

# PAPERMAKING

Contents

**The History of Paper and Papermaking**

**World Paper Industry Overview**

**Paper Raw Materials and Technology**

**Overview**

**Paper Grades**

**Paperboard Grades**

**Tissue Grades**

**Coating**

## The History of Paper and Papermaking

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### Introduction

It is difficult to imagine life without paper today. Paper has been a key factor in the progress of our civilization. The pulp and paper industry is nearly as old as civilization itself. Originating in the papyrus manufacturing discoveries of Egypt and the bonding of cellulose fibers in China, the industry has steadily marched forward. By the early part of the nineteenth century, paper manufacturing had stripped the supply of available cotton rags, the only known raw material. Serendipitously, the French, examining hornets' nests, leaped to the conclusion that paper could be made from wood, an event that happened shortly after the Fourdrinier brothers developed the continuous papermaking process. To this day, wood and continuous processes are used. The transformations in the past 200 years have evolved into an increased understanding of the sciences of forestry management, machinery foundations and dynamics, wood and papermaking chemistries, motive systems, computer control, logistics, and business finance and management. Thus we have moved from paper machines commonly as wide as the standard office desk using raw materials gathered within 1–5 km to machines one-third the width of the Panama Canal selling finished products around the world. We also have moved from the concept of print-and-distribute to distribute-and-print using the Internet.

### Up to 1900

The oldest extant document, the 40-m long Prisse Manuscript written on papyrus was made by the Egyptians in about 2000 BC.

In AD 105, Ts'ai Lun proclaimed his great invention of true paper – a thin, felted material formed on a flat porous mold from macerated vegetable fiber. In AD 400, the Chinese invented ink from lamp-black and used it for writing on paper. Gypsum and starch flour were used as sizing agents in about AD 700 in China.

Paper was first made the Chinese way in Samarkand in AD 751 and in Baghdad in 793, during the era of Harun Al-Rasid. In about AD 900 paper was made in Egypt and by AD 950 was already being transferred and made in Spain. Paper for packaging and wrapping was reported in Egypt in about AD 1035.

Papermaking appeared in Sicily (1102), in Constantinople (1100), in France (1189), and in Germany (1228). The Fabriano paper mills were established in 1276 in Italy and by 1282 the first watermarks were introduced in Italy. The first paper money was issued in Tabriz, Iran in both Chinese and Arabic texts. The first use of paper in England was reported in 1309 and by 1495 the first paper mill was established there.

In 1440, Johannes Gutenberg introduced to the world his invention of printing with ink on paper, combining movable cast metal type, ink, paper and press to produce printing that very much changed the world. The first newspaper with regular publication dates was published in Germany in 1609; a similar one appeared in England in 1622.

The first English patent pertaining to papermaking was granted to Charles Hildeyerd in 1665, for 'The way and art of making paper used by sugar-bakers and others.' In 1680, the 'Hollander' or beater used in the maceration of materials for making into paper was invented in the Netherlands. In 1798, the paper machine for producing a continuous web of

paper utilizing a wire mesh screen to form the paper was invented by Nicholas-Louis Robert in France.

A patent dated 24 July 1806 was taken out by Henry Fourdrinier under the following specifications:

A number of molds, of the description called laid and wove, are hooked together to form one long mold. A platform to hold the said molds in such manner that the molds shall slide along backwards or forwards, but in no other direction. A vessel or trough from which the paper stuff or material is caused to flow upon the molds through holes, each provided with one or more registers to limit or mark the flow of stuff. A set of cylinders, upon which is passed, in the manner of a jack towel, an endless web of felting. There is a third cylinder in contact with one of these cylinders, and this third cylinder communicates by means of another web of felt with an additional pair of pressing cylinders. When the molds arrive at the first cylinder, the felt web takes off the paper and conveys it to the first pair of pressing cylinders, whence it proceeds to the second pair, and afterwards to any fit place of reception, so that continuing the process, paper of any length may be made, and with separate molds.

Other important examples of inventions and discoveries during this period include:

- The cylinder paper machine was first introduced by John Dickinson in 1809 and by 1817, he was the first scientist to introduce steam-heated drying cylinders.
- The first dandy roll was patented by John and Christopher Phipps in 1825.
- Papermaking from mechanical groundwood pulp was first introduced in 1840.
- Chemical pulping using caustic soda was introduced in about 1854.
- The first use of toilet paper in roll form in America was introduced in 1871.
- The first coating of paper on both sides was first introduced in 1875 by S.D. Warren.
- The largest and fastest paper machine by 1900 was in Rumford, Maine, with a wire 4.1 m (162 inches) in width and 18 m (60 feet) long running at about 150 m (500 feet)  $\text{min}^{-1}$ .

The total paper production in the USA at the end of the nineteenth century was about 2 million tonnes  $\text{year}^{-1}$ .

## 1900–1925

In the first quarter century of the twentieth century, the organization and development of the paper industry looked little different than that of the nineteenth century. Electricity was still a novelty

and forestry practices had not become widespread. Hence paper was manufactured from either rags or locally harvested natural growth forests. Most likely, the mill was operated with a water wheel. As an aside, the Finnish suffix 'koski' means rapids and many Finnish mills were located in towns with names such as Kylmäkoski, Valkeakoski and so forth, as these were places on rivers and streams where water wheels could be built to power machinery.

In the USA, forestry management grew out of the keen interest of Gifford Pinchot (1856–1946) in the subject. His interest in Forestry Management led Pinchot to L'Ecole Nationale Forestière in Nancy, France for education on the subject, as academic work was not available at that time in the USA. Later President Theodore Roosevelt appointed Pinchot Chief Forester of the US Forest Service. Pinchot did much work in North Carolina, and in commemoration of his visionary work, the US Forestry Service, in cooperation with others, maintains the Cradle of Forestry Historic Site on US Highway 276 just outside of Pisgah Forest, North Carolina.

In this same time period, electric motors began to make an appearance in paper manufacturing. Along with light bulbs, which had been introduced in the later part of the nineteenth century, electric motors went a long way towards moving papermaking into the modern age. At last, papermills did not have to be sitting literally on top of a stream. It appears that electric motors first made their debut in paper mills in the USA, as that country was an early adopter of electric power. Additionally, at the same time, development had stalled in Europe due to World War I (except in Finland, where the Finnish Forest Research Institute was established in 1917). Interestingly, in those days, because there was no national power grid in the USA, there were few electrical standards, hence mills had voltages and alternating current frequencies of their own choosing. As late as the 1990s some older mills in the USA were still using their own power standards.

## 1926–1950

Paper Manufacturing moved forward on many fronts in this period. Professionals around the world were beginning to think of papermaking as a scientific endeavor rather than the 'black art' that it had been. In the USA, the Institute of Paper Chemistry was founded in Appleton, Wisconsin, for the study of wood and papermaking chemistry, and the granting of graduate degrees.

The malaise of nearly worldwide depression seriously affected development from 1929 until World War II. However, in the southern USA, a

precursor to post-World War II paper industry expansion was developed. This was the Tennessee Valley Authority (TVA) project instituted by President Franklin Roosevelt. This project harnessed the power of the Tennessee River for the production of electricity and the establishment, coupled with developments elsewhere, of a national power grid.

During World War II, paper recycling became important nearly everywhere. The survival of cylinder board paper machines to this day is highly dependent on the recycling infrastructure developed during World War II in Europe and North America.

Following World War II, there was an explosion in paper demand in the civilized countries of the world. In most of Scandinavia, this started soon after the war, but in Finland and mainland Europe, it came along slightly later due to extensive infrastructure rebuilding efforts. In the USA, big (for the time) southern mills sprouted to take advantage of the forestry work that had been done with southern pine and the electrical grid infrastructure of the TVA.

## 1951–1975

The 1950s saw an explosion in paper usage throughout North America and Europe. As standards of living rose, paper goods were consumed by people experiencing higher levels of disposable income. The widespread introduction of flush toilets in small towns, another US government program of the 1930s, increased people's awareness of appropriate sanitation measures, driving the use of paper products specifically designed for this service.

In the late 1950s, Procter & Gamble, the consumer goods giant from Cincinnati, Ohio, purchased a small paper company headquartered in Cheboygan, Michigan named Charmin. Although the pundits of the day thought this would be the end of Procter & Gamble, the marketers in Cincinnati had a different idea. First, they began researching the taboo subject of what attributes made a toilet tissue desirable to the discriminating user. Next, they found a way, once such products had been developed, to market them to a public still firmly rooted in Victorian mores. An explosion in the demand for high-quality sanitary goods was the result.

Also in the 1950s and early 1960s other universities, especially in the USA, founded undergraduate and graduate programs of study in pulp and paper. By the 1990s, there were 11 such programs in the USA, with many more in Scandinavia, Canada, New Zealand, the UK, and Australia. Real pulp and paper scientists with a firm understanding of cellulose chemical and physical properties were being trained in substantial quantities.

At nearly the same time, precipitous events were happening in Finland and the United Nations. By the mid 1950s, Finland succeeded in completion of payment of war reparations to Russia. It was time to turn to repairing and renovating their own industry. A young engineer by the name of Jaakko Pöyry became head of engineering for the first renovation project. It was immediately followed by another, then another. Finland, even though a small country, has always been driven to being a major contributor to the United Nations. The United Nations, from its beginning, looked to development of natural resources, such as forests, to aid undeveloped countries in their move from the Third World. At nearly the same time Jaakko Pöyry was looking to expand his business, Max Jakobson was appointed Finnish Ambassador to the United Nations. Max Jakobson and Jaakko Pöyry had been in the same unit of the Finnish Army in World War II, fortuitous events indeed. The Jaakko Pöyry firm was engaged to do many studies for the United Nations around the world. Some of these studies led to the realization of actual projects, such as the Aracruz manufacturing and forestry site in Brazil, one of the world's largest producers of eucalyptus market pulp.

In 1962, Rachel Carson's book *Silent Spring* gained attention and had an impact on the pulp and paper industry, the degree of which no one could have imagined. This book turned the conservation movement into the environmental movement. Starting about 1970, environmental laws were implemented on a nearly worldwide basis. Although of little impact in the balance of this quarter century, this time closed with another event critical to the paper industry: the rise of the power of the Organization of Petroleum Exporting Countries (OPEC). Several oil shocks caused the industry to spend time and money on basic power generation sources, such as bark boilers, detracting scarce resources from improving the products which the industry made.

## 1976–2000

By The last quarter of the twentieth century, papermaking had clearly become science. Many aspects of the microscopic and atomic-level processes were well established. The development of other basic engineering disciplines and sciences, such as dynamics, metallurgy, process control, and so forth, developed to the level that many formerly misunderstood parameters became routine to manage and control.

New and unfamiliar challenges, however, strained the industry in ways not seen before. The industry responded slowly to growing environmental

pressures, giving its detractors plenty of reason to seek control of it.

Plastics began to make serious inroads, along with reformulations of products formerly contained by paper (such as liquid detergents replacing powders). At the same time the Internet and the electronification of the office seemed to be a two-edged sword. No doubt more printers were making more copies than ever before, but it seemed as though certain paper grades were quickly obsolescing. No longer were printed stock certificates required, and interest in daily newspapers was waning. The impact of writing a letter on high cotton content paper was lost. Conversely, computers and associated software, coupled with changes in printing processes, led to many new and specialized magazines, as layout was easier and runs could be shorter. Overall, paper-makers seemed lost as to how to distinguish their products and avoid falling into a commodity-only business. How to go from a production orientation to one of marketing?

By the end of the twentieth century, it can be said that the science of papermaking was firmly established. High-speed equipment operated by skilled professionals, using massive computing capacity, tamed the process. Today, we know how to make paper at high speed, efficiently and consistently, in an environmentally sound way.

**See also:** **Packaging, Recycling and Printing:** Packaging Grades; Paper Recycling Science and Technology; Printing. **Papermaking:** Coating; Overview; Paper Grades; Paperboard Grades; Tissue Grades; World Paper Industry Overview. **Pulping:** Bleaching of Pulp; Chemical Additives; Chemical Pulping; Chip Preparation; Environmental Control; Fiber Resources; Mechanical Pulping; New Technology in Pulping and Bleaching; Physical Properties.

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## World Paper Industry Overview

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## Introduction

Paper is one of our most important materials. It has been a key to the growth in human communications and commerce since invented by T'sai Lun in China. Various historians rank the Gutenberg Bible and the invention of the printing press as among the most important developments in history.

Changes in society have had a major impact on the use of paper around the world. However, despite predictions in the 1980s and 1990s that some combinations of technology would eliminate the use of paper for common uses such as the daily newspaper, there is little doubt that it will continue to have a key role in the future. Nevertheless, the paper industry must maintain its competitiveness and viability by continuing to develop new products that can compete cost-effectively with alternate means of information dissemination and alternate packaging materials, as well as seek out new end-use applications. Paper must also be produced economically and in an environmentally responsible manner. There are many challenges to paper that could reduce its use in some applications. Conversely, as the economies of Second- and Third-World nations continue to develop, paper consumption and growth will grow, driven by established uses and new and innovative applications. A driving force for its sustainability is a renewable and relatively low cost principal raw material, namely wood.

The following major areas are discussed in this overview:

- raw materials and major products
- demand and consumption
- long-term growth trends