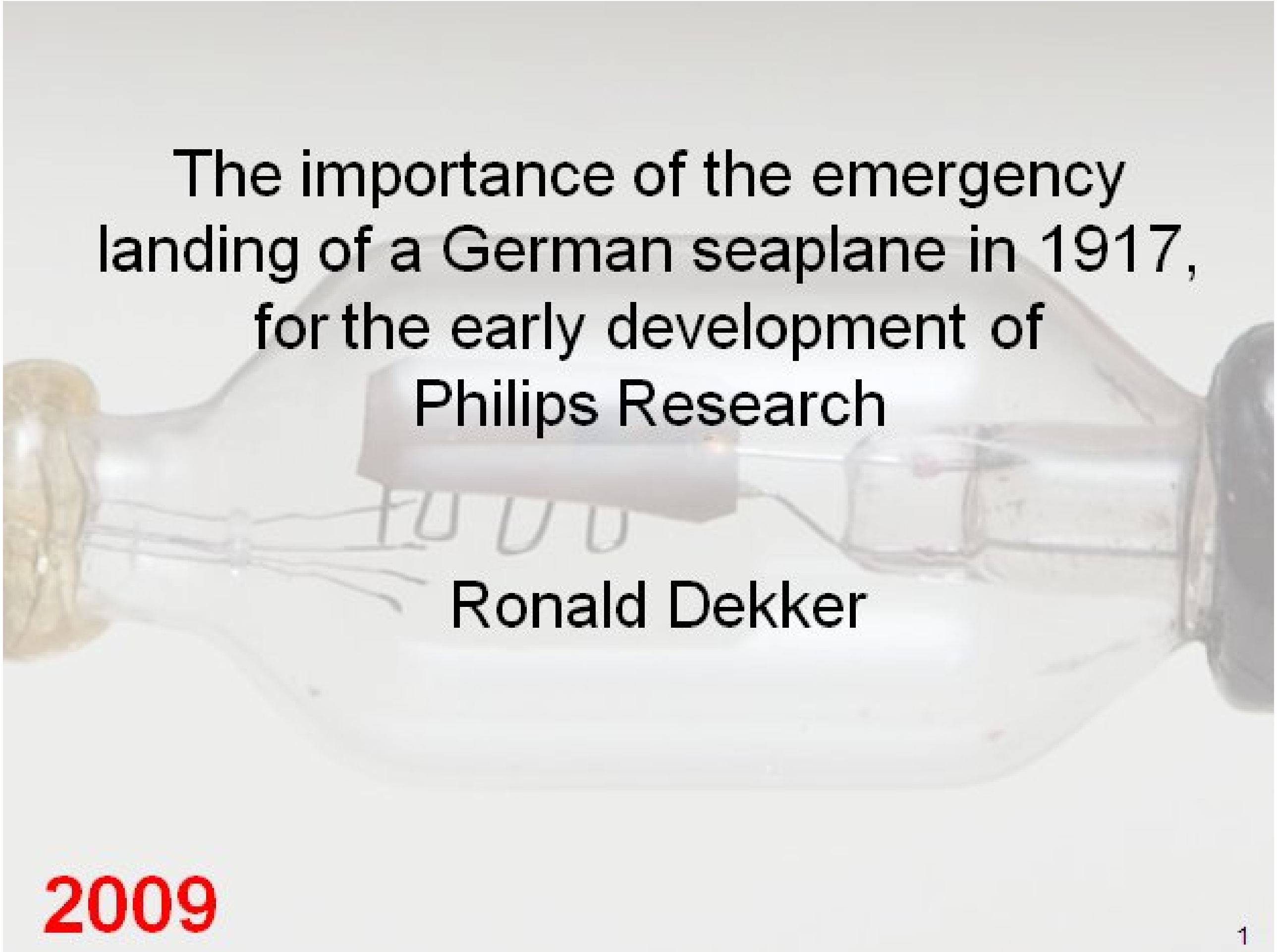
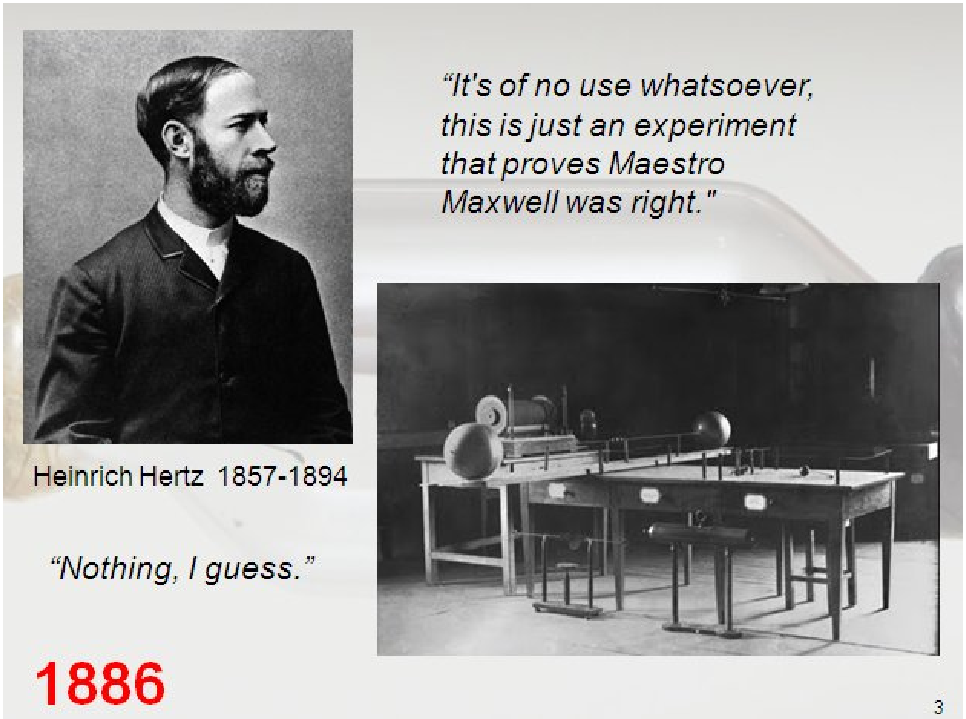


This presentation was first given during the SAFE/ProRISC Conference in Veldhoven on the 26th of November 2009 . The slightly modified version on this webpage was presented as the Christmas Colloquium at Philips Research the 18th December 2009.

Ladies and Gentlemen,
On a quiet summer evening in august 1917 , in the middle of the First World war, a small German Seaplane had to make an emergency landing in Dutch territorial waters in the north of Holland. During the First World War, Holland had assumed a neutral position. As a consequence they were obliged to imprison soldiers from both sides. So obviously they set about to rescue and capture the German pilot and to salvage his plane. In his plane they discovered something that surprised them: a radio receiver.

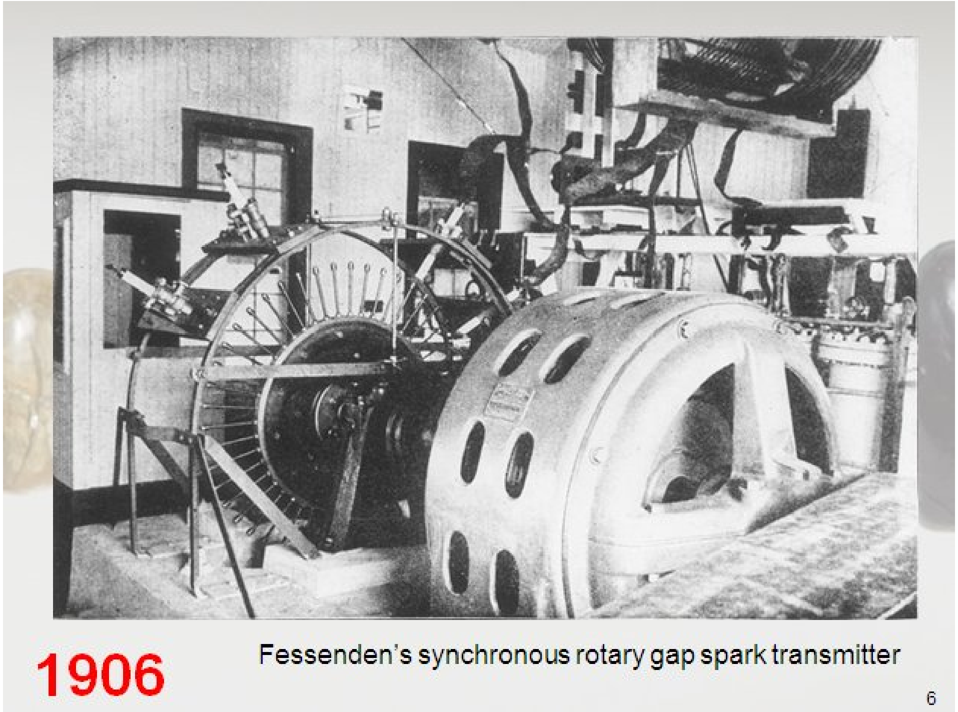


Now, radio was still something of a novelty in 1917. In 1887 Heinrich Hertz had demonstrated the existence of electromagnetic waves by inducing extremely small sparks in a resonant antenna. When asked about the practical importance of his experiments he replied: "It's of no use whatsoever, this is just an experiment that proves Maestro Maxwell was right." Asked about the ramifications of his inventions Hertz replied: "Nothing, I guess."

Well, that was not what 8 years later the Italian inventor Marconi had in mind. Marconi may well be called the Bill Gates of radio. Both man have a lot in common: they are both largely autodidact not finishing their educations, both man had a clear vision and an enormous drive to turn their vision into a commercial success, and finally, both man largely built their products on ideas from others. Marconi, inspired by the experiments of Hertz, had the vision of commercial wireless telegraphy. After furious experimenting and building on the work of Alexander Popov and Edouard Branly, Marconi built a "wireless telegraph" that could bridge a distance of 2.5 km. Finding little interest in his work in Italy, Marconi immigrated to England at the age of 22, to further pursue his dream. He gave several successful demonstrations for British postal and military officials, during which he gradually increased the transmitting distance of his system.

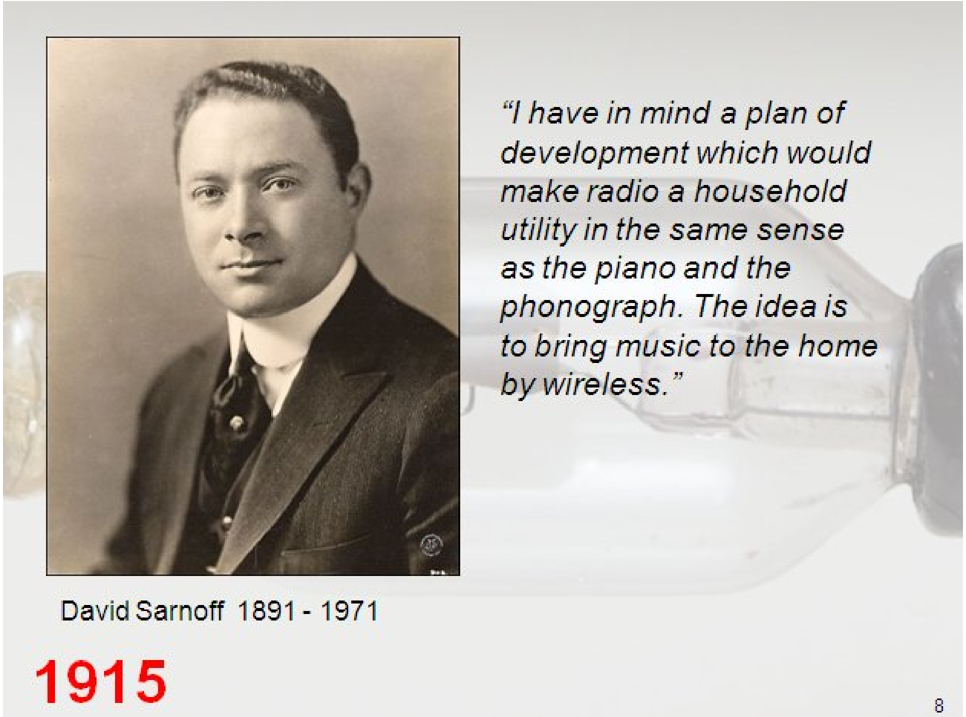
Finally, in 1903 he succeeded in transmitting a message over the Altlantic Ocean between Poldhu in Cornwall and Signal Hill near St. John in Newfoundland, a distance of more than 3000 kilometers. The Marconi system used damped electromagnetic oscillations generated by sparks. This worked reasonably well for telegraphy, but it generated an awful amount of noise and was therfore completely unsuitable for speech.

For speech transmission a continuous wave was needed, but the problem was that around 1900 nobody had the faintest idea how a continuous wave at reasonably high frequencies could be generated.



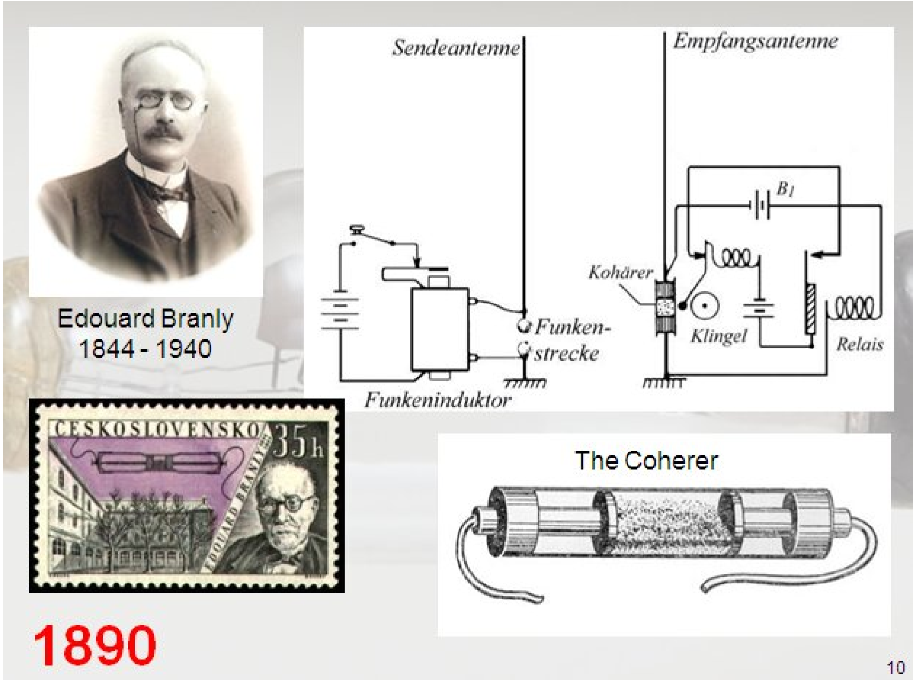
The first usable semi-continuous wave oscillation was generated with the synchronous rotary-spark-gap transmitter designed by the visionary American Reginald Fessenden. Fessenden, who by the way also didn't finish his high school education, learned his skills in Edison's Laboratory.

Using his Continuous wave transmitter, Fessenden broadcasted on Christmas Eve in 1906 the world's first radio program in which he made a speech an played the Largo from Handel on his violin. It was a milestone in the history of radio, but unfortunately remained an little known incident. For the next fifteen years radio and wireless telegraphy would be limited to military and maritime applications.



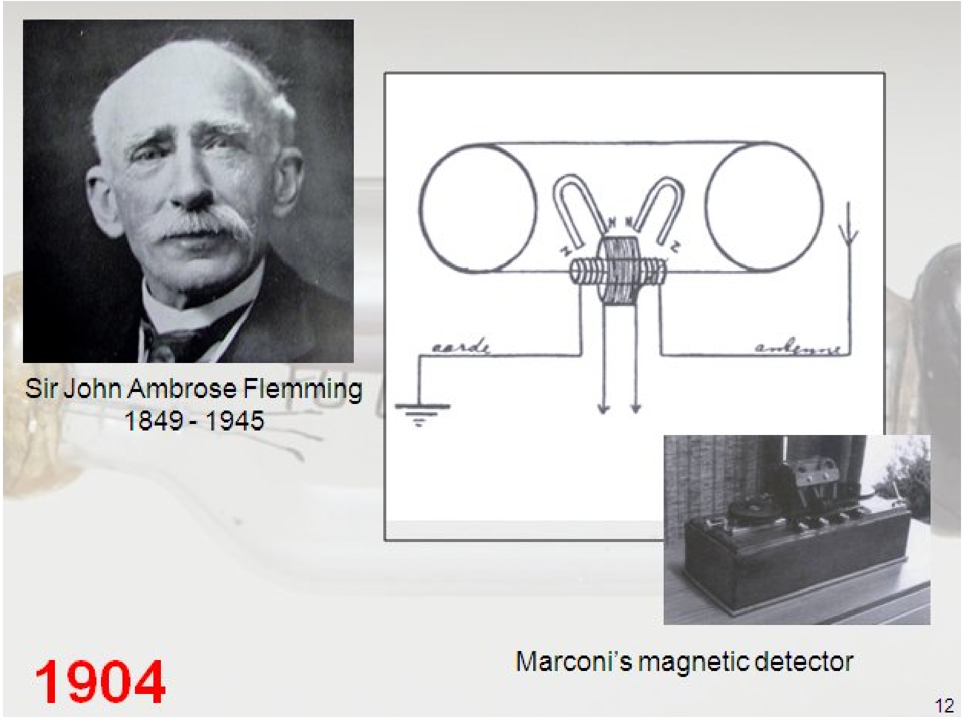
In 1915 a young employee of the American Marconi company and future founder of NBC, David Sarnoff, wrote a remarkable memorandum to the board of directors: "I have in mind a plan of development which would make radio a household utility in the same sense as the piano and the phonograph. The idea is to bring music to the home by wireless." The memorandum was rejected, because radio was considered to be an instrument for point-to-point communication. The idea of broadcasting information to a large audience was simply something unheard of.

This pretty much summarizes the status of radio at the time when the military discovered the radio receiver in the German airplane. As it turned out, it was quite an advanced radio because it used two EVN 94 vacuum tubes from Telefunken, switched in cascade! As you know, all radio receivers need some kind of a device to detect the presence of the radio waves.

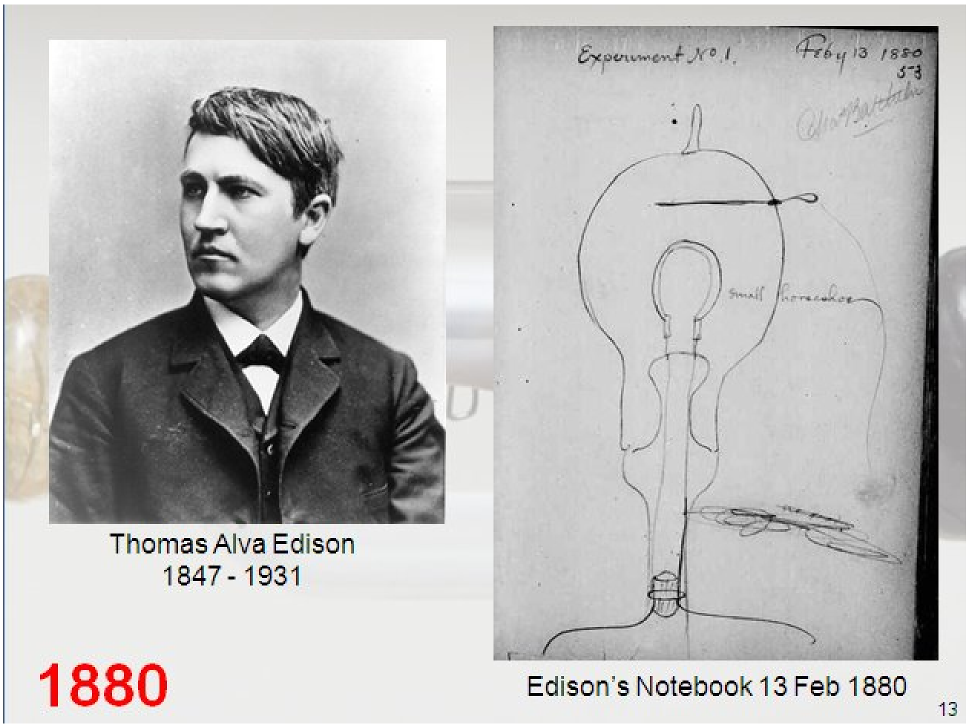


Marconi used in his wireless telegraphy instruments a so called coherer which was invented by Branly in 1890. A coherer is a device consisting of a glass tube filled with some metal filings usually nickel in between two platinum electrodes. In the normal off state, the DC resistance between the electrodes is very high. However, when an RF signal from an antenna is passed through the electrodes, the metal particles "weld" together so to speak, and as a result the DC resistance drops to such a low value that it for intance can ring a bell. By gently tapping the device, the DC resistance can be restored to its initial high value.

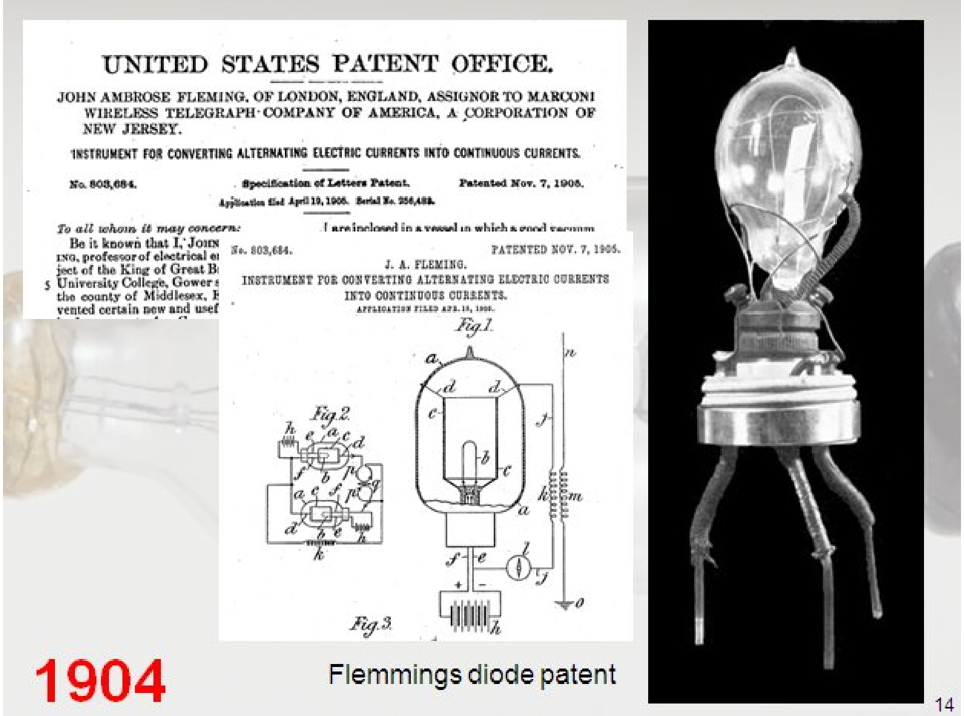
In the picture you see a coherer that Marconi manufactured in 1898. To increase the sensitivity he had reduced the distance between the electrodes to less than a millimeter. He also found that the coherer worked better when a small fraction of hard-silver was added to the nickel filings. Finally, the device was placed in a vacuum tube to prevent oxidation of the filling. In it's crude form this device already contained all the elements which were going to keep us device engineers busy for the next century: decreasing dimensions, material control and doping, and packaging!



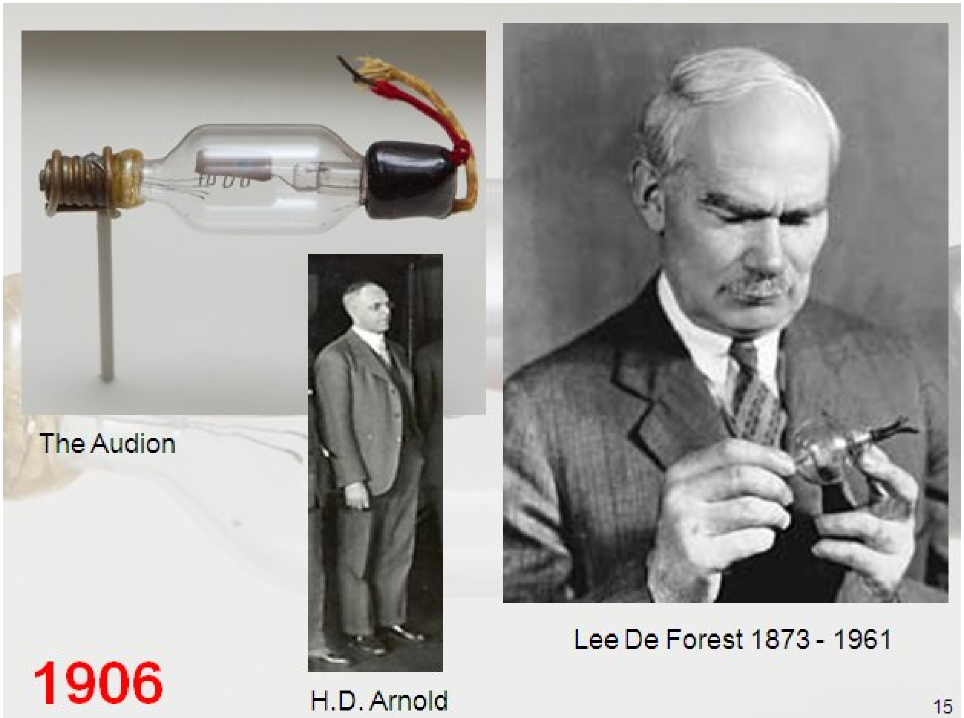
In 1904 the British physicist John Ambrose Flemming was, as scientific advisor to Marconi, studying the detection of electromagnetic waves using a new device: the magnetic detector. This detector reproduced the sparks from the transmitter as soft clicks in a headphone. Now Flemming was to a large extend deaf, so he had a problem in hearing these soft clicks, frustrated by his handicap, he started thinking about ways to make the signal visible, rather than audible. He remembered some experiments he had been doing almost a decade before when he was employed as a scientific advisor to Edison.



In these experiments he investigated an effect that Edison himself had discovered in 1886. Trying to reduce the blackening of the glass balloon of his light bulbs, Edison had placed a metal plate in the balloon. Edison discovered that this plate conducted a current when it was connected to a positive voltage, but that there was no current when it was at a negative potential. Edison had no clue to the explanation of this phenomenon and he also didn't have a practical application for it, but he patented it nevertheless just by habit.



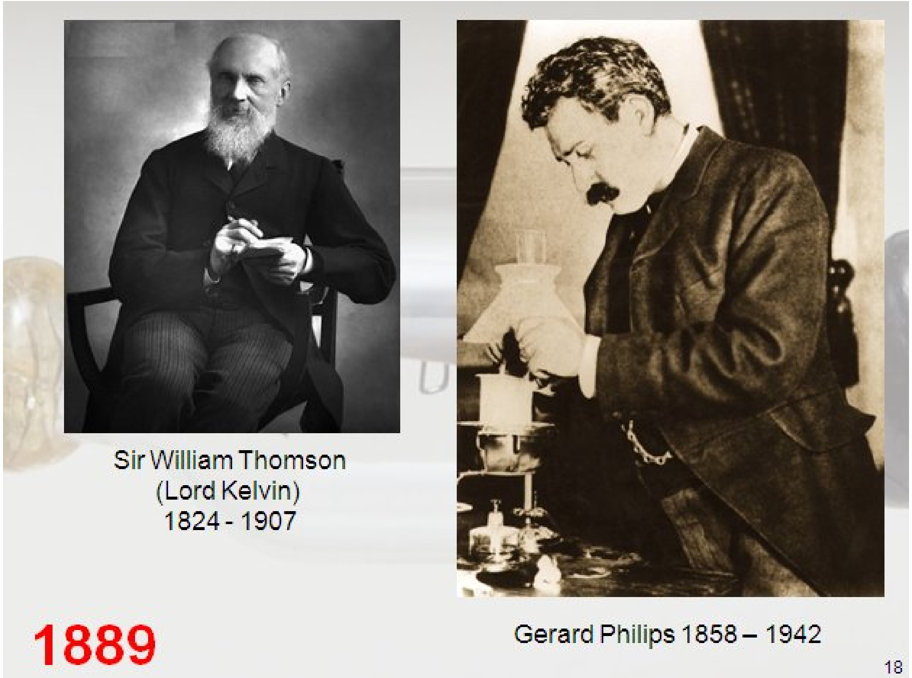
Remembering his old experiments Flemming dug up one of his old test lamps and in an improvised set-up demonstrated for the first time the detection of radio waves with a vacuum valve. It was an immediate success. The vacuum valve or diode quickly replaced the coherer and all the other cumbersome detectors that had been developed in the mean time.



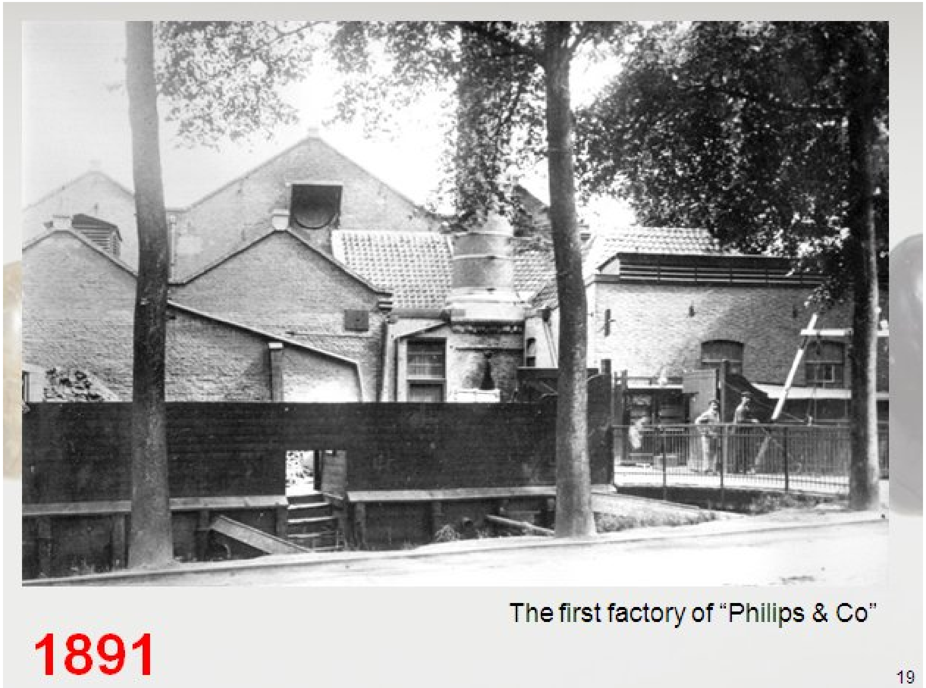
Lee de Forest and Flemming couldn't have differed more: Flemming was the settled and renowned scientist, while de Forest basically was a penny less entrepreneur. On one point however they had a common interest, during his PhD on the reflection of electric waves, also de Forest became obsessed by the search for a good and practical detector. In 1906, this quest left him, after several jobs and unsuccessful ventures, almost bankrupt. Desperate, de Forest then remembered how, several years before, his spark transmitter would affect the flames of the gas-lighting. In an act of desperacy he placed two electrodes in the flame of a Bunsen-burner, and low and behold it worked as a radio detector! De Forest explained his flame detector from an unknown interaction of RF-signals on ionized gasses. It was therefore only natural that his next step was a more robust system in which the flame was replaced by a heated filament in a gas filled tube. For de Forest his “Audion,” as he called his three terminal device, was just a detector, and as such it was used for the next years. Then in 1912 de Forest took up his experiments with his Audion again and he started to explore its properties as an amplifying device. After much tinkering he developed a three stage circuit that could amplify telephone signals and he sold the rights of his Audion to AT&T. AT&T placed the development of the Audion in the hands of H.D. Arnold. Arnold was a pupil of the famous physicist Robert Millikan and as such was much better informed about the latest developments in electron- theory than de Forest. Arnold immediately understood that the presence of gas in the Audion seriously hampered the flow of electrons, and he quickly replaced it by a vacuum. Within no time Arnold had improved the Audion so much, that it became a useful amplifying device, the triode was born. In 1913 the first oscillators using triodes were realized. At last there was an efficient way to produce continuous waves that could replace the bulky and especially noisy mechanical equipment that had to be used in the past.

The military must have been ecstatic! With the First World-War starting in 1914, it was the ideal device for wireless communication in a dirty trench fought war. This pretty much summarizes the situation in 1917. Radio was something exclusively for the post-offices and the military with the triode being an extremely new and still not well understood device.

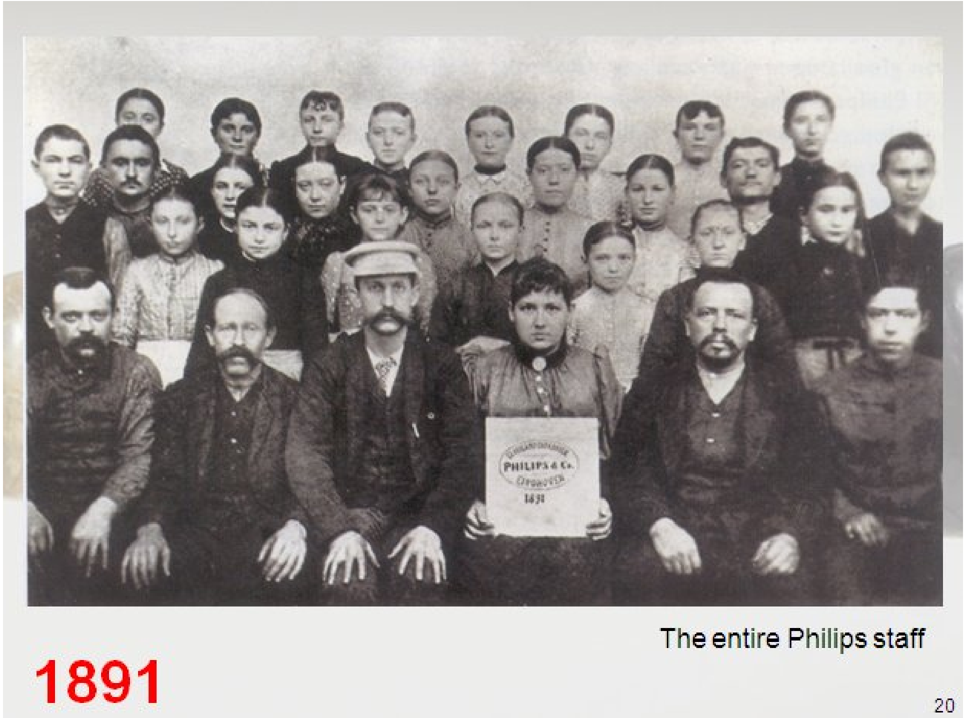
For Holland, which as you will recall was neutral during the conflict, all these developments had happened almost unnoticed. It is therefore not surprising that our military friends studied the radio in the German airplane with unusual interest. Understanding the potential of it for modern warfare, and facing an uneasy post-war relation with Belgium, they commissioned captain “de Blauw” to construct a number of radio sets. For the necessary radio tubes captain “de Blauw” naturally turned to the largest light- bulb manufacturer in Europe, our national pride: Philips. So after having reviewed the status of radio and radio tubes in 1917, let’s now for a moment recall the position of Philips in 1917.



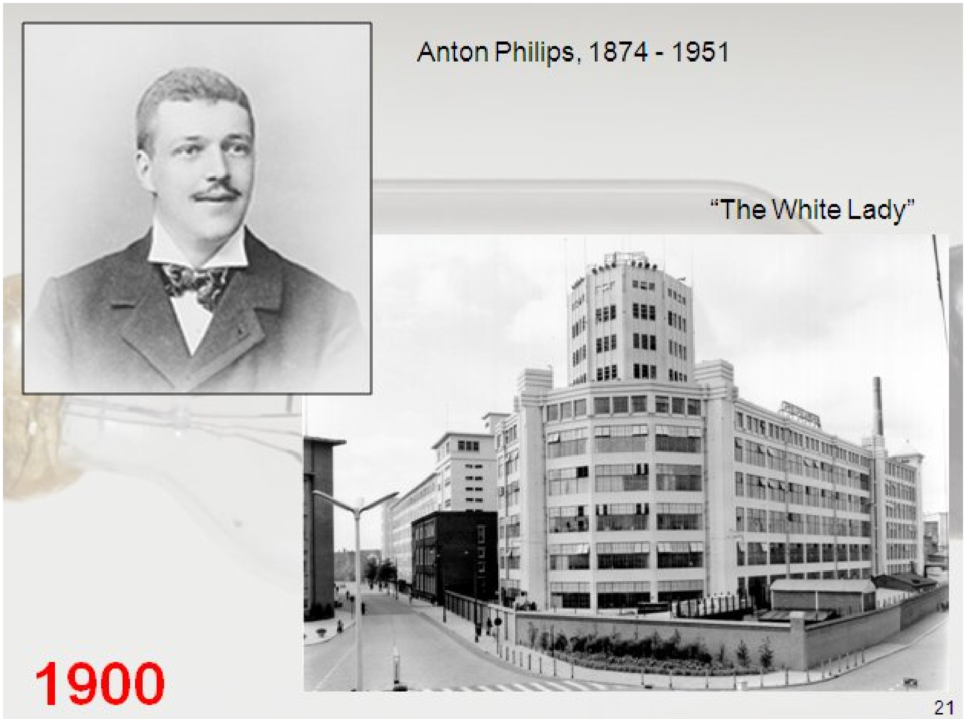
Philips was founded by Gerard Philips in 1891. Gerard came from a family of entrepreneurs. His father was a banker, but he also ran a tobacco trading company, a coffee roasting company a cotton mill and he owned a gas factory! Gerard's interest was however more in technology. In 1883 he graduated from the faculty of Mechanical Engineering in Delft and a few years later supervised the installation of electrical light on the Dutch steamer "Prince Willem of Orange" in Glasgow. During this trip to Scotland he came into contact with the famous physicist Thomson. He stayed with Thomson for a year, and during that period learned everything there was to learn about electricity. Back in Holland, Gerard developed his own technology for making light-bulbs.



With financial aid from his father he bought a small factory in the picturesque country village of Eindhoven and in 1891 the private partnership "Philips & Co" is founded.



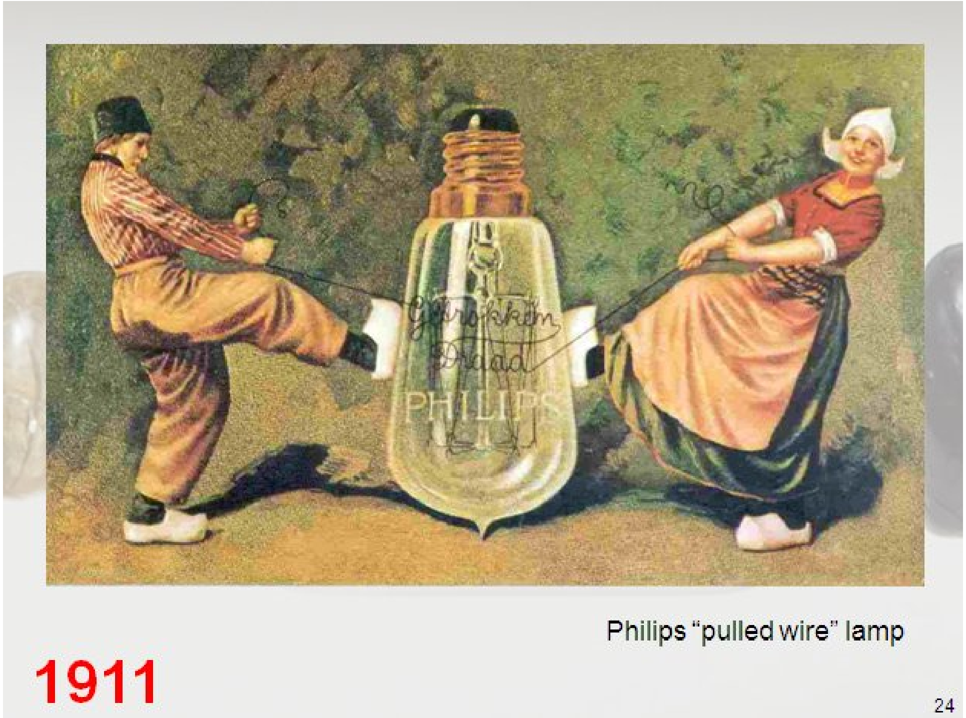
The first years are not easy for Philips. Fierce competition amongst light-bulb manufacturers, forces Gerard to lower prices and increase production. You see, high-volume and low-cost is in the very genes of Philips.



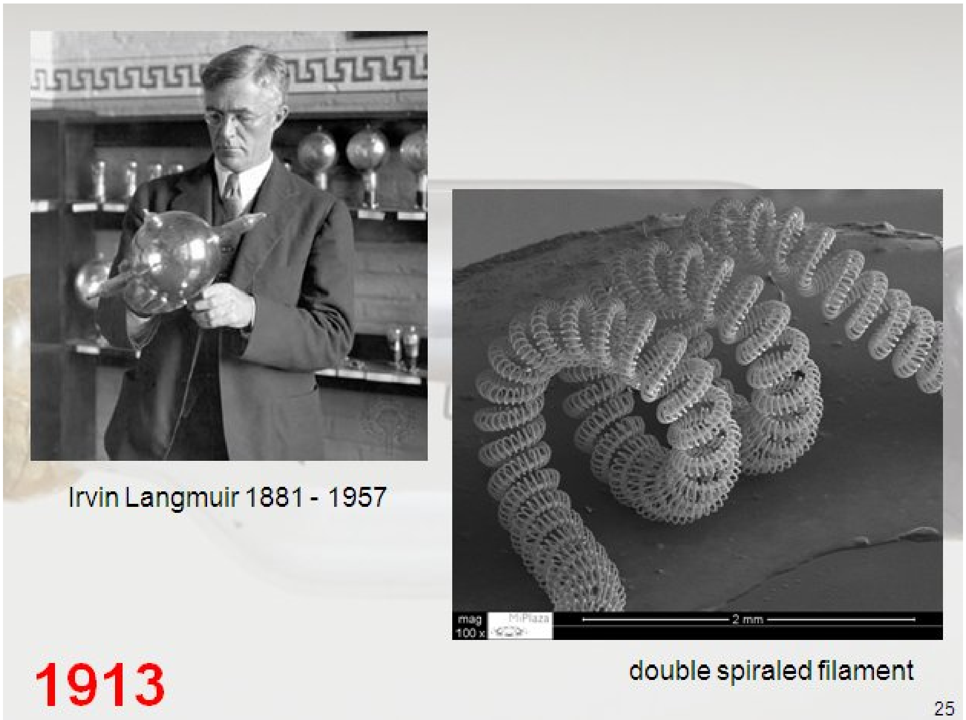
Facing fierce competition and expansion of his factory, Gerard makes a clever move: being himself more an engineer than a business man, he makes his younger brother Anton a co-director, responsible for the business aspects of the company. Together they form a golden pair in which Anton tries to sell more lamps than his brother can produce and vice versa. Business thrives, and across the road of the old factory new immense buildings are erected and Philips grows at an enormous pace. In 1900, less than 10 years after its foundation, production reaches 3 million light bulbs a year, making Philips one of the largest light-bulb manufacturers in the world!

By 1910 the number of employees has reached 2000. Philips is now the largest private employer in Holland. Then, an unexpected event upsets the otherwise so peaceful life of the two brothers. At General Electric, after years of intense research, William Coolidge had achieved a breakthrough by developing a method for the fabrication of ductile “pulled” tungsten filaments. Tungsten filaments can burn at much higher temperatures than carbon filaments, and therefore produce whiter and more efficient light.

This development takes the engineers in Eindhoven completely by surprise and they are at their wits ends. To save the business, Anton is forced to sail to the US in October 1911 to buy the necessary licenses and equipment. After his return, the equipment is quickly installed and through an immense effort operational in less than three months.



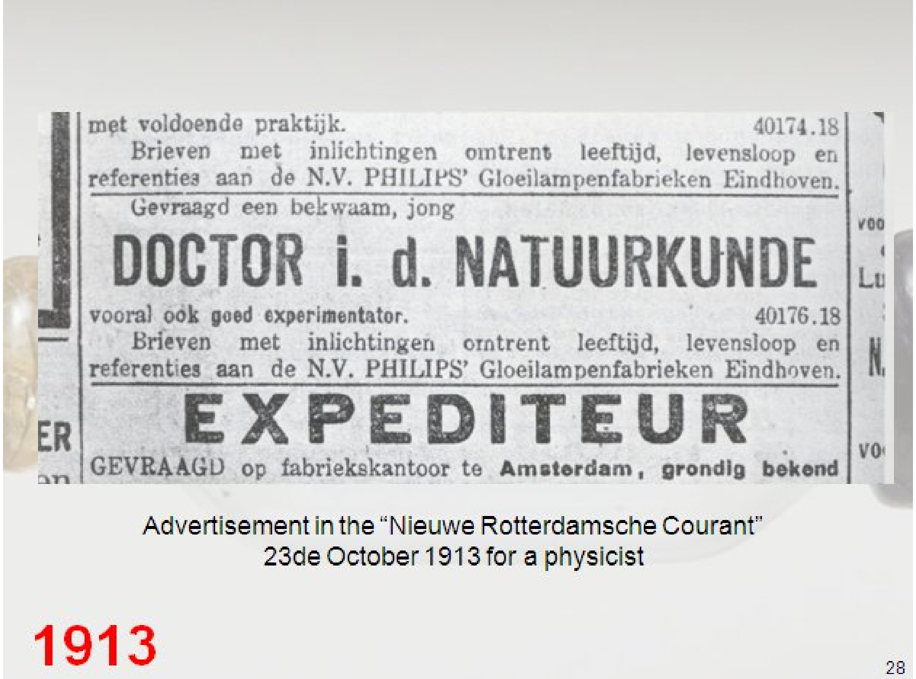
Again three months later the first lamps with a pulled wire are sold. Within two years, it is again General Electric who for the second time takes Philips by surprise when they introduce gas filled light-bulbs. In vacuum light-bulbs, the maximum temperature of the filament, and consequently the efficiency, is limited by the evaporation of the filament. It was well known that filling of the light-bulb with an inert gas reduced the evaporation. However, gas filling the lamp would also cool down the filament.



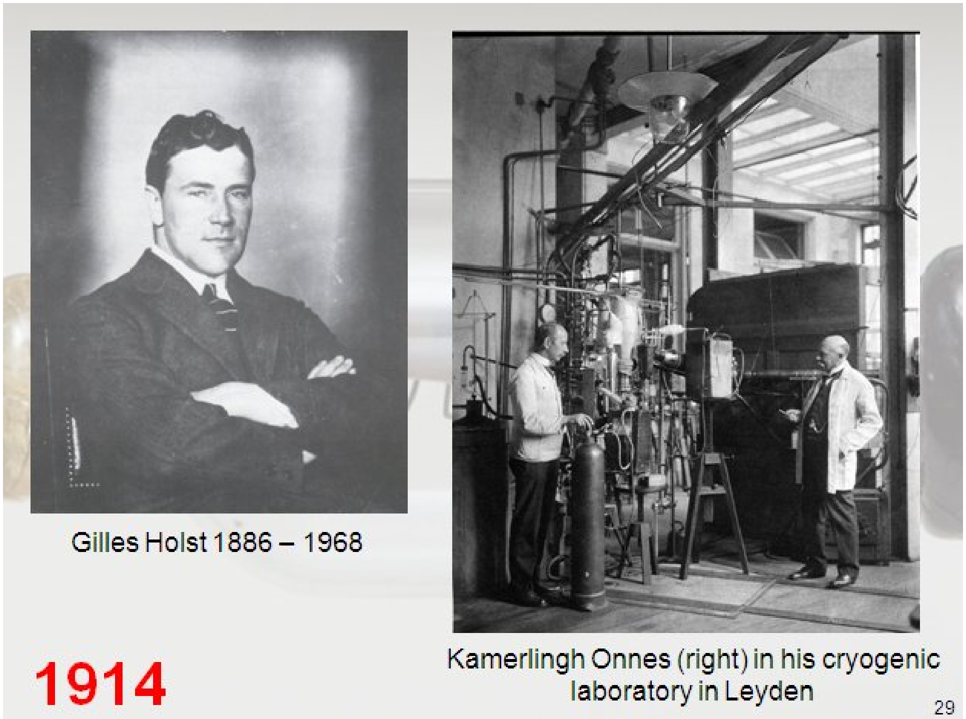
A breakthrough is achieved by Langmuir who, after an extensive study of the conduction of heat through gasses, proposes to use a thin double spiraled tungsten filament. This greatly reduces the heat-loss, while still a high electrical resistance is maintained. Philips is again forced to buy a license.

The technology is quickly introduced, and within no time the Philips Argon filled lamps even prove superior over the lamps of G.E. Gerard and Anton realize that the innovations from General Electric were the result of fundamental physical research.

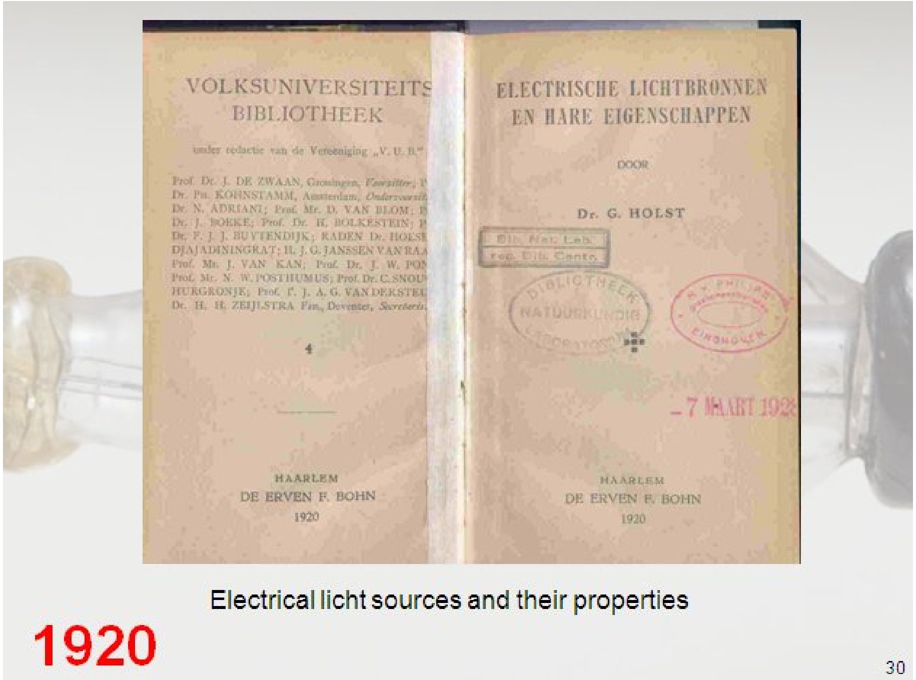
In the mean time, the Number of employees of Philips has now grown to over 3500 and the company is about to celebrate it’s 25th anniversary. The brothers recognize that for the future of the company it is vital that Philips embarks on its own fundamental research program.



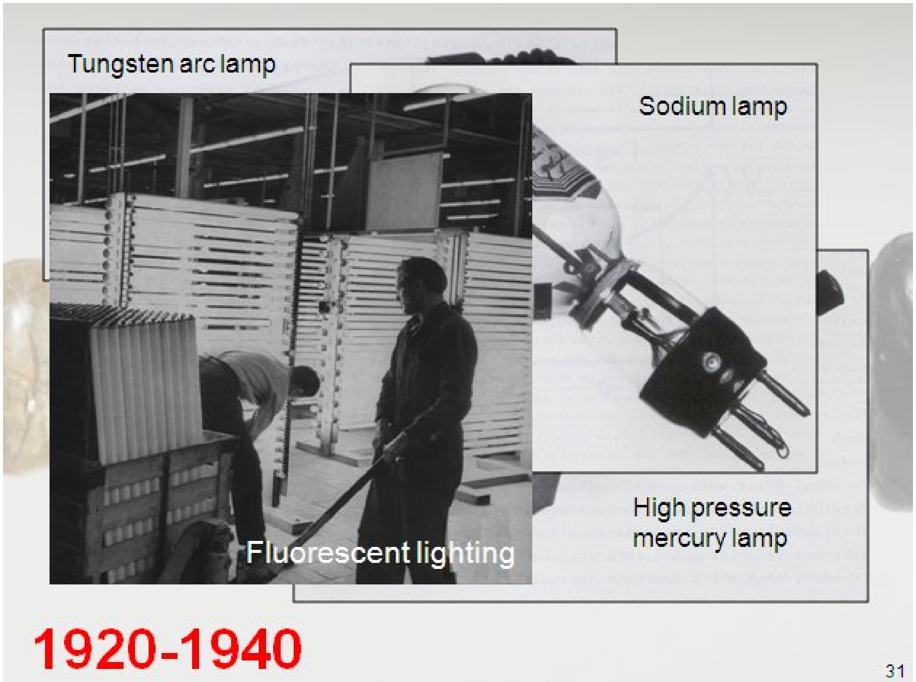
So an advertisement for a scientist with a PhD in Physics is placed in the newspapers. The scientist will be responsible for the setting up of a research organization that will make Philips less dependent on patents from others and that will generate new ideas for products.



Among the applications that they receive is one from Gilles Holst. Holst did his PhD under professor Kamerlingh Ohnes, who ran the low temperature lab in Leiden. Ohnes was the first to liquefy Helium and to discover super conductivity in mercury for which he received the Nobel Prize for Physics in 1913. It is very refreshing how short and to the point Holst application letter was. After a short C.V. he ends his letter with: 'I would be pleased to learn from you when it would be convenient to look you up so that we could discuss matters.' After the meeting, Holst is hired and he sets about organizing his lab. In 1914 Philips Research or the "NatLab" as it is known in Eindhoven is founded.



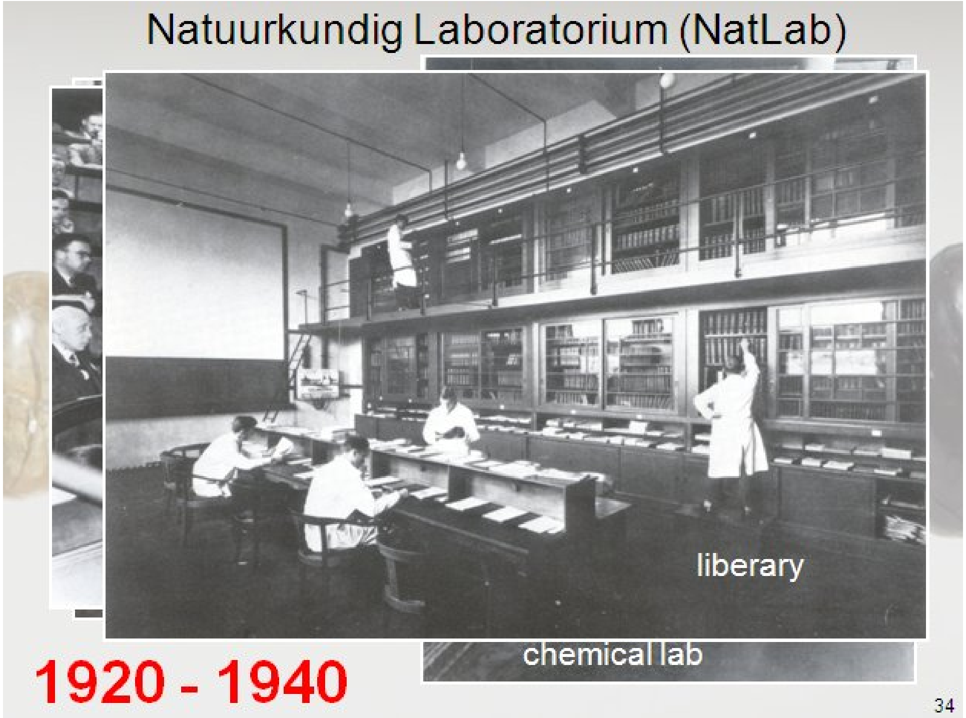
Holst starts his new job by investigating the state-of-the-art in electrical lighting and all of the aspects related to it. The results of his study are published in a small book titled “Lichtbronnen en hare eigenschappen” (“electrical light sources and their properties”). He concludes that it was already too late to carry out fundamental research on incandescent light. The time was ripe to work on a new source of electrical light: the discharge tube. Discharge tubes were still something very new and fancy in 1914. Even the glow discharge itself was a phenomenon which was still poorly understood at that time.



It is unfortunately beyond the scope of this presentation to elaborate on the enormous role that Philips Research would play in the understanding and application of gas-discharges. The Tungsten Arc Lamp, the high pressure mercury and sodium lamps, the fluorescent light tube, cathode sputtering, impurity gettering, the theory on discharges in gas mixtures are but a few of the innovations originating from Philips Research in the period between the two World-Wars. In the beginning however, Holst found it difficult to hire competent researchers. The concept of an industrial lab was something completely new for Holland in 1914. Holst was however determined in positioning Philips Research as an internationally recognized research organization.

In 1920 Holst is able to persuade the brilliant German physicist Gustav Hertz to come to Eindhoven. Amongst many other things, Hertz performed a beautiful experiment which established beyond all doubt that Bohr's electron states were linked to spectral lines. Later Hertz would receive the Nobel Prize for his work which, to a large extend, was carried out at Philips.

In 1920 Paul Ehrenfest gives a series of lectures on some recent physics topics. His example is followed by famous scientists such as James Frank, Otto Stern, Albert Einstein, Hendrik Kramers and Arnold Sommerfeld.



In the following decades, “het Natuurkundig Laboratorium” would grow into a Research organization that could measure itself with the most renowned industrial research labs in the world.

In the mean time captain “de Blauw,” still eager to get his hands on a supply of radio tubes, made an appointment with Gillest Holst. As it happens, this is the start of a remarkable chain of events. Holst politely receives him in Eindhoven and listens to his story and request for help in the fabrication of radio tube samples. Undoubtedly, Holst must have been fascinated by these new gadgets and the physics that made them work. However, Holst also knew that Gerard Philips considered radio and radio-tubes as a play thing for the military, and something with little practical and commercial value! Holst finds it difficult to do something that might upset his boss only three years after being appointed and although is tempted, reluctantly turns down captain de Blauw’s request for help.

Disappointed, captain “ de Blauw” turns to one of the dozen or so other light-bulb manufacturers in Holland: “de Metaaldraadlampenfabriek” in Utrecht. They are quite willing to help him, and a few weeks later the first radio-tubes manufactured in Holland are delivered to captain “de Blauw.”

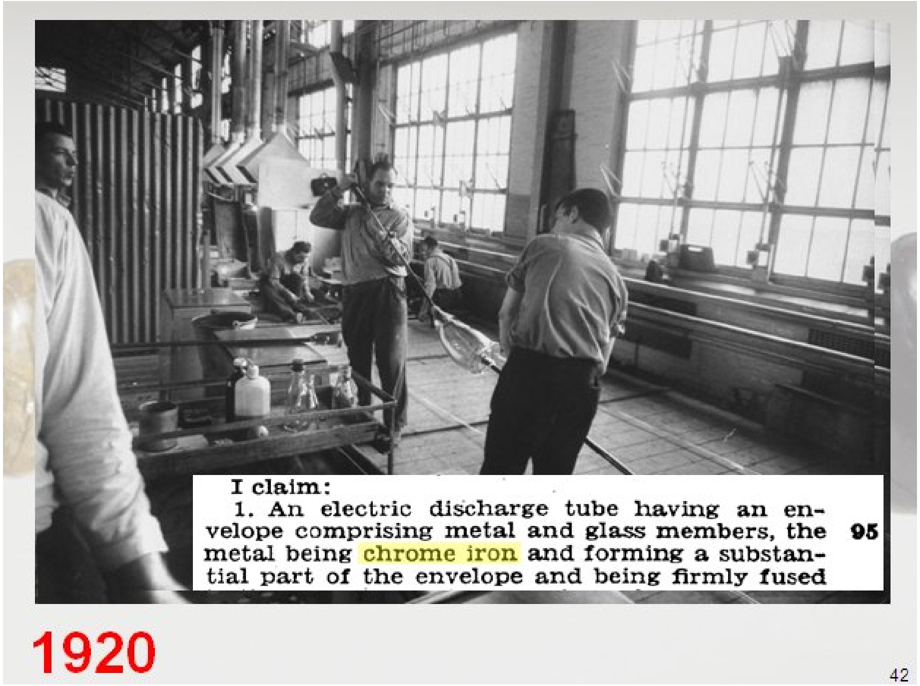
In the development of radio into something as we know it today, radio amateurs played an important role. The ending of the War, during which listening to radio was forbidden, gave an enormous impulse to the popularity of radio amateurism. But what to listen to? Most radio transmissions where in Morse code originating from post offices, news agencies and of course the odd spy. Transmission of speech, let alone music, was practically unheard of.

This was something that troubled the Dutch radio pioneer “Hanso Henricus Schotanus à Steringa Idzerda,” a long and difficult to pronounce name, even to Dutch standards. Idzerda, was an electrotechnical engineer and a keen radio amateur. Already during the war Idzerda run a small wireless instruments and consultancy agency from The Hague, mainly servicing the military. After the war, Idzerda changed the name of his company to “Nederlandsche Radio-Industrie.” It is his dream to build and sell radio receivers to ordinary civilians. Since there was basically nothing to listen to, he intents to provide the buyers of his radio sets with an interesting program consisting of news, music and radio plays transmitted from his company in The Hague. To realize his ambition, Idzerda needs a steady supply of radio tubes. So naturally he first turns to the “Metaaldraadlampenfabriek” in Utrecht, who a year earlier had provided captain “de Blauw” with radio tubes. They are however unable to supply him the tubes since they have signed a “contract of secrecy” with the Ministry of War. Idzerda now turns his hope to Philips.

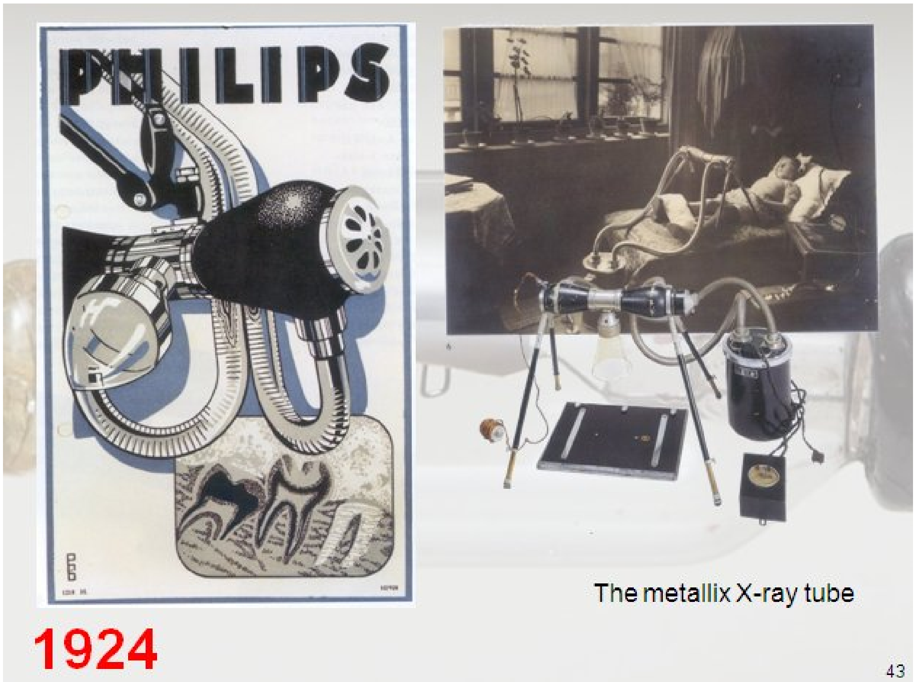
One way or the other, he is able to convince Gerard Philips himself of the economical significance of his vision, because Gerard orders Holst and his staff to fabricate the tubes according to Idzerda’s specifications. The tubes are advertised under the name “IDEEZET-lamps,” and in an advertisement in “Radio Nieuws” of January 1919, Idzerda proudly announces that already 1450 tubes have been sold. Following instructions from Idzerda, Philips also manufactures several transmission lamps.

In August that year the first transmissions take place from Idzerda's radio station, which transmits with less than 20 watts of RF power, and is heard within a radius of 60km around "The Hague." On the 5th of November 1919, Idzerda places an advertisement in the news papers, announcing a "Soirée-Musicale" for the following Thursday between eight and eleven. It is a world-premiere, since it is the first radio broadcast which is preceded by an announcement of the program in the news papers. The event is internationally recognized as the birth of public radio broadcast. Idzerda's radio transmissions are very popular but fail to become an economical success, since Idzerda entirely relies on voluntary contributions. The Dutch, although they appreciate the music, are apparently not willing to pay for such a frivolity! Fortunately, the English are more generous.

Idzerda's radio station, which by that time transmittes at a power level of 1kW, can be received in a large part of the South of England, and is highly appreciated by the English. A fund raising action in England organized by the popular magazine "The Wireless World," raises sufficient money. A few years later however, bankruptcy is inevitable. In the following years, the fabrication of receiver tubes remains a relatively insignificant activity compared to the fabrication of light-bulbs. This is however not the case for X-ray tubes and transmission tubes. There, a stroke of luck places Philips in ideal position.



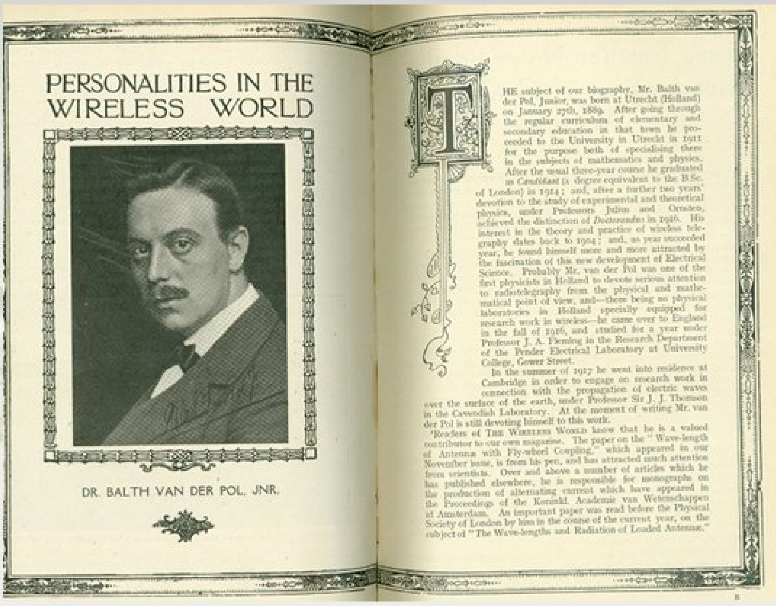
In the early days of 1920, Gerard Holst visites one of the glass-blowing factories where light-bulbs are being fabricated. He notices that some of the glass-blowers have more difficulty in removing the light-bulb from their blow-pipe than others. He finds this intriguing, and decides to investigate the cause. He discovers that when the blow-pipes are made from a particular chromium-iron alloy, they have an almost perfect adhesion and thermal match to the glass. The story goes that Holst after founding the cause, immediately rushed to the patent department and got the discovery patented. The patent indeed proved of immense value to Philips. Already during the war, Philips had repaired and fabricated on a small scale X-ray tubes for hospitals which were not able to get spare parts. After the war this activity was under fierce competition, especially from Germany.



The perfect chromium-iron to glass seal was just the thing Philips needed to give them a competitive edge. By making a part of the tubes from metal, it was possible to strongly reduce stray radiation, and to effectively cool them. These tubes became known as the METALLIX tube, and they formed the start of what is today Philips Medical Systems.

1931 The portable Metallix X-ray system used in the Forbidden City in China during the Qing dynasty 44

Begin thirties the Medical System Division had grown to such an extent that they had even penetrated the walls of the forbidden city in China! Finally in 1923 the idea of public radio broadcasts really sets of, and the demand for radio tubes explodes. Tube manufacturers are hardly able to supply the demand and Philips quickly changes gears. After the fabrication of light-bulbs was moved to a location just outside the center of Eindhoven, the huge plant on “de Emmasingel” became available for the production of radio tubes. Whereas in 1921 only 320 radio tubes were fabricated in total, in 1923 the production had increased to 1000 tubes a day!



PERSONALITIES IN THE WIRELESS WORLD

DR. BALTH VAN DER POL, JNR.

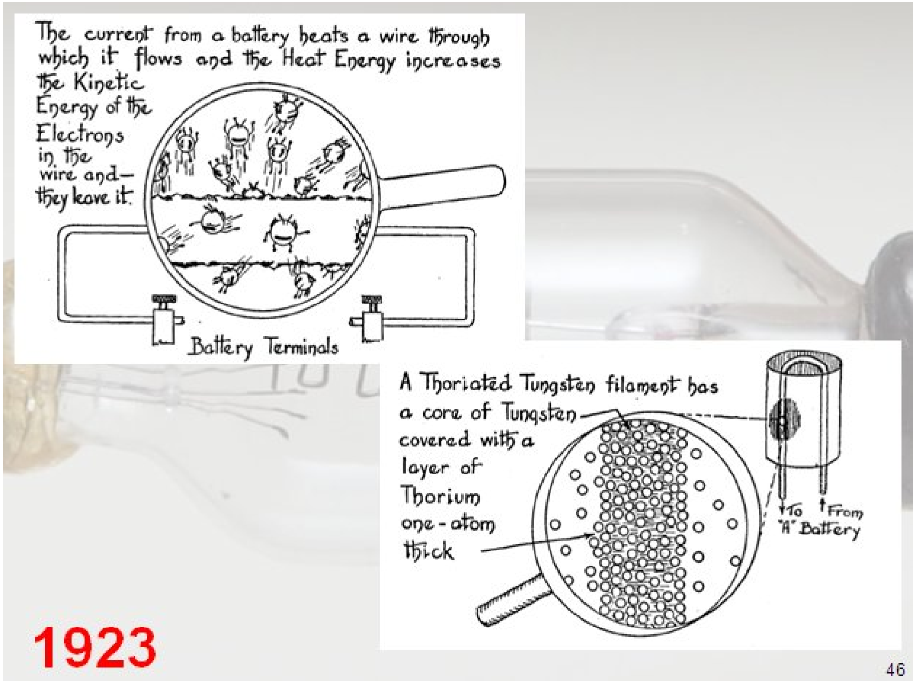
THE subject of our biography, Mr. Balth van der Pol, Junior, was born at Utrecht (Holland) on January 27th, 1889. After going through the regular curriculum of elementary and secondary education in that town he proceeded to the University in Utrecht in 1911 for the purpose both of specialising there in the subjects of mathematics and physics. After the usual three-year course he graduated as *Candidaat* (a degree equivalent to the B.Sc. of London) in 1914; and, after a further two years' devotion to the study of experimental and theoretical physics, under Professors Julius and Ornstein, achieved the distinction of *Doctorandus* in 1916. His interest in the theory and practice of wireless telegraphy dates back to 1904; and, as year succeeded year, he found himself more and more attracted by the fascination of this new development of Electrical Science. Probably Mr. van der Pol was one of the first physicists in Holland to devote serious attention to radiotelegraphy from the physical and mathematical point of view, and—there being no physical laboratories in Holland specially equipped for research work in wireless—he came over to England in the fall of 1916, and studied for a year under Professor J. A. Fleming in the Research Department of the Pender Electrical Laboratory at University College, Gower Street.

In the summer of 1917 he went into residence at Cambridge in order to engage on research work in connection with the propagation of electric waves over the surface of the earth, under Professor Sir J. J. Thomson in the Cavendish Laboratory. At the moment of writing Mr. van der Pol is still devoting himself to this work.

Readers of THE WIRELESS WORLD know that he is a valued contributor to our own magazine. The paper on the "Wave-length of Antennæ with Fly-wheel Coupling," which appeared in our November issue, is from his pen, and has attracted much attention from scientists. Over and above a number of articles which he has published elsewhere, he is responsible for monographs on the production of alternating current which have appeared in the Proceedings of the Koninkl. Academie van Wetenschappen at Amsterdam. An important paper was read before the Physical Society of London by him in the course of the current year, on the subject of "The Wave-lengths and Radiation of Loaded Antennæ."

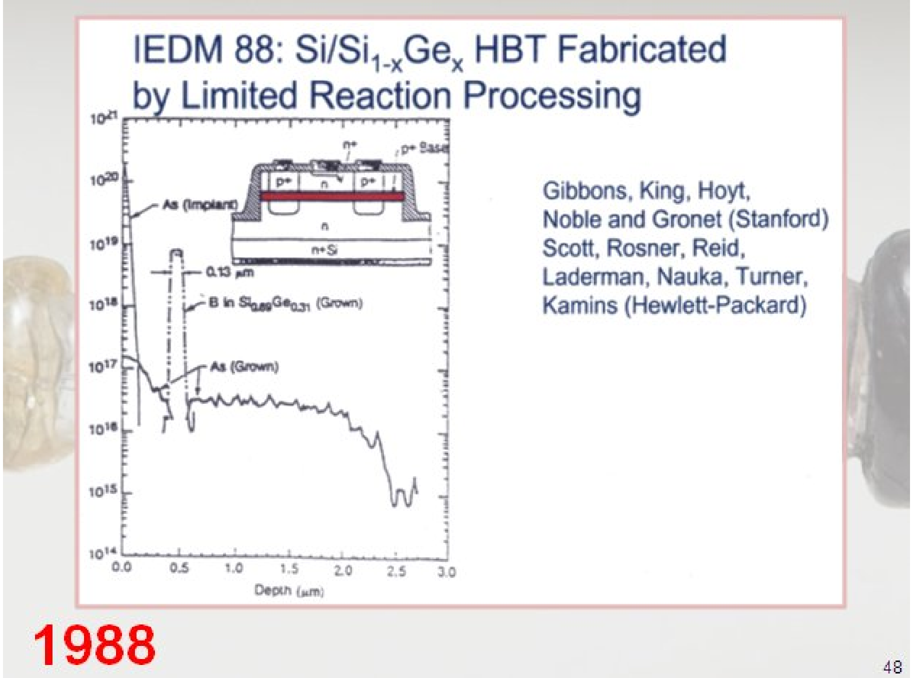
1917 Balthasar van der Pol in Wireless World 1917 45

In 1922 Gilest Holst hires the Dutch Scientist “Balthasar van der Pol” to head the research and development of radio tubes. Van der Pol who had worked under Thomson and Fleming in England was a brilliant scientist who already in 1917 in “Wireless World” had featured in an article “Personalities of the Wireless World.” Van der Pol’s first job was to work on oxide coated filaments.

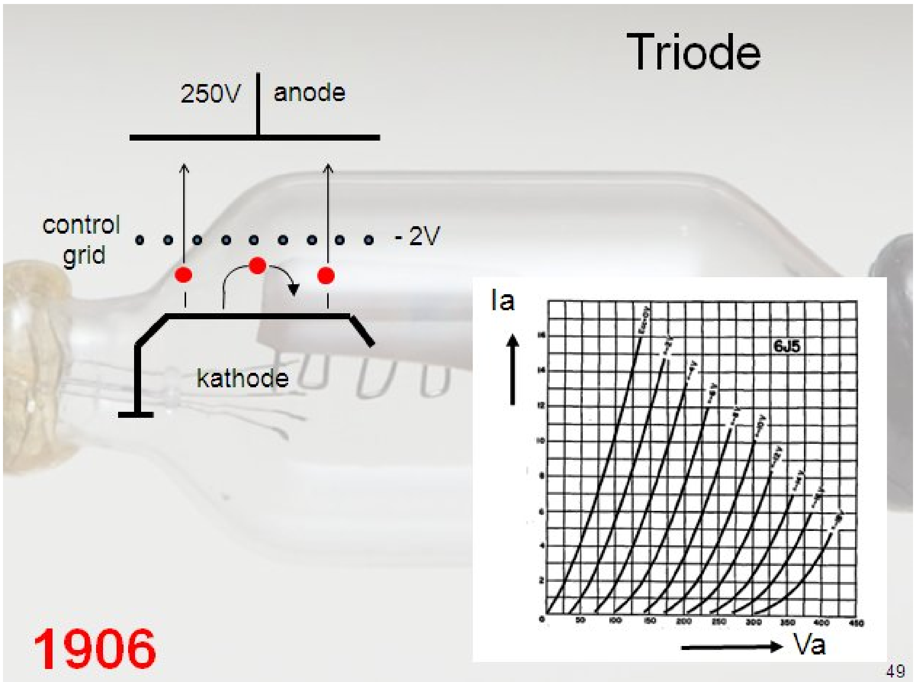


So far just normal tungsten filaments had been used in radio tubes. To get sufficient electron emission, these filaments had to be heated white hot, so that these tubes were cold "hel branders" or "bright burners." In fact the radios in those days gave as much light as sound. To save batteries and tubes, van der Pol and his staff developed barium and thorium coated filaments. The low work function of these materials strongly increases the electron emission of the filaments, so that they could burn at lower temperatures.

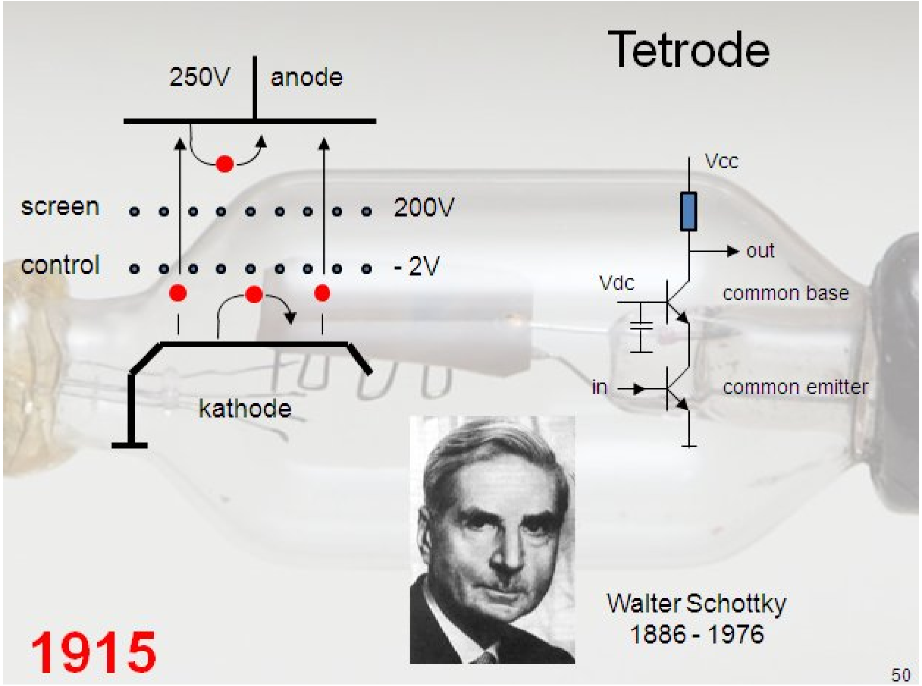
Philips successfully introduced these tubes in 1924 under the brand name "Miniwatt." At that moment already 9 out of the 16 researchers at Philips were working on radio tubes.



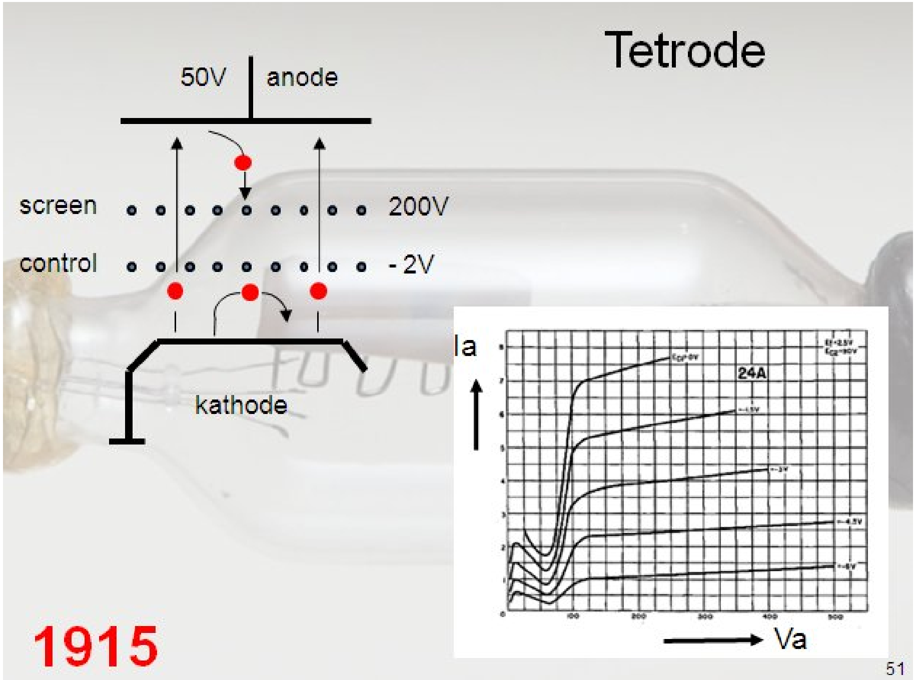
Sixty years later, researchers at Stanford introduced a very similar trick to boost the performance of bipolar transistors. This time it is the bandgap of the base which is decreased by the incorporation of a small amount of heterogeneous material: Germanium. The result is the same: a higher current density, which in this case is used to obtain higher switching speeds. In 1924 Bernard Tellegen joins the radio tube research group of van der Pol. He is then 24 years of age and has only just graduated. He was put on a very practical problem. Due to new safety regulations, the anode voltage in radio receivers was limited to less than 250V. At these low voltages it was difficult to generate enough output power for a loud speaker with a simple triode.



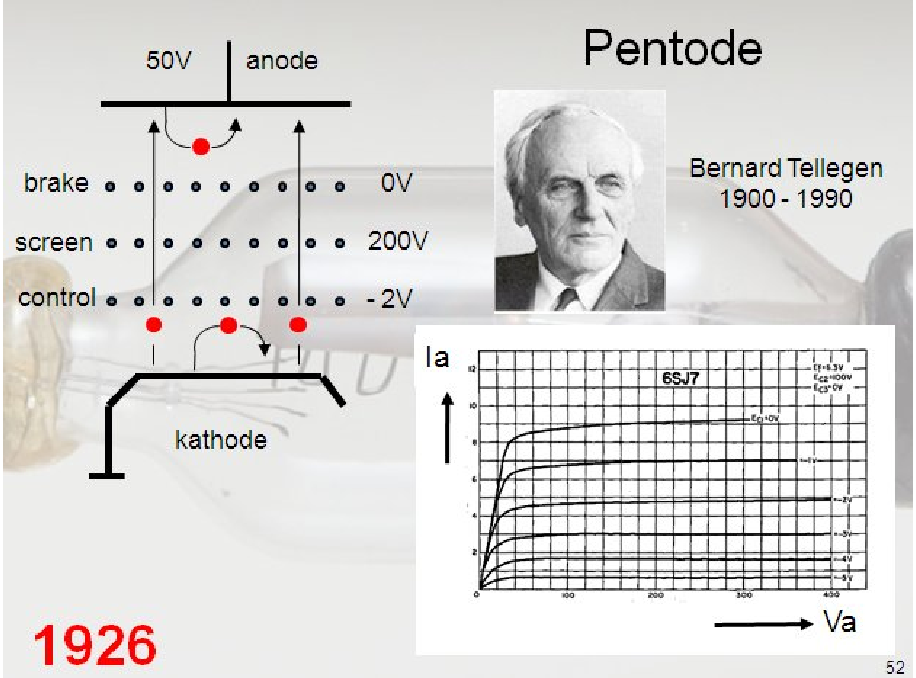
The triode had namely two serious drawbacks. First of all it didn't behave like a current source. In other words, the anode current not only increased with increasing grid voltage, but also with increasing anode voltage. In bipolar transistor terms we would say: "it had a low Early voltage." This seriously limited the maximum amplification and the output power of the tube. At the same time there was a strong capacitive coupling between the anode and the grid. This Miller capacitance limited the high frequency operation.



In 1915, a remedy to these drawbacks was found by an old acquaintance of us: Walter Schottky. By inserting a screen grid in between the control grid and the anode, which was held at a constant high potential, the anode potential is effectively screened from control grid. In its hybrid form this arrangement is of course still widely used, and is known as a cascode. The tetrode as is was called, represented an enormous improvement, but in its turn also had a drawback. Electrons accelerated by the high potential on the screen grid bombard the anode and generate secondary electrons.

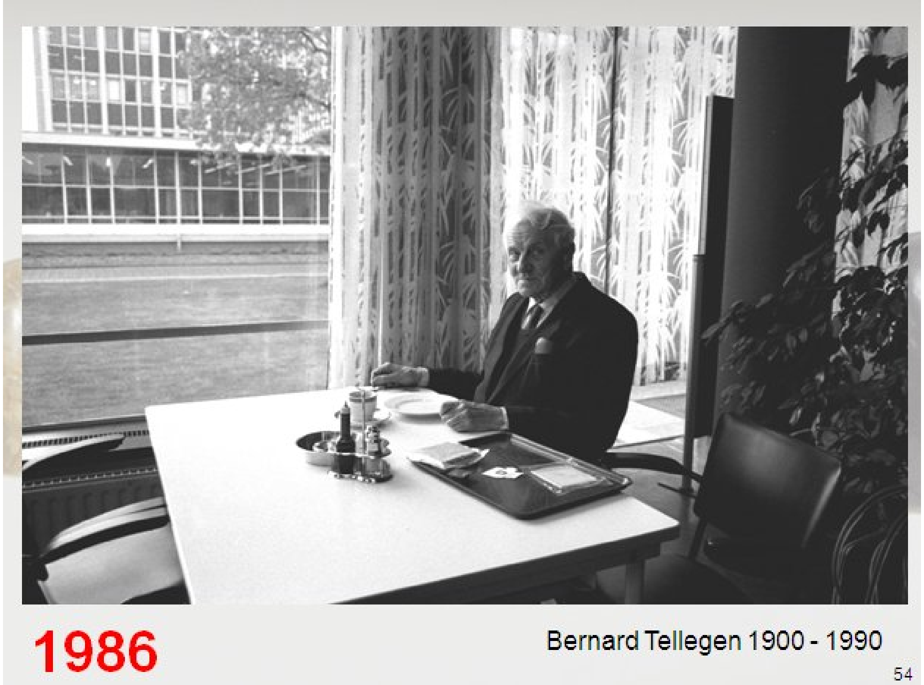


Unfortunately, in operating conditions where the anode voltage is low compared to the screen grid, these secondary electrons are accelerated to the screen grid, causing a current flow in the opposite direction. The result is a kink in the anode current characteristics, not unlike the kink in SOI MOSFET's. The problem especially occurred in output stages where the output voltage would swing between supply voltage and almost zero. Tellegen studied the problem, and came up with a very simply solution.

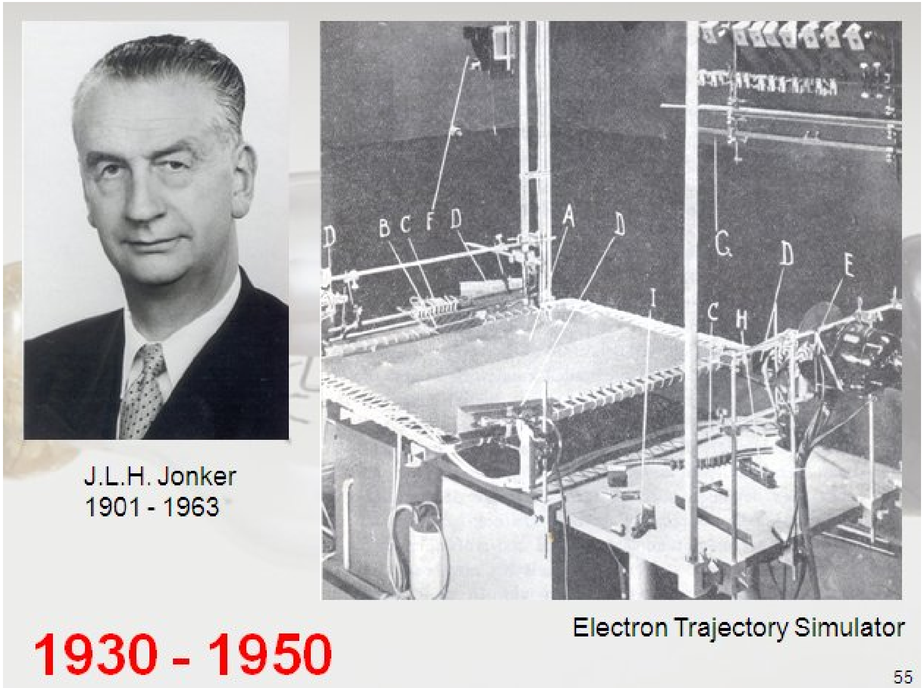


He simply inserted a third grid between the screen grid and the anode. This brake- or suppressor grid was connected to a low potential e.g. the cathode. The suppressor grid simply pushed the secondary electrons back to the anode and all at once all the disadvantages of the tetrode had disappeared. The pentode was a near ideal amplifying device with very high amplification and capable of delivering high output powers at relatively low voltages. Tellegen and Holst immediately applied for a patent on the 14th of December 1926.

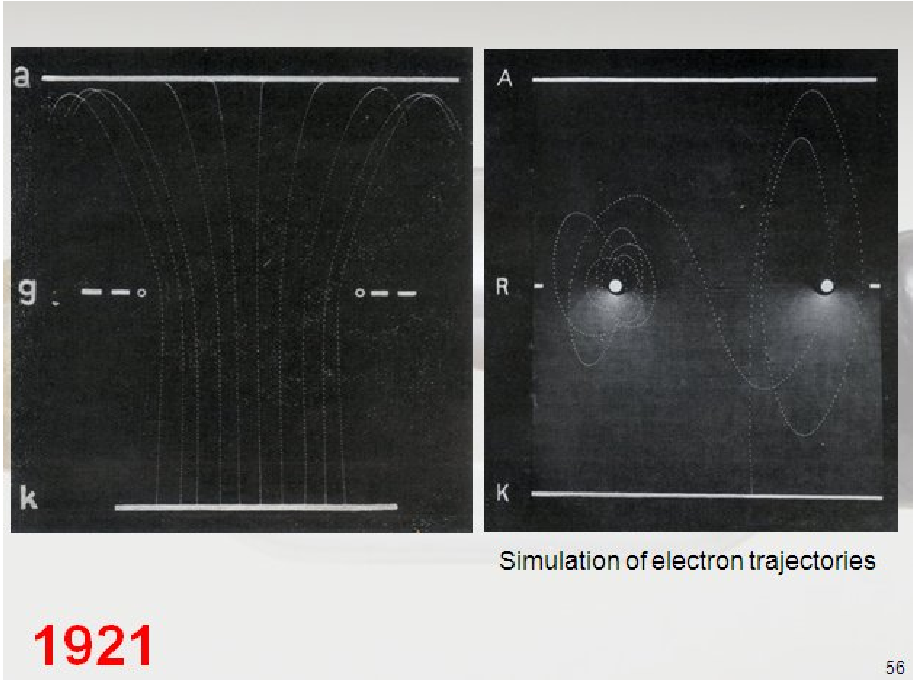
It turned out to be perhaps the most valuable patent of Philips ever. Philips sat on the patent like a tiger protecting its young. In 1927, Philips becomes the largest radio tube manufacturer in Europe. Because of the pentode patent the European market was not interesting for the Americans at all. As a result the European and American tube markets developed almost independently, with different type numbers, envelopes, sockets etc. The protectionism of Philips was so strong that they would even order confiscation of radio tubes that radio shop owners directly imported from the U.S.! In 1932, little more than 10 years after the first samples were made at the research lab, Philips produced it’s 100 millionth’s radio tube.



Tellegen remained extremely productive throughout his long career with Philips. He invented the Gyrator and developed “The Tellegen Theorem,” one of the most powerful theorems in network theory. In 1973 he received as first non American the IEEE Edison Medal Award. Up to a few years before his death in 1990, he continued to visit the library at Philips Research and after which he would enjoy a sober lunch in the canteen.



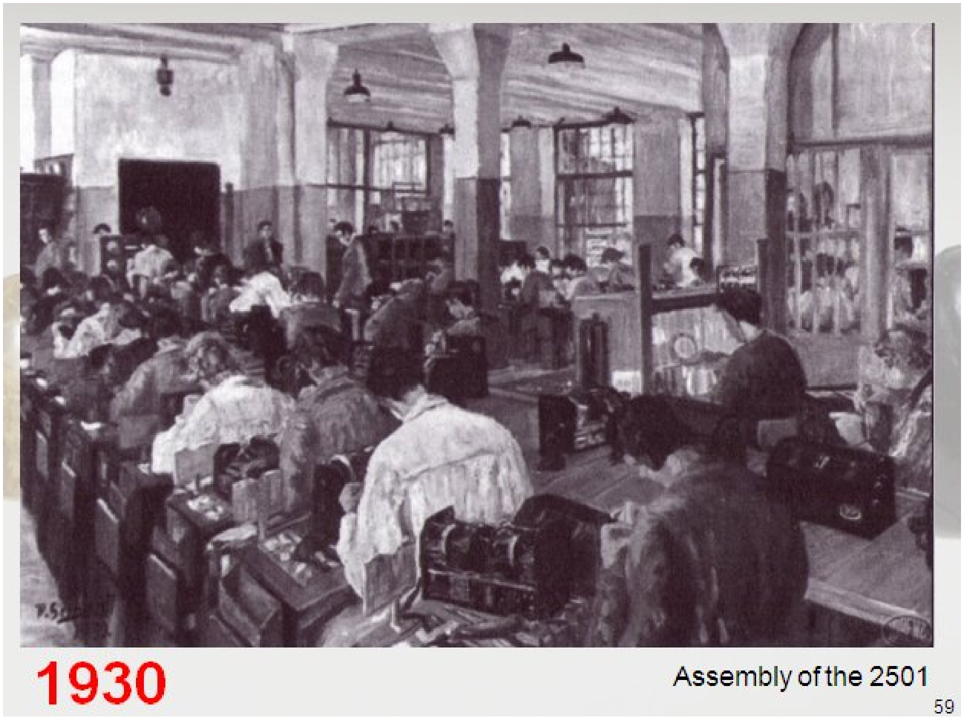
The mathematical treatment of multigrid tubes like Tellegens pentode was extremely complicated. That is why Jonkers at Philips Research resorted to a completely new approach: device simulation! Instead of using finite element calculations as we do today, he used a typical solution from the time of slide rules: a mechanical equivalent. The simulator consisted of a rubber sheet that was suspended in a frame. sticks, representing electrodes, were placed underneath the sheet of rubber that could push the rubber sheet either upward – in case of a negative potential - or pull it downward – in case of a positive potential.



At one side of the rubber sheet, at the position of the imaginary cathode, an array of tubes launched small metal bullets representing the electrons. A camera and a stroboscope recorded the trajectory and the velocity of the electrons. Simple, reasonably accurate and very fast!

In the mean time the popularity of radio increased explosively, and it had not remained unnoticed by Anton Philips that, whereas the price of a radio tube on average was 10 guilders, the price of a complete radio was about 200 guilders. So obviously making radio sets was a very profitable business. This combined with the fact that Philips now had their hands on a superior radio tube, the pentode, made them feel confident enough to start thinking about producing radio's themselves. For Philips in 1926 this was something of a revolution. So far Philips had been a component manufacturer. A radio was a system, and manufacturing a system would require a completely different approach! From the onset it was clear that the receiver had to be suitable for mass-production, it should be reliable, easy to use, of high quality and reasonably priced. Visits were paid to RCA in the US to study mass production. A thorough study was made on how something so complex as a radio could be made on a large scale with a high accuracy and yield by unskilled hands.

The result was the 2501, in Holland nick-named “the loaf of bread.” Because of the high gain of the pentode, only three radio tubes were needed compared to four in radios from competitors.



It was an enormous success. In 1927, 6000 receivers were built, in 1930 the production had already increased to half a million radio’s a year. Well, as they say; “The rest is History.” Philips grew and grew. In the beginning of the fifties the production of radio tubes reached 200 million pieces a year. By that time factories in France, England and Germany have been bought or built, which produce radio tubes under local brand names such as Mullard or Valvo.

In the factory of VALVO in Hamburg alone, 5000 people, mainly women, work on the assembly of radio tubes. With Philips, the NatLab grew and in the fifties it moved to the beautiful location were we are now.

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Well Ladies and Gentlemen, I see some impatient and I know that many of you have a Christmas celebration after this presentation, so let’s see if we can end with some conclusions:

Always listen to the Boss?
The questionmark needs some explaining. In Holland we have the popular tradition never to listen the boss whatsoever! However, in retrospect it was indeed a wise decision of Holst to listen to the wishes of his Boss Gerard Philips, when he turned down the request for help from the military. Suppose for a moment that Holst had decided to help them, in that case Philips would have been tied down by a secrecy contract and most likely the “metaaldraadlampfabriek” in Utrecht would have manufactured Idzera’s radio tubes. Possibly in that case they would have grown to become a multinational, buying up Philips as they grew, and as a consequence we would be having this colloquium in one of the suburbs of Utrecht instead of in Waalre. Of course Gerard Philips was not just any boss. In little more than 25 years he had built a multinational that had transformed a complete region of Holland. On top of that he was fully up to date with every technical and scientific aspect of his business. Obviously it depends on who actually the boss is. Unfortunately bosses like Gerard Philips are rare these days, so perhaps it is best to stick to our Dutch tradition!

Philips Research has been invaluable for the company!
This was only a very brief and short overview of the early years of Philips, I nevertheless think that you will agree with me that Philips indeed owes a lot to its research organization! The research on radio tubes directly led to the development of the consumer product division, while the work on X-ray tubes led to Philips Medical Systems. Together with light the three pillars that Philips is again resting on today.

Pay attention to details!
Edison saw a current flowing in one direction and not in the other. He didn’t understand it and could have ignored it as a measurement error. Instead he patented it and is still remembered for it. For De Forest it was the flickering of his gas light every time when he switched his transmitter on that set him on the trail of the triode. Holst observed that some glass blowers had difficulty in removing a glass balloon from their blow

pipes. He investigated this seemingly insignificant detail and discovered the merits of the chromium-iron alloy that eventually led to what is now Philips Medical Systems. Tellegen was annoyed by a small kink in the output characteristic of the tetrode and discovered the pentode. So details matter! Do not ignore them! Details make the difference between a great publication and a Nobel Prize.

l'Histoire se répète

Why bother with all this history stuff? What is the point in it? The people are all dead and technologies are obsolete. Well, I have tried to show you that in many respects the problems that faced the engineers and scientists in the early tube period were quite similar to the problems that we know from transistors and integrated circuits. More important, the same applies to the solutions that were found. Material and vacuum purity, gettering (a word even directly taken over from the tube period), the drive towards smaller dimensions, the need for higher current densities and the use of heterogeneous materials to achieve this, the importance of packaging and packaging parasitics. The list is endless. The transistor was to a large extend the work of a new and fresh group of engineers and consequently many things had to be "re-discovered." I strongly suspect that in the field of what we call "nano-electronics," the same is happening again today! For me personally, I find the study of the history of our profession inspiring and fun. Finally, and being here in the catholic south I can say this without hesitation, having fun in what we do is in the end the most important thing.