Author(s): Nykänen, Panu

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Chapter 3

Research and Development in the Finnish Wood Processing and Paper Industry, c. 1850-1990

Panu Nykänen

Department of History and Ethnology, University of Jyvaskyla, Finland

panu.nykanen@ttatv.fi

Abstract

This chapter describes the general history of research and development work in the Finnish pulp and paper industry from the mid-nineteenth century until roughly 1990, a period that witnessed it undergo drastic changes because of the altered political environment in Europe and general globalization. In addressing its subject, this chapter is mainly concerned with the operation of paper mills, but it also addresses the related subjects of technical research, formal higher education and work-related, practical learning. In addition, it briefly discusses the challenges inherent in researching the development of technology because of its research traditions.

Keywords

History of Technology; Research and Development; Finland

3.1 Two Cumulative Masses of Knowledge

The tradition of research and development in the paper industry is divided into two separate branches. One consists of technical chemistry, studying the possibilities of chemical wood processing and wood chemistry. The other is part of mechanical engineering, and its roots are in the construction and use of paper machines. The difference between these two traditions is widely acknowledged,[1] and the practical differences between them result from their dissimilar relationships to basic scientific, technical and applied research.

The aim of this chapter[2] is to describe the general history of research and development work in the Finnish pulp and paper industry from the mid-nineteenth century until roughly 1990, a period that witnessed it undergo drastic changes because of the altered political environment in Europe and general globalization. In addressing its subject, this chapter is mainly concerned with the operation of paper mills, but it also addresses the related subjects of technical research, formal higher education and work-related, practical learning. In addition,

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[1] For example, H.F. Rance, who wrote a presentation that was read by J. Carey at the fiftieth anniversary meeting of the Finnish Paper Engineers' Association in Helsinki in 1964, clearly delineated the fundamental distinctions between the two traditions.

[2] The author would like to thank the following persons for the invaluable co-operation they provided in conducting the research for this chapter: University Archivist Erin Dix, Lawrence University, Wisconsin, Jukka Kilpeläinen, DI, MBA, Helsinki, Sampsa Kaataja, PhD, Karjaa, University Archivist Sani Kivelä, Aalto University, Espoo, Archivist Ari Sirén, UPM Central Archives, Valkeakoski.

it briefly discusses the challenges inherent in researching the development of technology because of its research traditions.

As disciplines studied at the technical universities, the two branches (i.e., chemical and mechanical) had separate curricula at the Helsinki University of Technology (HUT, now part of the Aalto University) up to the 1940s. The first professorships in wood chemistry were established in the early 1920s. The research at that time was focused on turpentine chemistry. In contrast, paper-machine technology was a part of general machine technology. As an indicator of the change in the needs of technology for industry, the department of forest products technology was founded in 1941. The rapprochement of the chemical and mechanical branches of research occurred a few decades later. The first students of paper engineering to change their major from machine shop technology did so in 1943, and the initial research papers that focused on paper machine technology were finished in 1946.[3]

As a result of a long-lasting discussion, professorships in wood processing machinery were established from the late 1960s in Finnish universities in an effort to address the industry's special needs.[4] This chapter deals with the background of this development, and the aim of the study is to reveal the impetus behind the organizational changes that occurred.

The nature of technology has been under discussion roughly since the First Industrial Revolution in the eighteenth century. Around the same time the sciences started to develop

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[3] HUT, Department of Forest Products Technology minutes 1941–1948.

[4] The first Professor of Paper Machine technology in Finland was Uolevi Konttinen at the University of Oulu 1969.

rapidly in universities in Western Europe and a special branch of industrial and technical education was created alongside the traditional scientific universities. Thus, two different masses of knowledge emerged, namely science and technology.

The line separating these ‘mirror image twins’, (Layton 1971) science and technology, is blurry. As de Solla Price has aptly stated, science is papyrocentric and technology is papyrophobic. Science is based on conducting empirical research and the publication of academic papers. In contrast, technology is often seen as an art that makes progress through trial and error, and it intentionally aims to hide its achievements. (de Solla Price 1965, pp. 561–562; Wise 1985, p. 235; about the nature of technology see also e.g. Rosenberg 1994, p. 15)

There are two reasons for the papyrophobic nature of technology. In the first place, there is an inextricable link between technology and industrial activities, namely that there is always an economic motive in developing technology. As a result, it is counter-productive to a business to publicize the advances it makes in its industry because doing so could potentially benefit a rival in the never-ending competition to maximize economic efficiency. The second reason is that developing technology largely involves practising the art of engineering. Whereas science entails conducting a series of tests and recording the results, technology is about know-how, learning by doing, developing technical skills and solving problems, processes that involve generating very little, if any, data.[5]

[5] Eugene S. Ferguson effectively describes this reality in his study of the nature of engineering. (Ferguson 1977, p. 833; Ferguson 1993, pp. 1–40, 154)

In many cases the technology is not published or patented. A developer of technology must in every separate case predict if patenting technology is profitable, or alternatively whether the technology should just be launched and sold to customers. In many cases patent processes cause more harm than good for the company that is developing technology.[6]

The history of the art of engineering in the paper industry has been widely discussed. The literature describes how, after the Second World War, the rate at which technology became obsolete because of new developments quickened dramatically, and the art of engineering was gradually but surely almost forgotten. The question arose again in the 1960s, however, when the desirability of providing practical training and experience to formally-educated engineers became a hot topic at pulp and paper and engineers' conferences. (Mardon et al. 1969)

After the Second World War, the general idea of many successful Research and development (R&D) programs in the Finnish industrial culture was to connect science and technology even though this aim was not explicitly declared. There were, however, a few exceptions to this rule, one of which was espoused by Petri Bryk, the CEO (1913–1977) of Outokumpu Ltd., a metallurgy and mining firm. He was renowned for his aphorisms, one of which captured this

[6] About the patenting procedures see Kaataja 2010; Jukka Kilpeläinen, DI, MBA, Helsinki, comments on 10 March 2017.

notion: ‘to know how, you must know why’.[7] In practical terms this meant that Bryk required his personnel to appreciate the connection between science and technology.[8]

3.2 The Nature of a Paper Mill

Hughes (1987) used the term “Large Technological System” to describe the development of a complex technical structure, in which all the parts are developed and operated independently but they are connected to form a massive cluster. These dynamics are all present in a paper mill. The “Large Technological System” of a paper mill consists of several raw material flows, each of them grounded in the science of chemical engineering, and the paper machine’s main structure with all its supplementary machinery. Because paper machines are such complex apparatuses to develop, maintain and operate, usually their components are built to the highest standards of engineering science.

These factors have made paper machines and mills very difficult subjects for historians to analyse. In particular, the aforementioned lack of paper trail on the technological development side and the degree to which mills represent such huge, complex technological

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[7] Tapio Tuominen, CTO Outokumpu Ltd (ret.), oral statement 26 October 2015.

[8] Bryk was one of a generation of Finnish engineers, educated during the 1930s in the optimistic atmosphere of the HUT. After the Second World War a group from the same generation formed the informal luncheon club of “Pilkkula”, and it laid out a roadmap for modernizing Finnish engineering. The other members of this group were Jaakko Rahola, Heikki Miekk-oja and Erkki Laurila, all of whom would later become leaders in shaping modern Finnish technology policy.

systems that are exceedingly difficult to understand have caused historians to shy away from writing about these subjects. It has compelled most historians to focus on writing about these subjects only on their administrative or organizational levels. (e.g., Tuuri 1999)

These factors explain why much of this chapter, specifically those parts that are devoted to the history of technology, is based on so few sources.[9] Only in rare cases did the engineers who practised in this field create documents that discussed their aims or intentions, and it is even rarer that these papers have survived. Hence, oral interviews formed an important part of the research upon which this chapter is based.

Many more sources were available for the section of this chapter that deals with the question of the research and development work. For these sections, research was conducted in the archives of the HUT,[10] the Finnish Pulp and Paper Research Institute (KCL, Oy Keskuslaboratorio - Centrallaboratorium Ab), Kangas paper mill of G. A. Serlachius Oy (GAS)[11] and United Paper Mills Ltd (UPM).[12] The archives of HUT reveal the role that education played in this process, especially during the 1940s and 1950s. In the archives of the Kangas paper mill the memoranda of Niilo Ryti, at that time the Technical Director of the mill, are preserved, and they provide an exceptional opportunity to describe the inner-

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[9] These include the archives of the board of United Paper Mills for the 1960s and 1970s, and the archives of Kangas paper mill during the 1945–1960 period.

[10] In the archives of Helsinki University of Technology (HUT), Aalto University, Espoo, Finland.

[11] In the Central Archives of Finnish Business Records, ELKA, in Mikkeli, Finland.

[12] UPM Central Archives, Valkeakoski, Finland.

workings of a Finnish paper mill from 1950 to 1960. The archives of UPM contain the papers of Niilo Hakkarainen, CEO of the company (1970–1991), and Ingmar Häggblom, its Technical Director. Examining them helps trace the roots of R&D strategic thinking during the 1970s and 1980s.[13] Unfortunately, the existing research literature says very little about R&D in the realm of paper making machinery.[14]

The problematic nature of research and development work in the industry is presented by Archimbault and Lariviere (2011), who investigated the scientific publications of Canadian companies over 25 years' time. Their work highlights the lack of a paper trail that plagues historians of industrial engineering, whereby outsiders are seldom able to see what insiders were doing in developing new processes.

3.3 The Early Stages of Paper Manufacturing and Wood Chemistry

[13] On Hakkarainen's role e.g., Ojala 2001. p. 83.

[14] It is quite revealing that, even the history of Beloit, in its time the leading manufacturer of large printing paper machines, is not publicly accessible. The history of Beloit is however to be found in Robert Hodge & Larry Ely, *Beloit Corporation. Your partner in papermaking*. 1979. See http://paperindustryweb.com/partner/partmenu.htm. Accessed 11 October 2017. In the context of Finland, the topic is discussed to a limited extent in a few sources, including Nykänen (2005) and Komulainen (2014). The latter is a history of the Finnish Paper Engineers' Association, and in it Komulainen discusses the emergence of an R&D policy for paper manufacturing especially after the Second World War. Nykänen (2005) discusses the history of paper making machinery from the view of Finnish machine shops.

The first Fourdriniers in Finland, bought for J. C. Frenckell’s Tampere mill in 1842 and the Tervakoski paper mill in 1853, were operated by skilled craftsmen and used cotton fibres to produce quite expensive, high quality printing and writing paper. The first formally educated civil engineers came to Finland during the 1840s to work in the machine shops and textile mills in Tampere and Forssa. Specialized education in paper manufacturing began in the 1870s when mechanical engineering was separated as a special stream of education at the Helsinki Polytechnic Institute.

A major change in the method of production, and the technical and scientific support system behind it, occurred a short while later. The breakthrough came when the industry switched to using ground wood fibres and chemical pulp as the major raw materials for its rapidly expanding production. As a result, the cost of making these investments was significant when establishing new paper mills after the 1870s and thus represented a great risk for the industry’s entrepreneurs and financiers.

3.3.1 Tar Manufacturers and the Scientific Approach to Wood Chemistry

Research into wood chemistry in Finland is older than the modern, industrial-scale paper industry. It was initially associated with pine and birch tar production. In fact, pine tar rose to be the first branch of mass production in Finland during the eighteenth century, and it was based on the tar pit process that yielded products of various densities from the pyrolysis process. In addition, birch bark tar was produced, mainly for use as a lubricant in maritime vessels. Research into pine and birch bark tar products came to be the oldest government-steered technology project in the country beside metallurgy and mining.

The pine tar industry's low profitability was well known by the government and the Economic Society in Finland. The latter had been founded in 1797 and was a formal think tank at the turn of the century, and in the 1830s it launched a research project to improve the economics of tar production. A pitch factory was built as a pilot project in Oulu. (Blomenthal 1887, pp. 11–23) This enterprise was arguably the first chemical wood processing industry in Finland, but it was destroyed by the British Royal Navy during the latter's campaign in the Baltic during the Crimean War.

A second wave of tar production emerged during the 1850s after the founding of the Evo Forestry School in Southern Finland. Alexander af Forselles was the Director of the School for over one decade (1858–1869), and he launched a modern turpentine factory there. The purpose of the plant was to produce lamp oil, but the hopes surrounding it were crushed by the new standardized crude oil-based kerosene that entered the market after the American Civil War.

3.3.2 Formal Technical Education

The Helsinki Technical School was founded on 9 June 1847 based on the German model of "technische realschule" (i.e., a practical school for primary and secondary students that was geared toward educating future engineers). The school had three clear objectives in its operations. Before the elementary school system was organized in Finland, the technical school aimed to deliver basic skills of reading, writing, drawing and mathematics to the young apprentices working in the industrial shops. It also aimed to provide a "modern way" for apprentices to reach the status of craftsman instead of the professional guild system that still governed the life of small industries. The third goal was to raise Finland's level of competence in the chemical wood industry.

Its importance in the rapidly developing field of technical education is revealed by how it was organized. The technical school's curriculum provided for training in elementary subjects and two disciplines: technical chemistry and mechanical engineering. The lectures for both these disciplines were delivered in special laboratories, furnished and available for use from the beginning of the school's operation in 1849. Other technical disciplines were added to the curriculum after 1860 based on the German model of "technische hochshule" (i.e., a university-level institute of technology).

Anders Olivier Saelan was its first director (1848–1874), and he had a Master's degree in chemistry from the university in Helsinki. In addition, the chemists working in the field of wood chemistry played a leading role in recruiting new teachers to the school. For example, A. F. Soldan, H. A. Wahlforss and E. E. Qvist started as young researchers in the field of wood chemistry. Qvist and his student, H. A. Wahlforss, published a study in 1865 about *reten*, recin acids in the tar. This was arguably the first technical academic publication in Finland. H. A. Wahlforss completed his postgraduate studies, and published his PhD work, *Bidrag till kännedomen af retén* (i.e., the investigation of recin acids), in 1868. He completed his studies in the laboratory of F. K. Beilstein in St. Petersburg. He is considered the father of the chemistry involved in the traditional Finnish production of turpentine, and he educated the first research-oriented generation of chemists for Finnish industry in the 1880s.

Gustaf Komppa, who studied under Wahlforss, continued down the same research path, and was able to complete in 1904 his studies into synthesizing camphor, a chemical component used in making early plastic. Komppa continued his studies at the laboratory of Johannes Wiliscenus, and he listened to the lectures of Wilhelm Oswald. Gustaf Komppa took over responsibility for teaching technical chemistry after H. A. Wahlforss's health forced him to step aside. Komppa was able to complete the construction of the new chemistry laboratory at the Helsinki Polytechnic Institute in 1898. As a result, by the turn of the century Finnish research in the field of wood chemistry had made considerable progress.

3.3.3 The Origins of Research into Making Paper

The pulp and paper industry really emerged in the Finnish economy during the 1870s, when the development of a process for using wood cellulose made it possible to exploit the country's forest resources as the industry's main raw material. The first pulp and paper factories were built on the shores of lakes and rivers in southern Finland, where it was possible to obtain the raw material needed from the vast forests reaching up to Central Finland. Mills built in Tampere (1866), Mänttä (1868), Kuusankoski (1872), Kymi (1873) and Voikkaa (1873) are all examples of using strategic inland locations.

From the very beginning the industry had a controversial approach to the research behind its production. The machinery was imported from Germany and Britain, and the Finnish machine operators had sufficient practical knowledge to know how to run this equipment. After 1886 the industry financed the creation of a technical school in Tampere. At this point, those involved in the operation of Finland's papermaking equipment were not in need of formal knowledge because they had enough practical know-how. This was the rationale of the commonly feared and notorious Director of the Mänttä factory, G. W. Serlachius, nicknamed "The Devil of the Forest", who stated emphatically that there was no need for scientific education or research in the paper industry. (Nykänen 2007b, p. 50) His opinion probably reflected his own background, whereby as a penurious young man he had had no chance to obtain a formal education. On the other hand, Serlachius was later able to obtain a background in chemistry by earning a pharmacy degree.

3.4 In Independent Finland

The official testing of paper products in Finland started in 1908 at the State Material Testing Laboratory, which was attached to the Helsinki Polytechnic Institute. After Finland gained its independence in 1917, its leaders showed greater interest in developing the country's scientific capacity, including constructing the institutional infrastructure to conduct technological research. As part of this process, in 1922 the paper research division of the State Material Testing Laboratory was founded, but the laboratory was merely involved in efforts such as inspecting the physical features of paper products needed for state purposes. There were no resources for deeper scientific analysis of products. (Michelsen 1993, pp. 46–47; Komulainen 2014, p. 81) Incidentally, the State Material Testing Laboratory became the State Research Centre (VTT) in 1942.

Research into wood chemistry followed a totally different path. In 1916, when the effect of the First World War's economic restrictions started to fetter the operation of the pulp and paper industry, the paper companies founded a central laboratory (KCL) to search for substitutes for the raw materials that were difficult to obtain during the conflict. After the war KCL became strictly a material testing laboratory for the paper industry. KCL's standing remained precarious for a prolonged period, but ultimately its activities would fundamentally affect the field of wood chemistry. The idea behind the KCL was that all the partners in its operation would provide part of its basic funding and share in the results of its research. Some of the research projects were financed only by individual partners, and the results stayed in the possession of the respective financial backers.

After the First World War KCL was not the only co-operative organization the Finnish pulp and paper companies established. There were two cartel-like organizations, the Finnish Cellulose Union (Finncell) and the Finnish Pulp and Paper Association (Finnpap), which facilitated the cooperation of the various producers in exporting their products. In many cases the Finnish pulp and paper industry functioned as one family for several decades. For a long time, the independent research work conducted by the forest companies was focused on material testing. A typical actor was the chemical laboratory that was established by G. A. Serlachius, and it concentrated on studying the properties of cellulose and features of wood alcohol.[15]

Scientific publications in Finland have been traditionally administered by the country's scientific societies, and Finnish paper engineers founded an association of their own just before the First World War. Called the Finnish Paper Engineers' Association (PEA), it launched in 1917 a periodical magazine, *Suomen Paperilehti*,[16] and already during the 1920s it had published scientific articles in four languages; German was the traditional language of technology in Finland until the 1950s. Because the new markets for Finland's pulp and paper

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[15] See http://www.papermakerswiki.com/innovations/mets%C3%A4klusterin-tutkimuslaitokset-ja-aktiviteetit/ga-serlachius-oy. Accessed 6.3.2017.

[16] Later *Suomen Paperi-ja Puutavaralahti, Paperi ja Puu* (*The Finnish Paper and Timber Journal*).

industry were now in the English-speaking world, the other languages in which the publications appeared were English, Swedish and Finnish. (Komulainen 2014, pp. 86–87) (Finland is a bilingual country with Swedish being its second language.)

PEA's international connections were initially established with both its German sister associations and, most importantly, Nordic organizations. The British Pulp and Papermakers' Association (BPPA) created formal relationships with the association in 1937 by nominating the chair of the PEA's board, Helmer Roschier, as an honorary member.[17] Roschier had been the chief chemical engineer of Kymi-corporation since 1919. He was the second student to complete his Doctor of Science degree at the Helsinki University of Technology in 1918, and he was a well-known member of the turpentine researchers' school in Finland. Kymi's main commercial contacts were with Britain, and this was likely the reason why the connection to BPPA was established. Helmer Roschier started as the Professor of wood chemistry at HUT in 1939.

3.4.1 Formal University Education in Paper Technology

Paper engineering was introduced to the curriculum in technical education after the Helsinki Polytechnic School was transformed into the Polytechnic Institute in 1879. Paper manufacturing was included as part of the general lectures in mechanical engineering during the next decade, and they were delivered by German Rudolph Kolster. The pedagogical method of the era was that the lecturer simply read mechanical engineering encyclopedias, and he alone had responsibility over all the courses in mechanical engineering for two

[17] Komulainen states that the relationship was only nominal. (Komulainen 2014, p. 87)

decades. Kolster’s successor Max Seiling declared a few years later that the task was an impossible responsibility to fulfil. (Nykänen 2007a, p. 40)

The first attempt to create a separate discipline for studies in paper engineering was made at the turn of the twentieth century. The limited resources of the Polytechnic Institute prevented this endeavour from succeeding, however, although in 1904 the financing of the Institute was almost doubled to allow for the expansion of engineering education. Special instruction in machinery used in the paper industry started in 1908, and it was delivered under the rubric of general mechanical engineering.[18]

The professorship in paper technology was established in 1921, although it took another decade until A. J. Brax was hired as the first professor of paper technology in 1931. Paper technology was considered a strategic discipline, established to guarantee that technical research was conducted in fields of national importance. The other ones were shipbuilding technology, agricultural technology and wood chemistry. (Nykänen 2007a, pp. 183–185)

Probably the first master’s thesis in paper technology was written by Kaarlo Amperla in 1927. The topic was “General planning of a printing paper factory” (in Finnish “Sanomalehtipaperitehtaan suunnittelu”). Although the topic was rather general in nature, the paper was a turning point in the Finnish paper machine industry’s history. Amperla made his career in Kone ja Silta Oy (in Swedish AB Maskin & Bro), and he is considered to be the father of Finnish paper machine engineering.

[18] HUT, Program of Polytechnic Institute 1879–1908.

Before the Second World War in Finland twelve domestic paper machines were built. The major manufacturer was Wiborgs Mekaniska Verkstad, which built eight machines, and the Karhula Works produced two in the 1930s.[19] The overall size of the paper machine manufacturing sector was considerably larger, however, because long delivery times for obtaining foreign machinery created orders for the Finnish machine shops, which delivered parts to the existing machines that had been imported. For example, Kone ja Silta Oy in Helsinki entered into a contract in 1937 with the British machine shop Walmsleys Ltd. at Bury, Lancashire, which was the main manufacturer of the machines delivered for UPM. At the beginning of 1938 Kone ja Silta Oy, (later Wärtsilä Co.), established a paper machine division, the first of its kind in the country. Under Amperla, it first produced two paper machines for the Kauttua mill before the Second World War. (Nykänen 2005, pp. 57, 60)

The Finnish cluster of technical research took a giant step forward in the late 1920s when the HUT launched its Technical Laboratories program. The general idea was to create facilities to conduct the technical research the young independent state needed to support its industrial activities. The most important and first ones were the electric and power laboratories, and they were operational between 1927 and 1931. A huge laboratory building was erected on the Helsinki University of Technology's campus near Hietalahti Harbour.

Professor A. J. Brax got one floor of the new facility for his pulp and paper technology laboratories. There was room for two large pilot-plants, one for a cellulose-drying machine and another for a small paper machine. However, there was enough money for only the

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[19] Two machines built by Karhula to Pankakoski mill on 1910's were primarily board machines.

former piece of equipment because it was considered to be the more important of the two. After its delivery the university ran out of money due to the general economic depression. The researchers would wait for the pilot paper machine for several decades.

This delay did not have a major effect on the Finnish machine shops, however. By the mid-1930s, they were ready to start manufacturing modern, wide paper machines. At the time the Finnish machine shops lacked the expertise to start the effort from the ground up, and so all the major machine shops began their operation by depending upon foreign know-how. For example, Wärtsilä Co. planned to start with printing paper machines designed by Walmsley, and Tampella (Tampereen Pellava- ja Rauta-Teollisuus Osakeyhtiö) co-operated with widely respected American machine shop Black-Clawson to obtain the drawings for cardboard-making machines. The Finnish machine shops made an agreement over the division of products they would make, and the accord was named TAMAVAKA based on the initials of the corporations (i.e. Tampella, Maskin & Bro, Varkaus, Karhula, TAMAVAKA). (Nykänen 2005, pp. 58–61)

The outbreak of the Winter War between Finland and the Soviet Union on 30 November 1939 interrupted these plans. As a result, the Karhula Works was the only Finnish machine shop prior to the conflict to produce modern paper machines, but the other companies were quite close behind it in developing their own products.

3.4.2 War Time Crisis and Tar Oil Production

The Winter War cut Finland off from its international connections. For the Finnish economy, the war was catastrophic, and only the quick end of the fighting on 13 March 1940 rescued the nation's economy from collapse. The industry had little chance to react to the situation, and the scientific work totally stopped because all the country's human and material resources were committed to the war effort. For the machine industry, the effects of the wartime economy lasted until 1952.

After the Winter War ended Finland keenly tried to re-connect to North American countries. For example, the Finnish Paper Engineers' Association applied for membership in the Technical Section of Canadian Pulp and Paper Association and the Technical Association of the Pulp and Paper Industry (TAPPI). The outbreak of the so-called Continuation War in the summer of 1941 ended these initiatives. Finland entered into a formal alliance with Germany against the Soviet Union, and this caused Britain to declare war against Finland in 1942. Nevertheless, the US and Finland had no open hostilities against each other during the war, which facilitated re-establishing relationships between Finland and the West after the war.

During the Second World War Finland was cut off from international trade, notwithstanding the goods Finland traded with Germany during the Continuation War (1941–1944). The most difficult challenge for the national economy was its lack of lubrication oils and greases, and Sweden shared this same problem. As a result, in 1941 Finland and Sweden launched a co-operative project to produce substitutes for lubrication oils from pine tar. The effort was based on the long-standing turpentine chemistry and wood processing industries. The know-how and scientific basis for the project were delivered from KCL in Helsinki, although a significant contribution also came from the Swedish side of the project. (Nykänen 1999, p. 264)

For strategic reasons, the tar oil production in Finland was divided among several small factories. In 1944 Finland boasted 32 modern tar mills and four oil factories that produced tar oil. One of the major facilities was the Forsiitti-Dynamiitti Oy in Hanko, where young engineer Waldemar Jensen was trying to solve production problems. (Nykänen 1999, pp. 268–269) After economic relations between Finland and Germany collapsed and all imports of petroleum based products ended in the summer of 1944, Finland was totally dependent on domestic tar oil production. The situation lasted until 1948, when the import of crude oil products started again from Britain and the US. The shortage of petroleum products during the war had clearly demonstrated the vulnerability of the Finnish national economy if any crisis closed international trade. It took nearly ten years before Finland learned to handle this problem effectively.

3.5 A New Beginning after the War

Before the Second World War the master's theses of the students at the HUT had addressed industrial issues only on an abstract level, and for good reason. It related to an intellectual battle that was being waged in Europe between general and technical universities, and it underscored the gaping chasm that separated traditional from modern approaches to higher education. The former focused on delivering a conservative, classical education in which theory was front and centre and practical matters were not considered worthy of study; the latter reversed these priorities.

The challenge for the students and professors at the university was the fact that the conservative, classical paradigm reigned supreme prior to the mid-1940s. This meant that their research work had to concentrate on theoretical issues and shy away from solving practical problems; otherwise, they would be subject to intense criticism. This difficulty was first widely discussed by Paavo Pero, who became a leading figure in shaping the education of the applied sciences in Finland. (Nykänen 2007a, pp. 111–115)

The situation changed profoundly after the war. Finnish industry was pressed to its limits by the war reparation demands from the Soviet Union and the needs of the domestic economy. Students of technology came to occupy a central place in addressing both these demands. During the five years of war they had had little chance to complete their studies, but immediately after the conflict ended the number of M.Sc. Engineering degrees granted in Finland rose to an all-time high. In fact, the number of new engineers in the country in the mid-1940s was almost double the number that there had been before the war.[20] Many of these persons had been identified to work in the industry straight from the halls of the technical university.

The result saw many of the students' research topics focus on solving specific, practical industrial problems. Already in 1946 B. Immonen presented a final work concerning the post-processing of products at the Mänttä paper mill in Central Finland. The next year L. V. V. Sundström presented a work about the wire section of a rapid printing paper machine. The first generation of students, who started their studies after the war, finished their educations in 1951, and four of them had worked on topics concerning the production of paper. Clearly, a connection between the industry and the HUT had been established on a much higher level.[21]

[20] Eeva Pitkälä. Statistics over the degrees and students at HUT. 2010. HUT archives.

[21] HUT, the minutes of the wood processing department. Anders Lund, Torkning av papper på en Yankee-cylinder, 16 April 1951; Matti Vihinen, Voimapaperin kreppaus, 10 September

One of the newly promoted engineers was Niilo Erik Ryti,[22] who earned his degree from the HUT as a machine engineer on 7 December 1944. His major was industrial technology, and almost immediately he started work as Production Engineer at the Kangas paper mill in Jyväskylä, Central Finland, and which was owned by G. A. Serlachius Oy Ltd.[23]

After the end of the Second World War major changes occurred in the way master's theses were finished at HUT. With Finland in dire need of technical capacity, the formal master's theses were often based on serving the industry's most urgent needs. The university's professors were also recruited to the Board of War Reparations Industry, called SOTEVA. A long-lasting discussion over the division between the theory and practice concerning technical education and also the crucial question of co-operation between HUT and industry was solved once and for all because of the crisis over the need to maintain Finnish

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1951; Jori Pesonen, Sanomalehtipaperikoneen tuukiväli laboratoriotutkimusten valossa, 19 November 1951; Arvo Reipas, Äänekosken paperi- ja kartonkitehtaan laajennus-suunnitelma, 21 May 1951; Nils Lindberg, Över arkformeringsproblemet i allmänhet och speciellt skagningens inverkan på arkformering.

[22] Niilo Ryti was a son of Risto Ryti, Finland's Second World War-time president (1940-1944). His mother was Gerda Serlachius, whose grandfather was G.A. Serlachius, founder of the Mänttä Paper Mill. After his graduation in 1914 Risto Ryti founded a law firm with Eric Serlachius, brother of Gerda, and this led to his interest to the wood-processing industry. Both of his sons became professors at the Helsinki University of Technology; Henrik Ryti was later a professor of thermodynamics and machinery.

[23] HUT, a name record, Niilo Erik Ryti.

independence, which was threatened by the onerous war reparation demands from the Soviet Union. The country had been put into a practically impossible situation by the Soviet Union's demands for war reparations (e.g., they included giving the Soviets 4 entire paper mills and 20 additional paper machines), and adopting this new approach to technical education was essential if Finland were to survive.

3.5.1 Two Paths for Research and Development

It was clear that, during the 1950s, the science of papermaking in Finland was starting to undergo a slow but steady and dramatic change. The traditional paper consumers did not provide much of an impetus to the mills to develop new products, and so the long-established craftsman-like thinking and procedures remained entrenched. Two crucial developments fundamentally altered this situation, however, namely the competition between the international printing houses and the new approach to photojournalism. Demand for printing paper expanded when magazines like *Time* and *Life* spread all over the world, and the publishers started to seek better quality paper on which to print their products. Also, the increasing speed of papermaking machines and printing presses necessitated producing paper products that were more uniform in quality. Furthermore, growing demand for printing paper led to competition between the machine manufacturers, who had to address the need to produce paper that possessed greater printing capacity.

Need for better quality in printing paper required pilot tests with paper machinery capable of being used in trials that involved innovative constructions and special runs. The experiments were traditionally run with production-scale machinery, but this was getting to be too expensive after the speed and size of the machines had grown so quickly. The problem was solved by building laboratory-scale pilot paper machines for paper machine manufacturers' research and development programs.

Their laboratories really began emerging during the 1950s. In Britain there had been pilot machines already at the beginning of the century. T. J. Marshall built in 1906 a miniature paper machine that conducted the entire process. Also, Manchester University had a small paper machine for educational and research purposes by the end of the 1930s. (Komulainen 2014, p. 111)

The atmosphere in the research climate changed drastically during the 1950s. American Beloit was the first to build a special research paper machine for developing new and better processes. In Finland, the idea of testing new types of machines was based on the close contact between the machine shops and the paper mills. It was quite normal to use the mill's narrow paper machines for testing the new design, but usually the speed of the machines in these tests was restricted. The Tervakoski paper mill in southern Finland was the first one to construct a narrow pilot plant for testing the processes in the 1950s, and it used parts of several old machines for the project. (Nykänen 2005, p. 149)

Finnish machine shops began conducting laboratory tests during the 1960s, which is quite late in comparison to similar developments in other countries. Alhlström, the state machine shop, and Valmet and Tampella corporations constructed pilot plants that were designed to develop papers with different printing capacities, and during the 1970s research and piloting had become a standard procedure in development work. (Nykänen 2005, pp. 199–207) The HUT received its long-awaited pilot machine in the 1970s when it was finally built as a co-operative project with the university, the KCL and VTT.

The late emergence of pilot plants in machine shops did not necessarily mean that the development work was totally absent from the paper industry in the 1950s and 1960s but these developments are difficult to discern from archival sources. Nevertheless, one can trace the history of two typical projects in the archives of the Kangas paper mill. The first, a co-operative project that occurred in 1955, was the result of Valmet offering a new paper machine to the Kangas paper mill. After reviewing the product specifications sought by the customers, Valmet produced preliminary drawings for a new machine.

Engineer Ryti noted the high quality of engineering of the planned structure, but from the plans he also pinpointed problems in how the paper was formatted and dried (i.e., how the fibres were arranged). The close relationship between the customer and machine shop produced fruitful result that affected numerous paper machine projects in the future.[24]

It is difficult to discern how a new paper product is developed because the demand for it is usually outside the scope of the paper mill, and thus the archival sources are difficult to locate. But one example has been uncovered, specifically the development of a paper that was suitable to be used as insulation in electric transformers for the Dutch company, Willem Smit Transformatorenfabrik N.V., in the late 1950s. This paper had very exact specifications, because it if were too thick it would prevent the transformer from working properly. The project started in 1955, when Willem Smit's engineers first laid out the technical requirements for paper that could act as an insulator in building a new transformer. Four

[24] ELKA, GAS, memorandums of Engineer Niilo Ryti 1950–1960, paperikonetarjoukset (in Finnish), 22 June 1955.

years were allotted for the research and development work, and production of it was scheduled to begin in 1960. Because the Kangas paper mill had already been producing transformer paper for Willem Smit, the company turned to its known supplier. After several months of testing, the first samples of the new kind of paper were sent to Holland, where the machine shop could start the tests on a large scale with the new product.[25] Though the result was a brand-new type of insulating paper for transformers, and the research and development process took several years and consumed many resources in two technical laboratories, it did not represent a specific innovation. Instead, the end product, a new type of transformer paper, merely represented the refinement of an existing product.

3.5.2 Rebuilding the Connections

After the Second World War the Finnish war reparations administration, SOTEVA, started to work on solving the problems involved in providing the Soviet Union with the goods it had demanded. Because the list of demands consisted of several paper machines that could not be produced in Finland, SOTEVA turned to western manufacturers that, prior to 1948, had delivered several large items to the Soviet Union as Finnish orders. One of the manufacturers was the well-known American machine shop Bagley & Sewall. The western machine shops were soon caught in the political games being waged between the super powers and also pressed by the need to rebuild European industry. When the Cold War began in earnest in

[25] ELKA, GAS, memorandums of Engineer Niilo Ryti 1950–1960, a memorandum of Engineer Frowein (representing Willem Smit Transformatorenfabrik N.V., Nijmegen, Holland), regarding his visit at Kangas paper mill on 21 November 1956.

1948 the western producers refused to trade machinery with the east. The only possibility for Finland to survive in this situation was to create a domestic paper machine-making industry.

Kaarlo Amperla from Wärtsilä had first proposed this possibility in the autumn of 1945. The next year Finnish industry prepared to develop and produce Finnish paper machines. The Karhula machine shop and the Wärtsilä-corporation seized the moment, while the state machine shop Valmet also started to investigate both the possibility of producing paper machines and improving the efficiency of this production. Still in this new situation the TAMAKAVA agreement from the 1930s over the division of production that steered the plans of Finnish machine shops was still strictly followed. Tampella in the first place did not initially conceive of producing the entire machines, and instead aimed to make only the auxiliary machinery for Bagley & Sewall machines. (Nykänen 2004, p. 88)

Beginning in the late 1940s, countries in Western Europe used the financial and material aid delivered by the US under the Marshall Plan to rebuild their infrastructure. Finland officially stayed out of the Marshall Plan, and since it was not a member of the NATO, many considered Finland as part of the Eastern bloc. But the reality was very different. Relationships between Finland and the West were actively built on many levels, and some of them were clandestine or nearly so. In fact, many organizations in Finland received unofficial but meaningful economic support from the US. This aid was often hidden behind the aegis of normal trade whereby surreptitious aid was delivered to the Finns. (Nykänen 2008) Although Finland was wooed by both sides in the Cold War, it ended up on the western side of the Iron Curtain near the beginning of the Cold War.

Contacts among universities were an essential part of the relationship that developed between Finland and the West, and this was integral to the exchange of ideas and information. A major first step in this process occurred in the spring of 1948, when the Massachusetts Institute of Technology (MIT) invited six to eight Finnish graduate engineers to pursue a course at this institution in an effort to further their education.[26]

An important player in these events that involved reconnecting Finland to western economies was the PEA. During the 1930s PEA had been a leader in fostering relationships with the British profession of paper engineers, and had concluded a formal relationship with the Technical Section of the Paper Makers' Association of Great Britain and Ireland in 1937. The relationship fell into abeyance during the war, but in 1948 the organizations found each other again, and the representatives L. G. Cottrall and J. Chapman of the Technical Section took part in PEA's annual meeting that spring in Helsinki. Also, Bertil Nybergh from the KCL travelled to London to visit the Technical Sections meeting, at which he presented a paper.[27]

In 1949 the connections between Finland and the US were formalized through the execution in the US of Public Law 81-265, which created a remarkable situation. Finland had been the only country that had repaid in full the loans it had received from the US during the First World War, and it had gained the respect of the American government as a result. Even while Finland had been fighting the Winter War, it had continued to deliver its payments to the US.

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[26] HUT, OK 23 March 1948, § 16. The grants were given to Olli Pöyry, Juha Alhojärvi, Pekka Rekola, Osmo Korvenkontio, Bjarne Huldén, Nils Björklund, Leo Toivonen, Stig Landgren, Mauri Tanttu. About Risto Hukki Nykänen 2009, p. 97ff.

[27] ELKA, PEA, Francis Bolan to Torolf Lassenius on 24 March 1948; 21 April 1948.

Curiously, the US Treasury had collected these funds in a special account and had not simply deposited them into its general revenues. The aforementioned law that the US had enacted in August 1949 allowed the money the Finns had repaid the US after the First World War to be used as travel grants, thus creating the financial resources to support a massive student exchange between Finnish and American universities. The program in Finland was named Amerikan Suomen Lainan Apurahaohjelma (ASLA). In addition, these funds were used to purchase scientific instruments and the latest literature for the Finnish universities. Then in 1951, Finland joined the Fulbright program. Through both these programs, between 1949 and 1957 Finland sent 419 scholarship holders, 65 graduate engineers, 130 visitors and 5,454 interns to the US to further their technological educations. (Teknillinen apu 1958; Hietala 2002, p. 538–539)

Clearly, the demands to pay war reparations and of the Cold War forced Finland to modernize and greatly expand its machine-making industry. The major problem it faced in doing so was its lack of research and technical development capacity. Before the 1940s very few Finnish machine shops dared to compete with major foreign producers in building large industrial machinery. Nevertheless, during the Continuation War Finnish engineers were forced to solve problems that had previously seemed impossible, including those in the field of aviation. The State Aircraft Factory (in Finnish Valtion Lentokonetehdas, VL) educated some 500 competent constructors (i.e., engineers who create new technology) during the war for the engineering industries in Finland. After the war VL became part of Valmet. This was the major boost that made it possible to establish the Finnish paper machine-making industry on a large scale after the war.

On 19 November 1949, a very important meeting was arranged by the Paper Engineers Association (PEA) in Helsinki. For the first time in the history of the paper industry the PEA called a meeting of both the paper makers and paper machine manufacturers in Finland. The main subject that was discussed dealt with the ability of domestic machine shops to fulfil the needs of the pulp and paper industry both in the present and future.[28] This subject anticipated the time when Finland had paid its war reparations to the Soviets, and it was free to start marketing its industrial products to the western world again.

After Finland had paid its war reparations in 1952, the industry enjoyed a boom from the Korean War and the rising international demand for pulp and paper. But after the conflict ended, the Finnish paper industry again seemed to be falling behind its international competitors. It was given a huge boost in 1957, however, when the Finnish Mark was devalued by 30%, and a new era of investment began in the Finnish paper industry. The other reason that Finland was in dire need of modernizing its pulp and paper research and development program was the need to improve the quality of its products. During the Second World War, its international competitors – especially those in the US – had developed new, high-tech products for military purposes and conducted significant research into improving production. As a result, research and quality control had become an elementary part of production in those countries. This gave them a major advantage over paper mills in northern Europe, where production still relied heavily on "the art" of papermaking.

Modernization in the Finnish paper industry began at the Kangas paper mill in Jyväskylä in the early 1950s. Niilo Ryti started a project to modernize the mill's laboratory facilities

[28] ELKA, PEA, a circular, Torolf Lassenius, 6 November 1948.

immediately after his return from the US in 1949. With assistance from the KCL in Helsinki he furnished a material testing laboratory during the early 1950s.[29] The purpose of the investment was clear: the Kangas mill was focusing its production on high-quality writing and specialty papers. One of its main products was the cardboard for punch cards used in computer technology. By the end of the decade, IBM and Remington Rand were buying a great deal of their supplies of punch cards from the Kangas mill. It also manufactured a number of specialty products such as waxed paper.

Kangas mill was a pioneer in R&D work, but in general the attitude in the industry was becoming more geared toward this type of activity. In the late 1940s long-distance travel was quite expensive, and only a few Finns had the funds to cross the Atlantic to study the modern R&D laboratories in the US.[30] The status of the paper engineers was quietly discussed among the PEA in the late 1950s, when the effect of the currency devaluation in 1957 was having a major impact and Finland was at the peak of its huge investment boom in its paper industry.

The international connections enjoyed by the Finnish the paper industry created the possibility for it to make several inquiries about the differences between the Nordic producers and those in the West. Finnish salesmen and leading engineers could travel much more readily to Britain and North America to see the “modern ways” of production. Also, foreign officials began to visit the Finnish industry, specifically forest cities such as Mänttä, Jyväskylä, Tampere and Valkeakoski.

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[29] ELKA, GAS, memorandums of Engineer Niilo Ryti 1950–1960.

[30] E.g. ELKA, GAS, travelling documents, 1943-.

The exchange of information related to pulp and paper technology moved in both directions. This was clearly noted when Charles F. Payne from the Eastman Kodak Company visited Niilo Ryti at the Kangas mill in August 1957. Payne wondered how the Finnish and Swedish paper mills could operate successfully even though they employed so few engineers and researchers. Payne noted that a Swedish paper mill typically employed two engineers: a technical senior expert and his younger assistant. In contrast, in Rochester, New York, the Kodak paper mill had a research and development division with 35 scientists who were all formally educated.[31]

The need for further education of younger staff was clear, but in practice the recently graduated engineers and scientists were not able to take the time to travel abroad to enhance their professional development. In 1962 the secretary of the PEA, C. J. Ganszauge, made a study of the role of the paper engineers in the state bursary systems targeted to further studies overseas. The result was depressing. Of the Fulbright bursaries, only four of 84 had been received by paper engineers since 1949. E. Aaltio, Lea Valtasaari, Y. Hentola and R. von Konow had deepened their scientific knowledge after their researchers' degree (i.e., a licentiate, or first degree for a researcher between a masters and doctorate in Finnish universities). Of the more important ASLA bursaries that supported graduate students furthering their educations by gaining practical and work-related experience, only four of the

[31] ELKA, GAS, memorandums of Engineer Niilo Ryti 1950–1960, a memorandum of Engineer Charles F. Payne, Asst. Superintendent, Paper Mills Division, Eastman Kodak Co, Rochester NY regarding his visit at Kangas paper mill on 27–28 August 1957.

total 416 had been received by paper engineers. These were L. Hummelstedt, T. Ulmanen, A. Esilä and K. Sormanto, who had continued their studies in the US.[32]

Although Finland was attempting to make the pulp and paper industry the backbone of its national economy after the war, the situation was still in dire need of improving. It still lacked researchers, both in terms of process engineering and machine construction. One of the major problems in terms of both formal and practical education was that the country's rapidly expanding industrial sector was aggressively recruiting engineers with MSc degrees, and so they were in high demand. This meant that these young professionals were able to obtain well-paid jobs in industry without undertaking further education. (Komulainen 2014, p. 171) Nevertheless, the builders of the large technological systems, who were looking to the future of the paper industry, were in dire need of engineers whose education had gone beyond the MSc stage.

3.5.3 Over the Atlantic Ocean

One of the few paper engineers who had personal connections overseas and real possibilities to travel to international conferences was Niilo Ryti, who was appointed the director of the Schauman's Pietarsaari pulp mill in 1962. Ryti took part in the Oxford Symposium in Britain in that year. After returning home, Ryti wrote a letter to the PEA stating that something should be done to improve research resources in Finland; otherwise, he argued, the result would be disastrous. (Komulainen 2014, p. 172) Another Finnish paper engineer dealing with the same problem was Tapio Ulmanen, who was working for the KCL.

[32] ELKA, PEA, C. J. Ganszauge to Niilo Ryti on 25 August 1962.

An ideal contact was the Institute of Paper Chemistry in Appleton, Wisconsin. It had been established in 1929 as a partnership between Lawrence College and the local paper industry. It was designed as an institute in which students could gain specific practical and formal training on the road to becoming paper chemists, and it was organized and administered by the college but financed by the paper industry. The Institute had its own Board of Trustees and its own budget. Lawrence College awarded Master of Science and Doctor of Philosophy degrees to graduates of the Institute.[33]

The Finns knew they needed a liaison between themselves and the Americans during the Cold War, and specifically a go-between who could help establish a relationship between the Finnish paper industry and its engineers and the Institute in Appleton. Niilo Ryti asked Professor Waldemar Jensen, CEO of KCL, to try to be that contact with the Institute, because Jensen personally knew Dr. Roy Whitney, the Institute's vice president of academic affairs. Whitney responded quickly but guardedly. He could not promise anything but was open to the possibility of Finnish students applying for spaces at the Institute. The problem for the Finns was the cost of attending the school. One term cost about 2,500 USD, and for a Finnish student or young M.Sc. that represented an astronomical sum.[34] The task for the PEA's administration was thus to find the financing for the interested students. To realize this goal, three older funds in the PEA's custody, namely Uno Albrecht's, Frenckell & Son's and

[33] Lawrence University Archives (LUA), Seeley G. Mudd Library, Appleton, Wisconsin, Institute of Paper Chemistry Records, LU-RG10-001.

[34] ELKA, PEA, Niilo Ryti to C. J. Ganszauge on 10 April 1963.

Georg Holm's, were brought together to form a new travelling grant for young scholars.[35] In 1963, the first Finnish student attended the Institute, with financial backing from the PEA.[36] The aim of the PEA's program for further education was clear, because the Institute in Appleton dealt exclusively with wood chemistry, as did most of the Finnish fellows.

3.5.4 Engineering for the Industry

The art of engineering in the Finnish paper industry followed a different path than it did for wood chemistry. Jaakko Murto succeeded Helmer Roschier as the Professor of wood chemistry at the HUT in 1959. He found a partner in Jaakko Pöyry, who had graduated from the HUT in 1948. Pöyry was first recruited straight from the university for Wärtsilä Company as a construction engineer in the war reparations industry. In 1958 Jaakko Murto founded an engineering company with Jaakko Pöyry, and it specialized in paper industry engineering. From Wärtsilä Pöyry also took with him Matti Kankaanpää, who specialized in the design of paper machines; specifically, his work involved incorporating scientific principles into technical drawings. Kankaanpää was soon sent to work at Beloit in the US, however, and stayed there until 1963. During that period, he was involved in designing and constructing huge paper machines for UPM's mill in Kaipola and the Veitsiluoto Company. Murto left the company in 1961, and it was renamed Jaakko Pöyry Oy. The company became the world's leading engineering company in the forest industry during the 1960s, and Matti Kankaanpää became its vice president in 1963. (Oinonen 2002)

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[35] ELKA, PEA, C. J Ganszauge to Niilo Ryti on 16 April 1963.

[36] Appleton WI, PRI Archives PRI Board of Trustees minutes from 1963-10-03. Dix correspondence on 12 November 2015.

Also during the 1960s the HUT, Åbo Akademi, and the new Technical Department of the University of Oulu were constructing new links to the world's wood processing industry. The university now had a dedicated professorship for paper machine engineering, and the first person appointed to the post was the former chief of Valmet's Rautpohja machine shop in Jyväskylä, Uolevi Konttinen, in 1969. (Nykänen 2005, p. 79)

These developments were enormously important to Finland's paper-machinery making industry. By the latter part of the decade, Finnish machine shops were able to break into the highly competitive North American markets and by the 1980s they were the undisputed and dominant leaders in the world market. (Nykänen 2005, pp. 180ff) Having mastered the R&D part of the equation, the Finns increasingly focused on refining their machinery.

3.5.5 Building the Research Organization

A real turning point in the research and development culture of the Finnish paper industry occurred during the early 1960s. The decade saw the different research organizations and industries form a quasi-official network that fostered rapid advancements in many branches of the industry. The key figure in the network was Niilo Ryti, nominated to be the Professor of paper technology at HUT at the beginning of 1963. His appointment meant that he would be at the nexus of a network of all the organizations working with the pulp and paper industry. Ryti's right hand man was Pertti Aaltonen, who worked for the KCL in the 1950s and was nominated to be Ryti's assistant in the spring of 1964. Aaltonen's task was to convert Ryti's dreams into reality. His working time was divided evenly between the HUT and Jaakko Pöyry Oyj, so he formed a true connection between the industry and the university.[37]

One of Ryti's first tasks as a professor was to establish a link between the HUT, the KCL and the PEA. They were all needed to launch the scholarship program to educate young research oriented engineers in the paper industry. Ryti's role in the program was to select the applicants for the Paper Engineers' Association. The number of students of paper technology at the HUT was annually around 45 after the rapid expansion in the number of freshmen at the beginning of the 1960s. He hinted to some of the newly graduated students to apply for the stipend to travel to the Institute in the US to study.[38]

The first scholarship holder to study at the Institute of Paper Chemistry in Appleton was Tapani Kaila in 1963. He completed his PhD degree at the Institute, and this would prove to be common for Finnish students who attended it. Thereafter, the PEA sent one student yearly. The next ones were Matti Stén and Kari Ebeling. (Komulainen 2005, p. 302)

Then a change in the culture of Finnish paper engineers occurred during the 1970s. Those belonging to the "old school" had recently begun retiring, and the new class of more

[37] HUT, a name record, Pertti Aaltonen; Hannu Paulapuro, emer. prof. Helsinki, interview, 1 April 2015.

[38] Komulainen states that the low number of applicants was due to the lack of interest in participating in the program, but clearly some pre-selection of applications had already been done at the university before they were sent to the PEA. (Komulainen 2005, p. 173; Antti Arjas. Ret. Gen. Director, KCL. Espoo, interview, 14 April 2015)

research-oriented engineers gradually took over their responsibilities. One great benchmark was passed when the last of the great directors, Juuso Waldén, retired in 1969, and Niilo Hakkarainen took his place as CEO of UPM. As the firm's new leader, he led it through a period of massive innovation. The result saw industry now searching for data and research prior to making a decision about its operation; a new era of empirical-based decision-making had begun.

R&D in the factories that produced machinery for the pulp and paper industry was developing at the same pace. Until the 1950s the machine shops were completely dependent on feedback from the paper industry in developing new methods and equipment. Paul Ohlström from the Karhula works wrote in 1954:

> The launching of new inventions and constructions on the market absolutely requires the support and cooperation of industry. After we have made, installed and started up these innovations, we are forced to adjust some small details and therefore the cooperation of industry is extremely important. A new construction will, in any case, have been so carefully designed and tested that, when it is introduced in an industrial process, only a few small details remain to be adjusted. (Ohlström 1954, p. 200)

The 1960s thus saw the evolution of industrial research on two fronts – the R&D carried out by the machine shops themselves and the R&D that was dependent on the technical universities and the handful of university laboratories that were developing papermaking technologies to generate new knowledge. In addition, the machine shops established their own R&D laboratories in the late 1960s. Research facilities and laboratories were also built by Tampella at Inkeroinen, by Valmet at Rautpohja and Jyväskylä, and by Ahlström at Karhula. (Nykänen 2005, pp. 196–204)

A huge problem for the research laboratories in the paper and the machine industries was a lack of venture capital. UPM had invested heavily in basic production technology to raise the quality of its products. Many parts of the “secondary factory” activities, however, like handling materials and waste-water treatment, were left behind. The investments also aimed to increase employment levels and benefit the national economy.[39] The government tried to back up the progress and the Bank of Finland decided to devalue the Finnish Mark by 23.8% in 1967 in an effort to boost export industries, but by the end of the decade UPM was mired in deep debt because of its heavy investments.[40]

3.5.6 Time for Innovation

Near the end of the 1960s, it became increasingly common for Finnish R&D projects to be supported by public funding. Such possibilities had arisen for economic and regional development reasons, and the same phenomenon happened in all industrialized countries.[41] A prime economic funder was SITRA, the Finnish National Fund for Research and Development, which had been founded in 1967; it soon became a major source of R&D funding in Finland. In addition, the 1970s also saw the establishment of TEKES, the Finnish Funding Agency for Innovation.[42]

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[39] UPM, memoirs of Niilo Hakkarainen on 14 June 1971.

[40] UPM, memoirs of Niilo Hakkarainen on 21 January 1970.

[41] Of the early discussion over innovation processes, see Esilä 1968.

[42] A general view for the Finnish technology policy, see Murto et al. 2006.

The emergence of the national R&D policy eventually fuelled a larger discussion over the need for research and development organizations and the innovation processes. In 1970 a major conference over the problems involved in facilitating innovation was arranged. The Finnovation 70 -seminar[43] was organized by the Asko Foundation, and the main topic was how best to coordinate all the work that was going on. Since the mid-1940s Finland had seen significant R&D, but these efforts had largely been conducted independently of each other, and the goals now were to continue to foster a culture of innovation as well as develop a systematic approach to R&D. One of the organizers of the conference was Professor Erkki Laurila, an academic who had been steering Finnish technology policy since the early 1960s.[44]

The new approach to the innovation processes soon affected the paper industry. As a new policy, Niilo Hakkarainen, the newly appointed CEO of UPM, was well versed about the Finnovation meetings and he launched a program to modernize the information organization around the company's board. UPM's mills thus received special research, development and planning units, and a research division was created within the technical department of its central administration in 1971. UPM had high hopes regarding its decision to take a modern approach to research and development. The company appointed Antti Arjas as director of its

[43] Before the Finnovation 70 -seminar was Innovation 68 -seminar arranged by a group of young engineers and architects in Helsinki. This is probably the first meeting discussing over the innovation policy in Finland, and it was funded by newly established SITRA. (Jaakko Ihamuotila, oral communication on 28 February 2017) The history of Finnovation seminars is under research by the author and Sampsa Kaataja.

[44] UPM, memoirs of Niilo Hakkarainen.

research organization, and Ingmar Häggblom, who already had lengthy experience leading its research activities, stayed on to continue working in this field with the company.[45]

A similar process occurred with the firm G. A. Serlachius. Its new laboratory facilities in Mänttä[46] worked with samples from all the firm's mills, and it became a major site for the preparation of master's theses under the auspices of HUT's Department of Paper Technology. The Mänttä laboratory also had close connections to other research organizations, like the State Research Centre, VTT and KCL in Espoo (where it was relocated from Helsinki in 1972).[47] Niilo Ryti from HUT was behind these co-operative efforts. Although the mill in Mänttä already boasted a material testing laboratory, it established a separate R&D department in 1971. It gathered all the separate laboratories under the same umbrella organization, and in 1974 it was given a modern facility in Mänttä.[48]

The need for research in the pulp and paper industry came largely from outside the industry itself. The first reason was the growing population in the developing world and its increasing appetite for paper. In addition, there was an increasing awareness of the global environmental

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[45] Antti Arjas. Ret. Gen. Director, KCL. Espoo, interview, 14 April 2015; UMP, Häggblom archives, Oy Mec Rastor Ab to Ingmar Häggblom on 7 February 1974.

[46] G.A. Serlachius had already enlarged material testing laboratories in the 1950s at Mänttä Paper Mill.

[47] See http://www.papermakerswiki.com/innovations/mets%C3%A4klusterin-tutkimuslaitokset-ja-aktiviteetit/ga-serlachius-oy. Accessed 6 March 2017.

[48] See http://www.papermakerswiki.com/innovations/mets%C3%A4klusterin-tutkimuslaitokset-ja-aktiviteetit/ga-serlachius-oy. Accessed 6 March 2017.

issues during this period. Furthermore, increasing competition in the printing paper market made it clear that challenges were coming.[49] In terms of environmental issues, discussions over wastewater conditions had already started in the 1930s in Finland but it was not until the late 1950s that the first meaningful public consultations about the problem began. One manifestation of this development was a conference over water treatment that was conducted in Mänttä at G. A. Serlachius' paper mill.[50]

There was also an interest in conducting research into producing food as a by-product of the sulfite pulping process. During the war experiments had been conducted into using torula yeast as a fodder, and KCL developed in the mid-1960s a method to grow protein using *Paecilomyces varioti* bacteria. The process was named Pekilo and patent rights to it were reserved by the Tampella. In conjunction with UPM, it established a co-operative pekilo factory in 1972 in Jämsänkoski. Pekilo protein, which the yeast had produced by converting harmful substances to valuable ones, was used for animal fodder, but there was another benefit to this activity as well. In the process of recovering the protein researchers discovered that the conversion process had also decreased the harmful substances in the effluents from

[49] Of the environmental issues impact see e.g. UPM, Hakkarainen archives, E. Gray King, research Director, Georgia Pacific to Osmo Aho on 13 November 1972; see also Kaje 1968.

[50] See http://www.papermakerswiki.com/innovations/mets%C3%A4klusterin-tutkimuslaitokset-ja-aktiviteetit/ga-serlachius-oy. Accessed 6 March 2017.

pulp mills.[51] Pekilo production was discontinued at the beginning of the 1990s, however, when the production of sulphite pulp ceased because of environmental concerns.[52]

The sulphite process was being intensely debated already in 1975, when the ministry for agriculture and forestry collected information from the sulphite industry's daily operations. UPM declared then that the production of sulphite pulp was already diminishing because of the environmental issues it created. Nevertheless, the industry tried to slow down the transition to the sulphate pulping process by justifying its sulphite operations on the grounds that they generated strategic products such as alcohol and proteins.[53]

A general change in the role of the paper industry was on its way. The first steps in the globalization of the world economy were taken in the early 1980s. In a presentation in October 1981, Niilo Hakkarainen emphasized the value of the general understanding of technology as part of human society's evolution. The previous decade had seen a wave of

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[51] UPM, Hägglund archives, e.g. Osmo Aho to Reijo Salminen, Georgia Pacific, Bellingham, Washington, USA on 25 April 1973.

[52] See https://www.papermakerswiki.com/innovations/sivutuotteet/pekilo-proteiini. Accessed 13 February 2017.

[53] UPM, Hägglund archives, UPM to ministry for agriculture and forestry on 7 April 1975; see also PM 19 March 1976; 13 April 1976 of the sulphite production. PM Sulfiittiteollisuus maa-ja metsätalousministeriölle 6 February 1975; *Talouselämä* 7 November 1975.

research laboratories created by UPM. Progress had been rapid, and the discussion over the role of the R&D operations was well under way.[54]

At the same time, technologies involved in industrial processes experienced a profound change. The emergence of automation and control technologies slowly began creating the possibility of improving the quality of production in Finnish paper mills. They had first been introduced at the beginning of the 1950s, when Erkki Laurila had taken the initiative to begin producing control systems for paper machines. This effort did not succeed, however, and it was only in the 1960s when the modern inspection and control devices were attached to high-speed paper machines. A clear indicator of the rising importance of the automation technology was the discussion over the new technology's advantages and restrictions, a debate that really began in the early 1980s when Antti Arjas unleashed a public controversy. (Arjas 1981) At that time major innovations in paper machine technology were already well underway, and computers were now powerful enough to manage the complex tasks of process control. As a result, automation and control technologies were still considered in the 1960s and early 1970s to be supplementary technologies in running a paper mill, but became leading factors by the 1980s. (Nykänen 2005, pp. 90–94)

After Niilo Ryti had departed the scene, Hannu Paulapuro became the person who connected the different organizations. He took over responsibility for the R&D work conducted at HUT and education in the new global situation. This passing of the torch mirrored the turning point in Finland's research and development environment. Paulapuro was promoted from the

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[54] UPM, Hakkarainen archives, Niilo Hakkarainen 28 October 1981. The topic of the meeting where the speech was given is not known.

international tradition that Ryti had initiated two decades earlier. After earning his master's degree, he worked first for Pöyry and then in the US for four years. After returning to Finland he gained a position at KCL, but at the same time started lecturing in paper technology at HUT. He was promoted to full professor of paper technology in 1990, and over 20 years he supervised about 350 master's theses and 50 doctoral theses.[55]

During Paulapuro's time as a professor of paper technology, the research topics changed due to the new demands that were placed on the industry. He published papers, based on his students' research, mostly on process diagnostics, mechanical pulping, wet pressing and fibre and paper physics. This reflected the status of paper machine engineering at the time. Slowly, the age-old differences between the two traditions of R&D faded and they merged into one stream by the 1990s. The gulf between the art of engineering and science of paper chemistry no longer formed a barrier to progress.[56] Hannu Paulapuro continued the approach that integrated the pulp and paper mills, research laboratories, and academic research and education. He practically formed a personal union between KCL and HUT due to his positions in both of the organizations. Also, the State Research Centre, VTT, was central to the cooperative research.[57]

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[55] See http://www.paperhall.org/hannuviljamipaulapuro/. Accessed 6 March 2017; HUT, a name register, Hannu Paulapuro.

[56] Jukka Kilpeläinen, DI, MBA, Helsinki, comments on 10 March 2017: 'I did not notice a difference in between the engineering and paper chemistry'.

[57] Hannu Paulapuro, emer. prof. Helsinki, interview, 1 April 2015.

The international economy was changing, though, and creating numerous challenges for the pulp and paper industry. Specifically, this meant a decreasing demand for printing papers of all sorts (particularly newsprint), and a concomitant rising demand for cardboard, and personal hygiene and packaging papers. At the same time Finnish paper companies were undergoing significant internal changes, a process that was driven by their focus on maximizing profits. These firms were no longer guided by technical experts because the latter had lost their decision-making power to the companies' financial managers. The growth of the companies and the economy was due to the merger of the factories and a strong belief in globalization. As a result, R&D changed as well, whereby the aim was no longer the search for new products or new ways of producing them but rather low-level research and improving production without doing much to improve the mills' operations. A paper mill was now aiming to be a global leader by making only one or a few top of the line products. In essence, the wheel had come full circle in a century. The aim of R&D was again to exploit the existing technology, often found in one paper mill, and development was largely concerned with the technology transfer from other units of a global company or from the scientific community.[58]

The national organization of R&D changed rapidly in Finland, and the reason was simple. Competition was now occurring in this realm among the firms because they had internalized R&D to prevent their results from leaking out. In addition, the merging of several companies

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[58] https://www.puunjalostusinsinöörit.fi/biometsäteollisuus/innovaatiot/12-metsäklusterin-tutkimuslaitokset-ja-aktiviteetit/yhtyneet-paperitehtaat-valkeakosken-tutkimuskeskus/. Accessed 27 December 2017. Jouni Huuskonen 10 February 2009. Yhtyneet Paperitehtaat, Valkeakosken tutkimuskeskus. Accessed 20 February 2017; Jukka Kilpeläinen, DI, MBA, Helsinki, comments, 10 March 2017.

reduced the number of actors who owned KCL. At one time it had been owned by 24 companies but by the turn of the millennium this number had shrunk to four and then three after Myllykoski Paper was purchased by UPM. At the same time a wide debate over commercialization of R&D research dominated discussions in the Finnish innovation community. Also, the co-operation with international actors was unsuccessfully tried for a short time.[59]

3.6 Conclusions

The movement to teach Finnish society to value educating legions of engineers was not enough by itself to change the country's research culture. To realize that goal, several interested parties from industry and broader society were needed. Industry, research laboratories, universities and engineering companies came together to form a network to facilitate research and development, and a scientific society, the Paper Engineers' Association, acted as a catalyst in the process.

These entities emerged over a long period, and they were founded for various reasons. For example, KCL was created to look after substitutes for exported materials and because of the

[59] At the end of the first decade of the new millennium VTT bought the R&D division of KCL. The division was later returned to KCL Oy. See https://www.puunjalostusinsinöörit.fi/biometsäteollisuus/innovaatiot/12-metsaklusterin-tutkimuslaitokset-ja-aktiviteetit/keskuslaboratorio-kcl, Jan-Erik Levlin, 31 March 2009. For more details Levlin 2010, pp. 24–25; Jukka Kilpeläinen, DI, MBA, Helsinki, comments on 10 March 2017.

need for industrial standardization and material testing. Similarly, the universities had tried to respond to the need for engineering education. The machine shops, such as Valmet, Tampella, Ahlström and Wärtsilä, all of which were on the vanguard of this campaign, developed their activities based on the needs of the pulp and paper mills as well as their other customers. Jaakko Pöyry Oy was an independent actor in engineering and planning.

The crucial factor that made it possible for Finland to develop a cluster of organizations and interests around wood chemistry and paper manufacturing technology was the informal co-operation among the different actors. In a small profession in a small country, most of the actors knew each other. This co-operative, unofficial network lasted until the 1990s and was concentrated around key persons, of whom Niilo Ryti and Erkki Laurila were clear examples. One major reason why the networking succeeded was the war economy and war reparation industry, both of which compelled Finland to strive to create a lean and efficient means of domestic industrial production using minimal resources. The importance of Niilo Ryti as a pioneer of the modern R&D culture in Finland is obvious. He exercised his influence through a series of actions due to his ability to create networks in the community of paper making engineers, both in academia and industry.

This type of teamwork was unique to Finland and had a long tradition there, and it is probably without parallel models in other countries. Only the basic division between science and technology divided the papermaking profession, and that division was significant until the 1990s, when paper machine technology peaked. Near the end of the century, improvements in production seemed unattainable by taking steps that involved either technology or science; that aim would only be achieved by taking a holistic approach to the problem.

The nature of the relationship between the industry and the universities has not been a clear one. The concept of university-based research was well known in Finnish industry already by the beginning of the twentieth century. In fact, a basic model for this type of activity was enshrined in the original strategy for the Helsinki Polytechnic Institute in 1892, and there are good examples of dynamic and long-term co-operation between the university and industry at that time.[60] A new approach to the connections among actors affected all branches of industry from the 1950s. For example, engineering physics under the leadership of Professor Pekka Jauho and his protégé, PhD graduate Olli Lounasmaa, enjoyed strong and important relationships to the generation of modern industries that used electronics in their new lines of products. Corporations like Nokia, Neste and Outokumpu took a fearless attitude towards undertaking innovation in the 1960s. The atmosphere in the more conservative pulp and paper industry was more complicated. Quite often it maintained a traditional mentality that referred to theoretical education and research as being unnecessary. (Nykänen 2007b, pp. 230–235)

One of the limiting factors in the development of the relationships between the universities and the industry was the lack of financing for the basic research infrastructure in the universities. The new facilities at the HUT's Otaniemi campus were seen as being antiquated already by the 1960s. (Nykänen 2007b, p. 230) As a result, Finland's pulp and paper industry often decided to conduct the research it needed in foreign, well-equipped laboratories.

[60] Karl Axel Ahlfors was one of the major developers of Finnish machine industry during the first half of the century. A great deal of know-how over fluid mechanics was established by Ahlfors (Kaataja 2015).

The evolution of research and development in the Finnish pulp and paper industry was not a straight-forward and linear process. These activities must be understood as operations that affected components of large technological systems, which have been described by Thomas Hughes. The process of R&D cannot be seen or explained as an entirety, because all the independent projects have a unique nature due to their different purpose and context. Consumers typically note the presence of paper only when the product runs out. The aim of R&D in the pulp and paper sector has often been to improve the efficiency - and thus the profitability - of the production process. Typical R&D programs have been aimed, for instance, at minimizing the consumption of energy or raising the efficiency of the drying section of a pulp or paper machine. The results of these efforts are not visible to consumers, but if a large paper mill can lower its use of water the result might be felt at the level of the national economy. A good example of the important R&D work that is not well known is the use of raw materials during the 1980s and 1990s at the Helsinki University of Technology.[61] One major reason that the pulp and paper industry moved so slowly in terms of R&D is that it is a very capital-intensive industry. The investments needed for new machinery are enormous and take decades to re-pay. This leads to a strong path dependence. (Nykänen 2007b, p. 230)

One of the divides in the field of papermaking separates the traditions of chemical engineering from machine engineering. The fissure follows the general idea of de Solla Price, who has identified a difference between science and technology, as stated in the introduction. These two disciplines, both elementary for the paper industry, act in different ways. The research and development work in the pulp industry, including the by-products of processes,

[61] Hannu Paulapuro, emer. prof. Helsinki, interview, 1 April 2015.

is a typical discipline of science. It is papyrocentric, based on published scientific studies. On the other hand, the mechanical part of pulp and paper mills and the manufacturing process of paper is papyrophobic. The results and even the R&D work is intended to be hidden as much as possible.

The challenges inherent in chronicling the history of technical research and development in the paper industry can be seen in the available archival sources, or more precisely, the lack thereof. In contrast, the history of technical chemistry is relatively easy to chronicle because the sources are generally available and there is a fair amount of literature published in this field. In contrast, writing about the history of R&D work in the papermaking machinery industry and the production process itself is very difficult. Because of the papyrophobic nature of the work, the companies rarely document their activities, and the ideas and experiences have remained largely confined within the enterprises that conducted the work. Heikki Toivanen (2005) states that the basic components of paper machines have not changed dramatically since the Second World War. He explains most of the development in the speed and width of the paper machines came with the rapid development of automatic data processing that was surely one of the major components in progress. (p. 79) This approach ignores large areas of technical development if it is considered to be the only or major explanation for what occurred in this field. During the 1950s and 1960s new former constructions like Beloit-Walmsley's Inverform and Bel Bond formers or Black Clawsons Vertiforma, changed the main structure of the wet end of the paper machine. Also in the 1950s research on new material technology, like new forms of cast iron and ceramic structures, was published and taken to be an elementary part of machine technology. In addition, the theoretical understanding of a structure's physics leaped forward. The latter really made it possible to widen the rolls and increase their speed, thereby giving new possibilities to increase the efficiency of the modern paper machine.

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