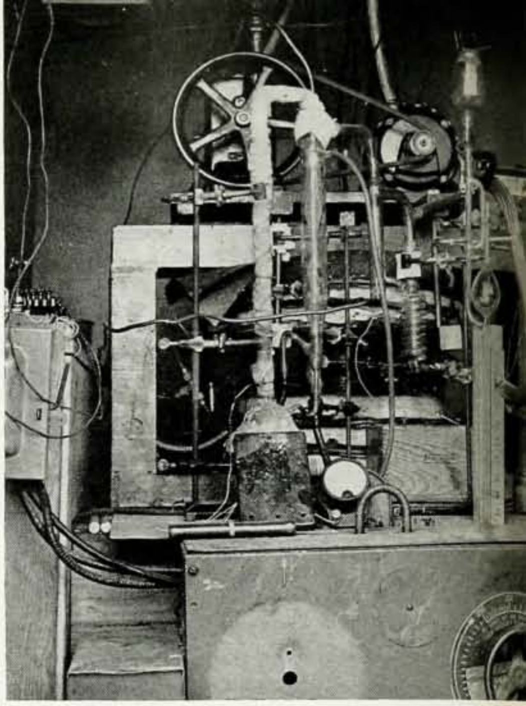
THE EL CERRITO CYCLOTRON



Martin Goldsm

There are probably less than three dozen cyclotrons in the entire world. One of them was built by four high-school boys in California.

by ***Benjamin V. Siegel*** *and* ***Richard C. Sinnott***

Cerrito in Spanish means "little hill," and in our El Cerrito High School sitting on a knoll, four senior students in the spring of 1947 were successful in constructing a magnetic resonance accelerator for ions, the highly complex machine for smashing and radioactivating atoms more commonly known as a cyclotron.

Born in the same year that Dr. Ernest O. Lawrence, Nobel laureate, built his first cyclotron at the University of California, the four students, Richard Sinnott, Karl Zellmann, Charles Williams, and Lee Danner, have the distinction of having built the twenty-fifth cyclotron in the United States and the first high-school cyclotron in the world. In 1942 there were thirteen cyclotrons in the United States and nine planned or in building. There were ten in other countries, including three in England.

Before the war, for an initial cost of some $50,000 and with annual running costs of $10,000 (all at prewar prices, of course), a cyclotron could yield energies of eight million electron volts, or the energy equivalent of gamma radiation from 100,000 grams of radium. At El Cerrito, over a period of slightly more than three months, the students designed, developed, and contrived by ingenious improvisations to construct a simply operable machine affording a million-electron-volt output at a cost totaling less than six hundred dollars.

How it Began

The cyclotron had its genesis in the aspirations of a small group of four senior physics students merely by controlling the temperature of the valve, which itself is controlled remotely by the voltage applied to the heater.

In the cyclotron chamber the atoms of hydrogen are bombarded by electrons emitted from a hot filament located between the dees. The hydrogen atoms are deprived in this manner of their single orbital electrons and become unipositively charged hydrogen atoms, or protons.

The target is placed within the dee. Because of the efficient design of the chamber, the target can be readily removed and replaced. The incorporation of a graded glass seal insulates the target and further simplifies its ready handling. The radio oscillator, which creates the high-frequency alternating current supplied to the dees, consists of a single tube (304TH) with direct feedback. The power supply is a full wave rectifier incorporating two 872A mercury vapor tubes. Its peak output is 2,000 volts at 1,000 milliamperes, or 2,000 watts.

Results to Now: Mostly Training

Thus far, no striking results have been attained. Shortly after the cyclotron was first constructed, the oscilloscope screen did indicate the production of a beam in the chamber. But this beam, unhappily, was of brief duration, because of a sudden and unexpected failure in the vacuum system. Since that experience much effort has been expended in exploring various methods of maintaining vacuums.

The most recently evolved technique, employing a helically shaped glass tube cooled by liquid air as part of the vacuum system, appears to be working out well. This in conjunction with the all-glass acceleration chamber promises an adequate vacuum system for future operations.

In addition to the original group, only one or two of whom find time occasionally to work on the machine, a new set of students has been trained in the basic techniques of cyclotron construction and operation, and have been encouraged to use their ingenuity and hands in furthering the effectiveness of the machine, both by way of refinement and innovation. This has been and is being successfully accomplished by the cyclotron committee, a school organization open for membership to all those with aptitudes and interests in this work. At present there are five students, ages ranging from 14 to 17, actively engaged on the project; several other students, while not actually working on the project, attend the weekly meetings and participate in the discussions. It is planned to allow them access to the machine from time to time, but space must limit the number participating.

Under the direct supervision of the writers these students have made gratifying strides. In their comparatively short span of participation these youngsters have accomplished a number of needed repairs, have proved of great assistance in new construction, and have been surprisingly fertile in ideas and suggestions. One student now is planning a series of experiments which, if successful, will be submitted in application for a Westinghouse science scholarship.

The interest and enthusiasm among the students for atomic study has been aroused to an extent sufficient to warrant its explicit inclusion in the curriculum. A six-week unit on atomic and nuclear physics is, therefore, now a regular part of the physics course. The students enrolled have as a rule had a year of chemistry and mathematics, and have taken or are taking trigonometry. Hence the approach to the unit, while admittedly elementary, can be carried out successfully in a synoptic manner. That is to say, it is possible to correlate and synthesize the manifold physical, chemical, and mathematical information so as to present to the students an integrated picture. The unit is notably useful in giving the students a firmer foundation in chemistry and a greater awareness of mathematical application. Concomitantly it affords a more profound understanding of the present role of atomic energy and a more wholesome appreciation of its future potentialities.

Apart from its value as a tool in teaching scientific concepts and in providing valuable training in the techniques of physics, the project in toto also has significance in its implications for general education.

In the course of the high-school curriculum there is little demand made upon the imaginative, the creative, the active, and the practical energies of the pupil. He feels that the work has no relation to his future life and leads nowhere. To obviate this sense of futility and to maintain and stimulate in its stead an ever-growing interest and zeal, there must be imparted to the student a sense of significance and urgency in his work. If the pupil could be offered a program of work that would make his education

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sound can be excited by means of periodical heating of a solid wall in contact with helium II. The second sound has actually been observed by Peshkov in Moscow and by Lane and collaborators at Yale University. The velocity of propagation as a function of temperature is in good agreement with the theoretical prediction.

Whereas the experimental evidence in favor of the complex hydrodynamics is overwhelming, its foundation on the Bose-Einstein statistics is less certain. Actually, several other theories have been put forward, the common feature of which is that they do not admit any connection between the superfluidity of helium and the Bose-Einstein statistics. Although these theories lead to more or less similar conclusions as the Bose-Einstein theory, an experimental decision of their relative merit is possible, owing to the existence of a helium isotope of the atomic weight 3, which obeys Fermi-Dirac statistics. If the Bose-Einstein statistics is essential for the superfluidity of the abundant isotope He^4, then He^3 should be not superfluid and a separation of the two isotopes by capillary flow should be possible. On the other hand, according to the other theories, no essential difference can be expected for the two isotopes.

Since He^3 is present in ordinary helium only as one part in ten million, experiments are difficult. Nevertheless, preliminary experiments of this kind have been recently carried out by Daunt and by Lane and their coworkers. These experiments indicate that He^3 is not superfluid and thus seem to justify the connection of Bose-Einstein statistics with superfluidity.

If the separation of He^3 in sizable amounts is indeed possible, the study of this substance would be of considerable interest. It would be the only case where two stable isotopes have radically different properties. It seems very likely that He^3 cannot exist in the liquid state at all. Such a liquid should have a vanishing dynamic viscosity and a high kinetic viscosity. Either we will have a liquid of entirely unheard-of properties, or the system will avoid the dilemma of the small and large viscosities by not liquefying at all, but will either freeze or rather stay a gas at vanishing pressure and temperature. It is to be hoped that the experimental decision of this question will be forthcoming before long.

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less aimless and would, on the other hand, demand all his energies and enthusiasm, this sense of significance and urgency, sadly lacking today, might be achieved.

The opportunity to take part in the building and the developing of one of science's most important machines gave to a group of four students the inspiration to pour all their intellectual vigor and enthusiasm into an undertaking few people would have thought possible. They worked diligently and seriously, but not from any external compulsion. Rather, confronted by a challenge which excited their intelligence, imbued with the importance of the nature of the venture, these boys brought to their project all the ability, resourcefulness, and initiative of which they were capable. They labored zealously after school hours and on holidays and weekends, manifested surprisingly mature leadership, and displayed a healthy readiness to accept responsibility.

The daring work of these students of El Cerrito High School has attracted attention on an international scale. Following newspaper accounts of their efforts, letters have come from all over the world—from individuals, high schools, colleges and universities—asking for plans and advice on the construction of the cyclotron. A steady stream of visitors still continues to come to see the machine. Three visiting Chinese physicists were so impressed that they requested permission to build an exact replica. Recently, a visiting professor of nuclear physics from the University of Calcutta, who built the first cyclotron in India (39 inches), spent a few afternoons of his precious time working with the students on their machine. He felt, he said later, that he had gained a great deal from this experience. He would return to India to tell the students there of what was within the realm of their capacity, if they would apply themselves.

The Research Corporation of New York City, which holds the patent rights to the cyclotron, as an assignee of Dr. Lawrence, has granted the high school science department a royalty-free license "to practice the art of this patent, for educational, scientific, experimental and research purposes." The educational and scientific aspects are presently being thoroughly treated. The experimental and research work, it is expected, will be undertaken seriously in the near future.