

AMERICAN PHYSICAL SOCIETY ESTABLISHES MAJOR PRIZE IN MEMORY OF LILIENFELD

Six years ago, when The American Physical Society first learned that it was the beneficiary of a bequest from the estate of Beatrice Lilienfeld inviting the society to establish a major prize in the memory of her husband, Julius E. Lilienfeld, the late Joseph Burton, APS's treasurer, wrote to Maurice Goldhaber, Robert Marshak and Mildred Dresselhaus inquiring, "Do any of you know [of] Julius Lilienfeld?"

Even now, six years later, he is not an easy person to identify adequately. A small obituary appearing in *PHYSICS TODAY* in November 1963 (and spelling his last name incorrectly) noted that he did experiments in the 1920s that "contributed to the development of the contemporary x-ray tube" and that he also "worked with Count Ferdinand von Zeppelin on the design of hydrogen-filled dirigibles." From an entry in the 1933 edition of *American Men of Science* we know that he earned a PhD in physics at the University of Berlin in 1905. That was the year that Max von Laue joined Max Planck as an assistant at the Berlin Institute of Theoretical Physics, but we do not know whether Lilienfeld studied with Planck or knew von Laue. Lilienfeld was a professor of physics at the University of Leipzig from 1910 until 1927, the year Werner Heisenberg joined the faculty at Leipzig, but we do not know whether Lilienfeld knew Heisenberg. Lilienfeld emigrated to the United States in 1927 to become director of research at Ergon Research Laboratories in Malden, Massachusetts, and in the mid-1930s he apparently moved to the Virgin Islands with his American-born wife, the former Beatrice Ginsburg. But from that point on we know little of his activities as a physicist. We do not know what generated the income that enabled Beatrice Lilienfeld, upon her death in 1980, to leave APS about \$200 000—now nearly \$300 000—to endow a major award in her husband's name.

What we do know is that in the late 1920s Julius Lilienfeld filed three



J. E. Lilienfeld, a pioneering but hitherto obscure figure in condensed-matter physics, is seen here in a photograph from his US citizenship papers, which were issued on 1 October 1934, when he was 52 years old and living in Winchester, Massachusetts. Lilienfeld was born in Poland, and his immigration papers say that he had brown hair and brown eyes, was 5 feet 6 inches tall and weighed 148 pounds.

patents that accurately described a prototype for what is now known as the field-effect transistor—two decades before the work of William Shockley, Walter Brattain and John Bardeen. With the establishment in his name of what is to be The American Physical Society's most lucrative annual prize, Lilienfeld's achievement will be more widely recognized and remembered.

Terms of the prize

According to the terms established by the APS Council early this year, the Julius Edgar Lilienfeld Prize will recognize "outstanding contributions to physics by an individual who has exceptional skills in lecturing to audiences of nonspecialists." The prize is to be offered initially in 1988, 1989 and 1990, and it consists of \$12 000, a certificate describing the recipient's contributions and the funds to support three lectures, which are to be delivered by the recipient at an APS general meeting, a research university and a predominantly undergraduate institution.

To comply with the bequest establishing the Lilienfeld Trust, a special committee will be selected each year by the APS Council during the January meeting. The committee will choose a candidate for the prize, making its recommendation to the council at the fall meeting. The prize will probably be announced at the November meeting or the following January.

The chairman of the first special committee is Eugen Merzbacher, the vice president of APS. Nominations should be addressed to Merzbacher at the Department of Physics and Astronomy, University of North Carolina, CB No. 3255, Chapel Hill NC 27514. The deadline for nominations is 15 August.

Merzbacher hopes that it will be possible to find recipients who can deliver outstanding talks on original research, so that the Lilienfeld lectures will be as successful as the Richtmyer Award lectures sponsored by the American Association of Physics Teachers.

In October 1925 and October 1926

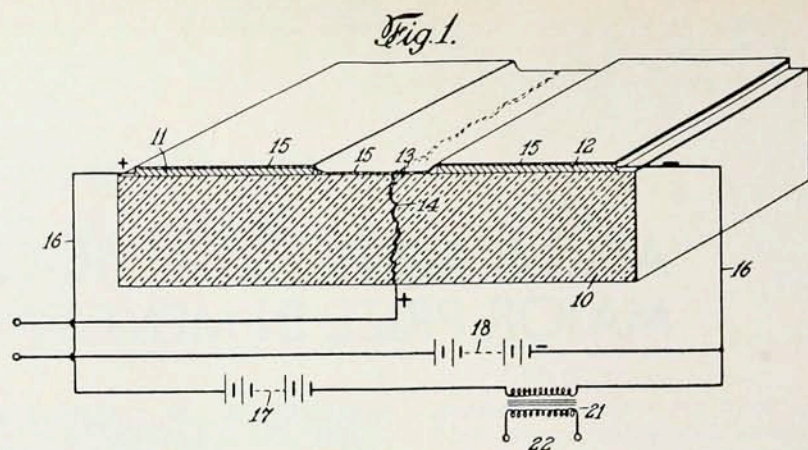
Lilienfeld filed patent applications in Canada and the United States for a "method and apparatus for controlling electric currents," and on 28 January 1930 he was awarded a patent for the device by the US Patent Office.

Lilienfeld's amplifier

"The invention," as described in the opening sentences of the patent, "relates to a method of and apparatus for controlling the flow of an electric current between two terminals of an electrically conducting solid by establishing a third potential between said terminals; and is particularly adaptable to the amplification of oscillating currents such as prevail, for example, in radio communication." The patent continues: "Heretofore, thermionic tubes or valves have been generally employed for this purpose; and the present invention has for its object to dispense entirely with devices relying upon the transmission of electrons through an evacuated space and especially to devices of this character wherein the electrons are given off from an incandescent filament. The invention has for a further object a simple, substantial and inexpensive relay or amplifier not involving the use of excessive voltages, and in which no filament or equivalent element is present. More particularly, the invention consists in affecting, as by suitable incoming oscillations, a current in an electrically conducting solid of such characteristics that said current will be affected by and respond to electrostatic changes."

In an article in the January 1964 issue of *PHYSICS TODAY*, Virgil E. Bottom argued that the "patent discloses the invention of a device which would be known as an npn transistor." In Bottom's view, "little doubt can exist that [Lilienfeld's] devices operate on the basis of conductivity modulation by minority carrier injection in semiconductors, which is the basis of operation of the modern transistor."

Four months later, in May 1964, *PHYSICS TODAY* carried a rejoinder to Bottom from J. B. Johnson, a research physicist for many years at Bell Laboratories. Johnson said that at one time he had attempted to reproduce the device according to Lilienfeld's specifications and "could observe no amplification or even modulation." Based on his experiments and his analysis of Lilienfeld's patents, Johnson argued that Bottom had confused n-type and p-type material in Lilienfeld's proposed devices, leading him to the erroneous conclusion that the devices would have operated like in-



Lilienfeld's 1926 patent application described what is now recognized as an early concept for a field-effect transistor. The base (10) is an insulating material such as glass, surfaces 11 and 12 are coatings of platinum, gold, silver or copper, 13 is an electrode of metal foil, and the entire upper surface (15) is coated with a compound of copper and sulphur.

jection transistors. "Dr. Lilienfeld deserves credit for having proposed a solid-state amplifier, even if his kind of amplifier has not come into wide use," Johnson concluded, "but he did not invent or even propose the injection transistor."

Johnson went on to say that Lilienfeld also made contributions in other areas, "particularly in the development of field emission of electrons for which he seems to be given less credit than is his due." In 1920, according to Johnson, Lilienfeld "published a paper on what he called auto-electronic emission, which spectacularly put field emission on the map." Walter Schottky had corresponded with Lilienfeld in 1922-23, Johnson had found, and he suggested that Schottky's work on high fields in thermionic emission "probably reflects a Lilienfeld influence, as does most of the work on field emission even now."

Bardeen's evaluation

Bardeen, cowinner with Shockley and Brattain of the 1956 Nobel Prize in Physics for the invention of the transistor, recently elucidated the character of Lilienfeld's achievement for us in a letter, which Bardeen rephrased somewhat in response to comments from Shockley. "There are two general classes of transistors, field-effect and bipolar. Shockley proposed field-effect transistors independently of Lilienfeld's ideas. Walter Brattain and I discovered the first practical transistor, a bipolar type called the point-contact transistor, in the course of experiments designed to make a field-effect amplifier. Even though at

about the same time Gerald L. Pearson and Shockley had demonstrated the field effect, it took about 15 years of development of materials technology to make practical devices. Nearly all present-day field-effect transistors make use of controlling the flow in an inversion layer of opposite conductivity type adjacent to the surface (such as an n-type inversion layer on p-type silicon). I have the basic patent on use of an inversion layer to confine the flow. Present-day bipolar transistors are of the junction type and are based on a patented structure Shockley invented while planning experiments to elucidate the dynamics of the point-contact transistor. The Bell Laboratories patent department was unable to obtain a patent on Shockley's field-effect invention because of Lilienfeld's patents and others."

"Lilienfeld's patents predated the work of Brattain, Shockley and me by nearly 20 years," Bardeen told us. "A considerable effort was made by J. B. Johnson and others to reproduce his results. For patent reasons it was necessary to distinguish our work from the prior art. Nothing was found that would suggest that the bipolar principle had been anticipated in the prior art of Lilienfeld and others, as pointed out in the article by Johnson." Lilienfeld's work did, however, anticipate the field-effect transistor, Bardeen says, and even if his devices did not quite work as described, there is no reason in principle why devices very like them could not have worked.

"Lilienfeld deserves great credit for his pioneering efforts to make a semiconductor amplifier," according to

Bardeen. "This was not long after copper oxide and copper sulfide rectifiers were discovered. He had the basic concept of controlling the flow of current in a semiconductor to make an amplifying device. It took many years of development of theory and materials technology to make his dream a reality."

In a talk at a history session during the March APS meeting in New Orleans, Bardeen mentioned the establishment of the Lilienfeld Prize and made some generous remarks about Lilienfeld's work. At the time Lilienfeld conceived of the "first active devices" for amplification by means of the field-effect principle, the understanding of semiconductors was very poor, Bardeen pointed out; the notion was that electrons could move about in a kind of plasma. Given that level of understanding, Bardeen said, Lilienfeld had "some very good ideas."

Fragmentary items in the possession of Beatrice Lilienfeld's executor indicate that Lilienfeld continued to work out ideas for a variety of inventions and to press patent claims until his death. In 1954 the US Patent Office rejected an application he made for a "method of and means for modulating oscillating current," but the year before that he had sold patent rights for a device of some kind to the Power Condenser and Electronics Corporation in Washington, DC, for \$84 750. He filed a patent for tubular aluminum lawn furniture of special design, and after his death his wife licensed a company to make and sell a fabric he devised for use in "shape-controlling garments" such as girdles and brassieres.

According to Stanley Relkin, the rabbi at the synagogue Beatrice Lilienfeld belonged to in St. Thomas, Beatrice and Julius lived in a simple house they designed and built them-

selves. Julius suffered from allergies and was rather a recluse who reputedly "worked very well with just a yellow pad." Beatrice was "alert, very much concerned with things around her, intimately involved with the synagogue, friendly, well read, knowledgeable about local and world affairs." Even when she was in her late seventies, Relkin says, "one did not have the feeling of being with an old person."

It was strictly her idea to leave a bequest to APS in her husband's name, Relkin believes. She felt that her husband had not received the recognition for his work that he deserved, and she thought this would be a way of setting things right. And so she made a will dividing the bulk of the family wealth between the bequest to APS and Julius Lilienfeld's only living relative, a nephew; she left their home to the local synagogue.

—WILLIAM SWEET

AIP SIGNS PUBLISHING AGREEMENT WITH USSR; EDUCATION UNIT MOVED TO WASHINGTON

The American Institute of Physics has concluded a set of new publishing agreements with agencies of the Soviet government, covering translation rights, joint publishing ventures and sale of AIP and member society journals in the USSR. The translation of Soviet physics journals is one of AIP's major activities serving physicists in the West, and there is great demand in the Soviet Union for US physics journals. The value of the journals sold by AIP to the Soviet Union is expected to total about \$600 000 this year.

AIP's governing board, meeting in Woodbury, Long Island, on 18-19 March, heard a report on the Soviet publishing agreements. It was also informed of a decision to move AIP's education division from Woodbury to Washington, DC; of the resignation of Robert H. Marks as Managing Director of Publishing; and of recommendations from the member societies on whether some of AIP's major activities should be relocated.

The board adopted the following resolution on the free communication of research results in superconductivity: "The governing board of the American Institute of Physics opposes the imposition by the Federal government of any constraints on the free and unfettered communication of scientific and technological information generated by government-supported research, by exemption to the Free-

dom of Information Act or any other means, unless that information is classified for reasons of national security."

Acting on a recommendation from AIP Executive Director Kenneth Ford, the governing board endorsed the idea of forming a committee to evaluate how AIP might establish a development office to assist AIP and the member societies in raising funds from private sources. It also approved a plan to build an all-new system of hardware and software for subscription fulfillment and member records, to be operational by spring 1989.

Publishing agreements

The new agreements with the Soviet Union were negotiated last February in Moscow by a team led by Ford, and they replace a previous umbrella agreement that was open-ended, with provision for cancellation on one year's notice.

"Because of *perestroika* [restructuring]," Ford said in a report on the negotiations, "our previous single agreement... had to be replaced by three agreements with three different agencies, each of which is now a 'tub on its own bottom,' responsible, for the first time, for profit-and-loss statements, and anxious to strike harder bargains with foreign partners such as AIP."

The first of the new agreements is a

multiyear contract with the Soviet copyright agency. Under the contract, AIP will continue to translate and publish 19 Soviet physics journals. A one-year agreement with Mir Publishers provides for continued translation and publication of the *Review of Scientific Instruments* by the Soviets. Under the third agreement, which is concluded with a Soviet importing agency, the USSR will continue to purchase AIP and member society journals for internal distribution.

AIP and the Soviets also are to cooperate in a marketing effort for the distribution of *PHYSICS TODAY* and *Computers in Physics* in English in the USSR, and they will explore the possibility of publishing the two magazines in Russian translation.

Locating operations

Consistent with the increased emphasis AIP and its member societies have placed on education in recent years, AIP's small education division is being expanded and relocated. Efforts to recruit a new manager for the division are well advanced, and once that person has been selected, another person will be hired to coordinate the Society of Physics Students. Both jobs previously were assigned to one person. AIP's leadership has decided, with the approval of the executive committee, to move the education division to Washington.