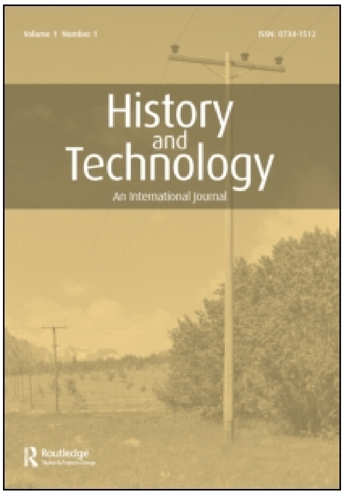

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STRUCTURAL WAYS TO EMBED A RESEARCH LABORATORY INTO THE COMPANY: A COMPARISON BETWEEN PHILIPS AND GENERAL ELECTRIC 1900–1940

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This paper compares the Philips Research Department and the Research Laboratory of the American company General Electric (GE).[1] It argues that it is, above all, the issue of the organization of industrial research, appropriate leadership and the embeddedness of a research department in the company as a whole that is important for an historical analysis of an industrial research department. The complex structures that Gilles Holst (the first Philips research director) and Willis Whitney (the GE research director during the first decades of the twentieth century) set up in their organizations enabled scientists to keep in touch with the resources provided by the universities, and made it possible for them to come up with articles, patents and devices for their respective companies. It enabled them also to strengthen their contacts inside and outside the laboratory's walls. However, more than his colleague Whitney at GE, Holst at Philips intended to integrate the research laboratory into the company as a whole. Holst's policy as a research director will be illustrated using the case of Philips' radio research. A comparative discussion of industrial research in the 1930s within both companies shows that the "successful" integration of research activities is context-dependent.

Keywords: History of industrial research; Organizational structure and culture; Science, technology and industry

RESEARCH IN INDUSTRY

The process of invention changed at the turn of the century from being an activity performed by hobbyists and individual entrepreneurs into a systematically organized discipline.[2] Thomas Hughes, in his analysis of the history of technology argues that: "The engineering departments, and later the industrial laboratories of these companies, with their far greater material and personnel resources, took over responsibility for the inventive activity . . .".[3] This happened first at the end of the nineteenth century in the German chemical industry; in other countries such labs emerged somewhat later.[4] In particular it was small dyestuff firms in Germany that used knowledge created in research laboratories. The electro-technical industry is the other sector in which laboratories were established. In the first decades of the twentieth century several industrial firms in America and Europe established in-house research departments and

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consciously sought to provide themselves with sources of up-to-date knowledge that were necessary to enter new markets. According to Reich, who wrote about the history of General Electric's (GE) Research Department, an industrial laboratory can be characterized as: " . . . set apart from production facilities, staffed by people trained in science and advanced engineering who work toward deeper understandings of corporate-related science and technology, and who are organized and administered to keep them somewhat insulated from immediate demands yet responsive to long-term company needs."[5]

The research departments and the companies' research activities fit well in Alfred Chandler's model of an integrated company with centralized management and a diversification policy.[6] And although his focus was first of all on the managerial hierarchies that appeared in the United States, the decision of several European companies, like Siemens and Philips, to establish a research laboratory are in line with the historical features of big enterprises as described by Chandler.[7] The question is, however, whether the Chandlerian organization structure and the R&D leadership was decisive in the relative success of industrial research departments, or if the technology that was developed at that time was just too important to ignore. The historian Bernard Carlson emphasizes, in line with Chandler's approach, the indispensability of the corporation's structure for diversification processes.[8] Innovation is a social process, which means the social setting of the research organisation shapes technology, and vice versa. More specifically, it is not useful to just analyze the organizational dynamics and then follow the individual researchers' or research director's activities, but it is the mutual relationship that has to be explored.

In line with this, Lou Galambos emphasizes that most in-house R&D departments were established in precisely those firms that had worked first to stabilize their internal organizational structures and that were characterized by a managerial hierarchy which coordinated a variety of operation units. After building a stable internal structure, the researchers working within these R&D settings were eager to keep in touch with the scientific community outside the companies' walls.[9] In other words, according to this body of literature, it is especially the issue of the organization of industrial research and the embeddedness of a research department in the company as a whole, which is important for an historical analysis of an industrial research department.

This article analyzes the history of the Philips Research Laboratory, established in the Netherlands in 1914, and compares it with the Research Laboratory of the General Electric Company, established in America in 1900. GE's Research Laboratory is often taken as an example for "how to do research in industry." Historians have referred more than once to GE as an international trendsetter.[10] While the Philips Research Laboratory was growing, Gilles Holst, Philips' first research leader, used the GE Research Laboratory as an example.

In what follows, the actors' motives, strategies, and first activities as well as the organizational structure of both labs will be investigated. Since the history of GE's early research department is already known from literature, this paper will focus primarily on Philips, bringing in the comparison with GE to explore the thesis that embedding the research department within the company was the key to success. I will analyze how and why Philips decided to do research in an industrial context. What were the strategies within Philips and what were the backgrounds of employees in the company? And how were the research activities structured in the research organizations in the early years? I will make clear that economic and business circumstances had an influence on the organizational structure of Philips' laboratory. Holst's policy as a research director will be illustrated using Philips' radio research. By demonstrating the dynamic interaction between Philips' individual radio researchers, managers, and organizational structures, I will present the way in which the

Philips research laboratory was integrated into the company as a whole. It is at this point that I will bring the history of the GE Research Department into the discussion, not only to show that GE's lab was an important model for Philips, but also to show that Holst and Whitney, as the research directors and key persons in the research institutes, molded their organizational structures in various ways. It will become clear that it is too easy to say that Holst blindly copied GE's research organization.

THE PHILIPS RESEARCH DEPARTMENT UNDER HOLST[11]

The Philips company was established in the Netherlands in 1891 by Gerard Philips as a light bulb company. Gerard started his company in a traditional way using family capital.[12] Around 1900 his younger brother Anton Philips, a salesman with a personal interest in technology, joined him. Together they were responsible for the turbulent growth of the company during the first half of the twentieth century. During negotiations with competitors about markets and technology, the Philips brothers realized that they needed to establish long-term solutions if they were to keep up with the technological and market race. In other words, it was not enough for Philips to simply have a tradition of innovation—they also needed to create a stable company structure that permitted the coordination between people and resources that was necessary for developing innovations.[13] Another reason for the Philips brothers to establish a Research Department was the re-introduction of a Dutch patent law in 1912. Through their activities on the international market, the Philips brothers knew all about the importance of patents.[14] The reintroduction of the Dutch patent law strengthened the need for an articulated patent policy.[15] The absence of a patent law in the Netherlands before 1912 enabled Philips to make extensive use of the inventions of others—Dutch industrialists were free to exploit inventions made by other (foreign) industrial companies. Dutch industrialists copied German and American technological developments and implemented them to exploit the domestic markets. Such a "highwayman" attitude was to change after the implementation of the new patent legislation.

The Philips Research Department's history started when, in the winter of 1913–14, Gerard Philips and his brother Anton (the company owners and the key-persons in its development at the time) decided to found the research organization as a separate part of their company in Eindhoven. The Philips brothers had advertised in a Dutch newspaper and asked for an "able young Doctor of Physics, must be a good experimenter."[16] Gilles Holst, a 27-year-old physicist, working at Leiden University, applied for the job and Gerard Philips invited him for an interview. Philips offered him the new position and on 2 January 1914 he started to work for Philips. His task was to set up a new organization within the Philips company. Holst was to be Philips' first researcher and later its first official research director.

At its inception, the Philips Research Department took on testing and trouble shooting incandescent lamps. Whereas the researchers' task had in the first place been to concentrate on trouble shooting, they also tried from the very start to carry out development-oriented research and to get a deeper understanding of physical phenomena. For that reason we can typify the Philips lab in this period as a hybrid research laboratory. Several researchers were hired to assist Holst in the research project. The Kamerlingh Onnes university laboratory proved to be an important source of knowledge and personnel. Kamerlingh Onnes received the Nobel Prize for physics in 1913 and he built up a research laboratory in Leiden.[17] All the work on perfecting incandescent lamps resulted in a stream of papers about lamp-related problems. From the Philips Research Department's publications it can be gathered that the research activities focused on light bulbs and related phenomena.[18] From the beginning, Holst introduced some academic-cultural aspects in a structural way. Particularly by attending colloquia and scientific publishing, the Philips researchers remained in contact with academic structures. Holst invited the professor of theoretical physics, Paul Ehrenfest from Leiden University, to set up a series of seminars to clarify theoretical and methodological scientific problems.

By trouble shooting and further developing incandescent lamps, the Philips lab accomplished the mission for which it had been established. The ability to combine technical and organizational capability proved to be the condition needed to survive in the incandescent lamp market and to enter into new markets. Whereas in America GE virtually had a monopoly on its domestic market after the “merger wave” and because of its patent portfolio, Philips worked on the European incandescent lamp in which a variety of firms competed. The strongest of the competitors eventually became partners in several cartels—especially in the Phoebus incandescent lamp cartel, which was set up at the end of 1924. This Swiss corporation set the rules, controlled prices, regulated sales, implemented policy and established a testing laboratory to ensure the product quality of its members.[19] GE concentrated its activities on its domestic market and did not participate in Phoebus although it held equity in major European firms like Philips, Siemens and AEG. A further step for Philips was that of obtaining more patents and assisting the company in its diversification process.

In 1923 the Philips Research Department moved into a new building.[20] It gave Holst the resources he needed and it enabled him to expand the scope of the research activities. The new building had services like a well-equipped library, research rooms and a meeting room that provided a climate in which transfer of knowledge was possible. The Research Department started in the 1920s with a diversification program in order to fulfil Anton Philips’ wishes and to satisfy his diversification policy. Work on artifacts, such as gas discharge lamps, X-ray technology, radio tubes, and later television and materials, expanded from then on. At that time, the function of a research department became a major question within Philips.

Holst’s idea about what an industrial laboratory’s task had to be, became clear in a proposal in which he claimed that: “an industrial laboratory is a facility where problems relevant to the industry are investigated with the aid of scientific methods and instruments . . . whereas, for example, in a university laboratory one can always think up a problem that can be solved with the aid of the available tools, in an industrial laboratory where the problems are given, one must always ensure that the necessary tools are available.”[21] Clearly, in his view, the company’s policy had to determine the direction of (new) research programs. It is not strange therefore, to see that Anton Philips’ policy strongly influenced the Research Department’s operations and dominated both the actual direction of research work and the choice of new research projects. Holst was to *follow*, rather than to *lead* the company’s diversification activities.

The 1927 Nobel Prize winner Arthur Compton remarked that, at the end of the 1920s, GE considered the Philips Research Department to be the biggest of all the European competitors.[22] While he may have exaggerated, its competitors did have good reasons for keeping an eye on Philips. The latter had expanded its facilities in electric lamps during the 1920s and, together with AEG and Siemens, it became one of GE’s biggest overseas competitors.[23] In fact, light bulb technology remained important to Philips because it was only after having entrenched itself in the lamp market, that the company had its hands free to pursue the diversification process. Along with the diversification program and the increase

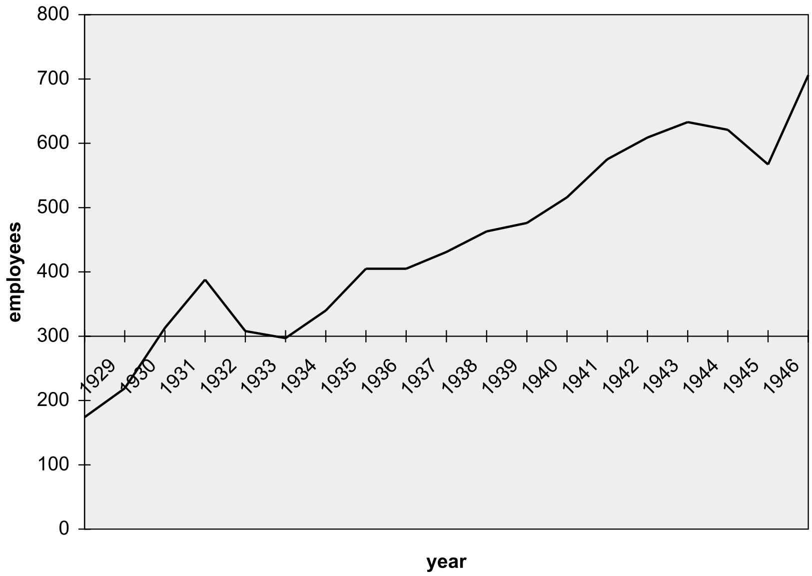

FIGURE 1 Total number of the Philips Research Department's employees 1928–1946.

in personnel, Holst changed the Philips lab's organizational structure into a more formal structure. He hired an Executive Engineer (the engineer Verff) to take over some administrative tasks. Moreover, numerous internal committees such as the radio (tubes and apparatus) committees, the lamp vacuum committee, the materials committee and several standardizing committees helped the researchers to stay in touch with each other's activities. Protocols, meetings, schedules, minutes and debates appeared everywhere in the Philips Research Department's organization.

Roughly speaking the laboratory's work in the 1930s can be divided into five main domains, namely research activities in the field of:

1. Light and the production of light, including gas discharges;
2. Radio, including acoustics;
3. Chemistry, including metallurgy;
4. X-ray investigation;
5. Mathematics and mathematical physics.

The number of employees (including assistants and administrators) working at the Philips Research Department between 1928 and 1946 gives clear evidence of the growth and is illustrated in Figure 1.[24] During the period of growth, Holst had formed what were known as research groups (three radio groups, an acoustic group, two chemical groups, a gas discharge group, an X-ray group and a miscellaneous group).

At first glance, this illustrates that the Philips lab's research structure had become more formal, but a careful investigation of the researchers' daily routines shows that this structure must not be viewed as a strictly formal pattern. Holst attempted to formalize his organization in order to cope with its expansion, but his idea was to organize the contacts within the Philips Research Department and to make them as informal as possible—he strongly believed in the “cross-fertilization” of ideas between researchers. Close contacts between scientists or groups of scientists would, he believed, enable researchers to think about combinations of knowledge. Yet through the formation of groups he prevented the Research Department from becoming disorganized. In 1936 Holst explained the Research Department’s structure to an outsider and he made clear that, although there were some group leaders, “We do not have the same organization throughout all the groups working in the laboratory . . . Our way to attack most problems is to make a general investigation in the field in question, thus forming people who have knowledge in this domain. In most cases this proves to be more advantageous than the direct attack on such a problem.”[25]

The Research Department provided Philips with a source of up-to-date knowledge, especially in X-ray technology, radio (both tubes and apparatus) and all kinds of materials (especially magnetic materials like ferrites). Thanks to the specific knowledge and skills of scientists and engineers, Philips was able to remain in touch with state-of-the-art technology.

During meetings of the company’s committees on Philips’ diversification policy, Holst represented the Research Department’s interests. He was able to do so during the meetings of the Board of Directors and the company Secretariat, but in particular during the meetings of the “Oriënterings Commissie” (abbreviated to “Orco” and meaning in English: Orientation Committee). Philips established the Orco in 1932 to guide its diversification policy.[26] It consisted of Philips’ senior managers, members of the Research Department and members of the Patent Office, and it functioned as a platform for mutual orientation on matters of scientific and technological significance, patent legislation, commercial activities and contractual questions. The Orco had the authority to make decisions in cases where there was significant overlap between the interests of different parts of the company.[27]

Philips’ radio research activities, which I present now as an embedded case-study, can illustrate the claim that Holst built strong connections between the Research Department and other departments within Philips. The history of the radio research program can offer us a partial, but clear insight in the emergence of more formal research structures within the Research Department’s organization and in the contacts between the Research Department and other parts of the Philips company. The radio research program displayed the important qualitative characteristics of the way Holst connected his department to other divisions within the company.

HOLST’S IDEAS ON HOW TO EMBED THE RESEARCH DEPARTMENT IN THE COMPANY: THE CASE OF RADIO RESEARCH

As we have seen above, the 1920s were a turbulent period for the Philips company, a period in which its general policy of expansion and step-by-step diversification began. It was especially the creation of the Phoebus organization cartel that had led to a period of calm for the international incandescent lamp industry. Philips decided to step into the growing international radio market. First hesitantly, but gradually more and more enthusiastically Philips got involved in the production of transmitting and receiving valves.[28] Although the first production of radio valves took place in the workshops of the Research Department Holst decided to prioritize research into light bulbs and electronic valves. It was Anton Philips himself who pointed the laboratory in a new direction. Radio technology became

Philips' most important diversification program from the 1920s and onwards. Although Philips was not a first mover in the radio market, the company soon proved to be a successful actor and innovator in this sector and a competitor that was to be taken seriously by the American radio industry. Indeed according to the British economist, Christopher Freeman, "Many of the important inventions concerning radio receivers between the wars were made by European companies, especially Philips and its subsidiaries. In 1937 Dutch radio exports were as big as those of the US."[29]

At the end of the 1920s, weekly radio apparatus sessions were held within the company. During the meetings, the technological features of radio sets formed the main topics of discussion. The shift in direction from the production of radio parts (like valves) towards the production of complete radio sets complicated the innovation process within Philips. In fact, it was on the way to becoming an integrated firm. Indeed, the research and development activities required for completing a radio set demanded a structural adaptation of the Research Department's organization. Furthermore, contacts between the Research Department and other Philips company sections were formalized. This was notably the case for the contacts between the Research Department and the Philips Apparatus Department. The Apparatus Department was built in 1928, which was a year of expansion for Philips in Eindhoven, and it was one of the biggest factories that Philips had at that time.[30] This department became involved in developing radio sets. For good knowledge interchange between the Research Department and this factory it was important to make specific, detailed agreements so that the transfer could be handled.

An appointment made in 1929 shows that the management involved in this transfer had become aware of what was required. Philips managers decided that there should be seven distinguishable stages in the development of new radio sets. The first two stages involved activities that took place in the Research Department: the research and development phase defining new concepts for radio sets. The Commercial Department became involved in the third stage and together with that department, the Research Department temporarily accepted the new device. The Design Department, and especially its industrial designer, the engineer Kalff, proposed a design which was discussed and revised. After a test fabrication of ten sets, the sixth stage would be arrived at and the radio set would be approved for mass production, which was the seventh and final stage.[31]

What is conspicuous about this route is that it still reflected a one-way development of radio sets. The new radio set had, so to speak, followed a road from the Research Department to the factory. Holst however, changed this into mutual development between the Research Department and the Apparatus Department. The mutual development of radio sets was possible after a reorganization of the factory's structure. This new organizational feature together with the responsibilities attributed to people working within this structure, paved the way for the combined development of radio sets.

At the same time, at top company level, Philips managers had installed radio committees in order to improve the innovation process.[32] By the end of the twenties, four committees had been formed by the Philips Board of Directors: the New Articles Committee, the Radio Tubes Committee, the Radio Apparatus Committee and the Radio Tubes and Apparatus Contact Committee.[33] The formation of these committees is illustrative of the varied nature of radio research, the involvement of various departments and Philips' attempts to restructure its organization. The director's initiative was not, however, a guarantee for good collaboration between the radio groups and departments within Philips. Bad collaboration between the designers of radio sets and radio tubes was often the topic of discussion during the meetings organized by these committees.[34]

Therefore, at the beginning of the 1930's the time was ripe for thinking about adapting the Research Department's organizational structure. Holst had formed several new research groups within his organization. Although the division into groups did not mean that in practice research was channeled into a strict pattern, group-formation did reveal the attempt to structure the innovation process. He was successful in his efforts to build up a sound organization and it was especially radio research that became well structured and embedded within the organization as a whole.

Holst reorganized the research structure of groups, for example the Radio Tubes Group. This process of organization and reorganization is illustrative of the dynamic 1930s period. From the minutes of the meeting of February 1934, the new Radio Tube Group structure becomes clear.[35] Three sub-groups had been formed within the Radio Tube Group. The task of the first group was to make improvements in radio tube cathodes. These researchers particularly investigated the working of getters, the evaporation of cathodes and the insulation of tubes. These were all technical problems that were generic to all sorts of tubes, they were not problems peculiar to radio tubes, so that the researchers could use their knowledge gained earlier when developing other tubes. The task of the second group was to work on the geometry or design of radio tubes. Finally the third group, headed by Van der Pol (who was the most important and gifted radio researcher at Philips), had to examine more complex questions like the issue of the secondary emission of electrons.

For the radio innovation process as a whole, this reorganization had enormous consequences. The change of organization structures at Philips' Research Department and within other Philips' departments influenced the manufacture of radio parts as well as research activities into radio technology.

PROTOCOLS FOR INNOVATION WITHIN PHILIPS

What we have seen thus far is that, like other Philips departments, the Research Department was reorganized in the 1930s. Of course, a formal (deliberated) organizational structure says nothing about good knowledge transfer between the departments. To evaluate this one must analyze the contacts between groups and departments. In other words, it is interesting to see if and how contacts between the Research Department and Philips' Apparatus Department became formalized. In this way we can see how the development of radio sets was to become very much a matter of co-operation. How these contacts became structured can be gathered from the protocol entitled "Agreements between the Research Department, the Apparatus Department and the Apparatus Laboratory concerning the normal developmental course to be followed for receiver apparatus," that was drawn up in December 1933.[36]

This protocol, that was drawn up by Bouman (head of the Radio Apparatus Department's design group) and Tellegen (a Philips researcher working closely together with Holst), structured the developmental course for new apparatus. It contained formal actions. First of all, a conference with members of the Apparatus Department, the Commercial Department, and the Research Department determined the development "route" to be followed by a new radio receiver type. For those types that could be developed by the Apparatus Department only the basic scheme of radio sets was discussed in a meeting with researchers. Such a radio set consisted of well-known principles and parts. For each radio set that the Research Department and the Apparatus Department developed together, there was a researcher who made up the basic scheme for the new set. This scheme was subsequently discussed with a member of the Apparatus Department laboratory. The outcome of that discussion was a shared responsibility for the new radio set.

The Apparatus Department's development group elaborated the details. During this developmental phase the researcher Rinia could be consulted on technical matters. Subsequently, temporary versions of the basic scheme were sent around within the Apparatus Department and within the Research Department, so that as many people as possible could take advantage of the newest knowledge. Bouman (see earlier) was responsible for the final version. A chassis would be designed by the Apparatus Department and discussed with the Research Department and the design group then made the prototype. The prototype was constructed in two stages. During the first stage a Philips researcher made only essential changes so that it would work. The second stage of development took place within the Apparatus Department's laboratory. This stage involved the updating of the basic scheme. When changes were necessary, the Research Department had to be consulted. Changes were implemented and written in the Apparatus Department's laboratory notebook and the apparatuses that had been modified were tested. For the total execution of the second stage it was again Bouman who was responsible.

To conclude, a clear and formal protocol structured the transfer of knowledge and production that was to become routine work. Of course, one should not only look at the content of the formal (deliberated) protocols, but also at the execution of them in practice. A well-structured plan on paper is not a guarantee for good co-operation. Interviews (which are left in the Philips archives) do, however, support the view that there was a degree of commitment from both sides to comply with the protocol.[37] From minutes of meetings held in the thirties, which were attended by members of the Research Department and by people from the Apparatus Departments laboratory, it can be concluded that technological exchange was intensive and detailed, with contributions being made by both parties.[38]

The intensive collaboration sketched above between Holst's radio research and the company's radio production, was not an exception. Holst used the same mechanism to structure the contacts between the lab and the Patent Department, which was done by means of a protocol that was formulated during the Patent Conference.[39] The protocol structured and standardized the route for obtaining a patent. When problems became visible during the execution of the protocol, Holst together with Hijmans, the director of the Philips Patent Department, were able to change and improve it. The formal structure shaped his researchers' actions enabling knowledge to be exchanged, but simultaneously Holst was able to modify this organizational structure as soon as it became constraining, and he created a new one over the course of time.

THE GENERAL ELECTRIC RESEARCH DEPARTMENT TAKEN AS AN EXAMPLE

The radio research case shows that it was essential for Holst to embed his department in the company as a whole. As his organization grew, Holst also looked into the way other companies tried to carry out research activities in an industrial context. He and his colleagues took the GE laboratory and its researchers as their main example. The GE Research Laboratory's Guest Book, which was left in Whitney's office between 1921 and 1935, shows traces of a visit by Dr Oosterhuis, who was Holst's right hand man during the period of his directorate, in March 1925.[40] He must have been enthusiastic about what he saw there because a few months later Holst and the most important Philips radio researcher Van der Pol also visited the GE Research Laboratory. Their entries in the Guest Book are dated September 1925. Three years later, Anton Philips and Holst visited the GE laboratories again to see what Whitney's organization was like.

Conversely, it also became obvious to GE that the Philips Research Department was an organization to be taken seriously. Several GE researchers visited the Philips lab on matters of general interest. In the winter of 1922–23 Rice, GE's honorary chairman, and Whitney traveled to Europe to investigate the state of scientific research and engineering work both at universities and in industry.[41] They spent some days in the Netherlands visiting Philips at Eindhoven and they remarked: "Philips is most progressive and has started a research laboratory under the charge of Dr Holst, assisted by a group of able young scientists. We were most favorably impressed with the character of these men and the quality of their work."[42]

As is well known among business historians, GE was one of the most important industrial research labs in the United States. Organized industrial research first emerged there between the time that the big railroad companies hired their first scientists at the end of the nineteenth century, and 1900, when General Electric's management decided to establish a research laboratory. The latter took the German situation as an example of in-house research in industry—the organization of industrial research was pioneered in Europe. By establishing a research laboratory, General Electric followed the example of German firms in hiring individual scientists to work in a new kind of a research organization.[43] One of the first and most successful inventions of this research institute, made by the researcher Coolidge, was the tungsten filament. This success gave GE a commercial advantage in the electric lighting industry.

Gradually, Whitney, the GE research director, transformed his Research Laboratory from constituting a modest part of the company to being an organization in its own right. GE's model of a research laboratory was then taken as an example by American industry. US companies such as DuPont, Eastman Kodak and General Motors sent people to Whitney to learn about his organization.[44] Only after having built a stable enterprise, could managers reflect on an in-house research program and product and data exchange between the laboratory and other departments became possible. This is also true for Philips. It took GE as an example because GE was the first firm to have such a laboratory. Thus historian George Wise has pointed out that ". . . evidence that the GE example exerted influence on the continent shows up in a 1922 letter from the Dutch physicist Balthasar Van Der Pol to British colleague Edward Appleton. Discussing a job offer he recently received from the Philips Company, Van Der Pol writes: 'new laboratories are being built in the American G.E.C. fashion . . . my job would be wholly independent of the work. Working in this general scientific way already pays. They have the example of Langmuir'."[45]

At that time—in the mid 1920s—the GE Research Laboratory was a fully-grown organization having about 300 employees, more than 130 highly educated researchers and some 25 people with doctorates.[46] Philips researchers only started to see the GE laboratory as an example when Philips and GE had been through a period of expansion in which the internal organization was strengthened. However, the way in which the research organizations became part of their company's structure and the paths taken by both firms to reach that point were different. Industrial research remained a fragile process and there was no guarantee of (organizational and technical) success.

Van der Pol's remark illustrates a striking feature of the firm's innovation process—the laboratories' tasks to improve and accomplish products and to deliver technical know-how—was a process that was not guided either by individual efforts or by organizational factors, but which rather comprehended both aspects in miscellaneous ways.

The historical study above illustrates how and why Philips set up a research laboratory under specific technical, economical and political circumstances. It also illustrates how Holst organized communication inside the organization via formal and informal lines. Philips' research director had to find ways of enabling individual researchers to maintain their professional status. He successfully used organizational innovations. As long as his laboratory was housed in or close to the factories Holst could adopt an informal "face to face" style of management. However, as soon as he was confronted with an expanding organization he was forced to change his informal style of leadership. Moreover, the distance between research and manufacture increased dramatically when Philips established a new laboratory building, which meant that the research director had to rethink how knowledge could be transferred to other parts of the firm.

In what follows, I will briefly investigate how GE's research director Whitney tried to exchange knowledge with managers from other company units using their organizational structures. In the end it will become clear that for the positioning of their research organizations Whitney and Holst used various strategies and that they had different management styles.

WHITNEY'S SCIENTIFIC RESEARCH IDEAL

According to his biographer, George Wise, Whitney found too much organization counterproductive. The growth of the laboratory, however, forced him to constantly re-think and re-structure his department to achieve work co-ordination. After the First World War, he nominated several of his best researchers such as Coolidge, Langmuir, Hull and Dushman to become informal group leaders, each with a different style of leadership.

With his style of management Whitney had found a compromise between a bureaucratic organization and an anarchic laboratory. Whitney believed that encouraging gifted researchers offered the best path to producing better light bulbs, patents and new products. However, although he stimulated his researchers to participate in committees like the Lamp Vacuum Committee, Whitney wanted to keep his distance from the GE factories.[47] According to Wise, Whitney stuck to this unsystematic style even when his organization expanded and the GE product portfolio diversified. Whitney, maintained that "committees cannot invent," noted that he feared a rigid organization and system and that he wanted to remain independent from other parts of the company.[48]

Before we analyze Whitney's policy, we must take the changing aspects of GE's structure into consideration. In the first decades of the twentieth century, General Electric had rapidly diversified its product lines and was headed by a rather complex management. Although it tried to centralize the organizational structure in the 1920s, GE became even less centralized than it had been in the 1890s. Divisions were set up as complete business entities and their own organizations were responsible for manufacturing and sales.[49] The most important decentralized departments of GE were the Incandescent Lamp Department encompassing several plants and sales departments, the Merchandise Department also including plants and field sales representatives, the Electric Refrigeration Department, the Air Conditioning Department, and the Plastics Department. The alleged advantage of this decentralization principle was that it would segregate certain activities so that the responsibility for results would be appropriately allocated to the management put in charge of those divisions.

However, the managers that GE employed for its new departments had a variety of backgrounds, which meant that the company had a heterogeneous group of managers.

Although GE had established dozens of committees for the exchange of knowledge and ideas among these managers, the main disadvantage of such company policy was that the various company departments continued to be isolated. Earlier, GE's management had tried to improve the integration of the departments. In order to control the activities of the Research Laboratory GE had established a Research Laboratory Advisory Council that took care of the laboratory's position within the company.[50] This council however, was terminated in 1919 and from then on research activities were coordinated with the help of numerous committees for radio, X-ray and lamp technologies and for engineering and standardizing questions. The idea was that by participating in a myriad of such committees, Whitney would keep into touch with the company.[51]

Still, Whitney used these committees for superficial contacts rather than to introduce standardized means for knowledge exchange between his organization and other parts of the company. Again, this was a result of his policy to stay away from everyday problems. It has to be said that the lack of cohesion between the Research Laboratory and other parts of the General Electric Company except for the Patent Department was not only Whitney's problem. Whitney worked in an expanding company in which there was little institutional cohesion in the 1920s. According to David Nye, who wrote a book about GE's image in the first part of the twentieth century, GE managers shared no common vision, and most of the individual managers operated in isolation.[52]

It is interesting here to see that the company set up various summer camps in Schenectady for its management between about 1910 and 1950. The company ran these camps on its own island, called Association Island. The Camp General had the most prestige and only a privileged number of promising young men (known as PYM—no women were invited) were invited to join the camp.[53] This camp served as a way of selecting future managers, thus functioning as a recruitment organization, but was also a means of establishing informal contact and exchanging knowledge between managers from various GE departments.[54] Whitney, Langmuir and Coolidge were frequently present on behalf of the Research Laboratory at Camp General.[55] There they participated in sporting events, and in competitions and in informal discussions together with managers from other GE departments. These discussions focused on the links between GE departments and management levels.

Whitney believed in such contacts. The slogan written above his office was illustrative of his characteristic philosophy: "Come in, rain or shine". It was a unique plea for personal contact between industrial researchers and managers. It reflected the spirit of the man and the type of organization he brought into being.

Whitney earned a lot of respect for his kind of leadership. But there was tension too. Whitney was too keen on having his laboratory become a scientific organization in its own right.[56] Whitney's rhetoric about the benefit of "pure" science for industry and his idea of organizing the research staff as a family, became something of a liability at the end of the 1920s. His organization had simply grown too big for a family approach and the contacts with other parts of the company could no longer rely upon informal lines of contact. The Research Laboratory's staff was reduced and its position questioned during the economic crisis of the early 1930s. According to Wise, Whitney's organization was shaken but remained intact, he himself did not. Whitney, the dean of industrial research, as he was called after his retirement[57], had to step down as research director in the fall of 1932. Coolidge succeeded him. The latter continued to pursue Whitney's idea about the value of science in industry but he also proved to be a more competent organizer.

Ironically, a month after Whitney's retirement as director of the Research Laboratory, Langmuir became the first American industrial scientist to win the Nobel Prize. In spite of the crisis that the GE's Research Laboratory was going through at the time, this prize can be seen as a reward for Whitney's efforts too for he had enabled talented researchers like Langmuir to practice science in an industrial environment. And although Langmuir's position was rather exceptional even under Whitney's leadership, he stands for Whitney's ideal of "the" industrial research worker. Eventually, it was Coolidge who improved Whitney's style that had become somewhat outmoded. He realized that planning, strategy formulation, structuring research and embedding the research organization in the company was becoming a more important task than merely stimulating his researchers.

WHITNEY VERSUS HOLST: SIMILARITIES AND DIFFERENCES IN STRATEGIES AND STYLES

Although Holst's first activities were meant to support production, he vigorously created an open academic sphere as the basis for his organization. In dealing with his contacts with the Dutch universities and The Delft Polytechnic, Holst drew on institutional structures from earlier experience gained at the Kamerling Onnes university lab where he had worked for a couple of years. Like Whitney at GE, Holst tried to co-ordinate research and the accommodation of researchers in industrial settings by stimulating people to publish scientific articles in external journals as well as in in-house technical publications. Above all else, the start of a series of colloquia in 1920 constituted part of a move to stimulate the transfer of knowledge from the Philips lab to the university and vice versa. In doing so, he was inspired by his colleague at GE, Whitney.

Interestingly, Ehrenfest, who had started the colloquia at Philips, had also visited the GE Research Laboratory in the mid-1920s to give a lecture.[58] During that visit he had learned, in his own words, "about the sense and value of industrial research."[59] Ehrenfest's visit to the GE laboratory enabled him to use the seminars for an extensive knowledge exchange. His contacts with GE researchers of course provided useful ways for Philips researchers to learn about their GE colleagues. Langmuir also visited Philips researchers in Eindhoven.

However, although it was important to publish scientific papers and to organize scientific lectures, that was not Holst's main task. After all, he was employed by an industrial firm and had to come up with patents and new products for his company. As we have seen in the radio case, Holst had formalized the knowledge exchange between his research organization and the other Philips departments.

Holst was fully aware of his position in industry—during the company committee meetings concerning the diversification policy, he represented Philips' research interests. The way in which the Philips organization was structured (like the earlier mentioned Orco-structure) enabled Holst to stay in close contact with other departments. According to Holst, the lab's growth as a reaction to the Philips diversification policy demanded stable structural integration within the firm. As we can see from the radio case, Holst was a gifted organizer who intelligently exploited various communication channels. What is clear is that Holst, in the footsteps of Anton Philips, had accurately integrated the Research Department into the Philips Company.

According to Holst an important task for an industrial research director was to position the Research Department in the company as a whole. His input during a discussion within Philips about the benefit of scientific research in the company can illustrate this. The discussion took place shortly after the economic crisis of the 1930s. In 1935 the Philips Board of Directors considered the possibility of transforming the Research Department into an independent corporation. The director of that corporation did not necessarily have to be a member of the Philips company. In that way the corporation employees could do research for any Dutch firm that wanted to pay for such a service by means of a subscription. Maintaining high level research activities was something that interested many companies. For Philips, such a structure could result in tax advantages.[60] Therefore, the company lawyer, F.E. Spat, carefully investigated the possibilities of carrying out the plan. He concluded that it was too problematic. In the first place he saw too many demarcation problems in detaching the Research Department and the factory labs from the Philips organization. For that reason Anton Philips, whose opinion was expressed by Spat during the meeting, opposed the construction. Philips Patent Department's head Hijmans agreed with him, adding that a considered patent policy would be impossible in such an organization. The Philips management, including Holst, came to the conclusion that the Research Department was so well integrated into the various parts of the company (the Orco meetings, for example, illustrate this) that doing away with the organization would give rise to too many demarcation problems.

This differed sharply from Whitney's organization that became more and more isolated from other GE departments. That was not only because GE was a more complex company than Philips, but it was also a consequence of Whitney's style of leadership.

DISCUSSION. THE HELPING HAND OF ORGANIZATIONAL STRUCTURE

Historical literature suggests that just those firms that were able to combine the outcomes of industrial research (both products and knowledge) with organizational arrangements, were able to utilize the laboratory sources of technology.[61] This is certainly true for Philips. As I have shown in this article, the institutional bodies Holst was working with assumed that the main aim was to come up with useful knowledge, products, and patents for the firm. That implies that he had to think about the embeddedness of the laboratory in the company as a whole, because the way the research organization was embedded has consequences for the transfer of knowledge from the lab to different company departments. Working on corporate-related projects forced him to articulate formal and informal processes required for the planning and coordination of the different organization levels within the firm.[62] Therefore, in this article I have focused on the Philips Research Department's institutionalization process and on its organizational dynamics. What I have tried to show was how this process took place at Holst's research lab.

When we compare the Philips Research Department with the GE's Research Department, it is first of all important to take the specific context into consideration. GE managed to become the leading electro-technical firm in America, but defending that position required a source of technical know-how. After the merger wave of 1895–1904, US antitrust policy forced firms like GE to seek growth alternatives which meant that research programs were indispensable. In the Netherlands, the situation was different. Philips, being involved in the European incandescent lamp market, which was quite chaotic, had to defend its market position within cartels with several competitors. That required an excellent product and solid patents. To defend their positions and in order to expand, both companies found a solution in the establishment of research laboratories.

Like Philips, GE drew on tremendous organizational capabilities to defend their market position and to enter new markets by diversifying their product lines. Thanks to the development of the "internal force" of research, Whitney and Holst were able to come up with the technological knowledge required for short-term demand and to enable their firms to think about long-term market developments.[63] However, their styles of leadership influenced the way both industrial research laboratories were organized. This is in line with Dennis' argument about why industrial research laboratories could differ: "Given Louis Galambos's argument that each firm literally reinvented the processes of managerial integration in the period between 1900 and 1914, why should we assume AT&T learned anything from GE on establishing a corporate research laboratory? The irony here is simple—in the midst of a wave of organizational histories we find that individuals made an important difference."[64]

Although Whitney inspired Holst, the latter did not blindly copy Whitney's organizational structure as if it was the best possible model. As I have shown, while the latter wanted to stay away from the GE factories as much as possible, Holst successfully managed to integrate the laboratory into the Philips company as a whole by following Anton Philips carefully in his policy and by making use of the available organizational structures. Holst's leadership drew on organizational structures where formal contacts and informal knowledge exchange were possible. Together with other Philips managers and with Anton Philips himself operating as a driving force, Holst shaped the Research Department in such a way that individual scientific action was made possible in a company that demanded specific outcomes of individual acts. He can be seen as an industrial research entrepreneur, vital to corporate innovation.

In conclusion, Philips learned to overcome numerous organizational problems and limitations. It was especially the Orco-meetings and its protocols that enabled Holst to stay in touch with other Philips departments. His strategy as a research director was a mixture of technical expertise and organizational capabilities. As a result, the Research Department became well embedded in the company as a whole. In brief, it was not as much technological, but rather organizational, innovation that made the Research Department a successful part of the Philips company.

NOTES

1. An earlier version of this article was presented at the 5th EBHA (European Business History Association) Conference in Oslo, August 2001 and at the SHOT 2001 Conference held in San Jose California, October 2001.
2. See for this theme also J. Schumpeter, *Socialism, Capitalism and Democracy* (London: Allen & Unwin, 1943).
3. Thomas P. Hughes, *American Genesis. A century of invention and technological enthusiasm 1870–1970* (New York: Viking, 1989), p. 22. See also D. A. Hounshell, "Hughesian History of Technology and Chandlerian Business History: Parallels, Departures, and Critics" *History and Technology* (1995), 12: 205–224.
4. J.J. Beer, "Die Teerfarbenindustrie und die Anfänge des industriellen Forschungslaboratoriums" in K. Hausen, R. Rürup, eds., *Moderne Technikgeschichte* (Köln: Verlag Kiepenheuer & Witch, 1975), pp. 106–118; G. Meyer-Thurow, "The Industrialization of Invention: A Case Study From the German Chemical Industry" *Isis* (1982), 73: 363–381. The organization of industrial research was pioneered in Europe, see:D.C. Mowery, N. Rosenberg, *Paths of Innovation. Technological Change in 20th-Century America* (Cambridge: Cambridge University Press, 1998), p. 11. Homburg analyzes the birth of the "industrial research laboratory" as a concept within seven German industrial firms. He carefully studies internal and external circumstances and forces—the German patent law of 1877, for example, is cited by Homburg as the most important impetus for the systematic creation of research activities within the German chemical industry. E. Homburg, "The emergence of research laboratories in the dyestuffs industry, 1870–1900" *The British Journal for the History of Science* (1992), 25: 91–111. Hounshell even speaks about the German research as the world's most complex and advanced research system at that time, see D.A. Hounshell, "The Evolution of Industrial Research in the United States" in R.S. Rosenbloom, W.J. Spencer, eds., *Engines of Innovation. U.S. Industrial Research at the End of an Era* (Boston: Harvard Business School Press, 1996): 13–85, p. 20. See also R. Fox, A. Guagnini, "Laboratories, workshops, and sites. Concepts and practices of research in industrial Europe, 1800–1914" *Historical Studies in the Physical and Biological Sciences* (1998), 29, Part I, pp. 55–139 and 29, Part II, pp. 191–294.

5. L.S. Reich, *The Making of American Industrial Research. Science and Business at GE and Bell, 1876–1926* (Cambridge: Cambridge University Press, 1985), p. 3. To challenge the myth of the unambiguous successes of industrial research laboratories, I want to emphasize that there were other ways for companies to acquire knowledge than just by establishing an in-house research laboratory.
6. A.D. Chandler jr., *The Visible Hand. The Managerial Revolution in American Business* (Cambridge: The Belknap Press, 1977). In Chapter 11 entitled "Integration completed" he pays particular attention to industrial research.
7. In later work, Chandler broadened his view of Europe in a comparative study: A.D. Chandler jr., *Scale and Scope: The Dynamics of Industrial Capitalism* (Cambridge: Harvard University Press, 1990).
8. Interview held at the University of Virginia, Charlottesville V, in November 2000.
9. L. Galambos, "The American Economy and the Reorganization of the Sources of Knowledge," in O. Alexandra, J. Voss, eds., *The Organization of Knowledge in Modern America 1880–1920* (Baltimore: The Johns Hopkins University Press, 1979), pp. 269–282.
10. See for example: Hounshell, "The Evolution of Industrial Research in the United States." One example that also contemporaries referred to GE is: T.A. Boyd, *Research. The Pathfinder of science and Industry* (New York: D. Appleton-Century Company, 1935).
11. This section is based upon the thesis of the author: F.K. Boersma, *Inventing Structures for Industrial Research. A history of the Philips Nat.Lab. 1914–1946* (Amsterdam: Aksant Academic Publishers, 2002). Nat.Lab. stands for Natuurkundig Laboratorium, the Dutch term for Physics Laboratory—in this article I will use the term (industrial) Research Department.
12. K.E. Sluyterman, H.J.M. Winkelman, "The Dutch Family Firm confronted with Chandler's Dynamics of Industrial Capitalism, 1890–1940" *Business History* (1993) 35: 152–183, and esp. p. 172. For the comparison with GE it is important to notice that although Philips had become a limited company in the summer of 1912, the Philips brothers remained dominant in the company.
13. This is also a point that is emphasized by historians, for example: W.B. Carlson, "Innovation and the Modern Corporation. From Heroic Invention to Industrial Science," in J. Krige, D. Pestre, eds., *Science in the Twentieth Century* (Amsterdam: Harwood Academic Publishers, 1997), p. 213 and Galambos, "The American Economy and the Reorganization of the Sources of Knowledge," pp. 269–282.
14. See: A. Heerding, *The History of N.V. Philips' Gloeilampenfabrieken Volume 2. A company of many parts* (Cambridge: Cambridge University Press, 1988), Chapter 3. Nevertheless by 1912 Gerard Philips had only acquired three patents, one in Germany and two in the Netherlands, see: PCA (abbreviation of the Philips Company Archives): Philips octrooien voor uitvindingen op het Lichtgebied aangevraagd vóór 1924.
15. The earlier patent legislation had been abolished in 1869, see F. Gerzon, *Nederland, een volk van struikrovers? De herinvoering van de Nederlandse octrooiwet (1869–1912)* (Den Haag, 1986), pp. 1–8.
16. Heerding, "The History of N.V. Philips' Gloeilampenfabrieken Volume 2. A company of many parts," p. 311.
17. K. van Berkel, A. van Helden, L. Palm, *A History of Science in the Netherlands* (Leiden: Brill, 1999), pp. 491–494.
18. B. van Gansewinkel, *Beschrijving van publicaties en verslagen van het Nat.Lab. 1914–1926* (Description of publications and reports by the physics laboratory 1914–1926) (PCA: Intern Verslag 1989).
19. I.J. Blanken, *The History of Philips Electronics N.V. Volume 3. The development of N.V. Philips' Gloeilampenfabrieken into a major electrical group* (Zaltbommel: European Library, 1999), especially Chapter 3: The Phoebus International Incandescent Lamp Cartel. See G. Jones, *The evolution of international business. An introduction* (London and New York: Routledge, 1996), Chapter 4: National Manufacturing.
20. N.A.J. Voorhoeve "Het Natuurkundig Laboratorium der N.V. Philips' Gloeilampenfabrieken," in *Nederlands Tijdschrift voor Natuurkunde*, 1924: 345–366.
21. A remark made by Holst in a proposal relating to the reorganization of the physics laboratory. Quoted from Blanken, "The History of Philips Electronics N.V. Volume 3. The development of N.V. Philips' Gloeilampenfabrieken into a major electrical group," p. 189.
22. PCA/NL 325. Correspondentie bezoekers (Correspondence visitors). The remark made by Professor Compton can be found in PCA/NL 402. map 1. He made his remark in an interview in Stockholm.
23. See: L.S. Reich, "Lighting the Path to Profit: GE's Control of the Electric Lamp Industry, 1892–1941" *Business History Review* (1992), 66: 305–334.
24. PCA/NL Jaarverslagen (Annual Reports) Nat.Lab.
25. PCA 726 NL. Letter from Holst to Dr. F. Kapitza, 18 June 1936.
26. Blanken, "The History of Philips Electronics N.V. Volume 3," pp. 67–68.
27. PCA 75:8. Orco. Minutes of the Orco, 12 and 13 April 1933.
28. Blanken, "The History of Philips Electronics N.V. Volume 3," pp. 181–185.
29. C. Freeman, *The Economics of Industrial Innovation* (London: Frances Pinter Publishers, 1982), p. 75.
30. Blanken, "The History of Philips Electronics N.V. Volume 3," pp. 250–255.
31. PCA/NL 539. Radio Apparaten Bespreking 1926–1929. Apparatenbespreking No. 21, 23 December 1929. Verslag van de Laboratoriumbespreking op Maandagmiddag.

32. In his analysis of Philips radio, Blanken pays attention to the adaptation of the Philips' upper management strata in reaction to the almost uncontrolled expansion, which had altered the size, and the nature of the business. Blanken, "The History of Philips Electronics N.V. Volume 3," Chapter 6.
33. PCA/NL 521. Ontvanglampen bespreking. Bijlage 6 bij de Agenda Algemeen Radiolampen Comité 6.11.1930.
34. PCA/NL 521. Ontvanglampen bespreking. Bijlage 6 bij de Agenda Algemeen Radiolampen Comité 6.11.1930.
35. PCA/NL 521. Radiolampenbespreking, 12 February 1934.
36. My translation of the title of the protocol. The protocol itself can be found in: PCA/NL 520. Afspraak tussen de Apparatenafdeling van het Natuurkundig Laboratorium en het Apparaten Laboratorium betreffende de normale ontwikkelingsgang van een ontvangapparaat, door J.A.J. Bouwman and B.D.H. Tellegen, 4 December 1933.
37. e.g. PCA 181.2. Interviews. Interview with Professor Ir. B.D.H. Tellegen, 11 May 1973.
38. PCA/NL 548. Radio Apparaten Bespreking Nat.Lab. – Apparaten Fabriek 1930–1932.
39. The conferences (as a way of control) were internal Philips business affairs with members of the Patent Department, the Research Department and/or the individual inventor. Crozier has clarified that the physical distance between offices allows space for potential control that is not available or useful in smaller organizations. M. Crozier, *The Bureaucratic Phenomenon* (Chicago: Chicago University Press, 1964).
40. Schenectady Museum Archives. Guest Book GE Laboratories.
41. Several years earlier, in 1906, Whitney had made a trip to Europe to investigate the European lamp manufacturing methods, see: A. Heerding, *The History of N.V. Philips' Gloeilampenfabrieken Volume 1. The origin of the Dutch Incandescent lamp industry* (Cambridge: Cambridge University Press, 1986), pp. 159–164.
42. E.W. Rice, "A Visit to Europe" *General Electric Review* (1923), XXVI, No. 11; 724–730, cit. p. 728.
43. The pursuit of scientific and technological development in America was an activity of individual geniuses, whereas in Europe scientific research was organized at universities that built upon a long scientific tradition. See J.W. Servos, *Physical Chemistry from Ostwald to Pauling. The Making of a Science in America* (Princeton: Princeton University Press, 1990), Chapter 2. Until 1900, university research in American was poor in comparison with their European counterparts. On both continents however, the emergence of industrial laboratories meant a watershed in the history of science and technology. With the appearance of industrial laboratories at the turn of the century both in America and in Europe, research work was no longer a privilege of university laboratories or of individuals, but it became the daily work of professionals working in industry.
44. Wise, "Willis R. Whitney, General Electric and the Origin of US Industrial Research," p. 180. In the mid-1920s Whitney also participated in an informal group of American industrial research pioneers which included people such as Frank B. Jewett of Western Electric, C.E. Kenneth Mees of Kodak, Boss Kettering of General Motors and Charles L. Reese of DuPont, see S.W. Leslie, *Boss Kettering*, (New York: Columbia University Press, 1983), p. 194.
45. G. Wise, *Willis R. Whitney, General Electric and the Origin of US Industrial Research* (New York: Colombia University Press, 1985), p. 234. I am indebted to Sally Horrocks of the Department of Economic and Social History of the University of Leicester, UK, for giving me the details of some correspondence between Appleton and Van der Pol. The entire passage of the letter of Van der Pol, about industrial research: "Further quite new laboratories are being built in the American GEC fashion, and my job would be wholly independent of the works. It concerns therefore purely scientific work. Moreover as Holst told me, they are working very freely. E.g. for several reasons they want to know a great deal more about gas discharges than is generally to be found in the textbooks. Hertz is the man for that. He simply spends all his time for finding out what really happens in a glow discharge and it appears that J.J. and Townsend are altogether wrong in many respects. Working in this general scientific way already pays. They have the example of Langmuir. Pensions belong to the job as well as cheap living in a Philips house. And though this is no definitely settled yet they offered me practically £1000 to start with. The drawbacks are: seven working hours a day; one month holiday a year and of course in such a job one is not as independent as in a university post." Van der Pol wrote this letter on 24 April 1922 (source: Edward Appleton Papers, Edinburgh University Library, Ms 2300 series).
46. Wise, "Willis R. Whitney, General Electric and the Origin of US Industrial Research," p. 246.
47. Reich, "The Making of American Industrial Research. Science and Business at GE and Bell, 1876–1926," p. 85 and Wise, "Willis R. Whitney, General Electric and the Origin of US Industrial Research," p. 181.
48. Wise, "Willis R. Whitney, General Electric and the Origin of US Industrial Research," p. 179–180. One exception perhaps, was the way in which contacts with the GE Patent Department were built up that resulted in stable interaction between both departments. Together with the Patent Department's head, Albert Davis, Whitney had set up standardized forms which researchers seeking patents applications could use. The employees of the Patent Department carefully investigated the reliability of the patent requests and used forms to docket the patent applications. Davis decided whether it was feasible to file a patent application or not. He and his colleagues often advised the laboratory researchers on how to improve their applications using technological and judicial knowledge. See Schenectady Museum Archives. Patent LTRS Microfilm 1904–1922.
49. Schenectady Museum Archives. Hammond File, L 6202.

50. Regrettably not much is left about the activities of this committee. In the archives of the American Philosophical Society in Philadelphia I only found the minutes of the committee meetings held on 4 October 1905 and 15 November 1905. During these meetings the following committee members were present: Davis, Howell, Rice, Steinmetz, Thomson, Weintraub and Whitney. They chiefly discussed technical problems related to light bulb technology (filaments) and rectifiers.
51. Reich, "The Making of American Industrial Research. Science and Business at GE and Bell, 1876–1926," p. 92.
52. Nye uses the GE's photographic collection to tell the story of General Electric's history, ideology and capitalism until the mid 1930s which was organized according to the emergence of industrial photographic communication: D.E. Nye, *Image Worlds. Corporate Identities at General Electric 1890–1930* (Cambridge: MIT Press, 1985). In Chapter 6 entitled *Managers: The Corporation as Tribe,* Nye describes how the top managers of the various GE departments came together at summer camps. See also photographs in B. Gorowitz, G. Wise, editors-in-chief, *The General Electric Story 1876–1986. A Photohistory* (Schenectady, New York: Hall of History, 1989). Nowadays, the General Electric Photographic Archives are housed in the Schenectady Museum. The collection encompasses more than 1 million photographs.
53. Later, Kurt Vonnegut parodied this camp in his technological dystopia *Player Piano*. It is apparent that Vonnegut worked for GE in Schenectady between 1947 and 1950 as a public relations specialist in the Research Laboratory, see H.P. Segal, *Future Imperfect. The mixed Blessings of Technology in America* (Boston: The University of Massachusetts Press, 1994), Chapter 10. What is also apparent is that the GE summer camps reflected the Schenectady's camp culture at that time.
54. Other social and even political questions formed topics of discussion. A conference organized by Steinmetz about electricity and socialism held at Association Island sponsored by the Society for Electrical Development in 1913 brought together electrical manufacturer representatives, utility companies, government, finance and press, see: R.R. Kline, "Electricity and Socialism: The Career of Charles P. Steinmetz" *IEEE Technology and Society Magazine* (1987), 6, No. 2: 9–17.
55. In 1935 E.W. Rice wrote to Professor Elihu Thomson: "I returned home to Schenectady Tuesday morning, in time to attend a meeting of our GE people—the regular Camp General, which, as you know, has been held in Schenectady in recent years, instead of at Association Island. It was well attended. Some three or four hundred representatives came from nearly every part of the country. We had many fine papers and addresses. I saw Mr. Emmons, Mr. Young, Judge Appleton, Mr. Swope, Doctors Whitney and Coolidge and many others." Elihu Thomson Papers, American Philosophical Society, Philadelphia, Series II.
56. According to Kline: "Steinmetz's laboratories stood midway between Edison's product-development laboratory and the science-based laboratory pioneered by Whitney. Edison's group used science and a scientific methodology more than is commonly assumed, but Whitney's lab paid much more attention to the production of scientific knowledge. Steinmetz's laboratories spanned the spectrum from product development to scientific research . . .," see Kline, "Steinmetz. Engineer and Socialist," cit. p. 160.
57. L.A. Hawkins, *Willis R. Whithney. Dean of Industrial Research* (Schenectady: GE Monogram, 1950).
58. Schenectady Museum Archives. Guest Book GE Laboratories.
59. Wise, "Willis R. Whitney, General Electric and the Origin of US Industrial Research," pp. 233–234.
60. PCA 144.81. Directie vergaderingen. Directievergadering, 10 November 1936: Bestudering van het voorstel van een jaar geleden om van het Nat.Lab. een stichting te maken (Examination of the proposal made a year before to turn the Research Department into a foundation).
61. See the introduction in: Carlson, "Innovation as a social process. Elihu Thomson and the rise of General Electric, 1870–1900."
62. Simon who discussed the informal aspects of a formal organization and draws certain conclusions on this: "It would probably be fair to say that no formal organization will operate effectively without an accompanying informal organization." H.A. Simon, *Administrative Behavior. A Study of Decision-Making Processes in Administrative Organization* (New York: The Free Press, 1976), pp. 148–149.
63. See for this theme: L. Galambos, "Theodore N. Vail and the Role of Innovation in the Modern Bell System." *Business History Review* (1992), 66: 95–126, pp. 124–125.
64. M.A. Dennis, "Accounting for Research: New Histories of Corporate Laboratories and the Social History of American Science" *Social Studies of Science* (1987), 17: 479–518, cit. p. 488. Galambos made this argument in: "The American Economy and the Reorganization of the Sources of Knowledge." See also Carlson in his study about Thomson. In the conclusion of his book he discusses the emergence of GE's lab as a result of entrepreneurial behavior and remarks: "The process by which the innovation function was institutionalized was contingent and shaped to a considerable extent by individual inventors, scientists, and managers", B.W. Carlson, *Innovation as a social process. Elihu Thomson and the rise of General Electric, 1870–1900* (Cambridge: Cambridge University Press, 1991), p. 361.