Tihiro Ohkawa

After a brilliantly innovative career spanning more than six decades, Tihiro Ohkawa died following a brief illness in La Jolla, California, on 27 September 2014. His scientific ingenuity was wide-ranging, but he is best known as a longtime champion and early leader of magnetic fusion energy research.

Born to an academic family in Kanazawa, Japan, on 3 January 1928, Tihiro was just 16 when he started out in science, volunteering at a local laboratory during the war years. In 1950 he matriculated at the University of Tokyo, where he studied nuclear physics. His first scientific publication, in 1953, described a new kind of particle accelerator. That led physicist Donald Kerst to invite him to spend a year at the University of Illinois at Urbana-Champaign and another at the University of Wisconsin–Madison, where Tihiro improved the design of the fixed-field alternating-gradient accelerator from his 1953 paper. He then returned to the University of Tokyo. Meanwhile, Kerst joined General Atomics (GA), a General Dynamics division that was trying to develop peaceful atomic energy.

After a year at CERN in 1959, Tihiro joined Kerst at GA in San Diego, California, and changed his focus to fusion energy research. Thus began what would be a highly successful 40 years spent seeking to bring fusion energy to realization.

Hydrogen nuclei fusing in the Sun and other stars are confined by gravity. Tihiro was particularly intrigued by the prospect that magnetic confinement fusion on Earth could give humanity an endless supply of energy. His early experiments with Kerst in small toroidal machines were designed to demonstrate that fusion reactions might occur in scaled-up devices.

Kerst returned to Wisconsin after a funding cut at GA in 1967, but Tihiro was ultimately able to obtain government funding to expand GA's research effort. Confinement research was key because several early experiments suggested that magnetic confinement in toroidal plasmas could be maintained no longer than the Bohm time—in which case magnetic fusion would not be practicable. The first major triumph from Tihiro and his group was the demonstration, in their 3-meter-high dc octopole, that the Bohm time was not an upper limit to confinement.

Tihiro saw that stably confining sufficient plasma pressure demanded

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highly shaped, vertically elongated plasma cross sections. He designed an elongated tokamak with a peanut-shaped cross section that he called a doublet, which he tried first in a tabletop version before building the larger Doublet II. Early results from those tokamaks were so encouraging that the group won a contract in 1973 to build a 9-meter-tall experimental tokamak, Doublet III.

By the end of the 1970s, Doublet III was a major national effort that employed more than 200 experimentalists, theoreticians, engineers, and technicians. To extend the program and obtain major additional funding, Tihiro secured participation from the Japan Atomic Energy Research Institute and thus formed the first of many international collaborations that now characterize the GA fusion energy effort. In 1979 Tihiro received the James Clerk Maxwell Prize for Plasma Physics from the American Physical Society.

Doublet III was later upgraded to DIII-D, which continues as a leading facility in international fusion research. Tihiro's legacy is evident in the vertically elongated shapes of modern tokamaks.

In 1980, with funding from GA and Phillips Petroleum, Tihiro tried another configuration, similar to a reversed-field pinch, which he called *ohte* (Japanese for "checkmate" in chess). The *ohte* machine ran for eight years, produced good results, and advanced the reversed-field pinch concept. While retaining his interest in fusion energy, in 1986 Tihiro broadened his research endeavors at GA. With a chosen group of scientists, he formed an "institute for the development of advanced technology." He explored many disciplines, including biotechnology, high-T_c superconductivity, and low-frequency communications.

He left GA in 1994 and spent the next 20 years developing innovative solutions to many problems. He formed three companies, notably the Archimedes Technology Group, which focused on a new method of remediating nuclear waste by using plasma processing. Another concentrated on biotechnology developments, and the third, formed with colleagues in Japan, centered on other spinoffs of plasma-physics technology. That period was in many ways his most productive. In all, he held more than 80 patents and was the primary author of more than 170 scientific publications.

We and his other close associates cherish our memories of him—his deep intellect, his originality, his contests to spur creativity in others, and his vast interest in all forms of innovation. Physics was clearly his passion, but he participated in a range of other activities. He followed local professional sports teams and played golf, tennis, and soccer. He enjoyed annual family skiing and Las Vegas trips. His broad intellectual reach and his internationalism made him truly a citizen of the world, a consummate scientist who excelled at transcending boundaries.

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Richard Freeman Post

Richard Freeman Post, one of three founders of magnetic fusion energy research in the US, passed away on 7 April 2015 at age 96. Dick developed the electromechanical battery using high-speed-flywheel energy storage and stabilized the battery with his magnetic bearing design, later employed to stabilize magnetically levitated trains.

Dick was a prolific inventor with 34 patents, 9 issued after he turned 90.

Starting in 1952 as a leader of mirror fusion research at Lawrence Livermore National Laboratory and later as the lab's deputy associate director for magnetic fusion energy, Dick contributed three seminal ideas that culminated in 1976 with the 2XIIB experiment, the first demonstration of a mirror plasma at thermonuclear temperatures. Those ideas were the yin–yang magnetic mirror design—developed with Ralph Moir—which provided magnetohydrodynamic stability; 20-keV neutral-beam injectors, with a million times more current than earlier versions, that created a plasma; and the theoretical discovery, with Marshall Rosenbluth, of the drift-cyclotron-loss-cone microinstability mechanism of plasma leakage in mirror machines, which could be stabilized by cold plasma injection. He also invented a method for direct conversion of plasma energy to electricity as a way to improve the efficiency of mirror fusion reactors.

His papers published in 1956 in *Reviews of Modern Physics* and in 1959 in *Annual Review of Nuclear Science* were among the first thorough reviews of hot plasmas for controlled fusion. They were immediately translated into Russian, the 1959 paper as a separate book. In 1987 his comprehensive review of mirror research filled the whole October issue of *Nuclear Fusion*. Despite termination of the mirror program in the US, Dick firmly believed that the mirror fusion approach, with its different physics and engineering advantages, was still worth pursuing. In early 2000 he came up with an idea of a "kinetic stabilizer" for axisymmetric tandem mirrors. At present, sizable groups are working on mirrors in Russia and China.

Dick's work on magnetically levitated trains was based on the idea that both levitation and propulsion would be provided by simple electrical circuits embedded in the track, whereas the cars would have passive magnetic structures made of specially arranged permanent magnets—so-called Halbach arrays. In 2004 *R&D Magazine* recognized the approach, which does not require superconductors, with an *R&D* 100 Award. The work continues, with researchers looking at its possible use as a launch system. Among Dick's other honors were the American Physical Society's 1978 James Clerk Maxwell Prize for Plasma Physics and a 2000 Popular Science Design and Engineering Award. He also was a corecipient of Fusion Power Associates' first Distinguished Career Award in 1987.

Equally innovative were Dick's studies of magnetic bearings. His creative

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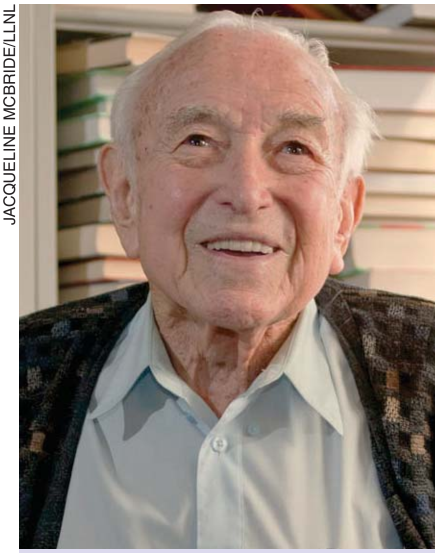

Richard Freeman Post

use of magnet arrays led to geometries in which the bearing would be passively stable, with no need for complicated feedback stabilization. Those magnetic bearings are an integral part of the novel, high-speed energy-storage systems that Dick developed.

Dick was born in Pomona, California, on 14 November 1918 and graduated from Pomona College in 1940. After working at the US Naval Research Laboratory for four years, he received his PhD in physics from Stanford University in 1951. He then joined the Livermore laboratory in 1952, just months after it opened. He continued working part-time at Livermore after his retirement in 1994 until the week before he died.

The epitome of a gentleman—kind, polite, and gracious—Dick had many friends and followers in the international fusion community. He loved the Swiss Alps and, until recently, he and his wife, Marylee, had spent one month each summer in Switzerland. He also became interested in German and would read German novels in the original language.

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