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Authors
Gordon, Hayden S
Behman, Gerald A

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University of California

Ernest O. Lawrence Radiation Laboratory

Berkeley, California

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ABSTRACT

The principal types of particle accelerators are described briefly according to operation and history. Known operating particle accelerators are listed with their pertinent dimensions.

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I. INTRODUCTION

A particle accelerator may be defined as any device designed to give kinetic energy to ions or electrons. Early X-ray and canal-ray tubes satisfy this definition, and modern technology owes much to these. However, the major development of most accelerators for inducing nuclear reactions has occurred since 1926.

The following material is organized according to the mode of operation rather than the chronological order of developments. This parallels the sequence used in the subsequent tabulation of machines.

II. "POTENTIAL-DROP" ACCELERATORS

The simplest way to accelerate a particle of charge e is to let it fall through a potential difference V. Thus it acquires a kinetic energy eV. The potential drop V can be either steady-state or time-varying. In all high-energy potential-drop machines, ions or electrons are accelerated by a potential difference uniformly divided across an evacuated accelerating tube. A number of accelerating electrodes are within the tube. It will be convenient from a functional point of view to subclassify these machines on the basis of the method used to produce the potential drop.

For more efficient operation and higher breakdown voltages, potential-drop machines frequently employ insulating media such as transformer oil or pressurized gas--dry nitrogen, sulfur hexafluoride, Freon, or mixtures including air.

Direct-Current Machines

Conceptually the simplest type of machine is one in which potential drop is constant. Practically it is more difficult to hold a fixed gradient than one applied intermittently, and direct-current machines must be more carefully designed from the point of view of maintaining uniform gradients and providing protection from transient surges if breakdown occurs.

Electrostatic Potential Generation

Some of the earliest X-ray tubes were powered with large Toepler-Holtz or Wimhurst electrostatic generators driven either by hand or by an electric motor.

R. J. Van de Graaff built the first electrostatic generator of the type now associated with his name at Princeton University in 1929. This machine employs a moving belt to carry a charge against a potential gradient and thereby build up the potential to some limiting breakdown value.

The embodiment of this principle with the incorporation of carefully designed voltage-grading systems has resulted in a large family of electron and positive-ion accelerators, culminating in the multistage tandem Van de Graaff machines. This latter interesting development is based upon U. S. Patent No. 2,206,558 issued to Bennett in 1940. Ions characterized by an excess of electrons are extracted from a source. These negative ions are accelerated through a column from ground potential to a positive electrode at a potential of 5 Mv. In this electrode the ions are passed through a stripping foil, which removes the electrons to give an ion of opposite sign. These positive ions, already with a kinetic energy of 5 Mev, are further accelerated through a second colinear column back to ground potential with a final kinetic energy of 10 Mev.

Other methods of charge transport have been used; e. g. a number of installations use the Felici design of electrostatic-induction voltage generator. As contrasted with the belt system of transport of the Van de Graaff machines, the Felici machine uses a dielectric cylinder which rotates about a slightly conducting glass stator. Thin steel strips charge and discharge the rotor as a result of induction from metallic inductors within the glass cylinder.

Electrical Rectification

Rectification of alternating current for industrial radiographic units is employed for voltages up to about 400 kv. This can be accomplished without the use of voltage-grading systems by the use of hooded targets and by placing the anode and cathode at opposite polarity with respect to ground. For electron acceleration above this energy and for positive-ion acceleration, voltage-multiplying and cascade-rectifying and generating schemes have been used. The most commonly employed circuit is a cascade-rectification system due to Greinacher which was used by Cockcroft and Walton at the Cavendish Laboratory at Cambridge to produce the first nuclear disintegration by artificially accelerated particles in 1932. A two-section accelerating tube was used to accelerate protons to 700 kev. This circuit has since been used for accelerators operating under atmospheric conditions at up to about 1 Mv, and with pressurized-gas insulation up to about 2 Mv. Early designs used vacuum-tube rectification, but the development of solid-state rectifiers in recent years has resulted in considerable simplification of the structure and improved reliability of operation. Since voltage regulation, which is important in the use of accelerators for nuclear research, worsens with an increase in the number of stages, each stage must be operated at the highest possible voltage. To go above 100 kv per stage requires the use of specially developed capacitors and rectifiers. The use of the Cockcroft-Walton accelerator to produce neutrons by the d-d or d-t reactions has become widespread in recent years. The required voltages permit the use of a machine operating at atmospheric pressure, with its attendant simplicity and ease of maintenance.

Alternating Voltage Accelerators

The use of unrectified alternating current at high voltages from transformer sources started about 1926 with the cascade tube of W. D. Coolidge of the General Electric Company, continuing with the work of A. Brasch and F. Lange in Berlin in 1927 and C. C. Lauritsen at California Institute of Technology in 1928. G. Breit at the Carnegie Institution of Washington started an investigation of the Tesla coil as a means of producing high voltages in 1926.

Unresonated Transformer Systems

Coolidge, Brasch, Lange, and Lauritsen all obtained high voltages through the use of unresonated transformer systems. From 900 kv to 1.2 Mv were obtained by these experimenters. The use of this method for obtaining high voltages has practically ceased except for applications in industrial radiography at much lower voltages.

Resonated Transformer Systems

The work at the Carnegie Institution using a Tesla coil resonated at 100 kc/sec produced voltages up to 5.2 Mv with oil insulation. However, the highest voltage that could be held on a 15-section tube was 1.4 Mv. Electrons and finally protons were accelerated to a little over 1 Mev. However, the advantages of the Van de Graaff machine resulted in a shift of emphasis to this type around 1931, and further work on the Tesla coil was abandoned. Pressurized gas-insulated resonant transformers are built commercially for voltages of 1 and 2 Mv, both for X-ray and direct electron irradiation at high beam powers where the lack of a monoenergetic spectrum is acceptable.

Pulsed-Voltage Accelerators

The use of a shaped voltage pulse for acceleration of electrons or ions in a potential-drop machine has unique advantages for certain applications. Higher voltages can be sustained for short periods, resulting in machines of greater compactness. Short bursts of neutrons can be obtained for reactor critical measurements of time-of-flight studies. Injection of electrons or ions into high-energy pulsed accelerators can be accomplished during their periods of acceptance. In all these applications, peak intensities many times the average can be achieved with the attendant advantages and without the high average powers required for continuous operation. Impulse generators using the Marx circuit were employed as early as 1930 by Brasch and Lange who succeeded in accelerating electrons to 2.4 Mev. In this circuit capacitors are charged through resistors in parallel and discharged through triggered spark gaps in series to give impulses whose characteristics depend on the inductance of the system. Alternatively, inductance-capacitance pulse-forming networks have been used with pulse transformers to give voltages up to 500 kv.

III. INDUCTION ACCELERATORS

The first practical induction accelerator was designed and built by D. W. Kerst at the University of Illinois in 1940, and his suggested name of "betatron" has been universally accepted. The betatron accelerates electrons in a continuous circumferential electric field and can be compared with a transformer with the secondary winding consisting of electrons circulating in an evacuated torus. An electron injected tangentially into this chamber with an initial high-voltage acceleration will move in a circular path as a result of a perpendicular magnetic field. The pole of the magnet is so designed that a part of the field passes within the torus and by virtue of its change with time provides the accelerating electrical field. Another part passes through the orbit region to provide the focusing and radial forces.

For a particle of charge e moving in a circle of radius r in a magnetic field of strength B, the basic equation of centrifugal and electric force applies:

$$Bev = \frac{mv^2}{r} . \tag{1}$$

For the momentum $p = mv$, we have (in gaussian units)

$$p = \frac{e}{c} Br. \tag{2}$$

If the flux ϕ through the orbit is changing with time, an electromotive force equal to $(1/c)(d\phi/dt)$ is generated around the orbit, which corresponds to an electric field of $(1/2\pi rc)(d\phi/dt)$ acting in the direction of motion. From the laws of motion, the change in momentum is

$$\frac{dp}{dt} = \frac{e}{2\pi rc} \frac{d\phi}{dt} . \tag{3}$$

For constant r, Eq. (3) shows that $p(\Delta p)$ is just proportional to $\phi(\Delta\phi)$, and Eq. (2) that Δp is proportional to ΔB. These relations are satisfied if the familiar "flux condition",

$$\Delta\phi = 2\pi r^2 \Delta B, \tag{4}$$

is met, and thus particles injected at radius r will remain there throughout the acceleration. The field at the orbit will be just half as great as the average field through the orbit. In iron-core machines the orbit field will be relatively low because of saturation effects.

Improvements on the basic concept have been made for machines of high energy used for research purposes. One such improvement is obtained by using separate windings to provide the flux for acceleration and the field for the orbit. This permits biasing the flux winding and doubling the change by going from a peak negative value to a peak positive value. After the energy has reached its peak value, the electrons normally are deflected onto a target to produce X-rays by a pulse passed through an auxiliary coil parallel to the orbit. Electrons can also be removed from a betatron by expanding the orbit into a channel of reduced magnetic field strength instead of onto a target.

IV. RESONANCE ACCELERATORS

The potential-drop accelerators previously discussed depend upon very high voltages to produce the very high energies; the dimensions of the machines become very large and the technical difficulties formidable. On the other hand, the resonance accelerator uses a high-frequency voltage applied to a series of gaps through which the particles pass. The frequency is matched to the time of passage from one gap to the next, so that the field is always in the accelerating direction as the particles cross each gap. The voltage may also be supplied by a traveling electromagnetic wave of proper velocity. The particles may move in a straight line (linear accelerator) or, under the influence of a magnetic field, in a circle (synchrotron or microtron) or spiral (cyclotron), passing repeatedly through the accelerating gap. These latter accelerators comprise the class known collectively as "magnetic resonance accelerators."

Linear Accelerators

The first operable resonance accelerator was described by R. Wideroe in 1928. The apparatus had three hollow cylindrical electrodes in line, the end electrodes being grounded while the center one was connected to an oscillator. In 1930 D. H. Sloan and E. O. Lawrence at the University of California built a tube having eight accelerating gaps, which later the same year was increased to 21 gaps to give 200-kev mercury ions with an applied potential of about 10 kv. Subsequently a similar machine produced 1.26-Mev mercury ions, and shortly thereafter the accelerating system of this machine was rebuilt to produce 2.85-Mev mercury ions. Sloan subsequently modified the design to produce high-energy X-rays, and other workers both in the United States and Germany made related proposals. Although these systems showed great promise, they were displaced by the cyclotron, and it was not until many years later that new high-frequency techniques revived interest in linear accelerators.

All modern linear accelerators use "hollow circuits" in which the currents and fields are enclosed within conducting envelopes, such as resonant cavities, wave guides, and coaxial transmission lines. High-frequency power is derived from magnetrons, klystrons, or triodes, and is pulsed so that very high instantaneous power levels can be reached without thermal damage to the equipment. The differentiation between linear accelerators for ions and for electrons has been in most part based upon the type of resonant-cavity. The standing-wave type in which the phase velocity is infinite has the radio-frequency voltage gradient everywhere the same at any particular moment. Acceleration occurs simultaneously at a large number of gaps between drift tubes which serve to shield the particles from the fields when the voltage gradients are in such direction as to decelerate the particle. The traveling-wave linear accelerator, on the other hand, feeds the radio-frequency energy in at the injection end of a wave-guide structure so designed that the phase velocity of the traveling wave is matched to the particle velocity of the particle being accelerated. The standing-wave machines, for the most part, are used for the acceleration of ions, while the traveling-wave machines are used for acceleration of electrons.

Standing-Wave Linear Accelerators

The present form was worked out in considerable detail by L. W. Alvarez in 1945 and built and put into operation at Berkeley, California in 1946-7. In this machine the resonant cavity in the form of a right circular cylinder has a series of drift tubes suspended on its axis, with the repeat length of the drift tubes increasing from the value required for the energy of the injected particle to that at exit. The cavity is driven at its resonant frequency in the TM_{010} mode in which the electric field is axial by a series of oscillators or power amplifiers coupled to the cavity through short transmission lines. Phase-stable operation results during the initial half of the time the voltage gradient is in the accelerating sense. Since these fields are defocusing during this period, the first linear accelerator used electrostatic focusing obtained by grids at the input end of each drift tube. Subsequent designs have also used either solenoid weak-focusing or quadrupole strong-focusing magnets inside the drift tubes.

A rough approximation to the layout of a linear accelerator may be obtained by considering the acceleration of a nonrelativistic particle from rest. The axial displacement x of a particle of mass m and charge e in a mean axial field $\bar{E}$ at frequency ν is

$$x = \frac{1}{2} \frac{e\bar{E}}{m} \left(\frac{n}{\nu}\right)^2 . \tag{5}$$

In practice, the point at which we have $n = o$, $x = 0$ is a "virtual origin" outside the accelerator, as the particles must be injected at considerable energy into the first gap to achieve a practicable geometry and acceptance.

Traveling-Wave Linear Accelerators

Late in 1946, W. W. Hansen at Stanford University and D. W. Fry at the Telecommunications Research Establishment in England successfully operated disc-loaded traveling-wave electron accelerators. The loading of the wave guide which matches the phase velocity to the particle velocity has taken the form of irises normally spaced at one-quarter wave length in a hollow, cylindrical wave-guide structure. For a number of years the traveling-wave machines operated at "S-band" frequencies, or approximately 2850 Mc/sec. More recently small machines for radiographic and medical use have been built at "X-band" frequencies, or approximately 10,000 Mc/sec, and for long pulse-length operation with very high beam power at "L-band" frequencies of about 1250 Mc/sec. Electrons are normally injected at energies of the order of 150 to 250 kev, since the particle velocity is so high ($v/c = 1/2$ at 79 kev) that good acceptance can be achieved without a specially designed entrance section. However, injection can be accomplished at much lower voltages--for example, 20 kev.

Magnetic Resonance Accelerators

Cyclotrons

Fixed frequency. 1. An azimuthally-constant field was used in the original cyclotron first proposed by E. O. Lawrence in 1929 and built in 1930. This machine is based on the Larmor principle that the time for each traversal is constant and independent of radius, as may be seen if we solve Eq. (1) for the radius

$$r = \frac{mv}{Be} . \tag{6}$$

The time to traverse the path is

$$T = \frac{2\pi r}{v} , \tag{7}$$

which by substitution of Eq. (6) gives

$$T = \frac{2\pi m}{Be} . \tag{8}$$

A slow decrease of the field with increasing radius produces a force component directed toward the median plane of the magnet gap and serves to focus the beam. This and similar methods are now termed weak focusing to distinguish them from strong-focusing (e. g., alternating-gradient) systems.

2. An azimuthally-varying field was shown by L. H. Thomas in 1938, to satisfy the relativistic requirement that the average field increase with radius to maintain isochronism for a fixed-frequency machine and simultaneously satisfy the requirement of focusing. It was subsequently realized that the Thomas cyclotron was a special case of the strong-focusing principle conceived by Christofilos in Athens in 1949 but first published by Courant, Livingston, and Snyder of Brookhaven in 1952. These studies showed the great benefits to be derived if the azimuthal variations were made large, and led to the alternating-gradient synchrotrons (to be mentioned later). A more sophisticated form of the Thomas cyclotron using spiral ridges on the pole faces rather than radial ones is now under development at a number of laboratories.

Frequency Modulation 1. An azimuthally constant field can be used for cyclotrons operating in the relativistic range if the accelerating frequency is modulated in such fashion as to maintain a constant relative phase as the particle increases in mass. This category of machine in the form of the "synchrocyclotron" provides a very simple and effective solution to the relativistic problem. All high-energy cyclotrons now in operation are in this classification as is the electron cyclotron or "microtron" originally proposed by Veksler in 1944. In this latter accelerator both frequency and magnetic field are held constant, but orbits are all tangent at one point where they pass through a resonant cavity. The cavity provides the acceleration. Successive orbits spend one integral number of radio-frequency cycles more time in each successive pass, thus in effect accomplishing a stepwise modulation of the accelerating field.

2. A cyclotron with an azimuthally varying field designed to operate at a fixed dee frequency for a selected particle can accelerate other particles to a higher energy than would otherwise be possible, by modulating the accelerating frequency. Of course, average current is thus sacrificed. This feature exists in the form of a proposed improvement to a cyclotron of the azimuthally varying field type.

Synchrotrons

The theory of phase stability published by V. Veksler and by E. M. McMillan in 1946 gave accelerator designers the reassurance they needed to invent more sophisticated machines such as the synchrocyclotron and the electron and proton synchrotrons. It had been assumed at first that the extraordinary criticality of frequency and field control could not be achieved in practice. However, it was shown that this was not true, and practical designs are relatively easy to achieve. By using a time-varying magnetic field, the particle radius can be held constant with increasing energy, and great economies can be effected in high-energy machines.

Electron Synchrotrons 1. An azimuthally constant field with a fixed frequency characterizes the ordinary synchrotron in which electrons are accelerated. The first machine of this type to operate was made by F. K. Goward and D. E. Barnes in England in 1946 by modifying a 4-Mev betatron to give 8-Mev electrons. As was noted earlier, in a betatron the guiding field is limited to half the value of the field providing acceleration by induction. The use of radio-frequency acceleration thus permits exploitation of the full guiding-field capability of the magnetic structure, and if injection can be accomplished at 2 Mev or better, the radio-frequency accelerating system can run at constant frequency. Such injection energies have been obtained both by pulse transformer supplying the electron gun or by lower gun voltage and "betatron injection" using flux bars through the orbit which saturate at an induction flux corresponding to these energies.

2. An azimuthally varying field with a fixed radio-frequency accelerating system results in the electron alternating-gradient synchrotron. The first circular high-energy strong-focusing machine to operate was an electron synchrotron built at Cornell University giving about 1 Gev (1×10^9 ev). Accelerating electrons much above 1 Gev in circular machines rapidly becomes more difficult because of the radiation loss from an electron moving in a curved path. This loss must be exceeded if any net acceleration is to result. Proposed electron accelerators extending into the multi-Gev range are based upon the principles used in the traveling-wave electron linear accelerator.

Frequency Modulation. If an electron can be injected into an accelerator at a velocity approaching that of light, the subsequent increase in energy aggrandizes the mass, and acceleration can occur at a fixed frequency in any resonance accelerator. However, for protons and heavier nuclei this is not practical, and the orbit radius or the magnetic field must vary with time. In the low-energy cyclotron, only the orbit radius varies with time, and in a simple manner, but for high energies, both orbit radius and radio frequency must vary with time or an azimuthally varying field must be employed. Then by analogy, if the magnetic field is varying with time to give a constant radius to the particle being accelerated, it is also necessary to modulate the accelerating frequency to compensate for the simultaneous change of mass and velocity that occurs for a large range in energy.

1. An azimuthally constant field characterizes the proton synchrotrons built at Birmingham, Brookhaven, and Berkeley, as well as the subsequent installations at Dubna, Saclay, and Argonne. It is slightly questionable to identify these machines as having an azimuthally constant field since they are of a "race track" type in which the particle travels a path consisting of alternate curved and straight sections so that the field is not completely free of azimuthal variations. In fact, in the Argonne machine the fringing field at the end of the magnet sectors has been specifically tailored to provide the focusing forces which are necessary in the weak-focusing type of machine.

2. An azimuthally varying field combined with the time variation of magnetic field and accelerating frequency represents both the most complex combination of variable accelerator parameters and most recent development in the accelerator art. This combination defines the high-energy, strong-focusing, proton synchrotrons, namely the CERN and Brookhaven alternating-gradient machines operating at 25 to 30 Gev as well as machines of still higher energy under construction. The great reduction in aperture that can be realized by the application of the strong-focusing principle permits energies to be scaled upward by a factor of four or five over the weak-focusing machines, without a corresponding increase in amounts of steel and copper used in the magnet or magnet excitation power. Magnetic-resonance machines now being constructed or proposed exploit these most complex combinations of parameters to achieve the desired performance at the minimum capital investment.

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VI. LIST OF PARTICLE ACCELERATORS

The following is a compilation of particle accelerators throughout the world which were in operation by June 30, 1960. These data were obtained largely from questionnaires returned to the authors by establishments operating the machines. In instances in which no reply or an incomplete reply was received, information for the list was obtained from references or by private communication. The superscript numbers before the name of each installation indicate the source of information. These sources are listed as footnotes on the first page of the list.

Abbreviations used in this compilation include:

VdG--Van de Graaff; C-W--Cockcroft-Walton; fil.--filament; es--electrostatic; mag.--magnetic; C.W.--continuous wave; F.M.--frequency modulated; and linac--linear accelerator. Other abbreviations are those commonly used in the scientific literature.

Acceleratora are listed in the five principal categories used in the foregoing text—potential-drop machines, betatrons, linear accelerators, cyclotrons, and synchrotrons. A total of 680 machines are listed. The distribution of these accelerators according to type and country is given in Table I. Table II shows the distribution of various classes of accelerators in the United States according to type of establishment.

Table I. Distribution of Machines, by Type and Country

Country	All machines--totals	Potential-drop machines	Betatrons	Linear accelerators	Cyclotrons	Synchro-trons
United States	321	197	40	34	37	13
Outside the United States	359	180	58	41	51	29
Algeria	2	2	0	0	0	0
Argentina	2	1	0	0	1	0
Australia	12	4	0	4	2	2
Belgium	9	5	1	2	1	0
Brazil	1	0	1	0	0	0
Canada	18	12	2	1	2	1
Czechoslovakia	1	0	0	0	1	0
Chile	1	1	0	0	0	0
Chinese People's Republic (Peiking)	1	0	0	0	1	0
Republic of China (Taiwan)	1	1	0	0	0	0
Denmark	3	2	0	0	1	0
France	46	32	3	6	3	2
Germany	37	11	19	0	5	2
Great Britain	64	30	1	19	9	5
India	3	2	0	1	0	0
Iran	1	1	0	0	0	0

Table I. (Cont.)

Country	All machines--totals	Potential-drop machines	Betatrons	Linear accelerators	Cyclotrons	Synchro-trons
Israel	2	1	0	0	1	0
Italy	18	7	9	0	0	2
Japan	41	20	9	2	5	5
Mexico	4	3	1	0	0	0
Netherlands	9	6	0	0	2	1
New Zealand	3	2	1	0	0	0
Norway	8	7	1	0	0	0
Pakistan	1	1	0	0	0	0
Poland	4	1	0	1	2	0
Portugal	2	2	0	0	0	0
Spain	2	2	0	0	0	0
Sweden	15	8	2	0	3	2
Switzerland	13	7	2	1	2	1
Turkey	1	1	0	0	0	0
Union of South Africa	2	1	0	0	1	0
Union of Soviet Socialist Republics	25	3	4	4	8	6
Uraguay	1	0	1	0	0	0
Yugoslavia	6	4	1	0	1	0

Table II. Distribution of establishments reporting accelerators in the United States, by type of machine and activity.

Type of machine	All activities--totals	Colleges and universities	Private firms	Federal government	Hospitals	Nonprofit institutions
All machines--totals	321	130	100	34	32	25
Potential- drop machines	197	67	68	22	24	16
Betatrons	40	9	17	9	5	0
Linear accelerators	34	17	10	1	3	3
Cyclotrons	37	27	5	1	0	4
Synchrotrons	13	10	0	1	0	2

Note: U. S. Atomic Energy Commission contractors are classified according to the type of establishment holding the contract.

LIST OF ACCELERATOR INSTALLATIONS

Potential-Drop Machines

In the United States

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (ft)	Accelerating tube Pressure (mm Hg)	Tank Length (ft)	Tank Pressure (psi)	Average beam current (μamp)	Principal use
[3]Aberdeen Proving Ground, Aberdeen, Md.	VdG	p, d	3	Rf	5.7	5×10^{-6}	11.6	260	200	
[3]American Chain and Cable Co., Bridgeport, Conn.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	360	250	
[3]American Cyanamid Co., New York, N. Y.	VdG	e, X-rays	3	Rf	5.7	5×10^{-6}	11.6	260	1000	
[1]Argonne Cancer Research Hospital, University of Chicago, Chicago, Ill.	VdG	e	2	Ta fil.	3.1	2×10^{-6}	5.4	395	200	X-ray therapy
[1]Argonne National Laboratory, Argonne, Ill.	C-W	p, d, α	0.25	Rf	~5	$\sim1\times10^{-6}$			50	
	VdG	p, d, α	3.5	Rf	~6	$\sim1\times10^{-6}$	~10	300	200-300	Neutron physics
	VdG	p, d, α	4.5	Rf	15	5×10^{-6}	25	150	30	
[1]Arkansas, University, Fayetteville, Ark.	Dc	p, α	0.15	Rf	2					Ion-atom collision studies.
	C-W	p, d	0.4	Dc arc	5	6×10^{-6}		2×10^{-7}	400-1200	Study of radiation damage and 14.8-Mev neutron-induced reactions.
[1,3]Arnold Greene Testing Laboratories, Inc., Natick, Mass.	VdG	e	1	Hot cathode	1.75	5×10^{-6}	4.2	200	250	Industrial radiography

[1]Information from questionnaires returned to authors by institutions noted.

[2]Gerald A. Behman, Nuclear Instruments 3, 181-200 (1958) and ibid. 5, 129-132 (1959).

[3]Nathan Tufts, High Voltage Engineering Co., Burlington, Mass., private communication.

[4]E. H. Krause, "Particle Accelerators," Section 8i in American Institute of Physics Handbook (McGraw-Hill Book Co., New York, 1957), pp. 172-201.

[5]Neil Norris, Applied Radiation Corp., Walnut Creek, Calif., private communication.

[6]R. Morel and J. M. Thomas, Societé Anonyme de Machines Electrostatiques, Grenoble, France, private communication.

[7]Dan Zarnik, Allis-Chalmers Mfg. Co., Milwaukee 1, Wis., private communication.

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[9]F. T. Howard, Cyclotrons and High Energy Accelerators-1958, Oak Ridge National Laboratory Report ORNL-2644, Nov. 17, 1958.

[10]Von Gunter Lehr, Die Atomwirtschaft 4, 277 (1959).

[11]G. A. Kolstad, Journal of First High Energy Physics Exchange Under McCone-Emelyanov Agreement, USAEC report, 1960 (unpublished).

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (ft)	Accelerating tube Pressure (mm Hg)	Tank Length (ft)	Tank Pressure (psi)	Average beam current (μamp)	Principal use
[1]Atomics International, Canoga Park, Calif.	VdG	e	1.7	Hot W fil.	4	1.5×10^{-6}	9	113	20-30	Metals irradiation
[2,3]Austenal, Inc., Chicago, Ill.	VdG	X-rays	1		1.75	5×10^{-6}	4.2	200	250	
[2,3]Babcock-Wilcox, Lynchburg, Va.	VdG	X-rays	1		1.75	5×10^{-6}	4.2	200	250	
[1]Bartol Research Foundation, Franklin Institute, Swarthmore, Pa.	C-W	d	0.1	Rf	0.8	$\sim1\times10^{-5}$			150 unresolved	Neutron source
	VdG	e	2.1	Fil.	~4	1×10^{-6}	9	400	3	Research
	VdG	p, d	1.75	Rf	5	1×10^{-6}	12.5	200	80	Neutron physics
	VdG	p, d, α	5.5	Rf	19	1×10^{-6}	35	315	20	Neutron physics
[2,3]Baylor University, College of Medicine, Houston, Tex.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	
[1]Bell Telephone Laboratories, Murray Hill, N. J.	VdG	e	1	Ta fil.	1.8	1×10^{-5}	5.4	200	250	Defects in solids and polymer irradiation
	VdG	e	1	Phillips "L" cathode	1.7	1×10^{-5}	4.2	200	25	Solid-state research
[1]Brookhaven National Laboratory, Upton, Long Island, N. Y.	VdG	e	2	Fil.	3	2×10^{-5}	4.5	350	200	Research
	VdG	p, d, α, He^3	3	Capillary arc	8	2×10^{-6}	18	200	100(p, d) 10(α)	Research
	VdG	p	3.5	Penning	12	2×10^{-5}	24	140	0.28	Injector for 3-Bev Cosmotron
	C-W	p	0.75	Penning	6	5×10^{-6}			0.5	Injector for 50-Mev linac
[1]Brown University, Providence, R. I.	C-W	d	0.175	Rf	3	1×10^{-5}			1000-3000	Neutron production
[3]Buffalo, University, Buffalo, N. Y.	VdG	e	1.5	Hot cathode	~3	5×10^{-6}	~7.9	260	1670	
[1]California Institute of Technology, Pasadena, Calif.	VdG	p, d, α, heavy ions	0.6	Rf	2.25	1×10^{-6}	6	200	35	
	VdG	p, d, He^3, α	2	Rf	8.5	1×10^{-6}	13	90	5	Nuclear reactions and nuclear energy levels
	VdG	p, d, He^3, α	3	Rf	9	1×10^{-6}	22	165	5	
[1,3]California Research Corporation, La Habra, Calif.	VdG	Positive ions	1		1.75	5×10^{-6}	5.1	200	50	Nuclear physics

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[1,3] California Research Corporation, Richmond, Calif.	VdG	e	2	Hot cathode	3.8	5×10^{-6}	6.4	360	250	Electron irradiation
[1] Carnegie Institution of Washington, Department of Terrestrial Magnetism, Washington, D. C.	VdG	p, d	4		19		46	65	6	Research
[1,3] Case Institute of Technology, Cleveland, Ohio	VdG	p, d	0.4		0.69	1×10^{-5}	4	100	150	Pulsed neutron source
	VdG	p, d, α	3	Rf	~6	5×10^{-6}	11	300	50	Time-of-flight neutron spectroscopy
[3] Charity Hospital of Louisiana, New Orleans, La.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	X-ray source
[2] Chicago, University, Chicago, Ill.	C-W	p, d	0.45		7.5					
[2] College of Agriculture and Mechanics, Ames, Ia.	C-W	p, d, α	0.3		5					
[1] Columbia University, Pupin Cyclotron Laboratory, New York, N. Y.	VdG	p, d, α, He^3	6.5	Rf	12	$\sim3\times10^{-6}$	23	200	0.1-2.5	Nuclear-reaction studies
[1] Connecticut, University, Storrs, Conn.	C-W	Positive ions	0.2	Rf	2.5	5×10^{-6}			1	Atomic collisions
[2,3] Cooper Alloy Corp., Hillside, N. Y.	VdG	X-rays	1		1.75	5×10^{-6}	4.2	200	250	
[2,3] Cornell University, Ithaca, N. Y.	VdG	e	2		3.75	5×10^{-6}	6.4	375	250	
[1] Dow Chemical Co., Midland, Mich.	VdG	p	2	Rf arc	3	2×10^{-6}	5	375	50	Research
	VdG	e	2	Fil.	3	2×10^{-6}	5	375	250	Research
[1] Dow Chemical Co., Pittsburg, Calif.	VdG	e	2		4.9	6×10^{-6}	7.2	400	250	Chemical research
[1] Duke University, Durham, N. C.	VdG	p, d, α	4	Rf	12	2×10^{-6}	24	100	40	Nuclear research
[3] Edgerton, Germeshausen and Grier, Boston, Mass.	VdG	d	0.4		0.69	5×10^{-6}	4	100	150	

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[1,3] E. I. duPont de Nemours & Co., Experimental Station, Wilmington, Del.	Resonant trans-former	e	2		8	2×10^{-6}	6	100	5000	Molecular-physics research
	VdG	e	2		4.8	3×10^{-5}	6.3	390	250	Research
	VdG	e	3		5.7	3×10^{-5}	11.6	260	1000	Research
[3] Electronized Chemicals Corp., Burlington, Mass.	VdG	e	1.5		~3	5×10^{-6}	~7.9	260	1670	
[3] Eli Lilly & Co., Indianapolis, Ind.	VdG	e	3		5.7	5×10^{-6}	11.6	260	1000	
[1] Ethicon, Inc., Somerville, N. J.	VdG	e	3		7	2×10^{-6}	12	339	1000	Radiation sterilization of sutures
	VdG	e	2		4	2×10^{-6}	6	400	250	Research
[1] Eugene Talmadge Memorial Hospital, Augusta, Ga.	VdG	X-rays	2		6	4×10^{-6}	7.6	360	250	X-ray therapy
[2,3] Evans Signal Laboratory, Belmar, N. J.	VdG	p, d, e	2		3.75	5×10^{-6}	6.4	375	250	
[1] Florida, University, Gainesville, Fla.	VdG	p, d	1	Rf	4	5×10^{-5}	10	100	50	Reaction studies
[1] Florida State University, Tallahassee, Fla.	Tandem VdG	p, heavy ions	12	von Ardenne	24	5×10^{-6}	34	250	0.5	Nuclear physics
	VdG	e	3		5.7	2×10^{-6}	11	300	1000	Radiation chemistry and biology
[2,3] Foster-Wheeler Corp., Mountaintop, Pa.	VdG	X-rays	2		3.7	5×10^{-6}	6.4	375	250	
[2,3] General Electric Co., Aircraft Nuclear Propulsion Dept., Cincinnati, O.	VdG	e	2		3.6	5×10^{-6}	6.4	375	250	
[1] General Electric Co., General Engineering Laboratory, Schenectady, N. Y.	C-W	e	1		13.3	1.5×10^{-5}			10,000	Radiation-damage studies; X-ray and heat source
	C-W	d	1	Rf	13.66	1.2×10^{-5}			3000	Neutron source
	Cascade rectifier	d	0.2	Rf	4	1.5×10^{-5}			700	Neutron source

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[1]General Electric Co., Hanford Atomic Products Operation, Richland, Wash.	VdG	e	2	W fil.	4		5	340	250	Research
	VdG	p, d	2	Rf	5	1×10^{-5}	8	360	5-20	Neutron dosimetry
[1]General Electric Co., Research Laboratory, The Knolls, Schenectady, N. Y.	Resonance trans-former	e	0.8	Fil.	2.5	1×10^{-7}	4	60	250	Chemistry
	Resonance trans-former	e	1.6	Fil.	5	1×10^{-7}	8	60	150	Solid-state physics
[3]General Motors, Detroit, Michigan	VdG	d	0.4		0.69	5×10^{-6}	4	100	150	
[3]Georgia Institute of Technology, Atlanta, Georgia	VdG	p	1		1.75	5×10^{-6}	5.1	200	50	
[3]Grace New Haven Community Hospital, New Haven, Conn.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	Therapy
[3]Grace, W. R., and Co. New York, N. Y.	VdG	e	2		3.75	5×10^{-6}	6.4	375	250	
[1, 3]Gulf Research and Development Co., Pittsburgh, Pa.	Rectified dc	d	0.13	Penning	1.8	5×10^{-6}			100	14-Mev neutron source
	VdG	p, d, e	3		5.75	5×10^{-6}	11	290	250(p, d) 1000(e)	Neutron production and radiation chemistry
[3]Harper Hospital, Detroit, Mich.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	Therapy
[1]Humble Oil & Refining Co., Houston, Texas	VdG	e	2		3.8	1×10^{-5}	6.4	377	50	Hydrocarbon irradiations
[1]Iowa, State University, Iowa City, Iowa	C-W	p, d	0.5	Rf	8	1×10^{-6}			300	Reaction yields, angular distributions and correlations
	VdG	p, d	4	Rf	20	1×10^{-6}	50	135	5	
[3]Johns Hopkins Hospital, Baltimore, Md.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	Therapy
[2, 3]Johns Hopkins University, Baltimore, Md.	VdG	p, d	3		6	5×10^{-6}	11.6	260	200	
[1]Kansas, University, Lawrence, Kansas	VdG	p	2.5	Rf	7	1×10^{-5}	15	150	10	Excited-states research

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[1]Kentucky, University, Lexington, Ken.	VdG	p, d	2	Rf	7.5	2×10^{-5}	10.5	90	15	Nuclear-physics research
	C-W	d	0.14	Rf	2	5×10^{-6}			2	Nuclear-physics research; neutron generator
[1]Lawrence Radiation Laboratory, University of California, Berkeley, Calif.	C-W	p	0.46	Penning	2.5	1.5×10^{-5}				Injector for Bevatron linac
	C-W	Heavy ions to A^{40}	0.07 per nucleon	Penning	4	3×10^{-6}			33	Injector for Hilac
[1]Lawrence Radiation Laboratory, University of California, Livermore, Calif.	C-W	d, p, He^3	0.5	Rf-excited plasma	6	2×10^{-5}			600	Nuclear physics research
	VdG	d	2	Rf	3	1×10^{-6}	7	100	150	Nuclear-physics research and reactor time-dependent studies
	VdG	e	2	e gun	4	1×10^{-6}	5	350	250	Radiography
[3]Leahy Clinic, University of Chicago, Chicago, Ill.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	
	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	
[1]Lemuel Shattuck Hospital, Jamaica Plain, Mass.	VdG	e	2		3.9	2×10^{-6}	5.5	375	250	Radiation therapy
[1]Lockheed Missiles and Space Division, Palo Alto, Calif.	VdG	p, d, He^3, α	3.5	Rf	7	5×10^{-6}	10	300	30	Nuclear research
[1]Los Alamos Scientific Laboratory, Los Alamos, N. M.	C-W	p, d, He^3	0.45	Rf	6	5×10^{-6}			250	Neutron production
	VdG	p, d, α	8	Rf	20	1×10^{-5}	~40	250	100	Neutron physics
	VdG	p, t, He^3	2.7	Rf	5.5	1×10^{-5}	16.5	150	100	Charged-particle reactions
	VdG	p, d	2.5	Rf	5.5	1×10^{-6}	16	150	400	Neutron source
[2,3]Los Angeles Tumor Clinic, Los Angeles, Calif.	VdG	X-rays	2		3	5×10^{-6}	6.4	375	250	
[2,3]Magnolia Petroleum Co., Dallas, Tex.	VdG	p, d	0.5		1.2	5×10^{-6}	4.5	145	150	
	VdG	p, d, He^3, α	2		3					
[3]Mary Fletcher Hospital, Burlington, Va.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	Therapy
[3]Maryland, University, College Park, Md.	VdG	p, d	3		5.7	5×10^{-6}	12.6	260	200	

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[1]Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, Mass.	VdG	p, d, α	8.5	Rf	18	$\sim 1\times10^{-5}$	31	400	0.25	Nuclear spectroscopy
	VdG	p, d	4	Rf	9	$\sim 1\times10^{-5}$	16	150	5	p, n reactions
[2]Massachusetts General Hospital, Boston, Mass.	VdG	X-rays	2		2.7					Therapy
[1]Mellon Institute, Pittsburgh, Pa.	VdG	e, p, d	3	Fil. (e) Rf(p, d)	10	1×10^{-5}	12	400	1000(e) 200(p, d)	Radiation-chemical studies
[3]Memorial Hospital, New York, N. Y.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	Therapy
[1, 3]Michigan, University, Ann Arbor, Mich.	VdG	d	0.4		0.67	5×10^{-6}	4	115	150	Neutron reactions
[1]Minnesota, University, Minneapolis, Minn.	VdG	Li^+	4	Fil.	20	1×10^{-6}	36	100	1	Nuclear cross-section measurements
[3]Missouri, University Hospital, Columbia, Mo.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	Therapy
[3]Mt. Sinai Hospital, Cleveland, Ohio	VdG	X-rays	2		2.75	5×10^{-6}	5.4	375	250	Therapy
[1]National Bureau of Standards, Washington, D. C.	VdG	p, d	2	Rf	3	1×10^{-5}	6	350	100	Nuclear-physics research and standardization
[1]National Institutes of Health, Public Health Service, Bethesda, Md.	VdG	e	2		3	1×10^{-6}	6	330	200	Therapy and research
	VdG	e	2		3	1×10^{-6}	6	330	200	Therapy and research
	VdG	e	3.5		8	1×10^{-6}	15	290	1000	Therapy and research
	VdG	p	0.4	Arc	3	1×10^{-5}	4.5	112	150	Neutron production
[1]Nebraska, University, Lincoln, Nebraska	C-W	p, α, He^3	0.4	Rf	5	1×10^{-5}			10	Stopping-power measurements
[3]New York University, New York, N. Y.	VdG	p	1		1.75	5×10^{-6}	5.1	200	50	
[3]North Carolina State College, Raleigh, N. C.	VdG	p	1		1.75	5×10^{-6}	5.1	200	50	

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[1]Northwestern University, Evanston, Ill.	VdG	e, p, d, α	5	Rf(p, d) Fil. (e)	12	1×10^{-6}	22	300	10(p, d, α) 100(e)	Nuclear spectroscopy and radiation damage
[1]Notre Dame, University, Notre Dame, Ind.	Electro-static generator	e, p, d, α, He^3	4.5	Rf	11	1×10^{-6}	32	190	5(p, d, α, He^3) 200(e)	Nuclear-physics research
	VdG	e	2		2.7	1×10^{-5}	5.4	350	100	Radiation-chemistry research
[1,2,4]Oak Ridge National Laboratory, Oak Ridge, Tenn.	Felici	p, d	0.3	Rf	3.5	2×10^{-5}			600	n and γ production for calibrations
	Cascade	p, d, α	0.6		8.5					
	C-W	d	0.25	Penning	3					
	VdG	p, d, α	6.3	Rf	12		26	225		
	VdG	p, d	3	Rf	4.7		12	200		
	VdG	X-rays	2	Fil.	2.7		5.4	350		
[3]Oklahoma, University Hospital, Oklahoma City, Okla.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	Therapy
[3]Oregon, University Hospital, Portland, Oregon	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	Therapy
[1]Pennsylvania, University, Philadelphia, Pa.	VdG	p	3	Rf.	12	$\sim1\times10^{-5}$	20	100	20	Photonuclear research
[3]Pennsylvania, University Hospital, Philadelphia, Pa.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	Therapy
[5]Phillips Petroleum, Bartlesville, Okla.	C-W	p, d	0.35	High-voltage arc	5	2×10^{-5}			500	Research
[2,3]Pondville State Hospital, Wrentham, Mass.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	
[3]Pratt & Whitney Aircraft, Hartford, Conn.	VdG	X-rays	1		1.75	5×10^{-6}	4.2	200	250	
[1,3]Princeton University, Forrestal Research Center, Princeton, N. J.	VdG	p	3		7	5×10^{-6}	~11.4	260	200	High-energy physics
[3]Purdue, University, Lafayette, Indiana	VdG	e	1		1.75	5×10^{-6}	5.1	200	250	

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[3]Radiation and Medical Research Foundation of the Southwest, Ft. Worth, Texas	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	
[1]RCA Laboratories, Princeton, N. J.	VdG	e	1		4	1×10^{-6}	6	200	250	Research on radiation effects in solids
[2, 3]Redstone Arsenal, Huntsville, Ala.	VdG	p, d	2		2.75	5×10^{-6}	6.4	360	50	
[1]Rensselaer Polytechnic Institute, Troy, N. Y.	C-W	d	0.25	Rf	3	1×10^{-5}			100	Fast-neutron generator
	VdG	d	1	Rf		1×10^{-7}		200	50	Source of pulsable neutrons
[1]Rice Institute, Houston, Texas	VdG	p, d, He^3, α	6	Rf	14	1×10^{-6}	28	250	2	Nuclear research
[3]St. Joseph Infirmary, Louisville, Ky.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	Therapy
[1]Sandia Corp., Albuquerque, N. M.	C-W	p,d,	0.25	Penning	4	1×10^{-5}			50	Atomic-collision cross sections
	VdG	p, d, e	2	Rf(p, d) Fil. (e)	4	1×10^{-5}	7.5	350	25(p, d) 250(e)	Radiation-damage studies
[1]Shell Development Co., Emeryville, Calif.	VdG	e	3	Fil.	7	5×10^{-6}	11	300	1000	Radiation chemistry
[1]Shell Development Co., Houston, Tex.	VdG	p, d, α, He^3	2	Rf	2.75	3×10^{-6}	6.4	350	50	Oil-well logging research
[1]Socony Mobil Oil Co., Dallas, Tex.	VdG	p, d, α, He^3	2	Rf	3.9	2×10^{-5}	6.7	350	5	Petroleum-exploration research
	VdG	p, d, α, He^3	0.5	Rf	~2	2×10^{-5}	5.25	210	5-10	
[1]Socony Mobil Oil Co., Stony Brook Laboratory, Princeton, N. J.	VdG	e, p, d	2	Rf	~6	1×10^{-6}	~7	350	250	Research
[3]Southern California Cancer Center, Los Angeles, Calif.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	
[1]Southern California, University, Los Angeles, Calif.	VdG	p, d, α	4	Penning	19	2×10^{-6}	28			Injector for 31.5-Mev linac

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[1]Stanford Research Institute, Menlo Park, Calif.	VdG	p, d	2	Rf	2.7	1×10^{-5}	6.4	350	~20	Surface analysis; nuclear physics
	C-W	O, N, Ar, heavy gas ions	0.005	Rf		1×10^{-5}			to 1000	Atomic-impact phenomena
[3]Strong Memorial Hospital, Rochester, N. Y.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	Therapy
[3]Swedish Hospital, Tumor Institute, Seattle, Wash.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	Therapy
[3]Syracuse University, Syracuse, N. Y.	VdG	p	1		1.75	5×10^{-6}	5.1	200	50	
[3]Temple University Hospital, Philadelphia, Pa.	VdG	X-rays	2		3.75	5×10^{-6}	6.4	375	250	Therapy
[1]Texaco Research Center, Beacon, N. Y.	VdG	p, d	3	Rf	8	1×10^{-5}	12	300		Activation-analysis research
[1]Texas Christian University, Fort Worth, Texas	C-W	p, d	0.15	Rf	~1.8	5×10^{-6}			1500	Production of 14-Mev neutrons
[1]Texas Nuclear, Austin, Tex.	VdG	p, d, α	2	Rf	2.75	5×10^{-6}	6.4	360	50	Nuclear research and irradiations
	C-W	p, d	0.15	Rf	~1.8				1000	
[2]Texas, University, Austin, Tex.	VdG	p, d, t, α	4		10					
	Full-wave rectifier	d	0.1		1.6					
[3]Thiokol Chemical Corp., Longhorn, Tex.	VdG	e, X-rays	2		3.75	5×10^{-6}	6.4	360	250	
[3]Thompson Ramo-Wooldridge, Los Angeles, Calif.	VdG	e	2		2.75	5×10^{-6}	6	360	250	
[3]Union Carbide Nuclear Corp., New York, N. Y.	VdG	p, d, α, e	1		1.75	5×10^{-6}	5.1	200	50(p) 250(e)	
[1]Union Carbide Plastics Co., Bound Brook, N. J.	VdG	e	2	Fil.	5	5×10^{-5}	7	400	250	Plastics research

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (ft)	Accelerating tube Pressure (mm Hg)	Tank Length (ft)	Tank Pressure (psi)	Average beam current (μamp)	Principal use
[2,3]University Hospitals, Cleveland, O.	VdG	X-rays	2		3.75	5×10^{-6}	6.5	375	250	Therapy
[1]Upjohn Co., Kalamazoo, Mich.	VdG	e	2	Fil.	3	1.5×10^{-5}	6	350	250	Pharmaceutical research
[2,3]U.S. Air Force, Air Material Command, Wright-Patterson Air Force Base, O.	VdG	p	2		3.75	5×10^{-6}	6.4	375	50	
	VdG	e	1		1.75	5×10^{-6}	5.1	200	250	
[3]U.S. Air Force Institute, Colorado Springs, Colo.	VdG	d	0.4		0.69	5×10^{-6}	4	100	150	
[1]U.S. Army Chemical Center, Radiological Laboratory, Edgewood, Md.	C-W	p, d	0.7	Cold cathode	9.5	10^{-6}			1500	Neutron source
[1]U.S. Army, Quartermaster Research and Engineering Center, Natick, Mass.	VdG	e, p, d	1.1	Rf	3	$\sim4\times10^{-6}$	~5.4	200	200(e) 100(p, d)	Study of radiation effects
[1]U.S. Army Signal Research and Development Laboratory, Belmar, N. J.	VdG	e, p, d	2	Rf	~3.3	5×10^{-6}	~6.6	380	250(e) 50(p, d)	X-ray and neutron source
[3]U.S. Naval Ordnance Laboratory, Silver Spring, Md.	VdG	d	0.4		0.69	5×10^{-6}	4	100	150	
[1]U.S. Naval Postgraduate School, Monterey, Calif.	VdG	p, e	2	Rf	3	5×10^{-6}	7		2(p) 50(e)	Student research
[1]U.S. Naval Radiological Defense Laboratory, San Francisco, Calif.	VdG	p, d, α, e	2	Rf	~3.8	1×10^{-6}	6.5	300	50(p, d, α) 250(e)	Neutron physics, solid-state studies, biological irradiation
	C-W	p, d	0.15	Rf	1.5	1×10^{-6}			1000	Neutron production for shielding and biomedical research
[1,3]U. S. Naval Research Laboratory, Washington, D. C.	VdG	p, d, t, He^3, α	2.2	Rf	2.5	1×10^{-6}	6.5	200	15	Low-energy nuclear physics
	VdG	e	2		4	$<2.5\times10^{-5}$	7.5	365	250(max)	Solid-state research
	VdG	p, d, He^3, α	6	Rf	14	2×10^{-6}	30	165	20	Low-energy nuclear physics
[3]U.S. Rubber Co., Wayne, N. J.	VdG	e, x-rays	2		3.75	5×10^{-6}	6.4	360	250	

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (ft)	Accelerating tube Pressure (mm Hg)	Tank Length (ft)	Tank Pressure (psi)	Average beam current (μamp)	Principal use
[2]Vanderbilt University, Nashville, Tenn.	C-W	p, d, α	0.4							
[1]Virginia, University, Charlottesville, Va.	VdG	p, d	1	Rf	3	5×10^{-6}	5.3	200	100	Fast-neutron production
[2,3]Watertown Arsenal, Watertown, Mass.	VdG	p, d	2		3.75	5×10^{-6}	6.4	360	250	
[1]Well Surveys Inc., Tulsa, Okla.	VdG	p, d, α, He^3	0.5	Rf	3	$<1\times10^{-4}$	6	250	100	Research, neutron source
[1]Wesleyan University, Middletown, Conn.	C-W	d	0.16	Rf	3	5×10^{-6}			200	Neutron scattering
[1,3]Westinghouse Electric Corp., Radiation and Nucleonics Laboratory, Pittsburgh, Pa.	VdG	e, p, d	2		3.75	1×10^{-6}	~6.7	350	250(e) 50(p, d)	Research and development
	VdG	X-rays	1		1.75	5×10^{-6}	4.2	200	250	
	VdG	e, p, d, x-rays	2		3.75	5×10^{-6}	6.4	375	50(p, d) 250(e)	
[2,3]Wisconsin, University, Madison, Wis.	VdG	p, d, α	4.5							
	VdG	p, d, α	2							
	VdG	p, α	10							
	VdG	p	12		12	5×10^{-6}	34	210	0.5	
[3]Worcester Polytechnic, Institute, Worcester, Mass.	VdG	p	2		2.75	5×10^{-6}	6.4	360	50	
[3]Yale University, New Haven, Conn.	VdG	e	1		1.75	5×10^{-6}	5.1	200	250	

Potential-Drop Machines

Outside the United States

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (cm)	Accelerating tube Pressure (mm Hg)	Tank Length (cm)	Tank Pressure (atmos)	Average beam current (μamp)	Principal use
Algeria										
[1]Institut d'Etudes Nucléaires de l'Université d'Alger, Alger	VdG	p, d, e	3	Rf	220	1×10^{-5}	300	20	200(p, d) 1000(e)	Study of nuclear levels; fast-neutron spectroscopy
	Felici	p, d, e	0.6	Rf	187.6	1×10^{-5}			500(p, d) 2000(e)	Study of nuclear levels; fast-neutron spectroscopy
Argentina										
[1]Comisión Nacional de Energía Atómica, Buenos Aires	C-W	p, d	1.2	Cold cathode	390	1×10^{-5}			150	Nuclear physics; biology
Australia										
[1]Australian National University, Canberra	C-W	p, d	0.5	Rf	244	$<1\times10^{-5}$			300	Nuclear physics
	C-W	p, d, α	1.0	Rf	518	$<1\times10^{-5}$			200	
[1]Melbourne, University, Victoria	VdG	p, d	0.75	Rf	229	$<1\times10^{-5}$			2	Low-energy nuclear physics.
	VdG	p, d	1.0	Rf	305	$\sim1\times10^{-5}$			10	
Belgium										
[2]Centre de Physique Nucléaire, Ecole Royale Militaire, Bruxelles	C-W	p	1.4							
[1]Centre de Physique Nucléaire, Université de Louvain, Louvain	VdG	d	1.5	Rf	250		400	5	25	Neutron source
[1]Faculté Polytechnique de Mons, Mons	C-W	p, d	1.4	Rf	500	1×10^{-5}			200	Nuclear reactions; neutron source
[1,3]Liège, Université, Centre de Physique Nucléaire, Liege	VdG	p, d	2	Rf	84	3×10^{-5}	196	24.2	50	Nuclear spectrometry
[2]Université Libre de Bruxelles, Bruxelles	C-W	p, d	0.85							
Canada										
[1]Alberta, University, Edmonton, Alberta	Felici	d	0.15	Rf	91	1×10^{-6}			100	Production of 14-Mev pulsed neutrons
	VdG	p, d	2.0	Rf	91	8×10^{-6}	198	24.8	30	Reactions with light elements

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (cm)	Accelerating tube Pressure (mm Hg)	Tank Length (cm)	Tank Pressure (atmos)	Average beam current (μamp)	Principal use
Canada (continued)										
[1]Atomic Energy of Canada Ltd., Chalk River, Ontario	VdG	p, α, He^3	3	Rf	274	5×10^{-6}	488	13.6	15	Fundamental research
	Tandem VdG	p, d, C^{12} O^{16}	12(p, d) 36(O^{16})	Rf	732	5×10^{-6}	1,067	15.3	1(p, d)	
[1]British Columbia, University, Vancouver, B. C.	VdG	p, d, α	2.25	Rf	488	2×10^{-6}	762	13.6	10	Nuclear-physics reaction studies
	H. T. set	p, d, α	0.05	Rf	61	5×10^{-6}			300	Neutron generation and reactions
[3]Canadian Defence Resource Board, Alberta	VdG	p, d, α	2		84 and 114	5×10^{-6}	196	24.5	50	
[3]Canadian Department of Defence Production, Ottawa	VdG	e	3		174	5×10^{-6}	352	17.7	1000	
[1]Defence Research Chemical Laboratories, Ottawa	C-W	d	0.15	Rf	46	5×10^{-6}			1000	Neutron source
	VdG	p, d, e	3	Penning	244	5×10^{-6}	305	19.5	200(p, d) 1000(e)	Radiation research
[1]Montreal, University, Montreal	C-W	p, d	0.5	Rf	76	3×10^{-6}	137		100	Neutron reactions
[1, 3]Ontario Cancer Institute, Toronto	VdG	p, d, α	3	Rf	174	5×10^{-6}	352	17.7		Therapy and research
Chile										
[1]Instituto de Fisica y Matematicas, Universidad de Chile, Santiago	C-W	p, d, α	0.72(p, d) 1.40(α)	Rf	450	1×10^{-6}			800	Research
Republic of China										
[1]National Tsing Hua University, Institute of Nuclear Science, Hsinchu	VdG	p, d, e	3		226	1×10^{-5}	305	18.7	200(p, d) 1000(e)	Training and research
Denmark										
[1]Institute for Theoretical Physics, University of Copenhagen, Copenhagen	VdG	p, d, α	4.5	Rf	420	1×10^{-6}	700	12	~1	Nuclear structure studies
	VdG	p, d, α	2.2	Rf	260	1×10^{-6}	450	8	~1	

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube: Length (cm)	Accelerating tube: Pressure (mm Hg)	Tank: Length (cm)	Tank: Pressure (atmos)	Average beam current (μamp)	Principal use
France										
[1,3,6] Centre d'Etudes Nucléaires, Saclay	C-W	d	0.3	Rf	220				250	Neutron physics
	VdG	p, d, α	4		363	5×10^{-6}	725	6.8	1670	
	Felici	p, d	0.3	Rf	80	1×10^{-5}			500	
[6] Centre d'Etudes Nucléaires, Bruyeres le Chatel	VdG	d	2							Research
	Felici	p, d, e	0.6	Rf(p, d) e gun(e)	190	1×10^{-5}			500(p, d) 2000(e)	
[6] Centre d'Etudes Nucléaires, Fontenay aux Roses	Felici	p, d	0.6	Rf	190	1×10^{-5}			500	
[1] Centre d'Etudes Nucléaires, Grenoble	Felici	p	0.6	Rf	185	5×10^{-6}			250	Nuclear-physics instruction
	Felici	e	0.6	Rf	185	5×10^{-6}			1500	Chemistry and X-ray source
	Felici	e	0.6	Rf	130	5×10^{-6}			1500	Chemistry and X-ray source
	Felici	p, d	0.15	Rf	33	5×10^{-6}			10	Neutron source
	Felici	p	0.3	Rf	90	5×10^{-6}			100	Nuclear physics
[3] Compaignie Francaise de Raffinage, Paris	VdG	e	2		114	5×10^{-6}	196	24.5	250	
[6] Ecole des Hautes Etudes, Paris	Felici	p, d	0.3							Research
[3,6] Ecole Normale Supérieure, University of Paris, Orsay	VdG	p, d, e	2		84(p, d) 114(e)	5×10^{-6}	196	24.5		
	C-W	d	0.6		210					
[6] Ecole Polytechnique, Paris	VdG	p, d	2							
[6] Faculté des Sciences, Orsay, Paris	Felici	p, d, e	0.6	Rf(p, d) e gun(e)	190	1×10^{-5}			500(p, d) 2000(e)	
	C-W	d	0.3							
[1] Institut National des Sciences et Techniques Nucléaires, Saclay	VdG	p	0.5	Penning	150	2×10^{-6}			10	Instruction
	Felici	p, d	0.15	Rf	50	2×10^{-6}			400	Instruction

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (cm)	Accelerating tube Pressure (mm Hg)	Tank Length (cm)	Tank Pressure (atmos)	Average beam current (μamp)	Principal use
France (continued)										
[6]Laboratoire Central d'Armement, Limeil	Felici	p, d	0.15	Rf	41	1×10^{-5}			500	
[1]Laboratoire de Physique Atomique et Moleculaire, Collège de France, Paris	Felici	d	0.15	Rf	40	5×10^{-6}			150	14-Mev neutrons
	Felici	d	0.3	Rf	76	1×10^{-6}			100	14-Mev neutrons
[6]Laboratoire de Physique Nucléaire, Faculté des Sciences, Grenoble	Felici	p, d	0.3	Rf	80	1×10^{-5}			500	
[6]Laboratoire de Synthèse Atomique, Ivry	Felici	p, d, e	0.6	Rf(p, d) e gun(e)	190	1×10^{-5}			500(p, d) 2000(e)	
	C-W	d	0.9							
	Felici	p, d	0.3							
[1]Lyon, Université, Institut de Physique Nucléaire, Lyon	VdG	p, d	2		115	1×10^{-6}	191	25.5	50	
	C-W	p, d	1.2							Lower-energy reactions
[3, 6]Strasbourg, Université, Laboratoire de Chimie Nucléaire, Strasbourg	Felici	p, d	0.15	Rf	41	1×10^{-5}			500	
	VdG	p, d, α	6		366	5×10^{-6}	701	12.9	25	
	C-W	p, d, α	1.5		500					
Germany										
[3]Deutsches Kernstoff Institut, Darmstadt	VdG	e, x-rays	1		53	5×10^{-6}	155	13.6	250	
[1]Institut für Kernphysik der Universität Frankfurt, Frankfurt/Main	C-W	p, d	1.5	Rf	420	1×10^{-5}			1500	Nuclear physics
[1]Institut für Experimentalphysik, Hamburg	VdG	p, d, α	3	Rf	222	1×10^{-5}	300	15.3	30	Nuclear research
[2]Institut für Physik im Max-Planck-Institut für Med. Forschung, Heidelberg	VdG	p, d, α, e	1		300					
[3]Leybold Hochvacuum, Cologne	VdG	e	2		114	5×10^{-6}	196	25.5	250	
[2]Max-Planck-Institut für Chemie, Mainz	VdG	p, d, α, e	5		350					
	C-W	p, d	1.5		425					

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (cm)	Accelerating tube Pressure (mm Hg)	Tank Length (cm)	Tank Pressure (atmos)	Average beam current (μamp)	Principal use
Germany (continued)										
[1]Physikalisches Institut der Universität Bonn, Bonn	VdG	e	1.4		100		250	11	50	Research
[1]Physikalisches Institut der Universitat, Freiburg, Freiburg	VdG	p, d, He^3, α	5.5		600		800	20.4	25	Nuclear physics
[3]Physikalisches Institut der Universität Giessen, Giessen	VdG	p	1		53	5×10^{-6}	155	13.6	50	
[2]Physical Institute, Free University, Berlin-Dahlen	VdG	e	1		200					
Great Britain										
[1]Associated Electrical Industries Ltd., Aldermaston, England	VdG	p, d	3.8	Rf	274	2×10^{-6}	549	10	100	Fundamental nuclear-physics research
	VdG	d	0.5	Rf	137	2×10^{-6}			60	Neutron source
[3]Atomic Weapons Research Establishment, Aldermaston, England	VdG	p, d, α	5.5		183	5×10^{-6}	700	12.9	25	
[1]Atomic Energy Research Establishment, Harwell, England	VdG	e	2	Hot cathode	122	$\sim1\times10^{-5}$	264	27.2	50	OMR organic-coolant research
	VdG	p, d, α	5	Rf	396	$\sim8\times10^{-6}$	732	9.2	20-30	Time-of-flight experiments
	Tandem VdG	p, d, O	12	Rf	853	1×10^{-6}	1372	17	8	Scattering experiments on high-Z elements
	C-W	p, d, t	0.6	Rf	183	1×10^{-6}			900	Reactions with light elements; neutron source
[1]Birmingham, University, Birmingham, England	C-W	p	0.48		107	1×10^{-6}			0.7	Research
[1]British Insulated Callender's Cables Ltd., London, England	VdG	e	2.0	Rf	124	1×10^{-6}	213	25.8	200	Electron irradiation of plastic-insulated cables
[2]Cambridge, University, Cambridge, England	C-W	p, d	1		366					
	C-W	p, α	1.4		488					

Installation and address*	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (cm)	Accelerating tube Pressure (mm Hg)	Tank Length (cm)	Tank Pressure (atmos)	Average beam current (μamp)	Principal use
Great Britain(continued)										
[1]Cavendish Laboratory, Cambridge, England	Es. generator	p, d, α, He^{3+}	3	Rf	274	5×10^{-6}	549	10	1-10	Nuclear-level properties
[2]Clarendon Laboratory, Oxford University, Oxford, England	C-W	p, d, α	1.1		366					
	C-W	p, d, α	0.5		183					
[1]Edinburgh University, Edinburgh, Scotland	C-W	d	1		396.5	1×10^{-5}			300	Reactions in light nuclei
[2]Hammersmith Hospital, London, England	VdG	d, e	2.0		229					
[1]Liverpool, University, Liverpool, England	C-W	p, d, α, He^3	2	Rf	366	1×10^{-5}			100	Nuclear-structure studies
[2]London, University, London, England	VdG	e	2							
[1]Medical Research Council, Harwell, England	C-W	p, d	1	Rf	173	5×10^{-5}	305	11	800	Neutron production for biological investigations
[1, 3]National Physical Laboratory, Teddington, England	VdG	e	2		114	1×10^{-5}	196	25.5	150	X-ray dosimetry
[6]Plessey Nucleonics, Northampton, England	Felici	p, d	0.15	Rf	41	1×10^{-5}			500	
[6]Queen Mary College, London, England	Felici	p, d	0.15		41	1×10^{-5}			500	
[3]Reading, University, Reading, England	VdG	e	2		114	5×10^{-6}	196	24.5	250	
[2]Royal Cancer Hospital, London, England	VdG	e	2		137					
[5]Royal Naval College, Greenwich, England	Felici	p, d	0.15		41	1×10^{-5}			500	
[1]Sheffield National Centre for Radiotherapy, Sheffield, England	VdG	e	2		84	$\sim1\times10^{-6}$	168	24.8	250	Radiotherapy

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (cm)	Accelerating tube Pressure (mm Hg)	Tank Length (cm)	Tank Pressure (atmos)	Average beam current (μamp)	Principal use
Great Britain (continued)										
[1]Standard Telecommunication Laboratories Ltd., Harlow, England	VdG	p, d, e	2		122	1×10^{-5}	213	25.5	50(p, d) 250(e)	Research on effects of radiation on materials
[1]Tube Investments Research Laboratories, Cambridge, England	VdG	e	2		148.6		213.4	25.5		Research
[1]Western General Hospital, Edinburgh, Scotland	VdG	e	2		80	2×10^{-6}	175	24.8	250	Therapy
[3]Westminster Hospital, London, England	VdG	X-rays	2		114	5×10^{-6}	196	25.5	250	
India										
[1]Tata Institute of Fundamental Research, Bombay, India	VdG	e	0.5	e gun	179	2×10^{-6}			50	X-ray production for biological research
	C-W	p, d	1	Rf	488	1×10^{-5}			100	Nuclear-reaction and neutron-scattering studies
Iran										
[2]Teheran, University, Teheran	VdG	p, d, α, e	3							
Israel										
[1]Weizmann Institute of Science, Rehovoth	VdG	p, d	3	Rf	173	2×10^{-5}	352	20.4	50	Nuclear reactions
Italy										
[3]Bologna, University, Bologna	VdG	X-rays	2		114	5×10^{-6}	196	25.5	250	
[1]Centro Informazioni Studi Esperienze, Milano	C-W	d	0.4	Arc with mag. field	100	$<1\times10^{-5}$			500	Neutron source
[1]Centro Siciliano di Fisica Nucleare, Universita di Catania, Catania	VdG	p, d	2	Rf	117	1×10^{-6}	198	25.5	5	Research
[1]Istituto di Fisica, Università di Torino, Torino	Felici	d	0.3	Rf	185	1×10^{-6}	300		500	Physical research

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (cm)	Accelerating tube Pressure (mm Hg)	Tank Length (cm)	Tank Pressure (atmos)	Average beam current (μamp)	Principal use
Italy (continued)										
[1]Istituto Superiore di Sanita, Rome	C-W	p, d, e	1.1	Rf	240	1×10^{-6}			500	Low-energy nuclear research
[1,3]Laboratori Nazionale di Frascati del C. N. R. N., Frascati (Rome)	VdG	e	3		173	5×10^{-6}	196	17.7		Pulsed injector
[1]Pirelli Societa per Azioni, Milan	VdG	e	2	Heated cathode	150	5×10^{-6}	207	26	250	Irradiation of materials
Japan										
[1]Electrotechnical Laboratory, Tokyo	VdG	p, d	2	Rf	215	1×10^{-5}	450	20.3	50	Neutron generation
[1]Hitachi Central Research Laboratory, Tokyo	VdG	e	1.5		120	1×10^{-6}	300	16	200	Polymer irradiation
	C-W	d	0.5	Rf	200	3×10^{-6}			900	Nuclear-reactor research
[1]Japan Atomic Energy Research Institute, Ibaraki-ken	VdG	p, d	2	Rf	114	1×10^{-5}	206	25.5	25	Neutron-physics experiments
[1]Japanese Association for Radiation Research on Polymers, nr. Osaka	VdG	e	2	Fil.	~160	1×10^{-5}	210	25.5	250	Radiation chemistry and physics
[1]Japanese Association for Radiation Research on Polymers, Tokyo	VdG	e	3		215	$\sim1\times10^{-5}$	400	24.2	250	Radiation chemistry and physics
[1]Konan University, Kobe	C-W	p, d	0.4	Rf	400	1×10^{-5}			50	Neutron production
[1]Kyoto, University, Kyoto	C-W	p d	0.6	Rf Phillips	210 300	$\sim1\times10^{-5}$ $\sim0.7\times10^{-6}$			200	Nuclear-physics research
[1]Kyushu University, Fukuoka	VdG	p, d	5	Rf	500	2×10^{-6}	900	9	~1	Nuclear reactions
[1]Mitsubishi Electric Mfg. Co. Ltd., Amagasaki	VdG	e	3		210	2×10^{-6}	441	20	200	Polymer irradiation
[1]Osaka University, Osaka	C-W	p, d	0.6	Rf	130	1×10^{-5}			50	Nuclear reactions;neutron source
	VdG	p, d, He	2.5	Rf	400	3×10^{-6}	650	8.7	5	Nuclear reactions
[2]Rikkyo University, Tokyo	C-W		0.2							

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (cm)	Accelerating tube Pressure (mm Hg)	Tank Length (cm)	Tank Pressure (atmos)	Average beam current (μamp)	Principal use
Japan (continued)										
[2]Scientific Research Institute, Tokyo	VdG		2.0							
[3]Sumitomo Atomic Energy Commission, Tokyo	VdG	p, d, e	3		173	5×10^{-6}	196	17.7	200(p, d) 1000(e)	
[1]Tohoku University, Sendai	VdG	p, d, α	5	Rf	400		755	15	20	Nuclear reactions
	Dc	d	0.15	Rf	70	8×10^{-6}			60	Neutron source
[2]Tokyo Institute of Technology, Tokyo	C-W	d	0.44							
[2]Tokyo Shibaura Electric Co., Tokyo	C-W		0.15							
[1]Tokyo, University, Tokyo	VdG	p	1.7	Arc with mag. field	450	5×10^{-6}	1000	6	2	Proton-induced reactions in light nuclei
Mexico										
[1]Instituto de Fisica, Universidad Nacional de Mexico, Mexico 20, D. F.	VdG	p, d	2.2	Rf	100	2×10^{-5}		27	25	Nuclear-spectroscopy research
	VdG	p, d, e	0.5	Rf	108	2×10^{-5}			50	Neutron-and electron-physics research
[1]Universidad de Guanajuato, Guanajuato	VdG	e	0.5	Fil.	108	2×10^{-5}			50	Electron-physics research
Netherlands										
[3]Asiatic Petroleum Co., Amsterdam	VdG	e, x-rays	3		173	5×10^{-6}	352	17.7	1000	
[2]Delft Institute of Technology, Delft	VdG	p, d	2.5							
[2]Natuurkundig Laboratorium der Rijksuniversiteit, Gröningen	C-W	d	0.6		300					
	C-W	p, d	0.6		160					
[1]State University of Utrecht, Fysisch Laboratorium, Utrecht	VdG	p, α	3.0	Rf	200	1×10^{-5}	300	20	200	Resonance reactions
	C-W	p	0.85	Rf	300	1×10^{-5}			50	Proton-capture reactions

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (cm)	Accelerating tube Pressure (mm Hg)	Tank Length (cm)	Tank Pressure (atmos)	Average beam current (μamp)	Principal use
New Zealand										
[1]Auckland, University, Auckland	C-W	p, d	0.6	Rf	322	5×10^{-6}			1500	d, n reactions
[1]Otago, University, Dunedin	VdG	p	0.6	Rf					~50	Teaching
Norway										
[2]Fysisk Institutt, Bergen University, Bergen	VdG	p, d, α	1.2		700					
[2]Municipal Hospital, Bergen	VdG	e	1.5							
	VdG	p	1.5							
[2]Norges Tekniske Høgskole, Trondheim	VdG	p, d	4.0		360					
[1,6]Oslo, University, Institute of Physics, Blindern	VdG	p	2	Rf	360	$\sim1\times10^{-5}$	700	15	5	Nuclear research, γ spectroscopy
	VdG	p	0.5	Rf	120	$\sim1\times10^{-5}$			15	γ spectroscopy
	Felici	p, d	0.15	Rf	41	1×10^{-5}			500	
Pakistan (West)										
[1]Government College, Lahore	C-W	p	1						1000	Nuclear research
Poland										
[1]Politechnika Gdanska, Danzig	VdG	p	0.5	Hot cathode	133	5×10^{-5}			30	Nuclear reactions
Portugal										
[1]Laboratorio de Fisica e Engenharia Nucleares, Sacavem (Junta de Energia Nuclear, Lisbon)	C-W	p, d	0.6	Rf	190	3×10^{-6}			1000	Neutron cross sections
	VdG	p, d, e	2		120(p, d) 150(e)	$\sim1\times10^{-6}$	206	25.5	50(p, d) 250(e)	Charged-particle and neutron reactions; γ irradiation.
Spain										
[1]Junta de Energía Nuclear, Madrid	C-W	p, d, α	0.6	Penning	200	$<1\times10^{-5}$			100	Neutron source
	VdG	p, d, α, e	2.	Rf	120	$<1\times10^{-5}$	220	25.5	50(p, d, α) 250(e)	Equipment calibration

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube Length (cm)	Accelerating tube Pressure (mm Hg)	Tank Length (cm)	Tank Pressure (atmos)	Average beam current (μamp)	Principal use
Sweden										
[1]Aktiebolaget Atomenergi, Reactor Development Division, Tystberga	VdG	p, d	5.5	Rf		$\sim 5\times10^{-6}$	719	17	10	
[1]Chalmers University of Technology, Göteborg	VdG	p, He^{+}	4	Rf	400	1×10^{-5}	700	16	100	Nuclear spectroscopy; radioisotope production
[1]Lund, University, Lund	VdG	p, α	4	Rf	500	5×10^{-6}	750	10	50	Nuclear reactions in light elements; neutron physics
[1]Nobel Institute of Physics, Stockholm	C-W	p, d	1	Rf	610	5×10^{-6}			10	Nuclear-reaction studies
[1]Research Institute of National Defense, Stockholm	VdG	e	1.5		64	1×10^{-5}	160	15	200	X-ray source
	VdG	p, d	1.6	Rf	200	1×10^{-5}	400	9	100	Neutron source
[2]Radiophysics Institute, Carolina Hospital, Stockholm	C-W	e, x-rays	1.2				350			
[2]Uppsala, University, Uppsala	VdG	e	0.8		150					
Switzerland										
[1]Basel, Universität, Physikalisches Institut, Basel	C-W	d	1	Rf	300	1×10^{-5}			200	Neutron physics
	C-W	p, d, α	4	Rf	380	5×10^{-6}	600	11	100	
	C-W	d	0.2	Rf	75	1×10^{-5}			500	d, t reactions, time-of-flight studies
[6]Laboratoire Recherches Nucléaires, Lausanne	Felici	p, d	0.15	Rf	41	1×10^{-5}			500	
[3]Neuchatel, University, Neuchatel	VdG	p, d	3		173	5×10^{-6}	383	17.7	200	
[1]Zurich, Universität, Physik-Institut, Zurich	VdG	p, d	5.5	Rf	380	6×10^{-6}	640	14	20	Low-energy nuclear physics
	VdG	p, d, α, He_4^{++}	1.8	Rf	165	4×10^{-6}	350	10	50	
Turkey										
[2]Istanbul, University, Istanbul	C-W	p, d	0.8		250					

Installation and address	Type of machine	Type of particle	Energy (Mev)	Particle source	Accelerating tube		Tank		Average beam current (μamp)	Principal use
					Length (cm)	Pressure (mm Hg)	Length (cm)	Pressure (atmos)		
Union of South Africa										
[2]Diamond Research Laboratory, Johannesburg	C-W	p, d, α, e	2.0							
Union of Soviet Socialist Republics										
[2]Physico-Technical Institute, USSR Academy of Sciences, Kharkov	VdG	e	1.0							
	VdG	p, d, e	3.0							
	VdG	p, d, e, α	5.0							
Yugoslavia										
[1]Institute of Nuclear Sciences "Boris Kidrich", Belgrade	C-W	p, d	1.5		500	5×10^{-6}			500	Physics research
	C-W	d	0.2	Rf	80	1×10^{-5}			500	Neutron source
[1]Institute "Ruder Boskovic", Zagreb	C-W	d	0.2	Rf	80	1×10^{-5}			200	dd and dt reactions
[1]Nuclear Institute "J. Stefan", Ljubljana	VdG	p, d	2	Rf	160	1×10^{-5}	450	10	10	Nuclear research

Linear Accelerators In the United States

Installation and address	Particle	Particle source	Length (ft)	Energy (Mev)	Operating pressure (mm of Hg)	Average beam current (μamp)	Wave type	Radio-frequency (Mc)	Peak rf power output (Mw)	Pulse repetition rate (pps)	Pulse length (μsec)	Principal use
[1] Applied Radiation Corporation, Walnut Creek, Calif.	e		6	8	1×10^{-7}	160	Traveling	2825	3	120	8	Service irradiation
[1] Argonne Cancer Research Hospital, University of Chicago, Chicago, Ill.	e	LaB cathode	16	50	2×10^{-6}	2×10^{-3}	Traveling	2857	30	60	2	Therapy
[1] Argonne National Laboratory, Argonne, Ill.	e	Heated cathode	10	19	$\sim1\times10^{-6}$	150	Traveling	2890	5	400	6	Radiation chemistry
[1] Bartol Research Foundation of Franklin Institute, Swarthmore, Pa.	e		1.17	1.27	1×10^{-6}	200	Standing	2850	0.9	10	1	Solid-state research
[1] Brookhaven National Laboratory, Upton, Long Island, N. Y.	p	Penning	110	50	5×10^{-6}	0.125	Standing	201	5	2.5	10	Synchrotron injector
[1] Brooks Air Force Base, School of Aviation Medicine, Brooks, AFB, Texas	d	Moak	2.75	0.1	2×10^{-5}	300	Standing					Neutron generation
[5] Cornell University, Ithaca, N. Y.	e	oxide-cathode e gun	~13	10	3×10^{-7}	6	Traveling	1300	10	30 or 60	0.1-1	Injector for 1.5-Bev Synchrotron
[1] E. I. du Pont de Nemours & Co., Radiation Physics Laboratory, Wilmington, Del.	e		8	10	2×10^{-6}	300	Traveling	2850	2	180	5	Molecular-physics research
[1] Ethicon, Inc., Somerville, N. J.	e		3.28	7	3×10^{-6}	500	Traveling	2850	2	800	5	Radiation sterilization of sutures
[1] General Dynamics Corp., General Atomic Div., San Diego, Calif.	e	Indirectly heated cathode	12	30	4×10^{-7}	150	Traveling	2824	10	720	5	Neutron- and reactor-physics research

Installation and address	Particle	Particle source	Length (ft)	Energy (Mev)	Operating pressure (mm of Hg)	Average beam current (μamp)	Wave type	Radio-frequency (Mc)	Peak rf power output (Mw)	Pulse repetition rate (pps)	Pulse length (μsec)	Principal use
[1]Lawrence Radiation Laboratory, University of California, Berkeley, Calif.	+ions to A^{40}	Penning	~120	10/nucleon	2×10^{-6}	1	Standing	70	3	15	2000	Nuclear-chemistry and physics research
	p	Penning	18	9.8	1×10^{-6}	1	Standing	202.5	0.5	2	600	Injector for Bevatron
	e	Ti fil.	3.33	6	1×10^{-6}	50	Traveling	2855	2	7.5-240	6	Research
[1]Lawrence Radiation Laboratory, University of California, Livermore, Calif.	e	e gun	7	11	5×10^{-6}	1	Traveling	2985	4	1	20	Radiography
	e	e gun	10	22	4×10^{-6}	100	Traveling	2856	10	200	2	Nuclear-physics research
	e	e gun	20	46	6×10^{-7}	30	Traveling	1300	20	10	30	Radiography
[1]Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, Mass.	e		21	17	2×10^{-6}	5	Standing	2805	10	120	0.003-1	Photo-nuclear research
[1]Michael Reese Hospital, Chicago, Ill.	e		10	40		0.5	Traveling	2856	20	60	1	Therapy and isotope production
[1]Midwest Irradiation Center, Rockford, Ill.	e		6	8	4×10^{-7}	820	Traveling	2825	3	360	12	Service irradiation
[1]Minnesota, University, Minneapolis, Minn.	p	Penning	100	68	3×10^{-6}	0.1	Standing	202.55	3.5	60	350	Nuclear physics
[1]Montana State University, Missoula, Mont.	e		3.17	7	3×10^{-6}	15	Traveling	2815	4	30	0.1-1.5	Research
[5]Phillips Petroleum Co., Bartlesville, Okla.	e		6	6	3×10^{-7}	700	Traveling	2825	2.8	360	12	Research
[1]Rensselaer Polytechnic Institute, Troy, N. Y.	e	Thermionic	50	35	1×10^{-6}	1250	Traveling	1300	135	720	0.1-6.0	Neutron production
[1]Southern California, University, Los Angeles, Calif.	p	Penning	41	31.5	2×10^{-6}	0.2	Standing	202.55	2.5	15	600	Nuclear physics

Installation and address	Particle	Particle source	Length (ft)	Energy (Mev)	Operating pressure (mm of Hg)	Average beam current (μamp)	Wave type	Radio-frequency (Mc)	Peak rf power output (Mw)	Pulse repetition rate (pps)	Pulse length (μsec)	Principal use
[1]Stanford Medical Center, Palo Alto, Calif.	e		6	6	1×10^{-6}	20	Traveling	2836	1	600	5	Therapy and research
[1]Stanford University, High-Energy-Physics Laboratory, Stanford, Calif.	e	e gun	220	700	$\sim1\times10^{-5}$	1	Traveling	2856	260	60	2	Physics research
	e	e gun	10	40	$\sim1\times10^{-5}$	0.2	Traveling	2856	20	60	0.6	Physics research
[1]Stanford University, Microwave Laboratory, Stanford, Calif.	e	e gun	20	75	$\sim1\times10^{-5}$	8	Traveling	2856	40	60	2	Accelerator development studies; medical research and therapy
[1]Texaco Research Center, Beacon, N. Y.	e		6	6	1×10^{-6}	600	Traveling	2800	2.5	360	10	Radiation chemistry
[1]Thiokol Chemical Corp., Brigham City, Utah	e		5	8	5×10^{-7}	100	Traveling	2825	3	180	8	Radiography
[1]Yale University, New Haven, Conn.	+ions to Ar^{40}		~120	10/nucleon	2×10^{-6}	~1	Standing	70	3	10	3×10^{3}	Nuclear physics and chemistry
	e		45	80			Traveling	1200	50	720	0.1-4.0	Physics research

Linear Accelerators

Outside the United States

Installation and address	Particle	Particle source	Length (m)	Energy (Mev)	Operating pressure (mm of Hg)	Average beam current (μamp)	Wave type	Radio-frequency (Mc)	Peak rf power output (Mw)	Pulse repetition rate (pps)	Pulse length (μsec)	Principal use
Australia												
[1]Cancer Institute Board, Melbourne, Victoria	e		1	4		16-160	Traveling	2998	2	50-500	1.8	Clinical
	e		1	4.3		200	Traveling	3000	2	100-500	1.65	Clinical
[1]Institute of Radiotherapy, Cancer Council, Perth	e		1	4	1×10^{-5}	50	Traveling	2998	2	≤500	1.8	Radiation therapy
[1]Queensland Radium Institute, Brisbane Base Hospitals, Brisbane, Queensland	e		1	4		125	Traveling	3000	2	200-500	2	Medical x-ray
Belgium												
[1]Centre de Physique Nucléaire, University Ghent, Ghent	e	e gun	2.5	5		10	Traveling	3000	0.8	250	1.4	Nuclear physics
[2]Ecole Royale Militaire, Centre de Physique Nucléaire, Brussels	p		5	10			Helix					
Canada												
[1]McGill University, Radiation Laboratory, Montreal	e	e gun	2.5	10	1×10^{-5}	10	Traveling	2800	5	200-360	2	Therapy
France												
[1]Centre Anticancéreux de Lorraine, Nancy	e	Fil.	2.2	4	1×10^{-5}		Standing	3000	1	375	2	Cancer therapy
[1]Centre d'Etudes Nucléaires de Saclay, Saclay	e		6.4	28		100	Traveling	3000	10	125-500	0.25-2.0	Neutron physics and photonuclear-reaction studies
[1]Centre de Radiothérapie, Nancy	e		2	4	2×10^{-5}		Traveling		1	325	2	Therapy
[1]Curie Foundation, Paris	e	Fil.	2.4	4	1×10^{-5}	35	Traveling	3000	0.75	300	1.4	Therapy

Installation and address	Particle	Particle source	Length (m)	Energy (Mev)	Operating pressure (mm of Hg)	Average beam current (μamp)	Wave type	Radio frequency (Mc)	Peak rf power output (Mw)	Pulse repetition rate (pps)	Pulse length (μsec)	Principal use
France (continued)												
[1]Laboratoire de L'Accelerateur Linéaire, Ecole Normale Supérieure, Orsay	e		130 (final)	200		2	Traveling	3000	300	50	1	High-energy physics
[2]Paris, University, Laboratoire d'Electronique et de Radioelectricité, Paris	e		1	2			Traveling					
Great Britain												
[1]Atomic Energy Research Establishment, Harwell, England	e	Hot cathode	6	30	1×10^{-6}	350,000 (per pulse)	Traveling	2998	36	<750	0.2-2.0	Research
[1]British Petroleum Co. Ltd., Research Centre, Middlesex, England	e	Pierce e gun	1	4.3	$<1\times10^{-5}$	185	Traveling	2999	2	100-500	2 or 2.25	Radiation chemistry
[1]Cambridge, University, Addenbrooke's Hospital, Cambridge, England	e		6	15	5×10^{-6}	20	Traveling	2999	1.8	<500	1.8	X-ray therapy
[1]Christie Hospital and Holt Radium Institute, Manchester, England	e		1	4	1×10^{-5}	100	Traveling	2998		350	1.8	Radiotherapy
[1]Hammersmith Hospital, Medical Research Council, London, England	e	W fil.	3	8	5×10^{-6}	15	Traveling	2999	2	350	2	X-ray therapy
[2]Liverpool Radium Institute, Clatterbridge Hospital, Babbington, Cheshire, England	e		1	4.3			Traveling					
[1]Manchester, University, Physical Laboratories, Manchester, England	Heavy ions	Pulsed dc arc	7.6	1 per nucleon	3×10^{-6}	Several	Standing	25	0.5	50	500	Research
[1]Metropolitan-Vickers, Manchester, England	e		1	4			Traveling					
	e		20	100			Traveling					
[2]Mount Vernon Hospital, Northwood, London England	e		1	3.9			Traveling					

Installation and address	Particle	Particle source	Length (m)	Energy (Mev)	Operating pressure (mm of Hg)	Average beam current (μamp)	Wave type	Radio-frequency (Mc)	Peak rf power output (Mw)	Pulse repetition rate (pps)	Pulse length (μsec)	Principal use
Great Britain (continued)												
[1]Mullard Research Laboratories, Surrey, England	e		1	4			Traveling	2999.5	2	500	2	Irradiation physics and radiographic investigations
[1]National Institute for Research in Nuclear Science, Rutherford High-Energy Laboratory, Harwell, England	p	Pulsed rf	30.5	50	5×10^{-6}	5	Standing	202.5	4	50	200	Nuclear physics research
[1]Newcastle General Hospital, Newcastle-upon-Tyne, England	e	W fil.	1	4.2	1×10^{-6}	150	Traveling	3000	2	100-400	1.7	Medical therapy
	e	Oxide-coated cathode	1	6	1×10^{-6}	40	Traveling	9250	1	600	1.7	Mecical therapy
[1]St. Bartholomew's Hospital, London, England	e	Therm-ionic	6	15		25	Traveling		2	1000	1.3	Research and clinical
[1]Vickers Research Limited, Berkshire, England	e	Oxide-coated cathode	1	6	1×10^{-6}	40	Traveling	9250		600	1.7	Therapy and industrial radiography
	e	W cathode	20	100	1×10^{-6}	5	Traveling	2856	20	50	5	Nuclear-physics research
[2]War Office, London, England	e		1	5			Traveling					
[1]Western General Hospital, Edinburgh, Scotland	e		1	4	1×10^{-5}	125	Traveling	3000	4	500	1.6	Therapy
India												
[1]Tata Institute of Fundamental Research, Bombay	e	e-gun	0.5	1	1×10^{-5}	100	Traveling	2998	2	to 500	2	X-ray production for biological research
Japan												
[1]Hitachi Central Research Laboratory, Tokyo	e		2.5	6	4×10^{-6}	90	Traveling	2800	4	36-360	2	Polymer irradiation and medical research
[1]Japan Atomic Energy Research Institute, Ibaraki-ken Pref.	e		6.1	20		200	Traveling	2856	6	300	0.5-4.0	Neutron experiments

Installation and address	Particle	Particle source	Length (m)	Energy (Mev)	Operating pressure (mm of Hg)	Average beam current (μamp)	Wave type	Radio-frequency (Mc)	Peak rf power output (Mw)	Pulse repetition rate (pps)	Pulse length (μsec)	Principal rate
Poland												
[9]Central Polish Nuclear Research Institute, Warsaw	p			10								
Switzerland												
[1]European Organization for Nuclear Research, Geneva	p			50			Standing					Synchrotron injector
Union of Soviet Socialist Republics												
[1]Joint Nuclear Research Institute, Dubna	p			9			Standing					Research
[2]Moscow Physical Institute, Moscow	p			40			Standing					Research
[9]Thermotechnical Institute, Moscow	p			20								Injector for 7-Gev synchrotron
[2, 9]Ukrainian Technical Institute, Kharkov	p		12.4	21			Standing			4	250	Research
	Heavy ions			9/nucleon			Standing	150				

Cyclotrons

In the United States

Installation and address	C. W. or F. M.	Particle source	Particles accel-erated	Energy (Mev)	Operating pressure (mm Hg)	Radio-frequency range (Mc)	Magnet: Field (gauss)	Magnet: Weight (tons)	Magnet: Pole-tip diameter (in.)	Azi-muthal field	Average beam current (μamp)	Principal use
[1] Argonne National Laboratory, Argonne, Ill.	C. W.	Dc hooded arc	H_2^+	10.8	9×10^{-6}	~11	14,900	265	62	Constant		Basic research
			d	21.6							200	
			α	43.2								
[1] Brookhaven National Laboratory, Upton, Long Island, N. Y.	C. W.	Modified Penning	p	3	5×10^{-6}	20	14,000	71	18	Constant	3000	Research
	C. W.	Arc	p	10	1×10^{-5}	11	15,000	240	62	Constant	250	Research
			d	20								
			α	40								
[4, 9] California, University, Los Angeles	F. M.	Open dc arc	p	21		22-25.6	15,000	80	41		0.3	Research
[1] Carnegie Institute of Technology, Pittsburgh, Pa.	F. M.	Hot-cathode arc	p	440	5×10^{-6}	19-31	20,000	1500	144	Constant	Few	High-energy nuclear research and nuclear chemistry
[1] Carnegie Institution of Washington, Washington, D. C.	C. W.	Rf	p	12		7-11	16,000	220	60	Shaded	400	Research
			d	16								
			t									
			α	30								
[1] Chicago, University, Enrico Fermi Institute for Nuclear Studies, Chicago, Ill.	F. M.	Modified Penning	p	450	2×10^{-6}	18.4 to 28.5	18,000	2000	170	Constant	1.5	Meson and proton particle physics
[1, 4] Columbia University, Pupin Cyclotron Laboratory, New York, N. Y.	C. W.	Moak	p	15	1.7×10^{-5}	10-25	17,000	55	36	Constant	200	Research
			d	11								
[1] Columbia University, Nevis Cyclotron Laboratory, Irvington, N. Y.	F. M.	Cold cathode	p	385	2×10^{-6}	17-28	19,000	2000	168	Constant	1.0	Meson physics

Installation and address	C. W. or F. M.	Particle source	Particles accel-erated	Energy (Mev)	Operating pressure (mm Hg)	Radio-frequency range (Mc)	Magnet: Field (gauss)	Magnet: Weight (tons)	Magnet: Pole-tip diameter (in.)	Azi-muthal field	Average beam current (μamp)	Principal use
[1]Harvard University, Cyclotron Laboratory, Cambridge, Mass.	F. M.	Hot-fil., pulsed arc	p	~160	1.5×10^{-5}	23.2-29.3	19,000	715	95	Constant	~1.0	Nucleon-nucleon scattering experiments
[1]Illinois, University, Urbana, Ill.	C. W.	Hooded arc	p d He_3^{++} α	15 14 37 27		9-18	16,000	65	43.5	Varying	500	Nuclear-reaction research
[1]Indiana University, Bloomington, Ind.	C. W.	Hooded cone	d α	11.3 22.6	1×10^{-5}	10.58	14,600	70	45	Constant	150(d) 75(α)	Nuclear-reaction research
[1]Lawrence Radiation Laboratory, University of California, Berkeley, Calif.	F. M.	Open arc	p d α He^3	730 460 910 1140	1×10^{-5}	13.5-18(d, α) 18-36(p)	23,400	4300	188.75	Constant	0.75	Nuclear physics, chemistry and biophysics research
[1]Lawrence Radiation Laboratory, University of California, Berkeley, Calif.	C. W.	Capillary	p d α Li^7 Be^9 C^{12} C^{13} N O	12 24 48 39 > 56 144 156 100-168 >104-<196	1×10^{-5}	10.7-12.3	19,700	221	72	Constant	50(p) 70(d) 60(α)	Research and isotope production
[1]Lawrence Radiation Laboratory, University of California, Livermore, Calif.	C. W.	Hooded arc	p d α	14 12 24	5×10^{-6}	4-9	8,300	320	90	Constant	10	Nuclear-physics research
[1]Los Alamos Scientific Laboratory, Los Alamos, N. M.	C. W.	Arc	p d He^3 α	9 14 25 28	5×10^{-6}	8.3-13.7	18,000	70	45.6	Varying	1000	Nuclear-physics research
[1]Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, Mass.	C. W.	Hooded arc	p d α	7.5 15 30	5×10^{-6}	13.1	17,000	90	42	Varying	50(p) 100(d) 15(α)	Isotope production and basic research

Installation and address	C. W. or F. M.	Particle source	Particles accel-erated	Energy (Mev)	Operating pressure (mm Hg)	Radio-frequency range (Mc)	Magnet: Field (gauss)	Magnet: Weight (tons)	Magnet: Pole-tip diameter (in.)	Azi-muthal field	Average beam current (μamp)	Principal use
[1,9] Michigan, University, Ann Arbor, Mich.	C. W.	Arc with cap	p	5	5×10^{-6}	10.2	~15,000	80	42	Constant	1000	Nuclear spectroscopy
			d	8								
			α	16								
[1] Midwestern Universities Research Association, Madison, Wis.	F. M.		e	0.4	2×10^{-6}	55-75	⩽ 150	0.55		FFAG, radial sector	0.01	Orbit-dynamics and acceleration-process studies
	F. M.		e	0.15	2×10^{-6}	60±1	⩽ 44	0.408		FFAG, spiral sector	⩽ 30	Studies of orbit dynamics, space-charge effects, and acceleration and injection processes
	F. M.	100-kev e gun	e	35	2×10^{-8}	22.94 to 29.48	⩽ 5200	32		FFAG, radial sector	3	Studies of beam stacking, space-charge and plasma effects, and colliding electron beams
[1] National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio	C. W.	Hooded arc	p	10.5	2×10^{-6}	10.7	14,600	250	60	Constant	100	Nuclear and solid state research
			d	21.5								
			α	43								
[1] Oak Ridge National Laboratory, Oak Ridge, Tenn.	C. W.	Moak	p	5	8×10^{-6}	9.7	6340		44	Constant	>2000	Cyclotron development
	C. W.	e-gun	e	~0.45		117.4	41.9		27(orbit)	Varying		Cyclotron development
	C. W.	Secondary emitter	e	0.19	1×10^{-6}	112	40		23(orbit)	Varying	~1	Cyclotron development
	C. W.	Moak	N^{3+}	27	5×10^{-6}	4.9	15,000		63	Constant	100	Nuclear research
	C. W.	Moak	p	22	5×10^{-6}	13.4	8,800	350	86	Constant	2500	Nuclear physics; isotope production
[9] Ohio State University, Columbus, Ohio	C. W.	Dc arc	p	6.2		11.2	15,000	90	47	Constant	50	Nuclear reactions and isotope production
			d	12.4								
			α	24.0								
[1] Oregon State College, Corvallis, Ore.	C. W.	Dc arc	d	7	3×10^{-6}	10.1	13,000	50	37	Constant	10	Research
[1] Pittsburgh, University, Pittsburgh, Pa.	C. W.	Capillary arc	d	16		11.8	16,000	100	47	Constant	5	Reaction studies

Installation and address	C. W. or F. M.	Particle source	Particles accel-erated	Energy (Mev)	Operating pressure (mm Hg)	Radio-frequency range (Mc)	Magnet: Field (gauss)	Magnet: Weight (tons)	Magnet: Pole-tip diameter (in.)	Azi-muthal field	Average beam current (μamp)	Principal use
[1]Princeton University, Palmer Physical Laboratory, Princeton, N. J.	F. M.	Hairpin fil. in cone	p	19	4×10^{-5}	25-28	19,000	48	33		0.7	Research
[1]Purdue University, Lafayette, Ind.	C. W.	Capillary arc	d	10	1×10^{-5}	12.3	16,300	45	36.5	Constant	20	Nuclear reactions; nuclear spectroscopy; radiation damage
			α	20								
[1]Rochester, University, Rochester, N. Y.	C. W.	Hooded arc	p	7.5	3×10^{-5}	10-22	~14,500	15	26.3	Constant	25	Study of nuclear reactions
			d	4.2								
			He^3	11								
			α	8.4								
	F. M.	Cold cathode	p	240	2×10^{-5}	18.7-26.7	16,800	1100	130	Constant	0.75	Nuclear interaction of protons and pi mesons
[1]Washington University, St. Louis, Mo.	C. W.	Hooded capillary	p	5		10.8	14,300	82	45	Constant		Nuclear-reaction experiments; isotope production
			d	10							300(d)	
			α	20								
[1]Washington, University, Seattle, Wash.	C. W.	Dc hot fil. with virtual cathode	p	10.5	$\sim1\times10^{-5}$	11.6	15,000	200	60	Constant	$150(H_2^+ \& D^+)$ $50(He^{++})$	Research
			d	21								
			α	42								
[1,9]Yale University, Sloane Physics Laboratory, New Haven, Conn.	C. W.	Hooded arc	p	2	1×10^{-4}	10.6	14,000	20	25	Constant	1	Nuclear-reaction studies
			d	4								
			α	8								

Cyclotrons

Outside the United States

Installation and address	C. W. or F. M.	Particle source	Particles accel-erated	Energy (Mev)	Operating pressure (mm Hg)	Radio-frequency range (Mc)	Magnet: Field (gauss)	Magnet: Weight (tons)	Magnet: Pole-tip diameter (cm)	Azi-muthal field	Average beam current (μamp)	Principal use
Argentina												
[1]Comisión Nacional de Energía Atómica, Buenos Aires	F. M.	Fil.	d	28	1×10^{-5}	10.46-10.88	14,314	187	180	Constant	14	Nuclear physics; radiochemistry; medicine
			α	56								
Australia												
[1]Australian National University, Canberra	C. W.	Fil.	p	8	1×10^{-5}	19.7	12,600	28.4	79	Constant	350	Injector for synchrotron
[1]Melbourne, University, Victoria	C. W.	Hooded arc	p	12	1×10^{-5}	8.5-22	14,000	42	100	Constant	500	Research
Belgium												
[1]Centre de Physique Nucléaire de l' Université de Louvain, Héverlé	C. W.	Fil.	d	12.5	3×10^{-6}	13	18,000	62	96	Constant	400	Isotope production; nuclear reactions
			α	25								
Canada												
[1]McGill University, Radiation Laboratory, Montreal, Quebec	F. M.	Cold cathode	p	100	5×10^{-6}	20.6-26.8	16,300	260	208	Constant	> 1	Isotope production and study of isotope properties
[2]Western Ontario, University, London, Ontario	Microton		e	4.5					35			
Chinese Peoples Republic												
[9,10]Atomic Energy Institute, Peiping	C. W.		p d α	6 12 24			14,000	120	120	Constant		
Czechoslovakia												
[9]Institute of Nuclear Physics Research, Prague	C. W.		d	12.5			14,000	120	120			Research
			α	25.0								
Denmark												
[1]Copenhagen, University, Institute for Theoretical Physics, Blegdamsvej	C. W.	Capillary arc	H_2^+	6		13	17,500	40	91	Constant	100	Nuclear-structure studies
			D^+	12								
			He^{++}	20								

Installation and address	C. W. or F. M.	Particle source	Particles accel-erated	Energy (Mev)	Operating pressure (mm Hg)	Radio-frequency range (Mc)	Magnet: Field (gauss)	Magnet: Weight (tons)	Magnet: Pole-tip diameter (cm)	Azi-muthal field	Average beam current (μamp)	Principal use
France												
[2]Centre d'Etudes Nucléaires de Saclay, Saclay	C. W.	Moak	d α N^{6+} O^{6+}	20 45 120 120					160			Nuclear research
[9]Nuclear Physics Laboratory, Collège de France, Orsay	C. W.	Rf-heated fil.	d α	6.7 12		11.5	17,000		35.5		10(d)	Nuclear reactions and isotope production
	F. M.	W-fil. arc	p d	155 80		20.2-25.2	16,260	659	280			Nuclear-physics research
Germany												
[1]Institut für Strahen-und Kernphysik, Universität Bonn, Bonn	F. M.	Low-voltage arc	d α	32 64		10.2-10.7	14,200	220	190		5(d) 0.5(α)	Nuclear research and isotope production
[1]Max-Planck Institut für Kernphysik, Heidelberg	C. W.	Capillary arc	p d α	6 12 24	8×10^{-6}	12.8	17,000	80	101	Constant	500	Nuclear reactions; β-spectroscopy; isotope production
[2]Universität Braunschweig, Braunschweig	Micro-ton		e	5					50			
[2]Universität Mainz, Mainz	Micro-ton		e	10					50			
[1]Zentralinstitut für Kernphysik, Rossendorf bei Dresden	C. W.	Capillary arc	p d α	13.5 27	5×10^{-6}	10.5-13.5	14,700	120	120	Constant	1000	Nuclear research
Great Britain												
[1]Atomic Energy Research Establishment, Harwell, England	F. M.	Dc fil. arc	p	175	1×10^{-5}	18.9-26.3	16,200	670	279	Constant	2	Cross-section measurements; scattering experiments
[1,2]Birmingham, University Birmingham, England	C. W.	Hooded carbon arc	d α N^{4+} He_3	10.5 21	3×10^{-6}	7.0-16.2	15,500	50	102	Varying		Nuclear research and isotope production

Installation and address	C. W. or F. M.	Particle source	Particles accel-erated	Energy (Mev)	Operating pressure (mm Hg)	Radio-frequency range (Mc)	Magnet			Azi-muthal field	Average beam current (μamp)	Principal use
							Field (gauss)	Weight (tons)	Pole-tip diameter (cm)			
Great Britain (continued)												
[1,2] Birmingham, University, Birmingham, England (continued)	C. W.	Enclosed arc	p	10	1×10^{-5}	11	18,000	300	156	Constant	500	Research
			d	20								
			H_2^+	20								
			He_4^{2+}									
			He_3^{2+}									
			N_{14}^{6+}									
			C_{12}^{6+}									
[2] Cambridge, University, Cambridge, England			p						90			
			d	8								
			α									
[1] Hammersmith Hospital, Medical Research Council, London	C. W.	Moak	p	8	5×10^{-6}	10.8	14,800	120	127	Constant	200-300	Short-lived isotope production
			d	15								
			α	30								
[1] Liverpool, University, Mt. Pleasant, Liverpool, England	F. M.	Cold cathode	p	381	1×10^{-5}	18.9-28.2	18,900	1700	396	Constant	1.0	Meson physics, nucleon interactions
	C. W.	Hot cathode	p	4.5	1×10^{-5}	12.5	18,500	53.5	91	Constant		Deuteron stripping reactions
			d	9								
			He_3									
[1] University College London, London, England	Microton	Field emission	e	28	1×10^{-4}	3000	1,060		203		~0.01	Research
	Microton	Field emission	e	4.5	5×10^{-5}	3000	1,060		48		0.1	Research
Israel												
[2] Hebrew University, Jerusalem	C. W.		p	1								
Japan												
[2,9] Kyoto University, Kyoto	C. W.	Hooded arc	p	7.6		13.1	17,500	80	105		40	Nuclear and biological research; isotope production
			d	16								
			α	30								

Installation and address	C. W. or F. M.	Particle source	Particles accel-erated	Energy (Mev)	Operating pressure (mm Hg)	Radio-frequency range (Mc)	Magnet: Field (gauss)	Magnet: Weight (tons)	Magnet: Pole-tip diameter (cm)	Azi-muthal field	Average beam current (μamp)	Principal use
Japan (continued)												
[1]Osaka University, Laboratory of Nuclear Studies, Osaka	C. W.	Hooded, low-voltage	p d α	6 11.4 24	1×10^{-5}	10.6	14,000	53	112	Constant	100	Nuclear reactions; isotope production
[2]Scientific Research Institute, Tokyo			d	4		11.4	15,800	22	66		30	Nuclear research and isotope production
[2, 9]Tokyo, University, Tokyo	C. W.	Hooded, low-voltage	p d	2-4 1-2		11-14	18,500	7	40		25	Nuclear research and isotope production
	C. W.	Moak	p d α	15 21 42		12.1-84	13,300	255	160		80	Nuclear research and isotope production
Netherlands												
[2]Instituut voor Kernphysisch Onderzoek, Amsterdam	F. M.	Dc arc with fil.	d α	26 52		10.05-10.43	13,720	200	180			Isotope production, irradiation, and research
[9]Technical University, Delft	C. W.		p	12		21.5	18,500		85			Accelerator studies
Poland												
[1]Cracow Centre of Nuclear Physics, Cracow	C. W.	Ion-arc type with slit	p	4.8	4×10^{-5}	10-24	18,000	6	47.5	Constant	50	Research in photo-nuclear reactions and Coulomb excitation
	C. W.	Ion-arc type with slit	d	13	1.5×10^{-6}	9-15	14,200	120	119	Constant	30	Research in nuclear reactions
Sweden												
[1]Gustav Werner Institute for Nuclear Chemistry, University of Uppsala, Uppsala	F. M.	Cold cathode	p	185	1×10^{-5}	25.8-33.0	21,500	650	230	Constant	1	Nuclear chemistry, physics, and biology research

Installation and address	C. W. or F. M.	Particle source	Particles accelerated	Energy (Mev)	Operating pressure (mm Hg)	Radio-frequency range (Mc)	Magnet: Field (gauss)	Magnet: Weight (tons)	Magnet: Pole-tip diameter (cm)	Azimuthal field	Average beam current (μamp)	Principal use
Sweden (continued)												
[1]Nobel Institute of Physics, Stockholm	C. W.	Modified open arc	p d α Heavy ions to Ne^{6+}	10.5 Mev/ nucleon	5×10^{-6}	8.0	20,000	400	207.5	Constant	300	Isotope production
	C. W.	Arc	p d α	3.5 7.0 14	5×10^{-6}	12	15,000	17	81	Constant	~5	Nuclear-reaction studies
Switzerland												
[1]European Organization for Nuclear Research (CERN) Geneva	F. M.	Pulsed Penning	p	600	4×10^{-6}	16.4-29.2	18,800	2500	500	Constant	0.3	High-energy physics studies
[9]Federal Institute of Technology, Zurich	C. W.	W fil.	p d α	7.2 14 28		13-16.6	19,800	60	84	Constant	150	Coulomb excitation, γ-spectroscopy, and scattering experiments
Union of South Africa												
[1]National Physical Research Laboratory, Pretoria	C. W.	Open type	p d α	8 16 32	1×10^{-5}	11.5-13.5	17,200	79	113	Varying	200	Nuclear research and isotope production
Union of Soviet Socialist Republics												
[1]Joint Nuclear Research Institute, Dubna	F. M.	Hot cathode	p d α	680 420 840	3×10^{-6}	13-26	16,650	7900	600		0.015	Research
[1]Radium Institute, Academy of Sciences, Leningrad	C. W.	Dc discharge	d	6.5	8×10^{-5}	9-11	14,000	30	102	Constant	50	Nuclear reactions and isotopes
[11]Physical Technical Institute, Sukhumi	C. W.		d	20		12.5	15,500		100		30	Production of isotopes
[2]Institute for Thermal Studies, Moscow	C. W.		d	14					120			Neutron studies

Installation and address	C. W. or F. M.	Particle source	Particles accel- erated	Energy (Mev)	Operating pressure (mm Hg)	Radio- frequency range (Mc)	Field (gauss)	Weight (tons)	Pole-tip diameter (cm)	Azi- muthal field	Average beam current (μamp)	Principal use
Union of Soviet Socialist Republics (continued)												
[2, 9] Moscow Physical Institute, Moscow	C. W.	Slit	d	22			13,600	330	150		200	Particle physics and nuclear chemistry
[9] Leningrad University, Leningrad	C. W.		d	4				30	76			
	C. W.		d α	12.5 25			14,000	120	120			
[9] Physical Technical Institute, Leningrad	C. W.		α N^{3+}	13.6 25					120		0.5	Heavy-ion reactions and Coulomb excitation
[9] Ukrainian Physical Institute, Kiev	C. W.		d	13.5								
Yugoslavia												
[1] Institute "Ruder Boskovic", Zagreb	C. W.	Moak	p d α heavy ions	8 16 4 Mev/ nucleon	1×10^{-5}	8-12	14,000	70	140	Constant		Nuclear-physics and chemistry research

Betatrons

In the United States

Installation and address	Orbit radius (cm)	Magnet Weight (tons)	Magnet Field (gauss)	Electrons per pulse	Resonant frequency (cps)	Energy (Mev)	Principal use
[1]Allis-Chalmers Mfg. Co., Milwaukee, Wis.	19	5	4300	1×10^8	180	24	X-ray inspection
	19	5	5000	1×10^8	180	28	Development
[1]M. D. Anderson Hospital and Tumor Institute, University of Texas, Houston, Texas	19	6	3950	1.37×10^6	180	22	Therapy and research
[2,7]Baldwin-Lima-Hamilton Corp., Lima, Ohio	19	5	4300	1×10^8	180	24	X-ray inspection
[2,7]Birdsboro Steel Foundry, Birdsboro, Pa.	19	5	4300	1×10^8	180	24	X-ray inspection
[1]Blaw-Knox Co., East Chicago, Indiana	19	5	4300	1×10^8	180	24	X-ray inspection
[1]Blaw-Knox Co., Coraopolis, Pa.	19	5	4300	1×10^8	180	24	X-ray inspection
[7]Boeing Airplane Co., Cape Canaveral, Fla.	19	5	4300	1×10^8	180	25	X-ray source
[1]Bonney-Floyd Co., Columbus, Ohio	19	5	4300	1×10^8	180	24	X-ray source
[1]Case Institute of Technology, Cleveland, Ohio	17	2.5	6000		180	22	Photonuclear studies
[2]Chicago, University, Chicago, Ill.	83	125	4000			100	X-ray source
[2]Detroit Arsenal, Ordnance Corps, Center Line, Mich.	14					15	X-ray source
[2,7]Electric Steel Foundry Co., Portland, Oregon	19	5	4300	1×10^8	180	24	X-ray inspection
[1]General Electric Co., General Engineering Laboratory, Schenectady, N. Y.	83	125	4000		60	100	Pulsed neutron source for cross-section work
[2]General Electric Research Laboratory, Schenectady, N. Y.	13.3					11.7	X-ray source

Installation and address	Orbit radius (cm)	Magnet Weight (tons)	Magnet Field (gauss)	Electrons per pulse	Resonant frequency (cps)	Energy (Mev)	Principal use
[2,7] General Steel Castings Co., Eddystone, Pa.	19	5	4300	1×10^8	180	24	X-ray inspection
[2,7] General Steel Castings Co., Granite City, Ill.	19	5	4300	1×10^8	180	24	X-ray inspection
[1] Illinois, University, Urbana, Ill.	19	4	4300	1×10^{10}	180	24	X-ray source
	129.5	400	9000	1×10^{10}	60 (6 pulse/sec)	300	Nuclear and high-energy research
[1] Illinois, University, College of Medicine, Chicago, Ill.	19	5	5000	1×10^8	180	28	Radiation therapy
[1,7] Hercules Powder Co., Cumberland, Md.	19	4.5			180	25	Propellant radiography
[1,7] Hercules Powder Co., Bacchus, Utah	19	7.5			320	25	Propellant radiography
[1] Los Alamos Scientific Laboratory, Los Alamos, New Mexico	19	4.5	4000	5.2×10^9	180	24	Industrial radiography
[2,7] Memorial Center, New York, N. Y.	19	5	4300	1×10^8	180	24	X-ray therapy
[1] Mesta Machine Co., Homestead, Pa.	19	5	5000	1×10^8	180	28	X-ray inspection
[1] Mount Sinai Hospital, New York, N. Y.	19	4.5	5000		180	24	Therapy
[1] National Bureau of Standards, Washington, D. C.	29	12.5	5768		180	50	Nuclear physics research and standardization
[2,7] Pennsylvania, University, Philadelphia, Pa.	19	5	4300	1×10^8	180	24	X-ray source
[2,7] Picatinny Arsenal, Dover, N. J.	19	5	4300	1×10^8	180	24	X-ray source
[2,7] Pittsburgh Steel Foundry Corp., Glassport, Pa.	19	5	4300	1×10^8	180	24	X-ray inspection
[1] Presbyterian Hospital, New York, N. Y.	19	6	4000	3.5×10^8	180	25	Therapy and research
[1] Radiation Center, Madison, Wis.	19	5	4300	1×10^8	180	24	Therapy and research

Installation and address	Orbit radius (cm)	Magnet Weight (tons)	Magnet Field (gauss)	Electrons per pulse	Resonant frequency (cps)	Energy (Mev)	Principal use
[1]Renssalaer Polytechnic Institute, Troy, N. Y.	29	7	3000		180	30	Photonuclear research
[7]Rock Island Arsenal, Rock Island, Ill.	19	5	4300	1×10^8	180	24	X-ray source
[2]U. S. Naval Ordnance Laboratory, Silver Spring, Md.	13					10	X-ray source
[2]U. S. Naval Research Laboratory, Washington, D. C.	18.5					21	X-ray source
[7]U. S. Naval Test Station, China Lake, Calif.	19	5	4300	1×10^8	180	25	X-ray source
[2]U. S. Navy Electronics Laboratory, San Diego, Calif.	21					26	X-ray source
[1]Washington University, School of Medicine, St. Louis, Mo.	19	4	3950	1×10^8	180	22	Therapy and research
[1,7]Watervliet Arsenal, Watervliet, N. Y.	19	5	5000	1×10^8	180	24	Industrial radiation source

Betatrons

Outside the United States

Installation and address	Orbit radius (cm)	Magnet Weight (tons)	Magnet Field (gauss)	Electrons per pulse	Resonant frequency (cps)	Energy (Mev)	Principal use
Belgium							
[1]Kliniek voor Roentgen-En Curietherapie, Rijksuniversiteit, Ghent	11	0.4	6,000	1×10^{11}	50	17.5	Medical
Brazil							
[2]Sao Paulo University, Sao Paulo	19					24	
Canada							
[1]Ontario Cancer Institute, Toronto	19	5	4,300	1×10^{8}	180	25	X-ray therapy
[1]Saskatchewan, University, Saskatoon, Saskatchewan	20.1	5	11,000		180	25	Research
France							
[1]Institut Gustave Roussy, Villejuif (Seine)	19	6	5,000	1×10^{8}	180	24	Medical
[1]Laboratoire Central des Industries Electriques, Fontenay-aux-Roses (Seine)	11	0.4	5,500	1×10^{11}	50	17	X-ray inspection
[2]Ministry of Health, Paris	19					24	
Germany							
[1]Allgemeines Krankenhaus St. Georg, Hamburg	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
[1]Czerny-Krankenhaus für Strahlenbehandlung der Universität, Heidelberg	11	0.4	6,000	1×10^{11}	50	15	Medical therapy
[8]Geschwulstklinik der Charité, Berlin	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
[8]Institut und Poliklinik für Physikalische Therapie und Röntgenologie der Universität, München	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy

Installation and address	Orbit radius (cm)	Magnet Weight (tons)	Magnet Field (gauss)	Electrons per pulse	Resonant frequency (cps)	Energy (Mev)	Principal use
Germany (continued)							
[1]Institut für Strahlenkunde der Universität, Erlangen	11	0.4	6,000	1×10^{11}	50	17	Medical therapy
[8]Max-Planck-Institut für Biophysik, Frankfurt/Main	22	3.5	5,000/ 17,000	1×10^{11}	50	35	Physical and biophysical research
[8]Mannesmann-Röhrenwerke, Duisberg-Huckingen	11	0.4	5,000/ 17,000	1×10^{11}	50	15	X-ray inspection
[8]Phönix-Rheinrohr AG, Mülkeim/Ruhr	11	0.4	5,000/ 17,000	1×10^{11}	50	15	X-ray inspection
[1,8]Physikalisches Institut der Universität, Heidelberg	22	3.5	5,000/ 17,000	2×10^{10}	50	35	Research
[1]Physikalisches Institut der Technischen Hochschule, Karlsruhe	24.5	4.0	4,200	3×10^{9}	50	31	Student research
[1]Physikalisches Institut der Universität, Würzberg	22	3.85	10,000	2×10^{10}	50	31	Physical and biophysical research
[1]Städtische Krankenanstalten, Medizinische Akademie, Düsseldorf	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
[1]Strahlenklinik, Bonn/Rhein	12.5	0.35	17,000	$\sim1\times10^{11}$	50	16	Radiation therapy
[8]Strahleninstitut der Universität, Tübingen	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
[8]Strahleninstitut des Universitäts-Krankenhauses Eppendorf, Hamburg	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
[1]Strahlenklinik und Poliklinik der Universität, Marberg/Lahn	11	0.66	18,000	1×10^{7}	50	16.7	Radiation therapy
[8]Technische Hochschule, Institut für Schweisstechnik, Hannover	11	0.4	5,000/ 17,000	1×10^{11}	50	15	X-ray inspection
[8]Universitäts-Frauenklinik Eppendorf, Hamburg	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy

Installation and address	Orbit radius (cm)	Magnet. Weight (tons)	Magnet. Field (gauss)	Electrons per pulse	Resonant frequency (cps)	Energy (Mev)	Principal use
Germany (continued)							
[1] Universitäts-Hautklinik, Göttingen	10.5	0.35	5,000/ 19,000	~3×10^7	50	15	Medicine, biology, and physics
Great Britain							
[1] Betatron Research Group, Christie Hospital and Holt Radium Institute, Manchester, England	19	8	3,600			20	Radiotherapy
Italy							
[1] Centro di Diagnosi e Cura dei Tumori, Ospedale Civile, Chieti	10	0.3	5,000	1×10^{11}	50	15.8	Radiation therapy
[1,8] Centro Provinciale Tumori, Ospedale Civile, Cagliari	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
[8] Consorzio Cura Tumori, Ospedale Civile, Udine	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
[8] Consorzio per lo Studio e la Lotta contro i Tumori, Palermo	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
[8] Istituto Fondazione Pascale, Centro Tumori, Neapel	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
[8] Istituto "Regina Elena" degli Istituti Fisioterapici Ospitalieri, Rome	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
[8] Ospedale S. Camillo Pio, Istituto S. Spirito, Rome	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
[8] Ospedale S. Lorenzo, Borgo Valsugana	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
[8] Universita-Istituto di Radiologia, Rome	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy

Installation and address	Orbit radius (cm)	Magnet		Electrons per pulse	Resonant frequency (cps)	Energy (Mev)	Principal use
		Weight (tons)	Field (gauss)				
Japan							
[1]Electrotechnical Laboratory, Tokyo	17.5	2.5	5,000		50	25	X-ray source
[1]Hitachi Central Research Laboratory, Tokyo	21	2.8	3,500		250	20	Radiography, medical research
[1]Mitsubishi Electric Mfg. Co., Amagasaki	18	2.5	6,000		180	30	Radiophotography and photonuclear reactions
[1]Osaka University, Laboratory of Nuclear Studies, Osaka	19	3.5	4,200	1.3×10^{12}	150	24	Research
[1]Shimadzu Seisakusho Ltd., Kyoto	14.5	1.4	3,560		180	15	
[1]Tohoku University, Sendai	23	8	4,000	$\sim1\times10^{11}$	50	25	Photonuclear reactions and radiochemistry
[2]Tokyo Shibaura Electric Company, Ltd., Mazda Research Laboratory, Kawasaki	10					15	
[2]Tokyo University of Education, Tokyo	8.5 29					6 30	
Mexico							
[8]Centro Medico, Mexico City	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
New Zealand							
[1,7]Wakari Hospital, Dunedin	19	5	4,300	1×10^{8}	150	24	Radiotherapy
Norway							
[2]Bergen University, Bergen	40					47	
Sweden							
[1]Radiumhemmet, Karolinska Sjukhuset, Stockholm	25	~ 0.4	17,000		50	15	Electron-beam therapy
[2]Royal Institute of Technology, Stockholm	8					5	

Installation and address	Orbit radius (cm)	Magnet Weight (tons)	Magnet Field (gauss)	Electrons per pulse	Resonant frequency (cps)	Energy (Mev)	Principal use
Switzerland							
[2]Physikalisches Institut der Universität Zurich, Zurich	30					31	
[1]Radiological Institute, University of Bern, Bern	25	4	4,500	0.375×10^{10}	50	31	Medical
Union of Soviet Socialist Republics							
[2]Lebedev Institute, Moscow						30	
[2]Moscow State University, Moscow							
[2]Tomsk						100	
[2]Tomsk						20	
Uraguay							
[8]Instituto de Radiologia y Ciencias Fisicas, Montevideo	11	0.4	5,000/ 17,000	1×10^{11}	50	15	Radiation therapy
Yugoslavia							
[1]Nuklearni Institut "Josef Stefan", Ljubljana	24.5	3.5	~4,000	$\sim6\times10^{9}$		31	Physics; therapy

Synchrotrons
In the United States

Proton Synchrotrons

Installation and address	F.M. or C.W.	Radio-frequency range (Mc)	Pulse length: Inject. (µsec)	Pulse length: Accel. (sec)	Particle source	Injector: Type	Injector: Energy (Mev)	Magnet: Weight (tons)	Magnet: Field (gauss)	Magnet: Pulse repetition rate (per sec)	Magnet: Azimuthal field	Operating pressure (mm of Hg)	Average beam current (µamp)	Energy (Gev)	Orbit radius (ft)	Principal use
[1]Brookhaven National Laboratory, Upton, Long Island, New York	F.M.	0.360-4.18	180	1	Moak	VdG	3.6	1720	14,000	0.2	Constant	3×10^{-6}	2×10^{-3} (5×10^{10} p/pulse at 3 Bev)	3	30	Particle research
	F.M.	1.5-4.5	10	1.2	Moak	C-W and linac	50	4400	13,000	0.33	Varying	5×10^{-6}		30	421.5	Research
[1]Lawrence Radiation Laboratory, University of California, Berkeley, Calif.	F.M.	0.360-2.46	600	1.75	Moak	C-W and linac	9.9	10,047	16,000	0.2	Constant	1×10^{-6}	5×10^{-3} (1.5×10^{11} p/pulse at 6.0 Bev)	6.2	50	Particle physics and chemistry research
[1]Forrestal Research Center, Princeton University, Princeton, N. J. (with University of Pennsylvania)	F.M.	2.5-30	25	0.020		VdG	3.0	380	13,950	19	Constant	1×10^{-6}	0.1	3	30	Research

Electron Synchrotrons

Installation and address	F.M. or C.W.	Radio-frequency range (Mc)	Pulse length: Inject. (µsec)	Pulse length: Accel. (µsec)	Particle source	Injector: Type	Injector: Energy (Mev)	Magnet: Weight (tons)	Magnet: Field (gauss)	Magnet: Pulse repetition rate (per sec)	Magnet: Azimuthal field	Operating pressure (mm of Hg)	Average beam current (µamp)	Energy (Mev)	Orbit radius (in.)	Principal use
[1,9]California Institute of Technology, Pasadena, Calif.	F.M.	38.4-40	0.6			Pulse transformer	1.0		10,000	1	Constant	1×10^{-6}	5×10^{-4}	1300	148	High-energy photoproduction experiments
[1]California, University, Radiological Laboratory, San Francisco, Calif.	C.W.	165	5		LaB_6 cathode emitter			6	8,500	60	Constant	1×10^{-5}		70	~11.4	Dosimetry research and therapy
[1]Cornell University, Laboratory of Nuclear Studies, Ithaca, N. Y.	F.M.	85-87	0.1-1		Hot fil.	Linac	10	20	1,100	30	Varying	1×10^{-5}	500	1300	150	Photoproduction studies of mesons and strange particles

Electron Synchrotrons (continued)

Installation and address	F. M. or C. W.	Radio-frequency range (Mc)	Pulse length: Inject. (μsec)	Pulse length: Accel. (μsec)	Particle source	Injector: Type	Injector: Energy (Mev)	Magnet: Weight (tons)	Magnet: Field (gauss)	Magnet: Pulse repetition rate (per sec)	Magnet: Azimuthal field	Operating pressure (mm of Hg)	Average beam current (μamp)	Energy (Mev)	Orbit radius (in.)	Principal use
[1]Iowa State University, Institute for Atomic Research, Ames, Iowa	C. W.	160						8	5,000	57	Constant	1×10^{-6}	3×10^{5}	60	12	Electron scattering
	C. W.	160						8	5,000	57	Constant	1×10^{-6}	3×10^{5}	45	12	Photonuclear cross sections
[1]Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, Mass.	C. W.	46.5				Linac	20	50	~11,000	0.1	Constant	1×10^{-5}	1×10^{9}	350	40	High-energy x-ray production for photo-meson research
[1]Purdue University, Lafayette, Ind.	C. W.	46	0.5	8000	W fil.			60	11,000	8	Constant	3×10^{-6}	1×10^{-4}	340	~40.2	Photopions and photo-nuclear reactions
[1]National Bureau of Standards, Washington, D. C.	C. W.	57			LaB_6 cathode		1.5	150	7,500	1	Constant	5×10^{-6}		180	33	Nuclear physics research and stand-ardization
[1]Virginia, University, Charlottesville, Va.	C. W.	163			Pulsed e gun			8		60	Constant	5×10^{-6}		75	23	Photo-nuclear reactions

Synchrotrons
Outside the United States

Proton Synchrotrons

Installation and address	F.M. or C.W.	Radio-frequency range (Mc)	Pulse length Inject. (μsec)	Pulse length Accel. (sec)	Particle source	Injector Type	Injector Energy (Mev)	Magnet Weight (tons)	Magnet Field (gauss)	Magnet Pulse repetition rate (per sec)	Magnet Azimuthal field	Operating pressure (mm of Hg)	Average beam current (μamp)	Energy (Gev)	Orbit radius (m)	Principal use
France																
[1] Centre d'Etude Nucléaires de Saclay, Saclay	F.M.	0.76-8.4	80	0.001-0.1	Moak	VdG	3.6	1,100	15,000	3.2	Constant	5×10^{-6}	1×10^{-3}	3.0	8.42	High-energy nuclear physics
[1] Lyon, Université, Institute de Physique Nucléaire, Lyon	F.M.								280					0.029	0.9	Research
Great Britain																
[1] Birmingham, University, Birmingham, England	F.M.	0.3-9.4	200	1.1	Rf	C-W	0.48	800	12,500	0.1	Constant	1×10^{-6}	1×10^{-4}	1	4.5	Research on nucleon-nucleon interactions
Netherlands																
[2, 9] Delft Institute of Technology, Delft	F.M.					Cyclotron	~10		17,500					1	3.25	
Switzerland																
[1] European Organization for Nuclear Research (CERN), Geneva	F.M.	3-10			Rf	Linac	50	3,530	14,000	0.2-0.3	Varying	1×10^{-5}	10^{10} p/pulse	28.3	100	Studies in high-energy physics
Union of Soviet Socialist Republics																
[1] Joint Nuclear Research Institute, Dubna	F.M.	0.19-1.45			Rf	Linac	9	36,000	13,000	0.08	Constant			10	28	Research
[9] Thermo-technical Institute, Moscow	F.M.	0.65-8.5			Rf	Linac	20	2,700	9,500		Varying			7	40	Research

Electron Synchrotrons

Installation and address	F.M. or C.W.	Radio-frequency range (Mc)	Pulse length: Inject. (μsec)	Pulse length: Accel. (μsec)	Particle source	Injector: Type	Injector: Energy (Mev)	Magnet: Weight (tons)	Magnet: Field (gauss)	Magnet: Pulse repetition rate (per sec)	Magnet: Azimuthal field	Operating pressure (mm of Hg)	Average beam current (μamp)	Energy (Mev)	Orbit radius (cm)	Principal use
Australia																
[1]Australian National University, Canberra	C. W.	480	5					3	10,000	50	Constant	3×10^{-6}		33	10	Nuclear photo-disintegration
[1]Melbourne, University, Victoria	C. W.	480	2	200	Thoriated W fil.			0.5	12,500	50	Constant	1×10^{-6}	1×10^{-3}	20	10	Research
Canada																
[1]Queen's University, Kingston, Ontario	C. W.	164.1	8	0-4,000	Thoriated W fil.			8	8,100	60	Constant	$\sim5\times10^{-6}$		70	29.2	Nuclear-physics research
Germany																
[2]Physikalisches Institut, Freie Universität, Berlin-Dahlen														12	7.5	
[1]Physikalisches Institut der Universitat Bonn, Bonn	F. M.	161-163	3			VdG	3	25	10,000	48	Constant		2×10^{-2}	450	260	Research
Great Britain																
[2]Cambridge, University, Cambridge, England														33	10	
[2]Oxford University, Oxford, England														125	46.7	
[1]Glasgow University, Glasgow, Scotland	C. W.	38.1	5	28	e gun			120	12,000	5	Constant	1×10^{-6}		450	125	Meson research
[1]Royal Cancer Hospital, London, England	C. W.	477	5	4	e gun			~3	8,000	50	Constant	$\sim7\times10^{-6}$		30	10	Photo-nuclear reactions

Electron Synchrotrons (continued)

Installation and address	F. M. or C. W.	Radio-frequency range (Mc)	Pulse length Inject. (μsec)	Pulse length Accel. (μsec)	Particle source	Injector Type	Injector Energy (Mev)	Magnet Weight (tons)	Magnet Field (gauss)	Magnet Pulse repetition rate (per sec)	Magnet Azimuthal field	Operating pressure (mm of Hg)	Average beam current (μamp)	Energy (Mev)	Orbit radius (cm)	Principal use
Italy																
[1]Istituto di Fisica, Universita di Torino, Torino	C. W.	164						8	10,000		Constant	5×10^{-6}	1×10^{-2}	100	29	Physical research
[1]Laboratori Nazionali di Frascati del C. N. R. N., Frascati (Rome)	F. M.	42.0-42.9	2			C-W	2	~103	10,200	20	Constant			1100	360	High-energy physics research
Japan																
[2]Osaka Prefectural University, Osaka														30	14	
[1]Tohoku University, Sendai	C. W.	164	1					9	8,500	50	Constant	5×10^{-6}		70	29	Photo-nuclear reactions; radio-chemistry
[1]Tokyo, University, Dept. of Physics, Tokyo		157		15,000				5.4	7,000	1	Varying	3×10^{-6}		170	93	Model test for high-energy accelerator
[2, 9]Tokyo, University, Institute of Nuclear Study, Tokyo		138.1				Linac	6	61	10,800	21.5± 2	Varying			1000	400	
[2]Tokyo Institute of Technology, Tokyo														25	15	
Sweden																
[1]Lund, University, Lund	C. W.	402				Microtron	5.6	35	11,000	12.5	Varying	1×10^{-6}		1200	540	Meson and electron physics
	C. W.	238						1.3	6,000	50	Constant	1×10^{-6}		35	20	Photo-nuclear reactions

Electron Synchrotrons (continued)

Installation and address	F.M. or C.W.	Radio-frequency range (Mc)	Pulse length: Inject. (μsec)	Pulse length: Accel. (μsec)	Particle source	Injector: Type	Injector: Energy (Mev)	Magnet: Weight (tons)	Magnet: Field (gauss)	Magnet: Pulse repetition rate (per sec)	Magnet: Azimuthal field	Operating pressure (mm of Hg)	Average beam current (μamp)	Energy (Mev)	Orbit radius (cm)	Principal use
Union of Soviet Socialist Republics																
[2]Leningrad Institute, Leningrad														150		
[2]Lebedev Institute, Moscow														240 600		
[2]Moscow Physical Institute, Moscow														200		