DEPARTED CYCLOTRON PIONEERS

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Abstract

Following the commemoration of Reg Richardson by Mike Craddock at the last Cyclotron Conference [1], it is fitting to recall the contributions of other cyclotron pioneers who have left us in the past few years. Included in the following text are descriptions of the contributions of 8 people, 6 "builders" and 2 "users". Their work was done from the 1930's up to the present and includes both experimental and theoretical contributions.

1 INTRODUCTION

Previous commemorations have been presented by Mike Craddock for Reg Richardson at the 15th Cyclotron Conference [1], and by Henry Blosser here at MSU for Francesco Resmini [2] at the 10th Conference. Here we review the work of other cyclotron pioneers who have done significant work in our field of cyclotron construction, development and applications.

In evaluating these contributions it is interesting to ask how the cyclotron field would have been changed without them. This kind of analysis was done in a recent book "What If" [3], a series of articles by military historians who ask how later history would have been affected by changes such as victories at Waterloo by Napoleon and by Hitler in World War II.

In a prime example in the cyclotron field we could look at the consequences if E. O. Lawrence had not browsed through the library at U.C. Berkeley one evening in 1929 to find the article by Wideroe on the resonance linear accelerator, which generated the first idea of a cyclotron. Certainly the discovery and development of the cyclotron would have been delayed. This would have delayed or prevented the growth during the 1930s of the "Rad Lab" at Berkeley, with its staff of people with expertise in ion sources, magnets and large vacuum systems. Without this staff the prototype Calutron for separating U-235 could not have been built at that time, no Calutron factory could have been built at Oak Ridge, and U-235 would not have been available for the Hiroshima A-bomb. The Rad Lab staff built a succession of cyclotrons, culminating in the 60-Inch Cyclotron in 1940, where Seaborg discovered plutonium. Without plutonium there would have been no Nagasaki bomb either. World War II would have ended quite differently, perhaps with the loss of an additional million lives.

Although not as dramatic as in the above example, the following achievements of these pioneers have changed the history of our field of cyclotrons. They are listed in the approximate chronological order of their contributions, with builders first and then users. These people are a personal choice of the author, based on his first hand knowledge and their contributions to the field. They passed away during the past decade. Others who could have been included are M. Stanley Livingston (died 1986), Luis Alvarez (died 1988) and Ed McMillan (died 1991), as well as people from other countries.

2 THE PIONEERS

2.1 Robert Wilson 1914-2000

Our first pioneer is Robert R. Wilson [4]. He attended U.C. Berkeley in 1932-36 to get his AB degree. He earned a PhD there in 1940 under Lawrence. During this time he worked on the early cyclotrons and wrote a paper on beam focusing [5]. He invented the Wilson seal, a movable shaft feed-thru into vacuum used in early cyclotrons. As a result of his experience in cyclotrons he proposed proton radiotherapy in 1946, leading to its use for many years in the Harvard cyclotron. At various times in his career he was a cowboy, physicist, engineer, architect, sculptor, human rights activist and leader in nuclear weapon control. After leaving Berkeley he spent time at Princeton, and then Los Alamos during the Manhattan Project. He built the high energy physics lab at Cornell, and then Fermilab, where he was known for his innovative artistic and scientific contributions.

Fig. 1: Robert Wilson

Fig.2: Bill Brobeck

2.2 Bill Brobeck 1908-1998

Another pioneer is Bill Brobeck [6], 1908-1998, the first cyclotron engineer. He had engineering degrees from Stanford and MIT. When Bill applied for work at the Rad Lab in Berkeley in 1937 he told Lawrence he wanted to work on cyclotrons. Lawrence couldn't afford to pay him so Bill worked without salary. When the Manhattan Project started in the 1940's there was no category of workers without pay, so Bill was required to accept a salary. Bill became Assistant Director and Chief

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Engineer. He brought sound engineering design to the construction of accelerators, which had previously been done by physicists. He designed the 60-Inch Cyclotron starting in 1939, and later the 184-Inch Cyclotron and the Bevatron. On Bill's retirement in 1957 R. Burleigh recorded Bill's philosophy in the Gospel According to St. Brobeck – Bill's 10 Commandments, and presented Bill with a copy. For example Commandment No. 3 reads: "When confronted with two solutions, both of which appear impossible, thou shalt choose the least expensive". Bill started an engineering firm in Berkeley. Among his projects were the construction of a bus run on steam power, and an automated electric lawnmower which would start itself, mow the lawn and return to the garage to recharge its battery. He had a pleasant personality, with a sense of humor, and was a talented tap dancer.

2.3 L.H. Thomas 1903-1992

L.H. Thomas [7] is best known to us for his proposal for adding sector focusing to cyclotrons in 1938 [8]. He was born in London and educated at Cambridge University in theoretical physics.

Fig.3: L. H. Thomas

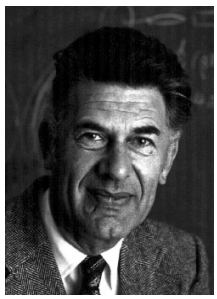

Fig. 4: Dave Judd

In 1929 he joined the physics faculty at Ohio State University. It was during his 17 years there that he proposed sector focusing. Bethe and Rose had shown that relativistic effects limited cyclotron energy because of incompatibility of resonance and focusing. Thomas pointed out that this conclusion applied only to azimuthally constant magnetic fields. If one allowed azimuthal variation the limit was removed. This idea was not utilized by the accelerator builders until the 1950s. His other interests included interactions of charged particles with matter, the study of molecules, wave propagation, spinning shells in gun barrels in World War II and early computer design. He is known for the Thomas-Fermi model of many-electron atoms. He joined the IBM Watson Lab. for Scientific Computing at Columbia University in 1946 and held a joint appointment as a professor at Columbia. He proposed the magnetic core memory for computers. In 1963 his interest returned to cyclotrons, when he proposed a new configuration for a cyclotron [9], Fig. 5, with one dee being a central disk and the other an outer annulus. The orbit accelerated with radial kicks, while it precessed around the machine center, until it reached extraction radius. This is quite a radical design, and was never built, as far as we know. He was a reserved man, but had a sense of humor, as shown by his membership in the Magpie and Stump society of undergraduate wits at Cambridge.

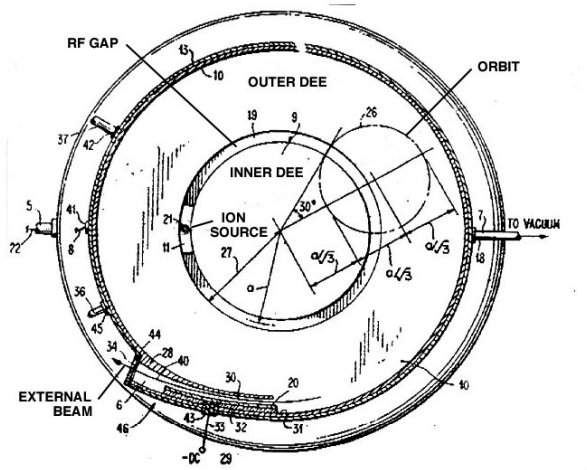

Fig. 5: Thomas's other cyclotron

2.4 Dave Judd 1923-1998

Dave Judd [10] is remembered for calculations of the beam dynamics of the first operating sector cyclotrons [11] – electron models - in the early 1950's. He was also responsible for the well-known set of cartoons "The Cyclotron as seen by …". He participated in the early Cyclotron Conferences. One of his remarks about accelerator building was that "conception is fun but delivery is often difficult". In a banquet speech he told about one of his young son's requests "daddy, take me up the hill to see the trons". He was well known for his courses in advanced mechanics, relativity and accelerator design in the U.C. Berkeley Physics Dept. Later he became head of the Physics Division at LBNL in 1965 and worked in the heavy ion fusion group there starting in the 1970s. He was an imposing figure with a booming voice which carried across an auditorium without a microphone.

2.5 Lloyd Smith 1922-2000

Lloyd Smith [12] received his B.A. from the University of Illinois and his PhD from Ohio State University. While working at the Illinois cyclotron his eyes were damaged while checking operation by sighting along the beam. In 1949 he became the first subject of successful surgery for neutron induced cataracts, a procedure later used to help victims of the atomic bombing of Japan. He joined the Radiation Lab at Berkeley in the 1950s, where he became a leading accelerator theorist. He is known in the cyclotron field for developing beam dynamics calculations for the 88-Inch Cyclotron with Al Garren [13]. He also invented the Smith-Garren method of phase measurement [14], which required only a beam probe and an X-Y

recorder to measure the radial dependence of the phase of the beam pulse relative to the rf. In other work, Lloyd spent time at high energy accelerators around the world, and worked on magnetic bottles for fusion reactors, and designed undulators in storage rings. At Berkeley he did calculations for the HILAC, and for heavy ion fusion. He had a gentle personality, but was quite forceful in speaking to a large audience.

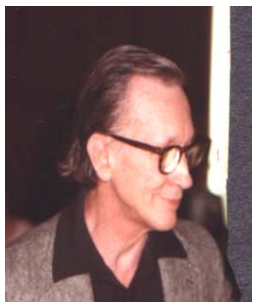

Fig. 6: Lloyd Smith

Fig.7: Martin Rickey

2.6 Martin Rickey 1927-1996

Martin Rickey [15] was born in Tennessee. He spent time in the U.S. Navy and Brookhaven National Lab., and got a PhD in nuclear physics in 1958 at the cyclotron at the Univ. of Washington. He then joined the faculty at the Univ. of Colorado, where a new cyclotron was being built. Here he made an important contribution to cyclotron development with the demonstration of the acceleration of H^- ions and their extraction by stripping [16]. He then joined the University of Indiana to design a 200 MeV proton cyclotron as the first separate sector, multi-particle, variable energy cyclotron, 1965-72. A high quality beam would be injected from an external source and adequate space was available between sector magnets for the variable frequency rf systems. Since this cyclotron went into operation in 1975, many other cyclotrons of similar design have built.

2.7 Users

A pioneer in nuclear chemistry was Glenn Seaborg (1912 - 1999) [17]. Glenn's cyclotron work started at the Berkeley 60-Inch, where he carried on McMillan's work on the trans-uranium elements, discovering plutonium. For this work he shared the Nobel Prize. He went on to many other achievements, including discovery of other transuranic elements, and formulating the systematics of the transuranic elements. He was chairman of the U.S. Atomic Energy Commission where he worked for both atmospheric and comprehensive test bans of nuclear weapons.

A pioneer in the use of cyclotron beams for medicine was Cornelius Tobias (1918-2000) [18]. Radioactive tracers were developed in 1945 with ^{11}C at the Berkeley 60-Inch Cyclotron. He worked with John Lawrence on radio-biology. At the 184-Inch Cyclotron and later at the Bevatron he started a series of experiments of passing beam particles through the eyes of scientists, to produce flashes of light. On the Apollo 11 moon mission the astronauts did see similar light flashes from cosmic rays.

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