ABSTRACT

This paper investigates the introduction of nylon, the first fully synthetic yarn, into the Dutch hosiery industry. Synthetic materials have often been studied from a producer perspective, emphasizing their efforts to introduce new or improved materials in the plants of processors. In this article processors are central, their knowledge base is emphasized and it is suggested that involvement of the material’s producer increases with the extent to which the material disrupts the markets and technologies of processors.

Nylon – the material and its challenges:
The case of Dutch hosiery firms, 1945–1965

On 2 January 1952, high ranking executives of AKU (Algemene Kunstzijde Unie) gathered in Emmen, in the Netherlands, to witness the start of nylon spinning. AKU was a large multinational producer of rayon, a semi-synthetic fiber made from cellulose, and as such threatened by the introduction of nylon, the first fully synthetic yarn in the world. The American company Du Pont had developed nylon in the 30s and had initially targeted hosiery. Success was immediate and that success did not escape Dutch hosiery firms. They planned to introduce nylon in their own plants shortly after the Second World War. In 1949, three years before AKU, seven Dutch firms started production of nylon stockings.

AKU and Dutch hosiery firms innovated in isolation from each other; neither did Du Pont assist Dutch hosiery firms. This is remarkable as the introduction of a new material is no easy task, often requiring additional innovation at the processor’s plant with the producer’s assistance. In this article, processors are central and their internal knowledge base is emphasized. This indicates that producer involvement increases with the extent to which materials disrupt the technologies and markets of processors.

Synthetic materials have often been studied from the perspective of their producers. These producers have to demonstrate the viability of their materials to the processors that manufacture end-products. Materials producers assist processors in solving problems. Sometimes material producers develop end-products and processes to manufacture these products. They also try to create demand for their materials by promoting the

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See: http://www.bintproject.nl/innovation.

† The title of this article is inspired by: Challenge of materials, London 1997.
use of end-products that incorporate them. In short, demonstrating the viability of a new material often entails additional innovations. If the material does not match processor practices, these practices have to be changed or the material has to be changed. Application research by the producer, research to investigate the properties of the material and to match the material with processor practices, all play a crucial role in the introduction of materials. In the case of nylon, Du Pont worked closely with hosiery producers and started a massive advertising campaign to introduce nylon. Similarly producers and users of plastics worked closely together.

A crucial factor in the producer perspective is the extent to which a new material disrupts manufacturing practices of processors. Disruption, however, is not conceptualized and, crucially, is assumed to be high, but without investigating processors and

\[\begin{array}{c|c|c}
\text{Niche creation} & \text{Architectural} \\
\hline
\text{Creates market opportunities} & \text{Defines configuration} \\
\text{through existing technologies} & \text{and markets} \\
\hline
\text{Entrench/conserv} & \text{Disrupt/obsolete} \\
\text{Existing competence} & \text{Existing competence} \\
\text{Builds on existing competences} & \text{New technologies} \\
\text{in existing markets} & \text{in existing markets} \\
\hline
\text{Regular} & \text{Revolutionary} \\
\end{array}\]

\[\text{Figure 1: transilience map}\]

5 Jochen Streb, Product differentiation by bundling standard good and innovative knowledge: Technological transfers in the German plastics industry from 1930s to 1970s, in: Journal of European Economic History 1 (2002), 71-106.
particularly their internal technological capabilities and their relations with specialized suppliers, customers and competitors. In this article the producer perspective is complemented by investigating the introduction of a new material in the plants of processors. To conceptualize disruption, this article uses the «transilience map» of William Abernathy and Kim Clark; this map makes a basic distinction between innovations that destroy or entrench existing technological capabilities and existing customer bases, leading to a taxonomy of four innovation types (Figure 1). Abernathy and Clark argue that such disruption is a crucial parameter of innovation. Typically, the more an innovation disrupts capabilities and markets, the more difficult the innovation process will be, and in the case of new materials, the more material producers may need to help processors.\(^6\) In the case of nylon this article suggests that not all new and/ or synthetic material disrupted the markets and capabilities of processors to the extent that they needed help from the material’s producer; in contrast, the processors own capabilities were crucial.\(^7\)

Nylon, the first fully-synthetic fiber in the world, is an interesting subject for this investigation. The hosiery industry is an obvious choice, given Du Pont’s targeting of that industry. Moreover, nylon presented two challenges to hosiery producers: in the period shortly after the Second World War, the yarn as such had to be introduced; in the 1950s, specific properties of nylon were used to reduce production costs and improve quality of seamless stockings. Finally, by focusing on the Netherlands, AKU can be investigated. AKU did not play a significant role in the introduction of nylon in the Dutch hosiery industry, but targeted the plastics industry, where it had to work much harder to get nylon introduced.

Two Dutch hosiery companies are studied in this article: Jansen de Wit (located in Schijndel, in the south of the Netherlands) and Hin (located in Haarlem, in the northwest of the country). These two companies were fairly large for Dutch business in general and very large for the knitwear industries. The Dutch hosiery and knitwear industries consisted of many relatively small companies.\(^8\) However, their stories provide an excellent insight into the response of hosiery producers to nylon and also complement each other. The example of Jansen de Wit can be used to study the introduction of nylon yarn shortly after the Second World War. Hin provides insight into the challenge presented by the rise of seamless stockings. AKU is analyzed to understand why it was absent from the innovation processes at Jansen de Wit and Hin and to understand why and how it targeted the plastics industry.\(^9\)


\(^7\) In this perspective, the innovation is the introduction of nylon. Innovation, in other words, means new to the firm, and consequently in this case new to the country.


\(^9\) The limited archival sources that remain have been used, alongside newsletters. For Jansen de Wit also Antoon Coolen, *Van de Breischei tot 75 gauge: Het verhaal van een kousenfabriek 1830-1955*, ’s-Hertogenbosch 1955; for Hin Freek Baars/Tony Lindijer, *Nette meisjes gevraagd: Kousenfabrieken Hin N.V.*, 1905-1969, Haarlem 1997. Finally, trade journals and textbooks have been used. For nylon, secondary literature has been complemented with research in several AKU journals. Little archival sources of AKU remain.
This article focuses on technology to knit together firm-level analysis of the textile and chemical industries. It starts with a short overview of the development of nylon, particularly at AKU, and proceeds to the introduction of the yarn in the Dutch hosiery industry. After a section that reviews AKU’s strategy, the rise of seamless stockings is investigated.

The material: the development of nylon

On 24 October 1939 the first nylon stockings were sold in stores in Wilmington (Delaware, United States), hometown of the chemical giant Du Pont. That company had developed the first fully synthetic fiber in the world as a result of fundamental research. Du Pont decided to focus its market development on the hosiery industry, where nylon would substitute silk. On 11 July 1938 Du Pont started a nylon pilot plant to develop the production process and a market. The first nylon produced was sold as bristle for toothbrushes. Bristle yarn was allowed to be thicker, which made it less difficult to produce than hosiery-grade yarn. The work of Du Pont did not go unnoticed at that other giant of the chemical industry. IG Farbenindustrie, a conglomerate created by the merger of the main German chemical companies in 1925, succeeded in what Du Pont had thought impossible: the German company started from caprolactam, instead of adipic acid (Figure 2). Although the intermediates were different, and although IG Farben named its fiber Perlon, the end-products were broadly comparable. The activities of the German company caused a stir at Du Pont. In May 1939 IG Farben and Du Pont signed an agreement. Du Pont licensed its spinning technology to IG Farben, but excluded the German company from the American market.\(^\text{11}\)

\[\text{Figure 2: Routes to nylon}\]

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\(^{10}\) Hounshell/Smith, *Science and corporate strategy* (cf. n. 4), 257–273.

Nylon competed with silk but also with rayon, a semi-synthetic fiber made from cellulose. Rayon entered the textile industry around 1900. AKU was a multinational producer of rayon headquartered in Arnhem, in the Netherlands. AKU had been created in 1929 through a merger of ENKA and VGF. The Dutch company ENKA (Nederlandse Kunstzijde Fabriek) was established in 1911 and also controlled the HKI (Hollandse Kunstzijde Industrie), a smaller Dutch producer of rayon established in 1919. The German company VGF (Vereinigte Glanzstoff Fabriken) was established in 1899 and was one of the pioneers of the rayon industry. The merger created a very large company, responsible for roughly 14 percent of the world’s rayon production in 1930.12 Nylon presented a major threat to AKU in its core business. The company had a formidable R&D organization in the Netherlands which started to investigate nylon in May 1939.13 In February 1940 AKU approached Staatsmijnen (now DSM), a coal mining company that was diversifying from its coking operations into chemicals, to look for cooperation. This failed due to the war but both companies independently continued their research. VGF, for its part, secured a license from IG Farben in 1943, but without technical assistance. IG Farben also kept control over the production of caprolactam and barred AKU’s subsidiaries outside Germany from the agreement.14 At the end of the war, VGF operated a small pilot plant.

AKU’s offices and production facilities in and around Arnhem were badly damaged in the final stages of the war. Because of the German interests in AKU, top level diplomacy was needed to secure AKU’s interests abroad, in the United States, but also in Germany and Italy.15 Against this background the work on nylon was restarted in 1946. In the same year AKU approached Staatsmijnen again. This time the two companies quickly reached an agreement. Staatsmijnen would focus on the intermediates; AKU on the polymerization and spinning steps. AKU also decided to pursue the caprolactam process and directed Staatsmijnen to concentrate on this compound at the end of 1946. Relationships between AKU and its subsidiary VGF were very tense, severely limiting knowledge transfer from Germany. IG Farben was in complete disarray but the Dutch government nationalized the company’s patents and made them available to AKU and Staatsmijnen. In addition, AKU licensed several crucial patents on nylon spinning from Du Pont in 1949. In the same year AKU and Staatsmijnen decided to build industrial scale plants. AKU started a pilot plant in 1950; the industrial plant followed in 1952. In the same year Staatsmijnen started an industrial caprolactam plant. Shortly after the plant started, AKU launched a major advertising campaign to familiarize the market with its trademark Enkalon.16

15 Dendermonde, Nieuwe tijden (cf. n. 12), 135-136.
16 ENKALON op de kous, De Spindop (1955), 8 (24).
The challenge: Jansen de Wit and the introduction of nylon

Marketing was important for AKU to establish itself as a nylon producer, the more so because seven Dutch hosiery producers had already started manufacturing nylon stockings. Jansen de Wit was one of these companies. To understand how the firm responded to nylon, some background is needed on its history.

Company and industry

In 1892 Martinus Jansen jr. established a hosiery company in the region of Eindhoven (in the south of the Netherlands). In 1917 the company moved to Schijndel, a village located about 25 kilometers north of Eindhoven, and started to grow rapidly. Jansen de Wit diversified from socks and stockings into other textile products such as sweaters. The workforce consisted of 83 people in 1919, but passed 1,000 people in 1938.

Martinus Jansen died in 1920, but his sons continued the firm. Martien Jansen (the third generation Martinus Jansen) was responsible for sales, while his brother Harry ran the plant. Harry had been trained in the company but also in the German hosiery industry. In 1919 Mathieu Jansen entered the firm, becoming involved in accounting but later also in production. Wim Jansen, finally, enrolled in 1927 after being educated in the British and German hosiery industry. Wim also attended courses at Leicester Technical College and Nottingham University, two British institutions that offered training related to the knitwear and hosiery industries. Harry and Wim secured their foreign education through the agency of a Dutch equipment trader and a British engineering works respectively. Jansen de Wit relied on foreign equipment suppliers for its production infrastructure. Experienced knitters were hired from Germany. Local boys assisted them, learning the trade as they worked. In the 30s, Jansen de Wit also hired Dutchmen with technical backgrounds to calibrate and maintain the machines.

In 1921 the Jansen brothers bought their first two flat-bed knitting machines. It was a significant step. There were two main types of knitting machines: flat-bed machines produced a flat piece of fabric; circular machines produced a hose. After knitting the fabric, it had to be processed into an end-product. Circular machines were small, fast and cheap. Economies of scale were non-existent; to make more products, a company typically added more machines. Flat-bed knitting machines were heavy, big and expensive pieces of equipment. They had a number of sections, called «heads», operating in parallel, providing economies of scale to the larger machines. Because these machines knitted a flat fabric, stockings had a seam along the back of the leg. Flat-bed machines could also widen and narrow the fabric they produced; consequently, stockings could follow the shape of the leg. Circular machines could not because they knitted with a fixed number of needles. Stockings made with circular machines, known as standard or...
seamless hosiery, were of a lower quality than stockings made with flat-bed machines, known as full-fashioned hosiery. Seamless stockings were cheaper, however, and appealed to the low-end of the market.

Very little is known of the many small companies in the industry, but Hin, located in Haarlem in the northeast of the Netherlands, provides a contrast to Jansen de Wit. In 1912 Cees Hin, a teacher by training, but a trader of German stockings and gloves since 1890, decided to start a small manufacturing operation. He sensed an opportunity and decided to take it. He bought some small, manually driven circular knitting machines and started production. During the First World War trade with Germany was suspended and Hin decided to expand. He bought several circular knitting machines in Great Britain. The investment was modest, and Hin had no trouble financing it from his booming business. He hired two German women and a Czech man to provide the company with some know-how of hosiery production; he also sent his son Floor to Leicester to acquaint him with hosiery manufacture and equipment. Hin expanded further after the First World War, even as German competitors reemerged. A new plant was built and second-hand circular knitting machines were bought. The first flat-bed machine entered the company in 1929, signaling a commitment to hosiery on a large scale. The company grew rapidly and employed 1,000 people in 1939. Hin started smaller than Jansen de Wit but grew even faster.

Nylon

As relatively big hosiery firms, both Jansen de Wit and Hin could not, and did not, ignore nylon. Shortly after the Second World War, both firms started planning to introduce nylon.

In 1947 Cees Hin died, leaving his son Floor in charge. Floor’s son Robbert went on a trip to the United States in 1948 and brought back a pair of nylon stockings and probably a small amount of yarn. Jansen de Wit was even faster than Hin. The Jansen brothers had bought a pair of nylon stockings in the United States in the late 30s and had kept them safe in their vault. Through their trade contacts they managed to obtain a cone of nylon yarn from Great Britain in 1947. This sparked experiments in the plant, led by Harry and Wim Jansen. Together with Mathieu (Martien had died in 1929), Harry and Wim did not doubt the market potential of nylon stockings. Their problems centered around securing a steady supply of nylon, buying equipment and introducing nylon in their plant.

Securing a regular supply of nylon was no easy matter. AKU’s pilot plant started production only in 1950 and even then the question remained as to whether its volume and quality would be adequate. Only Du Pont and British Nylon Spinners, a joint-venture of ICI and Courtaulds that worked under license from Du Pont, manufactured...
nylon on an industrial scale, but were flooded by domestic demand. In 1946 the American market normalized but foreign currency, particularly the US dollar, was in short supply in the Netherlands and consequently Dutch producers could not buy yarn from Du Pont.  

Mathieu Jansen and Floor Hin were also involved in Vertriko, the business association of the Dutch hosiery and knitwear industries. Vertriko continued the close relationships between companies in the industry that had grown, partly under pressure, during the Second World War. Vertriko was officially established in 1947, with Floor Hin becoming chairman (after March 1948 deputy chairman) and Mathieu Jansen a member of the board. In 1948 Vertriko started to lobby the Dutch government so that the necessary dollars would be freed to buy nylon. Vertriko argued that the Dutch hosiery industry needed nylon fast, or else it would fall behind foreign competition. Initially, the Ministry of Economic Affairs, which was responsible for allocating foreign currencies, rejected Vertriko on the grounds that nylon stockings were luxury articles. In 1949, however, Economic Affairs allocated some dollars to the hosiery industry so that nylon could be bought. Seven hosiery firms, including Jansen de Wit and Hin, then started regular production of nylon stockings. These products had to be exported to regenerate the scarce funds of foreign currency. A year later the obligation to export all nylon stockings was removed when the most severe shortages of dollars had passed. Crucially, however, the import of nylon hosiery was restricted for a year, enabling Dutch industry to build a strong position in its home market.  

Equipment

Dutch hosiery producers worked together to secure a supply of nylon. This was only part of the innovation process however. Jansen de Wit invested in its production facilities as well. In part, this was necessary because Schijndel and Jansen de Wit’s plant had been heavily damaged in September and October 1944. The company’s personnel tried to repair the machines as good as possible. The Jansen brothers also wanted to invest in new equipment to start manufacturing nylon stockings and to expand production generally. They had started planning for post-war expansion as early as 1943.  

Besides price, fashion was also an important factor in the hosiery market. Consumers had developed a preference for full-fashioned, increasingly smoother and finer hosiery since the 20s and this trend initially continued after the Second World War. To manufacture such hosiery, companies had to work with flat-bed knitting machines with a

28 Ontwerp voor een uitbreiding van Jansen de Wit’s Kousenfabrieken te Schijndel, 1943, in: Brabants Historisch Informatic Centrum Den Bosch, company archives Jansen de Wit, box archive material. (Hereafter: JDW); Coolen, Van de Breischei tot 75 gauge (cf. n. 9), 78, 86, 88, 124-130.
high gauge (a measure of the number of needles per 1.5 inch).\textsuperscript{29} Traditionally Jansen de Wit mainly looked to Germany for its equipment. Chemnitz, in Saxony, had been the center of the German knitwear and hosiery industries, and of specialized equipment works, but the Soviets occupied Chemnitz after the Second World War and dismantled the industry. Only in the early 50s, with the help of refugee engineers from the east, did a West-German textile machine industry emerge. British engineering works were technologically not as advanced as German ones and had been involved in war-related production; they needed time to catch-up and switch-over. That left only American equipment works. They had developed fast in both a technical and commercial sense in the 30s and 40s. The main company was the Textile Machine Works Reading (located in Reading, Pennsylvania and also known simply as Reading). It built the fastest and highest gauge flat-bed knitting machines, and built them in large numbers.\textsuperscript{30}

In December 1948 American Marshall aid became available for Dutch textile firms to buy equipment, by-passing a possible shortage of foreign currency. Also in December 1948 Mathieu Jansen traveled to the United States to look for equipment, either new or second-hand. Buying second-hand machinery was not uncommon in the industry and the company had done it before when in 1924 Jansen de Wit had bought circular knitting machines from a bankrupt Dutch company.\textsuperscript{31} Mathieu Jansen mainly visited the region of Philadelphia where many hosiery firms and engineering works were located. He picked up some information on production techniques for nylon stockings during his visits to hosiery manufacturers. American machine traders, who had excellent knowledge of the second-hand market, helped Mathieu establish contacts. Jansen de Wit also had some contacts of its own in the United States. In the 20s, with the help of a Dutch machine trader, the company had bought a flat-bed knitting machine from Karl Lieberknecht Inc. specifically for the production of rayon stockings. Lieberknecht Inc., located in Reading as well, was the American subsidiary of a German company with the same name, located in the region of Chemnitz. Lieberknecht used Kalio as a trademark.\textsuperscript{32}

At the end of January 1949, Mathieu visited the Textile Machine Works Reading. That company had a 51 gauge flat-bed knitting machine in production and was developing 54 and 61 gauge machines. Mathieu was not impressed. He reported to his brothers that he was «disappointed» with the design of the 51 gauge machine and that he thought that it was «old-fashioned». Mathieu also doubted whether the machine could knit European-size stockings. Finally, high gauge was a mixed blessing to him. Although American manufacturers worked with high gauge equipment, Mathieu sensed a crisis in nylon stockings. He concluded that high gauge was no guarantee for success in the market. Mathieu preferred Kalio. Lieberknecht Inc., the American subsidiary, had become independent of its German parent firm during the Second World War, but was much smaller than Reading. Mathieu reported to his brothers that Reading built 65

\textsuperscript{29} Chapman, \textit{Hosiery and knitwear} (cf. n. 8), 194, 196.
\textsuperscript{31} Coolen, \textit{Van de Breischei tot 75 gauge} (cf. n. 9), 81.
\textsuperscript{32} Nederland moet ook nylon kousen gaan maken, in: De Draadgeleider 3-4 (1948); Coolen, \textit{Van de Breischei tot 75 gauge} (cf. n. 9), 86.
flat-bed knitting machines a month while Lieberknecht only built 25. Lieberknecht would probably not deliver as fast as Reading. Moreover, Lieberknecht’s machines were more expensive than Reading’s.\footnote{Mathieu to Harry and Wim Jansen, 23.1.1949, in: JDW [Author’s translation]; Faure, Enige gegevens (cf. n. 30), 21.}

A couple of days before Mathieu visited the Reading company he had visited Kruse & Slattery, a firm that manufactured stockings and built hosiery machines. Kruse & Slattery wanted to sell its 51 gauge flat-bed machines but Mathieu thought the price was too high. The company was also willing to sell the design of the machine: it would supply Jansen de Wit with drawings and specifications, as well as the templates necessary to manufacture specific parts. Jansen de Wit would buy some key components from Kruse & Slattery but would build most of the machines itself. Mathieu was excited about this plan. He thought that the company had enough knowledge of flat-bed machines to build them. Jansen de Wit would become independent of equipment suppliers, which Mathieu considered to be a competitive advantage. The company would also become the first manufacturer of knitting equipment in the Netherlands, which was, according to Mathieu advantageous from «a national point of view».\footnote{Mathieu to Harry and Wim Jansen, 19.1.1949, in: JDW.} Wim and Harry Jansen’s reaction was much cooler, but their reasoning remains unclear. However, there was no need to build equipment in-house as at least Reading and Lieberknecht could supply the company with machines that were up-to-date. Building machines in-house was, to some extent, reinventing the wheel.\footnote{Cf. Arjan van Rooij, Building plants: Markets for technology and internal capabilities in DSM’s fertiliser business, 1925-1970, Amsterdam 2004, 238-248.}

As Mathieu could not find suitable second-hand equipment at a reasonable price, he and his brothers had to buy new equipment. They chose Lieberknecht. Mathieu’s assessment of Reading relative to Kalio and Jansen de Wit’s experience with Kalio must have been decisive.\footnote{No documentation remains, unfortunately.} The new machine would be put next to a Lieberknecht machine Jansen de Wit already owned and manufacture nylon stockings exclusively. Lieberknecht shipped the machine in one piece to Schijndel and provided little further assistance. Th.W. Dimmers led the effort to install the new machine. Dimmers had started to work for Jansen de Wit in 1934 and was initially assigned to a production support group where he worked on circular machines. Over the years, however, Dimmers specialized in flat-bed equipment, and he had also been closely involved in the reconstruction of the damaged plant after the Second World War. He now led the work on the installation of the new machine and concluded this work successfully. The Jansen brothers created a new department for the two nylon machines and put Dimmers in charge of it.\footnote{Onze zilveren jubilarissen, in: Contact 3 (1959).}

Jansen de Wit’s choice for Lieberknecht is remarkable. Reading captured a large part of the European market for flat-bed knitting machines after the Second World War. Hin also chose Reading, at the end of 1948. The first machine arrived in one piece in November 1949. Further machines would arrive in parts and in September 1949 Hin
sent A.J.M. Priem to Reading to study the machines and learn how to assemble them. A hosiery plant was associated with Reading and provided a testing ground for new machines. Priem also worked a while in this plant to gain practical experience with Reading machines. He went back to Haarlem in June 1950 and the disassembled machines arrived soon afterwards. Priem assembled the parts, assisted by one of Hin’s mechanics. Reading also provided written documentation, which was carefully studied in Haarlem. Assembly and installation caused no problems.18

Experimentation

With a supply of nylon and equipment to process it secured, production of nylon stockings could start. Both Jansen de Wit and Hin bought new flat-bed machines but were already familiar with this technology. Nylon yarn, however, had some specific properties that affected its processing.

In February 1937 Du Pont and a hosiery company started to experiment with the knitting of nylon stockings. Every yarn has specific properties that have to be taken into account when calibrating knitting machines; nylon was no exception. The most disruptive problem, however, was that the stockings looked awful: they wrinkled and had, according to the researcher involved, «a not too pleasant gray color roughly approximating gun metal».39 The stitches bulged and the slightest touch caused the stocking to run. To bypass these problems Du Pont patented a so-called pre-boarding technique. Nylon is a thermoplastic material: it can be shaped by applying heat. By pulling the stockings over a leg-shaped mould and applying heat, the stitches were fixed and the stockings were shaped in the form of a leg. The melting point of nylon is relatively high so that during normal use and washing it could keep its shape.40

Boarding as such was known to the hosiery industry. Autoclaves and presses were used to apply heat and pressure to stockings so that their shape and appearance improved. The procedure was used for both natural yarns and rayon.41 In the 30s, German machine builders developed a carousel-type machine that used metal leg-shaped moulds, which were heated from the inside out or moved through a heated space. Du Pont adapted the procedure for nylon and diffused it widely through equipment manufacturers. This cleared the highest hurdle and made it not too difficult for an experienced hosiery firm to introduce nylon.42 Additionally, Dutch publications in 40s and early 50s typically mentioned the need for boarding and shaping.43 TNO, a Dutch research institute, also

38 Naar de Verenigde Staten van Amerika, in: De Draadgeleider 3 (1949); Nieuws uit Amerika, in: De Draadgeleider 3-4 (1949); De heer Priem terug uit de USA, in: De Draadgeleider 10-11 (1950); Nieuws uit het bedrijf, in: De Draadgeleider 12 (1950); Tabel voor het afstellen van de coulierkoppelingen op verschillende «Reading» machines, in: Textiles Museum Tilburg, documentation folder on Hin; «Reading 100», in: ibid.
39 Cited in Hounshell/Smith, Science and Corporate Strategy (cf. n. 4), 266.
40 H. H. Kors, De fabricatie van kousen en sokken, Doctinchen 1953, 21ff.; Handley, Nylon (cf. n. 4), 39.
42 Nieuws op het gebied van het appêteren der kousen, in: De Textielindustrie 17 (1932), 656-660; De appêtuur van kunstzijden dameskousen, in: De Textielindustrie 1 (1941), 35ff.
43 Ibid. and Kors, De fabricatie (cf. n. 40), 21ff.; De behandeling van nylon kousen, in: De Textielindustrie 6 (1947), 90f. and 7 (1947), 111ff.
worked on nylon and diffused information about the yarn and its properties. AKU, finally, widely published the results of its research into the properties of nylon.

For Jansen de Wit the information available through publications must have helped to obtain a broad understanding of nylon yarn and its properties, but direct transfers of knowledge from Du Pont, AKU or TNO did not take place. For Jansen de Wit, the introduction of nylon in the plant was a process of experimentation. After a supply of yarn had been secured and machines had been bought, operators experimented to find the best way to process the yarn. By the late 40s, Jansen de Wit employed a number of experienced knitters. These men (women did not work as knitters in Schijndel) typically entered the company as boys in the 1920s and 1930s and learnt the trade from German knitters. As the Germans left in the 40s, Dutchmen took their place. Harry Jansen, later assisted by his brothers Wim and Mathieu, also worked in the plant to solve problems and optimize production. Similarly, boarding machines were bought and introduced in the plant without major problems. In January 1949 Mathieu Jansen had bought such a device from the Turbo Machine Corporation, an American company. Management and knitters were able to introduce nylon in the plant.

Jansen de Wit bought rayon from AKU, and consequently had contacts with AKU’s sales department. In June 1950 AKU sold the first 47 cones of nylon yarn from its pilot plant to Jansen de Wit. For Jansen de Wit buying from AKU had the advantage that it did not need scarce foreign currency. However, these contacts were not decisive in the introduction of nylon. Jansen de Wit started manufacturing nylon stockings on a regular basis in 1949, well before AKU had its pilot plant in operation. In the pilot plant phase, it seems more likely that knowledge flowed from Jansen de Wit to AKU than vice versa, as Jansen de Wit already had practical knowledge of processing nylon.

At Hin, experimentation was also decisive in the introduction of nylon in the plant. At the end of 1948 Hin’s management announced in the company’s newsletter that the most experienced knitters would be assigned to work with nylon. These men introduced nylon in the plant and experimented to find optimal working conditions. Boarding machines and procedures also posed no major problems. Nevertheless Hin was no stranger to AKU. In 1921 a merger, or so it seemed to Cees Hin, was considered but failed. AKU also targeted Hin with its advertising. In March 1950, for instance, AKU organized a lecture and showed movies. The editors of the Hin’s newsletter commented on the beauty of the women in the movies, which was disappointing, and on the nature of the evening, which was pleasant, but the lecture was lost on them. AKU mentioned its work on nylon and explained that it would first be used for bristles and only later for

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45 B. van den Berg, Voorschriften voor de verwerking van Einkalon op de cottonmachine, in: Rayon Revue 3 (1952), 171ff.
48 Mathieu to Harry and Wim Jansen, 2.1.1949 and 5.1.1949, in: JDW.
50 Een praatje bij een plaatje, op een historisch moment, in: De Draadgeleider 12 (1949); Wie is dit en wat gebeurt daar?, in: De Draadgeleider 9 (1950).
51 Baars/Lindijer, Nette meisjes gevraagd (cf. n. 9), 44ff., 70.
stockings. That left no impression on an audience from a company already producing nylon stockings.\footnote{AKU in Domi, in: De Draadgeleider 6 (1950).}

\textit{Regular innovation}

As Hin’s reaction to AKU’s public relations illustrates, nylon was a regular innovation for a hosiery producer. Nylon yarn was closely tuned to existing capabilities and existing markets (Figure 3). Nylon promised to expand that market, which contributed decisively to its attractiveness. Jansen de Wit and Hin did not need AKU to tell them that nylon could be interesting, nor did nylon really compete with other materials. Jansen de Wit and Hin also did not need AKU to tell them or teach them that nylon could be processed in their plants. Knitting hosiery was their core business.

\footnote{AKU in Domi, in: De Draadgeleider 6 (1950).}
AKU and its challenge

From the perspective of the hosiery industry, AKU was late with nylon. Part of the explanation are the circumstances AKU was in immediately after the Second World War. It had to rebuild itself before it could diversify or expand, and it had to catch-up with Du Pont. Another part of the explanation, however, is AKU’s strategy. The company chose a new market for nylon instead of an existing one.

AKU’s R&D organization had extensive application research facilities for textiles. In 1927 ENKA established a Textiles Laboratory (Textiellaboratorium) for routine testing and quality control. In the 30s, under the wings of AKU, this laboratory expanded and housed all major textile machines. The Textiles Laboratory made small production runs of textile products and fabrics. In this way, the quality of AKU fibers was tested and salespeople were provided with samples. The Textiles Laboratory also contributed to product development as its production runs were used to investigate which applications would be suited for a particular fiber. Application research performed important internal functions. After the Second World War, the Textiles Laboratory was further expanded and it also conducted field tests of socks, stockings and other products made from AKU fibers.53

In discussions with Staatsmijnen in 1940, Isaäc de Vooys, chairman of AKU’s executive board, and Steef van Schaik, deputy chairman, expressed doubts about the market for nylon because of its high price. In 1948, when AKU and Staatsmijnen were on the brink of deciding to build industrial plants, concerns of price had decreased because of the caprolactam route; nevertheless, caprolactam-based nylon was considered to be best suited for bristles. Van Schaik, who succeeded De Vooys in 1941, thought that adipic acid-based nylon was well-suited for hosiery but that this market was very limited.54

Although hosiery was a relatively small market in terms of volume, relative use of rayon, and later of nylon, was very high. After the Second World War, AKU tried to maintain the level of rayon use that the Dutch textile industry reached during the war due to the poor availability of natural yarns. AKU also continued promoting rayon for the hosiery industry. At an industry convention in 1949, the year Dutch hosiery producers started using nylon, an AKU salesman told an audience of hosiery producers that rayon was their yarn of choice and that its possibilities had not yet been exhausted. AKU stuck to this sales strategy in the 50s even as rayon use started to fall.55

To complement the defense of rayon, AKU’s board developed a strategy of diversification after the Second World War; the company should develop a «second leg» through diversification and reduce its dependence on the textile industry. Among others, AKU

55 CBS Productiestatistiek, several editions; Verwerking van rayon en rayonvezel, in: Mededelingen (1949), 315ff.
developed cellulose sponges and rayon tire cord.\textsuperscript{56} Nylon’s second leg were plastics, a new yet highly dynamic sector. For textiles, the polymerized caprolactam was spun into fibers and yarns. For plastics, polymerized caprolactam was processed into granules that could be used in plastic processing machines (Figure 4). To mark the difference to textiles, AKU chose Akulon as its trademark for plastics. In 1950, when the pilot plant started, it soon began making plastics granules and initiated product development to find out which applications would be most promising and to solve specific problems. AKU targeted applications in which nylon’s specific properties would stand out. For instance, AKU promoted nylon gearwheels, that required no lubrication and ran quietly in hot environments for a long time. In these types of application, for which the term engineering plastics later came into use, nylon found a significant market.\textsuperscript{57}

AKU also tried to develop a production process for nylon piping. Conventional plastics equipment could be used to make a pipe or hose from synthetic material but manufacturers of these products typically had no experience with this equipment. In the case of nylon, moreover, some adaptations were necessary to make a pipe that was perfectly round and that had an evenly thick wall. AKU’s R&D also developed a method to make large diameter pipes. The advantages of nylon piping were the resulting low weight, strength and resistance to a wide range of substances. In 1955 AKU was convinced that the problems were solved and tried to convince several Dutch engineering works to start manufacturing nylon pipes. Some field tests were conducted, but with limited success. Polyethylene and polyvinylchloride captured the major share of the market.\textsuperscript{58}

In the case of nylon, the plastics industry faced a much more disruptive technology than the hosiery industry (Figure 3). AKU therefore had to convince plastics processors

\textsuperscript{56} Klaverstijn, Samentwijnen (cf. n. 12), 23, 32ff.
\textsuperscript{58} Bronswerk gaat Akulon-buizen toepassen, in: De Spindop 9 (1956); Buizen van Akulon: Omwenteling in zicht, in: De Spindop 13 (1956), 4f.
that nylon could be used and had to convince them to use nylon instead of other materials; it tried to do so with application research and by offering assistance. In the case of hosiery, application research mainly performed internal functions like quality control. In this perspective, AKU’s relative neglect of the hosiery market is striking. Nylon disrupted AKU’s technological capabilities based in rayon. However, instead of aiming for hosiery, a known market, it aimed for plastics, an unknown market. The success of this strategy was limited. Although the share of the textile industries in AKU’s turnover dropped quickly by about 30 percent in the late 40s, this was largely due to the success of rayon tire cord at that time. In the 50s and 60s AKU still generated about 70 percent of its turnover in the textile industries. Nylon captured a market as an engineering plastic, but failed to compete with bulk plastics such as polyethylene.59

The challenge continued: Hin and the rise of seamless stockings

For Jansen de Wit and Hin the challenge of nylon did not end when it had been introduced. Changes in the market and closely related developments in knitting technology set a new challenge for hosiery producers. Hin provides the best example of this challenge.

Change

In the 50s and 60s nylon stockings captured a large part of the market as consumption of stockings in the Netherlands more than doubled from 3.5 pairs per female capita in 1947 to 7.4 pairs in 1959, and grew further to 26.9 pairs in 1970. Underneath this pattern of growth the structure of the market changed profoundly. In the second half of the 50s seamless stockings increasingly replaced full-fashioned products. In 1961, consumption of seamless stockings already accounted for half of the total. Nine years later, full-fashioned stockings had maintained only one percent of the market.60 The customer base also changed. Particularly younger women preferred seamless nylon stockings as a glamorous product that was easy in use (no shifting seams), and that seemed to show the leg. This market gained further weight with rising standards of living in the 60s.61 Finally, retail channels changed in the Netherlands. Specialized clothing shops traditionally sold hosiery. These shops needed a special permit from the government to sell textile products. In 1962 regulations changed, allowing any retailer to sell hosiery. Particularly supermarkets and chemists seized this opportunity. They were particularly interested in cheap hosiery to differentiate themselves from specialized textile retailers.62

61 Midgley, The seamless stocking saga (cf. n. 60); Bettie Aafink/Corlyn Bol, Cultuur en kleedgedrag in de 20e eeuw, Groningen 1985, 37-41, 88-89.
At Hin, they called it the «massification» of nylon stockings; hosiery changed from a luxury product to a mass consumer good.63 Nylon, however, was a relatively expensive yarn and remained so until the 70s.64 Technological change accompanied market change. Seamless stockings were manufactured with circular knitting machines that knitted a hose of the same width from leg to toe. The shape of the product was poor but production costs were low. By using the thermoplastic nature of nylon, seamless stockings could be shaped in the form of a leg with essentially the same boarding technique in use for full-fashioned products, which circumvented the need to widen and narrow during knitting and opened the possibility to produce a fine-fitting product at low costs. Firms could start to take advantage of these cost-savings as the preference for full-fashioned hosiery in the market declined; technology and markets worked hand in hand in this way.65 Additionally, the productivity of circular machines increased even further after the Second World War and particularly in the 60s when operating speeds were raised and Italian machine builders developed a design with multiple yarn

Graph 1: Production of hosiery in the Netherlands

Source: CBS Productiestatistiek, several editions.

64 CBS Productiestatistiek, several editions, Author’s calculations.
feeders. In Europe, Italian and German hosiery firms were among the first to seize the opportunities of fast circular machines. These companies targeted the Dutch market as well and used price cuts to enlarge their sales. Pressure on Dutch firms was severe. Between 1960 and 1965, they lost roughly 20 percent of their domestic, most important market.

**Markets and technologies at Hin**

The rise of seamless stockings from the late 50s onwards threatened to make investments in flat-bed machines worthless. Those firms that could tried to switch these machines to other products such as underwear, while investing in circular equipment to maintain their hosiery business; others wrote-off or scrapped their flat-bed machines. Changes were quick and deep (Graph 1).

In the 50s Hin continued to invest in flat-bed machines as demand remained strong. In 1951 capacity was enlarged by 45 percent; two years later capacity was doubled again. In the early 50s there were signals about an emerging shift to seamless stockings but Hin, like Jansen de Wit and other large hosiery firms, manufactured these products as well. In 1956 Hin also bought some new circular machines. Two year later, however, large stocks of full-fashioned stockings had accumulated while prices continued to fall. Something needed to be done fast. Floor Hin died in the same year, leaving his sonRobbert in charge. Robbert reduced the production of full-fashioned hosiery by 40 percent. At the same time, and because of continued strong demand for seamless stockings, Robbert decided to invest heavily in circular knitting machines. A new building would be erected to centralize production of seamless hosiery.

Crucially, in 1958 Robbert also decided to aim an expansion of sales under the company’s own trademark Libelle (dragonfly) because it seemed less vulnerable to price competition. According to Robbert, the high quality of Libelle stockings was decisive. As the pricewar of Italian and German producers intensified, Hin stuck with its marketing strategy of emphasizing the superior quality of its product. This strategy was deeply rooted in the company, going back to the processing of silk in the 30s.

In 1959 Hin decided to expand production of seamless stockings even further and bought extra circular knitting machines. Combined with the investments of 1958 the company spent roughly three times its net profits in these years. The new building for the production of seamless hosiery opened in 1960 but was built in such a way that it could house the much heavier flat-bed knitting machines as well. Hin kept its options open. The flat-bed machines still worked at less than full capacity, however, so the company tried to diversify its product range. In 1958 the production of underwear

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67 Janzing, *De ontwikkeling van de Nederlandse kousenindustrie* (cf. n. 63), 6.

68 Chapman, *Hosiery and knitwear* (cf. n. 8), 210ff.

69 *Structuurwijziging dameskousenindustrie*, in:

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Vertriko Visie (1960), 183ff.; Baars/Lindijer, *Nette meisjes gevraagd* (cf. n. 9), 107, 110.


71 Annual report 1958, in: HA.

started, followed by other products in later years. Sales were not strong, however, and part of the flat-bed knitting machines had to be written off. Some were even scrapped. This put an extra financial burden on the company at the time it was investing in circular knitting machines.\textsuperscript{74}

Hin also diversified its range of seamless stockings. In 1967 Hin was among the first companies that introduced the pantyhose (tights) onto the Dutch market.\textsuperscript{75} At first, conventional circular machines knitted two longer hoses, which were cut at the top and seamed together. In cooperation with the Hanes Hosiery Corporation, a leading American firm, and Pretty Polly, an innovative British company, Hin developed a method to knit a pantyhose in one piece, starting with the toe of one leg and finishing with the toe of the other leg. Cutting and seaming could be omitted, reducing production costs.\textsuperscript{76}

Such reductions in production costs became increasingly urgent in the 60s. While the company switched from full-fashioned to seamless stockings, Robbert Hin worried about productivity and production costs. Although production of stockings per employee had risen from 3,800 in 1950 to 8,400 in 1960, wages had risen as well and offset productivity gains. In 1961 Robbert hired British consultants to improve productivity. A year later he visited the Hanes Hosiery Corporation and left deeply impressed. Hanes’s level of productivity was 50 percent higher than Hin’s. In October 1962 Robbert hired F.J. van den Wildenberg as deputy plant manager and sent him to Hanes to learn their methods of production. When Van den Wildenberg returned, he reorganized seamless hosiery production.\textsuperscript{77} Hin also tried other measures to reduce production costs. In the early 60s, Priem, who had assembled the Reading knitting machines in the late 40s, and E.J. Brinck, a technician who entered the company in 1950, developed a machine to automate the packaging of stockings, an idea that equipment manufacturers had tried before with some success. Hin’s Pli-Pack machine folded and wrapped a pair of stockings and doubled productivity. In 1962 the machine earned Brinck a promotion to technical plant manager.\textsuperscript{78}

Hin was active and innovative in the 60s but stuck with its strategy of aiming at quality instead of low price. The financial results of the company became strained and it lost money for the first time in 1966. Under pressure from poor results, Robbert Hin changed course radically in November 1968. He now thought that the company should have responded to the shift from full-fashioned to seamless stockings not by emphasizing quality but by reducing costs.\textsuperscript{79} As losses mounted, Robbert decided to sell the company to Danlon in March 1969. Danlon was a Danish hosiery firm that had built a plant in Emmen, near AKU’s nylon plant, in 1953. Danlon had no intention of con-
tinuing production and disassembled Hin’s plant in April 1969, effectively knocking out a competitor.80

The demise of Hin

Some of the problems Hin faced were general problems of Dutch industry. In the 60s labor costs rose faster than productivity, pushing companies to invest to replace labor. Mergers were also tried to reduce costs.81 Jansen de Wit, however, had fewer problems adapting to the changes in the hosiery market than Hin.

The changes that ultimately led to the demise of Hin started with the thermoplastic properties of nylon which enabled the production of cheap seamless hosiery of satisfactory quality. Hin, however, failed to adapt its market strategy to these changes. Robbert Hin kept aiming at quality while the market kept asking for low price. Jansen de Wit did not emphasize quality and luxury as much as Hin did. In 1967, for instance, Jansen de Wit introduced a brand specifically targeting supermarkets.82 In addition, Hin was completely focused on hosiery. Jansen de Wit had never specialized in one product range to that extent and could easily switch flat-bed knitting machines to other products. In the late 60s, in a response to the introduction of the pantyhose, the company expanded its circular knitting operations in one go by 200 machines, bringing the total number up to 1,000. After the Second World War Jansen de Wit grew faster and larger than Hin, enabling a relatively easy response to rising demand for seamless hosiery.83 The example of Jansen de Wit, however, may be less typical of the hosiery industry than Hin. Unfortunately we do not know very much of other Dutch hosiery firms but the number of large firms started to decline markedly after 1965. The rise of seamless stockings marked the end of the postwar prosperity of the industry.84

Producers of nylon watched from the sidelines, although product development continued. AKU kept its pilot plant open after industrial production started in 1952 and even expanded it in 1954. The pilot plant cooperated closely with the Textiles Laboratory in the development of different types of nylon yarns. AKU introduced yarns that were, for instance, more elastic or voluminous than regular types.85 From the perspective of hosiery firms, such variations opened up possibilities for product modifications and other regular innovations but did not help them master seamless stockings.

Seamless stockings disrupted the knowledge base of hosiery firms to a larger extent than nylon yarn had done, but mainly disrupted the market: the customer base shifted towards younger women, retail channels changed and competition moved from quality to price. Compared to nylon plastics, this suggests that involvement of materials producers was higher when the material (also) disrupted a processor’s technological capabilities (Figure 3). Hin and Jansen de Wit understood circular knitting machines very well, even if these machines changed. Making nylon piping, for instance, required modified technologies and specific knowledge unfamiliar to a manufacturer.

80 Baars/Lindijer, Nette meisjes gevraagd (cf. n. 9), 12–136.
82 Ontsluiting van een nieuw afzetgebied met ons merk Veronica, in: Contact 3 (1967).
83 Coolen, Van de Breischei tot 75 gauge (cf. n. 9), 188; Kijkje op de afd. Standardbreieri, in: Contact 2 (1970), 3.
84 CBS, Productiestatistiek, several editions.
85 Het Enkalonproefbedrijf (CX) in uitbreiding, in: De Spindop 10 (1954); Annual report AKU 1955.
This article set out to investigate nylon in the plants of processors using Abernathy and Clark’s model. From this perspective, the introduction of nylon yarn was not very disruptive. Abernathy and Clark’s concept of regular innovation captures this innovation process well. Nylon presented a challenge to hosiery firms, but one that was closely tuned to their existing technological capabilities and existing markets. Nylon was so attractive to Jansen de Wit and Hin because it could boost demand to previously unknown levels. They utilised their in-house technological capabilities to buy equipment and introduce the new yarn in their plants. Jansen de Wit and Hin had experience with flat-bed knitting machines and employed capable knitters and technicians who could experiment and introduce nylon in the plant.

As nylon was tuned to existing capabilities and markets, material producers did not play a very important role in the innovation process. Direct transfers between producers and processors did not take place. Indirect transfers, such as diffusion of information through publications, were important for a broad understanding of nylon and its properties. AKU further amplified this pattern by neglecting hosiery in favor of plastics. Its application research, moreover, also had important internal functions in production support and product development.

The rise of seamless stockings disrupted the markets and technological capabilities of Jansen de Wit and Hin more than the introduction of nylon yarn had done. Particularly the changes in the market were profound and necessitated a response. The technology of circular knitting was known to Hin and Jansen de Wit, however, and widely available from equipment suppliers. This enabled them to adapt, although the demise of Hin shows the extent and impact of the changes.

The rise of seamless stockings also underlines the importance of equipment suppliers. Their modifications to circular knitting machines reduced production cost and enabled hosiery manufacturers to make cheap hosiery even though nylon remained relatively expensive. Similarly, the development of high gauge flat-bed knitting machines allowed to respond to shifting consumer taste. Equipment works also diffused the crucial pre-boarding machines necessary to make a nylon stocking of acceptable quality. Although hosiery firms were dependent on equipment suppliers for their means of production, these suppliers provided little assistance with installation, operation and maintenance. In-house knowledge of equipment and knitting was decisive.

The processor perspective of this article suggests that the role of producers of synthetic materials has been somewhat overestimated at the expense of the internal technological capabilities of processors. The case of nylon suggests that the involvement of material producers is necessary when the material disrupts the markets and, particularly, the technologies of processors.

Address of the author: Eindhoven University of Technology, Department of Technology Management/History of Technology, IPO 2.09, P.O. Box 513, 5600 MB Eindhoven, The Netherlands, j.w.v.rooij@tue.nl.