Systematic Survey on Newsprint Production Technologies in Japan

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Kiyoaki Iida

■ Abstract

Since its invention two millennia ago, paper has become near-universal as the medium of civilization. Paper-making was industrialized in the Industrial Revolution, transformed through the development of mass-production technologies, and continues to be developed and refined even today.

In Japan, the methods for hand-made paper, known as “washi,” were brought to the country back in the 7th century and gradually evolved over the centuries, but the paper industry would be transformed with the introduction of mass-production using Western European-style machine technology after the Meiji Restoration. While World War II left Japan's paper industry in ruins, it rose swiftly from the ashes to become the world’s second-largest paper producer. Though China’s recent economic surge has left Japan in third place, Japan remains one of the most important paper producers in the world.

Paper is something we use every day, so we may not notice how it changes, but compared to half a century ago, the materials and quality are very different, and the production equipment has also improved its performance and efficiency by leaps and bounds. It is this technological development in the sixty years following the war that is the focus of this paper.

In the 1950s and 1960s, paper mills in Japan were located throughout the country in areas where wood resources were available, and their capacities were 100 to 200 tons per day. However, increasing demand for paper caused a wood shortage, and the newsprint market also slowly opened to imports as tariffs were gradually abolished. So the Japanese paper industry found itself having to compete internationally. One important development in the industry was importing chips from overseas by chip carriers, a trend which started in 1964. Freed from the limitations of Japan’s domestic wood supply, the industry was now able to build large integrated pulp and paper mills near any port which could handle these large ships. Now there are several mills which produce upwards of 3,000 tons of paper a day, giving them the largest production capacity in the world.

There are about 127 million people in the crowded islands of Japan, who consume a massive 240 kg of paper per capita each year. This means, however, that there is no shortage of waste paper available. The technology for recycling old newsprint for newsprint production was developed back in the 1980s. Now, up to 70% of the total pulp of Japanese newsprint is recycled fiber. This unique use of the twin resources of imported chips and recycled fiber enables Japan to remain one of the biggest paper producers in the world.

Along with this development of resources, technological improvements in paper production have also helped Japan to remain competitive internationally. The technological capability of production is defined as having equipment with high productivity, operating it at high efficiency, and producing products with high levels of reliability and good cost performance. In the 1960s, Japanese equipment makers licensed the newest technology from leading overseas equipment suppliers and introduced it into the domestic paper industry. Japanese paper companies were some of the first in the world to invest in those technologies and improve their productivity. For example, standard paper machines in the 1950s were 3.5 m wide and ran at a speed of 300 m/min. In 2000, they were 10 m wide and ran at 1,800 m/min. That shows that Japanese paper companies were willing to take the risk of investing in new technologies. They also worked with the suppliers to modify the equipment, gaining an expertise in the equipment which could then be transferred worldwide. A relationship built on mutual trust has developed between paper companies and equipment suppliers in Japan.

One of the characteristics of Japanese technology is to operate equipment at high efficiency.

The operating efficiencies of paper machines in Japan are commonly more than 90%, a level which is very rare in other countries. This efficiency comes from efficient paper machine operation, as well as from the fact that mills are managed properly, from material supply to product delivery. This culture of efficiency, nurtured in these mills, has been gradually spread abroad through technology exchanges and overseas investments.

The other characteristic of Japanese technology is the reliability of the products. One of the main reasons for this is the strict quality demands made by Japanese newspaper printers, but the industry has been eager to satisfy clients to the greatest extent possible. This attitude results in extremely reliable products, trusted by clients, so there is little need to import newsprint from overseas.

However, a new situation now confronts the Japanese paper industry, and the unique way in which it has developed. Historically, the domestic market had expanded in step with the GDP. The industry's goal was to use that demand to control the market, which it was able to do. But with the domestic market saturated, the paper industry is now required to compete in the global market. To this end, the industry needs both the technological expertise to make its products competitive internationally, and at the same time, the quality and reliability that will continue to satisfy demanding Japanese clients.

■ Profile

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1960	Graduated from the University of Tokyo, Department of Engineering (Applied Chemistry)
1960	Jujo Paper Company Ltd.
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	1986 JAPAN TAPPI Award

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1 Introduction

Since its invention two millennia ago, paper has become near-universal as the medium of civilization. Paper-making was industrialized in the Industrial Revolution, transformed through the development of mass-production technologies, and continues to be developed and refined even today.

In Japan, the methods for hand-made paper, known as “washi,” were brought to the country back in the 7th century and gradually evolved over the centuries, but the paper industry would be transformed with the introduction of mass-production using Western European-style machine technology after the Meiji Restoration. While World War II left Japan's paper industry in ruins, it rose swiftly from the ashes to become the world’s second-largest paper producer. Though China’s recent economic surge has left Japan in third place, Japan remains one of the most important paper producers in the world.

Paper is something we use every day, so we may not notice how it changes, but compared to half a century ago, the materials and quality are very different, and the production equipment has also improved its performance and efficiency by leaps and bounds. It is this technological development in the sixty years following the war that is the focus of this paper.

Looking objectively, Japan’s paper industry is not located in a country particularly blessed with raw materials or energy. So it is an interesting question to ask how technology has contributed to the development of the materials industry, despite the dependence on raw materials and energy.

Therefore, this paper attempts to lay out the particular features of the development of the Japanese paper industry by taking a look at newsprint, which is the most commonly produced type of paper, and the one where the latest technology is often used first, and investigating the process of its technological development. As part of this, this paper emphasizes the following three historical developments. First, while the demand for quality in newsprint has changed (become increasingly strict) as technological reform has progressed in newspaper printers, the way this has been dealt with is the history of technological development, which will form the core of this paper. Second, in the paper industry, which uses materials and large-scale equipment, how the raw materials and energy were ensured is an important technological perspective. The third point is that it is necessary to maintain equipment in a competitive state, and the efforts for that are also part of the history of the technology.

This paper discusses the history of paper in Chapter 2, while the current state of the paper industry is presented in Chapter 3. Chapter 4 is an attempt at explaining the basic technologies required for understanding the technical explanations in Chapter 5 onwards.

Chapter 5 provides an explanation of how both the demand for newsprint and the quality demands made of newsprint have changed and how the paper industry responded to these. These historical changes were made possible by the technological responses detailed in Chapter 6 onwards, and form the basis of this paper.

From Chapter 6 onwards, specific technological developments are shown, with Chapter 6 explaining how the lack of raw materials due to expanded demand was solved through independent technological research in Japan. Next, in Chapter 7, paper machines are examined as equipment and their technological innovations presented, while the role that the Japanese paper industry played is considered. In Chapter 8, Japan’s abilities in production technology, one of the sources of the country’s international competitiveness, are considered in specific terms. Chapter 9 looks at the energy, environment, and technical training that indirectly contribute to newsprint production. These explanations are intended to show that in order to produce newsprint competitively, it is not enough to develop technology for production lines alone; the entire plant needs to be more efficient and cost less, and in order to achieve that, technological development and cooperation based on a relationship of trust with the suppliers of equipment and raw materials is necessary.

Chapter 10 will present the features of major paper-making nations around the world and summarize Japan's technological developments by way of contrast.

Chapter 11 will examine one particular newsprint machine (one of the largest in the world when first built in 1960, which even today, when equipment has grown huge, produces the highest quality paper of all newsprints), and present a specific history of newsprint production from forty years of operational records. These records are a valuable source of data underpinning this paper.

Chapter 12 will present related news in the form of a news chronology and summarize the years when major technological developments were made in the form of a technology chronology. In addition, an evolutionary chart that sums up the entire paper has been created.

2 A short history of paper making: from its invention to industrial sustainability

2.1 Spread of the invention

The basic process of paper making is believed to have been invented in AD 105 by the Chinese official Cai Lun. His process made sheets of paper by hand from vegetation and cloth rags. It is probably more likely that he compiled methods of hand-manufacturing sheets used in different regions into a single system.

This hand-made method spread eastwards as well as westwards. It arrived in Japan in the 7th century, and was refined there to become the traditional Japanese system before the Meiji period. Westwards, the technology spread through Central Asia to the Islamic world, arriving in the Iberian peninsula around 1150. From there, it spread further into Europe between 1200 and 1300, then crossed the Atlantic Ocean to the Americas around 1690. The traditional hand-crafted method became modernized in the Industrial Revolution, replacing rags with a new resource (wood) and improving the manufacturing process through the use of mechanization, establishing itself as the modern mass-production system. This method was imported into Japan in the Meiji period.

This means that in modern Japan the *washi* (Japanese paper) industry, based on traditional sheet manufacturing methods, co-exists with the modern mass-production paper industry. As the *washi* process is far less productive, it mainly produces specialty papers, and the market for *washi* is currently on the decline. There are, however, some successful *washi* products that are exported worldwide, such as battery-separator sheets and condenser paper.

Now, let us briefly review how the method of making paper sheets by hand developed into the modern mass-production system.

2.2 The Industrial Revolution

The Industrial Revolution, which started in England, allowed the development of a new paper-making process using wood rather than rags, producing paper through mechanical rather than human means. That process became the basis of modern paper manufacturing.

It was René Antoine Ferchault de Réaumur (1683–1757) who first noticed the possibilities of wood fiber, followed by Jacob Scheffer (1718–1790), who studied producing pulp from wood. Friedrich Keller invented the first industrial wood-pulping process in 1840, using wood logs. This was followed by methods such as alkali pulping, sulfite pulping and sulfate pulping that use chemicals to dissolve lignin. Wood finally became available as an abundant, cheap resource for pulp production.

Louis-Nicolas Robert (1798) of France came up with the idea of forming continuous sheets of paper by using a rotating (endless) wire mesh, instead of the traditional hand-made batch sheet method. This idea was developed into a paper-making machine in England by Henry Fourdrinier in 1804, and his paper machine, called the Fourdrinier machine, was widely used throughout Europe.

Thanks to these two core technologies, the paper industry prospered in the latter half of the 19th century. To give an example, one technical journal published in Germany for the paper industry, *Wöchenblät für Papierfabrikation*, had some 4,500 pages in its 1908 volume alone, very clearly demonstrating the underlying strength of the German paper industry at the time.

2.3 Developments in the U.S.A.

Modern paper making technology was introduced to the U.S. in the 1900s.

Historically, paper had been used as a carrier of information and culture, but new applications such as packaging and tissues were invented in the U.S. in the 1920s. These new applications caused the demand for paper to more than double. Thin, weak paper could be transformed into packaging materials requiring strength and durability such as corrugated containerboard, paperboard and milk cartons, becoming one of the greatest inventions in the history of paper. The "kraft" pulping process, which is the most common method used today, was established in the same decade as a complete chemical recovery system. It soon became the basis of pulp production, and is still the main method used by the industry. These technologies were introduced to Japan after World War II, helping the Japanese paper industry dramatically increase production.

2.4 The spread of office automation

The new revolution in office called office automation (abbreviated as "OA" in Japan) gave birth to new types of paper, classified as "communication paper." One of these types was paper for computer printouts. As computers became more common in offices, there was an increasing demand for computer printouts. And as computers became ever more sophisticated, they demanded better paper, so paper quality was improved as well. Other types of communication paper were also created, such as PPC paper, carbonless paper, thermal paper and inkjet printing paper. Though the OA movement was intended to reduce paper consumption in offices, it actually ended up increasing the amounts both consumed and discarded. This meant that waste paper from offices came to be seen as an environmental issue, and new technologies were developed to recycle it as a renewable paper resource.

This field sees rapid technological development, and as new multi-media types are developed, it will no doubt affect the ways in which paper is used.

2.5 Development as a modern large-scale process industry

As markets for paper expanded rapidly following the start of the 20th century, the paper industry became a typical large-scale process industry. At the time, large-scale process industries wanted, in principle, to have their equipment be as large as possible to ensure higher productivity and better returns on investment. Accordingly, the paper industry developed the technologies required for large-scale fabricating equipment. These days, some pulping lines have a capacity of 3,000 tons per day, with some paper machines being up to 10 m wide and producing paper at rates of up to 1,800 m/min. The increasingly large outputs of mills means that managing mills efficiently, from material supply to product delivery, and of course actual manufacturing, is becoming increasingly sophisticated.

2.6 Environmental conservation

When an industry gets big enough, environmental conservation methods become critical. Though the paper industry is now at a very good level of environmental preservation, in the past it was a major source of problems. This process of improvement could be said to be a type of technological development, and we will look at it in Chapter 9.

2.7 Industry sustainability

One of the concepts required for a major industry is how sustainable it is. Fortunately, the paper industry is one of those rare major industries which have internal sustainability, as illustrated in Fig. 2.1.

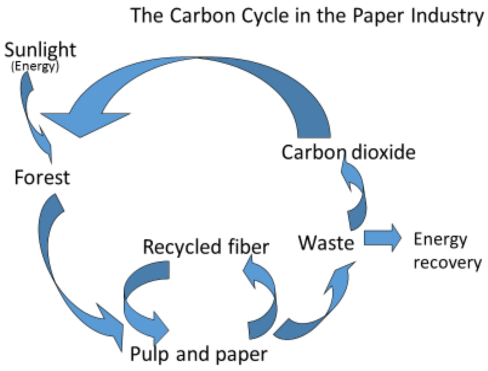


Fig. 2.1. The complete carbon cycle.

The key is the biomass (trees). Carbon dioxide in the air is converted into biomass by sunlight and stored in the form of the wood from which the paper industry produces pulp. This pulp is made into paper. The paper is used in any number of ways and then recovered as waste paper, which is then recycled to create more pulp. Any paper unsuitable for recycling is discarded as waste. This waste is burned, providing some energy recovery, and creating carbon dioxide, which is in turn becomes fixed in the form of wood biomass (such as a forest). As seen in the figure, the carbon dioxide cycle is complete, making the paper industry internally sustainable.

Bibliography

[1] K. Iida, “History, characteristics and ecology of pulp and paper industry,” *JAPAN TAPPI Journal*, vol. 55, No. 4 p. 417, 2001.

3 Significance of the theme and perspectives of the study

3.1 The paper industry in Japan

Quite a number of industries in Japan rank among the global top in terms of production volume. While not as internationally famous as cars or electronics, the Japanese paper industry was second only to the United States for a long time, until it was recently overtaken by China. Despite this, Japan's output is still greater than those of noted paper producers such as Canada and Scandinavia. However, while other industries in Japan are export-oriented, the paper industry has been domestically-oriented, and its export volume has been very small, amounting to no more than 5% of total production.

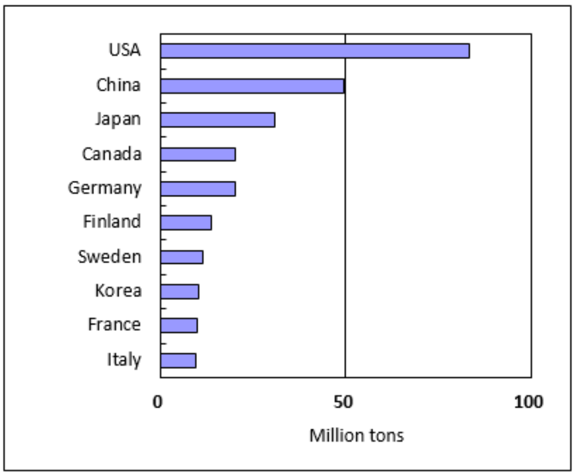


Fig. 3.1. Global paper and paperboard production (2004) [1].

Statistics from 2004 show that the annual output was about 30 million tons, and if downstream industries like paper processing are included, the value of the annual total output in money was 8.6 trillion yen, providing employment to 260,000 people (Statistical Report, 2004)[1]. This shows the importance the paper industry plays in the Japanese economy.

The paper industry was notorious for causing pollution and filling the surrounding area with foul smells. Since the 1970s, however, the industry has spent a great deal of money in improving its environmental conservation, and can now meet the severest regulations in the world, so these problems are a thing of the past (see Chapter 9).

To give a few examples of the industry's concern for the environment, in 1991, widespread dioxin pollution was noticed, which people blamed on paper mills. However, a study by the Environmental Agency found that the areas around paper mills did not show this pollution, proving that the culprit was not the paper mills after all. Yet although the biggest culprits were the municipal waste incinerators, the initial false report blaming paper mills remained in the peoples' consciousness for some time, and it has only been recently that this misunderstanding has finally been corrected.

Being a wood product, the paper industry is said to be devastating forests. It is true that tropical forests are being lost, but this is mostly due to agricultural development, not paper-making. In Japan, North America and Europe, where forests are managed properly, the volume of annual growth in forests is more than the annual harvest volume, and indeed the total volume of wood in forests is increasing. Japanese paper companies import wood chips, small chunks of pulverized wood made from waste wood left over from lumber production or harvested wood from planned forest plantations, so they are not a cause of deforestation. In addition, paper companies actively promote afforestation in areas unsuitable to farming, and contribute to environment conservation efforts.

The increasing volume of waste paper from offices also gives a bad impression of paper. But the industry recovers more than 60% of the paper it produces and uses it as recycled pulp, making it a classic example of a recycling industry. In Japan, recycled pulp accounts for 70% of the total pulp used to produce newsprint.

Thus, the paper industry is actually far better at environmental preservation than its common image would have it, and in ecological terms it is actually one of the few major industries to satisfy sustainability requirements.

3.2 Why focus on newsprint manufacturing?

Paper is classified into three main categories, depending on how it is used: paper for printing, paperboard for packaging, and other types like tissues and industrial applications. Paper and paperboard account for the bulk of all production.

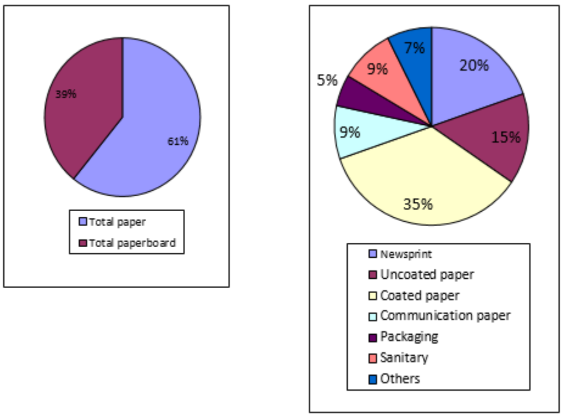


Fig. 3.2. Production volume by type in Japan (2004) [1].

Of paper and paperboard products, newsprint is probably the most symbolic product of paper industry: not only does it have a greater output volume than any other single product, it has also been frequently targeted for trialing new manufacturing technologies. Newspaper is something most people would see on a daily basis, so gradual qualitative changes are harder to notice. Yet technological developments mean that newsprint today is very different from that of fifty years ago. Similar things have happened in other industries, of course. For example, sheet steel for automobiles is still called by the same name, but its quality has been steadily improving, taking advantage of technological developments in steel production. In this paper, the history of newsprint manufacturing will be examined from several viewpoints by following technological developments.

3.3 Viewpoints for surveying technological developments

(1) Technological developments in response to shifting requests

Newspapers need be delivered to each subscriber's home by a certain time of a day without fail. A deep level of trust is maintained between newsprint manufacturers and newspaper printers that the newsprint will be delivered in time. Newspaper printers have improved their operations in numerous ways, including increasing the number of pages per issue, changing their printing systems, and restructuring their delivery depots, while at the same time they have been requiring better-quality newsprint. Table 3.1 summarizes the changes of the past fifty years, which will be discussed in detail in Chapter 5.

Table 3.1. Changes in newspaper printing

	Printing in the 1950s	Printing in the 2000s
Printing	Letterpress, black only: 4 pages/copy Printing speed: 320,000 pages/hour	Offset press, four colors: 40 pages/copy Printing speed: 6 million pages/hour Sheet break rate: less than 1/1,000 rolls
Newsprint	Basis weight: 52 g/m^2 Brightness: 45%	Basis weight: 43 g/m^2 Brightness: 55%
Consumption	500,000 tons/year	3.75 million tons/year

(2) Responses to international competition

Relatively soon after World War II, the tariffs on paper products were removed, opening up the market to overseas imports. With newsprint now an international commodity, Japanese newsprint manufacturers have faced severe competition. What has happened, however, there is very little importing of newsprint rolls, and very little export as well. This has come about due to the characteristics of the Japanese market and technological developments made by paper companies. These will be explained in Chapter 5.

(3) Overcoming geographical disadvantages

At a rough estimation, the cost of wood resources such as chips and recycled fiber accounts for 50% of the total cost of producing paper, while energy consumption accounts for 15% of the cost. As annual paper output has increased fourteen times in the last 40 years (currently 30 million tons a year), supplying enough wood resources and energy has been an indispensable part of this growth. These efforts will be described in Chapter 6 (for wood resources) and Chapter 9 (for energy supply).

(4) Technological developments that made the industry competitive

The fact that Japanese newsprint manufacturing has been competitive suggests that it must have had some degree of underlying technological capability. However, the phrase “technological capability” is perceived differently by different people. Those who work in R&D would evaluate technological capability based on R&D capabilities. However, those who work in manufacturing operation would evaluate it by low-cost high-quality goods manufacturing capabilities. In other words, “technological” can be broken down to several sub-technological categories. Therefore the technological capabilities of the paper industry will be reviewed in Chapters 6 to 9, based on the sub-technological categories listed below.

- Exploiting resources
- Manufacturing products
- Productivity, operating efficiency, product performance
- Energy-saving
- Environmental conservation
- R&D capability
- Education and training
- Strategic planning

3.4 Historical operational data from newsprint machines

Newsprint is manufactured using paper machines. Newsprint machines are generally operated for up to several decades, with intermittent rebuilds of various parts of their structure. This means that the operational data of a given paper machine during its lifetime, such as modifications of parts of the machine, operating conditions, pulp resources and operating efficiency, will form a history of newsprint production. For that reason, this paper will look at the records of one newsprint machine that was installed in 1960, which at that time was one of the biggest and fastest machines. That machine is still manufacturing newsprint of the highest quality, albeit at medium velocity. The historical record of its operational data is summarized in Chapter 11.

3.5 Characteristics as a large-scale process industry

The way technology is developed is greatly affected by the industry type. One type of classification often used is to distinguish between process industries and assembly industries. Industries like steel, oil refineries and chemicals are process industries, as is the paper industry. Automobiles, home appliances and electronics are assembly industries.

These two groups differ not only in manufacturing but also in managing plants in general, including issues such as plant site selection, plant control, and logistics.

Technological developments in newsprint production represent some of the characteristics of process industries, and will be discussed from that viewpoint in Chapter 8.

3.6 Chronological table and evolutionary chart

A chronological table is a database for reviewing history. Two separate chronological tables are provided in the Appendix.

- Chronological table of news of the industry
- Chronological table of technological developments in the industry

These tables are excerpts on newsprint production from the database prepared by JAPAN TAPPI.

In addition, a chart and a table showing the evolution of technology are provided to serve as a conclusion.

Bibliography

[1] *Pulp and Paper*, Japan Paper Association, No. 694, p.6, June 2006.

4 Descriptions of basic technologies

4.1 Pulp, paper and recycled pulp

4-1.1 Pulp

When a piece of paper is torn, small fluff is visible along the edges. This fluff is called pulp, and large quantities of this pulp form sheets of paper through mutual entanglement. This pulp comes from wood, so the next issue is to examine lumber and trees to see how pulp can be obtained from them.

In order for a plant to grow, water taken in by its roots is transported to the leaves, where it is converted to nourishment through photosynthesis, and this nourishment is then transported back to where it is needed. This means that trees need “pipelines” to transport water and nutrients. These pipelines have to lengthen as the tree grows. One efficient way of making a pipeline is to create pipes of a certain length then connect them into a single pipeline. This is how it is done for transporting oil, for example. One way to consider this is to imagine a standard drinking straw. If ten thousand straws are connected to each other, they will form an extremely long pipeline. Paste adhesive around those pipelines and combine a hundred million of them to form a huge column. One straw is equivalent to one piece of pulp magnified a hundred times. Under the same magnification, this huge column is equivalent to a tree one meter in diameter and twenty meters in height. So a tree trunk consists of a huge number of straw-like pulp particles which act as pipelines for transporting water. At the same time, they form a honeycomb-like structure which gives rigidity to the tree to help it stand upright (Fig. 4.1).

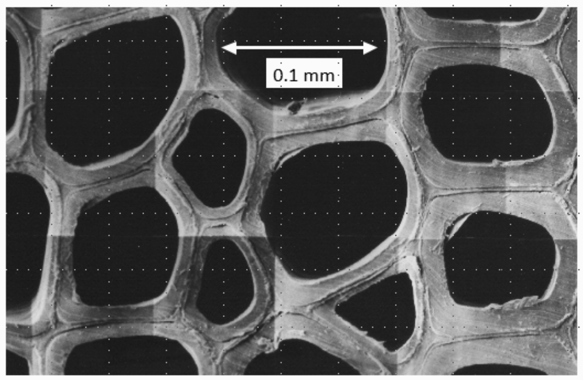


Fig. 4.1. Douglas fir trunk cross-section (magnified) [1].

We have seen how pulp can be seen as a straw. The next question is, what is the structure of pulp on the microscopic scale? Pulp walls consist of cellulose, a linear chain polymer made up of glucose units oriented parallel to each other at a given angle to the long direction. This angle means that cellulose molecules coil up, like a spiral, within the pulp wall. This structure gives pulp its toughness. Due to the orientation of cellulose, some hydroxyl groups of the cellulose molecules remain on the surface of the wall and can form hydrogen bonds with each other. This sort of structure is found in all plants.

To make pulp, wood has to be broken down to these pipe-like units. One way is to twist the wood using force to separate these units at their adhesive boundaries. This is called mechanical pulping. However, as this method is too coercive, some units end up being broken down, as shown in Fig. 4.2.

The other way is to dissolve the adhesive layer (called lignin) with chemicals and separate the units without damaging them. This is called chemical pulping. Both types of pulp have specific characteristics, so are blended with each other to get the desired paper quality.

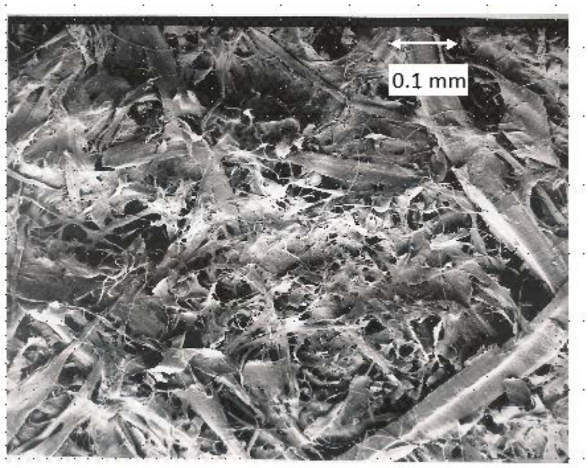


Fig. 4.2. Mechanical pulp (groundwood pulp) (magnified) [1].

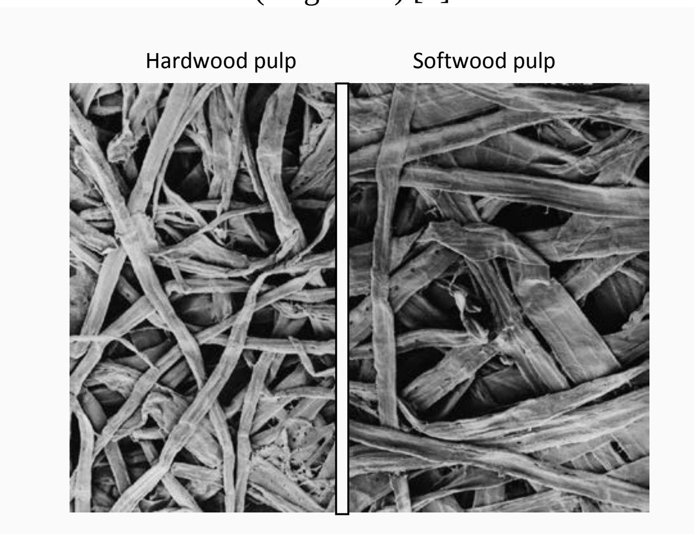


Fig. 4.3. Chemical pulp (magnified) [1].

Scanning electron microscope (SEM) photos for the two pulp types are shown in Figs. 4.2 and 4.3. Pulp from softwood is 3 mm long and 0.1 mm wide, while pulp from hardwood is 1 mm long and 0.03 mm wide.

One of the important technologies for the paper industry is the ability to continuously produce these types of pulp at high efficiency and using large-scale equipment.

Historically, softwood, which has long units of pulp, has been used. However, as Japan is poor in usable softwood, one of the issues of technological development has been ways in which to use hardwood for pulp.

4-1-2 Pulp notation

Pulp is broadly classified into two main groups, mechanical pulp and chemical pulp. Each group has several types and qualities of pulp, depending on the pulping process. Notations are commonly used to identify these different types. They are summarized below to help understand the explanations that follow. The actual pulping processes will be described in Chapter 6.

1) Chemical pulps

KP: Kraft Pulp or Sulfate Pulp

Pulp produced by the kraft process, using sodium hydroxide and sodium sulfide. Noted for its strength compared to the sulfite process.

SP: Sulfite Pulp

Pulp produced by the sulfite process, using calcium hydrogen sulfite. This was the main type of chemical pulp until KP became dominant around 1950.

2) Mechanical pulps

GP: Groundwood Pulp

The classic process in which logs are ground from logs using a grinder (see Fig. 6.3).

CGP: Chemi-groundwood Pulp

The shortage of softwood trees led to the development of this process. Hardwood chips are lightly treated with chemicals, then crushed by a refiner.

SCP: Semi-chemical Pulp

This process can make pulp from hardwood. Its quality falls between mechanical pulp and chemical pulp. Not much used.

TMP: Thermo-mechanical Pulp

Softwood chips are heated by steam and crushed by a refiner. This process became popular in Japan when softwood chips started to be imported. TMP is less damaged than GP and has higher strength. Its disadvantage is less opacity due to coarser content.

RGP: Refiner Groundwood Pulp

Softwood chips are simply crushed by a refiner. This process was modified to create TMP.

3) Recycled pulp

DIP: Deinked Pulp

Reclaimed waste paper is processed to create recycled pulp. DIP is a type of recycled pulp treated through a deinking process and is of good quality. Its details will be discussed in Chapter 4.1.4.

4-1-3 Paper

Paper consists of a huge number of pulp

fibers between 1 mm and 3 mm long and 0.03 mm and 0.10 mm wide. Figure 4.4 shows a SEM photo of the surface of newsprint. Figure 4.5 shows a newsprint cross-section, showing five to seven layers of pulp.

Fig. 4.4. Newsprint surface (magnified) [1].

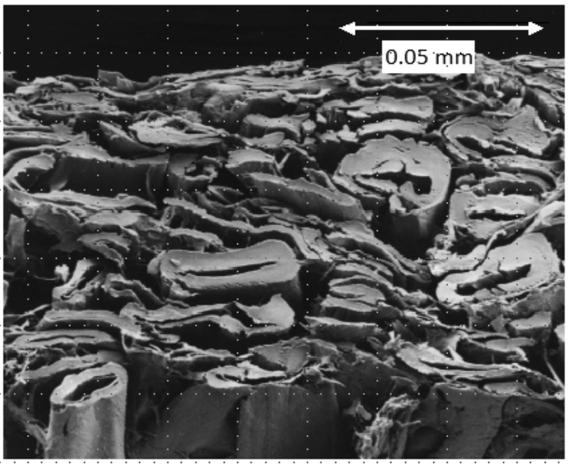


Fig. 4.5. Newsprint cross-section (45 degrees to vertical line) (magnified) [1].

As pulp is hydrophilic, due to hydroxyl groups on its surface, it can be dispersed as slurry in water. When pulp slurry is filtered on a wire mesh, it forms a two-dimensional sheet. As the wet pulp is flexible and tangled together, the sheet is just strong enough to be held by hand. This sheet is placed between two pieces of felt and pressed to squeeze the water out. Then it is dried using heat. As the sheet dries, numerous hydrogen bonds are formed between the pulp fibers, making the sheet strong. This means that the strength of paper is generated through the strength of these hydrogen bonds and the intrinsic strength of individual pulp fibers.

In Japan, old-style hand-made papermaking (batch process) is still done for paper for arts and crafts, but the modern paper industry uses a continuous, mass-production style.

4-1-4 Recycled pulp from used paper

When paper is immersed in water and disintegrated through mechanical agitation, these hydrogen bonds break up, releasing the individual pulp fibers. Though the pulp quality is deteriorated to some extent due to having been heated when the initial sheet was made, it is still strong enough to be used again. This is the principle behind paper recycling, one that is indispensable in the Japanese paper industry. At present, more than 60% of Japan’s pulp consumption is recycled pulp.

Recycled pulp has long been used as pulp stock for cardboard and the back layers of paperboard. A new development in the last twenty years allows recycled pulp to be refined through the deinking process so it can be used as the main pulp source of newsprint, which is a higher value-added product than paperboard. This is the key technology which has permitted the survival of the Japanese paper industry, and will be discussed in more detail in Chapter 6.

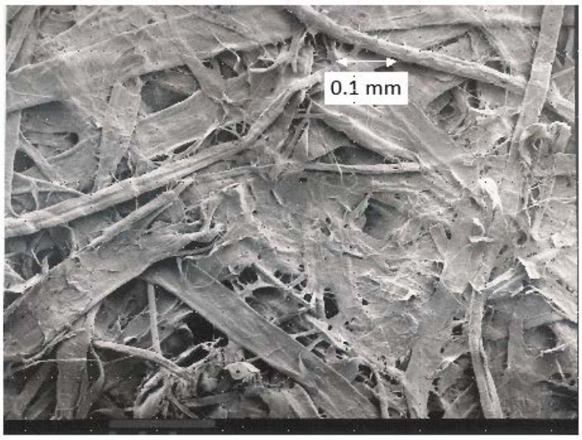


Fig. 4.6. Deinked pulp (DIP) from waste paper (magnified) [1].

As waste paper has been broken down to recycled pulp, the pulp quality is almost the same as the original waste paper. Therefore, the types of waste paper that should be recycled are key to the quality of recycled pulp, and will be discussed in Chapter 6.2.

4.2 Paper machines

Newsprint and other types of paper are manufactured on paper machines. Though the technological development of paper machine will be explained in Chapter 7, the concept of paper machines will be briefly described in this section to help in understanding Chapters 5 and 6.

The basic process of paper-making was invented in China. A wet sheet is formed from a pulp slurry of up to 1% concentration by scooping it with a drain board. The sheet is then peeled off and placed on a press to remove the excess water. Then the sheet is pasted on a wooden panel and left to dry naturally. This hand-made process of making paper in individual batches evolved to a continuous process using machinery, which rapidly developed in the 1800s.

In this section, the basic concept of the paper machine as it was in the 1950s is explained in order to provide a starting point for this paper. (Refer to Fig. 4.7)

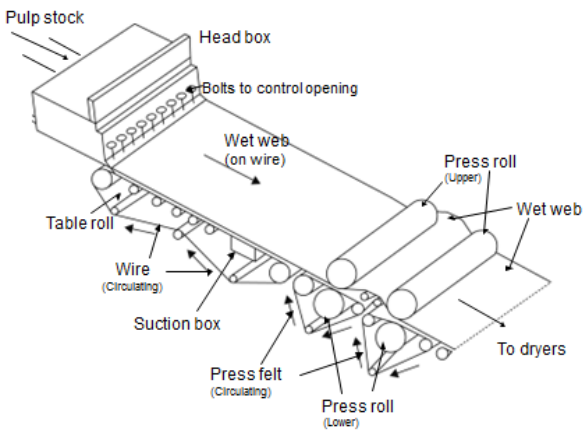


Fig. 4.7-1. Conceptual image of wire part and press part.

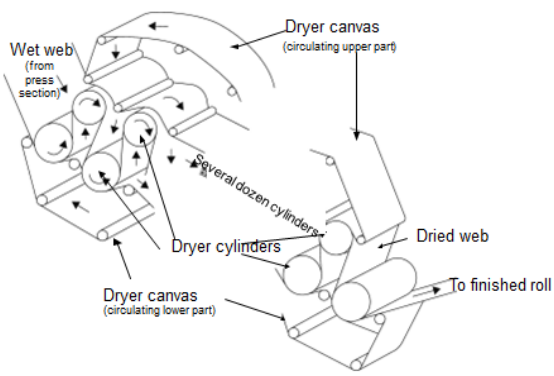


Fig. 4.7-2. Conceptual image of dryer part.

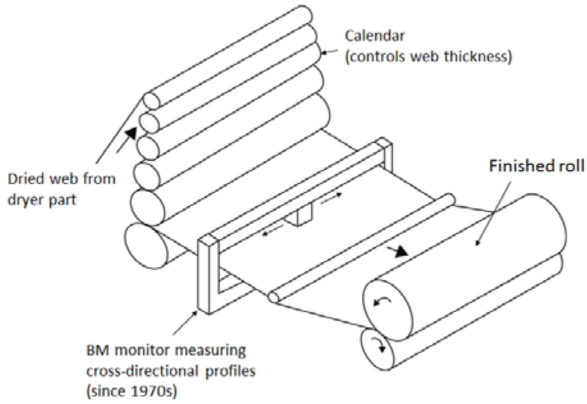


Fig. 4.7-3. Conceptual image of calendar.

A wire mesh (simply called a "wire" in the paper industry) moves from the start roll to the end roll, then returns to the start roll, so in other words, it is continuously rotating. Pulp slurry is poured on the wire and the excess water drains as the wire moves towards to the end roll to form a wet sheet. This section is called the wire part or the wire section. The wet sheet is peeled off at the end roll and transferred to the press part. In the press part, the wet sheet is laid on a moving felt bed. The wet sheet on the felt moves forward to pass between rolls under high pressure, where it is dewatered. The felt returns at the end in the same way as the wire in the wire part, coming back to receive the next incoming section of wet sheet. The dewatered sheet is peeled off at the end of the press part and is transferred to the dryer part. The dewatered sheet is then pressed against a dryer, which is a steam-heated rotating drum about 1.5 m in diameter. As one dryer is not enough for complete drying, the sheet is peeled off and pressed against another dryer, and another in series until it is fully dry. Dozens of dryers are needed in most cases. To ensure the sheet remains on track, two sets of canvas are used to press the sheet against the dryers, one from the top and the other from the bottom. Finally, the dried sheet is wound in a roll at the end of the paper machine.

It may be difficult for those who have never seen a paper machine to understand the concept, so therefore the series of illustrations in Fig. 4.7 may be of some help. Chapter 7 describes the way in which the design of this early model would be greatly changed through the technological development.

In the 1950s, a paper machine considered to be large would be about 3.5 m in width and run at about 300 m/min. These days, a large paper machine is 10 m wide and runs at 1,800 m/min. Their images are shown in Figs. 4.8 and 4.9.

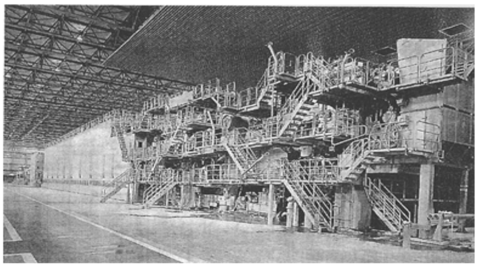


Fig. 4.8. View of a current paper machine [2].

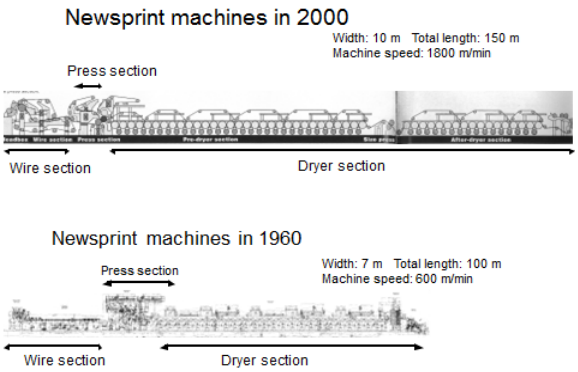


Fig. 4.9. Comparison of newsprint machine sizes (1960 and 2000) [3].

Large paper machines are about 150 m in total length. Paper has to pass along the entire length of the machine, and has to travel without any support as it moves from the wire part to the press part, and from the press part to the dryer part (see Fig. 4.7). Once in the dryer part, the paper has to pass from one dryer to another without any assistance. At this stage, the paper is still weak, and so it occasionally rips in a “sheet break,” which can be extremely dangerous. Once the paper has broken, the machine has to be cleaned and the process needs to be started again from the beginning.

As can be imagined from its size, a paper machine is a very expensive piece of equipment, costing tens of billions of yen. This means that a sheet break will decrease the machine’s operating efficiency and cause a major operational loss. One of the biggest challenges in technology development was to develop a machine which has less chance of the sheet breaking (see Chapter 7).

The paper machine also needs to be made as productive as possible in order to help offset its high cost. One way is make the machine as wide as possible and run it as fast as possible. This is another technology-related subject, and Fig. 4.10 shows how this was gradually implemented.

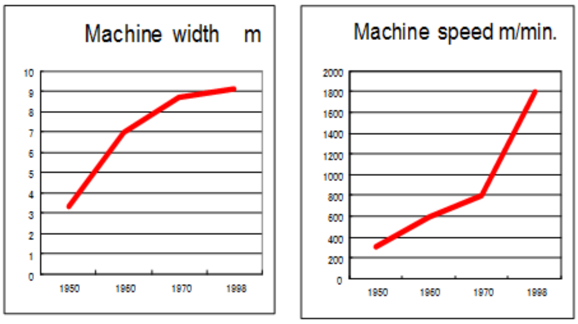


Fig. 4.10. Growth of paper machines in Japan (excerpted from the news chronology in Chapter 12).

One other key factor for productivity is operating efficiency. As will be discussed in Chapter 8, high efficiency is how the Japanese paper industry remains competitive.

As an example, the historical operation records for one paper machine over forty years will be presented in Chapter 11.

4.3 Newsprint and newspaper printing

4-3-1 Newsprint

The most basic property of any type of paper, including newsprint, is its basis weight. Basis weight is the weight in grams of 1 square meter of paper. For example, newsprint is 43 g/m^2, PPC (plain paper copier) paper is 64–75 g/m^2 and corrugated cardboard paper is 200–300 g/m^2. There is a suitable basis weight for each way paper can be used. If the function that the paper is used for can be satisfied with a lower basis weight, it will save resources and reduce costs. This is why trying to reduce basis weight remains one of the challenges for technological development in the paper industry.

Printing paper, which includes newsprint, has to have some basic qualities. Its surface has to be smooth enough for printing and be white enough to make the printed image clear.

It should be opaque enough that the printing does not affect the reverse, strong enough that the sheet does not break or get damaged during printing, and stiff enough to handle easily. These properties are met through blending different types of pulp. As noted in Chapter 4.1, pulp is produced by breaking up the structural units of trees. Chemical pulp is able to form strong sheets due to its ability to form hydrogen bonds. Mechanical pulp has extremely fine pieces, giving it a high specific surface area that gives opacity to paper by scattering light on the surface, though the sheets are not as strong as chemical pulp. The desired quality of newsprint is obtained by blending those two types of pulp. In the 1950s, newsprint was made of 80% mechanical pulp and 20% chemical pulp, both from quality softwood (fir and spruce). This balance is still used in Canada and in Scandinavian countries where softwood is abundant. Faced with a shortage of good softwood in Japan, a core of resource exploitation was the search for replacements. This will be discussed further in Chapter 6.

4-3-2 The rotary printing press for newsprint

Newsprint manufactured on paper machine is delivered to newspaper printers, where it printed on printing presses. Gutenberg is usually credited with inventing the modern printing system. His system was a type of lithograph, and book pages were printed in individual batches, like woodblock prints. The main feature of his system was arranging metal type on a holding plate instead of making individual wood blocks for each page, which was a far more efficient system.

As the name “press” suggests, this printing plate was repeatedly pressed against sheets to print them. The rotary printing press was invented in order to do this continuously. In this, the printing plate is wrapped around a roll rather than a flat plate, which is called the plate cylinder. Inking the plate cylinder and rotating it over a sheet that moves at the same speed will print an image on the sheet. If sheets are continuously fed from a roll and the plate cylinder keeps rotating, images will be printed continuously. In the 1950s, a flat plate was made by first picking and arranging metal type, then it was pressed against a thick, bulky piece of paper to form its replica, which was called the paper mold. Lead was poured into the mold to form a lead plate, which was then wrapped around a roll. Ink was applied to the projecting parts of the plate that were the shapes of the letters. Thus it was called letterpress printing. The most influential change in newspaper printing was from letterpress printing to offset printing, and this demanded a change in newsprint quality.

In offset printing, the printing plate is made in quite a different way. A photo-sensitive resin plate is exposed to light only on the areas that are to be printed (areas to be inked). The exposed areas harden and the rest is washed away. The hardened areas are hydrophobic and the washed-out areas are hydrophilic. This plate is wrapped around a cylinder, which is called the plate cylinder.

Water is applied to the plate by the water roller. This water only remains on the hydrophilic areas. Next, the ink roller inks the plate, and this ink only remains on the hydrophobic areas, without water. Finally, the image thus formed with ink on the plate is transferred to the blanket cylinder, and then printed onto paper.

Though offset printing requires more complicated equipment than letterpress, it does not need laborious type-setting, allowing significant cost savings. Due to this, rotary offset printing quickly became common among newspaper printers, as will be shown in Chapter 5.

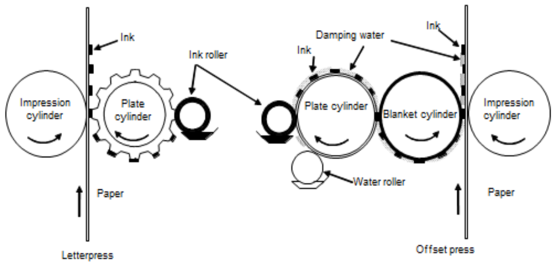


Fig. 4.11. Letterpress and offset press [2].

In offset printing, the area to print on the paper is controlled through the use of water. Paper, on the other hand, is very sensitive to moisture and humidity changes, and stretches readily when it gets wet. This means that paper that is as stable as possible is preferable. If paper does not react equally to water across its cross direction (width), problems will happen in printing. The paper surface needs to be smoother compared with that for letterpress, in which the plate is pressed against the paper. As the ink is tackier, the paper surface needs to be more resistant against being pulled by the ink. The use of offset printing enabled the printing process to be rationalized, but it also required increased quality from the paper.

Following the spread of offset printing, color printing became common. This affected newsprint quality, which will be examined in Chapters 5 and 6. For reference, this next section will provide a brief outline of color printing (color offset printing).

Color printing on newsprint is different from ordinary color offset printing. The first color printing system used for newsprint was called the satellite system, as printing rolls of different colors were positioned around the large cylinder like satellites.

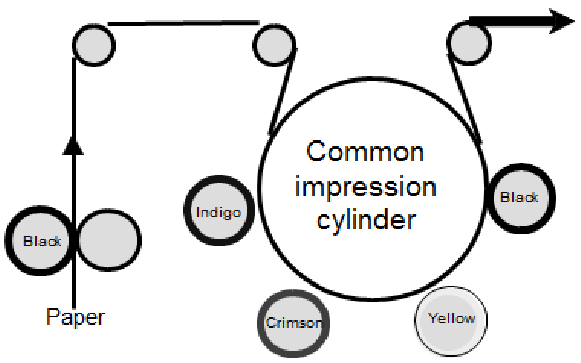


Fig. 4.12. Satellite multi-color press [2].

Using this system, paper can be printed with one color (usually black) on one side and four colors on the other side. On the color-printed side, dampening water is applied four times, so the paper has to be more resistant to water. The system currently in use is called a tower press, which can print four colors on both sides.

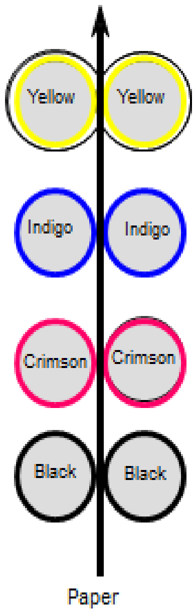


Fig. 4.13. Tower press [2].

As dampening water is applied four times on each side, for a total of eight times, the paper quality must be higher still. Paper quality has to be controlled more evenly in its cross direction in areas such as basis weight, thickness and moisture content, and its surface strength also has to be improved.

4-3-3 Printing operation in newspaper printers

This section will cover how newspaper printers print. Newsprint rolls are delivered to newspaper printers as what is called an A-roll, which is about 1.6 m wide, 13,000 m long and weighs about 900 kg. One roll is equivalent to eight pages of that day's newspaper run. If a newspaper has forty pages, as is common these days, five rolls are used to print it, one for every eight pages. In normal operation, one rotary printing press has five printing units and each unit prints eight pages. After printing, the paper from each unit moves forward with precise timing to be stacked up into a single copy, which is then folded and cut separately. The operation is a race against the shipping time. If a problem such as a paper break happens in just one printing unit, then the whole operation has to shut down. So newspaper printers demand high reliability from newsprint rolls. As printing speeds increase, these demands grow more and more severe. Printer use the term “sheet break frequency” as an index of reliability, which means the number of sheet breaks during printing per hundred rolls. This frequency was 1 percent (one break per 100 rolls) in the 1970s, but in the 2000s, it was down to less than one break per 1,000 rolls. This issue has been one of the subjects of technological development in newsprint manufacturing, and will be reviewed in subsequent chapters.

Bibliography

[1] Supplied by Nippon Paper Industries Co., Ltd.

[2] T. Naito, "Progress of newsprint manufacturing over the last 60 years," *Hyakumanto*, No. 126, p. 25 (Paper Museum).

[3] *Preserving and Publicizing Technological Archives of the Japanese Paper Industry*, "Four A-roll-capable paper machine largest and fastest in Asia (1960)," No. 6, p. 2, Oct. 13, 2004.

Chapter 4.1 drew on the following article.

K. Iida, "History, characteristics and ecology of pulp and paper industry," *JAPAN TAPPI Journal*, vol. 55, No. 4 p. 417, 2001.

5 History of newsprint production over the last 60 years

The core technologies for manufacturing newsprint were briefly reviewed in Chapter 4. This chapter provides a chronological review of how newspaper printers demands for quality changed and how the paper industry tried to meet these demands.

Prior to World War II, the Japanese paper industry was prospering in Hokkaido and Sakhalin where good softwood was available. Following its defeat, Japan lost Sakhalin and the paper industry lost its main pulp supply. The paper industry was devastated in the confusion following the war: production in 1946 was only 210,000 tons, of which newsprint was only 75,000 tons: a quarter of the maximum output before the war, and just one fiftieth of the present production. Post-war recovery had to start from this level.

Figure 5.1 shows some features of how newsprint production increased in Japan. One feature is that the number of copies published by newspaper printers increased at a constant rate. The other is that paper companies in Japan continued supplying newsprint, protecting the domestic market from international rivals.

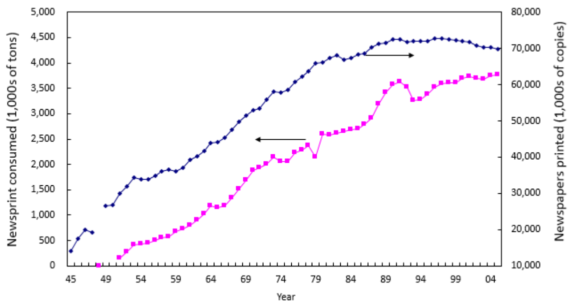


Fig. 5.1. Annual newspaper publication numbers and newsprint consumption [1].

As this chapter is simply a general overview, certain technical terms used here have not yet been defined in this paper. These terms will be explained in later chapters, such as Chapter 6 for pulp and Chapter 7 for paper machines.

1945–1955

Newspaper printers used rotary letterpress printers (single color), and their printing speed was about 80,000 copies per hour, four pages a copy. These printers were very slow compared with modern offset press printers that print four colors at 150,000 copies per hour, 40 pages a copy. The ink has to be quickly absorbed into the paper in letterpress printing, which means paper needs to be bulky, so the paper used during this period had a basis weight of 52 g/m^2. Groundwood pulp and unbleached sulfite pulp, both from domestic softwood, were used in an 80–20 ratio (see Chapter 6 for details). The paper machines were the Fourdrinier type, with a width of about 3.4 m and a speed of about 300 m/min.

1956–1965

During the period of high economic growth, demand for newspapers increased and many new paper machines were installed (refer to the news chronology in Chapter 12). However, this increased pulp demand caused a softwood shortage, so instead of GP, CGP (manufactured from hardwood and lightly treated with chemicals) was developed. The typical pulp composition of newsprint at the time was 60% GP, 20% CGP, and 20% SP. However, CGP was later replaced by TMP manufactured from imported softwood chips. To improve productivity, larger and larger paper machines were developed. In 1957, a machine wide enough for three A-size newsprint rolls (about 5.4 m wide) was installed, followed in 1960 by one that was 7m wide and ran at 600 m/min. Newspaper printers also improved their technologies, enabling them to print at rates up to 100,000 copies per hour, 16 pages a copy, and also tested out color printing.

1966–1975

Major newspaper printers started to publish copies with 24 pages, introduced a small number of offset printing presses, and began to print advertisements in color. Paper companies rushed to expand their capacity, with 21 new machines starting operation, two of which had a width of 8.4 m, wide enough for five A-size newsprint rolls, and ran at 800 m/min. On the pulp supply side, studies were started on changing over from the major chemical pulp at the time, SP, to cleaner KP, as pollution from its untreated effluent was becoming a serious issue.

1976–1985

Both newspaper printers and paper companies accelerated their technological innovations. Newspaper printers rapidly converted from letterpresses to offset presses, bringing in the CTS system, in which every page was edited on computer and displayed on monitors, and typesetting was done on resin film the size of one page. The transfer from lead plate to resin plate greatly improved productivity in printing operations. As productivity improved, printers required further improvements in newsprint quality. These requirements included a sheet break rate of 1%, improved ink setting on the wire side of the paper (the side of paper that faced the wire was inferior to the other side in terms of ink setting, due to the use of the Fourdrinier machine), and improved opacity.

The second oil shock caused a rapid rise in the price of imported softwood chips. To cope with this, newspaper printers and paper companies worked together to reduce the basis weight of newsprint. This cooperation was something that no other country attempted, and it lasted until the 2000s, gaining more and more traction. Specifically, the basis weight initially went down from 53 g/m^2 to 49 g/m^2, then to 45 g/m^2 and finally to 43 g/m^2. As shown in Fig. 5.2, once newsprint with a lower basis weight was developed, it very rapidly took over the share of heavier types.

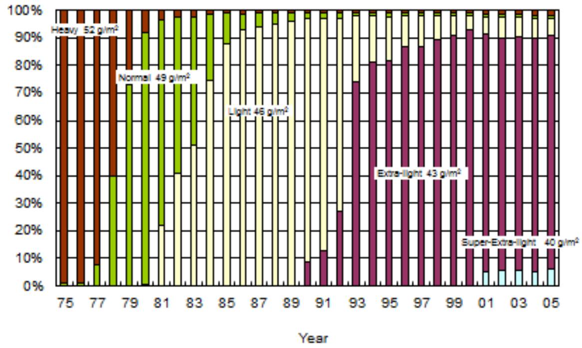


Fig. 5.2. Changes in basis weight shares of newsprint [1].

This reduction in basis weight required even further technological developments in newsprint production. Newsprint qualities such as strength, printability, opacity and brittleness had to be maintained at a lower basis weight, but not all quality requirements could be satisfied with the machinery of the time. Paper companies introduced such new technologies, as twin-wire formers, conversion from SP to KP, the use of DIP, and the use of oil-absorptive fillers like white carbon. These technologies will be further explained in Chapters 6 and 7.

1986–1995

As offset printing and color printing became increasingly common in the newspaper market, paper companies were required to provide further basis weight reductions. Offset printing uses tacky ink so it needs paper with a high surface strength. In multi-color printing, four different colors are printed on the same paper surface, which means even higher strength is required. In offset printing, dampening water is transferred to the paper, so if the paper is unable to stand up to this, issues such as color drift will occur. The lower the basis weight, the more chance of problems.

To satisfy the demands for a lower basis weight, Japan developed gate roll-type size press coated newsprint (see Chapter 7). With this improvement, newsprint could be printed at up to 150,000 copies per hour, 40 pages a copy, with few sheet breaks (perhaps 1–2 times per 1,000 rolls). This superior quality meant that there were almost no imports of newsprint rolls into Japan.

1996–2005

Color printing became more common, and a new type of multi-color printing press called the tower press was introduced, as described in Chapter 4.3.

This press can print both sides of the paper in full color. That meant that dampening water is applied to the paper four times per side, requiring stronger paper. This meant that paper had to be more uniform cross-wise in qualities like basis weight, moisture and thickness. To make printed images stand out more, the paper had to be whiter. In fact, paper brightness had increased by 10 points to 55% in the last fifty years. Brightness is a term expressing the whiteness of paper, and is expressed as a ratio in the scale in which a black body is 0% and magnesium oxide is 100%. As printing presses capable of printing 180,000 copies per hour were introduced and newsprint with a 40 g/m^2 basis weight came onto the market, newsprint performance demands became even stricter, requiring sheet breaks of less than 1 per 1,000 rolls. Paper machines kept evolving to cope with those demands. For example, to improve uniformity in the cross direction of paper machines headboxes were converted to consistency control methods (see Chapter 7) and soft-nip calenders were introduced to improve surface quality. In addition, greater amounts of recycled pulp could be used by refining the DIP process, and calcium carbonate could be used by converting to neutral sheet forming (see Chapter 6).

These technological developments are summarized in Table 5.1

Table 5.1. Technology changes over the past 50 years

	Printing in the 1950s	Printing in the 2000s
Printing	Letterpress, black only: 4 pages/copy Printing speed: 320,000 pages /hour	Offset press, four colors: 40 pages/copy Printing speed: 6 million pages/hour Sheet break rate: less than 1/1,000 rolls
Newsprint	Basis weight: 52 g/m^2 Brightness: 45%	Basis weight: 43 g/m^2 Brightness: 55%
Consumption	500,000 tons/year	3.75 million tons/year
Pulp and additives	GP: 400,000 tons/year SP: 100,000 tons/year	DIP: 2.6 million tons/year TMP: 0.75 million tons/year GP: 0.2 million tons/year KP: 0.2 million tons/year Calcium carbonate Surface sizing
Paper machine	Fourdrinier machine 3.3 m wide, 300 m/min Acid forming	Twin-wire machine 10 m wide, 1,800 m/min Size press Neutral forming

The future of newsprint production

The Japanese paper industry has had to develop a range of technologies to meet the demands of newspaper printers for improving their printing. Its success in this means that Japan needs to import very few newsprint rolls. Though the newspaper industry in Japan has grown steadily, supported by the home delivery system each morning, the domestic market is now saturated, which forces the paper industry to look for new strategies.

The strict demands of newspaper printers has left Japanese paper companies facing a dilemma. Japanese newsprint meets the high quality standards demanded by newspaper printers, which suggests that it would meet any standard globally, but there are cost factors to consider.

Paper companies have invested huge sums to modernize equipment in order to make their products satisfactory to their clients. This investment ends up making the paper cost more. In fact, Japanese newsprint is 40–50% more expensive than imported newsprint, which raises the question of why Japanese newspaper printers buy high-priced domestic paper. Their operating style, running massive, high-speed printing presses to ensure high productivity (see Chapter 4.3), unlike the way it is done in most other countries. Using imported newsprint would cause sheet breaks at higher rates, such as three per 100 rolls, and with the huge presses that are used in Japan, this loss of productivity would be quite significant: in the worst case they would need another entire printing press to ensure they could ship the newspaper on time. The high reliability levels of domestic newsprint are able to offset the extra expense of purchasing domestic newsprint.

Thus the apparent contraction of saving money by spending more money actually works to reduce the total cost. However, most overseas printing presses are not as fast, so the high reliability of Japanese newsprint is less of an advantage. Japanese newsprint, with its high prices but high reliability, is finding it difficult to expand overseas, which is a challenge that the industry is going to have to deal with.

Links to subsequent chapters

The changes discussed in this chapter form the essence of this paper. More details of the technological developments in pulp supply will be explained in Chapter 6, and for paper machines in Chapter 7, while the technological characteristics of the Japanese paper industry will be explained in more detail in Chapter 8.

The paper listed as [1] in the Bibliography section was used as reference with the kind permission of the author.

Bibliography

[1] T. Naito, "Progress of newsprint manufacturing over the last 60 years," *Hyakumanto*, No. 126, p. 25 (Paper Museum).

6 Technological development part 1: pulp resources

6.1 History of pulp resource exploitation

6-1-1 Introduction

Japan's demand for paper and paperboard increased almost in proportion to its GDP. The demand for newsprint increased in a similar way, going from 700,000 tons in 1960 to 3.8 million tons in 2000, a five-fold increase. As Japan lacked sufficient wood resources, the most important topic for the industry was how to secure the amount of pulp demanded by this expansion. However, the Japanese paper industry was able to successfully obtain a series of new resources to meet this increasing demand, allowing the industry to remain competitive against international competitors and retain its grip on the domestic market. This history will be reviewed in this section through a look at the changes in the pulping process.

The basic quality requirements of newsprint were described in Chapter 4.2. At the risk of duplicating that section, newsprint in the 1950s was made of chemical pulp that gave strength to sheets, and mechanical pulp that gave them opacity, stiffness and smoothness. Both types of pulp were made from softwood, and blended in a ratio of roughly 1 to 4. The quality of the newsprint was controlled by subtly adjusting that ratio.

However, the search for candidates for new pulp resources had to start, as softwood forests were scarce in Japan and could not keep up with the increasing demand. Fig. 6.1 depicts the types and amounts of pulp that were used for newsprint production in Japan.

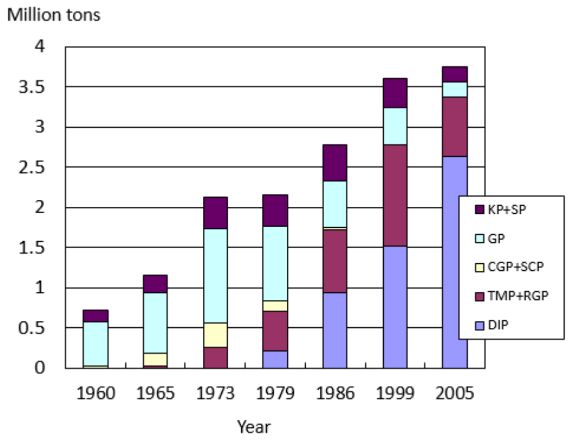


Fig. 6.1. Amount of pulp used for newsprint by grade.

(Abbreviations used in the figure are explained in Chapter 4.1.3, but are cited again for convenience.)

Chemical pulp group
- KP: Kraft pulp
- SP: Sulfite pulp

Mechanical pulp group
- GP: Groundwood pulp
- CGP: Chemi-groundwood pulp (made from hardwood)
- TMP: Thermo-mechanical pulp
- RGP: Refiner groundwood pulp
- SCP: Semi-chemical pulp (made from hardwood, quality between mechanical pulp and chemical pulp.)

Recycled pulp
- DIP: Deinked pulp (Deinked recycled pulp from waste paper)

Figure 6.1 is designed to show how the different types of pulp used for newsprint have changed over the past forty years. Though still called "newsprint," the present composition of pulp is far removed from that of the 1950s. Note that the values in Fig. 6.1 are calculated by the following procedure, and are not actual data.

Newsprint production volume statistics are shown in Fig. 5.1. The statistics of pulp production as a whole are also available, but there is no data to show the extent to which different pulp types were used in newsprint production. Therefore, the ratios of pulp composition at every period were first estimated from data in the literature and corporate records, and shown in Fig. 6.2. Then, using Fig. 6.2 and Fig. 5.1, consumption of a given pulp type at a given period was calculated as shown in Fig. 6.1. Though Fig. 6.1 does not use actual statistics, it gives a reasonably accurate depiction of pulp consumption by type at a given period in newsprint production.

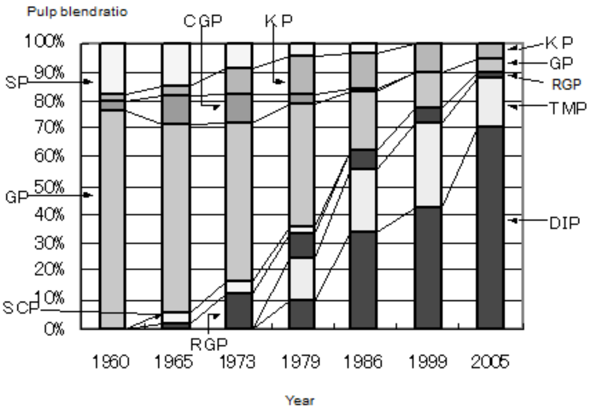


Fig. 6.2. Pulp blend ratios for newsprint manufacturing (estimated) [1].

6-1-2 1945 to 1955

As quality softwood for mechanical pulp production became in short supply, red pine, an endemic species of Japan, was used instead. Red pine contains a lot of pitch, and its tracheid cells, which are what becomes the pulp, have thick walls. These thick walls means that its pulp is brittle and weak. The high pitch content is particularly inconvenient. In mechanical pulp manufacturing, the pitch is dispersed in water during the grinding process, allowing it to coagulate on the machinery or stick to rolls. Though the shortage of softwood forced manufacturers to reluctantly use red pine, finding the necessary expertise to do so was not an easy job. The countermeasure adopted was seasoning, storing the logs in water or on land for at least six months. During seasoning, the pitch undergoes chemical modification and is also decomposed by microorganisms. Another measure was to add an aluminum sulfate solution, called "alum" in the paper industry, to pulp slurry to adjust its pH to about 4.0 and prevent it coagulating on paper machines. Numerous research papers were published in *JAPAN TAPPI Journal* during this period, as this was the first post-war technological breakthrough in the Japanese paper industry, and led to increased GP consumption, as shown in Fig. 6.1. Storing large numbers of logs for six or more months, then collecting and transporting them to a plant in time demanded high levels of mill management, which in turn affected operating costs. Developing and implementing this sort of high-level mill management techniques would become common in the paper industry.

A grinder for producing GP is illustrated in Fig. 6.3. Parallel logs are pressed against the surface of a rotating grinding stone about 2 meters in diameter, which crushes and grinds them. In mill operation, logs about 20 to 40 cm in diameter and 1 to 2 m long are floated along a channel. Ten or so logs at a time are picked up and inserted into what is called a "grinder pocket." After the first batch of logs is ground, rotation is stopped and a new batch is loaded into the grinder. It is a laborious, batch-based operation. The logs must be straight and of similar diameters. This grinder was replaced with a more efficient refiner.

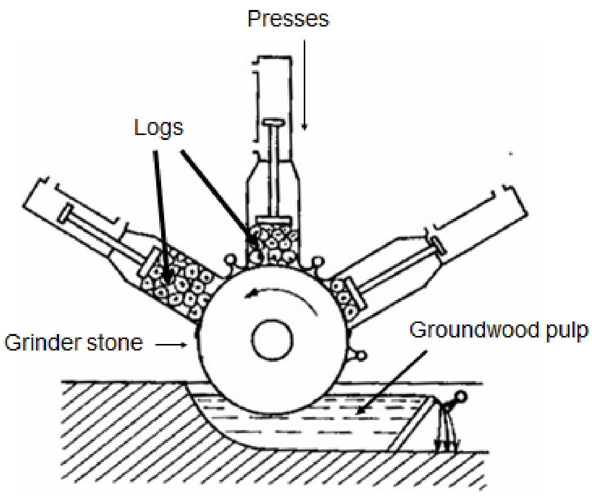


Fig. 6.3. Conceptual image of a grinder.

6-1-3 1956 to 1970

Further increases in demand caused severe mechanical pulp shortages. The limited amount of softwood available meant that the use of hardwood was studied worldwide, leading to the development of Chemi-groundwood Pulp (CGP) and Semi-chemical Pulp (SCP). In these processes, chips (small pieces of wood crushed from logs to a size of about 20 mm × 20 mm × 5 mm) were lightly treated with chemicals and disintegrated using a refiner. The advantage of using chips was that they could be fed to the refiner continuously, rather than in batches. Chips are continuously fed into the refiner from a conveyor belt. Chips are ground between two large disks driven by a powerful motor, and continuously discharged. Some modern refiners have disks up to 2 m in diameter, and are powered by up to 23,000 hp. The development of large refiners led to development of pulping processes such as RGP and TMP, increasing options in the pulp supply.

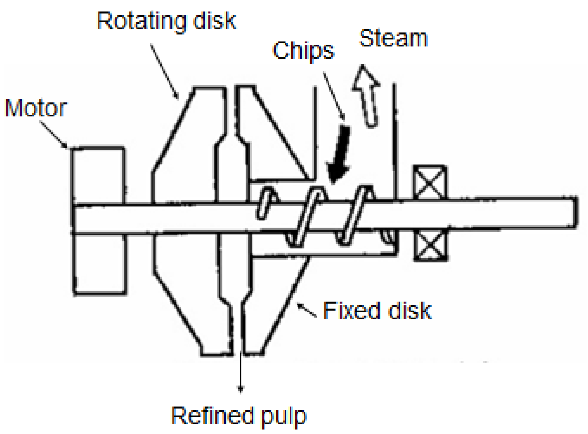


Fig. 6.4. Conceptual image of disk refiner. (Chips enter from the black arrow and are refined between the disks, one of which is rotating.)

Hardwoods have higher densities than softwoods, making them difficult to be pulped using grinders. The resultant GP was shorter, and only able to form weak paper. Treating chips with chemicals before refining dissolves some of the hemicelluloses in chips, making them easier to refine and improving pulp strength. The process was originally invented for the central corrugated cores, called the corrugating medium, of corrugated cardboard. In Japan, however, it was developed as a way to use CGP in newsprint in place of GP. There were two types of creating CGP: the first was to treat chips with sodium hydrosulfite at a neutral pH under high temperatures, and the second was to use sodium hydroxide at room temperatures. The former was suitable for white hardwoods like birch and beech, while the latter was mainly for brown hardwoods like oak. The resultant pulp was bleached with hydrogen peroxide, especially for brown hardwoods. (Limitations of room preclude a detailed discussion in this paper, and readers are requested to please refer to the bibliography at the end of this chapter.) This led to the manufacture of newsprint that consisted of SP, GP and CGP in a ratio of 2:5:3.

During the same period, the Japanese paper industry made fresh progress, establishing a solid foundation by producing kraft pulp from hardwood and using it to make a range of printing paper types. While very common these days, at the time making quality paper from hardwood pulp, far shorter than softwood pulp, was inconceivable. The Japanese paper industry built up its expertise in paper manufacturer by trial and error. The availability of hardwood as a pulp source meant that large-scale mills could be constructed. In general, paper mills manufacture a range of paper products. This means that, if a technological development reduces costs for the mill as a whole, newsprint manufactured in that mill will also benefit, becoming competitive with imported products. In this way, the technology used to manufacture printing paper from hardwood kraft pulp indirectly helped to reduce the costs of newsprint production.

In terms of quality paper made of hardwood kraft pulp, a special edition (September 25, 1952) of the *Kokusaku Tsushin* (the Kokusaku Pulp Co. newsletter) reported on the reconstruction of the Ufutsu Mill as follows: “Paper has been made there with 100% hardwood since May 1952. This was the first such trial in Japan, and one of the very few worldwide.” Ufutsu Mill was later amalgamated into Sanyo-Kokusaku Pulp Co., and now operates under Nippon Paper Industries Co. The reason they were interested in hardwood appears to be due to the abundance of birch around the mill (personal communication with the author). As paper machines at the time had many “open draw” parts, such as from the wire part to the press part, there was a far greater chance of sheet breakage than would be the case today. It is also apparent that adjusting speeds at different parts would have posed considerable difficulties. One advantage of birch is that it has relatively longer fibers compared to other hardwoods, so that there would be less chance of sheet breakage. The short pulp gave the paper a finer, smoother surface than softwood pulp, making it suited for printing. This unexpected benefit accelerated the use of hardwood in Japan. The development of the continuous digester (see below for details) also drove this change. As making fine quality paper from hardwood pulp has become popular globally, the demand for hardwood pulp has risen. This has given birth to large-scale pulping industries based around eucalyptus plantations, with the largest being in Brazil.

Japan made one more contribution to the world in terms of manufacturing kraft pulp from hardwood. At the time, chemical pulps, whether kraft pulp or sulfite pulp, were produced using batch digesters. A typical digester was a pressurized vessel with a capacity of 20 to 30 m^3. Chips were fed into the top of the digester, the top was closed, pulping chemicals were added to the digester, which was then heated using injected steam. In the sulfite process, pulping required heating at temperatures of 120 to 130°C for 7 to 8 hours, while in the kraft process, it was 170 to 180°C for 1 to 2 hours. After pulping, the bottom valve was opened to flush out the pulp. In 1938, the Swedish company Kamyr designed the continuous digester to improve productivity, and save both energy and plant space. The first test plant was installed in 1946 at the Karsbrug Mill in Sweden, while the first commercial plant, with a capacity of 50 AD tons per day for softwood, was installed in 1950 at Fengersfors Bruks AB, Fengersfors, also in Sweden. The second plant was opened in 1951 at Cartiera Vita Mayer & Co., Cairate (Italy), with a softwood capacity of 90 AD tons per day. On January 29, 1953, the third continuous digester started operation in Oji Paper Co.'s Kasugai Mill, in Japan. This digester was 2.5 m in diameter and 23 m in height, with a volume of 110 m^3 and a capacity of 90 tons per day. Chips were fed in at the top and pulped while moving down the tower, then discharged from the bottom. Initially, there were numerous issues to overcome, including a hammering at the high pressure feeder, unstable chip level in the digester, scaling on digester strainers and impregnating zone heaters, hanging, and air bubbles during washing. Oji Paper recorded that they were eventually able to achieve stable operation after considerable effort [2]. It is believed that these efforts by Oji Paper refined the equipment to allow its acceptance worldwide. These days, digesters are increasingly large, with the capacity of the biggest being 5,000 tons per day.

For reference, the photo in Fig. 6.5-1 shows the digester being brought into the Kasugai Mill building. Fig. 6.5-2 is a photo of the latest large-scale digester. The size of people in each photo gives a good example of how large they have grown.

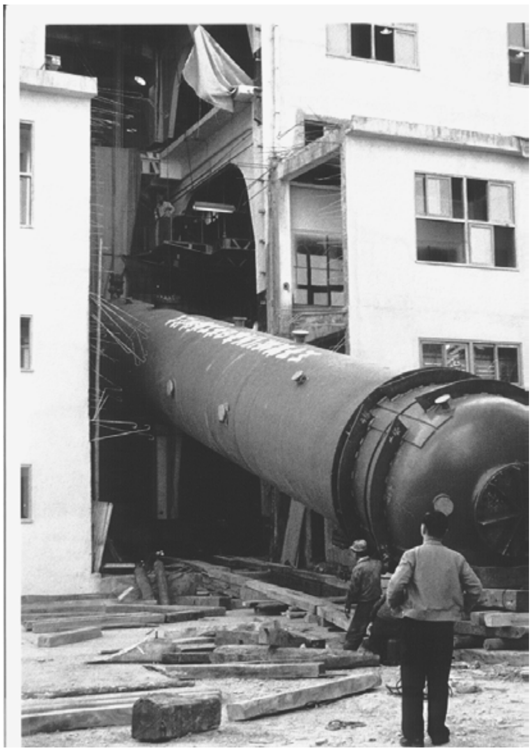


Fig. 6.5-1. Installing a continuous digester at Kasugai Mill, Oji Paper Co. (Source: Oji Paper Co.)

At this period in history, there were two competing chemical pulping processes, the kraft and sulfite processes, which strove to outdo each other in terms of technological developments. This was a key era in the industry, as it was also the first in which environmental concerns played a decisive role in the competition. Though a lot of research work for modernizing sulfite process was done, unfortunately in vain, I personally believe that it was a necessary step in order for the paper industry to become environmentally friendly over the next few decades.

Though the kraft process could produce pulp from a range of wood species by using a mixed aqueous solution of sodium hydroxide and sodium sulfide, the resultant pulp was dark brown, so it could not be used for newsprint and printing papers in that state. However, the technology of bleaching the pulp with chlorine dioxide to make it very white was already available and the color of the pulp was not the problem. Another point was that the kraft process used expensive sodium compounds, and these had to be recovered from the waste liquor, although a recovery process had established by that time. There were two mains problems: the bad smells generated from the sodium sulfide that permeated the air around mills, and the fact that mills needed to be big to be economical, and therefore needed huge investments.

Fig. 6.5-2. Modern continuous digester (largest size)
(Source: Metso Paper Japan).

The sulfite process, on the other hand, used a calcium hydrogen sulfite solution. Due to using a calcium base rather than a sodium base, the pulping solution did not penetrate into the wood as easily, meaning that only a few species of timber could be pulped. The waste liquor from pulping was discharged into rivers without any treatment, polluting the area around mills. One way to prevent this was to collect the waste liquor from pulping, recover the calcium base, and regenerate it into pulping solution. However, the technology required was daunting, and would be very costly, even if it were possible. The other way was to use soluble bases like sodium, magnesium and ammonia instead of calcium. Using these would allow the waste liquor from pulping to be recovered in the same way as the kraft process, greatly reducing pollution. This would also mean that the current pulping plants could be used, and the pulp would be white enough to be used in newsprint and other low-grade printing papers without bleaching. Scandinavian countries, with an abundance of softwood resources that were suitable for sulfite cooking, were interested in converting their calcium base to soluble bases. After carrying out extensive research and development, they came up with modified sulfite processes such as the Stora process, the Sivola process and the Magnefite process, which were put into practical operation in a few mills.

For example, Stora Co. built a new mill in Nova Scotia (Canada) using its proprietary Stora process that included the waste liquor recovery process and a two-stage pulping process using a sodium base. In Japan, Jujo Paper Co. converted its calcium base to sodium bases in its Fushiki and Yatsushiro mills in 1963, blending the resultant pulp with newsprint, although they did not recover the waste liquor. The Magnefite process offered excellent quality pulp as a substitute for SP in newsprint, with high whiteness, high yield, and more tree species supported, and so several newsprint mills in Japan started using this process in their operations in 1967.

The waste chemical recovery of the sodium base, however, was far more complicated than that used in the kraft process, which prevented it from becoming broadly accepted. A magnesium base, though it could be recovered easily, was not accepted either, as its pulp was not as strong as kraft pulp and it still could only be used with specific tree species [3].

In Japan, where softwood was scarce, the kraft process was accepted quickly, as it could produce pulp suitable for printing paper, especially quality paper, from a wide range of domestic hardwoods, as shown in Figs. 6.6 and 6.7, though the problems of bad smells and large-scale investments still remained. Research on finding a replacement for kraft pulping was still being carried out at this time.

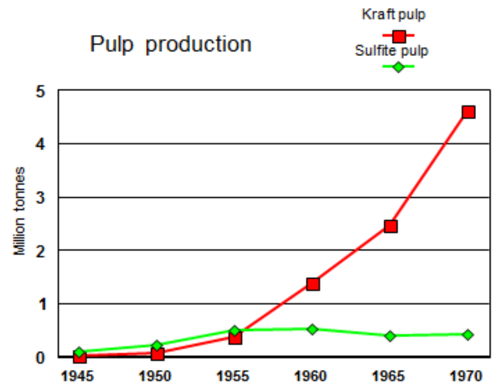


Fig. 6.6. Rapid growth of kraft pulp production [3].

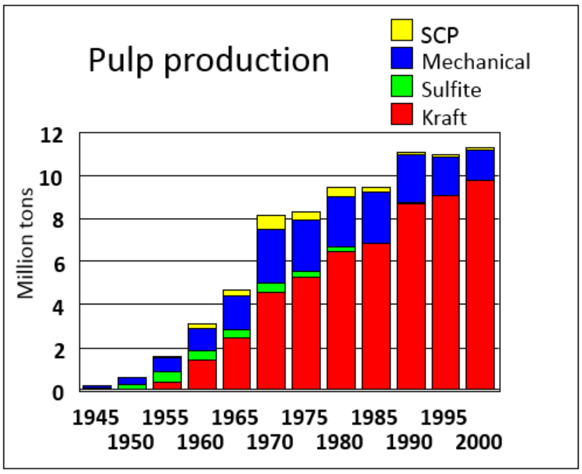


Fig. 6.7. Kraft pulp becomes the main pulp used [3].

The problem of waste liquor recovery eventually forced paper companies that wanted to continue using sulfite pulp for newsprint to convert to the kraft process.

The transition from sulfite to kraft was the first case in the history of paper technology where environmental concerns played the decisive role.

6-1-4 1971 to 1980 (Part I: Changes in wood resources)

As newsprint consumption increased steadily, new softwood resources were sought. In 1964, Toyo Pulp Co. and Daishowa Paper Co. tried to import softwood chips, mostly fir and hemlock, as well as Douglas fir eventually, from the west coast of the United States using special carriers designed to transport wood chips. At the time, this was a high-risk venture, but its success opened up new territories for the Japanese paper industry, and imported chips have been the principal means of its livelihood ever since.

Like Columbus's famous egg, after someone did it for the first time, it seemed to be nothing special. There still remained numerous obstacles, including collecting chips in the States, designing the chip carrier, handling chips to and from the carrier, transportation and evaluating the deterioration of chip quality during transportation. I feel this should be recorded as a technological heritage of Japan, but fortunately Morimasa Hanaya, who promoted the project with Toyo Pulp Co., has published a report [4].

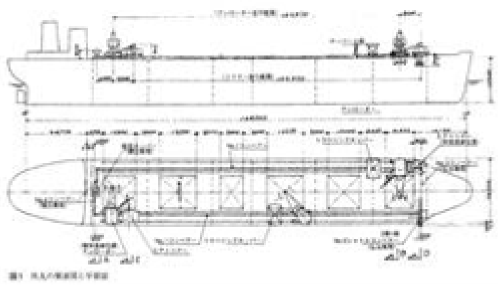


Fig. 6.8. First chip carrier (Kure-maru) [4].

The importing of softwood chips from the United States brought about a change in mechanical pulp production for newsprint. The refiner developed for CGP had been improved so that it no longer required chemical treatment. If softwood was available, there was no longer any need to manufacture an inferior alternative from hardwood. This meant that CGP was rapidly taken over by RGP and TMP, both of which guaranteed high quality. As RGP was the transitional stage to TMP, a short discussion of how TMP was produced is in order. The microscopic structures of wood were shown in Chapter 4.1. In this case, the tracheid cells that became the pulp are cemented with a layer of lignin. However, on heating to more than 100°C, the lignin layer softens and breaks under the stresses of refining, while the tracheid remains stiff. This means that TMP mechanical pulp produced in this way contains more undamaged fibers than conventional GP. In mill operation, softwood chips would be heated from 110 to 125°C for several minutes before being refined.

Fig. 6.9. GP (left) and TMP (right) [5].

Figure 6.9 shows photos of the differences between GP (left) and TMP (right). Though they are both mechanical pulp, they have different qualities. As Fig. 6.9 suggests, TMP has better strength and less opacity than GP. Initially, TMP was seen as an alternative to CGP, but with the technical improvements that will be described in Chapter 6-1-3, such as the use of amorphous silica, it was ended up being a substitute for GP itself.

As demand for printing paper grew steadily, domestic hardwood became in short supply. To alleviate this, hardwood chips, starting with eucalyptus, were imported. The first imports of eucalyptus chips were from old growth trees in natural forests, quite different from those harvested from plantation forests. At the time, eucalyptus wood was considered likely to cause numerous issues, and as of 1957, only one small mill in Australia was using aged eucalyptus. Planning large-scale KP plants using bulk imports at this stage required the decision to be made based on preliminary surveys and research. The technology which made this possible was available in Japan. This import of chips was, without doubt, due to a major technological development on the part of the Japanese pulp industry.

Importing chips greatly affected the concept and design of paper mills in Japan. First, one criterion for selecting mill locations changed. Until that time, the most favorable locations were close to domestic forests, a fact which is still standard in other countries. However, if chips were to be transported by ship, locations near major ports became advantageous, both in terms of wood supply as well as logistics such as supplies of the oil and coal which paper mills consumed in large amounts, and shipping out mill products. Second, freed from the restrictions on collecting logs, mills could be as large as needed. This gave rise to a number of mills large enough to be competitive globally, such as Oji Paper Co.'s Tomakomai Mill, Mitsubishi Paper Mills' Hachinohe Mill, Hokuetsu Paper Co.'s Niigata Mill, Nippon Paper Industries' Ishinomaki Mill and Daio Paper Co.'s Mishima Mill. This unique style of business, operating large mills in a country with a limited wood supply, helped the Japanese paper industry be internationally competitive and laid the foundations for its next expansion. The following statistics show how indispensable imported chips were to the industry:

Number of chip carriers in 2004: 84

Ratio of imported chips to total wood consumption in 2004: Softwood 43%, Hardwood 89%

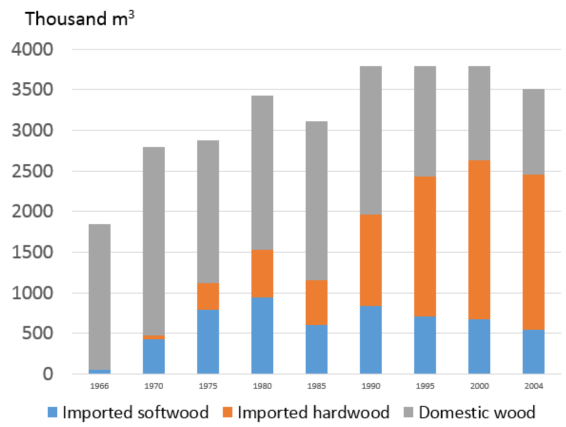


Fig. 6.10. Wood consumption by origin [6].

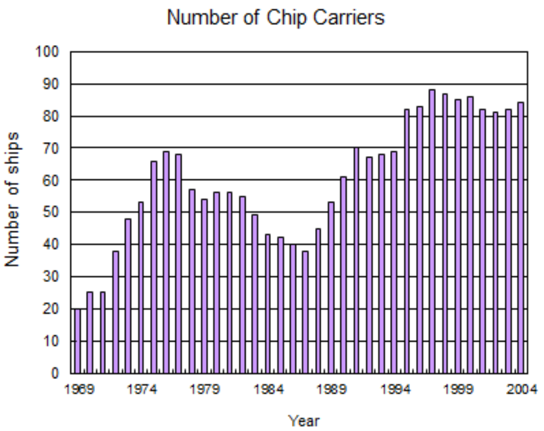


Fig. 6.11. Number of chip carriers [6].

These efforts also led to the new overseas afforestation ventures that the paper industry are currently promoting, which will be discussed later.

6-1-5 1970 to 1980 (Part II: Improving newsprint quality)

As discussed earlier, newspaper printers also revolutionized their technologies during this decade, converting from letterpresses to offset presses. The Computer Typo-setting System (CTS) was first installed at Saga Newspaper Co. in 1968. In the CTS system, a page was edited and displayed on screen by a computer, and the entire page was typeset on a film that was sent to be printed. This technology changed how printing plates were made, saving significant amounts of labor in the printing operation. With major newspaper printers starting to use this system in 1978, they required ever-higher newsprint qualities. The following requests were presented from printers in a meeting held between a newspaper printer and a paper company [1].

- A sheet break rate of 1% (one sheet break per 100 rolls)
- Better ink setting on the wire-side surface
- Better opacity: newsprint should have sufficient opacity so that images printed on one side should not show through on the other.

These demands forced paper companies to change their pulp blending prescriptions and even modify paper machines themselves, as will be described later in Chapter 7.

In addition, the second Oil Shock sent the price of imported softwood chips skyrocketing, meaning that paper companies, working in cooperation with newspaper printers, started a project to reduce the basis weight of newsprint. This project, called "*keiryō-ka*" or "lightening," was unique to Japan, and its successful outcome was shown in Fig. 5.2 in Chapter 5.

This *keiryō-ka* movement was not only for newsprint, but could also be applied to other kinds of paper or paperboard. Figure 6.12 shows the changes to linerboard as an example.

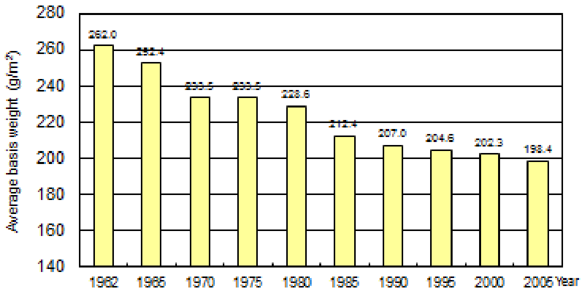


Fig. 6.12. Basis weight reduction in linerboard [7].

Copy paper for PPC also reduced its basis weight from 78 g/m^2 to its present 64 g/m^2.

If the basis weight of paper is reduced, the resulting paper weakens and its opacity lessens. To compensate for the loss of strength, stronger pulp should be used. We have already looked at the two types of chemical pulp, sulfite and kraft, and seen how hardwood kraft pulp was already the main pulp for printing paper. Softwood sulfite pulp, however, despite its environmental problems, was still used for newsprint production because of its cost advantage, as it could be used without bleaching. Kraft pulp, on the other hand, made stronger paper than sulfite pulp. As stronger pulp was needed to compensate for the strength loss, the small amount of sulfite pulp remaining was finally replaced with kraft pulp. For mechanical pulp, TMP was used instead of GP, as it was stronger (see Fig. 6.1), despite the fact that GP has good opacity, preventing images from showing through on the other side of the paper, and gives a smoother surface. If GP is replaced with TMP to get better strength, the print shows through. To prevent this, ink should be retained and less of it impregnated into the sheet. To achieve this, a pigment that can absorb oil is incorporated into the paper.

Specifically, amorphous silica was manufactured at mill sites and added to newsprint at a ratio of about 1%. The issue of how to compensate for downgrades in quality such as strength, opacity and stiffness due to the basis weight reduction remains the most important topic within the industry. This was also the case when recycled pulp became the main pulp in newsprint over the coming decades.

As the Fourdrinier machine drained water through a wire mesh, the wire side of the paper (the surface that faced the wire) contained fewer fine fibers, making it coarser than the top side of the paper. This resulted in rough printed images. When paper machines were ran at higher speeds to increase productivity, that difference increased, worsening the printed images on the wire side. This issue was overcome through the invention of twin-wire formers, which will be discussed in more detail in Chapter 7.

6-1-6 1981 to 2000

Until around 1975, newsprint and printing paper outputs increased neck-and-neck. Then, as people started to enjoy better lifestyles, they demanded better printed images. This trend increased the demand for printing paper, and meant that hardwood chips had to import from other countries than Australia, such as the southern United States or Chile. The sulfite pulp that had only been used for newsprint was finally completely replaced by kraft pulp and was no longer used, as the pollution problems it caused were too great.

The next resource to gain attention as a pulp source was recycled pulp. Waste paper had been widely used as recycled pulp for paperboard in Japan, and in fact, Japan developed its own linerboard made mostly of recycled pulp, which remains competitive with linerboard made from kraft pulp imported from the United States.

In 2006, 60.7% of the total pulp consumption in Japan was recycled pulp.

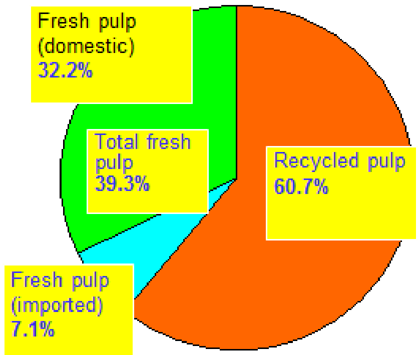


Fig. 6.13. Recycled pulp and fresh pulp categories (2006) [8].

Figure 6.14 depicts the ratios of recycled pulp in paper and paperboard. The top line is for paperboard and the bottom line is for paper (newsprint and printing paper). The general trend shows that reclaimed waste paper was mostly recycled into paperboard.

The initial concept was to recycle waste paper into newsprint and printing paper for purely economical merits, rather than for environmental concerns, so there were no announcements from paper companies about their use of recycled pulp in newsprint, and work on developing the technology proceeded quietly. However, starting in the 1990s, the public started to see the use of recycled pulp as eco-friendly, and demanded greater use of it.

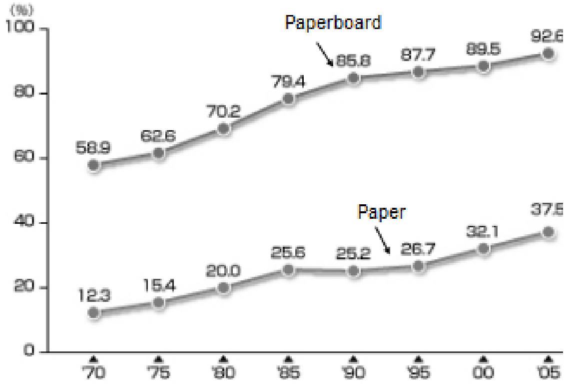


Fig. 6.14. Ratio of recycled pulp in paper and paperboard [9].

The first practical large-scale recycling system was recycling old newspapers into newsprint. However, as noted previously, recycled pulp is obtained from the original waste paper, so rather than being a specific type of pulp, it contains different kinds of pulp in essentially the same ratios as the original paper. For example, recycled pulp from old newspapers includes both mechanical pulp and chemical pulp. As other paper, such as advertising leaflets, are usually mixed in with newspapers when recycling, the pulp thus obtained usually consists of around 40 to 50% mechanical pulp and 50 to 60% chemical pulp. These two kinds of pulp are used as pulp sources for newsprint.

As recycled pulp became the industry standard, it affected the supply and demand of pulp sources. As mechanical pulp was replaced with recycled pulp, the demand for mechanical pulp deceased, which resulted in declining softwood chips imports. In addition, as recycling of high-grade printing paper increased, the demand for the hardwood chips used for them also plateaued.

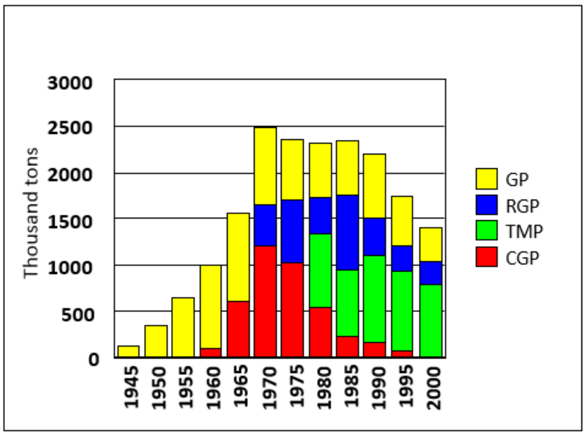


Fig. 6.15. Mechanical pulp production by year [10].

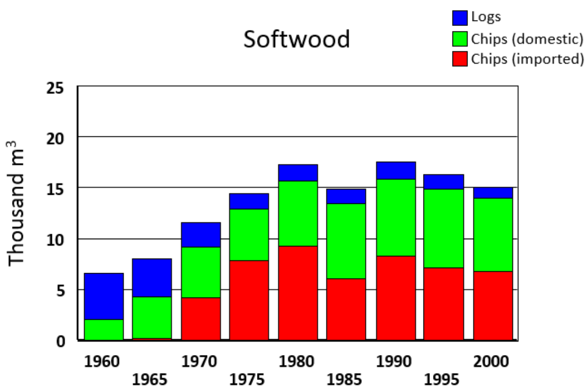


Fig. 6.16. Softwood consumption by year [10].

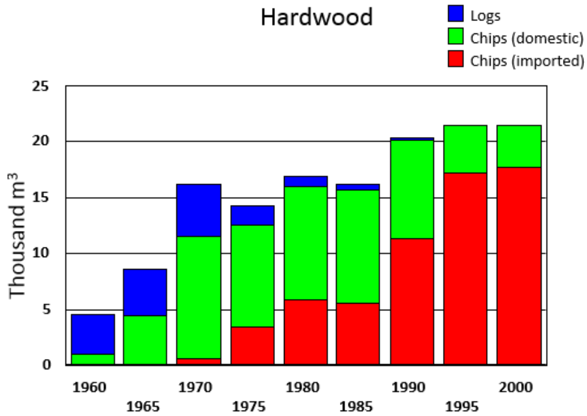


Fig. 6.17. Hardwood consumption by year [10].

As had happened so often in the past, the discovery of a new resource and the technological development that allowed its use quickly changed the structure of the industry.

Though the term “recycled pulp” is used in this paper, technically it should be referred to as “Deinked Pulp” (DIP). Waste paper, when reclaimed, contains contaminants, and the pulp fraction has to be separated from them, and then deinked. The technological developments which allow deinking will be described in Chapter 6.2. For the moment, the ways in which this deinked pulp could provide as much as 70% of the raw materials for newsprint will be covered.

As has been noted multiple times in this paper, newsprint needs both strength and opacity. Chemical pulp gives strength and mechanical pulp gives opacity. For example, if DIP made up of a 4:6 ratio of mechanical and chemical pulps is used as 70% of the raw pulp for newsprint, it means that the mechanical pulp accounts for 28% and the chemical pulp accounts for 42% of the final product. If 25% more fresh mechanical pulp and 5% more fresh chemical pulp is added to that DIP, the final share of mechanical pulp is 53% and that of chemical pulp is 47%. The pulp resulting from this blend provides ample strength, but it opacity is not high enough. As the trend in newsprint was towards lower basis weights with higher whiteness to make color images look better, opacity became increasingly critical, so as noted previously, amorphous silica was added to improve opacity.

In the 2000s, the active use of inorganic fillers in newsprint was tried. Traditionally, between 10% and 20% of inorganic fillers were commonly added to traditional printing paper, giving it the opacity levels and surface qualities required for printing. When printing paper was recycled, these fillers were mixed in with the resulting DIP. The filler most used recently is calcium carbonate, which decomposes in an acidic pH solution. The problem was that newsprint was manufactured at acidic pHs, such as pH 4, so as more recycled pulp was used, calcium carbonate would leach out from the printing paper-sourced pulp that had been mixed in with the newsprint. So the industry decided to manufacture newsprint at pH levels close to neutral, such as pH 6, and actively add new calcium carbonate to improve opacity.

Since the 1850s, paper had been manufactured in at acidic pH levels, using aluminum sulfate (called “alum” in the paper industry). The use of alum meant that traces of free sulfuric acid remained in the paper, deteriorating it over extended periods of time: paper would yellow and become brittle. Libraries around the world were faced with this issue, and it also became an issue in Japan during the 1970s. To cope with this problem, Japanese paper manufacturers changed to producing paper at neutral pH levels, without the use of alum. Neutral sheet forming has greater chances of problems during manufacture, such as generating slime and sticky contaminants, and needs greater expertise to operate the machinery than ordinary acidic sheet forming. However, it does have the advantage of being able to use calcium carbonate, one of the few fillers abundant in Japan. As a result, these days Japan is a world leader in neutral sheet forming for printing paper, and this technology is also being actively applied to newsprint manufacturing.

During printing, fillers adhere to printing plates, making them dirty. To cope with this, printing paper is generally coated with a thin layer of starch, using machines called size presses. Historically, these size presses were not considered necessary in newsprint machines, but the increasing speed of offset printing for newspapers in the 1980s meant that newspaper printers needed higher levels of printability, demanding newsprint which would cause less fiber piling on their plates. As a result, paper companies in Japan installed size presses, called gate roll coaters, in their newsprint machines (see Chapter 7.5). This meant that newspaper printers could print papers at a rate of 150,000 copies per hour, 40 pages a copy, with only a few sheet breaks (perhaps 1 to 2 per 1,000 rolls), and so there was almost no reason to rely on imported newsprint (see Chapter 5). These added gate roll size presses also made it possible to add calcium carbonate to newsprint, with the result that a new type of newsprint, formed at a neutral pH with added calcium carbonate, is currently manufactured in Japan. Its future market growth is a topic of some interest.

6-1-7 Current state of global newsprint production

This chapter has focused on Japan, but it is also important to examine what was happening globally at this time. Fifty years ago, newsprint contained 70 to 80% groundwood pulp, with chemical pulp making up the rest. At present, Scandinavian countries where softwood is still abundant still use 100% TMP. This is because TMP’s balance of strength and opacity make it well suited for newsprint quality. In the U.S., environmental concerns regulate blending with DIP, so the U.S. newsprint is a blend of TMP and DIP. Canada, which exports newsprint to the U.S., is also forced to blend DIP with TMP in its newsprint for that reason.

6-1-8 Future resources

In the belief that overseas plantation forests will be the next key pulp resource, Japan-based paper companies are engaged in afforestation in a number of countries world-wide. In most cases, the land they use is not suited for agriculture, or the afforestation is expected to improve the environment, so there is little competition with agriculture for this land. Unfortunately, limitations of space prevent more detail here.

6.2 DIP for newsprint

6-2-1 Technological development

While Chapter 6.1 provided a brief description of pulping equipment, readers are urged to refer to other works, such as those listed in the bibliography, for more details. However, as the development of DIP for newsprint is unique to the Japanese paper industry, more details on the process is and its background is provided here.

The process starts with the collection of waste paper. Waste paper has historically been reclaimed by paper collectors and classified by quality, with any contaminants such as metal and glass being removed. After sorting, old newspapers, along with the flyers included in them, are baled and delivered to processing plants. Newspapers are relatively uniform in quality, can be reclaimed in large volumes (making them suited for the mass production of pulp), and are printed using poor quality offset printing, making the ink easy to remove. A geographically compact country with over 100 million residents who consume paper at the rate of 240 kg/capita per year is well suited for recycling waste paper and developing sorting systems.

As described in Chapter 6-1-6, the technology of using waste paper for paperboard had already been established. However, it used waste paper to form the backing layers of paperboard, most of the ink was not removed, and small amounts of contaminants and undisintegrated pieces were acceptable. For newsprint, contaminant removal had to be improved, and most of the ink removed from the pulp. Deinking was, of course, practiced to some extent at the time. However, it was only on a small scale, just a few tons per day, and used what now appears to be a very old-fashioned process: air was injected into an open vessel and bubbles containing the ink that lifted off were skimmed out with a scraper. It required a lot of room, and the area around the vessel would become dirty due to spilled ink.

This antiquated technology was refined in Japan into a new process in which contaminants are removed and ink is separated from pulp at high levels of efficacy on a mass production scale. This was made possible thanks to the collaboration between paper companies and equipment suppliers. Historically, paper companies in Japan installed equipment developed by foreign suppliers at relatively early stages of their development, and worked together with the suppliers' Japanese licensees to put them into operation. The first installation of the continuous digester described above is an example of this, as is the introduction of the twin-wire paper machine that will be discussed later. However, Japanese suppliers like Aikawa Iron Works and Ishikawajima Machinery Co. also played an important role in developing the equipment for newsprint-use DIP. The surfactant is a key chemical in the deinking process, and traditionally ordinary soap was used. However, chemical suppliers in Japan (Kao Co., etc.) developed high quality surfactants, helping spread the technology. These developments are detailed below.

6-2-2 DIP production processes

Waste paper is immersed in water and separated out to its original pulp fibers in a process called disintegration. Next, this pulp slurry passes through a coarse screen to remove larger-sized contaminants, as although waste paper is sorted and classified by the waste paper dealers, it still contains contaminants such as metal, glass and plastic. Disintegration is done in a device called a "pulper," which is designed to disintegrate the waste paper as far as possible while keeping the contaminants as intact as possible. In most cases, the pulp is heated up to between 40°C and 50°C, and alkali is added to help the disintegration. Some of the ink peels off from the pulp during this disintegration process, but care is taken not to break down the ink into pieces that are too small, as ink particles smaller than 10 microns in diameter are difficult to remove in the succeeding floatation stage.

The resultant pulp slurry is moved to the screening and cleaning part. Contaminants are removed in stages, starting from the larger ones and moving down to the smallest ones. The first screen is the coarse screen, with round holes 3 to 4 mm in diameter through which the slurry is passed. It then moves to a fine screen which uses slits instead. If further screening is needed, narrower slits are used. However, the narrower the slits, the smaller the output volume, and thus the higher the costs. As newsprint quality restrictions became increasingly strict, these slits became narrower and narrower. This meant increased energy consumption, so energy-saving screens were developed. Next, the screened pulp slurry moves to the cleaners. The cleaners, which come in two types, one for heavy contaminants and the other for light contaminants, use centrifugal force to remove contaminants, based on their density

These steps have been traditionally used in paperboard manufacturing. Recycled pulp for newsprint has to be deinked after cleaning. After being printed, ink particles adhere to the pulp surface through the use of a binder, a component of ink shown in Fig. 6.18.

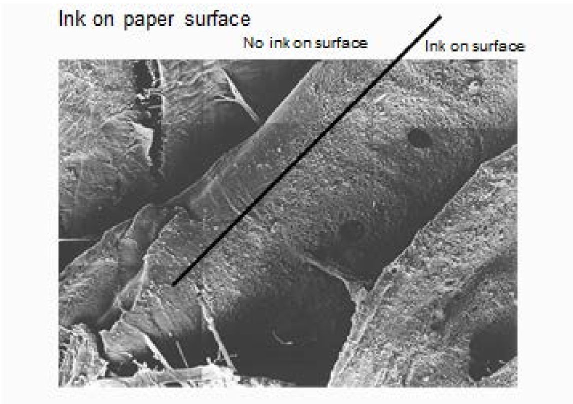


Fig. 6.18. Ink on paper surface [5].

By this stage, some of the ink has already come off through disintegration, screening and cleaning. Deinking targets any residual ink. First, the pulp slurry is dewatered to a concentration of 25 to 35%, and treated in a kneader or disperser, inside which the pulp rubs up against itself and the ink is mechanically rubbed off. In most cases, the pulp is heated to 50 to 100°C and alkali is added. Care also needs to be taken to not break the ink up into excessively small pieces. The slurry is diluted to a pulp concentration of about 1% and the rubbed-off ink is removed through floatation, the principle of which is illustrated in Fig. 6.19. A surface active agent (surfactant) is added to the slurry and then air is blown into it, which produces a lot of small bubbles. The ink particles dispersed by the mechanical rubbing adhere to the bubble surfaces, and float to the top. They are scraped out mechanically, using a paddle. Early equipment was small-scale and open on top, so the ink would splatter around the equipment. But a series of new equipment was later developed that had closed tops and offered higher capacities. The soap that was originally used as the surfactant was replaced with highly-effective chemicals developed by chemical manufacturers.

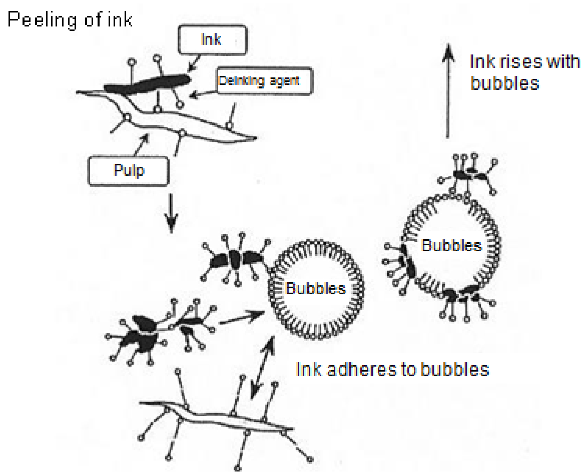


Fig. 6.19. Deinking mechanism [11].

After deinking, the pulp is screened and cleaned again to remove any fine residual contaminants. The next step is washing, in which the pulp is diluted and then condensed so that the remaining ink particles are washed out from the slurry. Finally, the finished pulp is bleached. The main bleaching chemical is hydrogen peroxide, and two-stage bleaching is normally used to get sufficiently high levels of whiteness. This allows DIP with brightness levels of 60% to be manufactured, and this accounts for between 50% and 70% of newsprint pulp. Figure 6.20 shows how a range of different equipment is installed in series in a DIP plant.

As newsprint requires increasingly refined DIP, engineering issues such as designing plants which can produce acceptable DIP at competitive costs become increasingly important. Japanese paper companies have developed their technologies through trial and error, and created a system that is becoming a global standard. The flowsheet of a typical DIP process is depicted below.

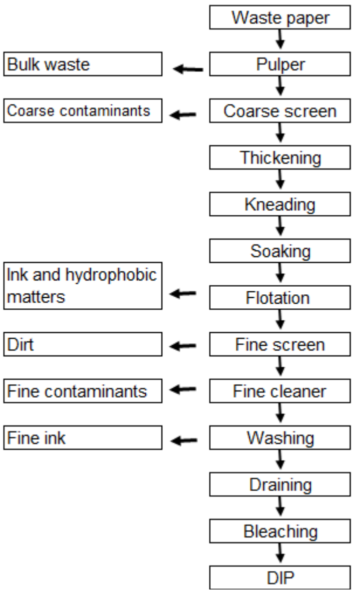


Fig. 6.20. DIP plant flow sheet.

Bibliography

[1] T. Naito "Progress of newsprint manufacturing over the last 60 years," *Hyakumanto*, No. 126, p. 25 (Paper Museum).
[2] *Preserving and Publicizing the Technological Archives of the Japanese Paper Industry*, No. 7, p. 1, "First continuous kraft pulp digester in Japan," Oct. 13, 2004, JAPAN TAPPI.
[3] *Preserving and Publicizing the Technological Archives of the Japanese Paper Industry*, No. 20, p. 1, "The technology demanded by environmental concerns (2): From sulfite pulp to kraft pulp," Oct. 10, 2007, JAPAN TAPPI.
[4] M. Hanaya, "Imported chips from lumber waste helped global environment" *Tech Times*, p. 113, May 10, 2007.
[5] Supplied by Nippon Paper Industries Co.
[6] *Preserving and Publicizing the Technological Archives of the Japanese Paper Industry*, No. 13, p. 1, "Imported chips helped growth of Japanese paper industry," Nov. 1, 2005, JAPAN TAPPI.
[7] *Preserving and Publicizing the Technological Archives of the Japanese Paper Industry*, No. 16, p. 1, "Reducing basis weight of linerboard," Oct. 2006, JAPAN TAPPI.
[8] *Pulp and Paper*, No. 694, p.14, Japan Paper Association.
[9] Excerpted from *Annual Report on Pulp and Paper Statistics* (METI).
[10] K. Iida, "Evolutional developments in the history of the Japanese pulp and paper industry," Pulp and Paper Symposium, Dec. 2003 (Pulp and Paper Research Committee).
[11] Y. Irika, "Deinking technology for waste paper," *JAPAN TAPPI Journal*, vol. 58, No. 7, p. 954.

Some references for pulping production methods are listed below.

References

1. *Handbook of Pulp and Paper Technology*, Jan. 30, 1992, JAPAN TAPPI.
2. *Pulp and Paper Manufacturing Technologies*, vol. 1 Kraft Pulp, May 1996, JAPAN TAPPI.
3. *Pulp and Paper Manufacturing Technologies*, vol. 2 Mechanical Pulp, Nov. 1997, JAPAN TAPPI.
4. *Pulp and Paper Manufacturing Technologies*, vol. 4 Recycled Pulp, Aug. 2005, JAPAN TAPPI.

7 Technological development part 2: paper machines

7.1 The basic concepts of paper making

The basic concepts of paper making and an overview of paper machine were provided in Section 4.2. A model outline is shown in Fig. 4.7. The key steps are, first, a 1% concentration of pulp slurry is dewatered on a wire mesh to approximately 20% concentration. The presses then increase the pulp concentration to 50%. Then, the dryer dries the pulp web to just a 6% moisture concentration level. These pulp to water ratios are converted to grams of water per gram of pulp and summarized in Table 7.1. Figure 4.9 in Section 4.2 shows an outline of the dryer part. Multiple dryers in sequence are required to reduce the moisture concentration to 0.94 grams of water per gram of pulp.

Table 7.1 The amount of water removed at each section of paper machine

		Stock consistency (%)	Water content (g/pulp g)	Water removed in each section (g/pulp g)
Wire part	Inlet	1	99	
	Outlet	20	4	95
Press part	Inlet	20	4	
	Outlet	50	1	3
Dryer part	Inlet	50	1	
	Outlet	94	0.06	0.94

Standard paper machines 50 years ago were 3.5 m in width and ran at 300 m/min, while current machines are 10 m in width and run at 1,800 m/min. This increase has been made possible through the technological developments that will be discussed in this chapter.

7.2 Wire part (Forming section)

7.2.1 Introduction

This section of the chapter will provide a review of the technological developments in the wire part. The wire part uses wire meshes, which are usually made of plastic these days. The purpose of this part is to form a wet web of pulp on a moving wire mesh and drain water through it (see Fig. 4.7-1). Key technological developments in the wire part are listed below.

(1) As paper machine widths increased, one issue was how to distribute the incoming pulp slurry uniformly over the full width of the machine. The solution was a distributor with multiple tapered tubes.

(2) The next issue was that the pulp slurry had to flow out on the moving wire mesh at the same velocity as the wire. In older designs, the slurry was kept in an open vessel (the head box) and was discharged simply by pressure. As machine speeds increased, this simple head pressure became insufficient and improvements were made, changing the head box from an open type to a closed pressurized type.

(3) When the pulp slurry flows out on the wire, the width of the flow-out gate opening is controlled to get a uniform sheet. As paper machines became wider, more precise control of opening width was needed. The solution was to use “slice and lip control,” going from laminar flow to turbulent flow, and from mechanical lip adjustment to consistency adjustment through dilution.

(4) Water must be drained from the pulp stock on the wire as fast as possible. To ensure this, a range of devices were developed and installed under the wire, such as table rolls, suction boxes and foil.

(5) The wet paper web has to traverse a short gap from the wire part to the press part felt without any support (see Fig. 4.7-1). As the wet web was weak and often

broke during this transfer, this was one of the main issues to solve, and the solution developed was the pick-up roll.

(6) Increasing machine speed meant that the wire part had to be longer to finish dewatering, which resulted in making the engineering harder. This was because water was only drained down through the wire. However, if the wet web was placed between a pair of wire meshes and dewatered on both sides, it would shorten the total length of wire mesh needed. This breakthrough from the old wire part design is called a twin-wire former.

(7) Wire is moving under tension, so it should move steadily and be resistant to abrasion from the supporting materials. To make it move more easily and smoothly, wire meshes changed from bronze wire to plastic wire.

(8) The wire mesh, like any textile, is woven with weft and warp wires, on the surface of which the wet pulp web rests. This means that any unevenness of the woven surface is replicated on the web surface. This unevenness has a significant effect on the final printed image. After studying how the wire threads should be woven, they were eventually changed from plain weave to multi-layer weave.

(9) As the pulp is very fine, about 40% of it ends up passing through the wire along with the drainage water. This drainage is used to dilute more pulp, recycling it. The question of how to improve the retention of pulp stock on the wire was a problem that was dealt with using wet end control.

As paper machines get larger and faster, these issues have been developed in order to allow the technology to stay one step ahead, an issue the industry still faces. As issues of length mean that it is impossible to review all of them in this paper, the first three items shall be described in relation to each other, with the sixth item reviewed in addition.

7-2-2 Distributing pulp stock evenly across the width of the paper machine

Pulp slurry at about 1% concentration is transported to a paper machine through a single large diameter pipe, so the issue is how to distribute it evenly across the width of the paper machine. To allow this, a device called a distributor was developed. Before paper machines became as wide as they are today, the pipe opening was simply expanded to the width of the machine in a fan shape. Later, a branched model was invented, in which the pulp slurry was fed through several small pipes branching from the main pipe to the paper machine. This branched pipeline was further modified in different ways, including adding cross flow and taper flow, and is now the industry standard.

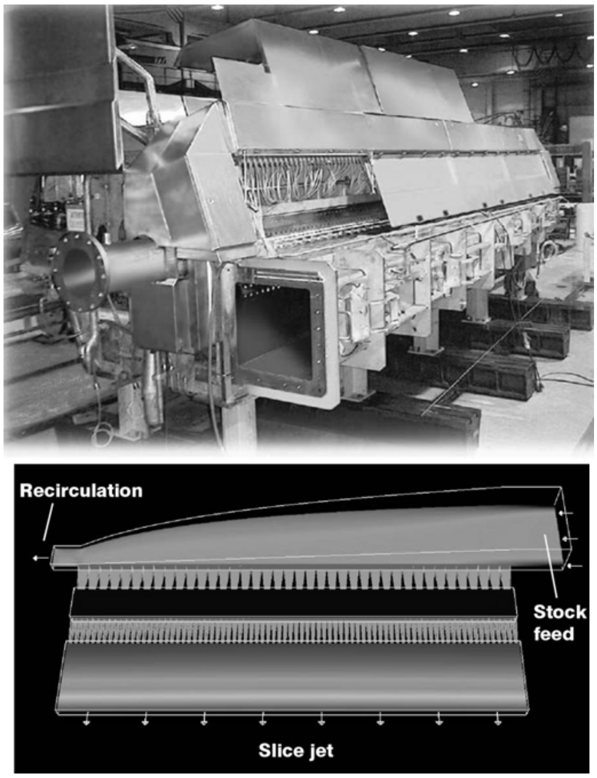


Fig. 7.1. Current distributor [1].

Figure 7.1 is an Opti-flow II head box made by Metso. Pulp slurry coming perpendicular to the paper machine is distributed through multiple branched pipes to the inner elements of the head box. The upper half of the figure shows a photo of the head box, while the bottom half is a computer simulation of stock flow in the distributor.

In the next stage, pulp slurry is ejected from the head box onto the wire at the same speed the wire moves. The name “head box” comes from it creating hydraulic pressure (head) within a box based on the height (h) of the pulp stock. If a thin slit is opened across its width at the foot of the box, the pulp slurry is ejected at a theoretical speed of $(2gh)^{1/2}$. In practice, some correction is needed, depending on the shape of the outlet. Operators also needed to know how to adjust the angle (jet angle) of impingement of stock on the wire or adjust the difference between the speed of the wire and the pulp slurry. At speeds of less than 400 m/min, this initial type of simple, open head box worked perfectly well. However, as machine speeds increased, increasingly taller heads were required, and eventually merely increasing the head height could not provide enough velocity, nor could they fit within the mill buildings. Therefore closed and pressurized head boxes were developed. The paper machine discussed in the case study in Chapter 11 had one of the first such head boxes. Once the head box became pressurized, it was freed from having to be considered a box, so a series of closed models were introduced by manufacturers.

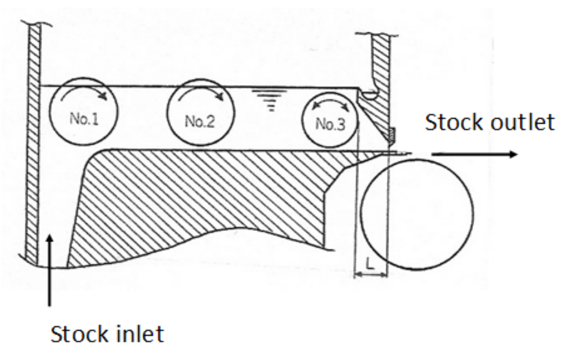


Fig. 7.2. Open type head box [2].

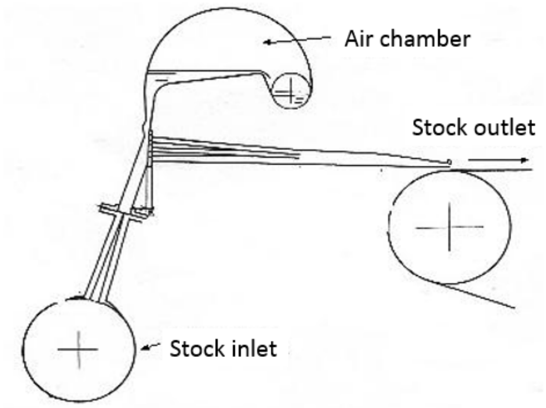


Fig. 7.3. Closed type head box [3].

One characteristic all head boxes have in common is that they have an air chamber as a pressure damper. As keeping the pulp stock well dispersed is needed to allow a uniform flow, lamellar flow was maintained as much as possible in the old style of head box. In high-speed machines, however, the pulp stock is dispersed with the addition of a strong shear force.

Finally, the pulp slurry flows out onto the wire mesh, where final adjustments are made to control the opening of outlet slit in the cross direction. A number of pressure bolts are fixed on the outlet at equal intervals across the machine, and by controlling the pressure on these bolts, the openings under them are adjusted to ensure that the flow becomes uniform across the entire width. These bolts are generally called "jacks" in paper mills (see Fig. 4.7-1). In earlier years, operators would observe the flow on the wire (such as uneven dewatering in the cross direction) and control the bolts manually, which meant that a considerable amount of skill and experience was required. However, a device which measured basic sheet qualities on-line as a profile of the cross direction was invented in 1969, bringing about a revolution in paper machine operation (see Chapter 7.6 for details). As this made it possible to monitor the moisture content and basis weight of the web as cross-directional profiles in real time on a monitor, finer adjustment of the bolts became possible. There was still one problem, however. When a bolt was tightened, the opening underneath became narrower. If the basis weight was reduced only at that position, adjustment would be simple. However, as pulp stock is a fluid, tightening one bolt affected the adjacent positions, so multiple bolt adjustments were needed to correct a profile. Skill and experience were still required. Nevertheless, the monitoring device was truly revolutionary, and cross-directional profiles were greatly improved. The next move, then, was to feed back data from the monitor to adjust the bolt pressure (lip opening) automatically, rather than manually. This was a task in which computer simulation excelled, and a model for standardizing opening profiles was developed. This meant that a considerable portion of the skill needed for operation was taken over by computers. Though final fine adjustment was still done manually by the operators, a significant part of operational expertise was transferred to a controller, like a black box, and used widely as core technology. As opening profiles were established as standard models, feed-forward control became possible. Paper machines would normally operate continuously, but were sometimes stopped under circumstances such as replacing equipment or scheduled shut-downs. When the machine was restarted, it could be quickly adjusted to the most favorable condition registered in its controller. This was a considerable merit for process industries. At the same time, paper machines were becoming larger and faster, and twin-wire formers were now used, which meant that operators could no longer visually check the pulp stock flow on the wire. Now, all paper machines have to operate under the surveillance of one of these on-line profile monitors.

As paper machines became larger and larger, controlling the opening became harder and harder, and was never an easy task. At this point, the next innovation was created. When an opening was pressed down by a bolt, it affected the neighboring pulp flow. However, if the pulp slurry was diluted with water, then instead of pressing the opening, the basis weight at the location could be reduced without disturbing the neighboring pulp flow. So the entire lip was divided into parts 3–6 cm wide, and pulp stock sent to each part independently, its consistency adjusted by adding water as needed based on the information monitored at the end of the machine. This meant that the basis weight profile across the width could be controlled without disturbing the neighboring pulp flows. With this technology, the long-awaited cross-direction automatic profile control finally became available, and large paper machines took advantage of it.

For reference, an example of a current cross directional profile (basis weight) is shown.

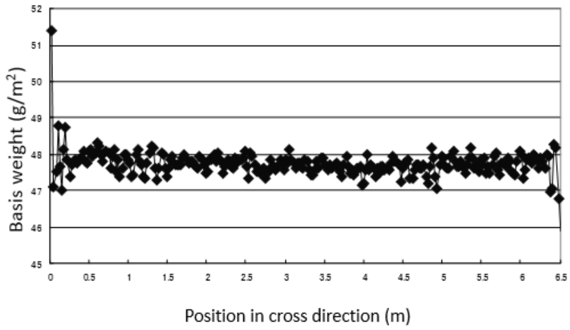


Fig. 7.4. Cross-directional profile of basis weight [4].

This series of technological developments is typical of process industries, to which the paper industry belongs. It took almost fifty years, during which new materials were invented and the process control was refined. Thanks to these developments, equipment increased in size, productivity improved, and product reliability was considerably improved. On the other hand, however, skill and knowledge became less significant. In fact, the process industries have been cooperating with equipment manufacturers to take a lead role in technological developments of this kind. Once a new technology was invented, it was incorporated into the standard equipment supplied to industry newcomers. In most cases, these newcomers would install large-scale, cost-competitive equipment. Though they may have lacked experience and skills, this improved equipment helped them produce products that were generally accepted by the market. That meant, however, that the inventor of the technology lost their advantage. While there remain differences in operation level, this is happening to Japanese industries such as paper and steel which manufacture basic raw materials, and methods for dealing with this are a major concern.

7.2.3 Dewatering

When making paper by hand, water is drained through the wire mesh by gravity. However, with the development of continuous sheet forming machines, hydrodynamics has been applied to efficiently accelerate dewatering through the wire. In the early stages, small rolls called table rolls were set parallel across the machine to support the moving wire (Fig. 4.7-1). These rolls were not driven, but were rotated by the wire mesh moving forward over them. As the roll rotates, negative pressure is produced at the back part of the roll, which sucks water from the web. Table rolls were later replaced by foils, which were fixed in position, non-rotating. The dewatering principles of table rolls and foils are illustrated in Fig. 7.4 and Fig. 7.5 respectively. The difference is that the table roll produces a spike-like suction while the foil dewaters with gentler suction over a longer length.

Another device, called a suction box, was also developed, which used suction to dewater.

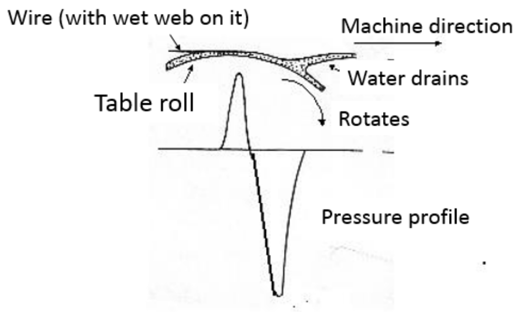


Fig. 7.5. Dewatering using table roll [2].

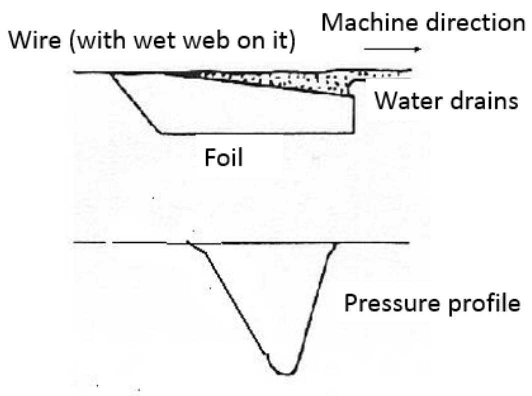


Fig. 7.6. Dewatering using foil [2].

Installing these devices allowed paper machines as wide as 7 meters to run at 700 m/min in 1960. The wire part of these machines was equivalent to a process unit which dewatered at a rate of 20 tons/min. The wire used for these machines was 7 meters wide and 40–50 meters long, seamlessly connected at both ends so it could keep circulating on an infinite loopy. It was subject to wear through abrasion, however, and needed to be replaced once a month or so. Physical and operational limitations meant that the wire could not be made longer. This meant that it seemed impossible to increase machine speed further.

Though paper machines ran horizontally and water was removed downwards (in the direction of gravity), dewatering was actually done by hydrodynamic forces such as negative pressure and suction, rather than by gravitational pull. So, if a wet web could be held between two wires and forcibly dewatered on both sides, the wire would only need to be half as long as for single-sided dewatering. Moreover, it would not be restricted to running horizontally, and could run vertically, allowing the wire part, which had an overall length of some 20 m, to be shortened. This idea gave birth to the twin-wire paper machine.

A set of wire meshes which hold pulp web between them is pressed from one side with shoe blades or rolls to curve it like a bow. The tension on the wire generated by this curving presses the pulp stock and squeezes water outwards through the wire. The shoe blades pressed against the curved wire work like table rolls or foils, draining water to their side through the negative pressure produced at their tips. This is the scientific principle, at any rate (see Figs. 7.7 and 7.8). However, the actual engineering requires technology. In the old horizontal paper machines, the wire was slowly shaken crosswise to improve stock dispersion on the wire and made the sheet smoother. This dispersal effect could not be replicated using a twin-wire system, so paper would have to be made using the pulp distribution that came out of the slice outlet. That meant that the profile in the cross direction would have to be more even than ever. In addition, though the length of the wire mesh would be shorter, two sets of wires would be needed. This meant that their lifespan would have to be longer than ever.

In spite of those problems, the first twin-wire machine was commercialized in 1968 by Black Clawson Co. But its machine, called the Verti-Former as it fed stock vertically downwards, ended up seeing use in only a few paper mills due to poor sheet formation.

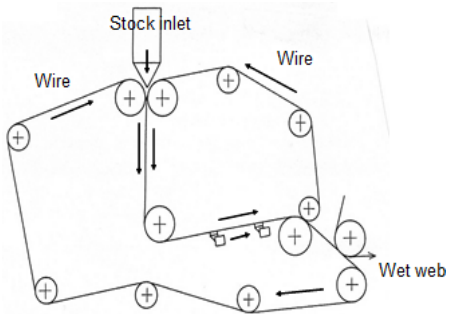


Fig. 7.7. Conceptual image of a Verti-Former [2].

The Verti-Former was followed by the Bel-Baie former, developed by Beloit Corporation, which became standard in newsprint manufacturing. Pulp stock was injected upwards and sandwiched between two wires. The set of wires was curved by having shoe blades press on them, with the pressure of the wire tension removing water outwards. The negative pressure produced at the blade tips also removed water inwards. The ratio of the amounts of water removed to both sides was roughly 6 to 4, with the inside being slightly greater.

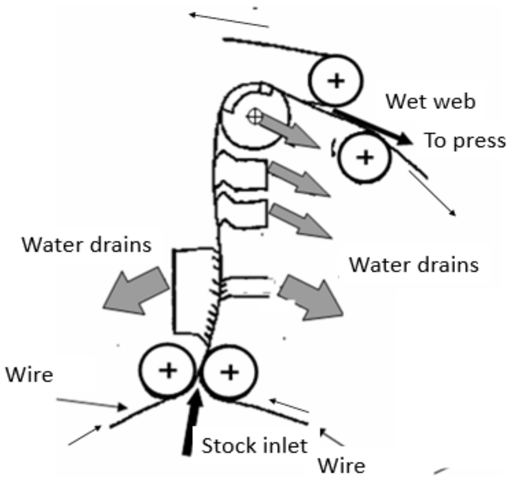


Fig. 7.8. Conceptual image of a Bel-Baie former [5].

In this former, the shoe blades were pressed against the wire with higher pressures than that in ordinary Fourdrinier machines, resulting in increased wire wear. Better wire and shoe blade materials had to be developed. By then, wire meshes were already made of plastic, not bronze, making their life much longer. Developments in ceramics helped create good quality shoe blades. These two developments made it possible to commercially operate twin-wire formers.

Though the twin-wire former revolutionized newsprint production, it was not accepted in manufacturing other grades of paper. Most grades of printing paper have heavier basis weights and demand higher quality sheet formation than newsprint. As a result, several types of hybrid former were developed, which had the high productivity of twin-wire formers and the quality sheet formation of Fourdrinier machines. In these hybrid machines, sheets were formed on a conventional wire part, over which a top-mounted former was added to remove some of the water from the upper side. These hybrid formers were suitable for many kinds of printing paper, so became commonly used for such in mills. One model, the Duo-Former, became essentially the de facto standard in Japan.

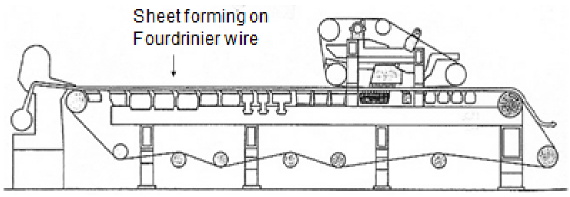


Fig. 7.9. Example of a hybrid former [6].

The concept of dewatering from both sides brought about a revolution in sheet quality. When water drains through wire, fine bits of pulp stock also fall out. The water containing this fine pulp is recycled to dilute incoming pulp stock. In conventional paper machines, water is only removed from one side. As sheet forming is a type of wire filtration, greater amounts of fine pulp remain on the top side of the sheet and lesser amounts on the wire side. Despite a thickness of less than 0.1 mm, the sheet has different materials on the top and bottom. As paper is printed on both sides, this two-sidedness affects the printed images. In most cases, the top side, which contains more fine pulp, has better quality printing. This two-sidedness is also a problem in printing operations, as it makes the paper curl when moistened. In addition, the faster the machine speed, the worse the conditions for drainage become and the larger the two-sidedness grows.

Paper machines using two-side dewatering solved this problem in an instant. At that time, newspaper printers were replacing their letterpress printers with offset presses, and increasing the number of pages per copy. For a newspaper with 40 pages, 5 newsprint rolls would be set on a rotary press and printed simultaneously on both sides. Every roll and every side would be required to behave in the same manner. This demand forced newsprint manufacturers in Japan to install twin-wire machines.

In this way, a major breakthrough in industrial technology like the twin-wire machine is accomplished not by an idea alone but through a combination of the needs (improved productivity for the mill, changes in quality demands due to client technological developments) and the technological innovations in related areas that make these needs possible (such as process control, plastic wire and shoe blades).

7.3 Press part (Press section)

7-3-1 Overview

This section will review the engineering issues in the press part. The purpose of the press part is to squeeze out water from wet paper web through mechanical force.

The word “press” is usually associated with machinery pressing a flat plate downward, in a batch operation. In traditional hand-made paper making, a number of wet sheets were stacked and pressed exactly in the way the word suggests. In modern paper making, however, pressing is used in a different concept, although the word is still in use. The basic design is illustrated in Fig. 7.10 (refer to Fig. 4.7-1 as well).

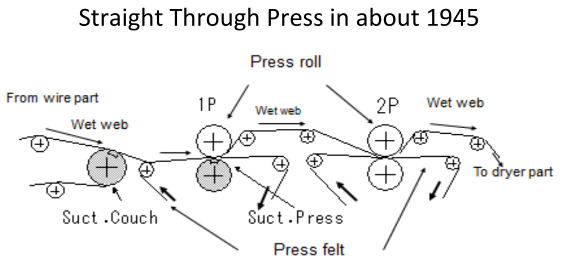


Fig. 7.10. Basic model of the press part [7].

When the wet paper web reaches the press part, it is like tissue paper that has been saturated with water (like wet wipes). This paper is squeezed by passing it through two rolls pressing vertically against each other. One large roll is called the stone roll and was traditionally made of granite, and the other is called the rubber roll and is covered with rubber. As the wet web is very delicate, it is carried on a bed of supporting felt (the actual machines sometimes have the wet web on the bottom of the felt) that moves at the same speed as the paper machine while the water is squeezed out by the pressure of the two rolls. In most cases, the wet web faces the stone roll. One set of rolls is not enough, so a press part will have between two to four sets of rolls.

Paper machines like that illustrated in Fig. 7.10, which were popular in the 1950s, ran at 300 m/min. The newest current machines run at 1,800 m/min. This increase has been made possible through the technological developments that will be discussed below.

(1) Water is squeezed from the wet web through the pressing actions of the rolls, and is absorbed into the supporting felt. When a wet web is peeled from a press roll, it absorbs some of this water back from the felt. To minimize this re-wetting, the rubber roll has been modified to rapidly remove water from the felt. These modifications are the use of grooved rolls (with grooves on the roll surface) or a suction roll (with a suction mechanism inside the roll).
(2) Three to four sets of press rolls are needed, but there have been attempts at using fewer, such as going from a straight-through design to Twinver and Tri-Nip designs.
(3) To prevent two-sidedness installing a fourth press was found to make it possible to make each surface of the web contact the stone roll surface.
(4) The pressure produced by a roll is a type of linear load. Pressure will be more effective if applied on a surface as an area rather than as a line. This idea, the shoe press, revolutionized press design.
(5) As paper machine speeds increased, larger diameter rolls were needed. Large rolls of uniform quality could not be made from natural granite, so substitutes were needed, leading to the development of the synthetic press roll.
(6) The press felt also had to be modified to

improve its performance, so new types of fiber, needle felt and laminated felt were developed.

(7) Adjustment of the roll crown to ensure that the nip pressure was even in the crosswise direction was another issue, leading to the development of rolls with crowns that could be controlled, called crown controlled rolls (CC rolls).

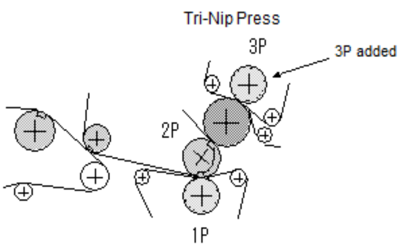
(8) Finally, as quality demands grew ever stricter, the development of heating through steam boxes made it possible to have uniform moisture profiles along the cross direction of the paper machine, especially at both ends.

Items (2), (4) and (6) will be reviewed below.

7-3-2 Arrangement of press rolls

Until about 1960, press rolls were arranged as shown in Fig. 7.10, with a horizontal series of roll sets. However, this design required a fair amount of space, and the weak wet web had to traverse long distances between the presses, meaning that it broke often in that area. This led to a more efficient layout of the rolls, as shown in Fig. 7.11.

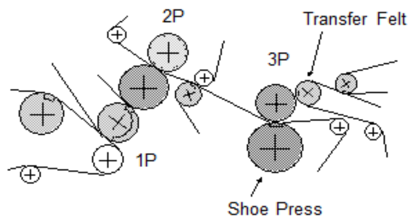
In this design, the No. 2 press (2P) and the No. 3 press (3P) share the same stone roll (the dark-colored roll), saving one roll. The same press suction roll (the darkish roll) is used for both the No. 1 press and the No. 2 press. Reducing the distance of the wet web run means less chance of sheet break, so the paper run in the press part was greatly shortened. Limitations of room prevent a review of the long history of press roll configurations. However, efficient press arrangements and the development of the shoe press, which will be covered in the next chapter, mean that modern paper machines are able to run at very high speeds.



1. The Tri-Nip press was developed by adding 3P to the Bi-Nip press in 1975.
2. Its dewatering and travel abilities were improved by installing No.3 press before the open draw.

Fig. 7.11. Tri-Nip press [7].

For example, a standard newsprint machine has both No. 1 and No. 2 presses and a shoe press, as depicted in Fig. 7.12, and runs at 1,800 m/min.



1. 3P in old Twinver-Com+3P newsprint machine was converted to shoe press in 1990 (1200 m/min).

Fig. 7.12. Typical press part of modern newsprint machines [7].

7-3-3 Shoe press

As noted earlier, rolls press the wet web linearly, but higher pressures are needed to make dewatering efficient. However, if excessive pressure is applied, the formed sheet is crushed, especially in paperboard with a heavy basis weight (about 5 to 8 times that of newsprint). In classical hand-made paper, the wet sheet was pressed with a flat plate in batches. This is surface pressure (plate pressing), not linear pressing. To mimic this plate pressing in the modern continuous process, the shoe press was developed. It consists of a shoe, which is fixed and concave along its top side, and a rotating roll with a curvature that fits the concave surface of the shoe. Rotating a roll against this fixed shoe surface mimics pressing by a plate. To prevent the moving paper web from being scratched on the solid shoe surface, a belt runs over the shoe surface at the same speed as the press roll. Thus, the roll, the web and the shoe belt are all moving at the same speed relative to each other, and better drainage is possible at lower pressures.

The first model is shown in Fig. 7.13. It was called an extended nip press, and supposedly the width of the nip was ten times greater than ordinary roll presses.

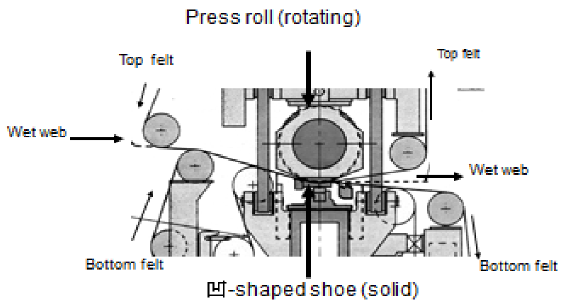
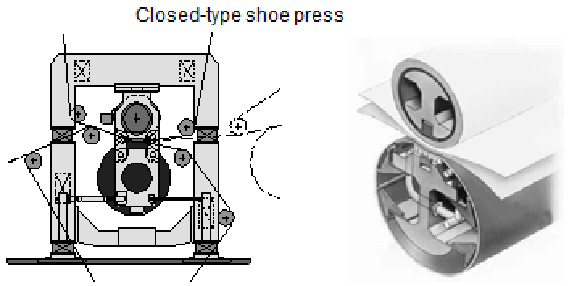


Fig. 7.13. Conceptual image of a shoe press [7].

Later, the closed type was developed, and this is now used in manufacturing not only paperboard, but also printing paper and newsprint.



1. The closed-type shoe press was developed to eliminate the defects of the open-type ENP such as oil spillage by enclosed the blanket end.
2. Use of the shoe press increased machine speed.

Fig. 7.14. Closed-type shoe press [7].

The other advantage of the shoe press is that the wet web is pressed with less pressure and is left bulkier. This bulk gives stiffness to paper that is supposedly proportional to the third power of its thickness. This added bulk is especially advantageous for newsprint, as newspapers are expected to be able to be read without the top falling over. In this sense, the shoe press was truly a revolutionary development [7].

7-3-4 Technological developments in press felt

Paper machines are different from chemical plants, which, though they are a type of continuous process, are generally a closed system, with every unit connected with pipes. Attempts to operate all the linked units of a paper machine at high speeds, however, will fail if the only strengthening is mechanical. Every part of the machine needs to have upgraded design and performance, with the help of suppliers of tools and auxiliary equipment. When the wire part was made larger and faster, the demands for improvements to the wire mesh, such as a longer working life, ease of replacement, and fewer wire marks on the sheet surface, were each satisfied. The same sort of technological development has been applied to the press felt, which is explained in more detail by Someya (2005) [8].

Water is squeezed from the wet web by the press pressure and absorbed into the press felt, where it is retained. When the wet web leaves a press roll, it reabsorbs water from the felt. This means that the press felt has to be able to absorb and retain as much water as possible. When this felt is pressed against the web surface, the uneven pattern of the felt is transferred to the web surface, leaving marks called felt marks. It was important that these felt marks were kept to a minimum, and at the same time, stable operation over extended periods of time was also vital.

Felt was originally woven with a raised warp and woof. Later, needle felt was developed, in which the butt (short fibers) is needle-punched into a base cloth. The availability of a range of butt and cloth types allowed multiple combinations, accelerating technical developments. In the base cloth itself, multi-filament threads replaced yarn, and recently have in turn been replaced by mono-filament threads as usage requirements have become ever stricter. For the butt, a mixture of wool and nylon fiber was initially used, then replaced by purely synthetic fibers. Later, the fibers were chemically treated to increase the abrasion resistance of the felt. Modifications were also applied to prevent it flattening as much under pressure (improving its flatness resistance qualities). These days, the quality of the butt is controlled through modifying its polymer structure rather than the use of chemical treatment.

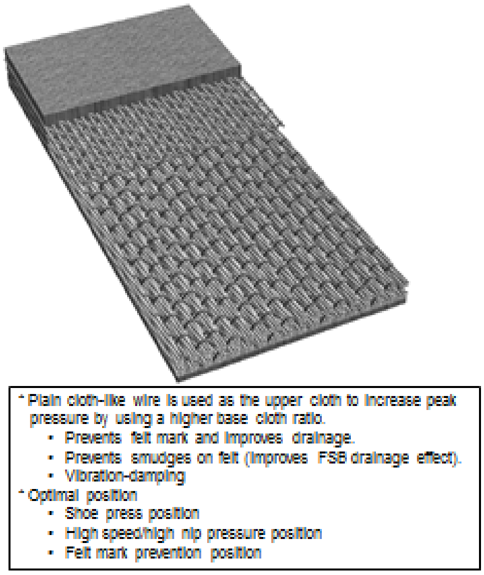


Fig. 7.15. Example of laminate felt [8].

In recent year, the increasingly strict requirements for felt have led to the development of new products. For example, laminated felt consists of two different cloth types to improve the surface quality at the same time as ensuring good drainage. Another new product has a special sheet or film inserted to prevent rewetting. Press felts, in most cases, are delivered as endless forms, but there is one type, the seam type, that can be joined at its ends. These new function-oriented products are expected to be the industry standard in the future.

The developments of press felt discussed above are summarized in Table 7.2, along with the press part developments. Although this table is based on fine paper machines, it is also applicable to newsprint machines.

There are many technical terms used in the table, but they will not be defined here, as the purpose of this table is to allow readers to understand the role and contributions of press felt in improving performance in the press part as a whole. Note, however, that the term “NMC” used in the table refers to the lifespan of the felt expressed as numbers of nip passes, one million passes being a unit. The table shows how this NMC value has been growing steadily, despite the increasingly severe usage conditions.

Table 7.2. Felt quality changes to meet developments in press part [8]

Year	Paper machine					Functions required for felt					Type of felt
	Press section		Fine paper machine								
	Type of press	Roll or shoe	Speed m/min	Total Pressure kg/cm	MNC	Travel ability	Squeezing	Surface quality	Anti-abrasion	Anti-flattening	
1804	Forward press	Plain press									Woven felt
↓	Reverse press	Suction press									
1931	Dual press										
1950	Straight-through press										
	Twinver press										
1960		Grooved				√	√	√			Needle felt
											(BOB)
	Uni-press	Suction G					√				Weftless felt
						√	√				BOM single
1970											
	Multi-nip press					√					Monofilament for wef
						√	√			√	BOM double
			800	270	1.7						
1980	Extended nip press		900	370	1.8	√	√			√	Laminate felt
	Multi-nip+4P										
		Nipco roll									
	Flexiso-nip press	Shoe press									
	Intensa-press	(closed)	1000	370	2.0						
	Press for carton board	Dina-rock									
	Distributed type	SimZ-roll									
1990			1300	410	2-3						
	Shoe press for newsprint										
	Shoe press for printing paper					√	√		√		Laminate felt
			1500	410	2-3	√	√	√	√		Super-fine laminate
2000	No-draw press		2000			√	√	√	√	√	
	Closed transfer press										
	Single nip press										

What has been discussed here is the bare bones of the felt technological development, in which a great number of prototypes and tests were repeated again and again. For example, roll manufacturers are responsible for developing the different materials used for different rolls. As the press felt absorbs and then expels water, it becomes contaminated, and therefore needs to be washed during operation. This washing unit and the washing chemicals are also developed by specialists. In this way, a wide range of specialist manufacturers all contribute to efficient operation in just the press part alone.

7.4 Dryer part (Dryer section)

7-4-1 Introduction

Following the press part is the dryer part. The wet paper web is put into contact with a heated rotating dryer to dry it. As one dryer is usually insufficient, the wet web passes through multiple dryers until it is completely dried, as shown in Fig. 4.7-2. There are usually several dozen dryers. The wet web is unsupported when it passes from one dryer to the next, meaning that there is a high risk of sheet break. Minimizing sheet breaks is a perennial issue for the dryer part.

The physical actions in the dryer part are as follows (Fig. 7.16). When the wet web contacts a heated dryer cylinder, inside which low pressure steam is injected, it is heated up, causing some of its moisture to evaporate from the back of the web. The web then leaves the first dryer cylinder, moves forward to the next cylinder, and is wrapped around it. During this free transverse between cylinders, more of its moisture evaporates and the web can cool down. The amount of water evaporated during this transfer stage is quite significant, totaling roughly half of the total evaporation, so efficiency here is very important. Once in contact with the next cylinder, the web receives more heat and its temperature goes up again. This cycle is repeated at every dryer cylinder.

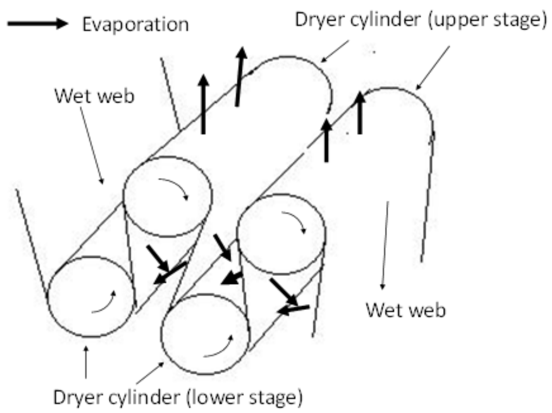


Fig. 7.16. Conceptual image of dryer.

The basic layout of dryer cylinders is as shown in Fig. 7.17. Cylinders are laid in a zigzag pattern, and the wet paper web moves from the upper cylinder to the lower one then back up again to the upper one. As the web travels a relatively long distance in total, it must be kept taut, without flapping or snaking. To achieve this, two sets of dryer canvas, one for the upper dryers and the other for the lower dryers, move over the cylinders to press the web against the cylinders, as shown in Fig. 7.17.

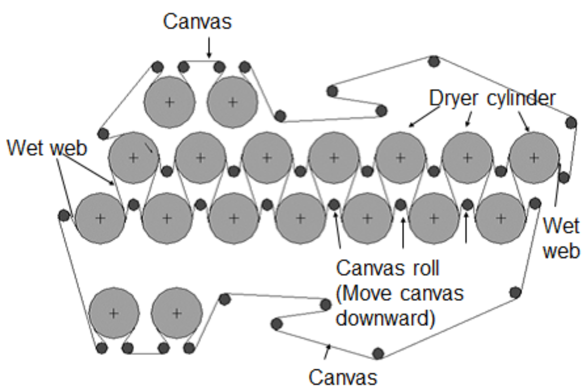


Fig. 7.17. Conceptual image of dryer canvas (seen from the side) [9].

The problems to be solved for the dryer part were as follows.

(1) The steam injected in to a cylinder to heat it remains as drainage water inside the cylinder. As this drainage water interferes with the heat transfer to the cylinder shell, draining it from the cylinder is important for improving heat efficiency. This becomes more critical over machine speeds of 1,000 m/min. The solutions developed include the rotary siphon, stationary siphon and the spoiler bar.

(2) Evaporating as much water as possible

from the wet pulp web while it is traversing between cylinders (this is called the dryer pocket) has been a major issue. Ventilation in the dryer pockets has been improved, and heating the wet web itself is another approach. The technology developed for this includes blow rolls, hot air ducts and infra-red heating.

(3) As paper machines grow wider and faster, the wet web in the dryer part becomes increasingly unstable, with greater chances of flapping and snaking when using a conventional canvas layout. Modifications have been developed to overcome this, such as the single canvas system, the single deck system and equipment for helping steady web running such as Uno-run.

(4) The quality of the canvas has been a subject of research and development, and improvements include needle canvas and high-permeability canvas.

(5) The steam evaporated from wet web has enthalpy which can be recovered to increase energy efficiency by, for example, enclosing the dryers in a hood or drying at a high dew point.

This paper will discuss items (2) and (3).

7-4-2 Evaporation in dryer pockets

Evaporation of moisture from the wet web in the dryer pockets is very important, and research has been undertaken on methods for increasing the amount evaporated by reducing humidity within the pocket. Until around 1980, the dryer canvas ran on the wet web, pressing the web against the dryer cylinder to prevent web snaking, as in Fig. 7.17. This type of canvas circulation meant that a dryer pocket became a space enclosed by wet web on both sides, as well as the cylinder and canvas, so had only two openings at either end widthwise across the paper machine. Water vapor that evaporated from the web accumulated in the pocket, increasing humidity and restricting further evaporation. To counter this, a system called a blow roll was developed, in which dry heated air is blown into the pocket, purging the vapor through the openings and reducing humidity. The support rolls for the canvas are perforated to allow the air to be injected.

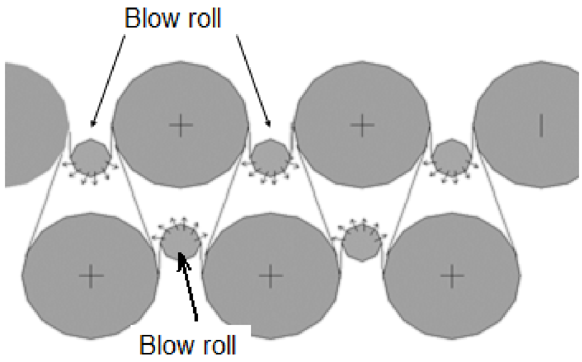


Fig. 7.18. Conceptual image of blow roll [9].

However, in this design, the air purged from the side ends is very humid, and negatively affects the moisture profile of the web in the cross direction, especially at both ends. To counter this, the blow box, as shown in Fig. 7.19, was developed. In this system a box blows air into the pocket at the point where the web leaves the cylinder and sucks humid air from the pocket through the canvas. The box is partitioned horizontally every meter, allowing the air flow to be controlled for every section.

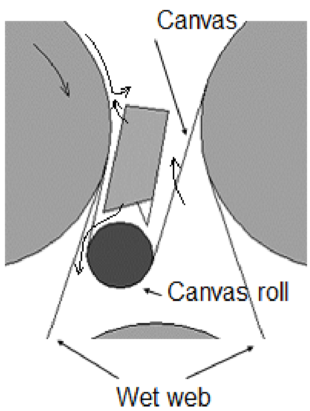


Fig. 7.19. Conceptual image of blow box [9].

With these modifications, machines can run faster with better moisture profiles in the cross direction.

7-4-3 Fluttering

When machine speeds exceed 1,000 m/min, wet web fluttering within the pocket grows worse, making the web very susceptible to breakage. To counter this, the single canvas system was developed. Normally, the wet web would flutter as it moved unsupported within a pocket, but using canvas that ran on the top and bottom, it could be supported against fluttering by changing its layout.

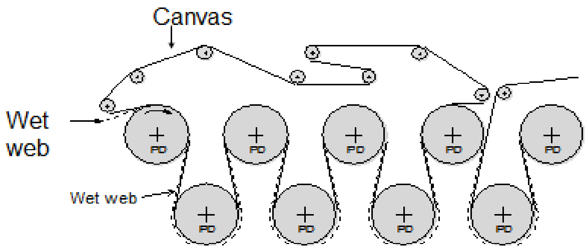


Fig. 7.20. Conceptual image of single canvas system [10].

Wet web is placed on the moving canvas and they are run together through the dryer part, as shown in Fig. 7.20. At one dryer, the wet web contacts the cylinder surface, and at the next dryer, the canvas contacts the cylinder surface. This layout inevitably results in lowered heat efficiency. However, air ventilation at the pockets is easy, as they are not enclosed. While a rather forced concept that would appear to be a step backwards in terms of energy efficiency, in actual use it worked fairly well. In addition, as existing dryer systems could be modified without much remodeling, the system spread rapidly worldwide due to the lack of a patent. The canvas was also modified to suit it better, such as increasing its permeability.

The next idea was a dryer layout with no free-run zones. The zig-zag layout of the dryers means that there were areas called "free runs" left between them. However, if dryers are arranged in a single stage, rather than two staggered ones, as in Fig. 7.21, there would be no free runs. This layout is called the single deck system.

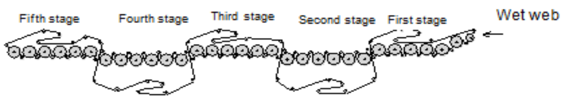


Fig. 7.21. Conceptual image of single deck system [10].

Though the single deck system requires more space, recent high speed machines need steady operation more than space, so this system is adopted.

The developments in the wire part and press part worked to save space. However, the dryer part, which had already been long, ended up removing all that saved length in machine design. Refer to the earlier Fig. 4.9 for details. Even today, breakthrough ideas like the Condebelt design are sought for the dryer part, but so far these remain at the research stage.

7.5 Size press

A paper machine consists of three main parts or sections, as reviewed above. In newsprint manufacturing, one other piece of equipment, called a size press, has played an important role (see Chapters 5 and 6). Paper has to have some degree of water repellency to control the penetration of printing ink, so sizing agents have been used commonly in printing paper production. The equipment that applies sizing agent to the paper is called the size press. The "press" part of its names originates from its roll layout, where two rolls press against each one, rotating in opposite directions. The sizing agent is added to the space between the two rolls at the top, the "nip," to form a small pool or "pond." Paper passing through this pond absorbs the sizing agent, which is then pressed into the paper as it passes through the nip between the rolls.

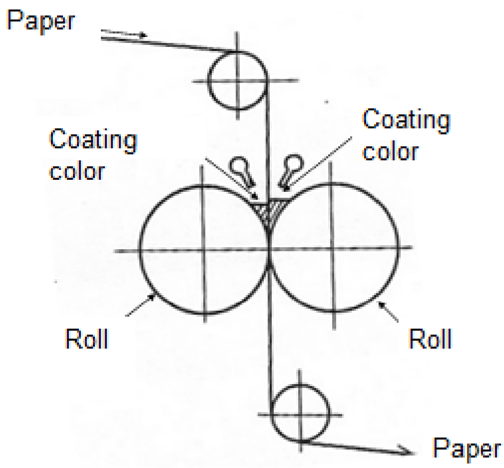


Fig. 7.22. Conceptual image of size press (conventional) [2].

As high-speed multi-color offset printing became popular for newsprint printing, the demands for newsprint surface strength became increasing strict. As discussed in Chapter 4.3, offset printing uses damping water, which removes small fibers from the web surface, which then accumulate them on the printing cylinder. This can cause blank areas to appear in the printed image. This also means that the printing machine has to be shut down for cleaning. To prevent this, a size press has commonly been included in paper machines producing most grades of printing paper, applying a thin layer (1 g/m^2 on each side) of starch, and this technology is now applied to newsprint machines.

The size press is located after the dryer part, which means that paper has to be rewetted. This rewetted paper is dried again by a dryer called the "after dryer," which consumes additional energy. To avoid this, considerable effort was applied to manufacturing newsprint good enough for offset printing without the use of size presses by controlling pulp quality and fine-tuning machine operation. However, the problems could not be solved this way, so the use of a size press is now standard in the industry.

Newsprint machines usually run faster than machines for printing paper. As their speed increased, however, problems arose with stable operation for pond-type size presses, as shown in Fig. 7.22. Attention focused on the gate roll coater, which had not been particularly popular in Japan until then. Using this gate roll coater instead of a size press greatly improved paper quality and satisfied the strict demands of Japanese newspaper printers. This means that at present there are almost no imports of newsprint rolls.

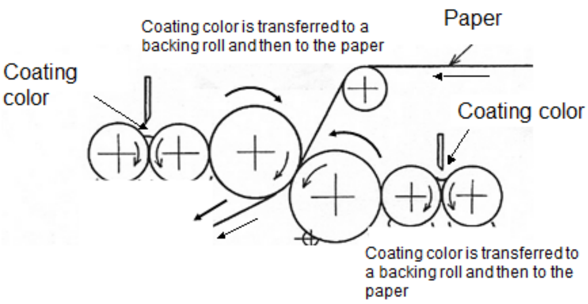


Fig. 7.23. Gate roll-type size press [2].

With the gate roll coater being revived to improve the surface quality of newsprint, new versions which were more suitable for high speed operation were also developed. The gate roll coater also found a new application in producing high-quality coated paper. The chemical agents on the surface, called the coating color, were once simple starches, but are now acrylic latexes that offer functional advantages.

Installing a size press requires additional investment costs and extra thermal energy. The reasons why it offers better cost performance are as follows. While the addition of a size press increases the costs of machine operation, it also offers more choice for selecting the types of pulp to use, which in turn reduces pulp costs and allows machine speed to increase, leading to higher productivity. The most important factor, however, is that newspaper printers can run their printers with higher efficiency due to less accumulation of fiber on the printer cylinders and thus less-frequent washing. The overall productivity gain is quite significant, more than offsetting the increased cost for paper manufacturers. In Japan, both producers and printers could share these advantages. In other words, the end users agreed to pay the additional amount to cover the cost increases in production. This demonstrates that if cost merits gained by users is greater than the cost increases borne by producers, the change will be acceptable for both of them. This mutual trust between them has been an indispensable part of the industry in Japan.

7.6 Process control

Process control technology has been heavily involved in order to operate the equipment efficiently and obtain high quality products.

(1) Widthwise profile control in paper machines

For modern paper machines, widths of 10 meters are common, and their widthwise variations in basis weight are as small as ±0.7 g/m^2, as shown in Fig. 7.3. This sort of small variation in the width direction is achieved by monitoring paper properties such as basis weight, moisture and thickness in the cross direction online and feeding this data back to machine operation. One major contributor to this is the BM monitor (a trademark of Yokogawa Electric Co. that has been genericized in Japan). The use of BM monitor data has greatly advanced equipment for controlling cross directional profiles like those at the slice lip (mechanical adjustment as well as consistency control), at the press part (CC roll and steam box) and at the dryer part. These days, other properties of paper, such as its ash content and fiber orientation, can also be monitored. In addition, monitoring is now done at the wet end or other positions on the machine other than the dry end.

The configuration is shown in Fig. 7-24-1.

Fig. 7.24-1. BM monitor [11].

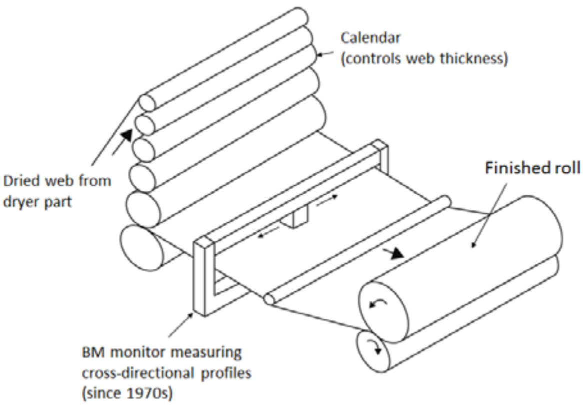


Fig. 7.24-2. Conceptual image of calendar.

A sensor head attached to a frame traverses back and forth across the width of the paper web without contacting it (one minute per traverse). As the paper web is moving under the sensor, data is picked up diagonally, not in a true width direction. However, statistical analysis can allow reliable width profiles to be calculated. In addition, the monitor not only provides real profiles, but also stores data tracked over time and can display this data as needed. The BM monitor has revolutionized paper machine control, and so is now found on almost all machines, even older and smaller ones.

(2) Controlling machine speed

It should be obvious that synchronizing the speed in each part is very important. Unfortunately, limitations of space prevent speed control from being discussed in this paper.

(3) Mill-wide control systems

With the popularity of DCS (decentralized control systems) along with BM monitors, the concept arose of optimizing mill operation as a whole through real operational data. Due to the wide range of equipment that must function in cooperation with each other in a mill, understanding exactly what is happening within the mill is an important tool for increasing competitiveness.

An automatic diagnosis system is currently being developed as a further step from localized operation control to better overall mill management. Preventive maintenance is a subject of great concern for mill operation, and Japan’s high operational efficiency is due to this having become part of the basic culture of mills. This new automatic diagnosis system points the way to future mill management systems.

7.7 Equipment development and contributions from Japanese technology

A range of different technological developments, some of which are not covered in this chapter, have helped to create and modernize paper machines. As the scope and scale of these technologies suggest, the paper industry has not created all these developments alone.

In Japan during the 1950s, paper companies took the initiative in developing equipment, which was actually manufactured for them by five or six iron works. However, as paper machines became increasingly sophisticated, fewer and fewer companies were able to manufacture them. In addition, some of Japan’s most important equipment manufacturers such as Mitsubishi Heavy Industries and IHI Corporation became licensees of European or American companies, so, starting in the 1960s, their focus switched to bringing in overseas equipment to Japanese paper companies. This final section will examine how Japanese equipment manufacturers and Japanese paper companies contributed to worldwide technological development.

Japanese equipment manufacturers had always been able to deliver reliable products and comprehensive after-sales services to their customers. As a result, Japanese paper companies, trusting them, installed this newly-developed equipment before overseas companies followed suit. They were also capable of evaluating the possibilities of this new equipment, and applying it in mill operation, taking on the risks of this investment. For examples, while twin-wire formers and hybrid formers were developed in Europe and America, it was Japanese paper companies and equipment manufacturers that contributed to them operating successfully in mills. The experience and expertise they gained was then spread to other countries (while there are no quantitative records on this topic, discussions with related parties have suggested this was the case). Even then, Japan was already the world's second-largest paper producer after the United States, and its paper consumption was increasing in step with its dramatically increasing GDP. This meant that there were plenty of opportunities for both investing in new equipment and developing expertise in their operation.

Recently, however, there has been an increasing trend towards an oligopoly of equipment manufacturers, and now there are only two paper machine manufacturers, both European, remaining in the market, both of whom are increasing their dominance in technological developments. Moreover, investment in Japan is stagnating, which results in fewer chances to actively try out new technologies and less contribution to global technical developments.

As equipment manufacturers lead developments, the question arises as to what part of these developments the paper industry has been responsible for. In other words, the technological abilities that have allowed the Japanese paper industry to retain its international competitiveness. This question is one of the main themes of this paper.

The answer can be summarized in three categories: exploiting a succession of new fiber resources as discussed in Chapter 6, operating equipment with the world's highest levels of productivity, and maintaining product reliability that is far superior to world standards. Productivity and reliability will be discussed in Chapter 8.

Japan's international competitiveness has been accomplished through cooperation between many paper companies and manufacturers (both equipment manufacturers and chemical and auxiliary materials manufacturers), providing the technological strengths of the paper industry. Paper companies realized what they needed in terms of technology, and informed manufacturers of what they wanted, occasionally urging them to develop better technology. The manufacturers in turn pursued these possibilities, cooperating with paper companies as they saw fit. This indispensable relationship of mutual trust through technological development with related industries, rather than simple equipment, is what has powered development in Japan.

It is possible that technological development based on this sort of mutual trust is one of the characteristics of the Japanese system, seen not only in the paper industry but also in other large-scale process industries. It also can be seen in other types of industry, such as the automotive industry, which works with component manufacturers to makes cars that have some of the best reputations in the world. A single genius may advance science, but technological development is the sum of all the energy of all the people involved.

Bibliography

[1] Supplied by Metso Paper Japan.

[2] *Pulp and Paper Manufacturing Technologies*, vol. 6 Paper Making, p. 56, Dec. 1998, JAPAN TAPPI.

[3] Supplied by Voith IHI Paper Technologies Co. Ltd.

[4] Supplied by Nippon Paper Industries Co.

[5] T. Naito, "Progress of newsprint manufacturing over the last 60 years,"

Hyakumanto, No. 126, p. 25 (Paper Museum).
[6] Supplied by Voith IHI Paper Technologies Co. Ltd.
[7] M. Iijima, “Theories of dewatering and the history of press felt,” in *Preserving and Publicizing the Technological Archives of the Japanese Paper Industry*, No. 8, p. 1, April 25, 2005, JAPAN TAPPI.
[8] H. Someya, “History of press part configuration and press roll design,” in *Preserving and Publicizing the Technological Archives of the Japanese Paper Industry*, No. 8, p. 15, April 25, 2005, JAPAN TAPPI.
[9] M. Ashida, “History of the dryer part and its future,” in *Preserving and Publicizing the Technological Archives of the Japanese Paper Industry*, No. 1, p. 1, Feb. 2004, JAPAN TAPPI.
[10] M. Sumiyoshi, “History of dryer canvas,” in *Preserving and Publicizing the Technological Archives of the Japanese Paper Industry*, No. 1, p. 36, Feb. 2004, JAPAN TAPPI.
[11] Supplied by Yokogawa Electric Corporation.

Some references for paper-making technology are listed below.

References

1. *Handbook of Pulp and Paper Technology*, Jan. 30, 1992, JAPAN TAPPI.
2. *Pulp and Paper Manufacturing Technologies*, vol. 6 Paper Making, Dec. 1998, JAPAN TAPPI.
3. *Pulp and Paper Manufacturing Technologies*, vol. 10 Process Control, April 1992, JAPAN TAPPI.

8 Technological Development Part 3: Production Technology and Mill Operation Culture

8.1 Production Technology: Productivity and product reliability

This paper has presented a typical model of technological development in the paper industry through the history of newsprint production. There is no doubt that production technology is one of the factors making the industry internationally competitive. Production technology is the provision of high productivity equipment (equipment productivity) that is operated efficiently (operating efficiency) to manufacture products that are reliable and cost-competitive (cost performance). This chapter will analyze the production technology of the Japanese paper industry from these three points.

8-1-1 Equipment productivity

In Japan, the price of paper in general has been largely constant, without major price hikes, over the last forty years, a situation which was forced by international competition. Meanwhile, the amount of production has increased fourteen times, and the costs of raw materials and labor have also increased. Despite these factors, the price has been kept almost the same by increasing productivity, such as installing larger and faster equipment that requires less labor. This is of course not limited to the paper industry, with other industries like steel having done the same. As discussed in a previous chapter, the first continuous kraft plant was installed in 1953, with a capacity of some 100 t/day. Modern plants now produce up to several thousand t/day. Similarly, the widest and fastest paper machines in the 1960s were 7 m wide and ran at 600 m/min, and now they are 10 m wide and run at 1,800 m/min.

Japan once led the world with this sort of investment in high-speed, large-scale machinery. Now, however, it lags behind countries like China and Brazil. As a result, Japan currently operates medium to large, rather than the largest, paper machines, but does so with high efficiency to produce paper with high reliability. In Japan, production technology is developed to allow the country to remain internationally competitive. The other characteristic of Japanese industry is its investment methods, different from that of scrap and build. While investing in new, large paper machines, the industry is still operating older, smaller machines. This combination machine sizes serves to supply the range of products demanded by the domestic market, which is sensitive to quality. But these smaller, older machines and equipment are destined to disappear soon.

8-1-2 Operating efficiency

One characteristic of the Japanese paper industry is that it operates a range of machines, from large to medium, at high efficiency: their overall efficiency is more than 90% in most cases (see Chapter 11), a rate which is very seldom seen overseas. For example, the figure quoted by machine manufacturers in their leaflets is 70–85%. In the process industries, high operating efficiency means that, as a direct return, total sales against investment are improved. However, there is an additional meaning. In paper mills, the running efficiency of the paper machine (the final stage of material flow) has a major effect on total mill efficiency. When a sheet breaks in a paper machine, operation must be restarted as soon as possible. Until the machine is restarted, pulp stock keeps getting fed to the machine, but as it cannot be used, it has to be returned to the storage tank. There is also a lot of wasted paper around the machine. Thus, every time a sheet breaks, steady operation has to stop, and product quality fluctuates (causing defective products) until normal operation resumes, causing total losses far greater than just time. Moreover, the waste paper stuck to the machine has to be cleaned off, which is a very labor-intensive task.

The frequency of sheet breaks is quite low in Japan, averaging about several times a month, a tenth of the world average. This means that the operating efficiency is very high. Conversely, should there be no sheet breaks at all, all production lines leading to it would be steady and there would be no need for emergency action. Utilities like power and steam would also be able to be operated at optimal efficiencies. Product quality would be stable and yields would be maximized. This means that production costs would be minimal while the volume produced will be maximal. This creates greater revenue than just increasing production.

This technology is noted for an operational management that is dependent on a highly-skilled workforce.

Operating efficiency means that paper machines must be good, but their efficiency will only increase when the mill as a whole is properly managed. In Japan, operation of a mill as a whole in this sense is based on well-established expertise. The issue for the next generation will be to systemize that expertise in the form of Japan's unique management routines. This topic will be discussed further in Chapter 9.

8-1-3 Product cost performance

While not isolated to the Japanese paper industry, one of its characteristics is that its products offer high cost performance, which lets domestic products remain competitive against imports. For example, newspaper printers are vulnerable to sheet breaks during printing, so count the frequency of sheet breaks per 100 rolls as an indicator. Newsprint produced in the United States breaks several times (perhaps 3 or so) per 100 rolls as an average. In Japan, however, the sheet break rate is less than one per 1,000 rolls. This difference is not due to the physical strength of the newsprint (as might be measured in a test lab), as the physical strength of the Japanese product is no greater than that of the American. The difference is due to careful operation, such as reducing defective spots in the sheet by removing foreign matter and maintaining even property profiles across the paper width and movement direction.

This falls under a type of operating expertise, using the latest process control technology, which undeniably improves product reliability. Product reliability does need a certain level of investment to improve it, and this investment does increase the cost of the products. This is why domestic newsprint is more expensive than imported, as significant money has been invested to modernize newsprint production (these ways include strengthening contaminant removal, converting machines to twin-wire types, introducing size presses, and installing the latest profile control for consistency adjustment). For printers, however, reliable newsprint gives them higher printing efficiency with less labor, and in some cases they could reduce the number of printing machines they needed. If the gain from reliable products is greater than the cost increase of buying it at higher prices, then printers will choose buying the reliable product despite its high price. This is the concept of cost performance. To supply products with high cost performance means to improve the efficiency of the social system as a whole. This high cost performance for products is what has supported industry in Japan as a whole, the paper industry among them.

8-1-4 Future issues

Equipment manufacturers have recently developed an interest in production technology, and are now supplying equipment controlled using automated systems based on operating expertise. This operating expertise is one of core technologies by which Japanese industries has been able to become globally competitive, and is now incorporated in manufacturer systems, akin to a "black box", for supply to anywhere in the world. As an example of how this back box system works, China, a latecomer in terms of modern paper manufacturing, currently does quite well operating some of the world's largest and newest paper machines, despite their lack of operational experience. This has meant a significant erosion of competitiveness for Japan, which is an issue the country must now face.

8.2 Mill operation culture

8-2-1 Image of a large paper mill

This section will present an image of a large pulp and paper mill that manufactures 3,000 tons of newsprint and printing paper a day. Each paper roll weighs about one ton, and so each day 3,000 rolls are shipped out by truck from the mill.

The mill covers about one million square meters of land, meaning that vehicles are used to move around it. It consumes about 4,000 tons of fiber sources (wood chips and recovered waste paper) a day, along with 1,200 tons of coal and 500 kL of oil. Water is a vital part of paper making, and this mill uses about 300,000 cubic meters a day. All these materials need to be brought into the mill every single day, and there is also an additional week's worth of each stockpiled in the mill. In the wood yard, wood chips are piled and stored in different areas, based on their tree species and country of origin. These chips are mixed in accordance with instructions from the pulping section and sent out to be pulped. Waste paper, another important resource, is also stockpiled according to quality, and sent on to the repulping plant as needed. There are usually a few pulping lines for pulp and repulping, with each line producing pulp with particular qualities, and these different types of pulp are distributed continuously to multiple paper machines. Each paper machine blends this pulp with other additives to produce its own type of paper, based on the mill management plan. In other words, pulping lines and paper machines are coordinated with each other, allowing them to change the quality of their output in accordance with instructions from the mill management. The manufactured paper rolls are stored in a warehouse and shipped out when an order comes in. Normally, this warehouse would stock about one week's production.

8-2-2 Mill operation culture and mill management culture

An indispensable part of mill management is to coordinate all operations, from bringing in stock to delivering products. This is especially necessary in large-scale process industries. This efficient operation of a plant as a whole is something Japan typically excels at. The same applies to paper mills in Japan, and their operating efficiency, an indicator of how well coordination is carried out, is outstanding (see Chapter 8.1).

There is no particular secret behind this high level of coordination; no special equipment nor extraordinary genius. The equipment is simply maintained as it should be, and the workers acknowledge the shared objective of the mill. The mill being kept clean and tidy is also due to the shared culture of the mill. However, this system cannot be built in a day: it takes a long time to establish a culture like this. Prior to writing this paper, the author interviewed a number of experienced paper mill engineers, who agreed with this understanding. While some readers may wonder if this is a type of technology, it could well be so, as it helps to improve the operating efficiency of the mill. The famous just-in-time system, the "Kanban system," Toyota invented is certainly a type of technology, as it improves efficiency and produces profit, and establishing an operating culture is the same.

8-2-3 Introducing operating culture overseas

Could this type of technology, which at first glance appears to be Japanese culture, be introduced overseas? This is a difficult subject to evaluate qualitatively, and so what follows are from the author's experiences and from discussions with acquaintances.

Historically, the management system used in Japanese paper mills has been introduced to Taiwan and Korea through personnel exchange. Most paper mills in Taiwan are managed similarly to Japanese mills, and carry out small group activities and meetings just as in Japan. From about 2000, China started to install large paper machines, expecting huge future demand. Taiwan provided a large number of managers to manage these mills and technicians to operate their machines, thus bringing over Japanese mill management systems to China as well. The author visited one large paper mill in China in 2006. Its managers were from Taiwan and the mill looked like one in Japan;

it was kept clean and had a poster showing the mill's small group activities; its operating efficiency looked to be close to that of Japan. The next Chinese mill visited was run using Finnish investment, with a Finnish manager, and the mill looked like one in Europe

In Canada and the United States, mills supported by Japanese investment incorporated Japanese management systems, and showed improve performance as a result. Some of these mills include Norpac Co. (Nippon Paper Industries Co.) and How Sound Pulp and Paper Co. (Oji Paper Co.). In other parts of the world, Hokuetsu Paper Co. provided support for APP Co.'s Indah Kiat mill in Indonesia, which reports say is operating smoothly.

In this way, the mill management systems developed in Japan are becoming management culture in other parts of the world.

The technological developments in newsprint manufacturing have been discussed in Chapters 6 through 8. Newsprint manufacturing competitiveness depends both on those technological developments and also on the capability of the mill as a whole in other technical areas, a topic which will be discussed in Chapter 9.

Bibliography

[1] K. Iida, "History, characteristics and ecology of pulp and paper industry," *JAPAN TAPPI Journal*, vol. 55, No. 4 p. 417, 2001.

[2] K. Iida, "Technological developments in the Japanese paper industry," *JAPAN TAPPI Journal*, vol. 61, No. 4, p. 393, 2007.

9 Other technologies in the paper industry

Newsprint manufacturing is only one of the operations carried out by mills, so the levels of technologies in areas other than paper-making have a considerable impact on the cost and quality of newsprint produced there. For example, energy costs are about 10 to 20% of the total cost in newsprint production, so if the mill's energy unit price can be reduced, newsprint will cost less to manufacture. In addition, effluent and exhaust gas disposal, while not directly related to newsprint production, has to be managed properly to ensure steady mill operation. For these reasons, the levels of these secondary technologies also need to be kept as high as possible in order to make newsprint competitive. This chapter discusses the technological developments in these areas.

9.1 Energy-saving technologies

The idea that the paper industry, one of the larger process industries, consumes a lot of energy is not actually based in fact. What follows is a breakdown of energy consumption per sector in Japan as of 1997 [1].

Industry sector: 49 %
Public and household sector: 26%
Transportation sector: 25%

The industry sector is broken down as follows.
Chemical industry: 13%
Steel industry: 12%
Cement industry: 3%
Pulp and paper industry: 3%
Other: 18%

Of these industries, the paper industry utilizes energy in a unique way. Manufacturing plants in general are powered by electricity, which is generated by steam produced from fuel. In this case, less than 40% of the potential energy of the fuel is converted to electricity. Paper mills have their own power plants, so they can generate electricity to operate their equipment and use the remaining low pressure steam to dry paper using the paper machines. This means that the total rate of energy utilization is very high, around 70%. In addition, when wood chips are chemically pulped, about 50% of the wood (biomass) becomes pulp and the rest is recovered as waste liquor. This waste liquor is condensed in evaporators and then burned in recovery boilers to recover the chemicals. This combustion, done at high temperatures and pressures, produces high-pressure steam that is used for generating electricity. Thus the energy produced from the unused parts of wood (classified as biomass energy) provides about a third of the industry's total energy consumption. This means that the paper industry is characterized by both a high rate of energy utilization and effective biomass utilization. Nevertheless, saving energy has still been an important issue in the industry, and much effort has been devoted to the development of this technology category.

Japan's energy utilization is very distinctive when compared to that of other countries. Though comparing electricity prices directly is difficult due to fluctuations in exchange rates, power in Japan is generally more expensive. As a result, technical developments in the energy sector have been aimed at lowering power consumption.

The Japanese paper industry has been working on reducing both energy prices and unit energy consumption. A rough estimation suggests that the Japanese paper industry produces paper using two-thirds of the unit energy consumption in the United States. This has been made possible not through revolutionary technologies, but through steady efforts to reduce energy consumption, as detailed below.

(1) Investment by management
A range of different investments have been made to reduce the unit price of electricity. These include increasing power self-sufficiency in mills by installing power plants (big mills are almost 100% energy self-sufficient),

promoting co-generation (effective use of low pressure steam), and installing high-efficiency recovery boilers (better utilization of biomass energy). Manufacturing equipment has also been replaced by equipment which consumes less energy. These investments were not just about saving energy, but also ensure that equipment was modernized at the same time, leading to mill operations becoming increasingly stable and efficient: a change, which, needless to say, also saved them energy. Inverter controls were also added to every large electric motor as a way to improve the unit energy consumption of equipment. This trend towards equipment investment was further driven by the high cost of mains electricity.

(2) Energy-saving efforts in mills
Minor savings at the small group activity level accumulate to major savings for the mill as a whole. To give an example, the process from pulping to paper making is a continuous process, and to ensure steady operation, the process involves a number of pulp slurry storage tanks in the process. Those storage tanks are agitated by a stirrer, and so keeping the level of stock in a tank as low as possible saves circulation energy. After the first oil price hike, every mill started doing this for all its storage tanks. Overall mill efficiency was improved as a result, though it required careful, detailed management. Reducing the volume of stock in the tanks also meant that impellers could be made smaller, further saving energy. These sorts of actions eventually added up to the development of energy-efficient mills, allowing them to maintain competitiveness.

JAPAN TAPPI has published statistics for unit energy consumption at every stage of operation in 1979 [2], 1989 [3], and 1999 [4]. Unfortunately, there is little data available from other countries, so they cannot be compared.

9.2 Technology to preserve the environment

Japan is a densely packed country in which the Japanese paper industry produced the second-greatest amount of paper and paperboard in the world, until China's output exploded several years ago. Mills are located all over the country, with many of them close to urban areas.

Fig. 9.1. Mill in an urban area [5].

This creates a different environment to other countries. Historically the paper industry caused a number of environmental problems, but during the years from 1970 to 1990 the industry invested huge amounts of money in protecting the environment, and now it meets the world’s severest restrictions in categories such as effluents, gas emissions and noise. The industry provides a model of sustainable development in a crowded country with so many people producing goods to create the second-highest GDP in the world. Japan just manages to stay ahead in protecting the environment, and so is far from lagging when it comes to these issues.

The Japanese paper industry is the most ecological in the world. Its unit energy consumption for paper manufacturing is believed to be the smallest in the world, which means that the least amount of carbon dioxide is emitted during paper manufacturing. The recycle rate of waste paper, more than 70%, is probably in the minimum zone of environmental load predicted by LCA (life cycle assessment).

The Japanese paper industry started treating effluent somewhat earlier than other counties, reducing SS, COD and BOD discharges. As a result, Japan is the only one of the major paper producing nations that did not suffer from dioxin pollution, while Scandinavian and North American countries were, forcing them to prohibit fishing and warn against eating fish from polluted areas. While there are differences in the production processes, Japan was able to remain unaffected by this problem thanks to the significant investments in environmental conservation its paper industry had been making since the early years.

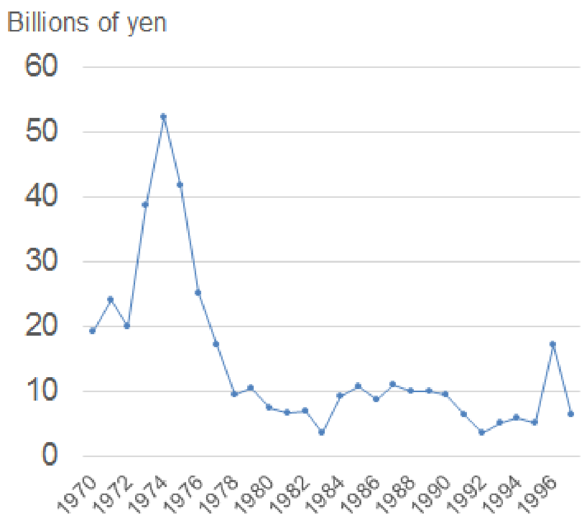


Fig. 9.2. Financial investments in environmental conservation [6].

Dealing with environmental problems, however, has not been so scientific, and was done through installing equipment largely to pass targeted numerical levels of pollutants. Recent environmental problems are more difficult to tackle, however, as they are intertwined with other phenomena that affect daily life such as global warming and hormone-disrupting chemicals. Rather than simply setting acceptable values, scientific proof and evidence are required to deal with them.

These technological efforts have helped mills to operate efficiently, making the paper industry globally competitive. They also represent some of the characteristics of Japanese industry as a whole.

9.3 Research and development

Though the Japanese paper industry did not develop equipment that was noticeably innovative, it managed to expand its output through creatively improving what it could, in spite of its handicaps in terms of fiber and energy sources. Newsprint production provides a typical example, suggesting that Japan has some degree of research and development capability, and has provided enough manpower to carry it out. Though this statement is based on personal information rather than firm data, it does appear that Japanese paper companies assign more manpower to R&D than paper companies in other countries, and it is probably this greater manpower in R&D that has enabled the industry to expand and grow.

Japanese companies have made investing in improving the quality of their product (paper) their first priority. To show an example, the fierce competition in the coated paper market in Japan means that four paper companies have their own high speed pilot coaters, while only one coater is available in laboratories in Scandinavia and probably none in North America (based on information from 1998: more recent information is unavailable). Japanese companies are also leading in developing high quality thermal and inkjet printing paper products. The efforts put into satisfying customers' sometimes extreme requests have improved the cost performance of products in general and made them competitive against imports. Newsprint production in Japan is a typical case of this effort.

Japanese paper companies are, however, trimming technical staff now. If this continues, there are serious concerns that Japan's technological capability will be negatively affected, which would mean that new product development and international competitiveness will be weakened, and finally the paper industry itself will be in danger. The issue facing the industry is how to increase the efficiency of its technical staff.

Another question is how many researchers there are in public institutions and universities compared to other countries. Each year, JAPAN TAPPI surveys the research topics carried out on wood chemistry and other areas by public institutions and universities and publishes the results in its journal. Quite a number of researchers are involved in this area. However, there are few topics that are related to the paper industry, and research on the paper making process is quite rare [7]. Moreover, universities are now officially classified as independent administrative corporations, and university researchers note that it is difficult to obtain government research funds on subjects relating to the pulp and paper industry. There is a problem in terms of coordinating research among government, academia and industry here, which is not managed as well as in Finland, for example. An analysis needs to be carried out on the reasons why it does not work, and this area remains a major topic for study.

9.4 Education and training

Newsprint production in Japan has been able to remain internationally competitive due to the advanced technological capabilities of the mill as a whole, rather than relying solely on the latest equipment. Technical education and training have played an important role here. It is the understanding of the author that Japanese mills have more technical staff and maintenance crews than mills in other countries. As every mill manufactures its own range of products, it is difficult to compare them on a simple basis, especially as these statistics are not published. However, more manpower in technical jobs means higher labor costs. The question then arises, of course, of the return on these higher costs.

It is the author's belief that the large number of technical staff in mills is one of the characteristics of the Japanese system; one that has definitely produced returns. As mentioned in the discussion of newsprint production, business circumstances such as requests by clients, fiber source supplies and equipment renewal are always changing, and it is how they have been dealt with that has created the industry’s international competitiveness. For example, when a mill decides that it must use more waste paper, each mill has to have its own supply network, depending on its location. They have to plan what type of waste paper they should collect, and how much they should collect; the type of equipment they should select and what its capacity should be. They need to evaluate how the fiber from waste paper affects both paper machine operation and the final product quality; determine how to deal with any effects this has and how to proceed with trial operation or test printing by the user before investing in equipment. In most cases, these are new initiatives without any existing models to refer to as they forge ahead into new areas. This is precisely what happened with newsprint production in Japan, and it happened for other paper products as well. The force behind all this has been the technical staff in the mills.

Operating a mill efficiently requires maintenance staff who are both capable and responsible for maintaining equipment. This is different from mills overseas, where maintenance work is usually outsourced.

The large numbers of technical staff in mills means that R&D can be done through coordination with suppliers such as equipment and chemical companies. The cases described in Chapters 6 and 7 are examples of successful cooperation.

Technical staff are trained by their companies in a range of ways. Information is also exchanged among mills extremely frequently. From the standpoint of information exchange, the high number of mills in a relatively small country like Japan is advantageous, as the cost of exchange is far less than in countries like the United States, Canada or China, where mills are located all over the country. For example, if a conference is held in Tokyo, participants from all over the country can arrive in Tokyo in just two hours, something which is impossible in the United States or China. This is an advantage for Japan that cannot be put into hard figures.

Technical education and training in Japan has been developed in a uniquely Japanese manner, based on the country’s traditional lifetime employment system and geographical characteristics. This employment system is changing now, however, and so the education system may have to change as well.

Bibliography
[1] A. Takahashi, "Energy situation of the pulp and paper industry in 1997," *JAPAN TAPPI Journal*, vol. 53, No. 4, p. 64, 1999.
[2] Energy Committee, JAPAN TAPPI, "The first survey on energy consumption," *JAPAN TAPPI Journal*, vol. 33, No. 1, p. 110, 1979.
[3] Energy Committee, JAPAN TAPPI, "The 6th survey on energy consumption," *JAPAN TAPPI Journal* vol. 44, No. 5, p. 447, 1979.
[4] Energy Committee, JAPAN TAPPI, "The 7th survey on energy consumption," *JAPAN TAPPI Journal*, vol. 55, No. 5 p. 573 and vol. 55, No. 6, p. 737, 2001.
[5] Supplied by Nippon Paper Industries Co.
[6] *Pulp and Paper Manufacturing Technologies*, vol. 12, Environment, p. 13, May 2002, JAPAN TAPPI.
[7] Wood Science Committee, JAPAN TAPPI 2006, "Research projects of universities and government research institutes," *JAPAN TAPPI Journal*, vol. 61, No. 5, p. 584, 2007.

The following article was also referenced in compiling this chapter.

Reference
1. K. Iida, "Technological developments in the Japanese paper industry," *JAPAN TAPPI Journal*, vol. 61, No. 4, p. 393, 2007.

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10 Summary: International comparison of paper industry business models

Finally, this chapter covers the business models of paper industries in other countries as a way to better understand the characteristics of the Japanese paper industry.

(1) Brazil

In Brazil, eucalyptus trees are planted in vast plains and harvested before being replanted, in a seven or eight year cycle much like growing crops. The chips from this eucalyptus wood are pulped in some of the world’s largest digesters (5,000 tons per line per day, as shown in Fig. 6.6) to produce bleached kraft pulp. This is sold to paper companies around the world which lack their own pulp sources. These eucalyptus plantations were planned from the beginning to supply wood to pulp and steel manufacturing. The decision-making behind such a large project is definitely a type of technology.

(2) The U.S.A.

With its ample resources, the United States is the world’s largest paper producer. Its advantage comes from having developed a unique form of wood use that produces timber and makes pulp from waste wood. While Canada has excellent softwood for newsprint production, such as spruce and fir, softwood in the United States, such as Douglas fir and pine, is not suitable for newsprint. However, these species grow fast and are widely used as housing timbers. Douglas fir forests can easily be planted and harvested in the United States, and the resulting logs are sawn to timber first, with the residual waste chipped for kraft pulping. The kraft pulp is then sheeted to form linerboard. Linerboard made from Douglas fir kraft pulp is rigid and strong, and is the best material for the linerboard of corrugated container. As a result, American linerboard currently predominates worldwide.

(3) Finland

Finland has abundant, good quality softwood, which it is using to expand worldwide. Up until the 1980s, their mills were small, and Finland was not a major presence in the industry. However, following the depression of the 1980s, the country formed a national policy of supporting industry, academia, and government links to promote R&D, and also promoted scrap and build in mills to make them suitable for large-scale production. They use their top-quality spruce to manufacture products such as lightweight printing paper and coated paper. Thanks to smoothly-functioning industry, academia, and government R&D coordination, they sell the machinery and equipment they developed to customers around the world.

(4) Germany

Early in the 20th century, Germany was the largest paper producer in Europe, boasting the most advanced technology of the time. One of the German technical journals for pulp and paper at that time published around 4,500 A4 pages a year during this time. Germany used fir forests as their pulp source and had a big market in Europe. However, due to environmental concerns, they prohibited the construction of kraft plants in the country. The kraft process was notorious for its smell, and no countermeasures were available at that time. This decision prevented Germany from expanding as much as other countries, and its former glories were lost.

In this way, every country developed its own unique business pattern, using its circumstances as best it could. In comparison, Japan could be summarized as follows.

In the 1950s and 1960s, paper consumption in Japan was about 3 million tons a year, a tenth of the present consumption, and only domestic wood was used as fiber sources. Mills that could produce some 100 to 200 tons a day were located in different areas around the country to utilize the wood growing near the mills. As demand increased, companies increased their capacities. This had the result of reducing the wood supply, and the price of paper went down due to competition caused by excess capacity. In addition, import duties on pulp and paper were gradually removed. This meant that competing against imported products became a common issue for the industry as a whole, so R&D was started for survival reasons. One technology which had a decisive influence on the Japanese model was to transport chips from overseas to Japan using specially-designed ships. Freed from a reliance on the domestic wood supply, mills could now use large-scale machinery and equipment, and integrate all stages, from pulping to paper making, in a single plant. As a result, mills for newsprint and printing paper were sited near ports large enough for bulk carrier vessels to berth at, and huge mills were constructed, as big as any in the world and with capacities in excess of 3,000 tons a day.

With over a hundred million people living on relatively little habitable land, and one of the highest consumption rates per capita (240 kg/per capita) of any country, there was a massive amount of waste paper generated, which could be collected easily. After 1980, the industry was interested in using more waste paper as a source for dinked recycled pulp, a change which made the industry even more competitive. Technological breakthroughs such as large coastal mills and the use of waste paper demonstrated the technological capabilities which have allowed the Japanese paper industry to remain one of world's largest.

In addition to this resource management, technological capabilities in manufacturing have helped the Japanese paper industry. These manufacturing technologies include the installation of highly productive equipment (equipment productivity), efficient operation (operating efficiency), and the provision of reliable, cost-competitive products (product cost performance). The first to be discussed here is productivity. Many of Japan's major equipment manufacturers became licensees of European and American paper machine manufacturers during the 1960s, after which machinery and equipment developed overseas was brought into Japan, earlier than other countries. The Japanese paper industry's willingness to bring in new equipment ended up renovating their machinery and improving its efficiency. For example, in the 1950s, paper machines in Japan were about 3.5 meters wide and ran at about 300 m/min. Now, in 2000, there are machines that are 10 meters wide and run at 1,800 m/min. When new machines were brought in, the abilities to evaluate this new equipment and put it into operation were needed, as was the management will to take these risks. In the course of these innovations, the paper industry worked with manufacturers on modifying and improving the equipment, rather than merely being passive users. There have been many techniques developed in Japan through this cooperation with manufacturers that are now common worldwide. This process shows the level of sincere trust between manufacturers and users.

One of the characteristics of Japan's technology is that equipment operation is highly efficient. It is quite normal in Japan to operate paper machines at an overall efficiency of more than 90%, which rarely seen elsewhere in the world. That figure is possible thanks not to just the efficient operation of paper machines but by properly managing a mill as a whole, including other process equipment, based on a culture that has been nurtured in mills over many decades. This mill culture is gradually becoming more and more common overseas through the use of technology exchanges and direct investment overseas.

The other characteristic is product reliability. As mentioned before, newsprint is a good example. While newspaper printers in Japan have stricter demands for product quality than other countries, the Japanese attitude of prioritizing customer satisfaction has encouraged R&D and produced a reliable product that is unique in the world. As a result, while newsprint is an international commodity, very little is imported to Japan.

In this way, the Japanese paper industry has built itself a unique place in the world, but it is now confronted by a new problem. Paper consumption (including newsprint) in Japan increased in pace with the GDP, and the paper industry was focused on ensuring footholds in the growing domestic market.

However, as the domestic market is not expected to expand much from this point, the industry will be forced to expand internationally to grow. For this to be a success, Japan needs new technological capabilities which will both satisfy the strict demands of domestic customers and also deliver products at internationally competitive prices.

Bibliography

[1] K. Iida, “Evolutional developments in the history of the Japanese pulp and paper industry,” Pulp and Paper Symposium, Dec. 2003, Pulp and Paper Research Committee.

11 Operational data for a typical newsprint machine

11.1 Introduction

This chapter will discuss the operational data for a single newsprint machine over a forty year period. When it was installed in a Japanese mill in 1960, this paper machine was one of the biggest in the world at the time. Since then, paper machines have become increasingly wider and far faster, but this paper machine is still in operation today, fitting in as a medium size machine under the present standards, but is run at the highest levels of efficiency, allowing it to produce the finest quality newsprint rolls. The operational data of this paper machine over the past forty years has been made public by courtesy of the mill management to show how technologies were developed in newsprint production.

This paper machine is the No. 6 newsprint machine in Nippon Paper Industries Co., Ltd.'s Kushiro Mill. When the machine was installed, its design was considered revolutionary, as can be seen from the materials supplied by its manufacturer, Mitsubishi Heavy Industries Ltd [1]. The operational data has been summarized from three viewpoints: (1) machine modifications history, (2) production efficiency history, and (3) product quality history.

11.2 Machine modifications history

Historically, the Japanese paper industry modified then ran older paper machines in parallel with the installation of large, up-to-date machines to cope with steady increases in demand. Modifications used the newest technologies of the time to improve productivity and product quality, and maintain competitiveness. Repeated modifications, which required relatively small investments in general, allowed the industry to react quickly to the market's changing requests. It was quite a Japanese way, being quick and adaptable in nature, and different from that of Scandinavia, which was mostly a scrap and build style.

Actual examples are provided by Document 1 (Machine Modifications History). The newsprint machine was frequently remodeled through the installation of what were then new technologies. Auxiliary materials, such as wire, felt and canvas, were also modified, and the pulp types fed to the machine also changed as pulp resources diversified. These facts suggest flexible and adaptable management of operation on the part of the mill as a whole.

In terms of specific figures, the machine was designed to run at 606 m/min, but was remodeled to 1,200 m/min through upgrades to the drive unit, allowing it to run at 1,050 m/min. The records show when new technologies were put into practice and, at the same time, the characteristics of technology development in Japan.

11.3 Production efficiency history

Document 1, which contains the yearly newsprint output of the machine, shows that there was a drop from 1991. One reason for this decrease was that products other than newsprint were also produced on this machine, and their volumes are not included in the figures. The other reason was the trend towards newsprint with lower basis weights, which resulted in a lower tonnage output for the same square area. For these reasons, Document 2 (Production Efficiency History) can more reasonably be seen as the productivity history. The machine's speed increased gradually, jumped up after major modifications and then increased incrementally. This gradual increase was achieved by continuous, steady development in operational expertise, one of the characteristics of Japanese mill management. Also note the number of operators (Document 1). When the machine was first put into use, it had a total of 48 operators in a three shift system, consisting of 13 operators per shift plus 3 assistants per shift. However, by 2008, it only required a total of 20 operators in a four shift system with 5 operators per shift. This reduction was greatly helped by the introduction of mill automation, such as in winder operation, and these efforts to increase reductions are ongoing.

The overall efficiency of the machine as shown in Document 2 is also noticeable. Overall efficiency is the ratio of the volume produced with acceptable quality against the volume which should be produced within the planned operating time. This ratio exceeded 90% within three years after start-up (1963), and reached 95% by 1977. Paper machines in Japan are commonly referred to as being run with high efficiency, but no data has ever been published to demonstrate this. This is, therefore, the first case in which data, especially dating from when the machine was first started up, has been made public, and subsequent access to this data should be of great value to future researchers.

11.4 Product quality history

Document 3 (Product Quality History) show how a certain level of quality has been maintained throughout despite the frequent changes of pulp sources and the steady reduction of basis weight. At one stage there were specifications on paper strength agreed on with newspaper printers, but these were discontinued in the 1980s, and replaced as an index by the sheet break rate on the printing press.

As newsprint became lighter, sheet thickness, density and opacity were also being reduced. Opacity was greatly improved through the neutral sheet forming described in Chapter 6-1-6, while paper strength increased through greater use of DIP, which contained kraft pulp to give better strength. It is clear how the sheet properties that were measured changed to suit newspaper printers' shifting quality demands. The reason that the coefficient of friction was listed under quality control is that this coefficient measured the degree to which newsprint was prevented from slipping during handling.

One influential change was the conversion to neutral sheet forming (Chapter 6.1), dramatically improving opacity and brightness. It will be interesting to see where this trial, unique to Japan, will end up.

The most important measure for quality is the sheet break rate announced by newspaper printers. This rate cannot simply be explained by the physical strength of paper as measured in test labs. As discussed previously, the expertise in operating mills such as maintaining steady operation and reducing accidental defects in rolls plays an important part. In addition, the appearance of the printed image is also an important index.

11.5 Summary

These specific operational records can be analyzed from various perspectives and will be helpful in studying the history of technology.

Documents: History of the No. 6 paper machine at Nippon Paper Industries Co.'s Kushiro Mill

1. Machine Modifications History ········p. 71
2. Production Efficiency History ··········p. 72
3. Product Quality History ·················p. 73

Bibliography

[1] "Newsprint machine capable of four A rolls installed in 1960," in *Preserving and Publicizing Technological Archives of Japanese Paper Industry*, No. 6, p.1, Oct. 13, 2004.

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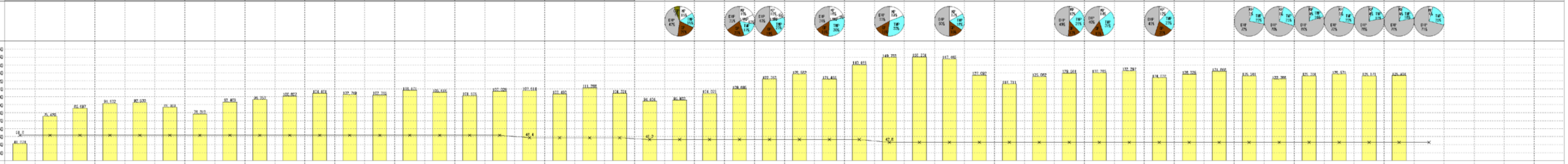
Document 1. Machine modifications history of the No. 6 newsprint machine in Nippon Paper Industries Co., Ltd.'s Kushiro Mill

Revised on Jan. 29, 2008

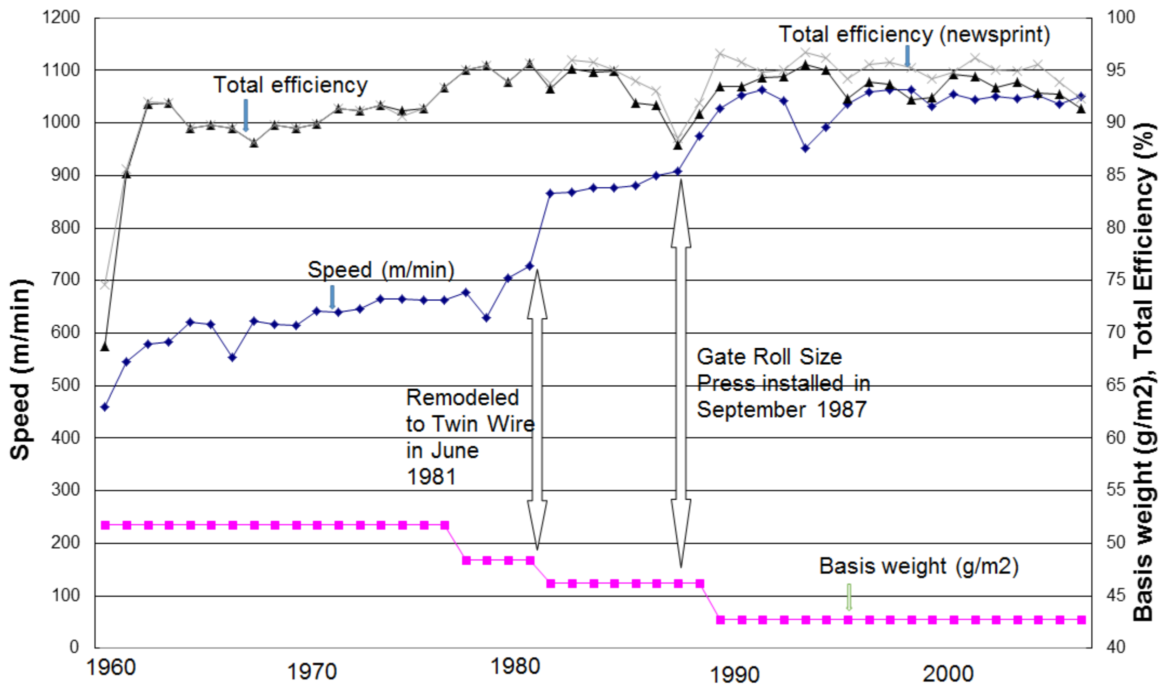
Year	Age	Mill Topics	Pulp	Drive	Wire	Felt	Canvas	Number of operators	Modifications to machine
1960	0		CGP: 1958 -	700 m/min	Bronze Nippon Filcon Co.	Woven felt	Woven canvas	13 operators/shift (+ 3 assistants/shift)	Started in June
1961	1			→	→	→	→	→	
1962	2			→	→	→	→	→	
1963	3			→	→	→	→	→	
1964	4			→	→	→	→	→	Machine speed: 660 m/min (May)
1965	5	7M/C started		→	→	Cotton yarn	→	→	
1966	6			→	→	→	→	→	
1967	7			→	→	→	→	→	Screening system modified (Yanson screen installed) Calender rolls modified (increased diameter) Heat recovery system modified (dryer hood fully enclosed)
1968	8		RGP: Installed	→	→	→	→	→	
1969	9			→	→	→	Spun type	→	
1970	10			→	→	→	→	→	Inlet slice lip replaced Modification to No. 1 dryer part
1971	11			→	→	→	→	10 operators/crew (introduced a 4 crew 3 shift system)	
1972	12			→	→	→	→	→	
1973	13			→	→	→	→	→	#3 press modified to Venta-nip
1974	14			→	Plastics (single) Hyke (Germany)	→	→	→	Improved foil arrangement in wire part
1975	15		SP: Ended in Oct. KP: Installed TMP: Installed	→	→	→	→	→	
1976	16			→	→	→	→	9 operators	Labor-saving modifications BM monitor installed Press rolls modified to CCR
1977	17	8M/C started	RGP: Ended in June	→	→	→	→	→	
1978	18			→	→	→	→	→	
1979	19	Newsprint imported from Norpac	1DIP: Installed	→	→	→	→	→	Calender rolls modified to CCR
1980	20			→	→	→	→	→	
1981	21	Short-term operation		1,000 m/min	#1 LL 2.5 layer #2 ? ? ?	Multifilament	Multi type single	6 operators	Replaced Fourdrinier with Twin Wire (Bel-Baie) Installed automatic reel change system Introduced start-up/shut-down instrumentation Replaced screen in front of machine (Iruha)
1982	22			→	→ SS 2.5 layer	→	→	→	
1983	23			→	→	→	→	→	
1984	24			→	→	→	→	→	
1985	25	4M/C ended		→	→	→	→	→	
1986	26			→	→	→	→	→	
1987	27			1,010 m/min	TT 3.5 layer LL 2.5 layer	→	→	→	Installed size press (gate roll type) Installed rotary siphon in dryers Upgraded BM monitor Upgraded winder
1988	28			→	→	Piled mono + single mono	→	→	Installed spot detector (contaminates on sheet) Installed calto-roll for calender Replaced head box
1989	29			1,050 m/min	→	Piled mono + Piled mono	→	→	Installed Aquato-roll in dryer part (moisture profile control) Replaced screen in front of machine (Iruha to Rameau–Aikawa)
1990	30			→	→	→	→	→	
1991	31			→	→	→	→	→	Installed wire outside roll
1992	32			→	→	→	→	→	Upgraded start-up/shut-down instrumentation
1993	33			→	→	→	→	→	
1994	34			→	→	→	Multi type	→	
1995	35	5M/C ended		→	→	→	→	→	
1996	36	NBKP started		→	→	→	→	5 operators	Installed belt for sheet transfer Installed automatic splicer in winder operation Installed automatic core feeder in winder operation
1997	37			→	→	→	→	→	
1998	38			→	LTT 3.5 layer →	→	→	→	Installed double doctor at the top roll of #3 press Press center roll converted to ceramic Installed double doctor at the top roll of #3 press
1999	39			→	→ TT 3.0 layer	→	→	→	
2000	40		GP: Ended in Dec.	→	→	→	→	→	Installed automatic winder spacer
2001	41			→	→	→	→	→	Changed to stationary siphon at pre-dryer
2002	42			→	→	→	→	→	
2003	43			→	→	→	→	→	
2004	44			→	→	→	Flat mono type	→	Upgraded BM monitor
2005	45	Neutral sheet forming		1,200 m/min	→	→	Flat mono type (all)	→	Replaced stock inlet (Mitsubishi to Metso) Upgraded drive system
2006	46			→	→	→	→	→	Replaced soft calender (hot soft nip) Changed to stationary siphon for all dryers
2007	47			→	→	Fused type (piled mono + piled mono)	→	→	
2008	48								

Pulp: SP, GP, CGP, RGP, KP, TMP, 1DIP, 2DIP

Pulp composition; Basis weight (g/m²); Production (1000 tons)



Document 2. Production efficiency history of the No. 6 newsprint machine in Nippon Paper Industries Co., Ltd.'s Kushiro Mill

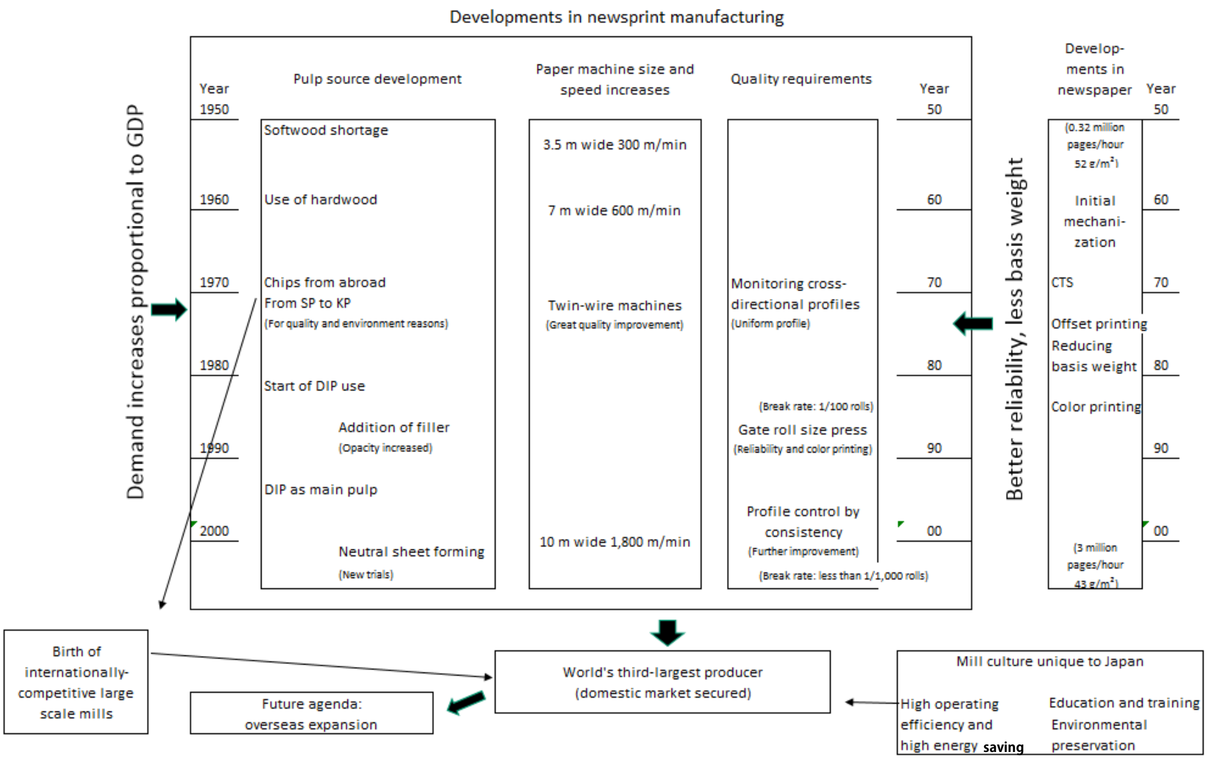


Document 3. Product quality history [1] (Kushiro Mill, Nippon Paper Industries Co. Ltd.)

	Nominal basis weight			H (51.8 g/m^2)						S (48.4 g/m^2)			L (46.2 g/m^2)					SL (42.8 g /m^2)					
	Machine No.			4							4	6	6					8	8	6	6	6	6
	Sheet forming			Acid						Acid			Acid			Acid	Neutral	Acid	Acid	Acid	Acid	Neutral	Neutral
	Year				1978		1978		1978		1978	1989	1989	1989	1989	2001	2006	1989	1990	2001	2001	2006	2006
Sheet quality				Specification	Average	Specification	Average	Specification	Average	Specification	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average
	Moisture	%		6-8	7.5	6-8	6.9	7.0	7.5		7.4	8.7	8.4	8.5	8.6	8.4	8.6	9.0	8.1	8.4	8.4	8.4	8.4
	Basis weight	g/m^2		52-55	53.1	52-55	52.9	53±1	53.3	48.4	49.1	49.1	46.6	46.6	47.0	46.1	45.9	43.5	43.0	43.2	43.6	44.2	44.5
	Thickness	μm		82-92	83.0	82-92	84.5		85.5		81.0	74.5	75.0	75.0	79.5	70.0	71.4	75.0	69.5	74.7	74.6	74.3	72.6
	Density	g/cm^3			0.64		0.63	0.62 ↑	0.63		0.61	0.66	0.62	0.62	0.59	0.64	0.62	0.58	0.62	0.56	0.57	0.58	0.60
	Tear strength	gf	MD									28.6	24.0	24.4	25.0			25.0					
			CD	28 ↑	29.3	28 ↑	30.2	30 ↑	32.4	30 ↑	31.6	42.0	35.3	37.0	40.0	42.8	37.0	36.5	42.5	41.3	43.4	38.1	38.8
	Tensile strength	kgf	MD	2.7 ↑	2.85	2.7 ↑	2.82		2.37		2.12	3.22	3.63	3.62	3.75	3.53	3.81	3.40	3.27	3.74	3.79	4.04	4.06
			CD									1.12	1.24	1.24	1.33		0.73	1.16				0.73	0.74
	Elongation	%	MD		1.22		1.12		1.11		1.01	1.29	1.42	1.42	1.41	1.50	1.39	1.36	1.32	1.59	1.57	1.36	1.36
			CD										2.28	2.18	1.21		2.54					2.39	2.48
	Smoothness (F)	sec	Ave.									71	55	62	42	77	42	53	61	34	35	27	33
	Smoothness (W)	sec	Ave.	40 ↑	55	40 ↑	52	50 ↑	57		55	70	51	52	37	65	43	46	67	26	26	22	29
	Brightness	%	F	52 ↑	53.3	52 ↑	53.2	50 ↑	50.7	52 ↑	52.6	51.8	51.8	52.3	51.5	54.7	56.3	51.8	51.5	53.8	53.8	54.8	54.9
			W									51.8	52.0	52.2	51.5		56.1	51.9		55.4	55.4	55.2	55.2
	Opacity	%		89 ↑	91.4	89 ↑	91.9	93 ↑	94.4		91.8	91.6	89.4	88.9	89.3	94.4	95.5	88.6	86.2	93.3	92.6	95.2	95.5
	Friction coefficent											0.47	0.52	0.57	0.57	0.55	0.58	0.54	0.56	0.55	0.55	0.57	0.58
	Oil absorption	sec			57		47		47		39	71	65	65	68	88	63	76	59	70	80	58	60
	Ash content	%						3.0	3.5		3.1	3.2	2.3	3.3	2.9	6.2	11.5	2.7	1.8	5.6	5.1	11.9	12.0
	Print through	%	F																84.6	87.5	85.3		91.2
			W																83.5	86.1	84.8		90.8
Pulp blend ratio	Mechanical pulp	%			85-100		85-100		83-84		82-84	46-51	38-42	33-47	24-25	70-80	70-80	48-60	48-60	22-34	20-32	15-25	15-25
	Deinked pulp	%			0		0		0			19-59	17-48	33-35	34-42	18-25	18-25	20-33	20-33	60-70	60-70	65-80	65-80
	Kraft pulp	%			0-15		15		16-17		16-18	16-19	27-28	23-29	25-40	2-4	2-4	20-22	25-27	6-8	8-12	8-10	4-10

12 Evolutionary chart and chronological table

Historical development of newsprint production technologies in Japan



Chronological table of technological developments in newsprint production

* Indicates a specific year; Years without asterisks (*) indicate an approximate year.

Year (last two digits only)		50					55					60					65					70					75					80					85					90					95					00						
Newsprint																																																										
Production	Production followed demand increase		*16				*73					*115					*115					*188					*206					*259					*270					*358					*340					*370						
(10,000 tons)																																																									
Basis weight	Increasingly less	$52 g/m^2$																											$49 g/m^2$			$46 g/m^2$											$43 g/m^2$										$40g/m^2$					
Brightness	Increased to improve image appe	45% min.																													50-52%																						55%					
Sheet break rate	Goal: extreme printing efficiency																																			1/100 rolls														1/1,000 rolls									
during printing																																																										
Newspaper	Lead plate to resin plate											Initial innovation								Second innovation																												Computer to Plate										
printing	Mechanization											Era of mechanization								*Introduction of CTS										*CTS at major newspaper printers																				(Plate preparation directly from computer)										
technologies	CTS to C to P											Teletype for kanji characters								Lead plate to resin plate																																						
												Automated type picking																																												
Letterpress	Single color printing	Single color, 4 pages a copy and 80,000 copies per hour										16 pages a copy and 100,000 copies per hour										24 pages at major newspaper printers																		32 pages,							40 pages, 16 in color															
																						Color ad started																		8 in color								48 pages, 24 in color														
	↓											Color printing started																																												
Offset press	High speed color offset printing																					Offset printing gradually comes into use																						Tower press																	
																											*73 offsets out of 1,024 rotary printing presses																															
																																	*294 offsets out of 1,219 rotary printing presses																									
																																					*Offset ratio:35%										Offset ratio:92%											
Typical pulp blend	Softwood	SP 20%										SP 17%					SP 15%								SP 10%						SP 3%																										
	↓											KP 3%					KP 3%								KP 10%						KP 17%							KP 10%														KP 5%							
												CGP 4%					CGP 10%								CGP 10%																																	
		GP 80%										GP 76%					GP 66%								GP 55%						GP 45%							GP 13%														GP 5%							
																	RCP 6%								RGP 15%						TMP+RGP 25%							TMP+RGP 34%														TMP 20%							
	DIP (deinked recycled fiber)																														DIP 10%							DIP 43%														DIP 70%							
Resource	Hardwood	GP from red pine																																																						
exploitation	▼															*Chip imports using carriers started																																									
	Imported chips															RGP started										TMP in operation																																
	▼										CGP used																				End of CGP																											
	DIP KP from SP																										DIP started											DIP becomes the main pulp																					
																						KP from SP																																		Calcium carbonate added		
	Improving opacity																																			White carbon added																						
Paper machine																																																										
Fourdrinier type	Wide, high speed	*2 A-roll width, 300 m/min.																				*21 newsprint machines installed, 43 in total																																					
	↓								*3 A-roll width																																																	
												*4 A-roll width, 600 m/min										*5 A-roll width, 800 m/min																																					
twin-wire type	twin-wire																							*Introduction of twin-wire machines									*Most newsprint produced by twin-wire machines																									
																													*4 A-roll width																													
																																*5 A-roll width, 1,100 m/min																	*5 A-roll width, 1,800 m/min.										
																																															*9 m wide, 1,700 m/min											
Auxiliary	Improving productivity and quality																				Introduction of BM monitor																			Gate roll size press														Profile control using consistency adjustment							

Chronological table of core technologies in newsprint production

(Data provided by the corporations that developed the technologies)

(Excerpts from "Chronological table of technological developments in the Japanese paper industry" by JAPAN TAPPI (May 2004 and June,2005)

Year (last two digits)		55	60	65	70	75	80	85	90	95	00
Pulping and stock preparation	*Continuous liquid stage digester (Kvaerner)										
	*Super-refiner type 150 (Aikawa Iron Works Co.) for stock preparation										
		*Deluxfiner type 100 (Aikawa Iron Works Co.) for stock preparation									
				*Double disk AW-20 (Aikawa Iron Works Co.) for stock preparation							
			*Topfiner A type (Aikawa Iron Works Co.) for stock preparation								
					*Screen B type 1000 (Aikawa Iron Works Co.) for machine approach						
					*High consistency pulper (Aikawa Iron Works Co.) for DIP preparation						
						*Floatator box type (Aikawa Iron Works Co.) for DIP preparation					
						*Doctor type DST (Aikawa Iron Works Co.)					
								*Doctor double type (Aikawa Iron Works Co.)			
									*Poseidon type PPM200 (Aikawa Iron Works Co.) for effluent treatment		
Paper machine			*Newsprint machine (4 A-roll width)(Mitsubishi Heavy Industries)								
				*Newsprint machine (5 A-roll width, 1000m/min.)(Mitsubishi Heavy Industries)							
					*Paper machine for newsprint and telephone directories (Bel-Baie II, converflow head box) (Mitsubishi Heavy Industries)						
									*Duofomer D (paper machine) (IHI Voith Paper)		
									*Duofomer D (paper machine) (IHI Voith Paper)		
			*Gate roll size press (Mitsubishi Heavy Industries)								
									*Symsizer (Sumitomo Heavy Industries)		
				*Penta-nip press (Mitsubishi Heavy Industries)							
				*Controlled crown roll (Mitsubishi Heavy Industries)							
						*Aquato-roll (Honeywell)					
						*Thermato-roll, zoom profiler (Honeywell)					
							*Steam box (Sumitomo Heavy Industries)				
							*Extended-nip press (Mitsubishi Heavy Industries)				
							*Uno-run blow box (Sumitomo Heavy Industries)				
								*Edge flow control (Sumitomo Heavy Industries)			
								*Automated basis weight profile control (IHI Voith Paper)			
								*High dew-point closed hood (Sumitomo Heavy Industries)			
					*Full-automated roll wrapping (Kawanoe Zoki Co.)						
						*Automatic winder changer (Mitsubishi Heavy Industries)					
						*Vari-roll winder (IHI Voith Paper)					
Wire, felt and canvas		*Dryer canvas using synthetic fiber (Shikishima Canvas Co.)									
			*Plastic canvas (Shikishima Canvas Co.)								
					*Needle canvas (Shikishima Canvas Co.)						
							*Full automatic canvas washing (Kawanoe Zoki Co.)				
			*Multi-filament wire (Nippon Filcon Co.)								
							*Mono-filament double woven wire (Nippon Filcon Co.)				
								*Seamless felt (Ichikawa Co.)			
								*Belt for shoe press (Ichikawa Co.)			

Instrumentation	*1936 Automatic control valve (Yamatake Sangyo Systems)
	*Electromagnetic flowmeter (Yokogawa Electric Corporation)
	*Electromagnetic flowmeter (Yamatake Sangyo Systems)
	*Online basis weight monitor (Yokogawa Electric Corporation)
	*Analog BM monitor (Yokogawa Electric Corporation)
	*Digital BM monitor (Yokogawa Electric Corporation)
	*B/M7000XL (Yokogawa Electric Corporation)
	*Photodiode spot detector (Omron Corporation)
	*CCD camera spot detector (Omron Corporation)
	*CCD system streak detector of (Omron Corporation)
	*Defect imaging system (Omron Corporation)
	* System 2000(Honeywell)
	*Decentralized Control System (DCS) (Yokogawa Electric Corporation)
	*YEWMAC (Production line control system) (Yokogawa Electric Corporation)
	*Large-scale DCS system (Yokogawa Electric Corporation)
	*Large-scale DCS system (Yokogawa Electric Corporation)
	*Fully-automatic cutter sorter (Omron Corporation)
Non-chlorine bleaching agents	*Hydrosulfite at Tokyo plant (Mitsubishi Gas Chemical Co.)
	*Hydrogen peroxide through self-oxidation at Yokkaichi plant (Mitsubishi Gas Chemical Co.)
	*Hydrogen peroxide by self-oxidation at Kashima plant (Mitsubishi Gas Chemical Co.)
Sizing agents	*Cationic polymer as sizing agent for internal surface sizing (Arakawa Chemical Industries)
	*Rosin-derived emulsion sizing agent for internal sizing (Arakawa Chemical Industries)
	*Rosin-derived neutral emulsion sizing agent for rinternal sizing (Arakawa Chemical Industries)
	*Neutral rosin sizing agent for internal sizing (Harima Chemicals Group)
Starches	*Cationic starch for internal sizing (Oji Cornstarch Co.)
	*Starch for surface sizing on newsprint (Oji Cornstarch Co.)
	*Polyacrylamide modified by mannch reaction for internal sizing (Harima Chemicals Group)
Deinking agents	*Anionic surfactant for deinking (Kao Corporation)
	*Deinking system using unsaturated-fatty-acid/nonionic detergent, licensed from West Germany (Kao Corporation)
	*Deinking system using saturated fatty acid/foaming agent, good for floatation (Kao Corporation)
	*Deinking agent using higher fatty acid with AO addition (nonionic) (Kao Corporation)
	*Deinking system using fat with AO addition/saturated fatty acid/foaming agent (Kao Corporation)
	*Deinking agent using refined alcohol with AO addition, standard as of 2005 (Kao Corporation)
	*Deinking agent for paper recycling (Harima Chemical Industries)

Chronological table of pulp and paper industry news items

Excerpts from "Chronological table of news in the pulp and paper industry," prepared by JAPAN TAPPI, June, 2004.

Names of Japanese paper companies are given in the Roman alphabet as pronounced rather than in their English names, as some companies no longer exist and their English names are not available.
Names of companies other than paper companies that no longer exist are given phonetically in the Roman alphabet, not in their English names.

	Chips	**Pulp**	**Newsprint**	**News**
1949		Kanzaki, Kanzaki Seishi: No. 1 grinder. Kofu Pulp: started GP.		
1950			Osaka, Osaka Seishi: No. 1 machine (1,880 mm)	
1951	Ishinomaki, Tohoku Pulp: Kamyr drum barker. Yatsushiro, Jujo Seishi: multi-blade chipper.	Kitagami Seishi: first chip CGP.		
1952		Fushiki, Jujo Seishi, Wood Machinery ring grinder (Canada). Tomakomai, Tomakomai Seishi: magazine grinder (2,690 kw). Iwakuni, Sanyo Pulp: Foxboro automatic controller for digestion. Akita, Tohoku Pulp: Foxboro automatic controller for digestion.	Osaka, Osaka Seishi: paper machine (1,880 mm)	
1953		Marusan Seishi: first SCP production. Nihon Seishi: SCP (1,020 t/month).	Nihon Seishi: newsprint only with SCP	
1954		Fuji, Honshu Seishi: first Kamyr grinder (1,100 kw, 870 kw, 1,120 kw). Kokura, Jujo Seishi: Kamyr-type double piston ring grinder (8 units). Toyo Pulp: refiners instead of beaters.		
1955		Kushiro, Jujo Seishi: SP (10 t digesters).		
1956	Hardwood use increased since 1954 due to softwood shortage: 1.11 million m^3 in 1956, 13% of total consumption. Test import of pulp wood from USSR, 5,600 m^3.		Kawanoe, Maruzumi Seishi: paper machine (1,960 mm)	
1957		Tomakomai, Oji Seishi, continuous digester for SCP by Hitachi Zosen (70 t/day). Nishinippon Pulp: SCP.	Tomakomai, Oji Seishi: 3 A-roll newsprint machine (5,280 mm). Sakamoto, Jujo Seishi (3,160 mm).	MITI required a certain amount of forest to be planted for new pulp capacity. MITI required the

	Chips	Pulp	Newsprint	News
		Iwakuni, Sanyo Pulp: SCP (globe digester 33 t/day), using acidic SCP from hardwood for newsprint. Nikko, Takasaki Seishi: SCP by continuous KP process. Ishinomaki, Tohoku Pulp: magazine grinder (750 kw, 15 t/day, No. 1 & 2) Fuji, Daishowa Seishi: magazine grinder (15 t, No. 6)	Mishima, Daio Seishi (3,610 mm, No. 10).	curtailing of some operations.
1958	Increase in use of scrap wood chips	Ishinomaki, Tohoku Pulp: magazine grinder (15 t/day). Kanzaki, Kanzaki Seishi: additional SCP. Mishima, Daio Seishi: new SCP.Kushiro, Jujo Seishi: CGP (Bauer 40 t/day). Ishinomaki, Tohoku Pulp: CGP (Bauer 34 t/day).	Ishinomaki, Tohoku Pulp: 3,610 mm. Kushiro, Jujo Seishi: 3,610 mm.	Edogawa, Honshu Seishi: problems with Urayasu fishermen's union regarding SCP effluent.
1959	Sharp increase of scrap wood chips (4x previous year's volume).	Ishinomaki, Tohoku Pulp: magazine grinder (15 t).		
1960		Shiraoi, Daishowa Seishi: SCP (75 t), CGP (126 t), magazine grinder (117 t) for newsprint. Kushiro, Jujo Seishi: additional CGP (Bauer). Tomakomai, Oji Seishi: Cold soda CGP (152 t). Mishima, Daio Seishi: CGP. Ishinomaki, Tohoku Pulp: magazine grinder (15 t), CGP (Bauer 6 m^3, 40 t/day × 3 units).	Kushiro, Jujo Seishi: No. 6 (4 A-roll machine, 6,960 mm). Ishinomaki, Tohoku Pulp (5,280 mm), Tomakomai, Oji Seishi (5,280 mm). Shiraoi, Daishowa Seishi (5,400 mm).	
1961		Hardwood CGP, 3× volume produced in the previous year. Nichinan, Nippon Pulp: conversion to KP. Fushiki, Jujo Seishi: bleach plant (80 t).		
1962		Yatsushiro, Jujo Seishi: CGP (Sprout-Waldron 67 t/day). Nakatsugawa, Chuo Itagami: SCP.	Asahikawa, Kokusaku Pulp (6,960 mm).	
1963	Scrap wood chips from Douglas fir	Yatsushiro, Jujo Seishi: 2-stage SP. Number of mills using 2-stage SP increasing	Kawanoe, Maruzumi Seishi: newsprint (3,700 mm).	Capacity: paper 22,261 t/day, pulp 17,537 t/day. Production: paper 6.38 million t/year, pulp 4.577 million t/year (data for June 1993).
1964	First import of chips from North America using Toyo Pulp's Kure-maru chip carrier .Daishowa Seishi's Daishowa-maru (chip carrier) went into service.	Fushiki, Jujo Seishi, RGP (DDR 600 kw × 2 units), first in Japan. RGP installations continued. Tomakomai, Oji Seishi, RGP (117 t/day), cold soda CGP (146 t/day). Ishinomaki, Tohoku Pulp, new SP for newsprint from Japanese cedar.	Tomakomai, Oji Seishi, N-1 machine (6,960 mm)	

	Chips	Pulp	Newsprint	News
1965	Daishowa Seishi chip carrier docked at Shimizu Port.	Fuji, Daishowa Seishi: RGP (84 t/day). Kushiro, Jujo Seishi: CGP (Asplund 160 t/day). Niigata, Hokuetsu Seishi: BGP (66 t/day). Kanzaki Seishi: conversion from Ca-SP to Na-SP.	New newsprint machines: Fuji, Daishowa Seishi: 3,710 mm, Kushiro, Jujo Seishi No. 7 (6,960 mm).	
1966		Kushiro, Jujo Seishi: CGP (Asplund continuous digester). Hachinohe, Mitsubishi Seishi, CGP (Asplund continuous 615 m^3, 55 t/day). Headquarters, Koyo Seishi, DIP plant.		
1967	Chip carriers into service: Tokai Pulp, Honshu Seishi, Daio Seishi, Maruzumi Seishi.	Shiraoi, Daishowa Seishi, CGP (Asplund 156 t/day). Kushiro, Jujo Seishi: magnefite process.		
1968	Chip carriers into service: Oji Seishi, Jujo Seishi, Sanyo Pulp	RGP: Kushiro, Jujo Seishi (170 t/day), Tomakomai, Oji Seishi (59 t/day), Fushiki, Jujo Seishi (45 t/day). SCP: Okayama Seishi. CGP: Yoshinaga, Daishowa Seishi (150 t/day), Tomakomai, Oji Seishi (120 t/day)	Tomakomai, Oji Seishi: N-2 machine (6,960 mm)	
1969	Kojin: mangrove chip production at Sarawak. Tokai Pulp: imported chips from New Zealand. Use of old-growth eucalyptus.	Mishima, Daio Seishi: CGP (Asplund). Kawanoe, Maruzumi Seishi: RGP (120 t/day, Verti-finer). Ishinomaki, Jujo Seishi: CGP (150 t/day, Asplund).	Futatsuka, Tonami Seishi: No. 2 (3,710 mm). Mishima, Daio Seishi: No. 15 (3,610 mm). Yoshinaga, Daishowa Seishi: Verti-former (3,700 mm), first in Japan. Iwanuma, Daishowa Seishi (86,900 mm), widest in Japan.	
1970		Tomakomai, Oji Seishi: RGP (448 t/month). Fushiki, Jujo Seishi: additional RGP (90 t/day).	Tomakomai, Oji Seishi: N3 (5 A-roll, 8,640 mm), largest newsprint-only mill in the world. Mishima, Daio Seishi: No. 16 (3,610 mm). Osaka Seishi: No. 5 (3,610 mm). Kawanoe, Maruzumi Seishi (3,700 mm).	Third liberalization of capital in pulp and paper manufacturing. Edogawa, Honshu Seishi: SCP shutdown. Fuji, Honshu Seishi: clarifier (31 m) × 2 units.
1971	Ishinomaki, Jujo Seishi: chip imports from Tasmania using 2 carriers. Sanyo Pulp: expansion of Iwakuni harbor facilities (berths for 40,000 ton chip carriers). Agreement on chips between Japan and USSR (for development in Siberia). Honshu Seishi: JANT PTY	Kokusaku Pulp, Oji Seishi and Carter (New Zealand): RGP and lumber.		Water Pollution Control Act enforced nationwide (daily average: COD and BOD 120 ppm each, SS 150 ppm. Max.: 160 ppm each and 200 ppm).

	Chips	Pulp	Newsprint	News
	for New Guinea development.			
1972		Tomakomai, Oji Seishi: CGP (Asplund 270 t/day), RGP (168 t/day). Ishinomaki, Jujo Seishi: DIP (30 t/day)	Tomakomai, Oji Seishi: N4 (8,690 mm).	
1973	Rapid increase in chip carriers (20 carriers in the 35–50,000-ton class scheduled). Medium-sized paper companies become interested in overseas resources.	Recycled paper centers established in Tokyo and Osaka. 13 companies in Kansai established a stockpile company for waste paper. MITI studied paper recycling systems. Demand for waste paper in 1973: 5.9 million tons (10.8% increase, recovery rate: 38.8%). MITI organized a study group for dissolved pulp demand. MITI proposed a center for recycling paper and paper products.	Mishima, Daio Seishi: N3 (8,600 mm)	Dispute over sludge pollution in Iyo-Mishima; 13 mills ordered to improve. Third sludge treatment in Tagono-ura. Agreement on pollution prevention among Yamaguchi Prefecture, Iwakuni City, Sanyo-Kokusaku Pulp and Nihon Shigyo. Daio Seishi: agreement on pollution prevention with local district. Toyo Pulp: agreement on numerical-based odor pollution prevention. Tomioka, Kanzaki Seishi: introduction of pollution fund system. Kitakami River: designated as water quality standards classification. 57 mills in Fuji district converted from heavy oil to city gas. Wakayama Prefecture implemented severest add-on regulations. Suzukawa, Daishowa Seishi: work on preventing KP stenches (350 million yen). 6 mills in Ehime Prefecture ordered to stop operation. 17 mills in Shizuoka Prefecture ordered to stop operation. Hachinohe, Mitsubishi Seishi: PDP series for white water recovery.

	Chips	Pulp	Newsprint	News
1974	Toho Wara Pulp imported straw from Korea and Taiwan. Marubeni, Daishowa Seishi, Sanyo-Kokusaku Pulp: started study on resources in Chile. Honshu Seishi: chip production in New Guinea (150,000 m³/year). Five companies (Jujo, Kojin, etc.): chips from mangroves. Chip carriers now number 51 ships.	Oji and Jujo: policy to introduce TMP.	Iwanuma, Daishowa Seishi: Duo-former started. Honshu Seishi ordered drive system using Thyrista from Toshiba (high precision and long life). Kushiro, Jujo Seishi and Shiraoi, Daishowa Seishi: returned to coal.	Investment in the paper industry in 1974: 251.5 billion yen (28.6% of which was for pollution control). Kushiro, Honshu Seishi; strict agreement with Kushiro City (Sox, soot and dust and effluent). Iwakuni, Sanyo-Kokusaku Pulp: pilot plant for treating bleach plant effluent (300 t/day). A cooperative in Ehime Prefecture tried to incinerate sludge incineration and produce active charcoal. Standards for sulfur oxides became severer. Ehime Prefecture: snap inspection of 80 mills. Kasugai, Oji Seishi: facility for recycling water (BOD 70 ppm). Ishinomaki, Jujo Seishi: No. 4 Clarifier (diameter: 106 m). Kawanoe, Iyo-Mishima and Takaoka, Fuji had their own joint incinerators for PS. 73% of effluent in the paper industry treated with coagulation system (MITI data).
1975	Excessive chip imports from the U.S. caused problems in Japan.	Kushiro, Jujo Seishi: started TMP. Fuji, Honshu Seishi: DIP plant (30 t/day) to replace LBKP.		15 companies in Fuji city: cooperative union for solidifying PS. Completion of Fujinomiya, Fuji Film Co., flue-gas desulfurization equipment. 8 levels for Sox in flue gas. Planned investment for pollution control in 1975: 63.3 billion yen (30.6% of the total investment). Revision of Air Pollution Control Act. Okayama Seishi started full-scale operation of treating paper sludge with earthworms. Daido Sanso industrialized pure oxygen aeration process.

	Chips	Pulp	Newsprint	News
1976	Chip Carrier Issues Committee launched (13 companies, 65 ships).	Major paper companies interested in wastepaper. Settsu Itagami: hot dispersion system from Kobayashi Engineering Works.	Jujo Seishi and Weyerhaeuser (U.S.): joint venture for newsprint production (210,000 tons/year), 50% of production imported into Japan. Iwanuma, Daishowa Seishi: moved to lower basis weight (from 53 g/m² to 49 g/m²).Kushiro, Jujo Seishi: B/M CENTUM from Yokogawa Electric Corporation (overall control system of paper machine)	Clean Japan Center makes progress. Cooperative of pulp companies in Ehime finished activated sludge plant. Mishima, Daio Seishi/Nichinan, Nihon Pulp: finished work for odor control. Pulp sludge in Tagono-ura increased by 200,000 m³ in a year. 2 million m³ of pulp sludge on the seabed at Iyo-Mishima. Otake Shigyo: agreement with Hiroshima Prefecture on pollution prevention. Mishima, Daio Seishi: facilities for pollution control. Fushiki, Jujo Seishi: equipment for flue-gas desulfurization (the fourth in the company).
1977			Paper companies testing lower basis weight. Kushiro, Jujo Seishi: No. 8, Bel-Baie II (324 t/day). Mishima, Daio Seishi: N-4.	Kure, Toyo Pulp installed activated sludge facility (11,000 m³/day).
1978		Dramatic increase in ratio of DIP in newsprint (64,000 tons/month).	Light basis weight newsprint rapidly increased share (41.7% in Sept.). Mishima, Daio Seishi: computer control of in-house power plant.	Takahagi, Nippon Kako Seishi: cleared the prefecture's additional regulations of 20 ppm BOD by using an activated sludge process. Investment for pollution prevention over the 6 years from 1972 was 183.3 billion yen, passing its previous peak.
1979				1.46 million tons of pulp sludge in Tagono-ura treated since 1972.
1980		Aikawa Iron Works: introduced DIP technology from Rameau (France) and Feldmühle (Germany). Waste paper recovery rate: 46.2% (highest ever).	Tomakomai, Oji Seishi: N-5 (8,950 mm, Bel-Baie, 530 t/day). 46 g/m² newsprint: 93%/46 g/m² newsprint undergoing R&D.	Hachinohe, Mitsubishi Seishi: duct-type gas holder for odor control.
1981			Yokogawa Electric Corporation: "B/M 80" BM monitor.	Sludge problem in Tagono-ura cleared up (6.8 billion yen, 1.82 million tons).

	Chips	Pulp	Newsprint	News
1982	Chip manufacturers decreased (down by 1,600 in a year from 6,305 mills).	Toyo Pulp: additional DIP (15,000 tons/month).	Sanshu Seishi: smallest Bel-Baie former in the world (70 t/day). Tomakomai, Oji Seishi: N-2 converted to twin-wire. 46 g/m² newsprint share reached 42%, re-named to "lightweight" from old name of "super-lightweight."	
1983	Reconsideration of domestic chip supply (chip carriers down to 48 from 69 in 1976).		White carbon output: 2,000 t/month.	
1984		Mishima, Daio Seishi: doubled CTMP capacity.	Oji Seishi: on-site manufacturing of white carbon. Light weight grade up to 55%. Mishima, Daio Seishi: N5 (300 t/day). Mishima, Daio Seishi finished the first stage of mill-wide computer control of production.	
1985		Waste paper recovery: 9.63 million tons, recovery rate: 50.5%, 93.4% for newspaper in particular. Tomakomai, Oji Seishi: DIP 750 t/day in total, 30% of its pulp consumption.		
1986	Nagoya Pulp: new chip yard in Handa city for Australian eucalyptus. Tomakomai, Oji Seishi: new PGW.	Tomakomai, Oji Seishi started PGW.	Mishima, Daio Seishi: 207 m tall chimney. Kushiro, Jujo Seishi: powdered coal boiler.	Mihara, Mitsubishi Heavy Industries: pilot paper machine (500 mm, 1200 m/min). Mitsubishi Seishi opened R&D center
1987		Mishima (new), Daio Seishi: additional PGW.	Mishima (new), Daio Seishi: Duo-former F (newsprint total: 60,000 tons/month). Iwanuma, Daishowa Seishi: converted No. 3 to Bel-Baie. Kushiro, Honshu Seishi: converted to newsprint from liner board in No. 2 machine. Ishinomaki, Jujo Seishi: powdered coal boiler and turbine, and roofed coal yard (13.4 billion yen).	Daishowa Seishi started manufacturing BCTMP (250 t/day) for its Iwanuma mill at Quesnel River Pulp Co. (joint venture with Daishowa), and acquired Port Angeles (U.S.) for 80 million dollars.

	Chips	Pulp	Newsprint	News
1988	15 paper companies founded a joint venture company with for developing eucalyptus in Thailand. Daio Seishi: chip carrier (35,700 t).	Yoshinaga, Daishowa Seishi: DIP (100 t/day) for newsprint.	Tomakomai, Oji Seishi: large-scale modification to No. 11, newsprint capacity increased to 1,500 t/day. Futatsuka, Chuetsu Pulp: No. 3 (400 t/day). Maruzumi Seishi: Bel-Baie III (600 t/day). Mishima, Daio Seishi completed N-7 machine.	
1989		Mishima, Daio Seishi: PGW (4,400 kw × 2 units).Mishima, Daio Seishi: DIP (6,000 t/month, Voith), bleached to high brightness.	Mishima, Daio Seishi: N6 (5,730 mm, 1,400 m/min). Oji Seishi planned Howe Sound (newsprint, 200,000 tons/year, starting 1991). Iwanuma, Daishowa Seishi, will finish No. 4 (9,000 mm, 1,500 m/min, Bel-Baie III) in 2001.	Daishowa Seishi: joint venture for newsprint in UK with Reed Pack. Nippon Keizai Shimbun promoted lowered basis weight newsprint (from 46 g/m² to 43 g/m²) to publish at 40 pages a copy.
Data not available from 1990 to 1992.				
1993	Oji Seishi: chips from South Africa and Brazil.	Tomakomai, Oji Seishi: additional TMP and new hydrogen peroxide bleaching. Kasugai, Oji Seishi used thiourea dioxide for bleaching.	HSPP (joint venture with Oji Seishi) produced newsprint at 43 g/m² (super-lightweight) with gate roll coating.	Nippon Seishi, Honshu Seishi, Mitsubishi Seishi, Nihon Shigyo and Daishowa Seishi established their environmental charters.
1994		Mitsubishi Gas Chemical Co. marketed in-house production system for thiourea dioxide.	Iwanuma, Daishowa Seishi: gate roll coater on No. 4 machine. Kawanoe, Daio Seishi: gate roll coater on No. 2 machine.	Hokuetsu Seishi licensed production technology to Thailand Paper (Siam Cement Group).Nippon Seishi guided operation work at Barito Pacific pulp mill (Indonesia).
1995	Nippon Seishi and Mitsui & Co.: large-scale plantation forest in Australia. Mitsubishi Seishi and Mitsubishi Corporation: joint plantation venture in Tasmania.		Fuji, Daishowa Seishi: gate roll coater on No. 11 machine (3,255 mm, 168.3 t/day).	
1996	Daio Seishi and Kawatetsu Shoji: plantation in Tasmania.	Fuji, Daishowa Seishi: DIP (200 t/day). Futatsuka, Chuetsu Pulp: DIP (50 t/day, started in September).	Yatsushiro, Nippon Seishi: newsprint machine (240,000 tons/year, scheduled to start in 1998). Daio Seishi: new mill for paperboard and newsprint in Iwaki, Fukushima Prefecture (scheduled to start in late 1997).	Chuetsu Pulp supported state-owned paper mill in Vietnam. Daio Seishi trained 8 staff from Vietnam's largest newsprint maker.
1997	Nippon Seishi and Mitsui & Co.: eucalyptus plantation in Australia (10,000 ha, 100,000 GDT/year). Chuetsu Pulp, Hokuetsu Seishi, Maruzumi Seishi and Marubeni		Tomakomai, Oji Seishi ordered a paper machine (9,150 mm, 1,800 m/min.) from Mitsubishi Heavy Industries, scheduled to start Oct. 1998. Iwaki, Daio Seishi: ordered a	Japan Paper Association formulated a voluntary action plan on environment and a voluntary management plan on toxic air pollutants.

	Chips	Pulp	Newsprint	News
	Corporation: plantation in New Zealand (acacia, 400 ha, expected to expand to 10,000 ha in the future).		paper machine (12,000 tons/year, using only DIP).	
1998	Paper companies enlarged their plantations. Oji Seishi, C. Itoh, Dengenkaihatsu and Kodansha: plantation in Australia (10,000 ha 10 years later).	Iwaki, Daio Seishi: DIP (300 t/day). Nippon Seishi: expansion of DIP to 2,700 t/day (increased by 700 t/day). Nichinan, Oji Seishi: DIP for printing paper (270 t/day).	Iwaki, Daio Seishi: newsprint machine in operation (12,000 tons/year using only DIP).	Mitsubishi Heavy Industries developed 2,000 m/min. newsprint machine. World's largest paper company formed from a merger between Enso (Finland) and Stora (Sweden): 13 million tons/year.
1999	Daio Seishi enlarged plantation in Chile (to 100,000 ha from 64,000 ha). Ratio of chips from plantation increased to estimated 30% of softwood chips and 50% of hardwood chips.	Nomachi, Chuetsu Pulp: DIP (100 t/day). Fuji, Daishowa Seishi: DIP (200 t/day).	Mishima, Daio Seishi started N5 (Duo-former, 5,210 mm, 380 t/day).	
2000		In 1997, 96 DIP facilities, 4.039 million tons.		Nippon Keizai Shimbun used ultra-super-light basis weight (40 g/m^2). Ratio of super-lightweight in Jan.: 94.8%.

List of Candidates for Registration as Newsprint Manufacturing Technology

No.	Name	Type of article	Location	Address	Year	Comment
1	Fourdrinier-type paper machine	Model	Paper Museum	1-1-3, Oji, Kita-ku, Tokyo	1960	A model of the newsprint machine installed in 1960 as the No. 6 machine in the Kushiro Mill, Jujo Seishi. At the time, this was one of the most advanced in the world. 1:30 scale (36 × 352 × 25 cm)
2	World's first continuous paper machine	Model	Paper Museum	1-1-3, Oji, Kita-ku, Tokyo	1955	A model of the first continuous paper machine, invented by Louis Robert in 1798 1:2 scale (70 × 111 × 77 cm)
3	Cylinder Yankee-type paper machine	Model	Paper Museum	1-1-3, Oji, Kita-ku, Tokyo	1952	A model of a cylinder Yankee paper machine 1:10 scale (60 × 106 × 75 cm)
4	Kamyr-type continuous digester	Model	Paper Museum	1-1-3, Oji, Kita-ku, Tokyo	1974	A model of the Kamyr continuous digester installed in the Kushiro Mill, Honshu Seishi, in 1974. Created for the construction work. 1:25 scale (67 × 140 × 167 cm)
5	Equipment drawings	Actual item	Tomakomai Mill, Oji Paper Co. Ltd.	2-1-1 Oji-machi, Tomakomai, Hokkaido	1963-	Equipment drawings and flow diagrams of pulping facilities and paper machines dating back to 1963.
6	Equipment drawings	Actual item	Kasugai Mill, Oji Paper Co. Ltd.	1, Oji-cho, Kasugai, Aichi	1953-	The drawings and layouts of every item of equipment installed in the mill since 1953, when the mill started operation. They are stored in ledgers as well as in digital form. Total: 40,000 items.
7	Quality specifications	Actual item	Asahikawa Mill, Nippon Paper Industries Co. Ltd.	505-1, Parupu-cho, Asahikawa, Hokkaido	1973-	Quality specifications on production control, quality control and unit requirements. These were used as the company standards since its inception as Sanyo-Kokusaku Pulp. Those from 1973 to 2005 are stored as paper media, while those from 2005 are stored as digital files.
8	(Deleted from original paper due to inaccuracy)					
9	Product sample book	Actual item	Kishu Mill, Kishu Seishi Co. Ltd.	182, Udono, Kiho-machi, Minami-muro, Mie	1980-	Product sample books for colored fine paper dating back to 1980.