

The Notebooks of Kamerlingh Onnes and the Discovery of Superconductivity

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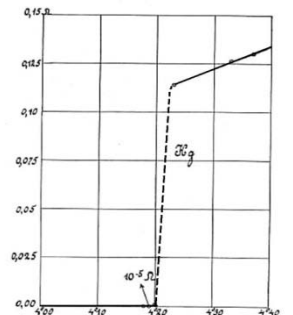
HKO



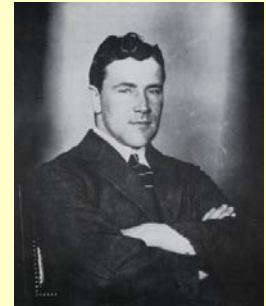
FLIM



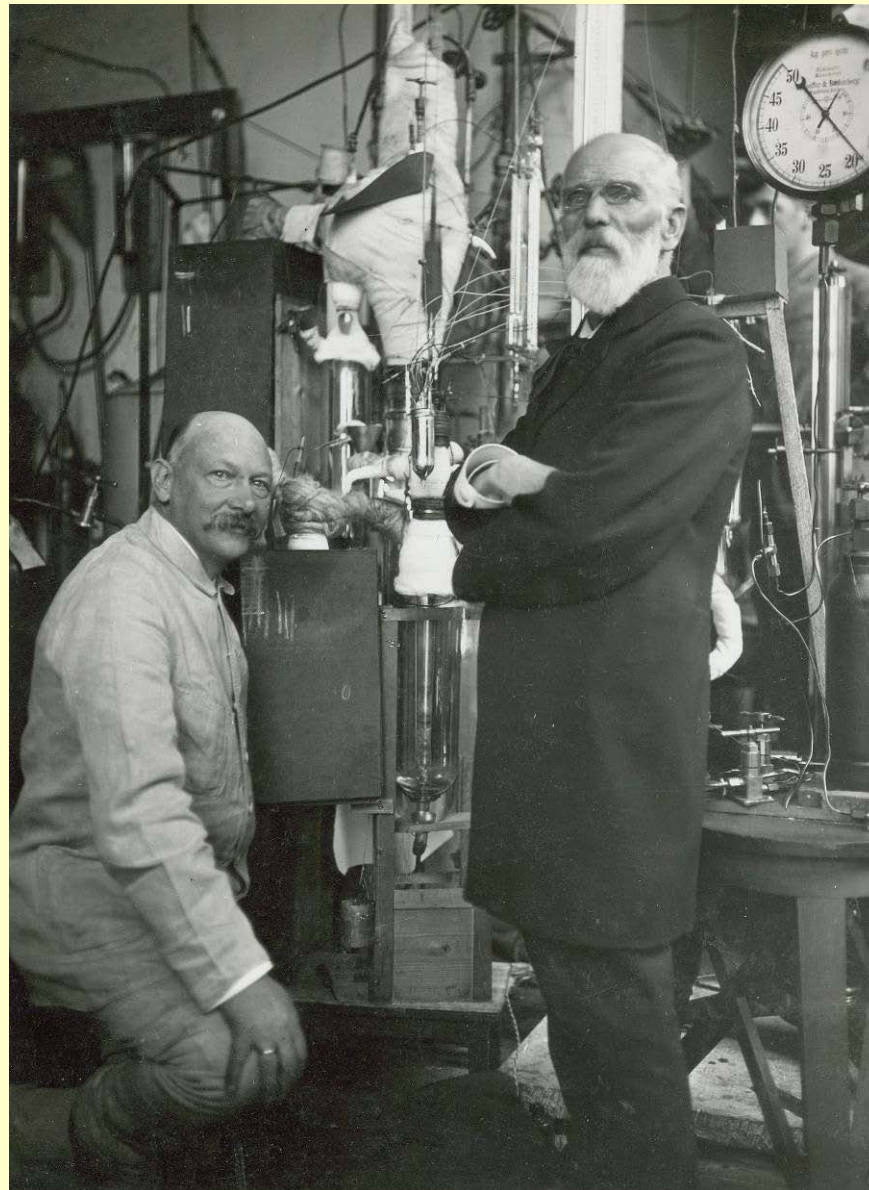
KESSELRING



DORSMAN



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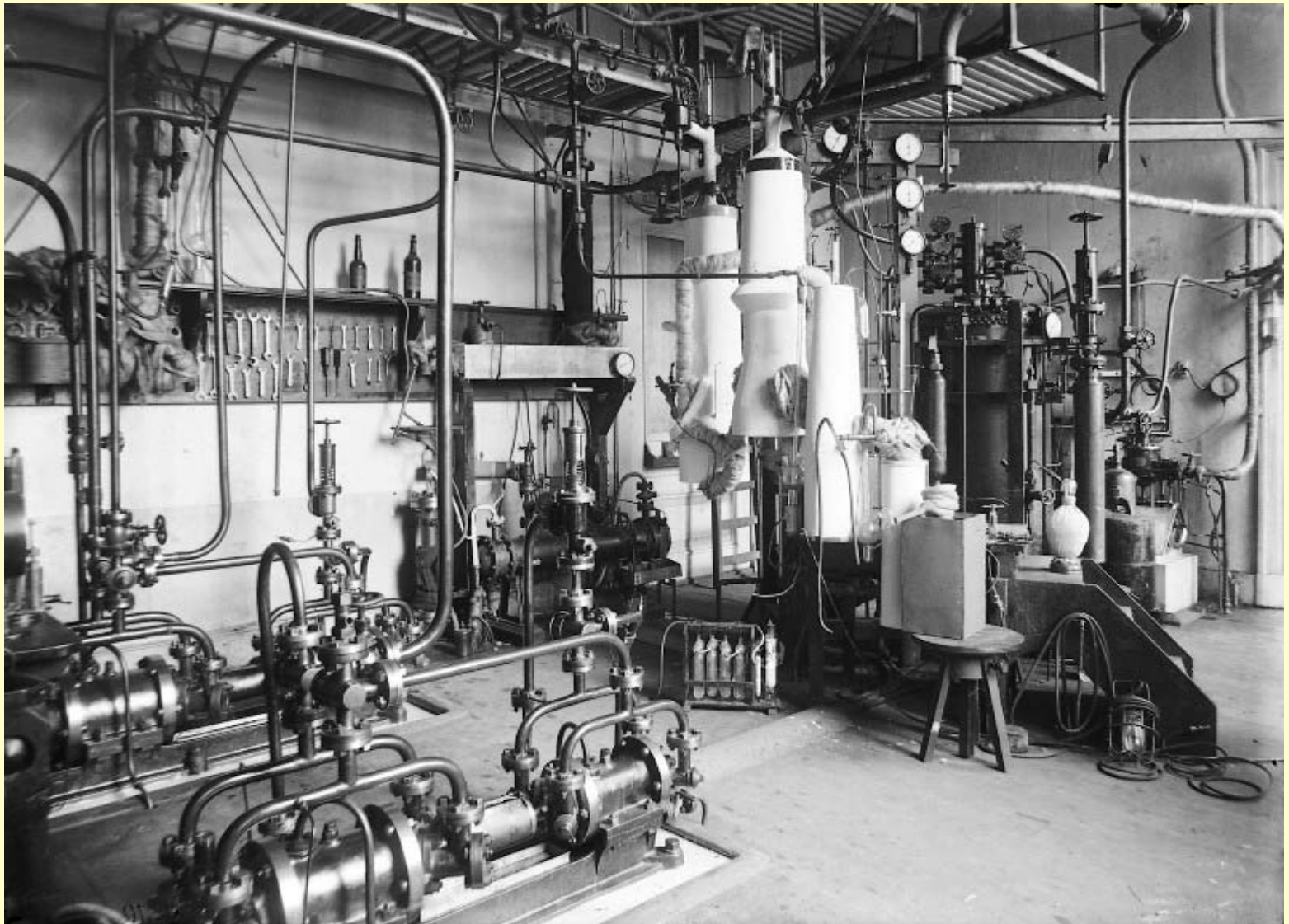
Heike Kamerlingh Onnes and Johannes Diderik van der Waals (1913)



Laboratory for physics, chemistry, anatomy en physiology (~1880)



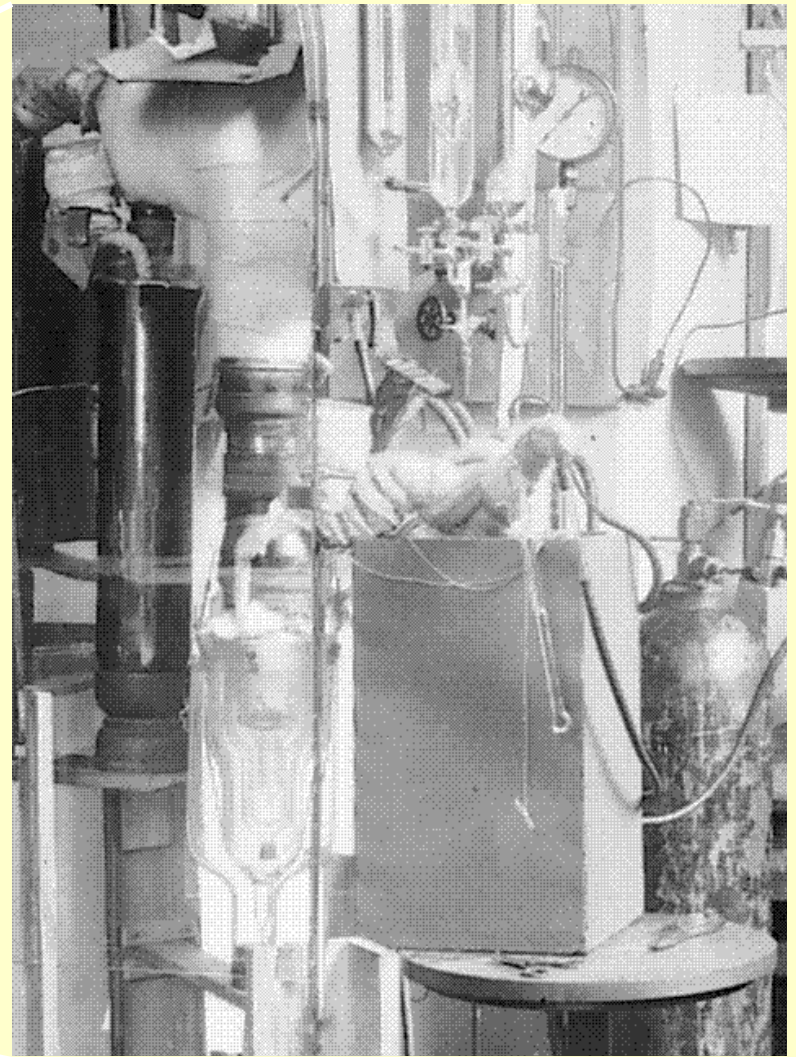
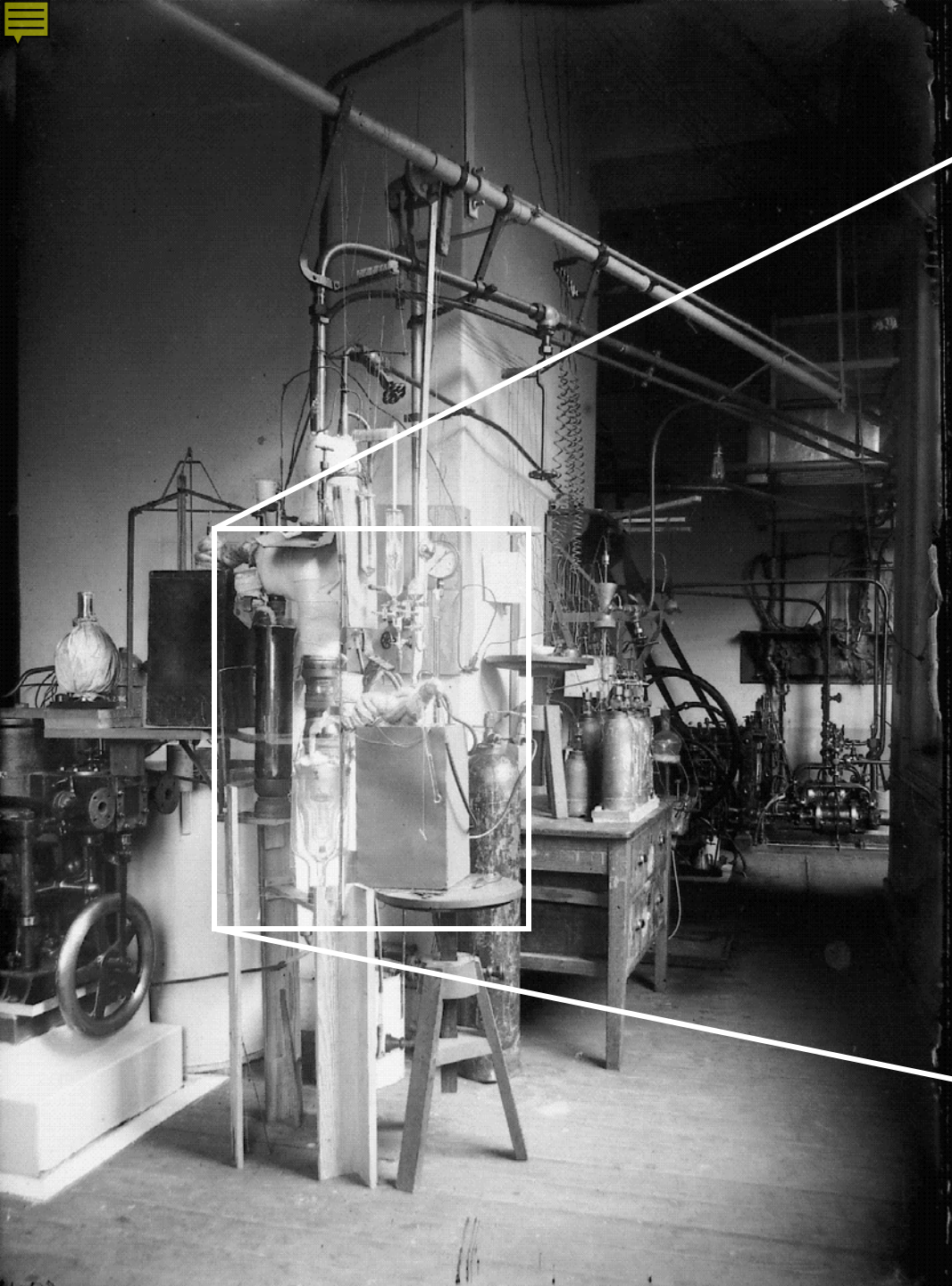
Fig. 17. — Plan du laboratoire cryogène de Leyde. (1908)



Production facility for liquid air (1892)



Hydrogen liquefier (1905)



He liquefier (1908)



Premier Congres International du Froid, Paris, Octobre 1908

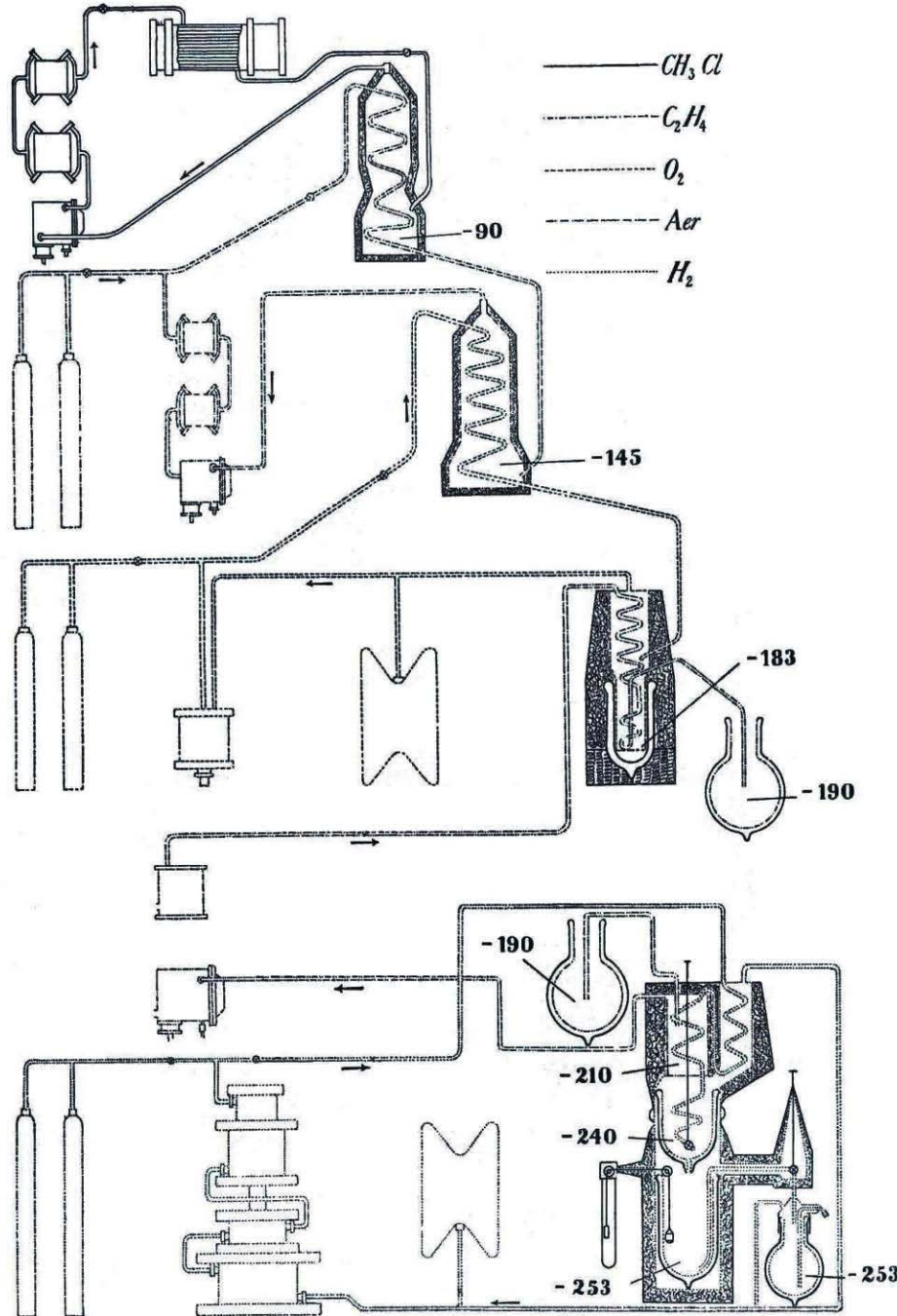


Fig. 1. — Cycles de la cascade du laboratoire cryogène de Leyde.

degrees C (°C) (degrees) K(elvin)

0 °C — +273 K

1892

-190 — +83 (liquid air at 1 atmosphere)

1905

-253 — +20 (liquid H_2)

-273 °C — 0 K

Trait pointillé : cycle d'hydrogène.
Trait plein : cycle d'hélium.

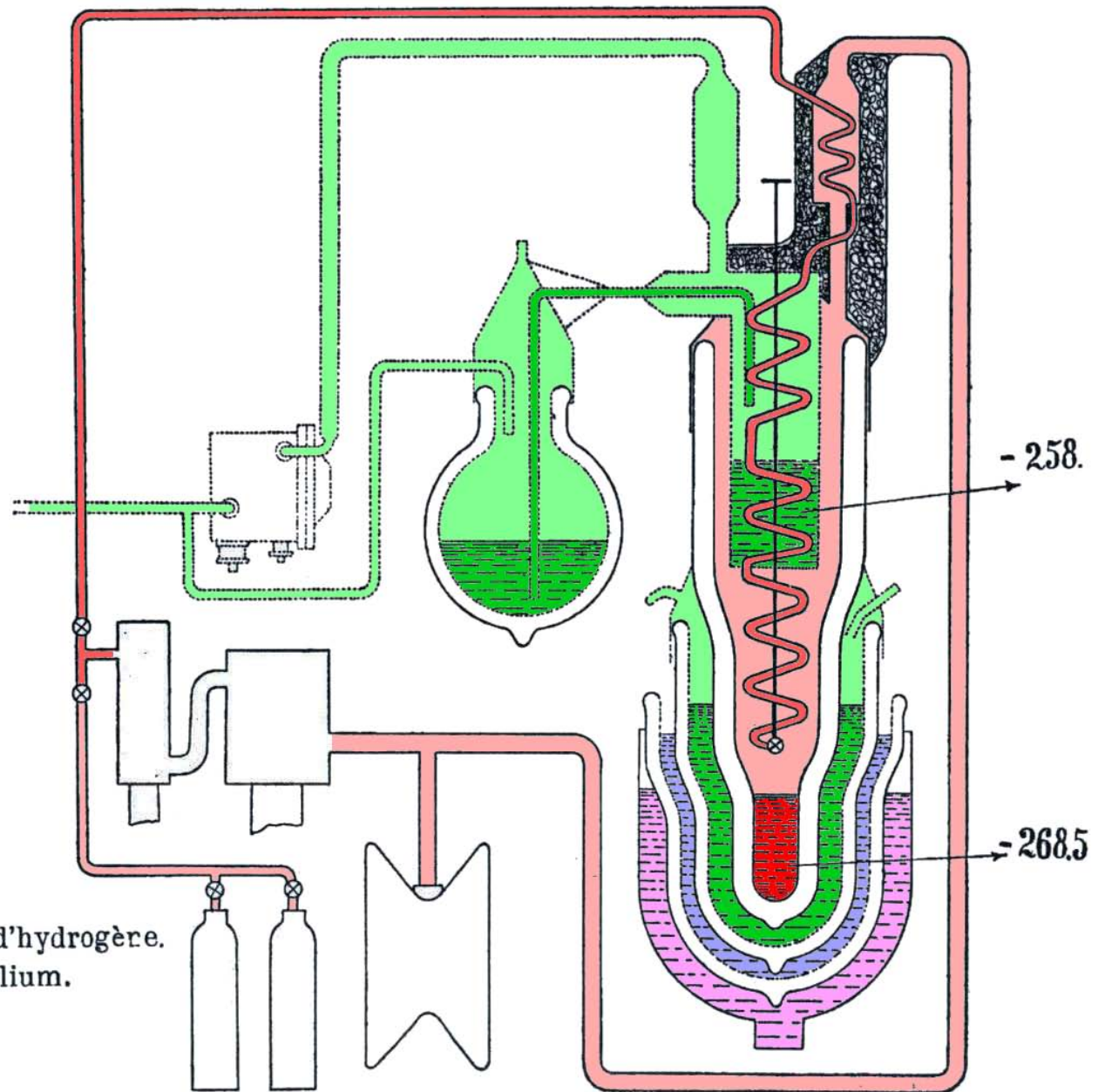
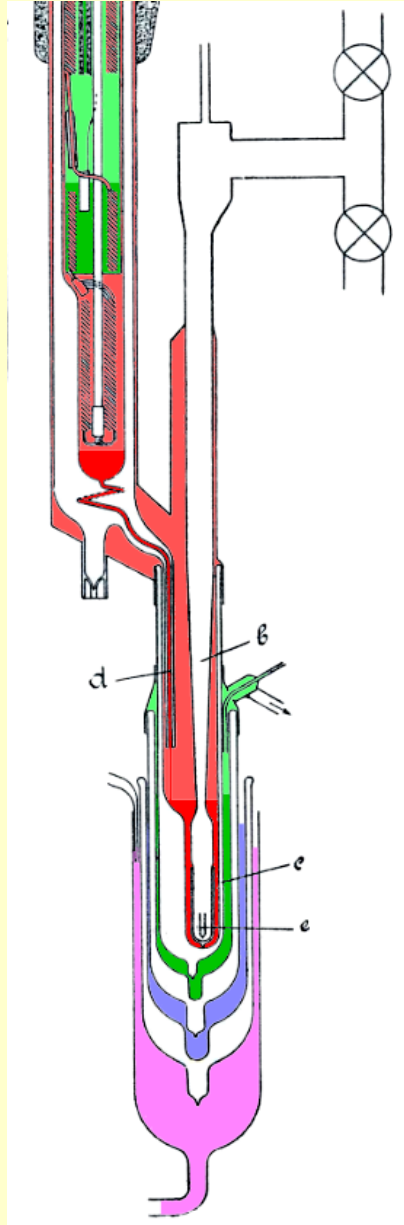
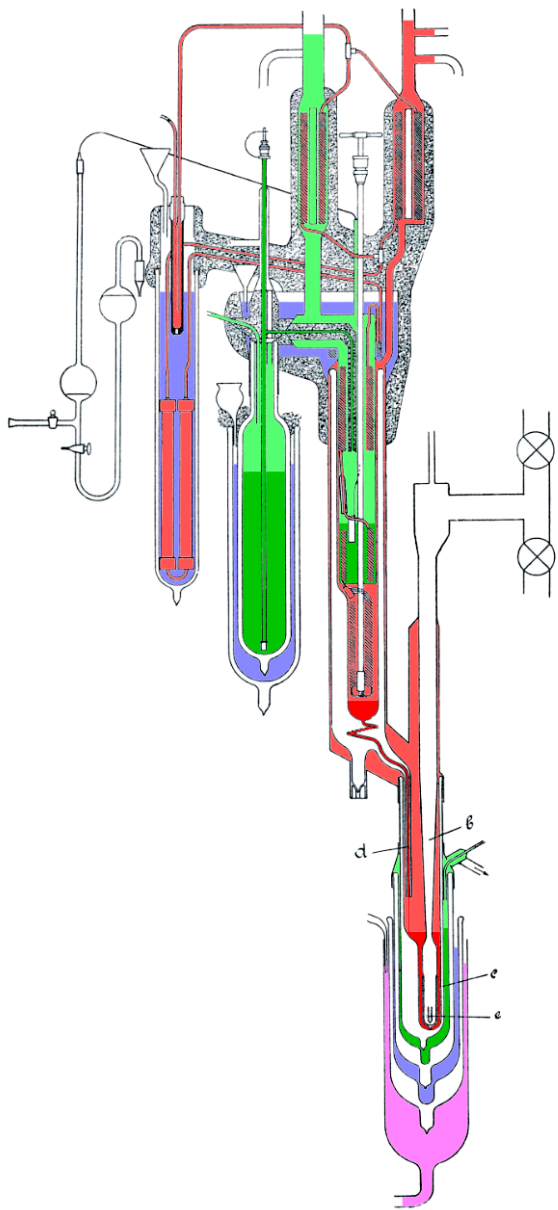
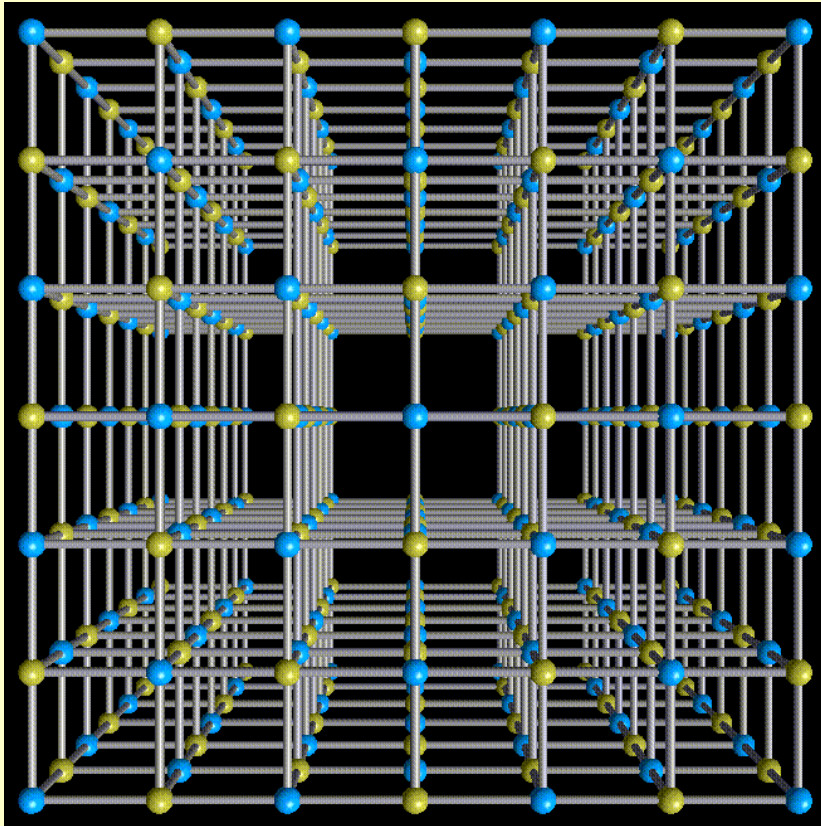


Fig. 4. — Schema de l'appareil de liquéfaction de l'hélium. 10 July 1908



First attempt to transfer liquid helium from the liquefier to a separate cryostat (12 March 1910)



For the experts

Kamerlingh Onnes's model

$$R(T)/R_0 = \sqrt{(TE_T/T_0E_0)}$$

with

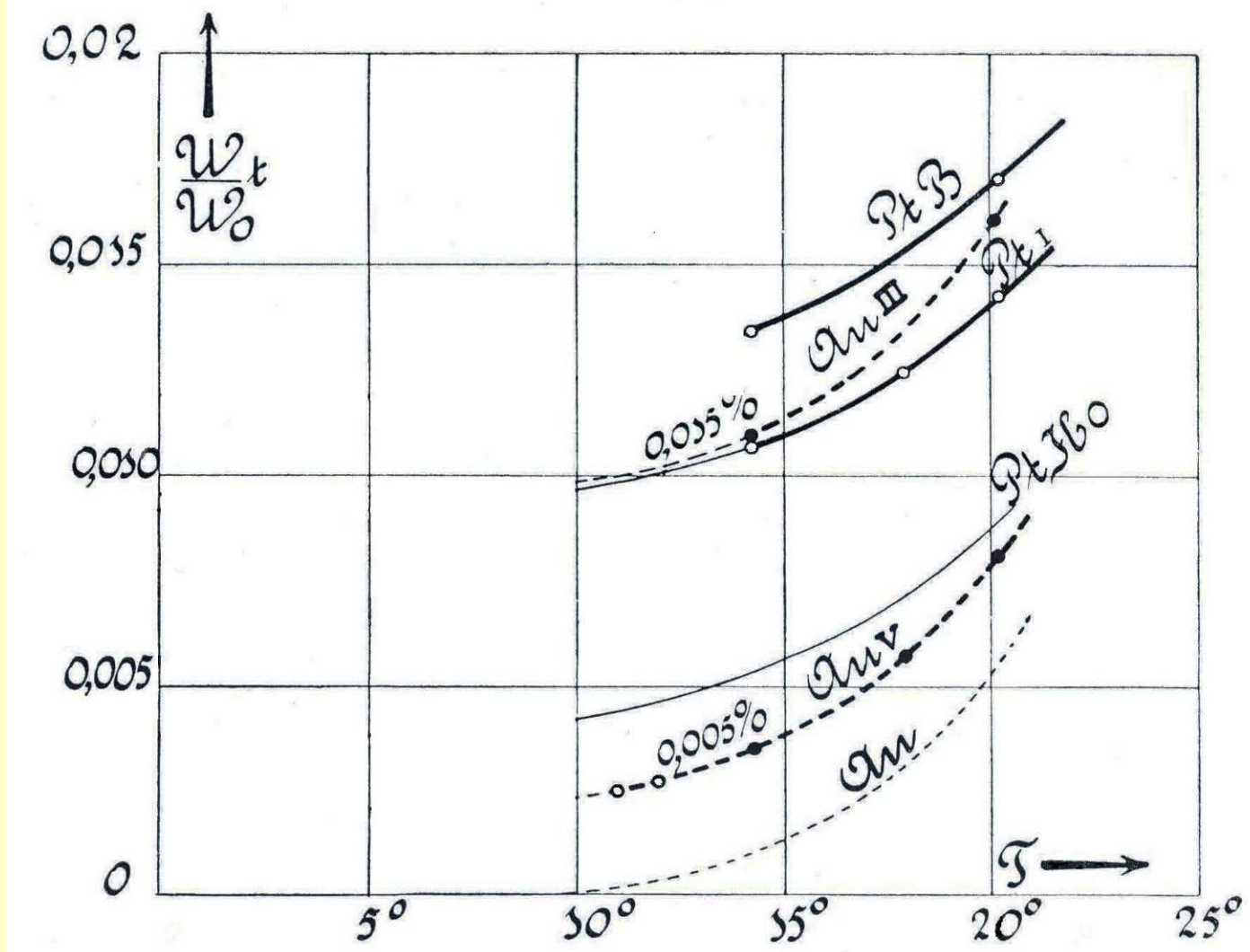
$$E_T = 3R\beta\nu[\exp(\beta\nu/T - 1)]^{-1}$$

$$\beta\nu = h\nu/k_B$$

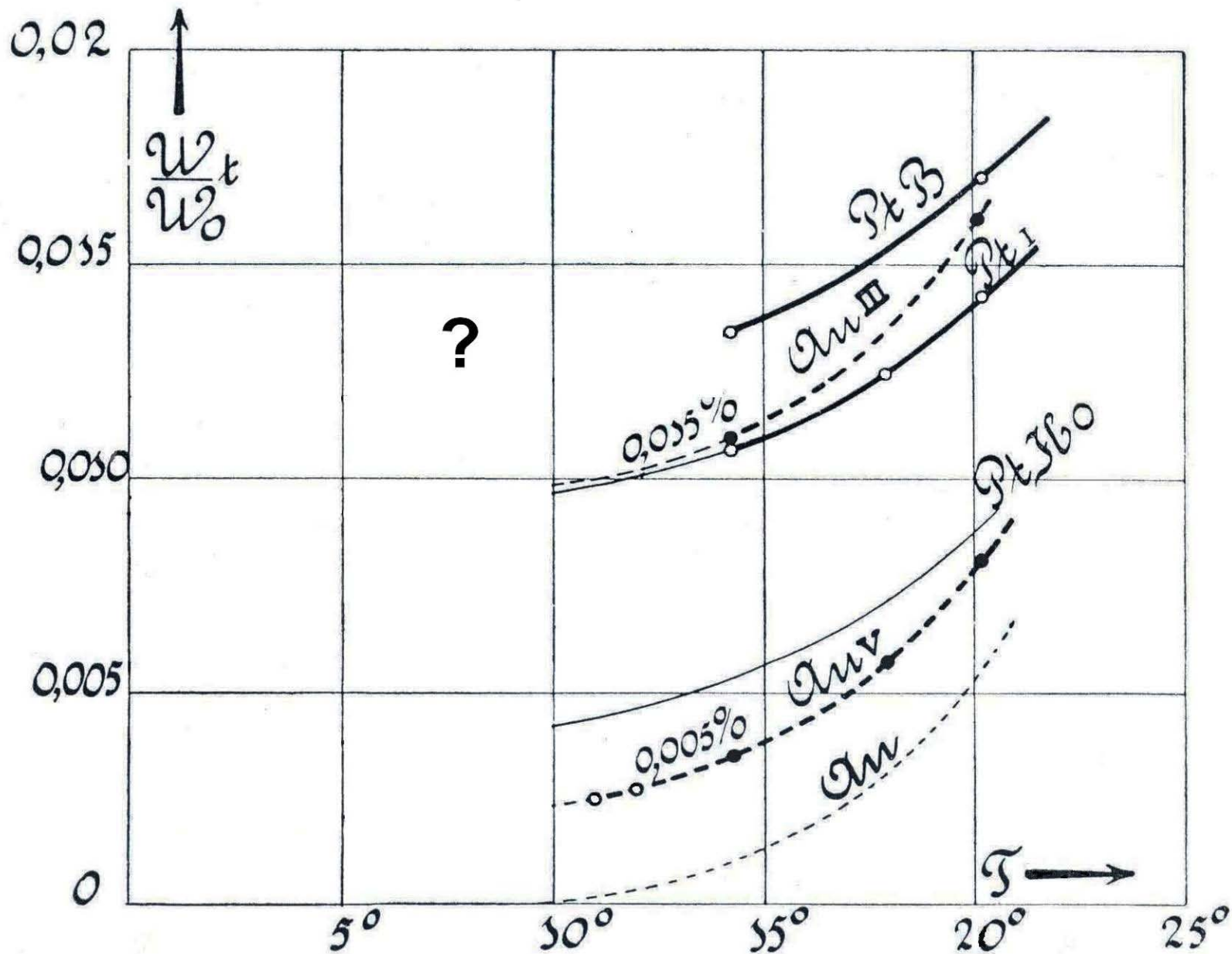
ν frequency of Planck vibrator

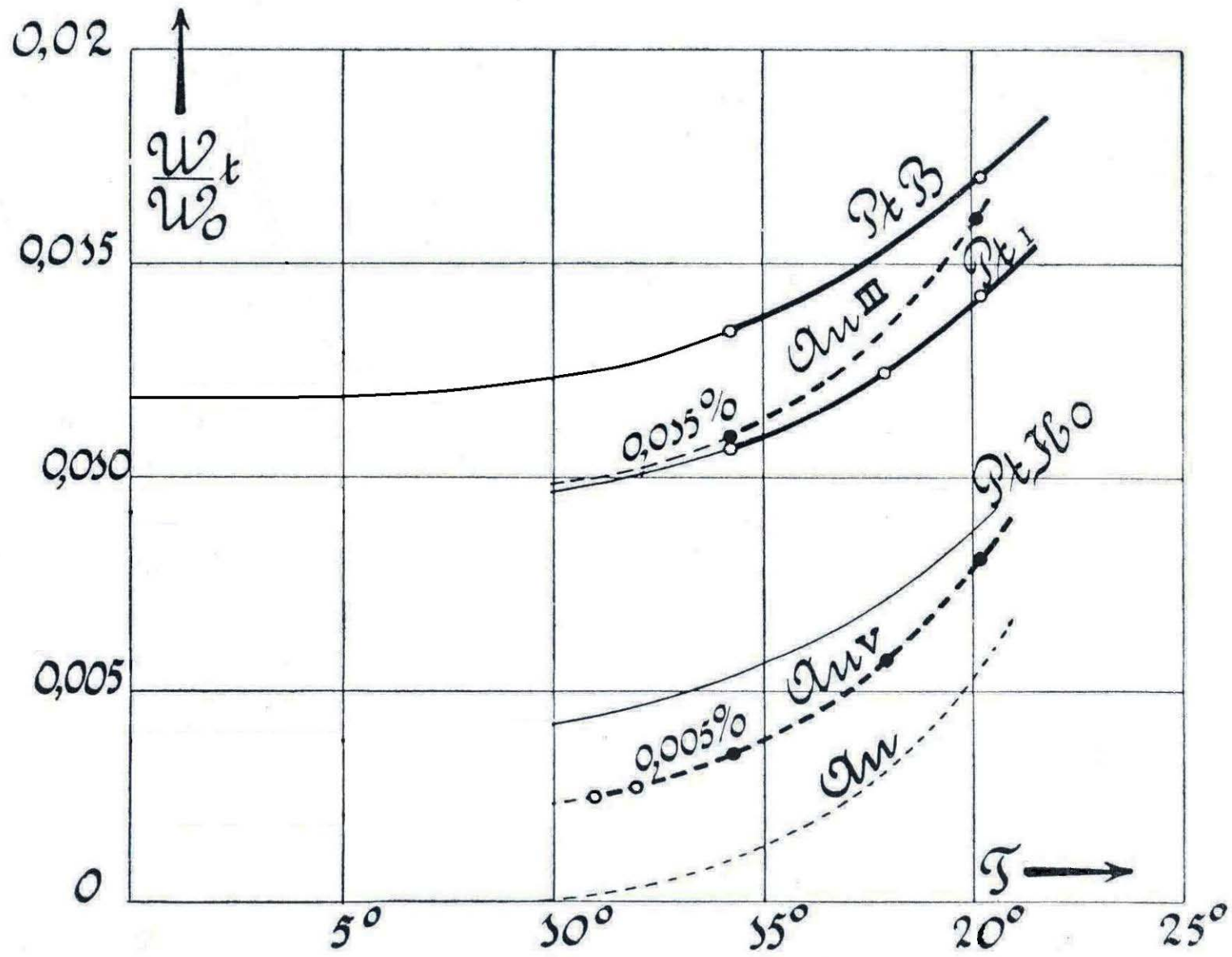
Crystal lattice

The conduction electrons in a metal will be scattered by the thermal vibrations of the lattice atoms and by static impurities

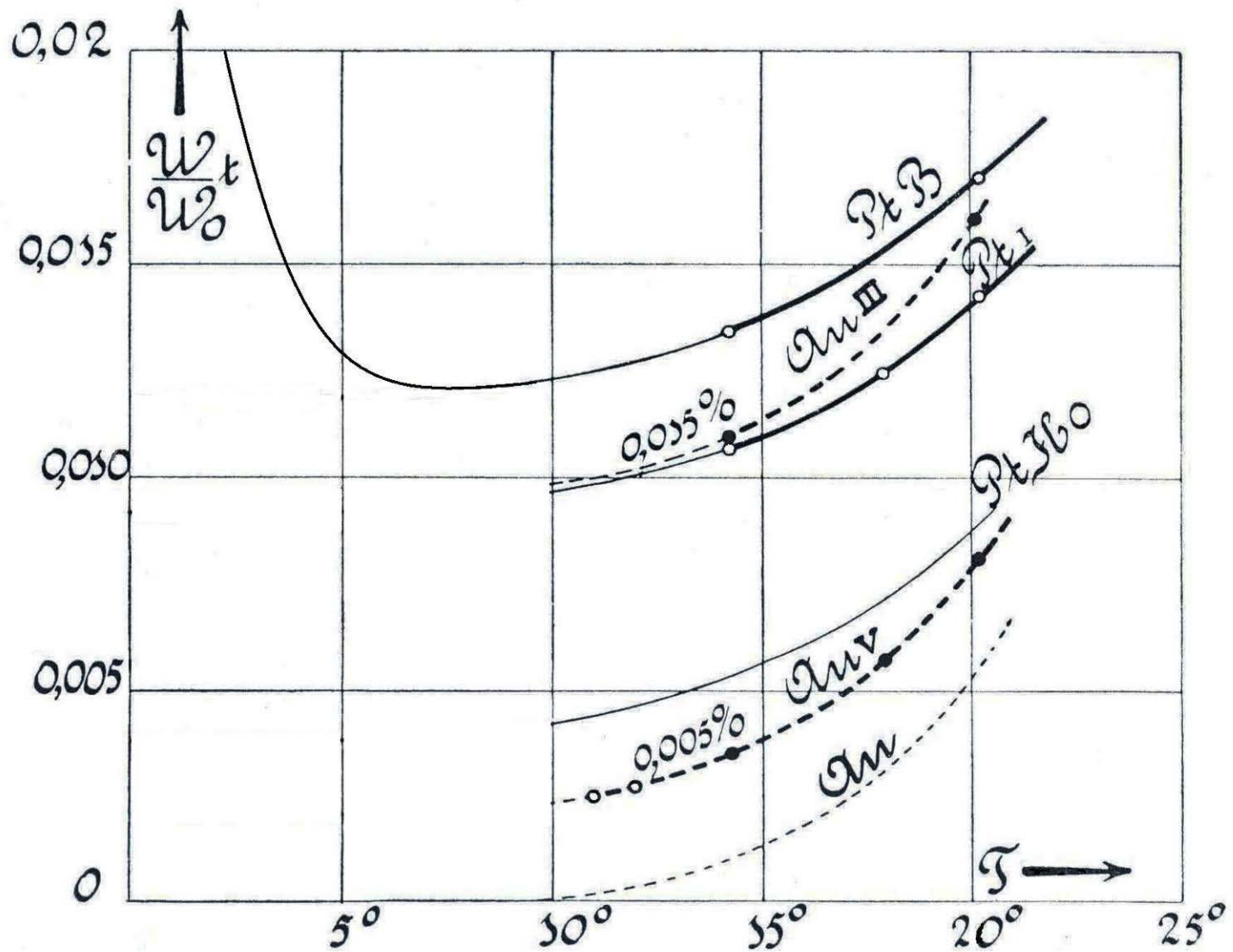


Resistance versus temperature of Platinum and Gold resistors (1907)

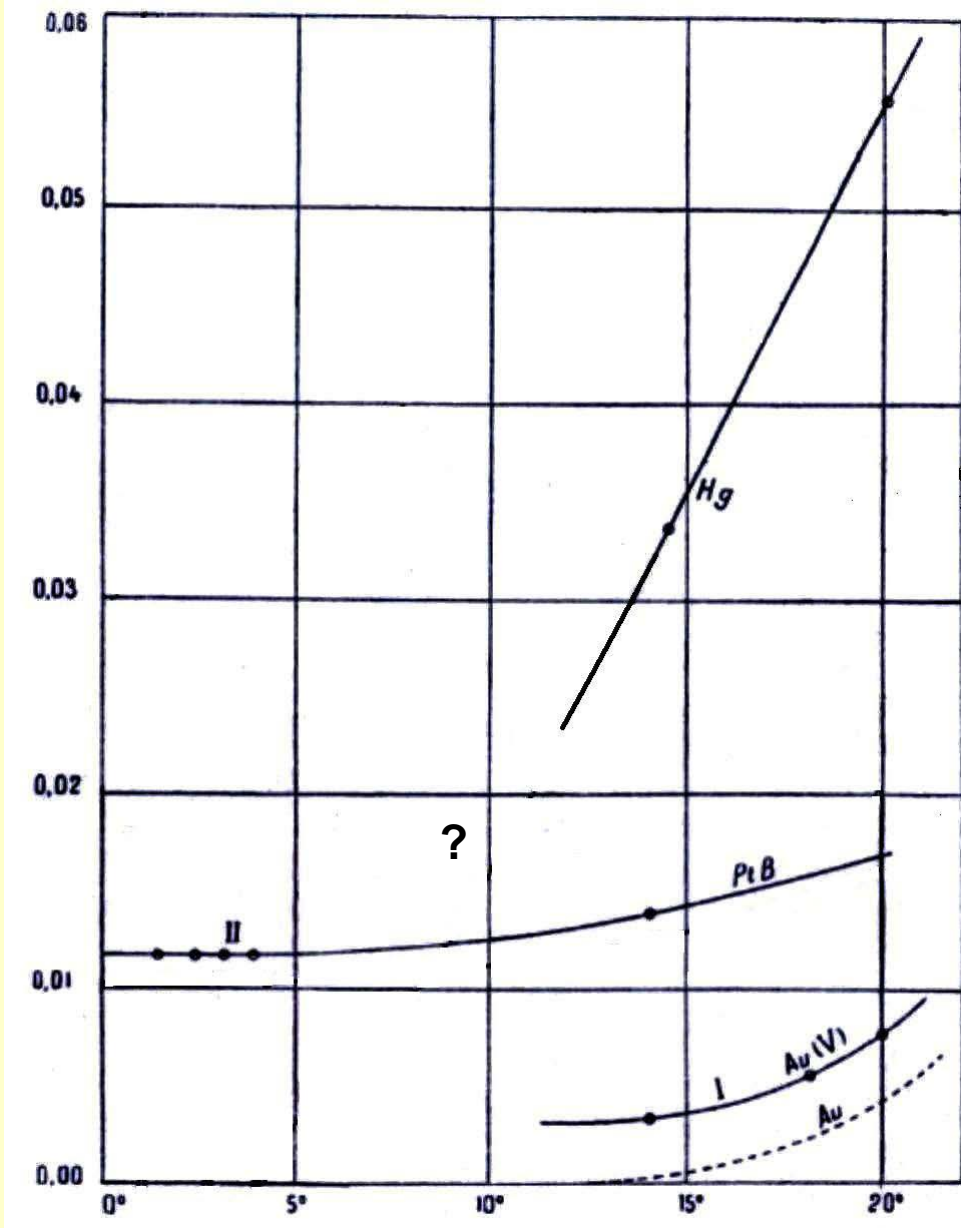




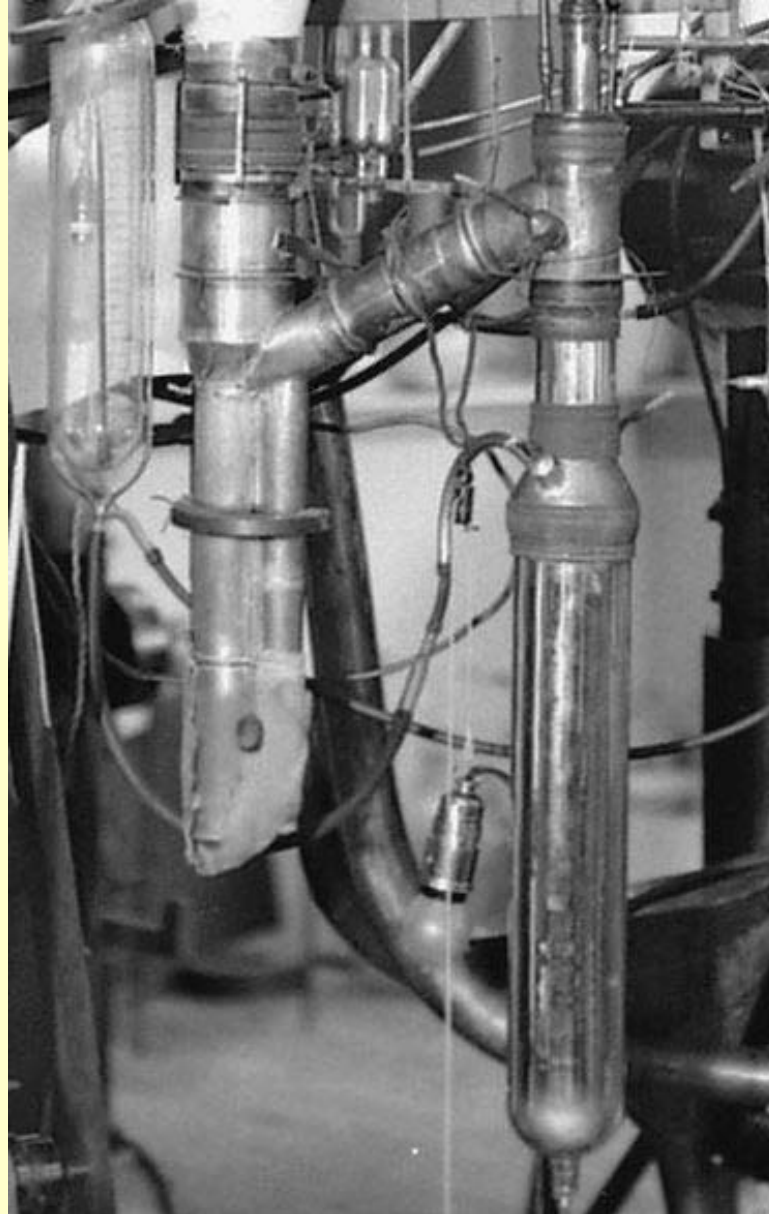
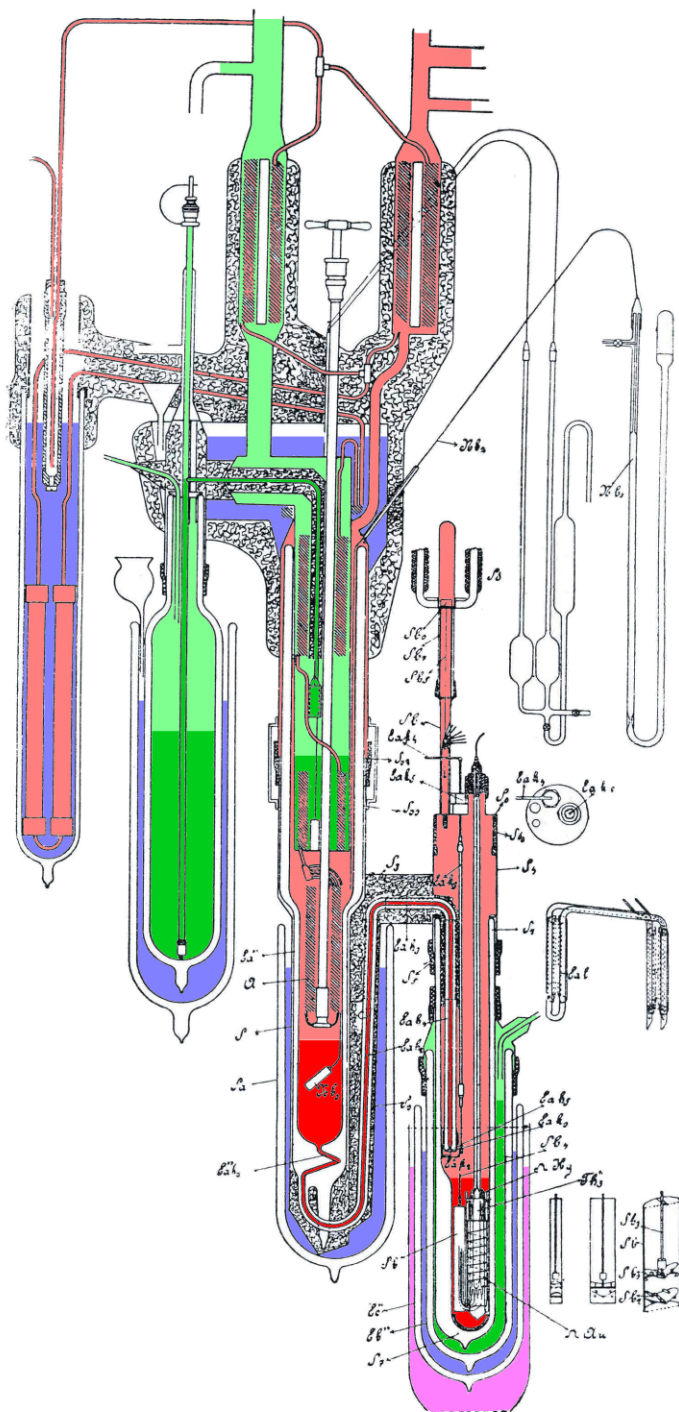
Scattering by Planck vibrators and lattice impurities



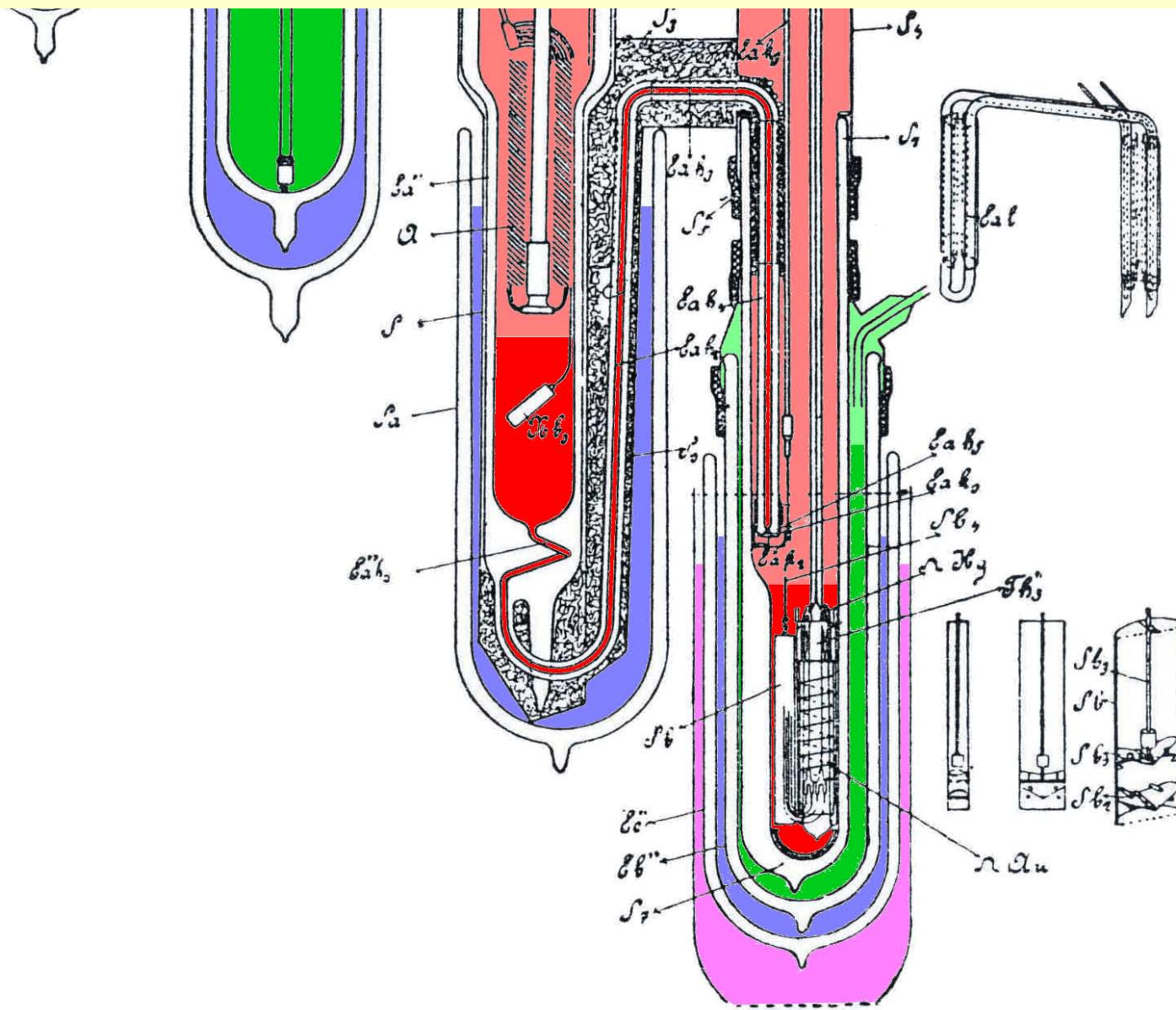
Freezing out of mobility of conduction electrons, Lord Kelvin (1902)



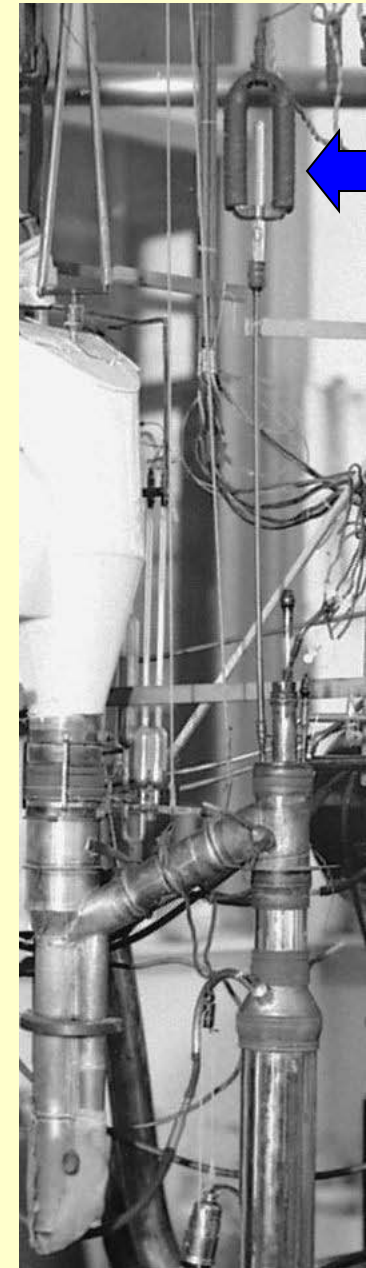
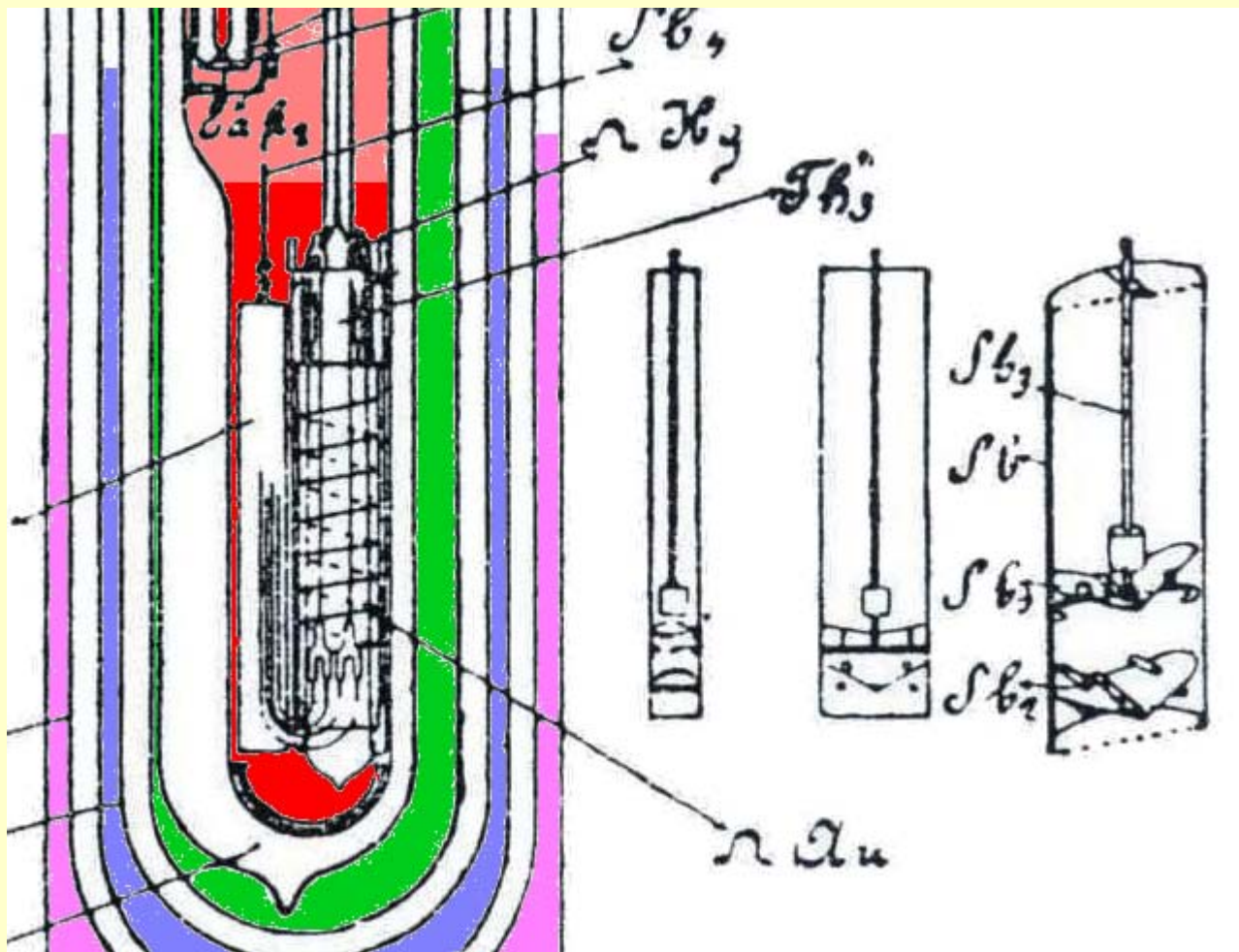
R vs T of mercury resistor in comparison to platinum and gold



Set up of 8 April experiment




Transfer tube with valve controlled from outside the cryostat



What was placed inside the cryostat?

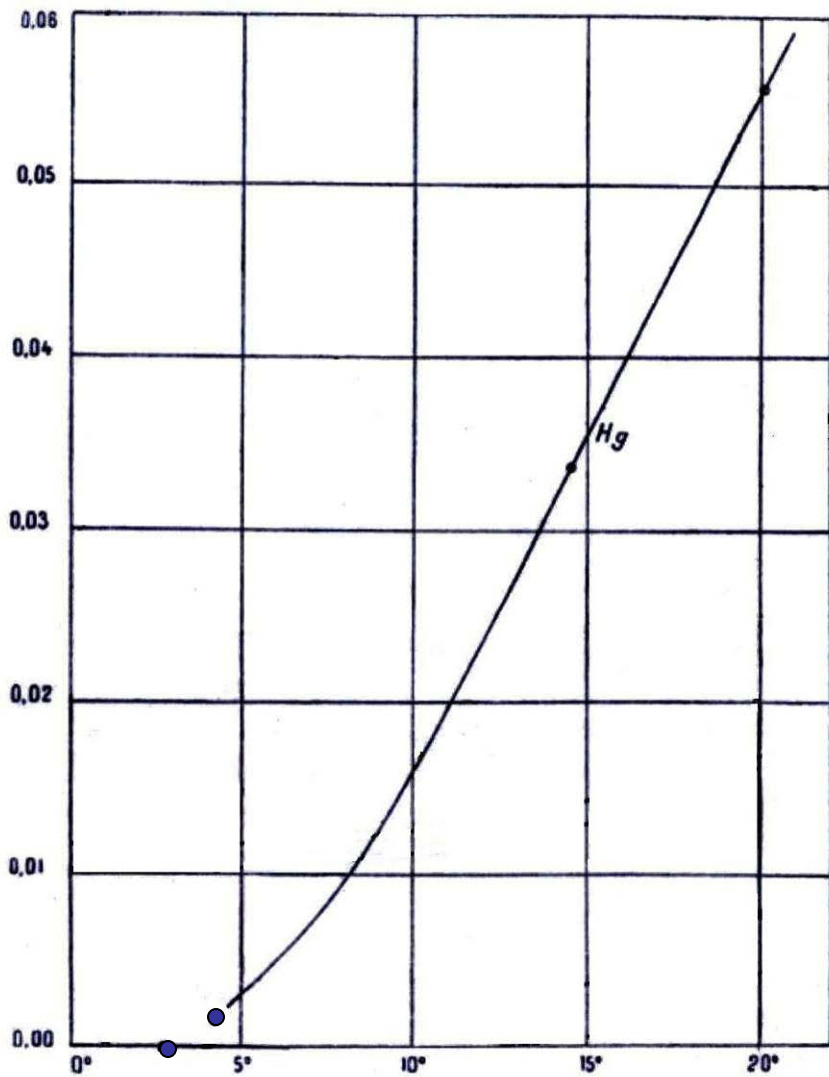
The stirrer (“het pompje”) electromagnetically driven. It functioned well.

“Pompje werkt prachtig”, HKO writes in his notebook.

200 klein verzelfde te maken. De temp
 in helen cyclus is nu veel gelken 200° in
 12⁴⁰ ' gewalt met helen
 12⁴⁷ ' pompje smelt, nu een klein
 water om de buis van pompje. Pompje smelt

 prachtig 1² ' verdampt
 is nu op te maken om dat
 er iets om te maken. Verdampt is
 waanbrak om een wholeje. 1⁴ ' gewalt
 tot vlakke en platte van 2 en andere
 geometrische gelykdommen van. Verkeerde
 hul. Delectische om te ont gemaakte, geheel
 bewerd. Temperatuur gemaakte
 2¹⁵ ' geen overblijft tot tenster 12⁴⁷ '
 bevestiging. Nu. myt nu 8° in
 2⁴⁰ ' weer te gemaakte, by toerbeide van
 danest er niets minkens. Merit om
 helomnis er al by. 1¹⁵ ' om te zilveren
 meting gemaakte verkeer, met over
 temp om de vrees.

inre
 Darme huff ook gecontroleerd 0 punt,
 waanbrak lek in water. bl.
 Verdampt buis gemaakte met helen
 3⁵⁰ ' nu een gemaakte met gemaakte van
 Conclum dat gecondensate helen
 actus gering - spec. namet van huff te
 Kerk huffing en byende vrees.
 3⁵⁸ ' gemaakte verdampt van
 hul, tot op 14, 7 an gemaakte stand
 van vrees, gelukkig met vrees
 schent by helen, die waanbrak huffing
 in tenster tenster stand.
 4¹⁵ ' is afgevoerd tot op pompje van. De meting
 van temperatuur gemaakte. Kerk huffing hul
 Verkeer met gemaakte.
 Hand helen met. Pompje is by gemaakte van
 van helen.
 Darme nu, lichte vrees, ^{huffing} met
 Wetsen om te gemaakte. Darme gemaakte
 van helen van helen. Met huffing

THE page from HKO's notebook



Experiment of 23 May 1911

They increased the temperature from 3.0 K

HKO's notebook says:

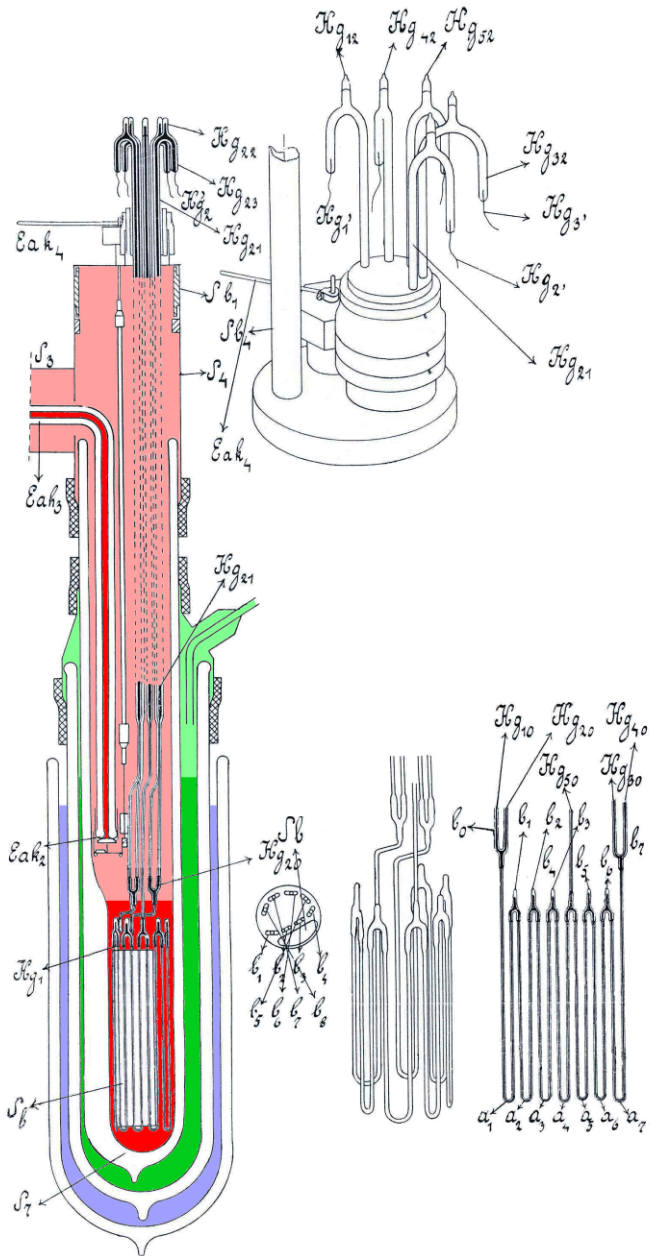
At 4.00 [K] not yet anything to notice of rising resistance.

At 4.05 [K] not yet either.

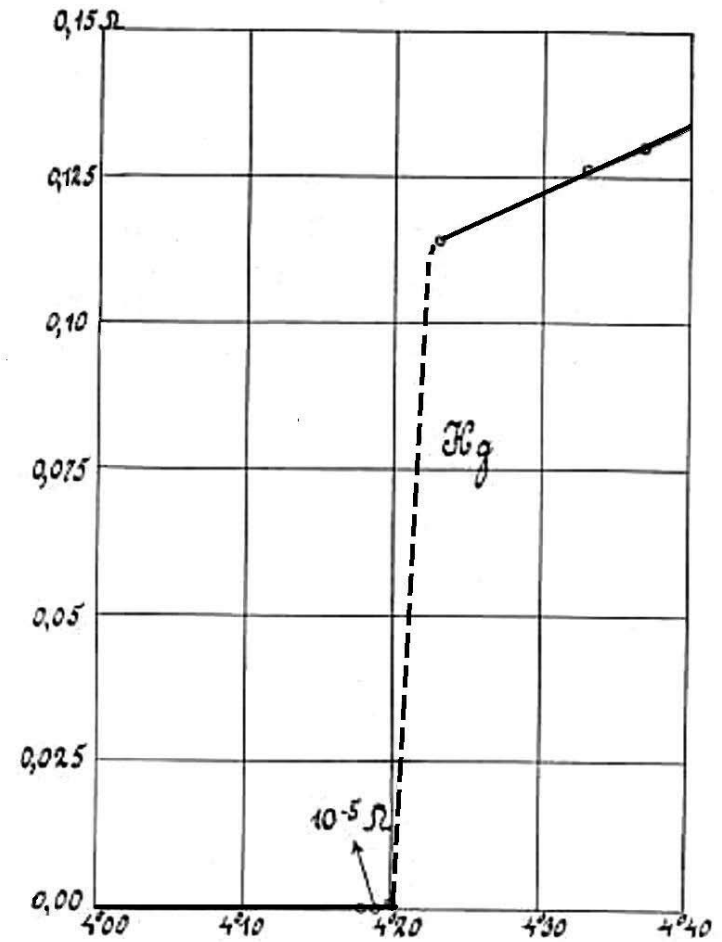
At 4.12 [K] resistance begins to appear.

Notebook entry of May 26: no short circuit!

Only two points were measured.
HKO: my model works indeed!
The superfluid transition of He was
not mentioned in the publications.



Experiment of 26 October 1911 with the historic plot showing the resistance jump at 4.20 K.



Subsequent developments

Holst was actively involved.

Was it a phase transition? Specific heat experiments failed.

22 June 1912: Mercury with gold or cadmium turned out to be superconducting as well. Even with amalgam for backing of mirrors the resistance disappeared with a jump and at a higher T_c !

Autumn 1912: also tin (3.8 K) and lead (~ 6 K) were superconducting.

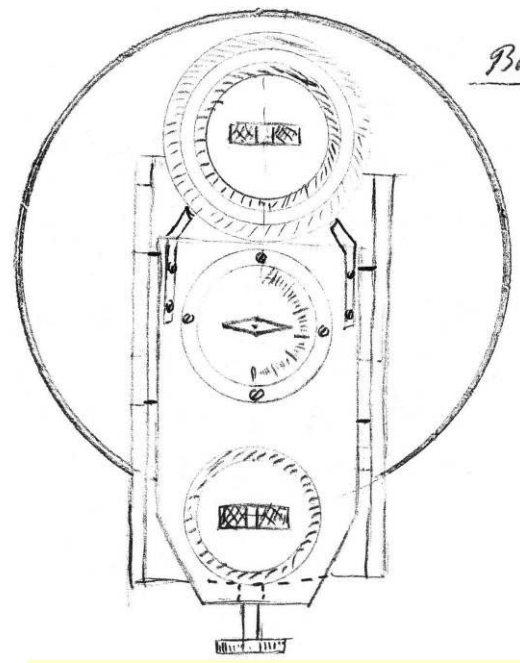
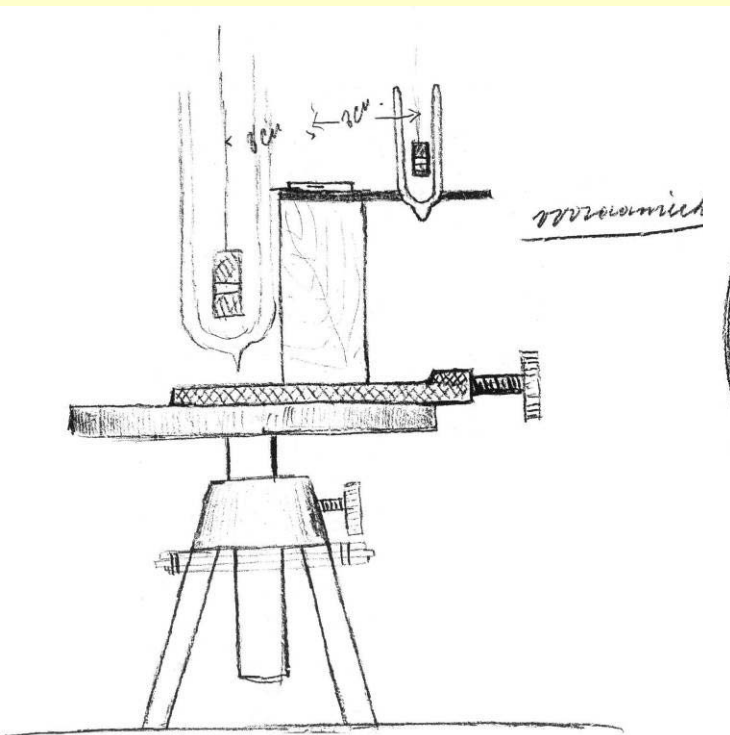
Dreams of big magnets (almost) without losses. December 1913: a big disappointment, the resistance came back in a few tens of mT (a few 100 Gauss).

Were the Planck vibrators responsible? No measurable isotope effect of Pb.

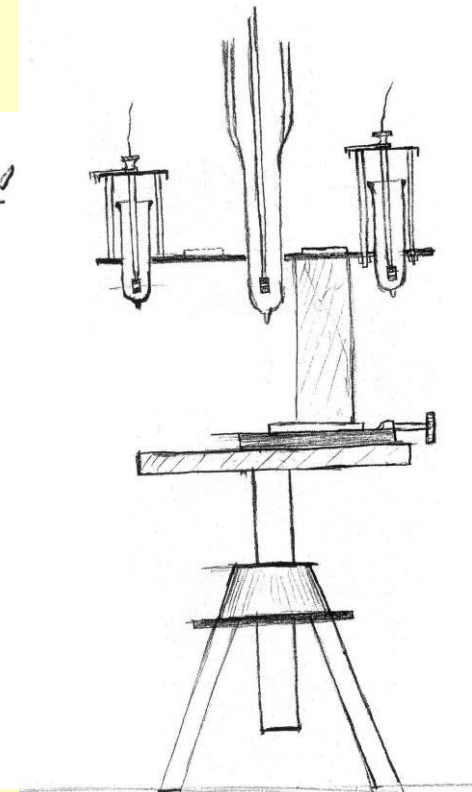
Spring and early summer 1914: persistent current experiments.

This exciting result spread quickly and convinced even the theoreticians .

Then World War 1 broke out and experiments were discontinued until the early 1920's.

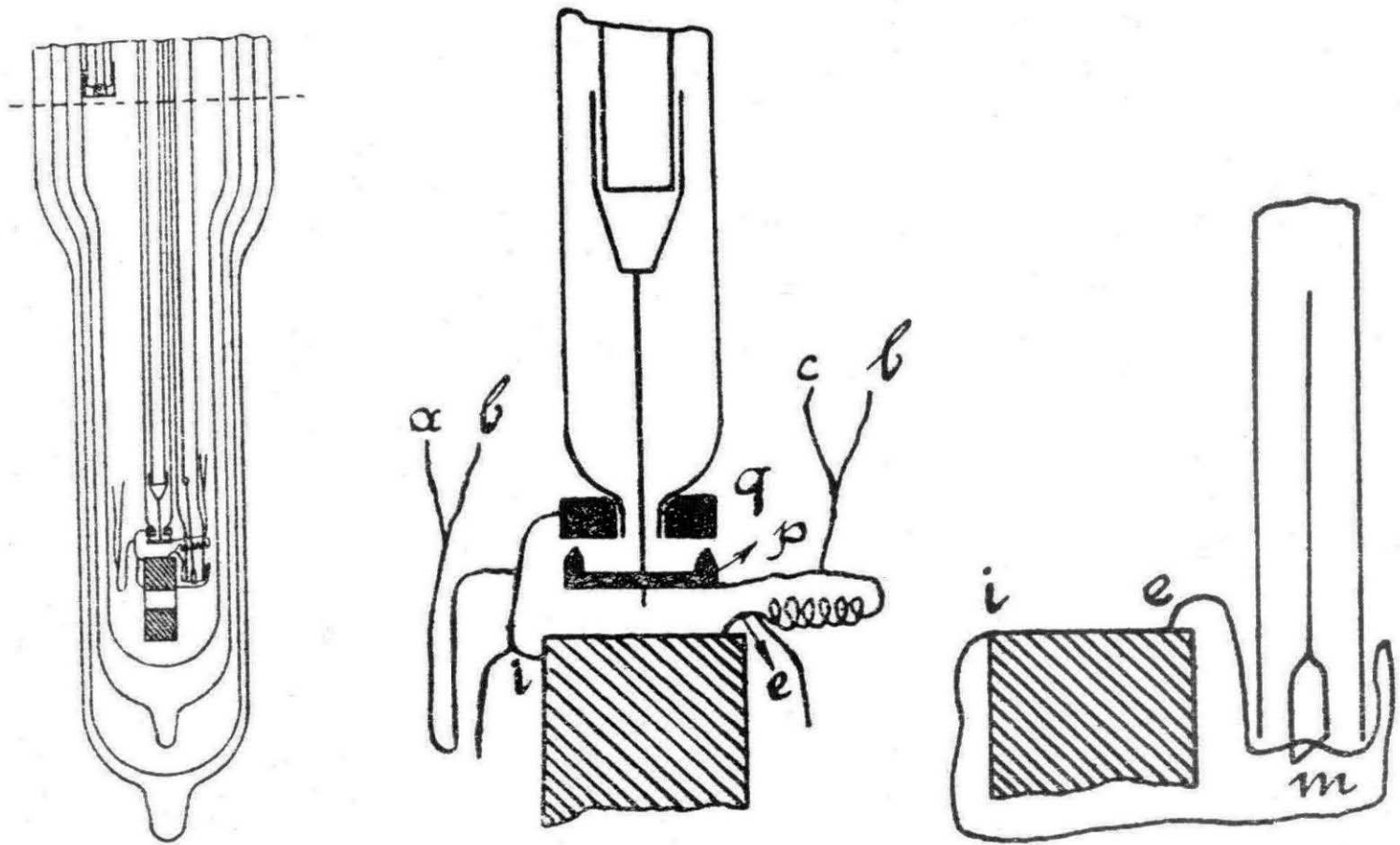


Bovermannschicht



The persistent current experiments of 1914 finally convinced the theoretical





The first (mechanical) persistent mode switch and
a cutting device (1914)