collection of review articles on the multitude of engineering problems and applications that involve the linear-accelerator art.

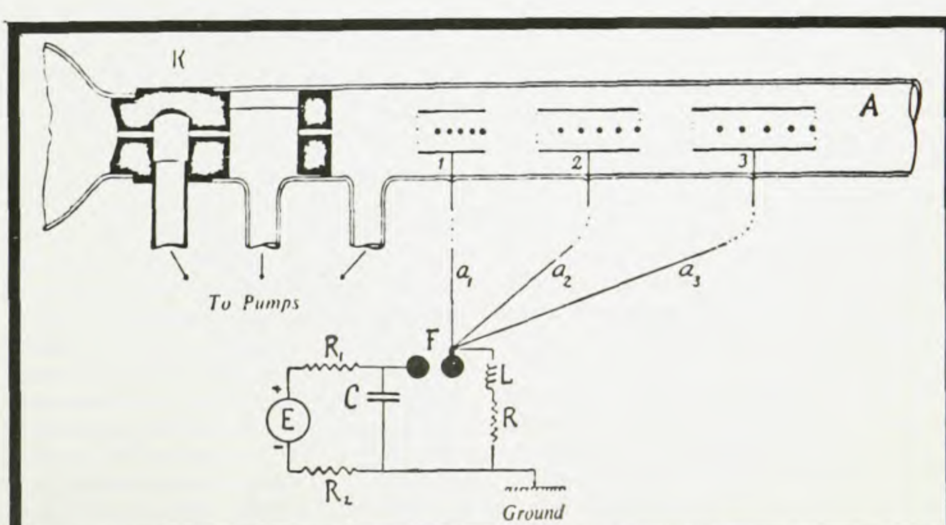
The book is written by a group of specialists in each field, and each summary article is unusually comprehensive in its respective area. It is obviously impossible to do justice to each of these review articles separately, nor will I list the authors.

Linear Accelerators is divided into three basic sections. First there is an outline of linear-accelerator history, which this reviewer found particularly illuminating. For instance, it is not well known in the high-energy physics community that the first linear accelerator was proposed by G. Ising in Sweden in 1924, well before the invention of the cyclotron. The second section of this first part is a discussion of those general topics that pertain to all kinds of linear accelerators—for protons, electrons or heavy ions—be they traveling-wave or standing-wave devices. The subsequent portion of the book is divided into separate treatments of electron and proton accelerators. This division is quite logical since most electron accelerators are completely relativistic; external focusing is of minor significance and operation at microwave frequencies is practical. In contrast, proton accelerators operate at lower frequencies and external focusing elements play a prominent role in their design. Therefore, problems of technology and of beam dynamics tend to be distinct.

The electron linear-accelerator section contains a very exhaustive treatment of theoretical aspects, including accelerator structures, orbit dynamics and the various collective phenomena such as beam loading and beam breakup. It is quite interesting that many of these latter phenomena were not well understood when initial design was undertaken but have now received comprehensive analytical and numerical treatments, which are thoroughly described in this book.

Following the theoretical chapter are sections on the technology of electron linear accelerators, which go into considerable detail on fabrication techniques of the type of microwave structures needed for the injector and principal accelerating structures. Tolerances and metallurgical and other control problems in the manufacture of electron linear accelerators pose extreme requirements, so it is very gratifying to have this much extensive documentation. There is also a section on microwave power sources at high power and other radiofrequency problems.

About one third of the part of the book dealing with electron accelerators is devoted to discussion of applications of these machines to special purposes and to the design of accelerators toward that end. It is well known that limits of power generation and consumption make it necessary for electron linear accelerators to operate at a small duty cycle. However, for medium-energy applications (up to 1 GeV) higher duty cycle devices are being built without the use of superconductivity; these are discussed both in terms of their design and applications. Other roles of electron linear accelerators discussed in separate



Rolf Wideröe's linear accelerator (1928). This instrument, the first successful linac, was capable of accelerating sodium or potassium ions to 50 KeV. The ions were provided by a hot filament source and the rf voltage across the three drift tubes was 25 kV. (From the book reviewed on this page.)

sections are as injectors into circular machines and as positron sources for injection into storage rings or for direct use of positron beams. There is a very interesting discussion on radiofrequency particle separators which, although logically not belonging in the category of electron accelerators, generally use the same technology.

The proton and heavy-ion linear accelerator theory and realization occupies the second half of the book. The organization is similar to that of the electron section; there is first a very extensive treatment of the theory of the accelerating structures, including a very useful section on numerical computation. This is then followed by analyses of orbit dynamics, including numerical methods of solving focusing and phase problems. Of particular importance is the inclusion of extensive papers on collective effects and imperfections; much of this had not been available in the literature.

The sections on proton linear-accelerator technology are written in a somewhat encyclopedic manner, since there are such a large number of relatively smaller topics to discuss, ranging all the way from basic considerations of structures to the more common accelerator items such as beam monitoring and shielding.

A chapter discusses the applications of various ion linear accelerators that are now in practical use. The principal role of proton linear accelerators at this time has of course been as injectors for circular machines, and for this purpose they have been continually improved. Although the proton linear accelerator was first used by Alvarez and collaborators as a primary source of beams for nuclear-structure physics, this use is only now returning to the forefront at the Los Alamos Meson Factory. Heavy-ion machines have of course seen use in nuclear chemistry for some time. Some more esoteric applications, neither of which have come into practical realization, are the use of extremely high-intensity ion linear accelerators as intense neutron sources (such as the now terminated ING project in Canada), and as a "negative control rod" to use such neutrons to convert depleted uranium in a subcritical reactor assembly into fissionable plutonium. Again, application has been discontinued after the experimental work carried out at Livermore almost two decades ago. It is clear, however, that the proton linear accelerator at this time remains the most powerful tool developed for the generation of extremely high-intensity high-energy beams.

Superconducting techniques are discussed in a separate division because they are still suffering from major unknowns in terms of actual realization. Applications are, in increasing order of difficulty, microwave particle separators, microwave accelerating structures to be used as adjuncts to circular accelerators, microwave electron accelerators and, finally, proton linear accelerators. Each of these applications and their present technological status is fully discussed.

This book is, of course, not of very general interest to high-energy physicists because it is fundamentally a compendium of specialized contributions describing all facets of linear accelerators—theory, practice and applications. The quality and editorial control of each article appears uniformly high and the book will remain a standard reference book on the subject. This reviewer feels that for the first time he has been paid very highly for writing a book review in exchange for retaining a copy of the book, since this particular volume sells for an incredible $61.00.

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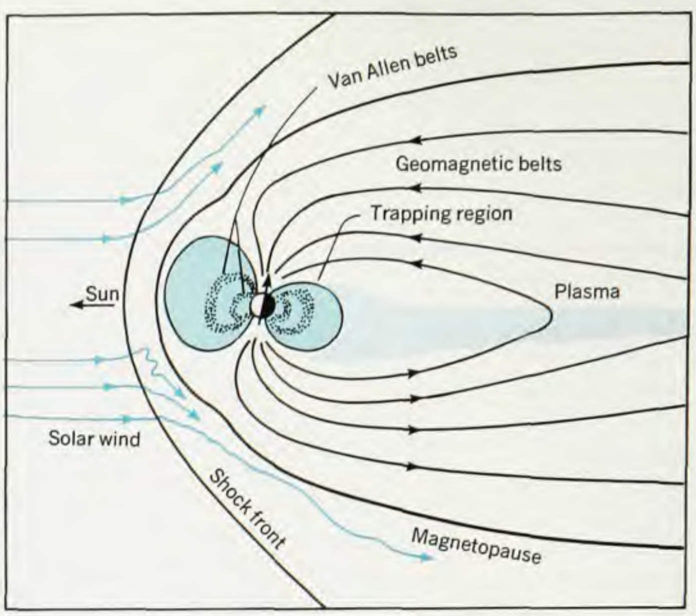
Wolfgang Panofsky, who has worked for many years in high-energy physics and particle accelerators, has been director of the Stanford Linear Accelerator Center since 1961.



Interaction of the solar wind with the earth's magnetic field. (From *Space Observatories* by Jean-Claude Pecker, Springer-Verlag, New York, 1970.)

Plasma Dynamics

By T. J. M. Boyd, J. J. Sanderson
348 pp. Barnes & Noble, New York, 1970. $10.75

Interest in the study of ionized gases, that is, plasmas, dates back to the 1920's, when it centered around the phenomena of electric discharge in gases. Since then the importance of plasma physics has increased tremendously in connection with the efforts toward controlled thermonuclear fusion and direct conversion of heat into electricity, and lately in relation to the spectacular growth of space sciences, such as planetary ionospheric, magnetospheric, and radiation-belt physics. Astrophysics is yet another discipline where a knowledge of plasma physics is valuable.

A book on plasma physics, therefore, attracts a large audience. Naturally, quite a number of books exist dealing with the various aspects of plasma physics. Even so there appears to be a need for introductory textbooks aimed at the undergraduate or graduate level. In this context, T. J. M. Boyd and J. J. Sanderson have done a welcome job in preparing this text on plasma dynamics. Because of their involvement in university-level teaching for the past few years, the authors have been quite successful in their attempt at writing this text.

The layout of the chapters in the book is logical. It starts with a description of the orbits of charged particles. The macroscopic equations are introduced next, paving the way for the presentation of hydromagnetics. Plasma waves are dealt with at some length, separate chapters being devoted to waves in cold and warm plasmas. Plasma kinetic theory is presented in the last chapter.

Each chapter is extensive in scope. For example, the chapter on waves in cold plasmas touches upon all sorts of topics: Alfvén waves, ion cyclotron waves, Appleton and Hartree's magnetoionic theory, whistlers, etc. But the treatment is not in depth. This is, probably, because the book is aimed mostly at undergraduate or graduate level students. In the discussion of radiation processes in plasmas, the scope has been restricted to the discussion of fully ionized plasmas. The consideration of plasma line (or band) radiation, which requires quantum-mechanical treatment, has been omitted.

The very useful topic of plasma kinetic theory is squeezed into one last chapter. Naturally, only simple applications have been chosen. The discussion is limited to one-component (electron) plasmas by using the simplifying assumption of fully ionized plasmas with