The Discovery of Superconductivity

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Citation: Phys. Today **49**(9), 40 (1996); doi: 10.1063/1.881517
View online: http://dx.doi.org/10.1063/1.881517
View Table of Contents: http://www.physicstoday.org/resource/1/PHTOAD/v49/i9
Published by the American Institute of Physics.

The Discovery of Superconductivity

Though Kamerlingh Onnes always stressed the importance of precise measurement in his work, it was an accident that led to the first detection of superconductivity.

Jacobus de Nobel
Introduction by Peter Lindenfeld

In their book La guerre du froid,[1] *Jean Matricon and Georges Waysand describe the first liquefaction of helium in 1908, including the moment of recognition after a bystander suggested that the cryostat be illuminated from below. They go on to state that no similar firsthand account exists for the discovery of superconductivity three years later, which also took place in Heike Kamerlingh Onnes's laboratory at Leiden University. In their words, "Although we have an account full of life and spirit of the liquefaction of helium, the birth of superconductivity has come down to us only as a cold scientific report of the measurement."*

I was surprised. Some years earlier, my friend and colleague Jacobus "Co" de Nobel had told me about his conversations with Gerrit Jan Flim, the master technician who had played a crucial role in both experiments. It became clear that Co could well be the last link to that historic moment, and so I wrote to him, urging him to write down his recollections. The result is the account that follows, evocative not only of the discovery itself, but of the social and scientific context of the time.

As Matricon and Waysand point out, Kamerlingh Onnes's contributions went far beyond the two epoch-making discoveries. He was the originator of a new style of doing science, the first to recognize the importance of large-scale technical support, and his laboratory and staff were the forerunners of the "big science" projects of our day. The success of the laboratory was the result of the importance he gave to infrastructure, combined with a rigorous scientific program that was firmly based on theoretical insights, all of which transcended his controversial motto "Door meten tot weten" *("Through measurement to knowledge").*

A vital component of Kamerlingh Onnes's grand design was the Leidse Instrumentmakersschool *(Leiden School for Instrument Makers), which he founded. The school continues today, and its graduates can be found in laboratories throughout the world. Co de Nobel has been its most important patron for many years. In addition to providing a major endowment, he has taken a fatherly interest in many of the students and graduates. Now in his eighties, de Nobel continues to live in Leiden, close to the school that has been his family for so long.*

JACOBUS DE NOBEL *was for many years a research staff member of the Kamerlingh Onnes Laboratory at Leiden University in The Netherlands.* PETER LINDENFELD *is a professor of physics at Rutgers University in New Brunswick, New Jersey.*

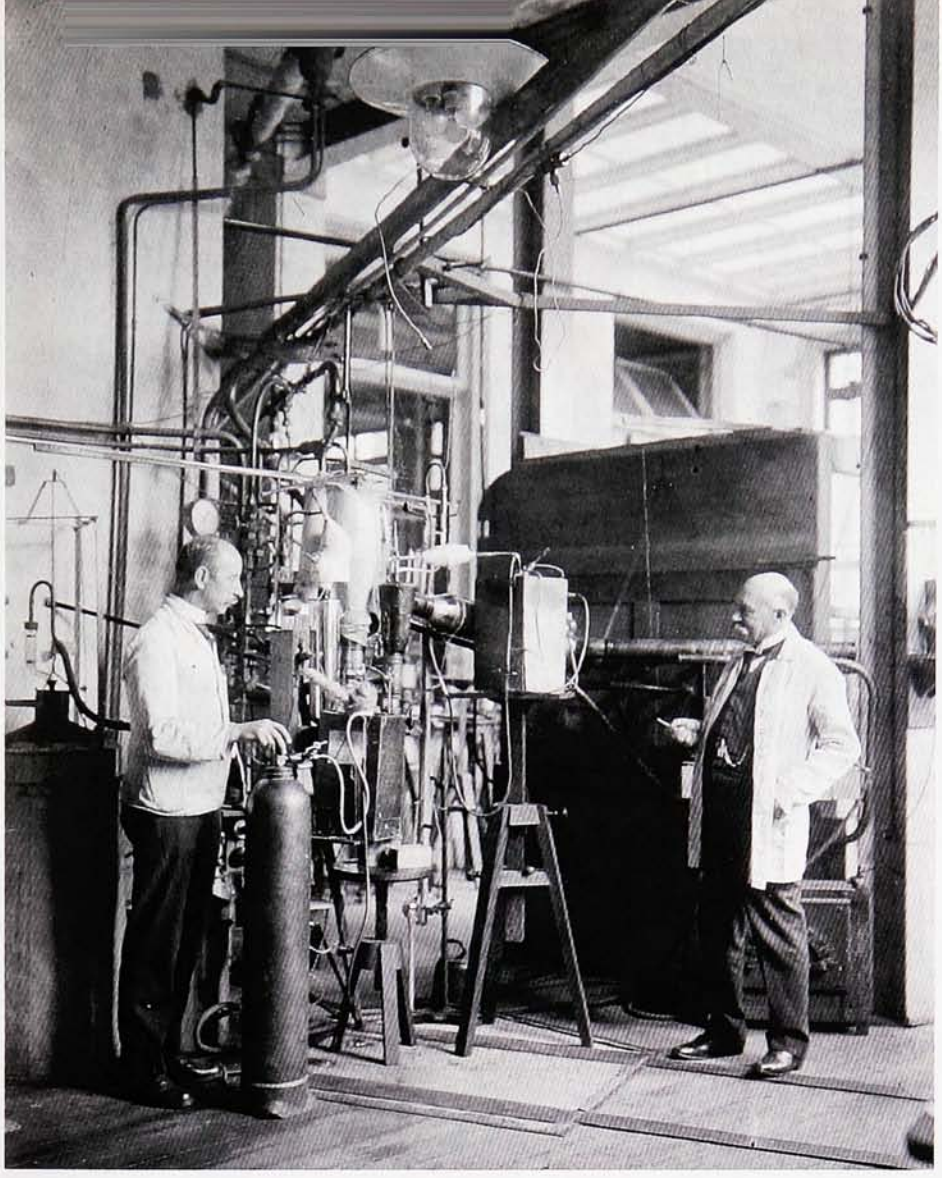
Jacobus de Nobel's recollections

Shortly after I entered the Cryogenic Laboratory of Leiden University in 1931, I met the senior technician of the laboratory, Meester Gerrit Jan Flim. ("Meester" is Dutch for master, a title left over from the medieval system of guilds.) As a student in physics, I assisted H. Bremmer with his measurements of the thermal and electrical conduction of superconducting alloys and of a tungsten single crystal. To make measurements at liquid-helium temperatures in those days, the whole apparatus, including its high-vacuum system with the MacLeod gauge and gas thermometer, had to be transported to the helium liquefier in room E′ of the laboratory, where Meester Flim was in charge.

Flim had been the right-hand man to Heike Kamerlingh Onnes for many years, and his technical assistance had contributed much to Kamerlingh Onnes's discoveries, in particular the first liquefaction of helium in 1908. Flim also supplied the liquid helium for the experimental investigation of the electrical conduction of pure metals, which culminated in the discovery of superconductivity in mercury in 1911.

Soon after my first meeting with Meester Flim, we began to have long talks. I was privileged to know him right to his last days; he died at the age of 95 in September 1970. Over the years, he told me many stories about his working days with Kamerlingh Onnes. They both lived along the Old Rhine River, but on opposite sides. It often happened that when Kamerlingh Onnes had a new idea, he rang the brass ship's bell on the side of his house, summoning Flim, who promptly rowed over to discuss the new idea with him.

Kamerlingh Onnes often paid social calls on his technicians on Sunday afternoons, driving his horse-drawn coach and wearing his top hat. When, on one of these occasions, Meester Louis Ouwerkerk, who was in charge of the hydrogen liquefaction, asked for a wage increase, Kamerlingh Onnes refused, adding, "Haven't you just bought two nice bicycles?" Another time, Kamerlingh



HEIKE KAMERLINGH ONNES (right) in his Cryogenic Laboratory at Leiden University, with his faithful assistant Gerrit Jan Flim, around the time of the discovery of superconductivity. (Courtesy of Huygens Laboratory, Leiden.)

Onnes advised Flim to send his three sons to a technical school. Flim, who had a higher education in mind for them, complained, "But they are my sons, aren't they?" All three boys eventually went to university; two of them became physicians, the middle one an engineer.

In room E′ of the laboratory, Meester Flim explained to me the construction of the first liquefiers and of the cascade cooling system, which was still present in the adjacent room E, although no longer in use. He told me about the difficulties they had obtaining the required amount of helium gas. In the beginning they had tried to collect it by crushing pieces of rock imported from Iceland, without much success. It was only after they obtained a shipload of monazite sand from North Carolina that 360 liters of helium gas could be collected. The amount of liquid required for an experiment was only about a quarter of a liter, which used up only a fraction of the available stock.

Once he had succeeded in liquefying helium, Kamerlingh Onnes set about measuring the electrical conduction of pure metals at low temperatures. Flim told me that after the measurements on platinum and gold were completed, mercury was chosen because it could be made extremely pure by repeated distillation. Gilles Holst, who carried out the measurements, used a U-shaped capillary glass tube that had platinum wires on both ends and was filled with purified liquid mercury at room temperature. Measurements of the electrical resistance, taken successively in the temperature ranges of liquid oxygen, liquid nitrogen and liquid hydrogen, showed the well-known regular decrease. At liquid-helium temperatures, however, Holst found zero resistance, which the researchers attributed to a short circuit somewhere in the cryostat. The measurement was repeated several times, which took quite a long time, since liquid helium was not available every week. But each time, the supposed short circuit was found.

A DRAWING OF FLIM made in 1921 by a nephew of Kamerlingh Onnes's shows Flim at work next to the cryostat. (Courtesy of Kamerlingh Onnes Laboratory, Leiden.)

JACOBUS DE NOBEL at age 25, during his early days at Leiden in the 1930s.

GILLES HOLST, who made the first measurement of superconductivity, later became the first director of the Philips Research Laboratories in Eindhoven.

It was then decided to replace the U-shaped tube with one in the shape of a W, again with platinum wires at both ends and also at the three kinks. In this way, the resistance in four separate segments could be measured. But to the experimenters' great disappointment, all four segments showed what they still believed to be a short circuit.

It was only by accident that the real cause was recognized, Meester Flim told me. To make sure that none of the precious helium would escape because of a possible leak in the cryostat, the vapor pressure in the cryostat was always carefully kept somewhat below the atmospheric pressure; the incoming air would freeze and thereby close any leak. The vapor pressure was controlled with a differential oil manometer and a sensitive valve in the pump line, with a 40-cm-long lever used for fine tuning.

The rather boring job of keeping the oil level in the manometer steady for several hours was given to a student of the School for Instrument Makers. Housed in the same building, the school had been founded in 1901 by Kamerlingh Onnes, aware as he was of the need for skilled technicians in the laboratory. These students were called "blue boys" (*blauwe jongen*), because of the blue overalls that they had to wear in those days.

It was often difficult for the blue boys to stay alert during such assignments, and one day, while Holst was measuring the resistance of his W-shaped mercury wire, the blue boy on duty did nod off. As he dozed, the pressure in the cryostat started to increase, and the temperature rose from below the boiling point of helium to near 4.2 K, thereby passing through the transition temperature of mercury. Holst, sitting in the central dark room in which several of the laboratory's galvanometers were located, saw the light beam of his galvanometer suddenly deflect, indicating that the resistance of the mercury had been restored. And so superconductivity was discovered, the result of a moment of inattention on the part of a blue boy!

After the discovery

Kamerlingh Onnes, who was very precise in matters of terminology, initially named the new phenomenon "supraconduction"—not "superconductivity"—because conductivity signifies the specific value (in ohm meters) of the conductance of a material. The transition point he called the *sprongpunt* because of the sudden jump (*sprong* in Dutch) of the galvanometer's deflection first observed by Holst.

Although it had been Holst who had made the decisive measurement, he was not a coauthor on any of the early publications that resulted from his work with Kamerlingh Onnes. But he apparently did not consider his treatment by Kamerlingh Onnes to be unusual or unjust. Holst later became the first director of the Philips Research Laboratories in Eindhoven, and in my time, he was given an Extraordinary Professorship in physics at Leiden University.

One last note on the blue boys: The practice of using blue boys for observing experiments lasted until the 1960s, and I often had them help me with my own work. To alleviate their boredom, I tried to engage their interest by explaining the purpose of the research and by telling them afterward about the results of the day. The Leiden School for Instrument Makers still prospers at Leiden University, and today more than 150 students specialize in instrument making, glass blowing, glass grinding and laser techniques.

I would like to thank Huug van Beelen of the Kamerlingh Onnes Laboratory, who read the manuscript, redrafted it and improved the English.

Reference

1. J. Matricon, G. Waysand, *La guerre du froid*, Editions du Seuil, Paris (1994). ■