My Production Facility, My Laboratory of Discovery

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By exercising of one's curiosity, in combination with a lot of persistence, it is possible to solve some seemingly intractable problems. Many readers of this journal will have spent much, if not all of their careers, in university laboratories. In such settings there is an understandable emphasis on understanding underlying reasons. In other words, one is expected to focus on "why things happen" rather than just getting results. But if such an approach works well at the university, how about applying it at the production facility? This editorial features the stories of a man who was brave enough to spend his career asking "why" questions while working to improve the operations of paper mills.

Keywords: Curiosity; Asking "why" questions; Problem solving; Paper mill troubleshooting

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Asking the "Why" Questions in Industry

Unlike academic scientists, who tend to publish and present their work at a frantic pace, it is less common to see published accounts from an engineer working at a production facility, dealing with the same general topics. And even when one is able to read patents from such engineers, it is rare to encounter an open discussion about how such an engineer goes about gaining a better understanding of their industrial system.

A while back, while searching the shelves of NC State University's Natural Resources Library, I came across a little book entitled *Science in the Pulp & Paper Mill – A Personal Perspective* (Cowan 1998). And as I began to read the account by Wavell Cowan, I thought to myself, "This needs to be shared!"

Cowan joined the paper industry in 1954, working in a newsprint mill in Canada. In the early 1960s he served as Technical Manager at a paper mill in Scotland. He was blessed with a mind full of curiosity, and with bosses who provided him with the freedom to try to satisfy that curiosity – even to the point of trying various things out "at production scale" for the first time. You can tell that someone really loves his work when, upon his retirement, he writes a book to provide guidance for his successors.

Cowan is best known as the inventor of the Pulmac system for zero-span testing of paper strength as a means of evaluating the tensile strength of individual fibers. Cowan describes "an early program" in which a series of Canadian paper mills contributed samples of "bad paper" and "good paper" of their typical products. Cowan hypothesized that the self-identified "bad paper" might happen to be correlated to the inherent low strength of the component fibers. In other words, "bad pulp, bad paper." Indeed, results of the study confirmed the hypothesis. Results for the paper's tensile strength *vs.* fiber strength (FS) are replotted in Fig. 1. According to the author, the same trends were confirmed in multiple follow-up studies.

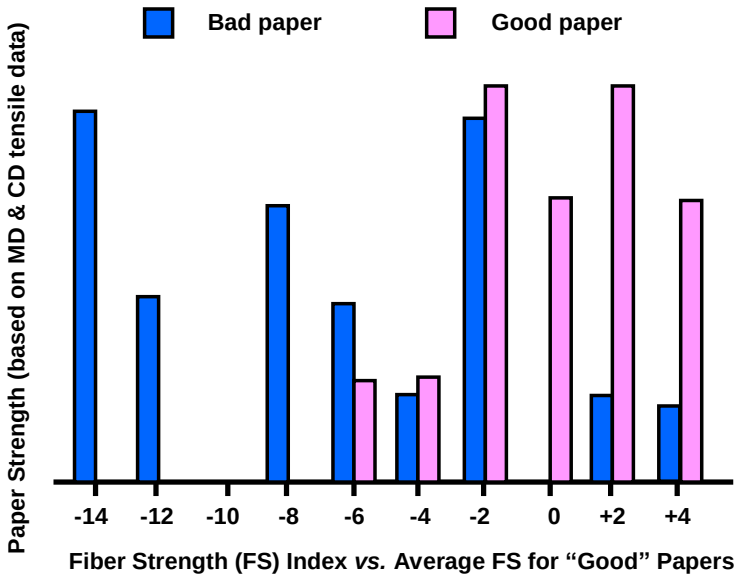

Fig. 1. Good paper and bad paper as a function of fiber strength

What do these test results mean? Is it reasonable to expect that most paper quality problems can be blamed on pulp quality? Presumably, low zero-span tensile strength – indicating low tensile breaking forces of individual fibers – might sometimes be a consequence of over-pulping or over-bleaching. But it seems unreasonable to expect that those issues will consistently dominate other issues, such as the quality with which the fibers are formed together into paper, *etc.* Logic would suggest that at least some of the "bad paper" could be due to excessive or inadequate refining, wrinkles in the sheet, or problems with the starch application system, for instance.

Persistence and Curiosity

Cowan tells a story of a beverage board product that was leaking. He listened to each member of his production team, in turn, and found that 100% of them were convinced that the problem was due to papermaking variables. There was a problem though. No two members of his team could agree on what was the cause or provide any credible explanation. None of the team, including Cowan, knew anything about laminating. It was only when attention and effort was shifted to monitoring the conditions of lamination, and doing some optimization, that the problem was solved.

In another story, Cowan and his team were struggling to figure out why a paper machine, which had recently been rebuilt, was experiencing frequent breaks of the paper web. The mill manager was grumbling about operators not properly running their equipment. Cowan interjected that if that was the case, maybe the management team ought to work shifts and keep an eye on how both the equipment and the employees were performing. Needless to say, he was not popular among his fellow engineers and managers. But by carefully looking at every gauge on the machine, taking notes, and looking carefully at each broken tail of the web, Cowan was able to locate two serious flaws in the equipment. The problem was soon on its way to being solved, and the managers' shift work was able to be canceled after just a few days.

Roots of Our Curiosity

Maybe I am intrigued by the work of Cowan, and his urge to share his love for his craft, due to my own upbringing. My father was a manager of research in the now-closed Great Northern Paper Company mill in Millinocket, Maine. My father would tell me about the social aspects of getting various concepts tried out during production runs on the commercial paper machines. Operators were often reluctant to "host" such trial work on their production machines, and nobody seemed to be listening to their input. So my dad made a practice of taking some of the operators aside several days ahead of such trials and explaining exactly what to expect. On the day of such a trial, with all of the engineers present – as well as their bosses – the trial runs were invariably smooth and successful. The operators would have a glint in their eye, knowing that they had secretly conducted a "pre-trial" on their own during a previous midnight shift when none of the engineers were around. A cynic might suspect that the operators just wanted to look good in front of their day-shift spectators. But based on the idea of curiosity being a strong motivator, one could say that they just wanted to understand for themselves how the new concept actually worked before they were called upon to run an official trial of it.

It occurred to me, while reading Cowan's accounts of the wild concepts that they tried out on paper machines in the 1950s and 60s, that maybe times have changed. The industry has matured. There is more attention to following procedures and getting approval for anything out of the routine. Maybe the "good old days" are gone – the days when an individual could tinker around with full-scale manufacturing systems and satisfy their curiosity about what might be possible.

And then I thought about an article that we recently published: Zhang *et al.* (2016) showed that it is possible to gain an improved understanding of the functional relationship between different process variables just by looking at routine process data, without any "mill trial" activity at all. Often there is enough random variation in such data to be able to train an artificial intelligence algorithm. While such an approach might not have the same charm as the reminiscences of a pioneer in our field, it can help us to more fully understand systems with which we work– even on the production floor.

Another thing that concerns me is that the modern paper mill has fewer people. And if one visits a modern production facility, it is likely that one will find many of the people "glued to their screens," maybe more focused on the software than on the process itself. There may be a danger that modern day operators are not being challenged to fully understand their processes, and are rather being encouraged to act as caretakers for the automation. My dad had a vision, back in 1980, that future software systems would allow the process to "speak to" the operators (Hubbe 1980). Control systems certainly have come a long way since those days. But is anybody listening to the process itself?

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