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Memories of a Dying Industry: Sense and Identity in a British Paper Mill

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Abstract: Frogmore paper mill is a kind of time machine that allows historians of technology and the senses to study mechanized paper-making as it was done one hundred years ago. Before the introduction of instrumentation and automatic process control paper-making depended profoundly on the embodied skills of the workers. This paper will focus on the *sensory knowledge* and *skills* required for monitoring and controlling old machinery. Investigating skills-in-use will help to unravel the close link between sensing and acting to keep a continuous production process stable and running. Paper-makers would shift intuitively between different senses and sensory modes of monitoring and diagnosing sensory tell-tales to balance the production process. The importance of sensory knowledge and embodied skills also shaped paper-makers' self-perception and professional ethos. The paper will examine the impact of new process control technology on the crucial role of sensory skills for the paper-makers' individual and collective identities.

Keywords: paper industry, paper-making, continuous process industry, sensory history, sensory knowledge, sensory skills, professional identity

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Introduction

On my first visit to Frogmore Mill, in January 2013, I observed paper-makers Jim Patterson and Gary Fuller operating a small pilot machine—built in 1902 (see fig. 1). One of the first things I noticed was that Jim and Gary were constantly walking up and down the machine, and were reaching with their arms between the hot drying cylinders to touch the paper web, pulling a handle here, turning a knob there. They later explained to me that they used to listen to the howl of the vacuum box and the hum of the boiler, watch the tension of the paper web, and touch the paper at different stages of the process to feel the moisture content and the character of its surface. Jim and Gary deployed all their senses to monitor the production process, and manually adjusted the machinery as soon as they felt that this process was running out of control. This could be that the product was running out of specifications or the paper web would brake and stop the actual production process.

Frogmore Mill, up until 2000, the world's oldest mechanized paper mill still in operation, and now part of the Apsley Paper Trail, is a kind of time machine that allows us to experience paper-making as it was done, by and large, one hundred years ago.[1] Such an inroad to old paper-making technologies gives us a new "notion of technological time," to borrow a phrase from historian of technology David Edgerton (2008, xi), that reveals the often surprising long-term persistence of certain technologies and practices. Studying long-standing technology thus helps to overcome the innovation-centric focus of many a history of technology (Edgerton 2010, 689). Such histories of technology-in-use, Edgerton has claimed in *The shock of the old* (2008), should centre on the artefacts and machines which were used for many decades, like most paper machines, or remained to be utilized after the introduction of novel technologies, such as horse-and-cart in the age of the automobile. However, while

Edgerton himself has mainly focused on the *maintenance and repair skills* that helped to prolong the life of old machines, I will put the skills which are essential for *operating* old machinery centre stage. Before the wide introduction of automatic control of industrial processes, industries like the paper trade depended heavily on the embodied skills of workers who ran the machines. Frogmore Mill is a unique site as these old sensory skills can still be observed in action.

Like photocopier technicians, car mechanics, scientists or computer engineers (Orr 1996; Krebs 2012; Mody 2005; Alberts 2000), paper-makers have used their senses to observe and regulate paper machines. These *sensory skills* are a kind of "felt knowledge of materials and procedures"—a "knowledge that accrues to the sentient body in the course of its activity; knowledge inscribed in the labouring body—in hands, fingertips, wrists, feet, nose, eyes, ears, skin, muscles, shoulders, arms, and legs" as social psychologist Shoshana Zuboff has put it based on her analysis of classical studies of industrial history (Zuboff 1988, 36, 40). Sociologist Douglas Harper (1987) has called it "working knowledge" and shown how car mechanics acquire a kinesthetic sense and intimate knowledge of materials through years of practical experience.

In the 1960s and 70s, industrial psychologists and ergonomists have investigated the work of human operators in different continuous process industries including paper production (see collection in Elwyn and Lees 1974). Ergonomist Edward Crossman (1974 [1960], 5-8) studied paper-makers' intuitive understanding of maintaining "a combination of qualities in the product by a complex balance of conflicting requirements" and of spotting signs of trouble that required preventive action. Industrial psychologists J. Spencer and D. Attwood examined the work of machinemen in the paper industry and emphasized that one problem these men had to deal with in their daily routines was the time delay between the adjustment of machines and its effects. Often the exact delay was unknown to the operators. Still, the paper-makers developed the right feel for monitoring and controlling the production

process (Attwood 1974 [1970], 123). Spencer called this feel for the running machine and the timing of the production flow "process skills" (Spencer 1974 [1961], 67). These studies in ergonomics and industrial psychology did not reveal the sensory details of what happened on the shop floor, however. In contrast, I will zoom in on the paper-makers' *sensory knowledge* and investigate how paper-makers used their *sensory skills* to run old machines within the confines of particular production specifications. I will for instance examine how different sensory experiences complemented each other in the monitoring process and how paper-makers shifted between different modes of seeing, listening, touching. I will draw on Pinch's and Bijsterveld's distinction between "monitory listening"—listening *if* something is wrong, and "diagnostic listening"—listening for *what* is wrong (Pinch and Bijsterveld 2012). By doing so, I aim to unravel the significance of sensory knowledge and skills for process control in big industrial facilities, notably its *function* in preventing that complex and costly industrial processes collapse.

Another aspect I would like to explore is the entanglement of sensory skills and the paper-makers' professional identity. The Canadian historian Joy Parr has emphasized how a focus on "bodies" is crucial for understanding the connections "between the people whose histories we read and write, their tools and places where they live, work, and play" (Parr 2015). Like the actors Parr studied in her monograph *Sensing Changes* (2010), the paper-makers have learned to *make sense* of the technologies they used and of the professional world they inhabited through their labouring bodies. The habituation of their bodies allowed them to feel at home, competent, and safe in the paper mill, although actual working conditions were often far from safe and healthy. The embodied experience has shaped the workers' self-perception and has contributed to the identity formation within a distinct community of practice.

*** insert fig. 1 around here

Fig. 1: Paper-makers (from left to right) Steve Fuller, Jim Paterson and Gary Fuller in front of the drying section of the 1902 built pilot machine (2009, Courtesy of Apsley Paper Trail).

In my paper I will show that studying the sensing, labouring bodies of the paper-makers at Frogmore Mill can inform us about skills-in-use, skills that have gradually been attuned to run ageing paper machines. To explore the sensory experiences of the three paper-makers at Frogmore Mill I will draw on observations and in-depth interviews. During my two stays in Hemel Hempstead, Hertfordshire (United Kingdom), I have spent time in the mill to see Jim and Gary running the pilot machine (see fig. 1), preparing pulp, picking and packing the finished paper, and demonstrating paper-making to school classes on their visit of the Apsley Paper Trail. In the mill I have taken notes, photos and short videos. During longer breaks or in the evenings, I have conducted semi structured interviews with Jim Patterson,

Gary Fuller, and Steve Fuller. I have complemented my observations by a close reading of contemporary trade journals and handbooks, the historiography of paper industry, industrial psychology and ergonomics studies of paper mills in the 1960s and 70s, and an interview with Wim Quint, current quality manger at Maastricht Mill (Maastricht, The Netherlands). In addition, I have conducted oral history interviews with two former Frogmore Mill employees, and analysed video interviews from the Frogmore Mill Memory Bank project.[2]

I have paid special attention to moments of mismatch and disruption. Studies of medical doctors and car mechanics have shown that these moments often help to reveal the otherwise hidden traces of embodied, sensory skills (Harris 2011; Krebs 2014; Krebs and Van Drie 2014). In the paper industry, the increasing use of automatic process control since the 1960s triggered such moments of mismatch in which habitual practice was disrupted and the meaning and significance of sensory skills were re-defined. On a more fundamental level, the fast decline of the paper industry in and after the 1980s destabilized the paper-makers' local community of practice. Joy Parr has argued that such major disruptions often surface people's "awarenesses […] usually held beyond telling as habit and reflex [that now] became urgently speakable" (Parr 2015, 18). The award winning Memory Bank project of the Apsley Paper Trail testifies of such an awareness by the paper-makers. The Memory Bank, a public oral history project set up to capture local knowledge before it would be entirely lost, collects and displays a series of video interviews with former paper-makers and residents of Hemel Hempstead, and provides a rich source for studying the history of paper technology-in-use. Many interviewees describe their former work in great detail, and they emphasize how local identity was lost through the shutdown of the paper mills. In one of the interviews paper-maker Steve Fuller bemoans "that we are loosing all that local knowledge […] a lot of knowledge has been lost along that river in the last years."[3] The introduction of process control and the end of the paper industry in Hertfordshire thus constituted moments of

disruption that allowed me, as historian of technology, to study the connections between the senses and technology, and between sensory knowledge and professional identity.

Shock of the Old? Paper-Making at Frogmore Mill

In our innovation centric Western world it is a "shock" to learn that industrial machines may occasionally run profitably for more than hundred years. A very long lifespan of machinery and equipment is not uncommon for continuous-process industries in general, and the paper industry in particular (Bartels 2011; Clapperton 1952).[4] Still, Frogmore Mill is an exceptional case: in its nearly 200 years as commercial paper mill, it had only three paper machines in operation—with Number 2 machine, built around 1895, making profits up until the 1990s!

It was in 1804 that the very first commercial paper machine was established at Frogmore Mill. The machine itself, though, had been invented in France a few years earlier. In the 1790s, Nicolas Louis Robert had started to explore the idea of making paper with a machine during his employment at the Essonnes paper mill, twenty miles south of Paris (Clapperton 1952, 3). Because of patent quarrels in France, mill owner Leger Didot asked his brother-in-law John Gamble, an Englishman, to help him in getting the machine patented for England instead. With the financial support of Henry and Sealy Fourdrinier, wealthy stationers in London, Gamble indeed managed to receive an English patent on October 20, 1801.[5] Two years later, the Fourdriniers acquired a lease for Frogmore, and in the following year the first commercial paper machine was set up (Bayerl and Pichol 1986). Although they successfully sold almost twenty paper machines to different companies and the Fourdrinier machine became the dominant type of paper-making machines (Hills 1988, 105-118), the Fourdriniers themselves were declared bankrupt in 1810—development costs had turned out to be excessive (Clapperton 1967). Subsequent technical improvements, like steam-heated drying cylinders and vacuum boxes, complemented the so called "wet-end" of the Fourdrinier machine (Clapperton 1952).[6] By the 1860s, mechanized paper-making entered large scale

production and the working principles of paper-making machines changed little in 120 years that followed (Von Hössle 1929).

For our understanding of what happened at Frogmore Mill after the Fourdriniers bankruptcy, the founding of the British Paper Company (hereafter BPC) in 1890 by Herbert Sanguinetti and the work done by his son Cecil are most relevant (Pilkington 1990, 27-29). BPC took over the first paper machine from a predecessor, a machine probably based on the first commercial paper machine installed at Frogmore in 1804.[7] In 1907, another machine ("Number 2") was bought second-hand. It was a 180 centimetres wide Fourdrinier machine that had been built around 1895. By the time it was installed at Frogmore (see fig. 2 and 3), the size of the machine was already lagging behind the state of the art of contemporary paper technology (Von Hössle 1929; Bartels 2011). Despite its modest dimensions, however, Number 2 machine became the workhorse of the BPC and stayed in operation until 2009!

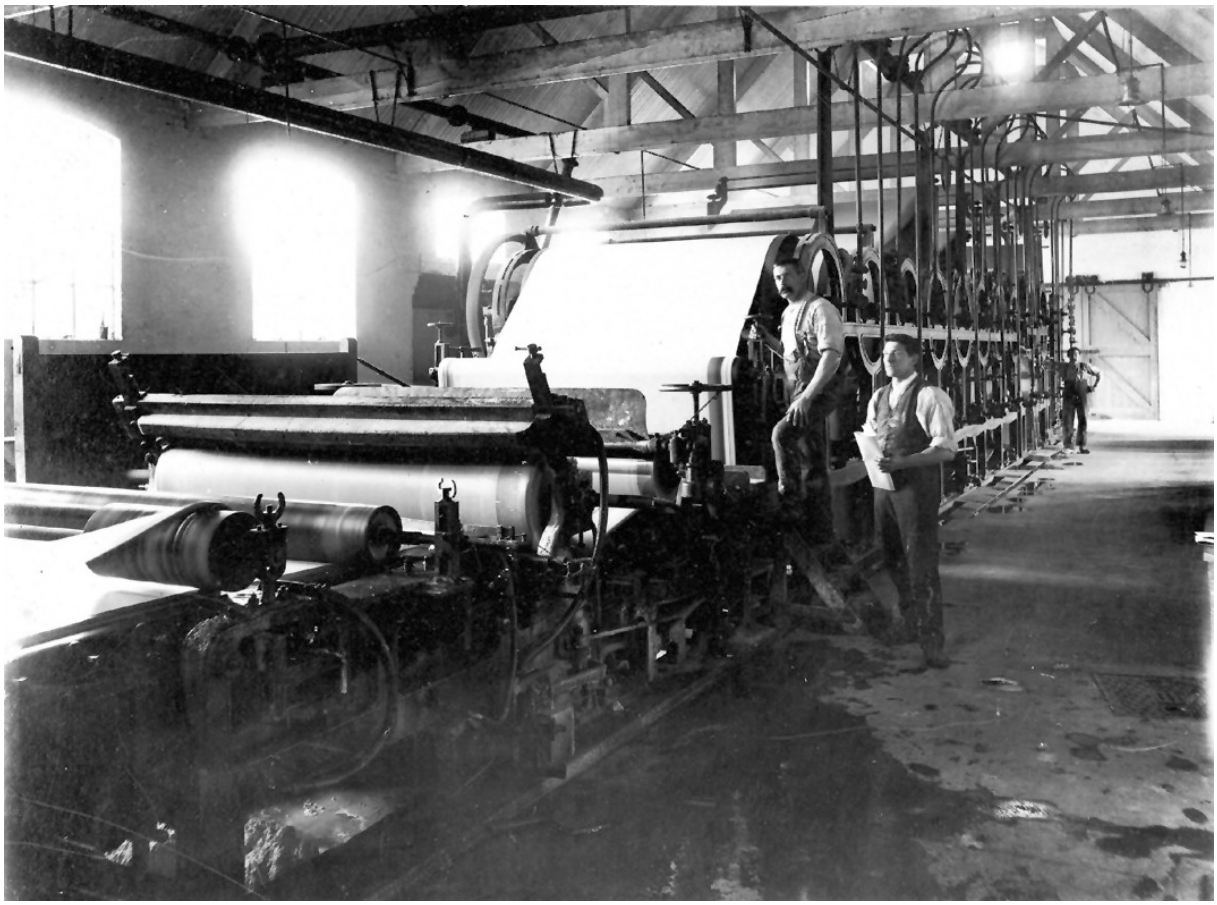

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Fig. 2: The newly commissioned No. 2 machine in 1907. In the foreground the wet-end with parts of the Fourdrinier table; the two paper-makers stand at the transition from the wet- to the dry-end; behind them the long row of drying cylinders (1907, Courtesy of Apsley Paper Trail).

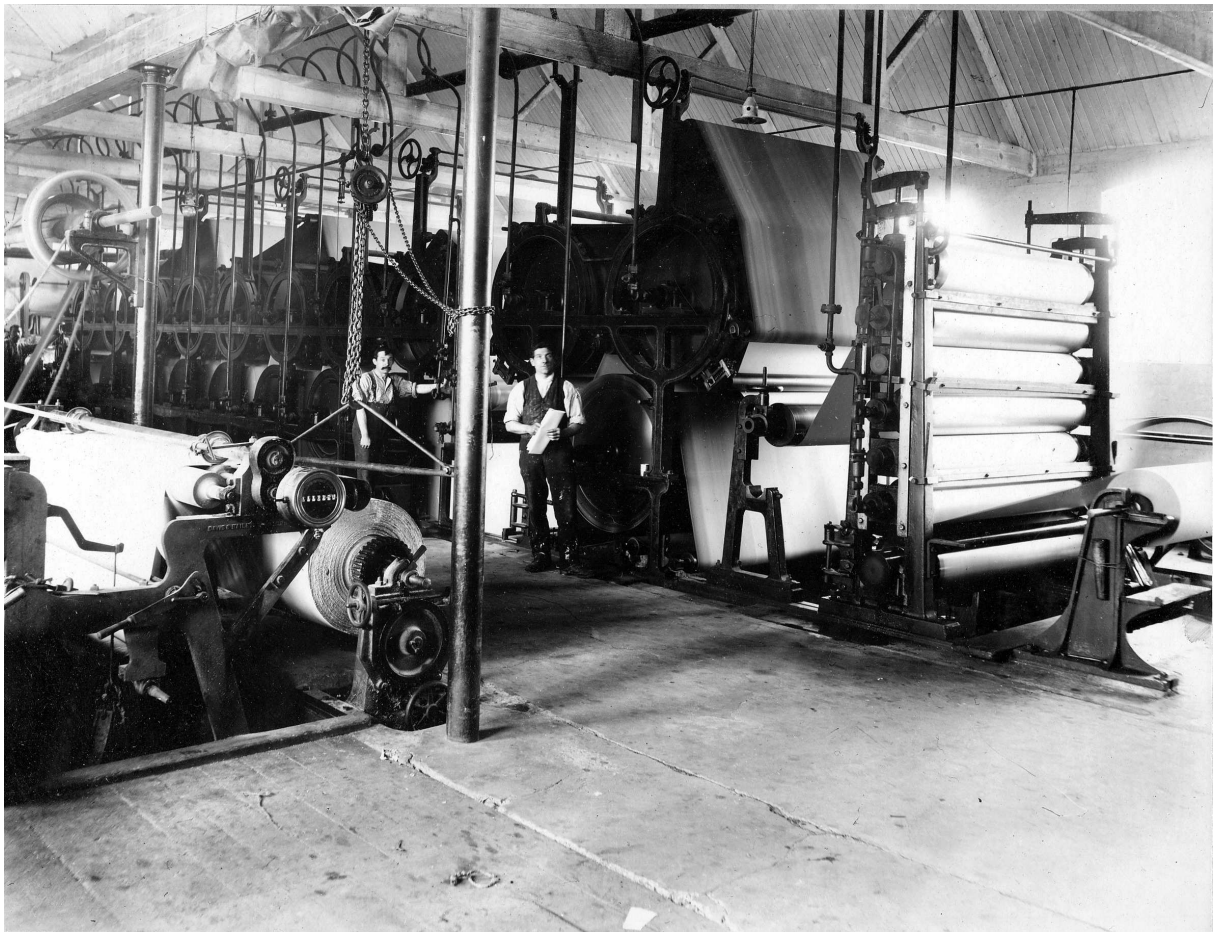

Fig 3: View of No. 2 machine's dry-end. On the far right the reel onto which the paper is rolled for further processing; before the reel one can see the calender stack. It is used to make paper surface smooth and glossy. In the background the series of steam heated drying cylinders (1907, Courtesy of Apsley Paper Trail).

Apart from moderate improvements, "very little was spent on the plant and equipment other than essential maintenance and replacements" (Pilkington 1990, 39-45, here 44). At the

beginning of the 1960s, a third machine was acquired. This machine was of a new type, a Rotiformer, in order to diversify the mill's product range. But the machine happened to be so unfamiliar to the paper-makers, that its operation resulted in great losses of raw material. After an unsuccessful attempt to re-modify the Rotiformer, the machine was shutdown in the early 1970s. To add up to the problems, Number 1 machine, after having been in operation for almost 170 years was struck by a fatal accident in 1972. Termination of the mill was envisioned for mid-1974 and it looked like Frogmore would suffer from the same fate of as many other British paper mills that had to close in the mid-seventies.

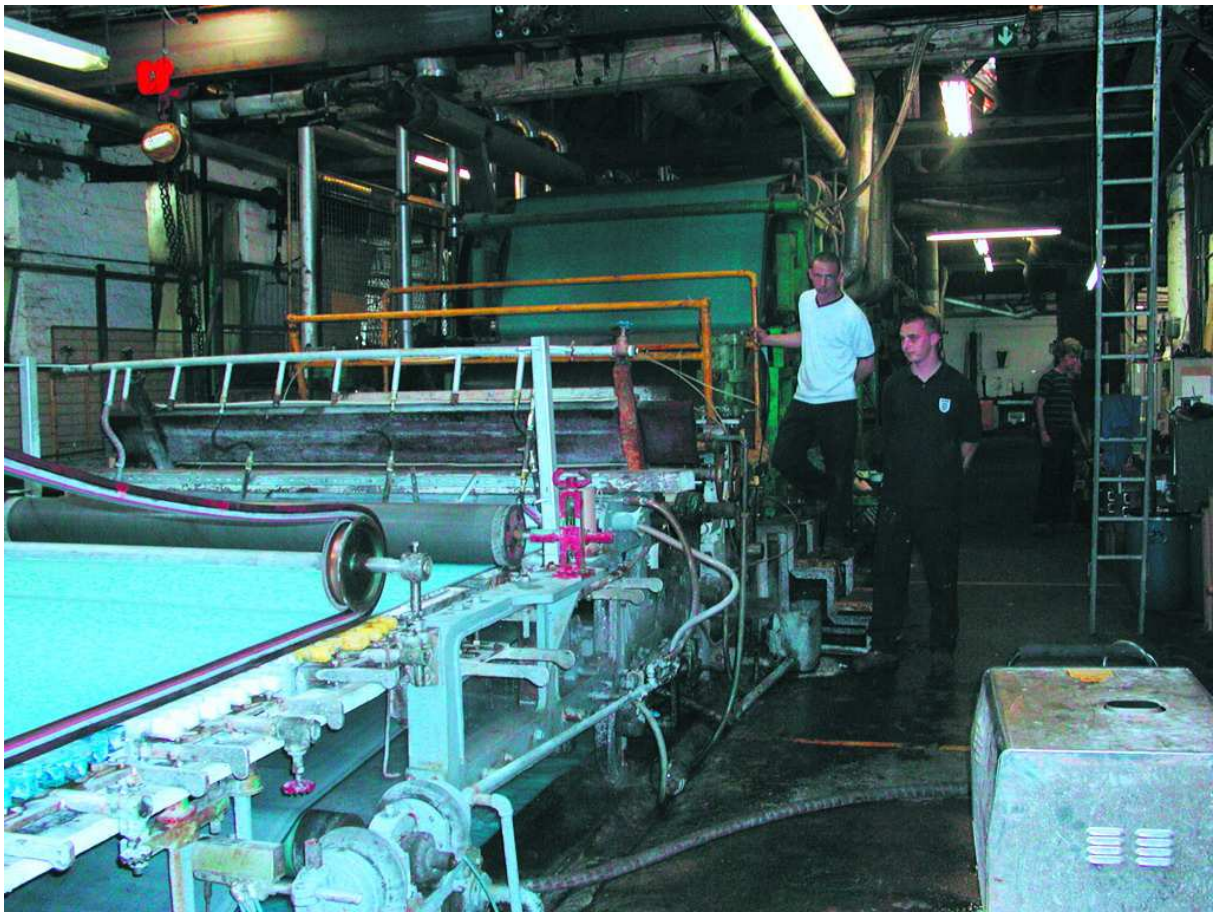

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Fig. 4: Almost the same view on No. 2 machine as fig. 2 is showing; about 100 years later (2002, Courtesy of Apsley Paper Trail).

Amidst this turmoil, however, the mill acquired new business for machine Number 2 that would soon outstrip the available production capacity (ibid., 52-59). With only one machine left, the company gave priority to maintaining Number 2 machine and kept investments limited to incrementally improving its quality, capacity and machine control system. With this approach Frogmore Mill survived all neighbouring paper mills and produced, until the liquidation of the BPC in 2000, 3.000 tons per year of pulp boards, ticket boards, manilas, laminating middles and other papers (ibid., 83-86; Bower 1996).[8] After the closure of BPC in 2000, Frogmore became a living museum. Number 2 machine remained in operation until May 2009 (see fig. 4). Today, a pilot machine from 1902 is still used that was in operation at the University of Manchester to train paper-makers for many years before it was donated to the Apsley Paper Trail. Since 2006, the Two Rivers Paper Company runs the mill. Its owner and manager is Jim Patterson, who worked for BPC from 1976 to 1985 and returned to Frogmore to keep paper machines running at the birthplace of mechanized paper-making.[9] Nowadays, Jim Patterson and a small team of former mill craftsmen produce 100 tons of craft papers. It is important to underline, however, that keeping the old machinery running required and still requires particular engineering and paper-making competences. The operation and maintenance of the ancient equipment has asked for traditional *sensory knowledge* and increasingly for improvisational skills.[10]

Operating (Old) Paper Machines

Compared to the operation of modern paper machines, making paper on an old machine is still a "touchy, feely" business. When I observed the paper-makers of Two Rivers Paper at Frogmore, I immediately noticed, as I mentioned in my introduction, the importance of the sense of touch in operating the pilot machine: Jim and Gary constantly went up and down the machine, reached over and touched the paper web at different points of the process. During an interview, Steve explained that "feel, obviously feel, feel the reel, the way across, feel the

moisture in the machine, travelling up the machine, you get to know certain points in the machine where the paper becomes a little bit dryer it gets dryer and you can feel that with your fingers." Controlling the moisture content at different stages of the production process is essential because "being too dry it [the paper] becomes brittle, static" and causes all kinds of technical problems. Steve added that "you know basically where you want that moisture to be" and "just by touching" you can check if it is where you want it to be.[11] These quotes show the central role of the paper-makers' sensory knowledge to observe the production process and to constantly keep it within specifications through small adjustments to the machine.

The reel at the end of the drying section is another point where paper-makers usually touch the paper to control the smoothness and quality of the paper surface. Jim recalled that prior to the installation of control instruments,

> a dryerman would, virtually everybody that worked on a paper machine, when they walked passed the reel would feel the building reel, with their hand, if something was starting, if there was a thin spot, what we call a rope, because they eventually started to form like a rope pattern on the reel, as to began it form, you could feel a snag between, on the palm of your hand or the end of your fingers, you could just feel it.[12]

Once the paper-maker noticed a thin spot he could do some local adjustments to reduce the contact pressure—I will come back to this kind of sensory based adjustments below. What Steve and Jim described is the paper-makers' intimate knowledge of the material, in this case paper in its different stadiums and grades, and the sensory knowledge to just "feel" the right moisture content, the texture of paper at different stages of the production process.

Less apparent but equally significant for controlling paper production were listening skills to continually monitor paper machines, and, in the case of a problem, to diagnose its cause for taking steps to keep the production process running. Paper-makers' handbooks explained, for instance, that the howl and hum of the suction boxes had to be observed to notice the overworking of a box which resulted in cloudy-looking paper or in case of too little

suction a crushed and greasy appearance (Clapperton 1952, 279).[13] Gary confirmed the importance of listening to the sound of the suction boxes: "you listen out, you can hear things changing, for example if you start, if your pulp or your stock becomes wetter, you can hear the vacuum change, that's the most significant noise, I think, on a paper machine is the sound of the vacuum, you can just hear when it starts to, it gets a lot louder, you know there is something changing."[14] Steve also stressed the meaning of the vacuum's steady noise: "there's a constant drowning, you don't really notice, there's a constant drowning, any little change, it would, you would have to go and investigate any small change in that noise, follow the origin of the, you know, the noise or what you have diagnosed being a change."[15] He explained that the sounds change because the vacuum has to work harder when the stock is getting wetter. This can, for example, be caused by over-refining which makes the stock holding more water. The constant drowning of the machine thus reassured paper-makers that the stock preparation went well and that the wet end of the machine was working properly. Alterations in such noises also contained acoustic cues that helped the paper-makers to find the cause of this alteration. What is crucial here is the interdependence of sensing and acting: the paper-makers sensed the paper web or parts of the machinery and compared it with their sensory knowledge to then take all necessary measures to keep the production process balanced and running. Thus sensory knowledge of the production process, sensory skills to observe and control it on the shop floor, and the knowledge of the technology to do the right adjustments were intimately entangled with each other.

Gary's and Steve's descriptions underline the importance of "monitory listening" to constantly observe the smooth running of the paper machine. Like car drivers or auto mechanics (Krebs 2012, 2014), paper-makers had to familiarize themselves with the normal sound of the machinery first before they would be able to discriminate between audible alterations. Given the intense sound levels in the paper industry, it is astonishing that paper-makers are able to notice these acoustic cues. Jim Patterson compared this ability to pick out

significant sounds from the cacophony on the shop floor with the experience of picking "out your name in a crowded bar"—although it should be drowned in all that noise. Jim elaborated on this sonic skill in one of his anecdotes. He remembered

> that the noise was so great, that, you could, if you were tired, as you often were late at night, the noise, you would begin to hear things, so you begin to hear choirs or orchestral music, that kind of thing, just, just a kind of dream or an auditory daydream would come about, and it's something I actually found that I can control, so I could actually hear pieces of music that I knew well, but I could hear them, and clearly what was going on was my brain was filtering out what it didn't need, and it wasn't the same as in a quiet room imagining the music, in that noise I was actually hearing it.[16]

What is interesting in this story is that Jim, although wandering off in auditory daydreams, still deployed his listening skills to monitor the proper working of the machine. As soon as his musical experiences would be interrupted, he would know that something significant had changed. Steve's earlier elaborations about the technical causes of typical sonic alterations point out that "monitory listening" and "diagnostic listening" can go hand in hand. In the paper-makers' rendering of what happened on the shop floor, these two analytically distinguished listening modes do not so much follow upon each other, as consecutive practices, but are part and parcel of one continuous practice. Noticing a change in the sound of the suction box and, at the same time, interpreting it as an acoustic signal that the stock is getting wetter can be described as an immediate *shift* from one mode of listening into the other. The importance of such shifts between different modes of listening in practices of knowledge making has also been stressed by Supper and Bijsterveld (2015).

What's more, monitory and diagnostic listening do not seem to require a particularly good sense of hearing but, first and for all, a sensory intimacy with the "natural" soundscape on the shop floor. This becomes clear from Jim's description of the former mill manager at Frogmore; one day the manager

> came into the machine house when I was standing there, all the noise, and told me that a particular bearing, and you have to, I would think that there are probably about 200 bearings on that machine, individual bushes or roller bearings, certainly over 200 hundred rolls and cylinders, hmm, there are probably more, he told me, a particular bearing had failed, and that would be very damaging.[17]

They used a strobe light to inspect that particular bearing and soon found out that it was, indeed, damaged. Jim's story shows the mill manager's outstanding sonic skills: he is able to pick one particular sound from the noisy cacophony inside the machine house. These skills are even more surprising once Jim has revealed that the mill manager was able to select such sounds even though he was "notoriously deaf." Jim's presumption is that what the mill manager "was hearing was the vibration, which is the way modern bearing monitoring is done, you have vibration monitors on all bearings on a big plant." Another aspect the anecdote stresses is the mill manager's technical knowledge as he easily located the damaged bearing. This suggests that he had a kind of mental map of Number 2 machine which allowed him to associate the sound he heard, or rather the vibration he felt, with the working principles of the machinery. His diagnosis was based on his technical knowledge and long-time sensory exposure: his attunement to that particular work environment. For checking on single bearings or gear boxes they might also use listening aids like screwdrivers, small pipes or simple stethoscopes. This kind of diagnostic work, however, was usually done by the engineering crew and not the paper-makers.[18] In this case, monitory listening and diagnostic listening were distinct practices performed by distinct actor groups. A similar distribution of sonic skills exists in the field of automobile technology: here car drivers use their listening skills to monitor the proper functioning of the automobile while driving, and, in the case of a technical flaw, auto mechanics listen diagnostically to identify its cause (Krebs 2012).

The intimate interplay of monitory and diagnostic techniques can also be observed for the sense of touch. During night shifts, Jim used to read books when working at the dry end of

the machine. While reading he would feel the reel to recognize thin spots, walk around the reel and adjust the corresponding air feeds. One night the foreman caught him and said: "you bugger, you did that and you never took your eyes off the book, cause I hadn't, I had actually done it completely, I don't know how." He emphasized that checking and then making the corrections had become so familiar that he "could do it without any conscious calculation."[19] From Jim's book reading story one can conclude that the shop floor practices honed the senses to specific working conditions and that continuous repetition ingrained these sensory skills into the labouring body so that an experienced paper-maker could deploy them intuitively. The continuous process of paper-making forced paper-makers to carry out the same checks and operations over and over again. The often dull and painstaking recurrence gradually embodied sensory skills into the paper-makers' body—gradually establishing the close link between sensing and acting in order to continuously monitor and adjust paper production.

The analogy between monitory and diagnostic listening on the one hand and monitory and diagnostic touching on the other emphasizes the entanglement between different sensory skills on the shop floor. Skills linked to different senses, such as seeing and listening, complement each other, and are a source of reassurance. In his description of an experienced work crew's monitory skills, Jim shifted back and forth between sonic and visual skills. He elaborated:

> A good crew, a good crewman would read the machine, they would, they would, there would be tell-tales to say that it was changing, so if you were making paper and it was right and the sounds were the same then you could guess pretty well that what you were still making was right, there were visual tell-tales as well, the amount of give in the paper over sprung rolls, you could read, you could watch, you could watch the points in which, it's called the dry line, when the paper is formed on a Fourdrinier,

> there is a point where it's glossy and wet and a point where it's, where the fibres are peaked through the pond of water, and that line will advance or retreat.[20]

Jim's account of a good crew's practice oscillates back and forth between visual and sonic skills. In addition, he intertwines descriptions of sensory skills with general explanations of the paper-making process and specific technical details. For one, he shows that visual and sonic skills complement each other in monitoring the production process. Both senses are "tuned" to notice alterations to common pictures or sounds. The paper-makers then shift to diagnostic modes and focus their attention on specific parts of the machinery like the dry line (fig. 5); here a more general understanding of the process and a specific knowledge of the local paper machine work together to inform or guide the paper-makers' senses. Jim continued his explanations by pointing out that the dryline

> would change in profile, but it goes very fast, quite difficult to see, but you can train your eye, train your brain to read that to say that the …, well you could train it to differentiate between it becoming heavier because if the paper suddenly becomes heavier because there's a change in the mass flowing forward that will bring the dry line forward, if the paper is the same weight, but the fibre nature changes or the amount of refining, preparation, beating, the working of the fibre, it will carry more water, it will look the same (laughs) but it will sound differently, the note will change depending on whether it's a matter of it's increasing in speed or an increasing in wetness.

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Fig. 5: Video still showing the dry line on the pilot machine's Fourdrinier table (2013).

Jim's emphasis on training the senses points out that paper workers' sensory knowledge from previous experiences help them to identify visual or audible tell-tales; they are familiar with certain alterations of the vacuum's drowning or the advancement or retreat of the dry line and match their sensory input with their understanding of the machine and the process to then adjust a particular parameter. Key aspects of this sensory practice are both the paper-makers' sensory awareness and a learned repertoire of sensory tell-tales. Jim also underlined the difficulty of recognizing the sometimes very subtle visual or auditory cues and the necessity to train sensory skills in many years of work practice to actually perceive these slight tell-tales. His stories emphasize the crucial *function* of sensory knowledge when operating paper

machines: these are necessary to keep them running within certain parameters and to avoid interruption or collapse of the production process.

The process control of old paper-machines was thus to a large extent based on sensory knowledge and skills. The technical instability of stock flows and machine speed required to constantly *feel, see* and *hear* the machine. The paper-makers' skilled senses were the only immediate instruments to make sure that the machine was running within specifications. A series of test instruments was available (Chamberlain 2005ff.), but off-machine testing took time, and by that time "you had made 10 to 15 tons of rubbish." The paper-makers also used their senses for some ad-hoc paper tests; for instance, they licked the paper with their tongue to check proper sizing, to *feel* how their spittle was absorbed by the paper.[21] However, these sensory tests were only used as rough assessments during the actual production process and not as measurements that could meet customer specifications.[22]

Acquiring Paper-Making Knowledge

Given the crucial role of working knowledge and especially sensory working knowledge in the paper-making industry, it is quite surprising that the British paper trade had no formal apprenticeship system.[23] While printers had to serve an apprenticeship and were hence recognized as skilled craftsmen, paper plants were run by semi-skilled workers. Paper-making was learned by doing: future paper-makers needed no formal qualifications to enter the trade. They simply had to start on the lowest job level in the mill and then gradually work their way up. A typical career would develop from being a pressboy, responsible for carrying the break out if anything went wrong, to second dryerman's assistant, first dryerman's assistant, dryerman, machineman and finally shift foreman. Paper-makers were supposed to "gradually pick up, watching other people, maybe a little bit of instruction, but not that much."[24] When advancing to a new position it was common to first work for a short time, between one and several weeks, with a more experienced colleague: "you would sit next to Nellie, and Nellie

did it, and you did what Nellie did."[25] Jim described this way of learning through observing and mimicking as "shadowing" of senior colleagues. If you were lucky, they would be willing to teach you. If not, you had to learn from observing the others, from mistakes, or simply had to find out things by yourself. Very little working knowledge was formalized, even though the personal use of notebooks as aide-mémoire was a commonly employed technique.[26] The informal apprenticeship system imposed a strict hierarchical order to the learning process. More senior paper-makers implicitly demonstrated what had to be considered as the best sensory skills in the local mill. However, they rarely explained or discussed these sensory techniques. The sensory awareness and attunement of junior paper-makers was thus less guided by explicit teaching than by implicit demonstration and imitation or simply working-on-the-shop floor.[27]

In addition to learning on the job, some formal training was offered by regional training centres in Aberdeen, Manchester, Berry and Kent. Here, paper-makers aspiring lower management positions followed block-release courses, for example in colour matching. While working for a mill in Kent, Jim was sent to these courses: "in that period I acquired technical training and a little bit of statistics, little bit of engineering." Next to attending paper-making courses he also worked as a crewman at a paper machine, thus receiving practical and theoretical training side by side. Although he regretted that such courses offered little electrical and mechanical engineering, they prepared him to become mill manager at Frogmore later.[28]

In the absence of a formal apprenticeship system it took a long time before junior crewmen were allowed to take over more responsible positions: you had to "gradually" make your skills "increasing … over years," Steve asserted. After training your senses for an average of seven to ten years you would finally be "able to taste and feel the quality of your paper or board whatever you are making."[29] To get a better position one had to either leave the mill or wait until a position on the next work level became available, but this could take

many years. Keneth Walter remembered the disappointment of his father who started aged 15 as cutterboy and by the time he got married was still a cutterboy—in the end, he became beaterman for Number 1 machine (Pilkington 1990, 91).[30] The advantage of this slowly evolving hierarchical system and often long time commitment to one paper mill was the steady accumulation of local (sensory) knowledge.[31] It also granted the long time-periods necessary in this "reluctant" training environment to pass working knowledge on to next generations of paper-makers. If this was quite common for the paper industry in general, both in and beyond the United Kingdom, it was of particular importance for a mill like Frogmore that local skills for operating obsolete paper machines were preserved and relayed (ibid., 87-94, 112-116).[32]

Sentient Bodies, Identity and Modern Paper-Making

The Memory Bank that I have mentioned in the introduction of my article is a collection of audio and video interviews that captures the personal stories of changing work life, leisure activities and community feelings of former paper-makers and habitants of Hemel Hempstead. In many of these interviews, the labouring body features prominently. It plays an important role in the discourse of paper-making identity, as interviewees commemorate hard physical labour and harsh working conditions as key characteristics of the local paper industry.[33] A celebration of masculine stereo-types and craft traditions disguise the occurrence of serious health and safety problems or a lack of solidarity between crews. Working in dangerous situations features as a cavalier attitude, and accidents resulting in losing a fingertip are displayed as a kind of rite-de-passage of the paper trade. Crews did not always share working knowledge, for instance when shifts competed for production bonuses. Yet this is presented as part of the paper-makers' tradition to cling to ones secrets.

My description of the paper-makers' sensory knowledge has shown that the sentient body was crucial for the workers' self-perception as competent paper-makers. Steve declared

that as a young crewman he did not identify himself as paper-maker. He first had to gain years of work experience and learn all required bodily skills "until you have enough knowledge inside you to class yourself a paper-maker." He emphasized that this bodily knowledge is hardly visible on the shop floor because experienced paper-makers would make it look easy to operate a paper machine. Jim also stressed this aspect. He recalled his first job in a paper mill in Gateshead: "It was a very old plant, the workers didn't seem to work, the supervisors didn't seem to supervise and the managers didn't seem to manage, but somehow there were three reels of paper night and day winding up, it was magic, and I very quickly became very interested." In the absence of formal training it took very long before young paper-makers were accepted as competent members of the local community of practice.

Skilled senses were also essential for the self-perception as competent paper-maker in how these skills helped to bridge the time delay between adjustments and effects. Being able to give meaning to adjustments through sensory observations reassured the worker to be in control of the production process. Steve tried to describe the role of sensory skills for that feeling of being in control: "it's very hard to explain, but it's satisfying, you may change from one tree to another tree and you can actually see it on the machine, you can feel it, you can taste it. I found it fantastic."[34] Using sensory knowledge to make the right decisions and then to see, hear, feel or taste that these adjustments were actually producing the desired effects made paper-makers' *feel* at home on the shop floor. Possessing sensory knowledge and mastering sensory skills also contributed to the paper-makers' identity formation as these distinguished *senior* paper-makers from beginners and unskilled workers.

After the 1950s, it became more and more common to enclose newly built as well as refurbished paper machines. Closing the drying section, for instance, helped to reduce the machine's energy consumption, and responded to health and safety requirements as touching the paper web in the machine was hazardous. However, the enclosure of paper machines implied that paper-makers could no longer touch the paper to feel its moisture content or

surface texture. In contrast, they had to substitute their sensory observations by numerical information provided across visual displays. Of course, sounds and fumes were not fully cut off from the paper-makers' senses, and indeed, the noise of the vacuum or the smell of chlorine remained important sources of information.[35] Still, the wider use of measuring instruments with visual displays created new sensory hierarchies: the old equivalence of touch, sight and hearing gave way for visual dominance.

The new work environment with its enclosed machines and visual instruments did no longer provide the rich sensorial context of *traditional* paper-making and thus hampered younger paper-makers in training their sensory awareness and acquiring sensory knowledge as their more senior colleagues had been able to do in their youth. This physical detachment seemed to implicate a loss of sensory knowledge. Nevertheless, the quality of the more senior paper-makers' work with new forms of process control depended partially on their prior sensory skills, as two distinct stories about the start-up of new paper machines reveal. After his formative training in the British paper industry, Steve left for South Africa to work as machineman on the start-up of a huge newsprint machine. When the production process started in January 1985, the machine was equipped with all the latest controls and displays. As he and three other British paper-makers had seen the machine being built, they knew "90 percent of the geographical positions of every pump, motor, everything." Even though operating this machine was quite a different sensory experience than he had been used to, Steve enjoyed working with this new process technology. What's more, he could still deploy some of his sensory knowledge and thus experienced instrumentation as an extension of his sensory control. Because of his knowledge of how the machine was built he felt at home in the plant and enjoyed to show engineers where to find a particular pump or valve. In contrast, Jim told the story of another start-up crew that had only been trained on a computer before they began running a newly built paper machine. One night they had a wire ridge and could see a thin spot developing on the control screen. Jim stressed that everybody who has worked

for a couple of years on a paper machine would have recognized a wire ridge, but this was beyond "the orbit of these guys." All they knew was to follow the manual, but they didn't leave their control room for an on-site sensory inspection of the machine. Instead, they had to wait until, with day shift, an experienced paper-maker came, shut down the plant and changed the fabric. This machine crew lacked the necessary sensory knowledge and awareness. They might be familiar with the new control equipment but were obviously unfamiliar with the paper production proper, for example the tactility of paper in the different stages of the production process. This was why, in Jim's account, they did not really classify as paper-makers.[36] Whereas Steve's story showed that traditional sensory skills could to some extent complement the use of instruments, Jim's account emphasized that new paper-machines hampered the honing of the paper-makers' sensory skills. Junior paper-makers with no experience on older machines lacked the practical experience how important sensory knowledge had been to make things work.

Not all experienced paper-makers embraced instrumentation like Steve did. Resistance and hostility were common reactions of senior paper-makers. They feared to loose their skills or, more precise, the status of their "enskilled senses" (Grasseni 2007). As Jim put it quite simply, no one wants to loose experience. Moreover, process control technology messed up socio-technical hierarchies on the shop floor as junior and senior paper-makers had to learn new skills side by side. Similar problems with the introduction of new instrumentation can be observed in other crafts like car mechanics (Krebs 2014). Growing up with new process technology made it easier for junior paper-makers to familiarize themselves with its novelties, while their experienced colleagues still preferred to deploy their traditional sensory skills. In addition, initial technical problems and limited reliability fostered the paper-makers' resistance. Jim inferred that older paper-makers only "started to accept instrumentation when they …. realized it actually made their live easier, made a huge difference, but initially it didn't (laughs), it made it more complicated."[37]

Paper-makers' traditional work ethos was shaped by the harsh working conditions in the mills and the intimacy of the paper-makers' labouring and sensing body with machinery and production processes. To identify oneself as a paper-maker presumed year long acquisition of *sensory knowledge* and *skills*. The introduction of new machines since the 1970s distanced paper-makers' bodies and senses from the actual paper-making as machines were enclosed and the increasing speed of paper machines made it too hazardous to touch the paper web. Old paper-makers experienced this distancing as a loss of competences and thus a loss of individual and collective identity. The unsettling of the paper-makers' identity also reflected in the senior paper-makers' disdain of younger colleagues who were unfamiliar with old technology and lacked *sensory skills* and *knowledge*.

Conclusion

The case study of Frogmore Mill, of technology-in-use, has shown the crucial *function* of *sensory knowledge* and *skills* in monitoring and controlling large industrial processes like the operation of paper machines. Paper-makers had to deploy their senses to prevent that machines would run out of control and collapse. Their sensory *working knowledge* was based to a large extent on an intimate sensory knowledge of paper in its different aggregate states and textures. This knowledge included all five senses but privileged touch, sight and hearing.

Their sensory skills can be described as the paper-makers' "process skills" (Spencer 1974 [1961]). They combined sensing, perceiving, predicting, familiarity with controls and decision making into continuous, often unconsciously performed, embodied practices. Workers acquired these skills through learning on the job within a local, socially scaffolded context. The informal apprenticeship of paper-makers can best be described as an "education of attention" (Ingold 2000, 22; see also Grasseni 2007). Working their way up from the lowest position in the mill upwards, novices gradually learned to *feel* this, *hear* that, or *watch* out for a particular tell-tale. They gradually learned how their senses complemented each

other. The paper-makers' accounts reveal interesting analogies between the senses as they used their ears, eyes and hands to control the paper-making process. They often shifted promptly between different sensory modes of monitoring and diagnosing sensory tell-tales. They embodied these sensory skills in order to continuously and intuitively respond to ever-changing production situations.

During their long and informal training, novice paper-makers gradually fine-tuned their perceptual skills, their sensory awareness before they dared to classify themselves as "paper-makers." Professional identity and embodied, sensory knowledge were thus closely linked. The paper-makers' senses were honed to specific machines and places. They were transferable to other machines and other places but kept their local cachet within a small community of practice. This became even more apparent when the paper industry moved from old machinery to more modern paper machines. These machines required different types of knowledge, for which sensory skills were less important.

Paper-making at Frogmore Mill reveals the long persistence of apparently outdated technology and work practices. Number 2 machine, built in 1895, was in operation for more than hundred years and still produced profits up until the 1990s. The history of technology can learn from this case study to focus more on technology-in-use and the niches in which old technologies could "survive." Frogmore Mill also questions the standard narrative of innovation based industries in Western countries. Furthermore, paper-making with old machinery required particular *sensory knowledge* and *skills*. For sensory scholars the close link between sensing and acting, and the temporal dimension of the paper-makers' *process skills* are interesting issues that could be studied in other (continuous process) industries—past and present. Finally, the case of paper-making has emphasized the connection between *sensory skills* and professional identity, a connection that is not only important for skilled crafts and trades but also in industrial contexts with little to no formal apprenticeships.

Studying these more informal communities of practice can help us to understand the impact of new technology on professional identities and work satisfaction.

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Notes

[1] The Apsley Paper Trail is a conservation and education chariry. Frogmore Mill has become a living museum with the pilot machine still producing around 100 tonnes of specialist grade paper every year. For more information see www.thepapertrail.org.uk. Another intriguing example is the German Büttenpapierfabrik Gmund GmbH & Co. KG. In Gmund, they still operate two paper machines from 1883 and 1930, respectively; see de.gmund.com.
[2] I analysed twelve full video interviews from the Frogmore Paper Mill Memory Bank (hereafter FMB) (videos are partly available on the Apsley Paper Trail website, see www.thepapertrail.org.uk).
[3] FMB, video interview with Stephen Fuller.
[4] PM 6 of Sappi's Maastricht Mill is a good example; the machine, built in 1962, was refurbished in 1996 and is today one of the largest triple coated board and paper machines. Interview with Wim Quint, conducted January 31, 2014, in Maastricht.
[5] The Fourdrinier brothers were already involved in paper-making; since 1791 they had leased Two Waters Mill, a few hundred yards upstream from Frogmore Mill. Around 1800, Hertfordshire had already a more than 300 year long tradition in manual paper-making (Shorter 1993; Bower 1996).
[6] Fourdrinier paper machines have two operational sections, the "wet-end" and the "dry-end." The wet-end of the machine consists of the head or breast box from which the pulp issues onto the moving wire, the Fourdrinier table with the moving wire, suction box(es) and suction and press rolls; the dry-end consists of a series of steam heated drying cylinders and the reel onto which the paper is rolled for further processing.
[7] Number 1 machine stayed in service for almost 170 years, until a fatal accident in 1972. Interview with Keneth Walter, conducted February 12, 2013, in Hemel Hempstead.
[8] FMB, video interview with Cliff Martin.
[9] For more information about Two Rivers Paper, including the company's hand mill in Somerset see www.tworiverspaper.co.
[10] Interview with Keneth Walter, conducted February 12, 2013, in Hemel Hempstead.
[11] Interview with Stephen Fuller, conducted February 11, 2013, in Hemel Hempstead.
[12] Interview with Jim Patterson, conducted January 15, 2013, in Hemel Hempstead.
[13] The suction box is a box with a perforated cover over which the wire of a paper machine passes and to which suction is applied in order to remove water from the wet paper web.
[14] Interview with Gary Fuller, conducted January 16, 2013, in Hemel Hempstead.
[15] Interview with Stephen Fuller.
[16] Interview with Jim Patterson.
[17] Interview with Jim Patterson.
[18] Interview with Stephen Fuller; interview with Keneth Walter; FMB, video interviews with Keneth Walter and Robert Jones.
[19] Interview with Jim Patterson.
[20] Interview with Jim Patterson.
[21] Jim emphasized that they would not see but feel the spittle being sucked into the paper. Interview with Jim Patterson, see also Steve "tasting" paper in www.youtube.com/watch?v=TOM3fKknKrg at 3:37 min.
[22] Interview with Terry Bromage, conducted February 12, 2013, in Hemel Hempstead; interviews with Jim Patterson (quote), Stephen Fuller and Keneth Walter; FMB, video interview with Steve Cleaver. For sensory paper tests see also Dow 1964, Bartels 2011.
[23] In comparison, the German paper trade had a formal apprenticeship system (Bartels 2011).
[24] Interview with Stephen Fuller.
[25] Interview with Jim Patterson.
[26] Paper-making handbooks rarely mentioned paper-making skills, e.g. Clapperton 1952, 1967; interview with Jim Patterson.
[27] In his interview, Jim Patterson remarked several times that this was the first time that he actually spoke about particular sensory experiences and practices. On the shop floor sensory observations were translated into technical jargon or instructions. For aspects of informal and on-the-job teaching of sensory skills see Harris & Van Drie 2015.
[28] Interview with Jim Patterson.
[29] FMB, video interview with Stephen Fuller.
[30] Interview with Keneth Walter.
[31] Periods of employment at Frogmore of more than 25 years was not uncommon. Pilkington 1990: 112-116.
[32] Interview with Wim Quint.
[33] FMB, video interviews with Keneth Walter, Robert Jones, James Chandler, Shirley Jones and Terry Bromage.

[34] Quotes from interviews with Stephen Fuller and Jim Patterson.
[35] Interview with Gary Fuller.
[36] Quotes from interviews with Stephen Fuller and Jim Patterson.
[37] Interview with Jim Patterson.