

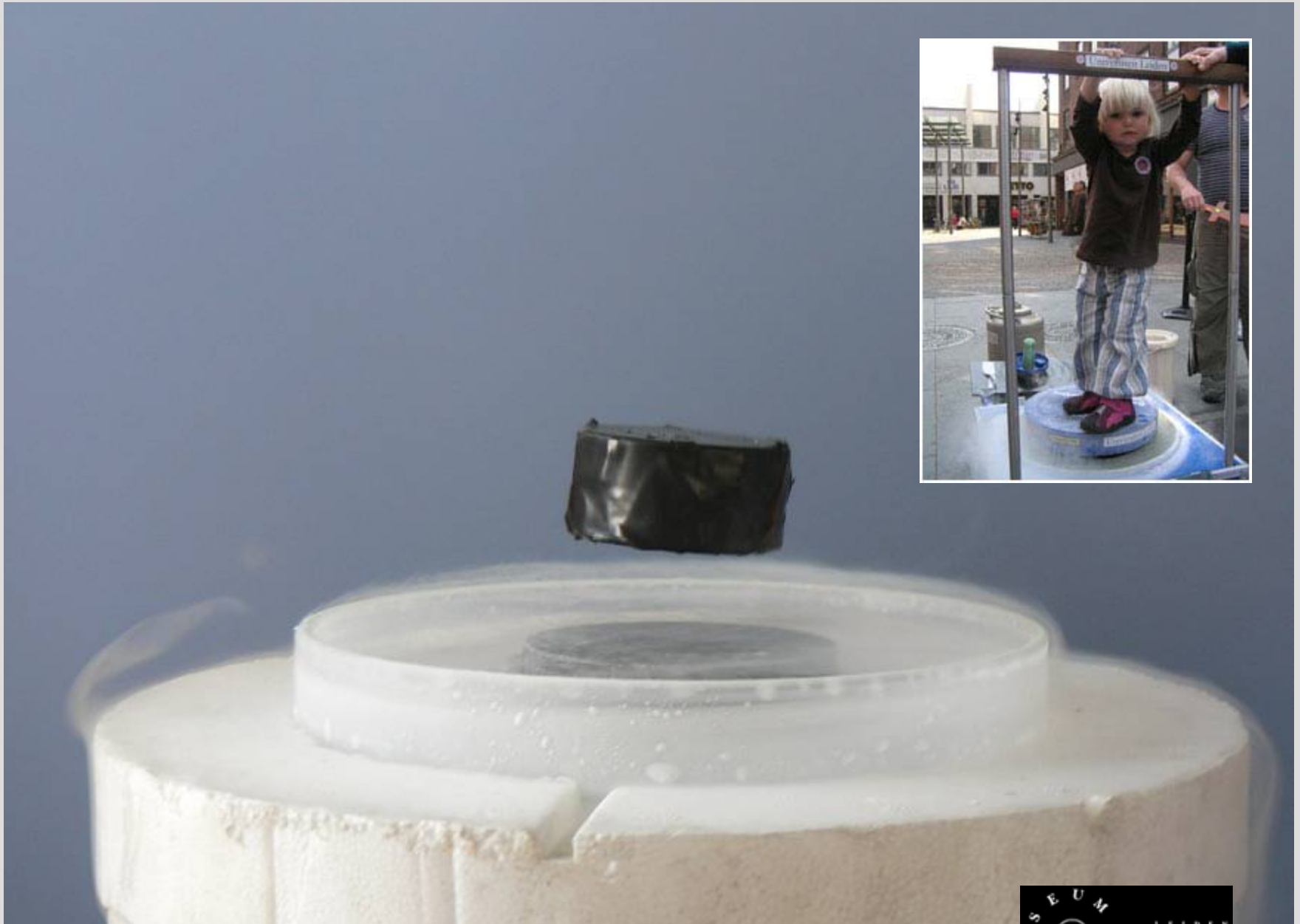
Heike Kamerlingh Onnes and the Road to Superconductivity



APS March Meeting 2011
Dallas, March 21

Dirk van Delft
Museum Boerhaave
Leiden University



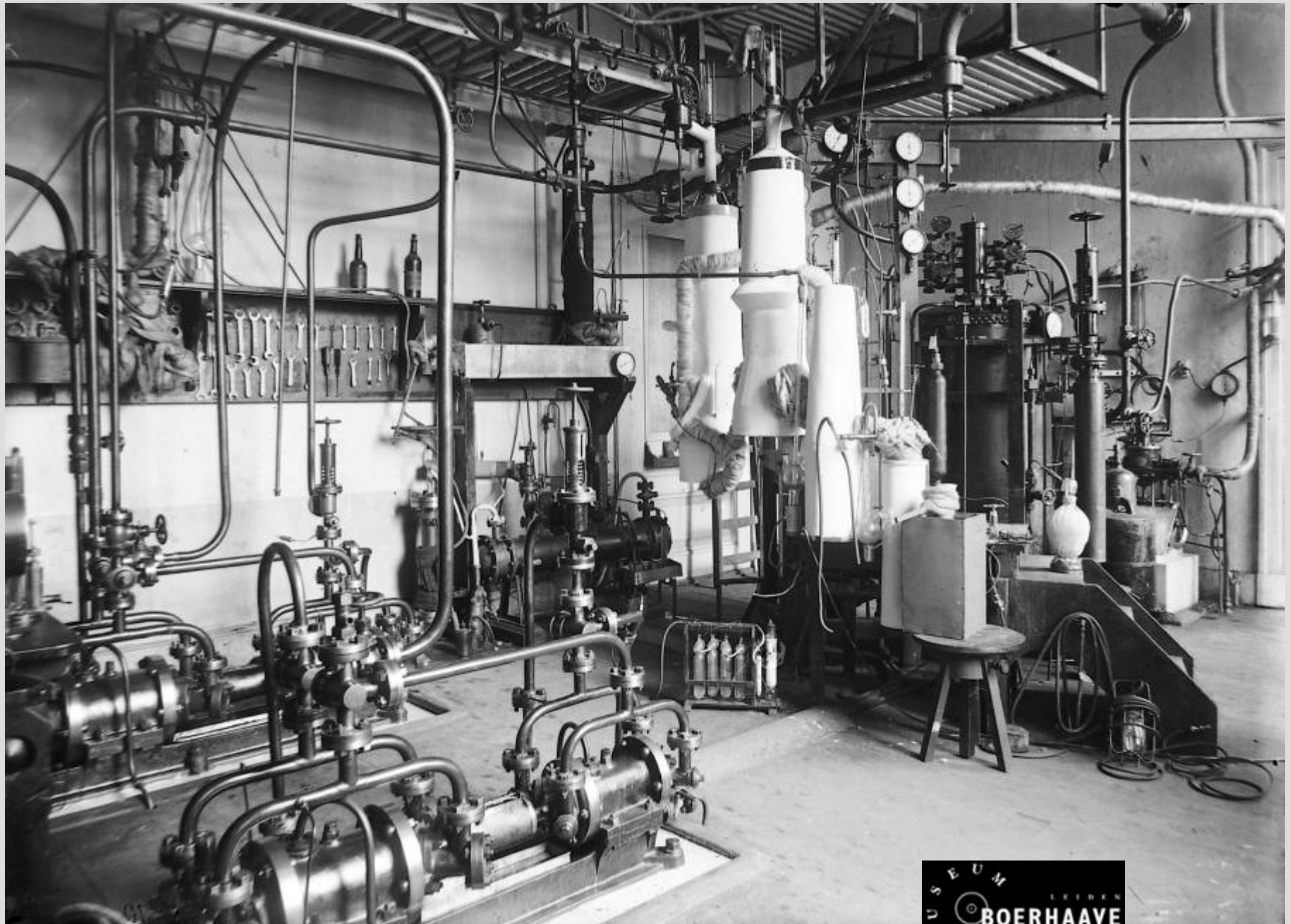




Leiden Scientific program:

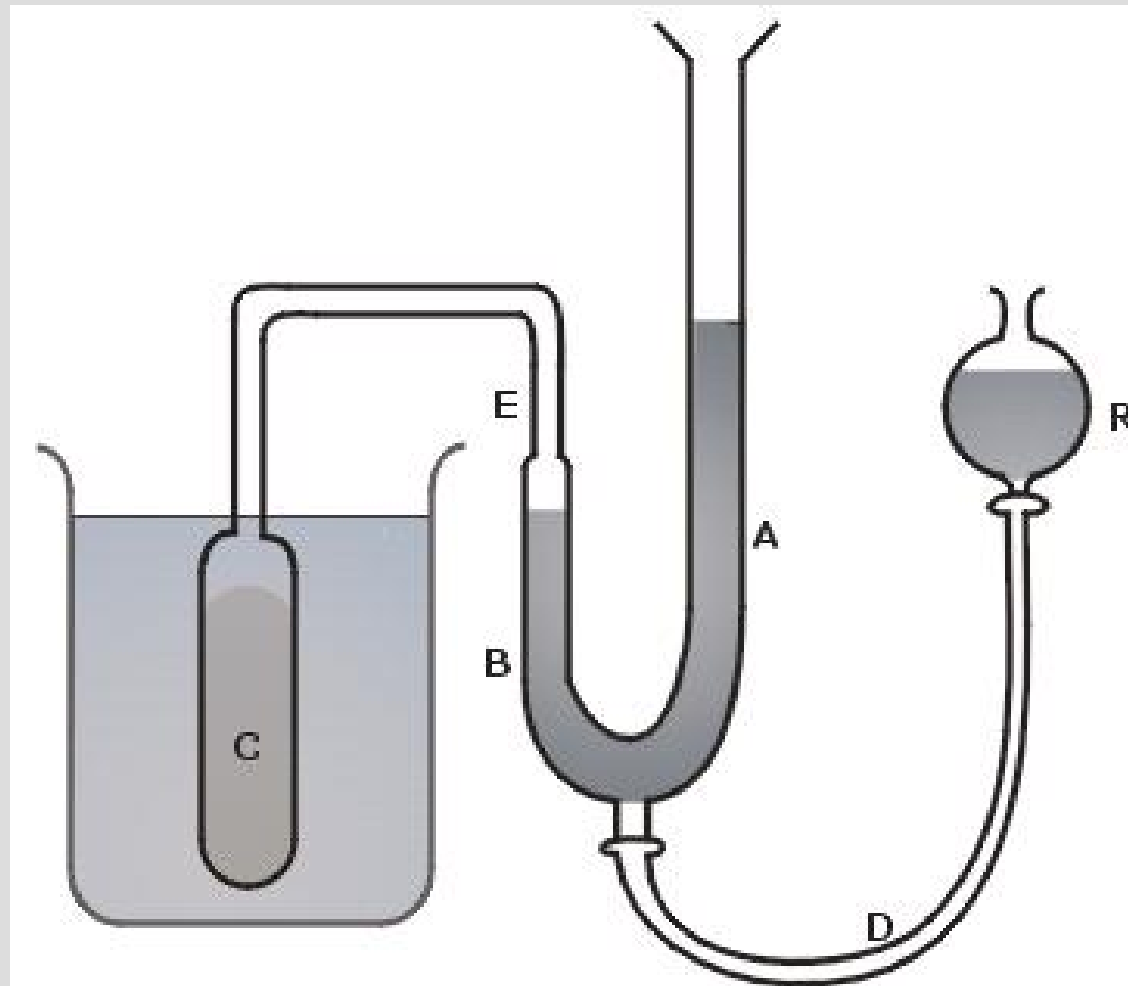
molecular theories
J.D. van der Waals

Leiden Cryogenic Laboratory, 1895





Gas thermometer



Constant volume gas thermometer

1860

William Siemens

Proposal platinum resistance thermometer

1885 – 1900

Hugh Callendar

Experimental work on platinum thermometer

1899

Proposal Callendar international temperature scale

Platinum thermometer

Quadratic interpolation formula

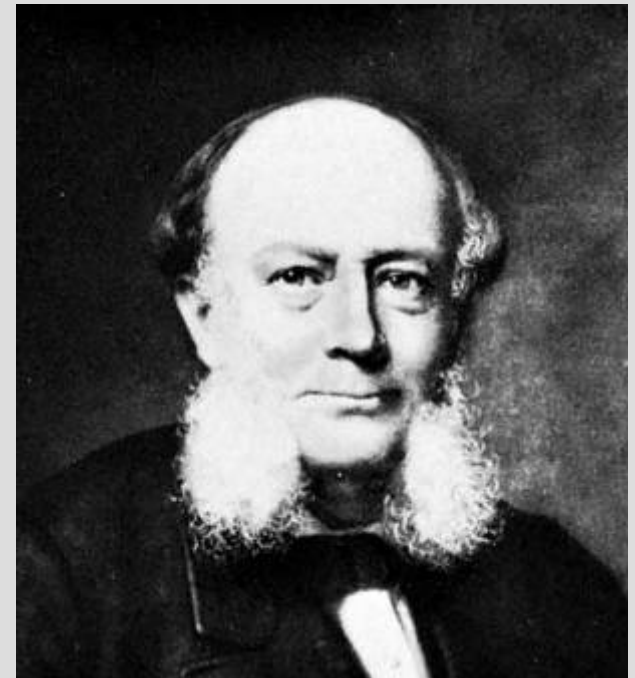
3 fixed points

Range: -100 °C - 650 °C

$$R_t = R_0 (1 + At + Bt^2)$$



Hugh Callendar
Cavendish Lab, Cambridge



William / Wilhelm Siemens



Jacob Clay

Calibration resistance thermometers:
Gold and Platinum wire
since 1902 used in Leiden



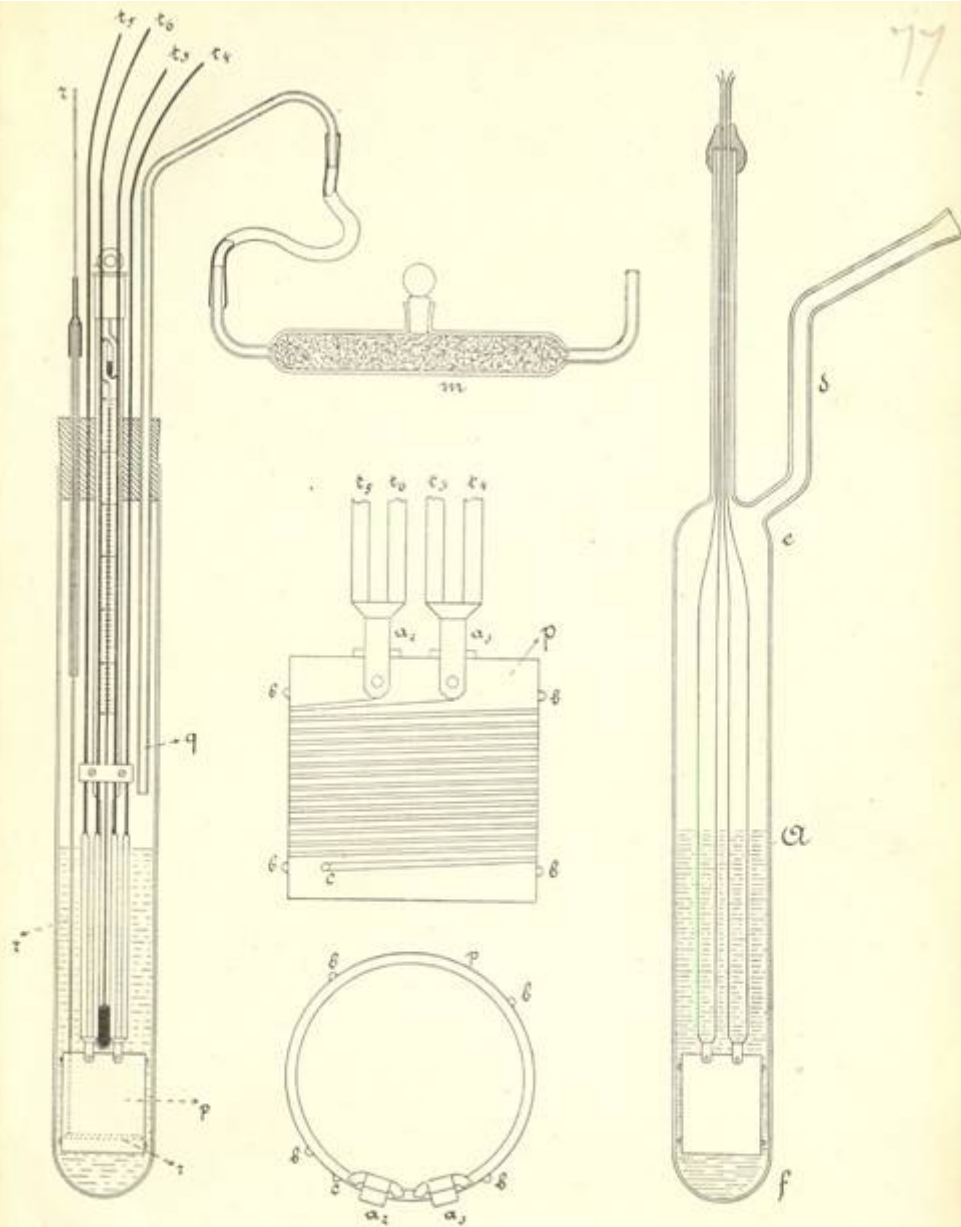


Fig. 4.

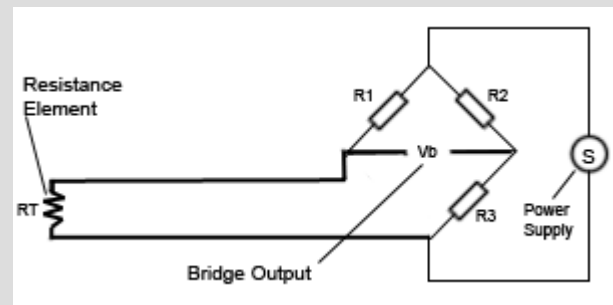
Fig. 1.

Fig. 3.

Communication No. 77.

B. MEILINK. „On the measurement of very low temperatures IV. Comparison of the platinum thermometer with the hydrogen thermometer.”

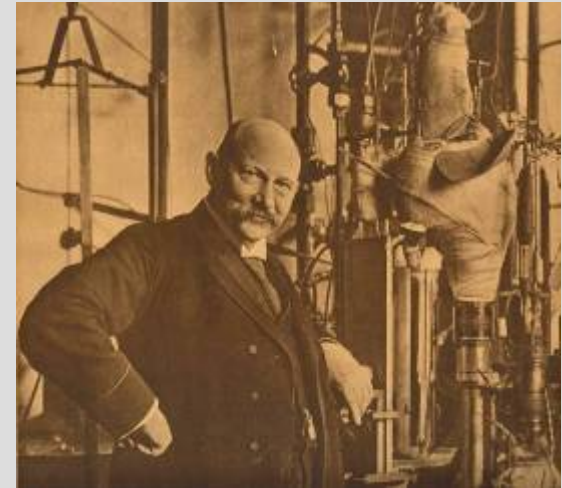
77



Open question: What would happen to the resistance of a metal as its temperature approaches absolute zero?

Practical importance: can metal wires still be used as thermometers at very low temperatures?

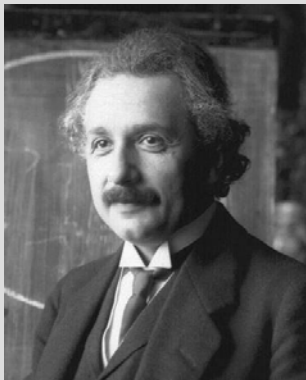
Theoretical importance: two rivalling theories



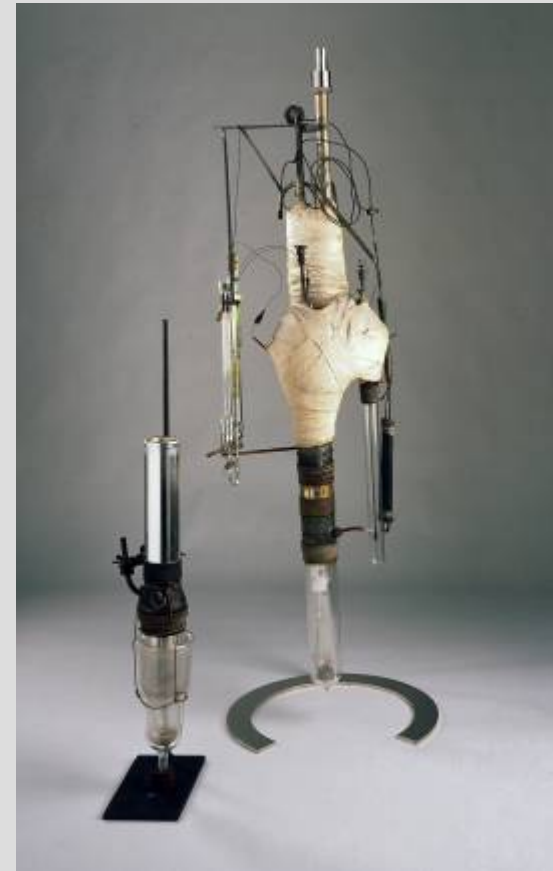
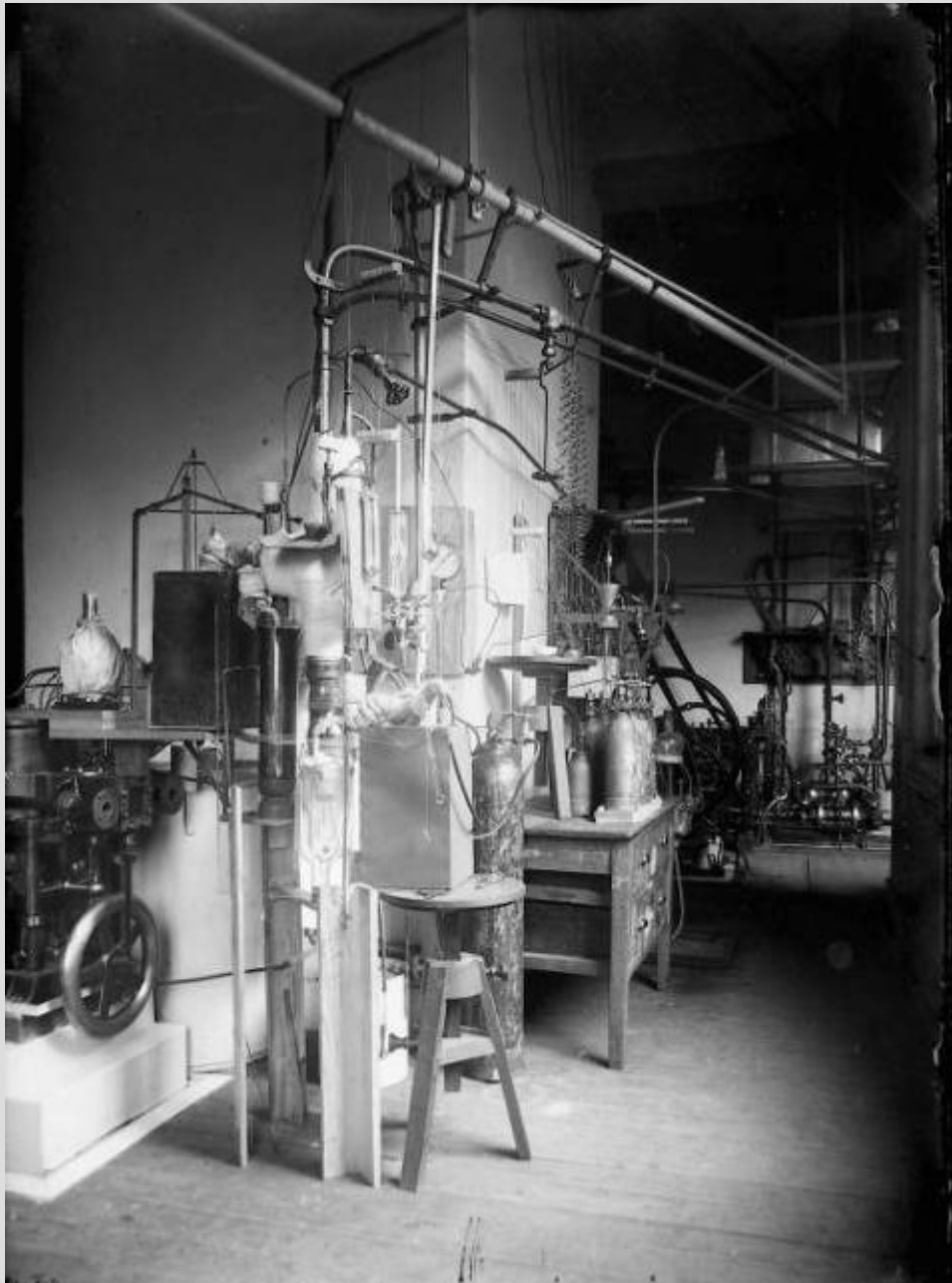
Lord Kelvin: the electrons 'freeze', no mobility, resistance goes to infinity

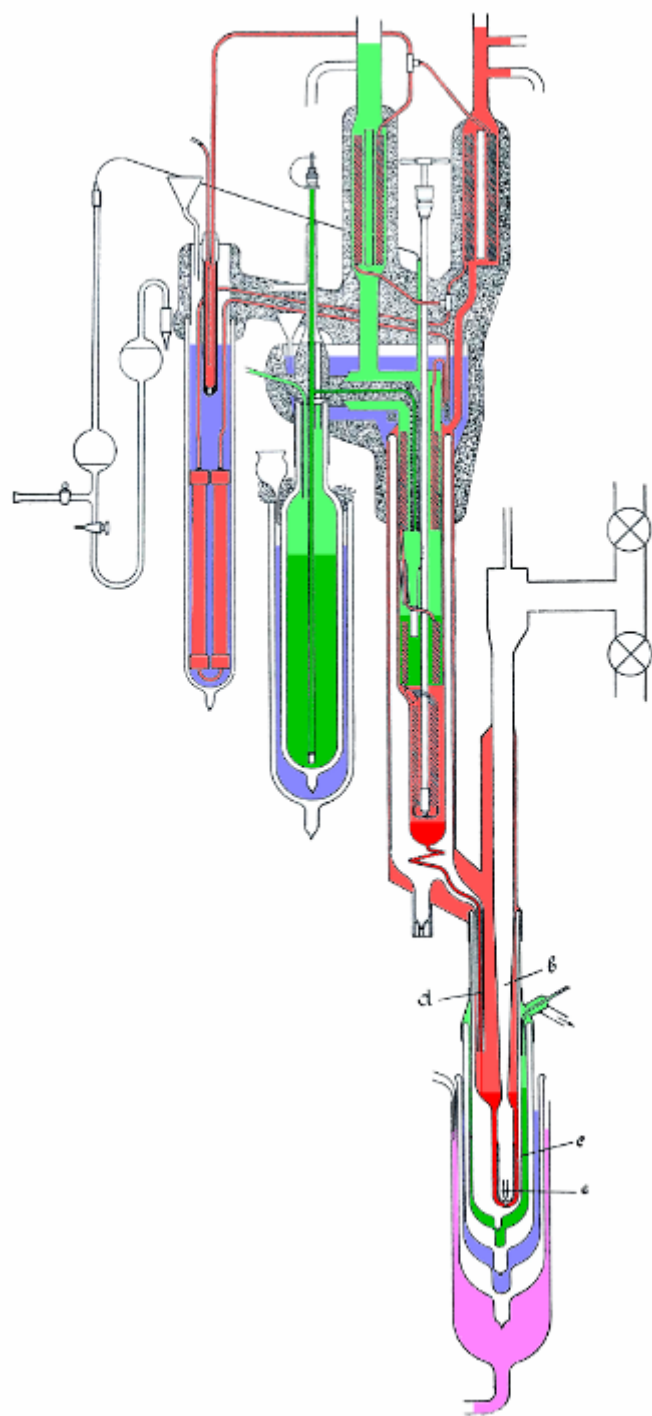
Paul Drude: electron gas in a metal; resistance gradually approaches zero

So Kamerlingh Onnes, who tinkered with a theoretical Planck vibrators model himself, devised experiments to decide these matters



10 July 1908: Liquid Helium



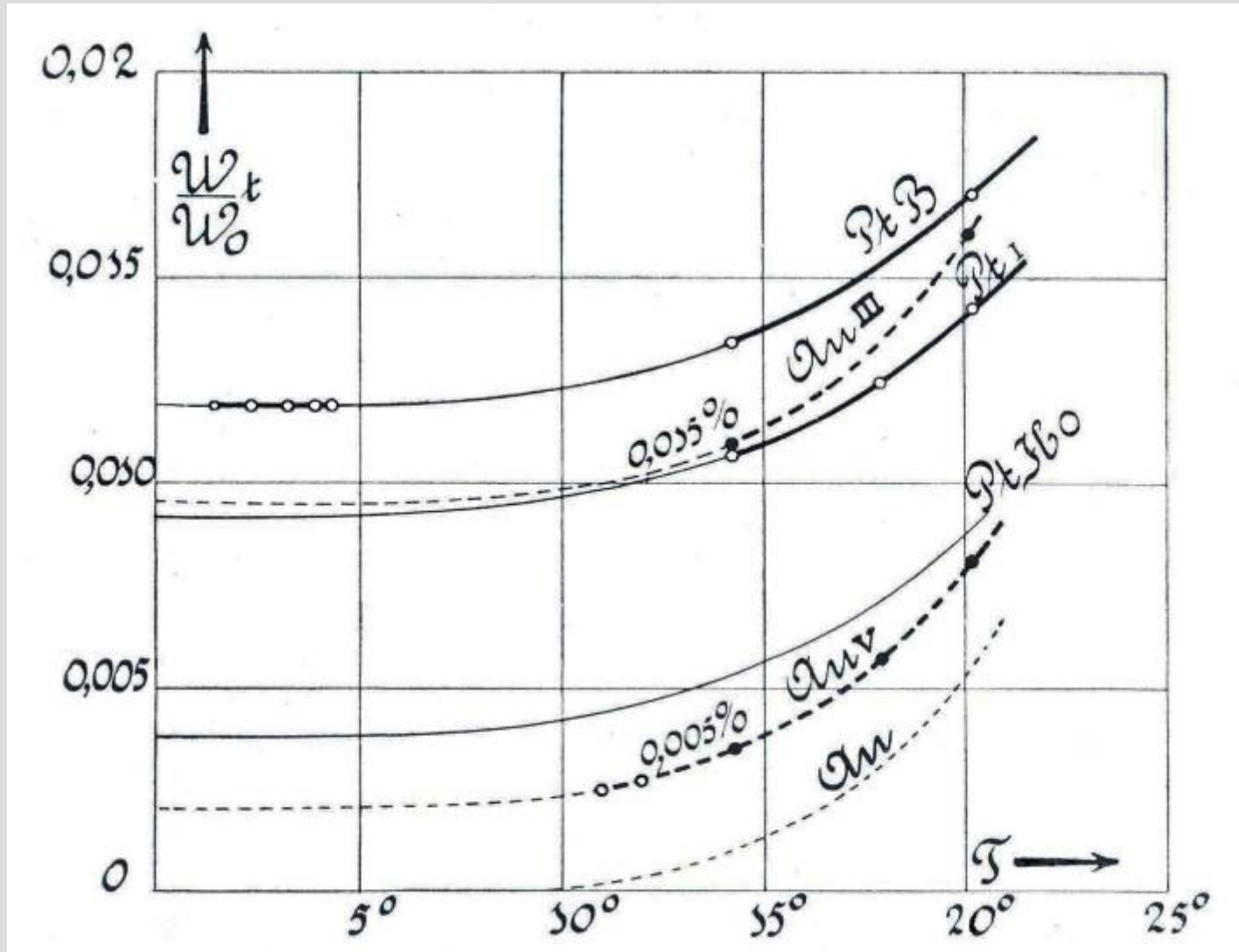


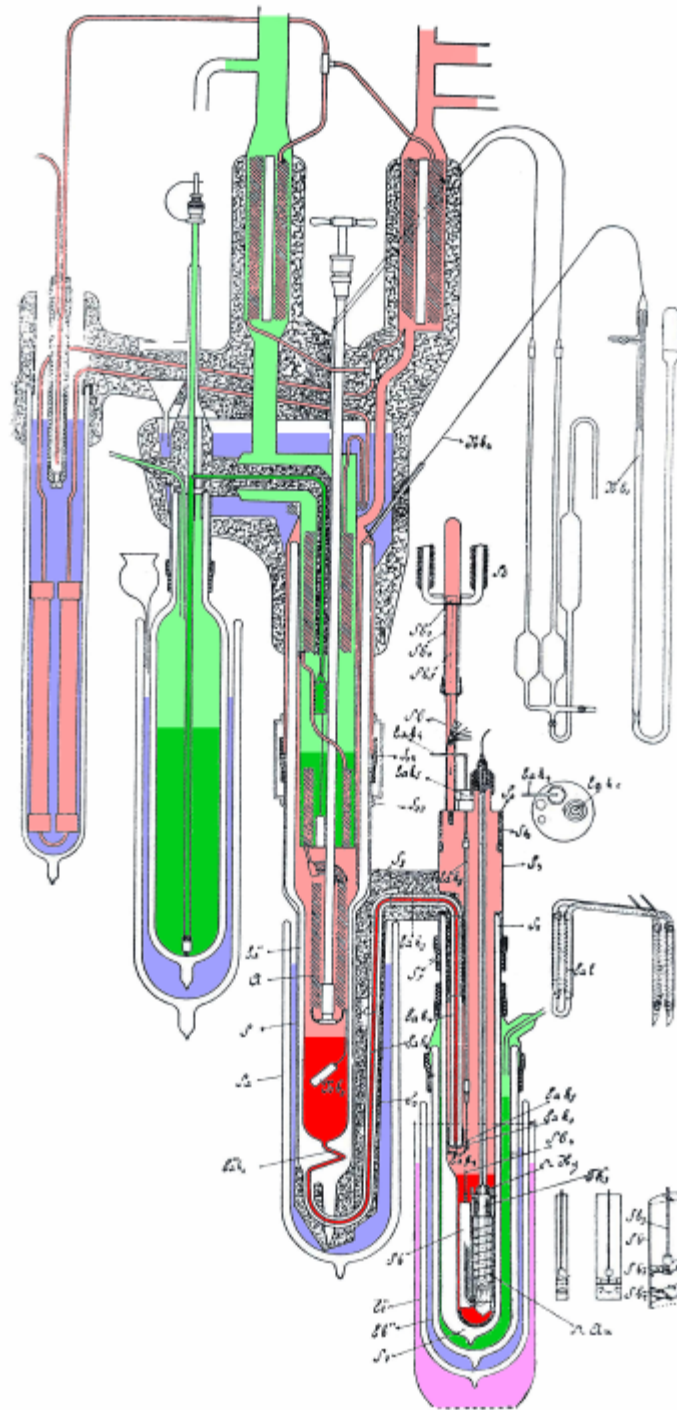
Transferring helium to a
separate cryostat
12 March 1910



Flim, Kesselring and some
'blue-collar boys'

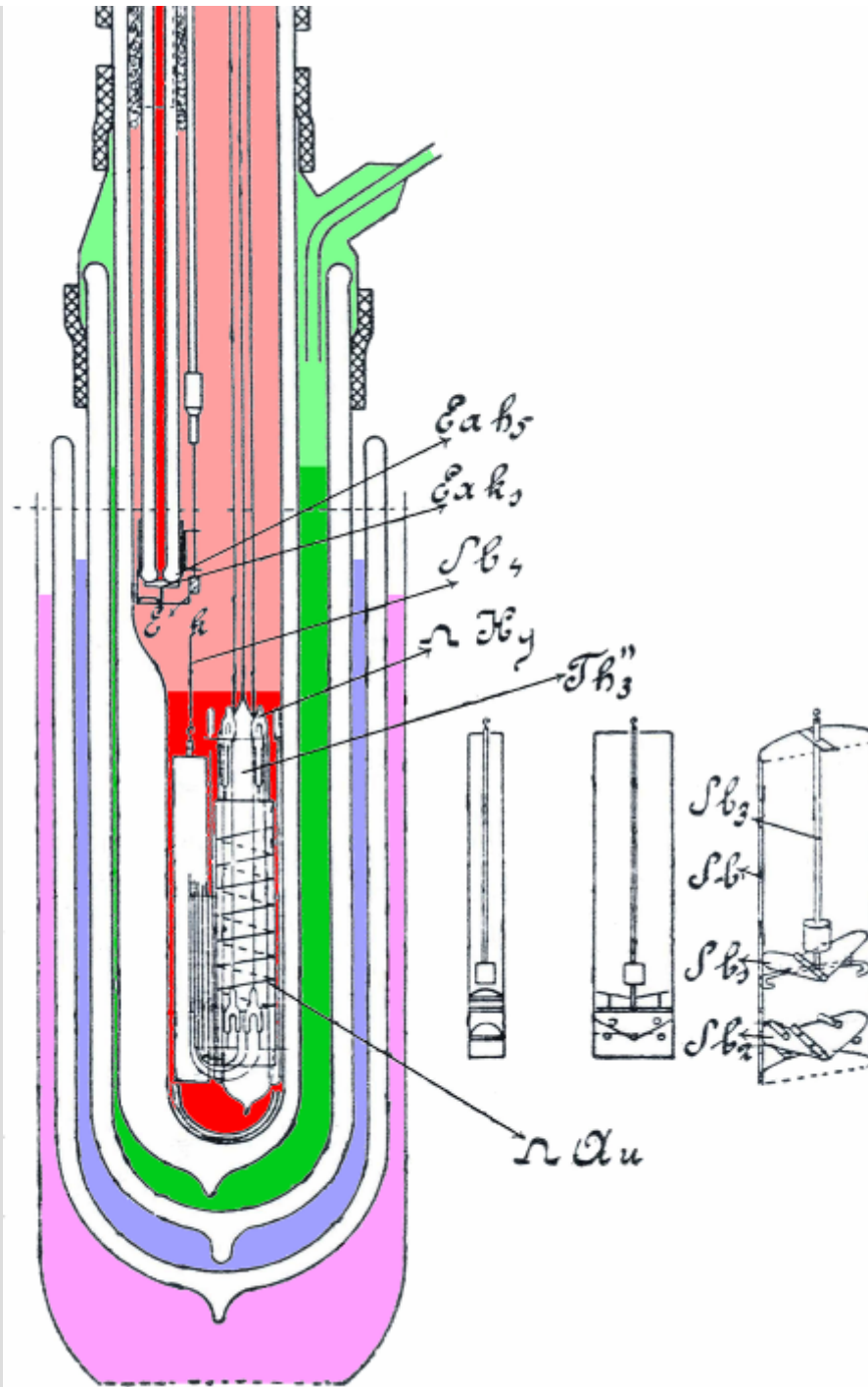
(R,T) graphs Platinum and Gold wires; December 1910






Helium liquefier and
cryostat, April 1911

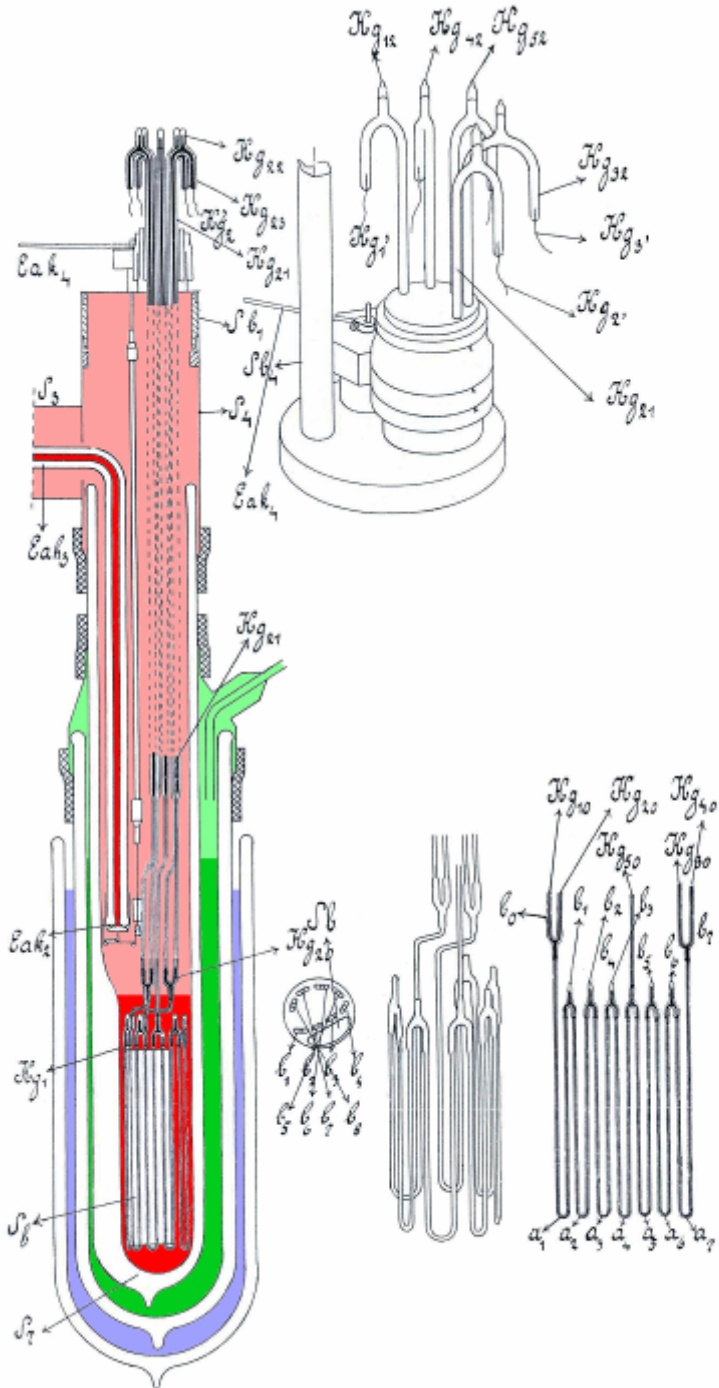
Helium cryostat



Notebook #56

200 klein mogelijk te maken. De temp
 in helin cyclus is nu niet geluk 200° A
 12^h 40' gewalt met helin
 12^h 47' pompje werkt, nu is een vlak
 over een klein pompje. Pompje wordt
 prachtig 1^h 2' ^{hormel} verdamp

 is niet op te maken om dat
 er iets om te plaatsen. Het is
 waarschijnlijk om een schelpje, 1^h 4' gewalt
 tot vlakke, vrijwel rond 2 cm. in omvang
 geometrisch gelijkvormig. De structuur is
 heel. Deels is het constant gemiddeld, geheel
 hoort op. Temperatuur gemiddeld
 2^h 15' geen verdamp tot 12^h 47'
 bedroeft. Nu, nu is 8° A
 2^h 40' waarschijnlijk, bij 12^h 40' nu
 de meest en niet merkbaar. Merkt men
 het om is al bij. Het is nu 12^h 40' nu
 richting goed versterkt herhaald, met andere
 temp om 12^h 40'.

inre
 De warmte heeft ook gecontroleerd 0 punt,
 waarschijnlijk is een grote bol.
 Verdampf buiten de pompje, nu is een
 3^h 50' nu is het gewalt met verdampf nu is
 Concluse dat verdampf nu is het
 actueel gering - spec. nu is het nu is het
 herhaald nu is het nu is het.
 3^h 50' gewalt met verdampf nu is
 het, tot op 14, 7 an gewalt tot
 om nu is het, geheel nu is het
 schied bij het nu, die nu is het nu is het
 in de nu is het nu is het.
 4^h 15' gewalt tot op pompje nu. De richting
 nu is het nu is het. Nu is het nu is het.
 herhaald nu is het.
 Het nu is het. Nu is het nu is het
 nu is het.
 De nu is het, nu is het nu is het, nu is het
 het nu is het nu is het. De nu is het
 geen nu is het nu is het. Nu is het

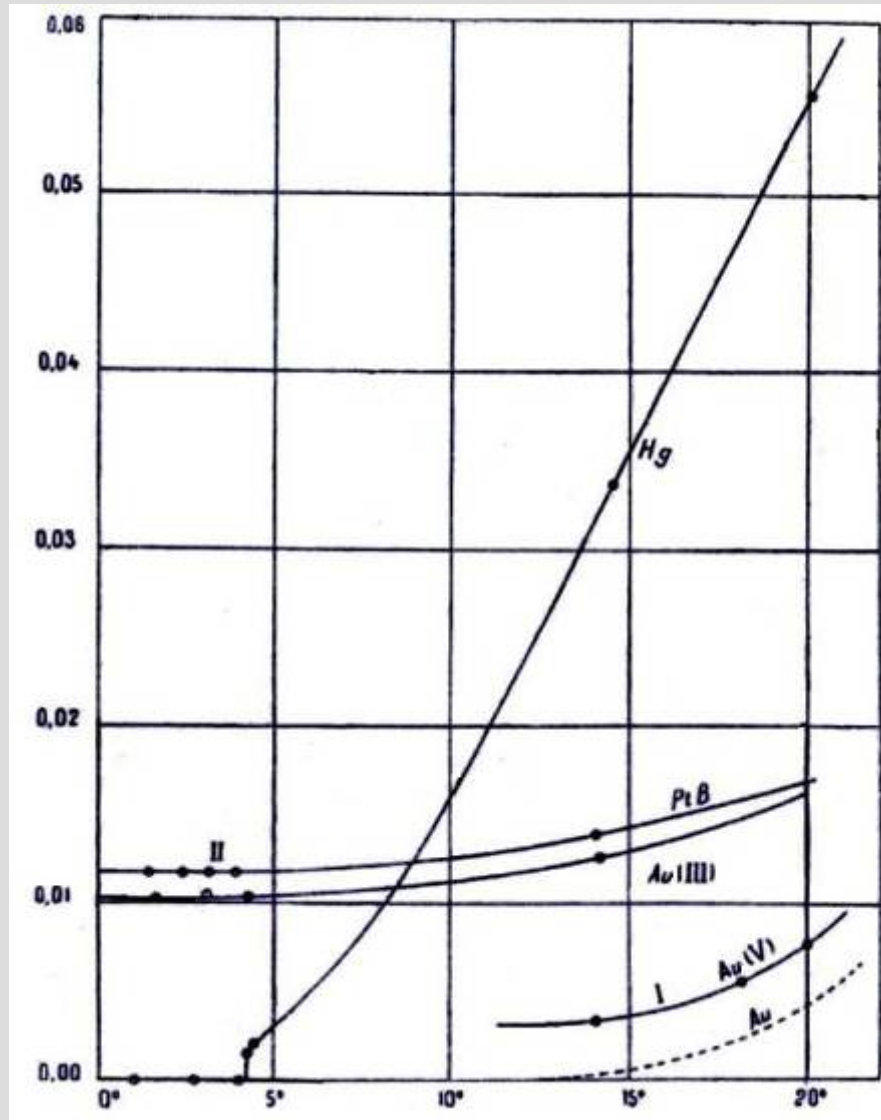


'Mercury practically zero'
 8 April 1911

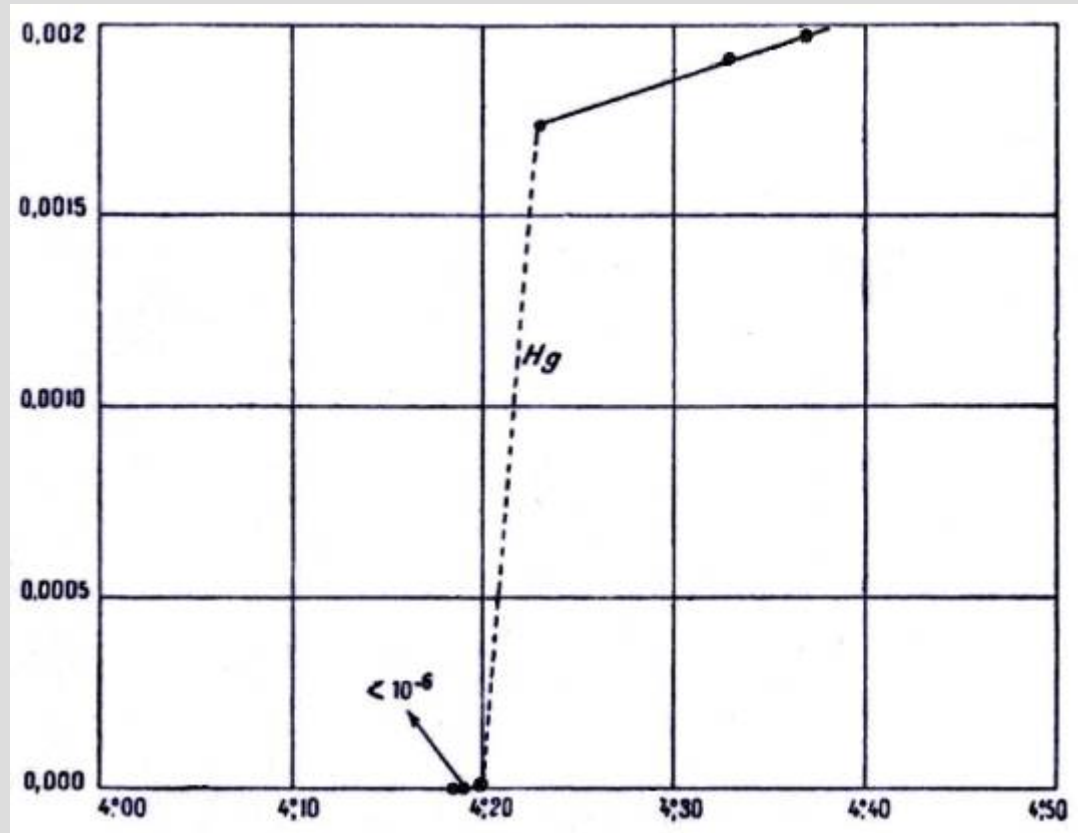




R,T graphs Hg, Pt, Au







October 1911

First Solvay Conference, October/November 1911



Who discovered superconductivity on 8 April 1911?

Heike Kamerlingh Onnes: director, took the initiative to the mercury measurements

Gerrit Jan Flim: chief technician of the cryogenic laboratory, responsible (together with Kamerlingh Onnes) for the cryogenic apparatus

Cornelis Dorsman, assistant, handled the gas thermometer (temperature measurement)

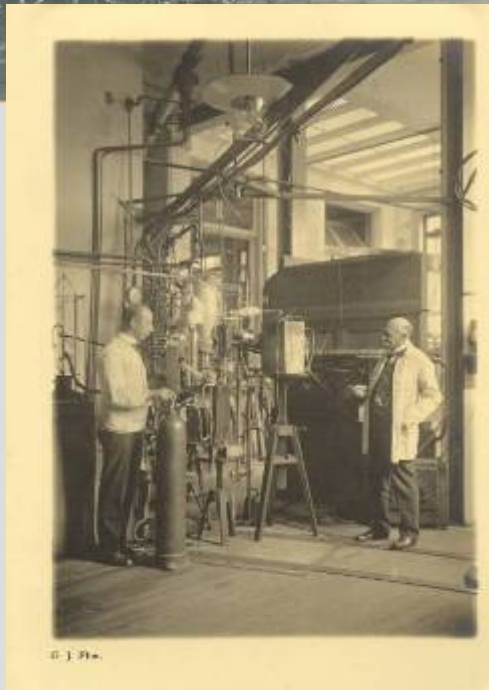
Gilles Holst, assistant, measured the resistance of the mercury using a Weastone bridge and a mirror galvanometer in Room I. He noticed a sudden swing of the galvanometer. Short circuit? No!

Oskar Kesselring, master glassblower, built the capillaries filled with mercury.

Single author superconductivity publications: H. Kamerlingh Onnes

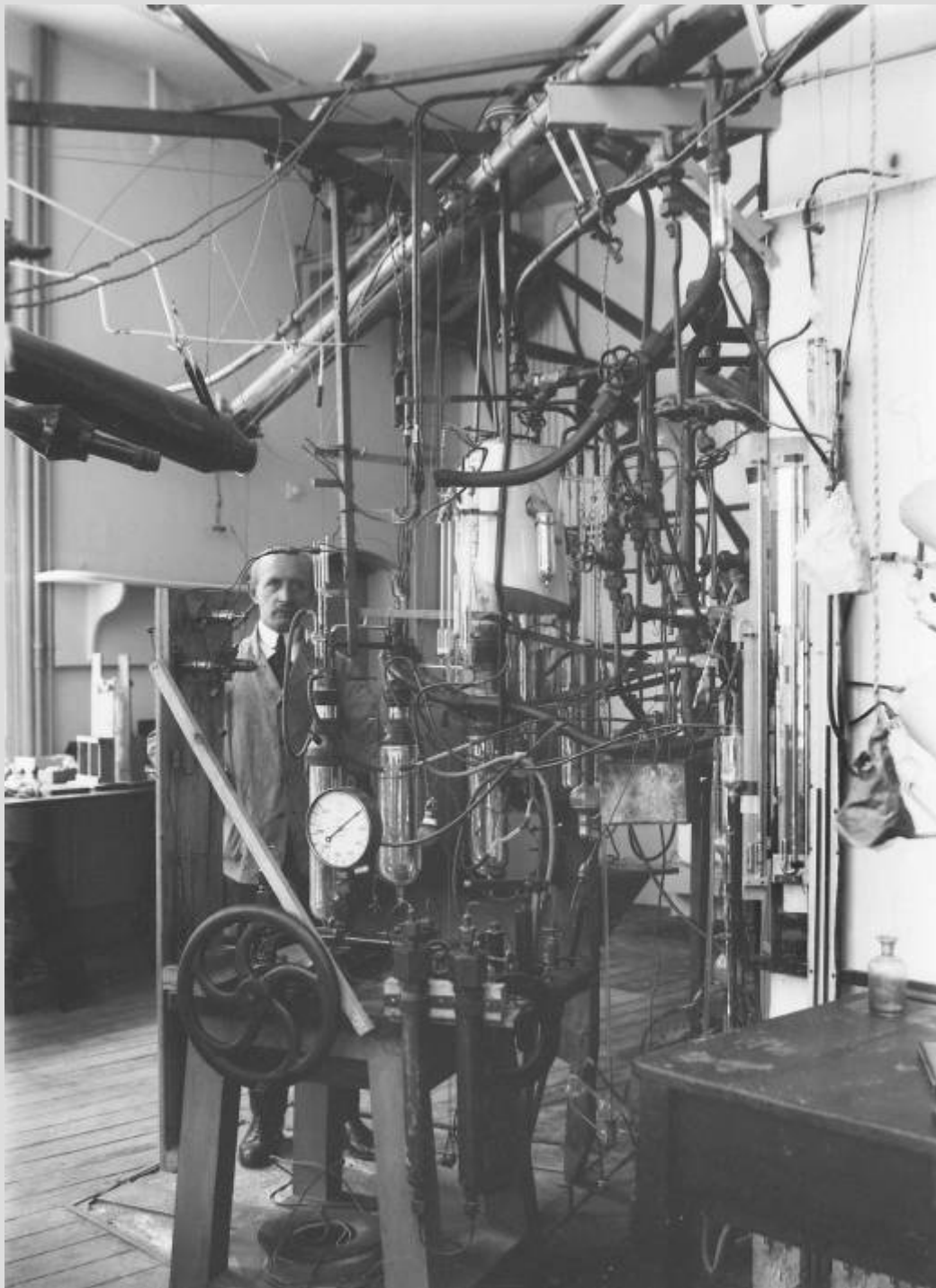
Acknowledgement of 'most valuable help' by Holst, Dorsman, Flim and Kesselring





G. J. 214.





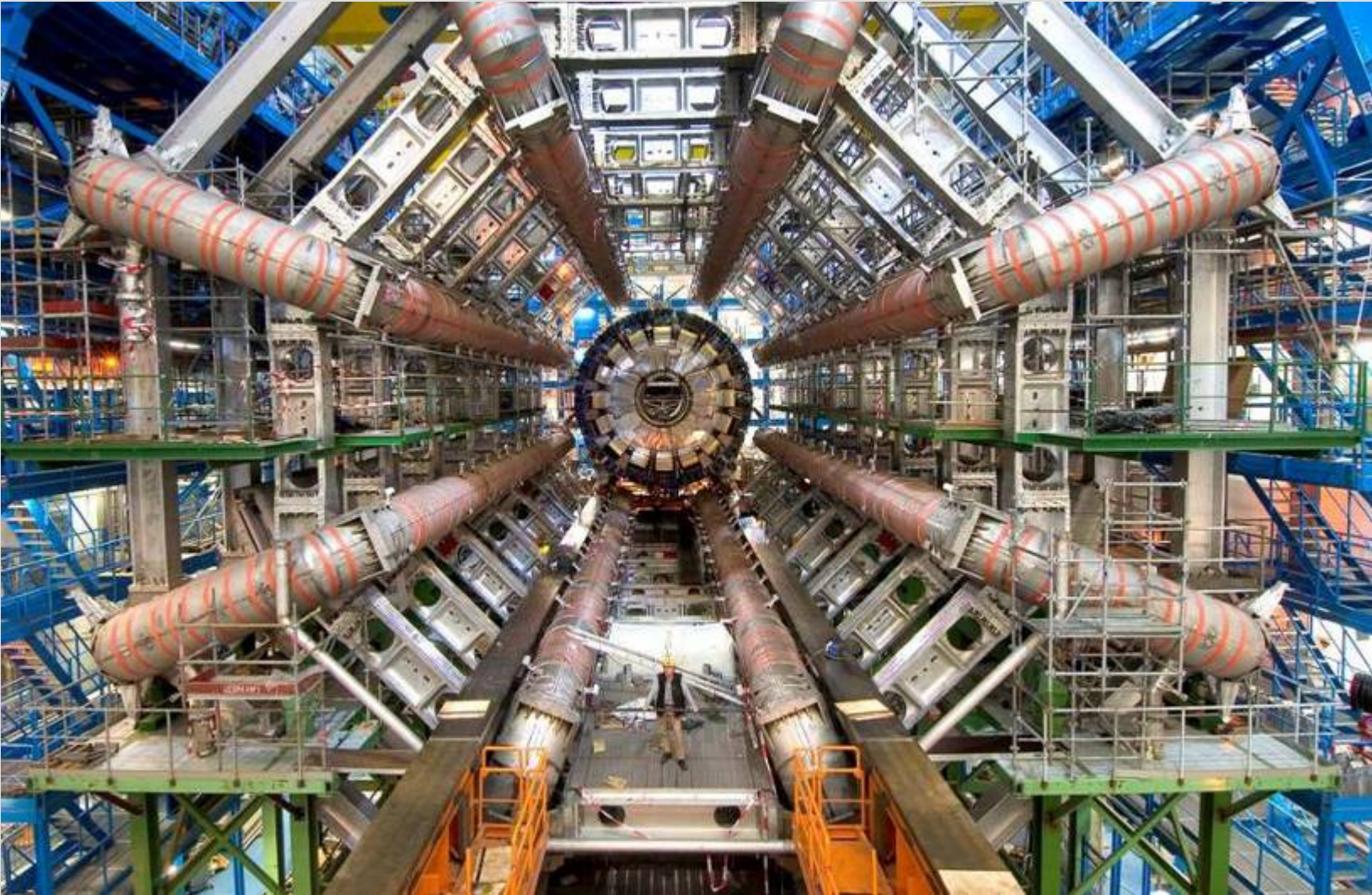
First example of Big Science

First superconducting lead coil, 1912
Threshold value (4.25 K) only 600 Gauss





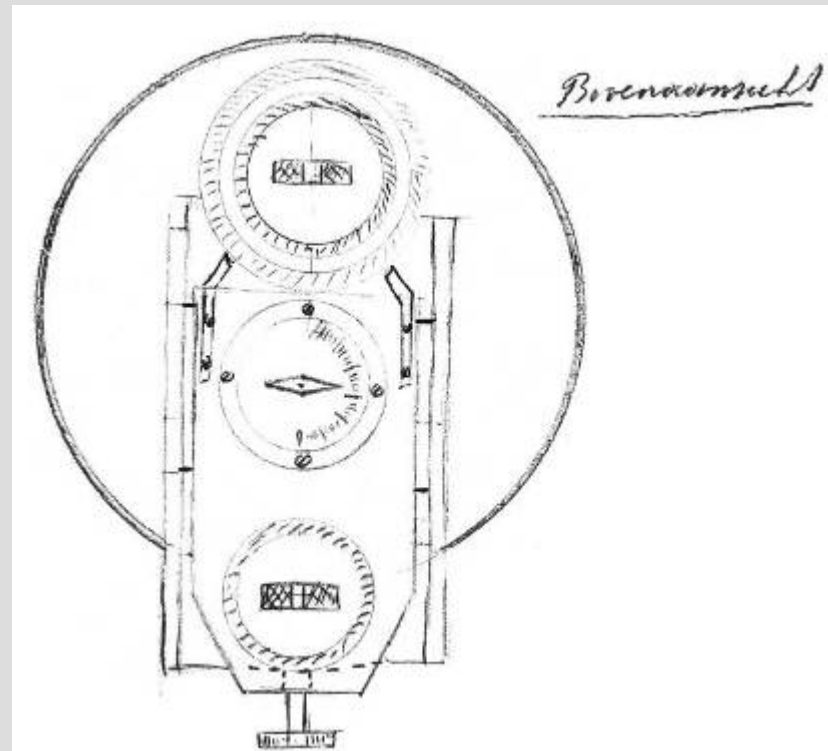
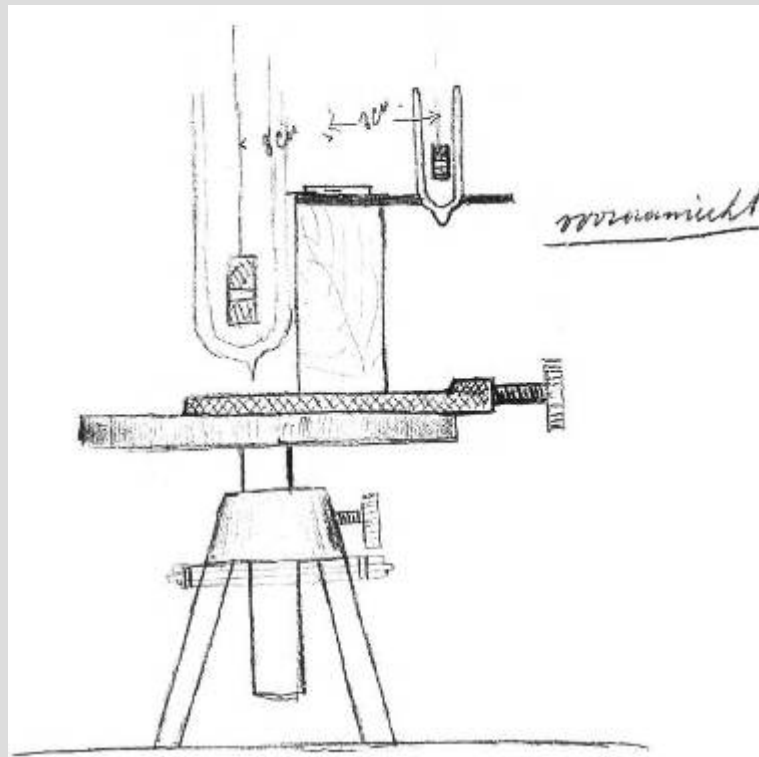
ATLAS-detector Large Hadron Collider





MRI scanner

Persistent current experiment, 1914



Drawings by Flim



Paul Ehrenfest

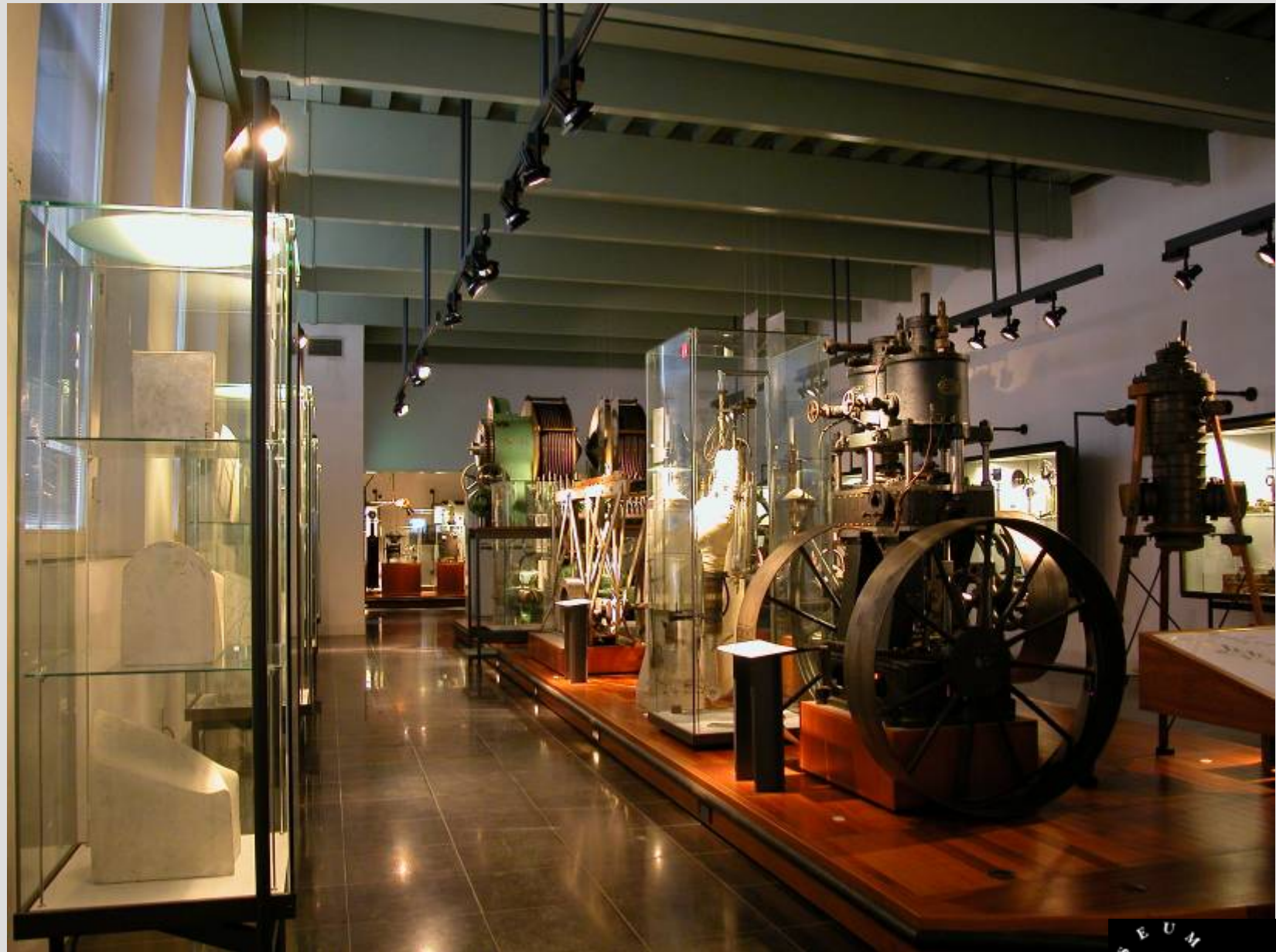
'I attended a fascinating experiment at the laboratory. Unsettling, to see the effect of this "permanent" current on a magnetic needle. It is almost tangible, the way the ring of electrons goes round and round and round in the wire – slowly and virtually without friction.'

Demonstration persistent current in Royal Institution (London), 1932





Museum Boerhaave, Leiden



IEEE MILESTONE IN ELECTRICAL ENGINEERING AND COMPUTING

Discovery of Superconductivity, 1911

On 8 April 1911, in this building, Professor Heike Kamerlingh Onnes and his collaborators, Cornelis Dorsman, Gerrit Jan Flim, and Gilles Holst, discovered superconductivity. They observed that the resistance of mercury approached “practically zero” as its temperature was lowered to 3 kelvin. Today, superconductivity makes many electrical technologies possible, including Magnetic Resonance Imaging (MRI) and high-energy particle accelerators.

April 2011

