Chapter 10
Wilhelm Heinrich Heraeus—Doctoral Student at the University Frankfurt

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The 702nd WE-Heraeus Seminar, conducted from September 1st–5th 2019 in the historic physics building in Frankfurt, commemorated the great discoveries in Quantum Physics made between 1919 and 1922 at the Frankfurt university in particular by Otto Stern and Walther Gerlach. These milestone discoveries were made in the theoretical institute of physics under the directorship of Max Born and Erwin Madelung by Otto Stern, Walther Gerlach, Max Born, Elisabeth Bormann and last not least by Alfred Landè. In this period in the early twenties Wilhelm Heinrich Heraeus was working on his doctoral thesis in Frankfurt and met Gerlach and probably Stern, Bormann, Landè and Born too (see Fig. 1). He was thus a contemporary witness to these great pioneering achievements, many decades before he and his wife Else would establish the Wilhelm and Else Heraeus Foundation.

Wilhelm Heinrich Heraeus was born on February 3rd 1900 in Hanau/Hessen, which is located about 25 km east of Frankfurt. He was the grandson of Wilhelm Carl Heraeus (* March 6th 1827; † September 14th 1904), the founder of the Heraeus company in Hanau. He described the first 23 years of his life in a short curriculum vita when he enlisted in 1923 at the University of Frankfurt for the Ph.D. examination. According to this, he had to leave grammar school, having just turned 17, with the emergency certificate, before he worked for a year, until Easter 1918, in the "patriotic emergency service". His subsequent studies of physics and natural sciences in Bonn were interrupted after only a few months by another military service, and the same was true of his subsequent studies in Göttingen, where Heraeus took part in lectures and practical exercises by Debye, Hilbert and Courant. From the fall of 1921 he finally studied in Munich, where he worked for "Geheimrat" (Privy Councilor) Wien and attended lectures by Sommerfeld, among others, before moving

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Fig. 1 Wilhelm Heraeus' student card [Archiv, Goethe-Universit¨at Frankfurt, Frankfurt, Germany]

to Frankfurt in late 1922. There he took part in lectures and practical exercises by Gerlach, Madelung, Lorentz, and carried out his doctoral thesis with "Geheimrat" Wachsmuth and Gerlach.

Professor Richard Wachsmuth, the director of the experimental institute, together with Professor Walther Gerlach (the co-author of the famous Stern-Gerlach experiment) supervised the dissertation of Wilhelm Heraeus. The experimental doctoral research studies were performed in the laboratory of the Heraeus company in Hanau. The results of Wilhelm Heraeus' work are described in the 26 pages of his dissertation with the title: "Die Abhängigkeit der thermoelektrischen Kraft des Eisens von seiner Struktur" (The dependence of the thermo-electrical force of iron on its structure). Wachsmuth had to apply to the dean Professor Fritz Drevermann, that the submitted scientific work of Wilhelm Heraeus fulfilled the requirements of a dissertation. Wachsmuth wrote in July 1923:

> A paper appeared in the Annals of Physics about 1 year ago, in which the author Borelius, by measuring thermoelectric forces between two samples of pure iron, one of which was pretreated by heating to temperatures up to 500°C and subsequent quenching, the other was untreated, has shown that in this interval a large number of internal iron conversion processes have now been found. Mr. Heraeus, to whom the resources of the father's company were available, seemed to me to be the suitable man for a revision. When the experiment was

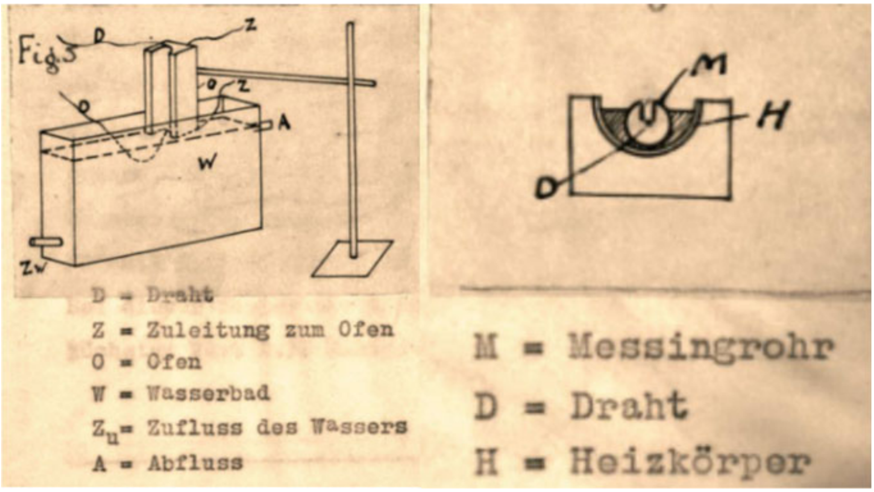

Fig. 2 The new experimental apparatus of Wilhelm Heraeus [Archiv, Goethe-Universität Frankfurt, Frankfurt, Germany]

> extended up to 950 °C, the results were so interesting that this little extra work became a doctoral thesis.
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> Not only has the author of the present work discovered the errors in the Borelius's arrangement and the thermoelectric curves between "iron heated" and "iron unheated" up to the Borelius border without its discontinuities, but he has also been able to increase the temperature further. He found a decrease in the thermoelectric force between 500 and 790 °C and a new increase between 800 to 870 °C. He also associated this phenomenon with signs of recrystallization and checked it for clarification by means of appropriate tests and documented it with metallographic images. The work was carried out very carefully and conscientiously, but also completely independently. … I propose the work to the faculty for acceptance and apply for the rating "very good".
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> [Archiv, Goethe-Universität Frankfurt, Frankfurt, Germany]

In the introduction of his thesis Wilhelm Heraeus asserts: In order to develop a theory of the electrical conductivity of metals, detailed thermoelectric studies are necessary. So far, there is little data on this topic existing, as pure metals have so far hardly been available. Low impurities can have a decisive influence on the thermodynamic behavior of the metals. For this reason, for the present investigation, melted electrolytic iron was chosen, which was treated in the cold state with special care in order to avoid contamination from the carbon-containing iron of the rolls and from the material of the drawing dies. The investigation of the thermoelectric behavior of annealed versus un-annealed iron is also of particular interest insofar as there are already studies by Borelius and Gunnesson [1]. The results of this work have led to conclusions on structural changes in the temperature range from 60 to 500 °C, which are in sharp contradiction with other methods of investigation.

The new measuring device built by Wilhelm Heraeus allowed to heat an electrolytic iron wire in an electric oven with temperature steps of 10 °C (see Fig. 2).

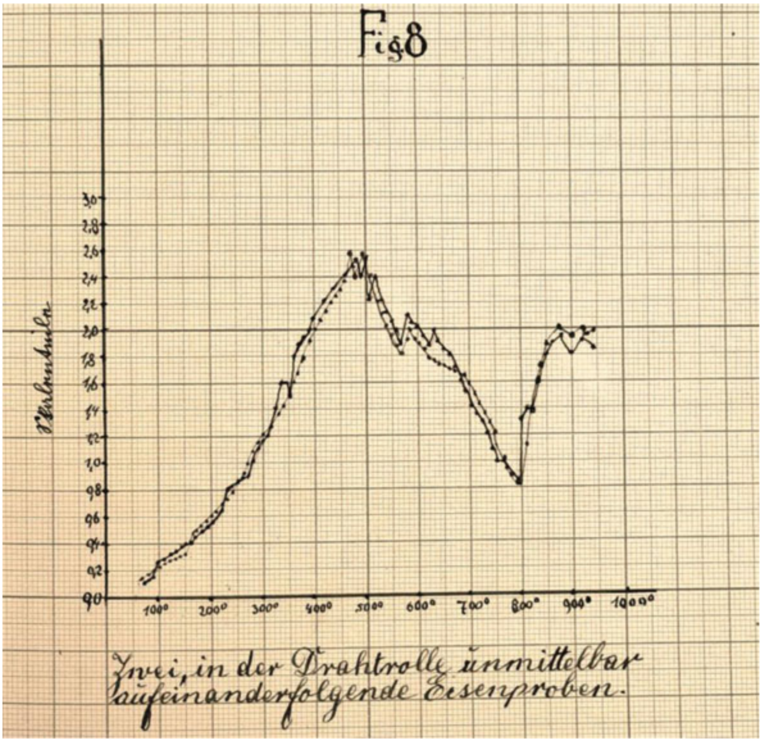

Fig. 3 Typical data sets [Archiv, Goethe-Universit¨at Frankfurt, Frankfurt, Germany]

After heating, the wire was quenched to room temperature in a water bath below. The two ends of the quenched iron wire were then connected to a galvanometer and the thermal force was measured. The measurement series were reproducible. Even if the galvanometer was connected in the opposite direction, the same values were obtained for both directions.

The Borelius' investigations were repeated by Wilhelm Heraeus. The samples were brought to a certain temperature T by means of an electric furnace and then quenched in water. Then the voltage difference was measured relative to another untreated sample. An experimental setup was chosen which was identical to that of Borelius. Even the samples were identical, since Borelius also obtained the iron wires from the Heraeus company. Wilhelm Heraeus then states: The curves (temperature on the abscissa and the measured voltage on the ordinate) of Borelius are characterized by their inconsistent, complicated course (see Fig. 3). The order of magnitude is the same for Borelius and Heraeus. However, what is completely missing is the reproducibility of each individual measurement. If the same wire was taken out of the arrangement several times and put back in again, the galvanometer deflections were completely different. It even turned out that the galvanometer showed a rash, even though the copper block was not warmed. The rashes could not therefore have resulted from a thermoelectric force; the investigation showed that there were contact forces between iron and copper, i.e. the pressing forces of the clamps. Even the smallest changes in temperature affect the measurement results (1 °C results in 0.05 to 0.15 microvolts). The fluctuations observed by Borelius can therefore all be explained by these influences.

Wilhelm Heraeus also took photomicrographs of the samples to identify structural changes. He was able to clearly identify recrystallization in his investigations, which also has a significant influence on the properties of iron. The type of recrystallization could also be influenced by the duration of the heating.

Wilhelm Heraeus concluded his written dissertation as follows.

The available studies therefore show:

1. That the experimental methods used by Borelius and Gunnesson when examining the thermocurve of un-annealed pure iron versus annealed pure iron led to incorrect results because (a) Contact forces occur, (b) the wires to be examined are mechanically stressed during the measurement, (c) the oxide formation is not taken into account. The curve of B and G could be reproduced with the Borelius arrangement, and the pure thermal curve was obtained further after the arrangement errors had been eliminated.
2. A new observation method for the observation of the thermal forces of annealed pure iron against un-annealed pure iron is described and the following observations were made: The temperature curve in the temperature range between 60 and 900 °C is a virgin curve in the sense that the curve is not reproducible at lower temperatures. The course of the thermal curve is thus determined during heating by the course of the recrystallization. The shorter the duration of the annealing, the sharper the kinks in the thermal curve between 60 and 900 °C.
3. The wires used for the investigation were examined microscopically, and the start of the recrystallization occurred approximately at 500 and up to 900 °C.

Finally in the acknowledgment Wilhelm Heraeus mentioned as his supervisors Wachsmuth and Gerlach as well as Professor Fränkel.

After passing the dissertation exam he acquired first experience in the precious metals company of his uncle in Newark, N.J., USA. In 1925 he joined the W.C. Heraeus company, and in 1927 he became a third generation member of the executive board. As head of technical development, he expanded the group's product range and, after 1945, also managed the reconstruction of the destroyed plant. In 1965 he changed from the management to the supervisory board of the family company.

Together with his wife Else († 1987) (they had no children of their own) he founded in 1963 what is now the Wilhelm and Else Heraeus Foundation, which supports scientific research and education with an emphasis on physics. Organizing WE-Heraeus Seminars is the most important and oldest funding activity of the foundation. In 1983, two years before he passed away, Wilhelm Heraeus became an honorary member of the German Physical Society (DPG).

Reference

1. G. Borelius, F. Gunnason, Annalen der Physik, 67 227 and 238 (1922); Annalen der Physik, 68 67 (1922)