

SMALL-SCALE PAPER MAKING

All words marked with an asterix (*) are shown in the Glossary at the end of the document.

Introduction

Paper is used for writing and printing, for wrapping and packaging, and for a variety of other applications ranging from kitchen towels to the manufacture of building materials. In modern times, paper has become a basic material, commonly found in almost all parts of the world. The development of machinery for its production in large quantities has been a significant factor in the increase in literacy and the raising of educational levels of people throughout the world.

The basic process of making paper has not changed in more than 2,000 years. It involves two stages: the breaking up of raw material (which contains cellulose* fibre) in water to form a pulp (i.e. a suspension of fibres*), and the formation of sheet paper by spreading this suspension on a porous surface, and drying, often under pressure.

Records suggest that paper was first made in China around AD 105. The technology was practised solely in China for the subsequent 500 years, and then spread to Japan in 610, and later into Central Asia. It appeared in Egypt about AD 800, but was not manufactured there for another 100 years. A variety of raw materials were used and these included mulberry bark, old rags and hemp.

Paper was introduced to Europe by the Moors on their invasion of the Iberian Peninsula, and the first mills were established in Spain in about 1150. The craft then spread into most of the rest of Europe during the next two centuries. The development of printing technology in the 15th century saw the start of the widespread publication of books and this greatly stimulated the paper-making industry. The first paper mill in England was established in 1495, and the first such mill in North America in 1690.

A crisis arose in the early 19th century as raw material for paper production was in shortage. European papermakers had grown used to using rags for paper manufacture and the shortage forced manufacturers to seek alternative raw materials. This gave rise to the use of wood for paper manufacture. The solution to the problem of a cheap, readily available, raw material for paper making was achieved by the introduction of the groundwood* process of pulp making about 1840.

At the same time, technological advances in paper making technology were taking place with the development

Fact file

- More than 286 million tonnes of paper and board were produced in 1994
- 34% of all paper produced is derived from recycled materials
- 10 to 17 trees are required for one tonne of paper (approximately equivalent to 7,000 national newspapers)
- It takes 2.7kg of wood, 130g of calcium carbonate, 8g of sulphur, 40g of chlorine and 300 litres of water to produce 1kg of paper in a large scale paper mill.
- The pulp and paper industry is the fifth largest industrial consumer of energy, accounting for 10% of all industrial energy consumption (although energy efficiency within the industry has improved greatly, and continues to improve)
- In the USA, the papermaking industry is amongst the highest polluters, the major outputs being biochemical oxygen demand and total suspended solids, with significant outputs of CO and volatile organic compounds.

Source: World Resource Foundation, 1997

technical brief

of the first practical papermaking machine by Nicolas Louis Robert in 1798. Later, this machine was further improved, and put into manufacture, by the British brothers, Henry and Sealy Fourdrinier, their name still being closely associated with paper-making machinery today.

Today's paper-making plants are capable of producing 1,000 tonnes of pulp and paper per day, using sophisticated technology based on chemical as well as mechanical processes for reducing raw materials to pulp. Modern day raw materials are many and varied, depending on availability, cost, geographical location, etc. These are covered more fully in a later chapter.

Hand paper-making has enjoyed a major revival over the past 30 years, using new and innovative approaches to this ancient craft. Handmade paper has a unique texture and an individual quality that makes it not only a surface to write, paint, or print on, but an object of beauty in its own right. In addition, the versatility of paper in its wet form has led artists to experiment with paper-making as an art medium, creating two- and three-dimensional images of textural richness and diversity, some on a vast scale.

This Technical Brief aims to cover only the area of *small-scale* papermaking technologies for application in developing countries. For this purpose we will define scale in paper-making as shown in Table 1 below.

Category	Output (tonnes of paper per day – t.p.d.)
Large scale	More than 100 t.p.d.
Medium scale	Between 30 and 100 t.p.d.
Small scale	Less than 30 t.p.d., including hand-made paper

Table 1: Definition of scale in papermaking

Source: Small-scale papermaking, ITDG Publishing.

Typically, a hand-made paper producer will manufacture only a few tonnes of paper per year (depending on the number of employees) often for a highly specialised market. Mechanised plants, on the other hand, only become economically feasible when dealing with an output above several tonnes per day. In India, where paper making machinery is manufactured indigenously, and hence costs are kept lower, mechanised paper making on a small scale is very common, with plants operating at outputs of 5 tonnes per day and upwards.

Paper making in developing countries

Statistics show that there is a strong link between the per capita income of a country and the amount of paper consumed. Whilst in the industrialised countries of the world consumption can be as high as 300 kg per capita per year, in some of the world's poorest nations this figure can be as low as 1 kg, and rarely exceeds 15kg per capita per year in the developing world. Illiteracy is also closely associated with low levels of paper consumption, as few books or newspapers are available and schools lack basic resources. As per capita income grows, and society demands higher rates of literacy, so the demand for paper grows. Only with indigenous manufacturing capacity and locally sourced raw materials can this demand be met at a reasonable cost, avoiding import taxes, high purchase prices and loss of valuable foreign exchange.

Technically, there are several ways of meeting this demand. Large-scale paper making plants are one solution, but these larger plants often fail to meet the broader socio-economic requirements of developing nations. Smaller mills provide higher levels of employment, not only in the mill, but amongst associated industries, such as waste paper collection and machinery manufacture. Smaller mills are more flexible in their acceptance of raw materials. With the growing concerns over deforestation and natural resource depletion in many parts of Asia, Africa and South America, the use of agricultural residues such as baggase, wheat or rice straw for paper production, is often a necessity. The product range is also more flexible in small paper making plants, with the ability to cater for a variety of demands, albeit, sometimes, with a slightly lower quality than that of the larger dedicated plant.

With many governments now opting for rural and regional development as a model for their country's growth, it is becoming more popular to assist in the development of small-scale industries in the regions. Paper making is an ideal example of how small industry can be developed to make use of local resources, both in terms raw materials and energy, while cutting transport costs and catering for a slowly growing local market.

The initial capital investment requirement for small-scale papermaking plant is also lower and therefore more attractive to prospective small business people with limited capital to hand. This is especially so in countries like India where machinery and equipment for manufacture is produced in-country. Government measures are often needed to support such initiatives, and where such measures are put in place small-scale industry can flourish.

Types, characteristics and physical properties of paper

Paper comes in an enormous variety of shapes, sizes, qualities, grades, colours and finishes. There are as many types of paper as there are uses for paper. Some common types of paper in production include the following:

- Printings and writings (stationery paper)
- Newsprint
- Corrugated case material
- Light-weight coated paper for magazines
- Wrapping and packaging paper
- Currency paper
- Hygienic tissue paper
- Photographic paper
- Paper card
- Solid board for boxes

The above probably make up 80 – 90% of all paper produced

Physical properties of paper. Some of the typical characteristics used to determine paper quality are given here. The types of tests that will be carried out on a batch of new paper depend upon the use for the paper.

- Weight in grams per square metre (referred to as gsm or grammage)
- Thickness or calliper (measured in microns)
- Density or bulk (a function of the previous two qualities)
- Tensile strength
- Burst
- Folding
- Brightness / shade
- Porosity
- Smoothness / gloss
- Oil-resistance
- Moisture absorption
- Moisture content
- Optical properties (adjustable using mineral fillers)

The quality of paper is often controlled by the National Standards organisation in the country concerned. It is always worth consulting these Standards well in advance if contemplating setting up a paper manufacturing facility.

Raw Materials and Additives

Raw Materials

For economic production of paper there must be a secure supply of suitable raw material at a reasonable price. Fortunately, there are many fibres which are well suited to paper making. In tropical developing countries, where wood is often in short supply there are a number of other sources of fibre, often by-products of the agriculture or textile industries. Below are some examples.

Raw Material	Source	Suitability
Straw (e.g. from wheat, barley or rice)	Between 5 and 10% of all straw which is produced is burned.	Short fibred (1.5mm), it is often mixed with other pulp to provide a suitable pulp stock for a variety of uses.
Bagasse*	From sugar cane after the sugar has been extracted.	Slightly longer fibre than straw. Suitable for high quality writing and printing paper.
Maize stalks	Remaining after maize harvest.	The high moisture content and need for collection make maize stalks suitable only for very small-scale production. Properties similar to straw.
Bamboo	Grown for use.	Fibre length of 2.7mm, suitable for all types of paper making without addition of other fibre. Supply is often limited.
Cotton	Cuttings, lint and fluff from cotton mills.	Cotton is a high value fabric and is therefore only used for specialist papers. Has a fibre length of 25-32mm.
Rags (from cotton material)	Collected	Often require sorting and bleaching.
Flax	A residue from the manufacture of linen.	Long fibres make this material suitable for high quality paper.
Hemp and sisal	From old ropes and tow from ropemaking factories.	6mm fibre length, processing similar to that of cotton.
Jute	From old sacks and hessian.	Jute does not bleach well and is therefore used for its strength rather than for high quality grades

Table 2: Raw materials commonly used for paper production

Waste paper

Compared with producing a tonne of paper from virgin wood pulp, the production of one tonne of paper from discarded paper may use half as much energy and water. It results in 74% less air pollution, saves 17 pulp trees, reduces solid waste going into landfill sites and creates 5 times more jobs (Earth Care, 1988).

Thirty four per cent of the worlds pulp is derived from reclaimed paper (WRF, 1997), and it is estimated that it could contribute 30% of the needs of developing countries.

Box 1

Recycling in the Paper Industry

Have you ever wondered what happens to a piece of paper when you recycle it? The paper industry is responsible for most of the recycling now taking place. 1993 was the first year in history in which more paper was recycled than was buried in landfills. But recycling is not as simple as it may seem...

Paper can be recycled only 5 to 8 times before the fibres in the paper become too short and weak to be reused. Old newspapers are commonly used to make tissue and cardboard, while magazines are often recycled into newsprint. Interestingly, the clay originally added to the paper to make it glossy will help to separate the ink from the paper during recycling.

How Paper is Recycled

First, the waste paper must be collected. One of the most expensive parts of recycling is the collection, sorting, baling, and transportation of waste paper.

The next step in the recycling process is re-pulping. The bales of sorted waste paper are disintegrated in a hydro pulper, where they are reduced to individual fibres. Chemicals are added at this point so that ink particles, coatings and additives, and extremely small contaminants such as fillers start to separate from the paper. Depending on the required level of improvement, the pulp is sent through several stages, where heat, chemicals, and mechanical action may be used to further improve the pulp. Finally, the pulp mixture enters a flotation

device, where calcium soap and other chemicals are added. Air bubbles in the mixture float the remaining ink and contaminants to the surface as a scum, where it is skimmed away. The pulp is now sent to the stock preparation area, where it is treated and loaded into the flowbox* of a paper machine. From this point, the pulp is treated just the same as if it had been freshly made from any other raw material rather than recycled.

At the end of the recycling process, a new paper product has been produced from material that might otherwise have been dumped in a landfill. Recycling is an important way for consumers and papermakers to work together for a cleaner environment.

Source: Web site of The Robert C. Williams American Museum of Paper Making

<http://www.ipst.edu/amp/index.html>

Additives

Below we will look at some of the chemical additives used in the small-scale paper making industry. Many other chemicals are used for dyeing, tinting, cleaning and quality improvement.

Chemical	Application
Caustic soda (NaOH)	Used in the cooking or digestion* process in small mills.
Lime (CaOH)	Used for the cooking of low quality materials such as jute or old rags.
Ammonia and calcium sulphate	Other chemicals used for the digestion of raw materials to form a pulp.
Chlorine	Used for bleaching paper. Chlorine is losing favour due to environmental pressures and is being replaced by other agents, such as hydrogen peroxide (H ₂ O ₂), ozone or enzymes.
Hypochlorite	Also used for bleaching paper.
Alum	For pH correction, which is necessary for many of the finishing processes.
Rosin	Used for sizing* paper. Normally used in conjunction with alum as a 'sizing system'.
Alkyl ketene dimer	Now used as a sizing agent in place of the alum and rosin system.
Starch	To improve stiffness of paper and board.
China clay /chalk	A filler used to improve opacity, brightness, quality and finish of paper. Up to 20% clay is used for some grades of paper. Fillers are often cheaper than fibre and used liberally.
Talc	Can be used instead of clay where the where the pH is close to neutral. Also used to reduce 'stickiness' of pulp.

Table 3: Additives used during production of paper

The paper making process

The process of making paper is based on the fact that wet cellulose fibres bind together when dried under restraint. The processing of paper usually involves the initial separation of the cellulose fibres to form a wet pulp, some form of treatment, such as beating and refining, while in the pulped state, to enhance the quality of the final product, then forming of the sheet paper by hand moulding or by paper making machine, and drying. Some further processing is often carried out before or during drying to acquire the desired finish.

It is worth remembering that paper production and the related technologies are often complex and sophisticated and only a brief overview with a few examples can be given in this document. In this section we will look at the stages involved in transforming raw materials into paper in a small-scale mill. The process is similar, whatever the raw material (or mixture of raw materials), and at whatever scale of paper production, but the complexity of the technology involved may vary considerably.

Delivery and Preparation

Depending on the size of the plant and the arrangements for procuring raw materials, deliveries will be made either by truck, or by collectors who deliver small quantities of recycled material. It is important to ensure that there is sufficient storage capacity for the raw material. This is

particularly important where seasonally available raw materials, such as straw or bagasse*, are used and a large supply will have to be stored for later use. The storage requirement can be considerable. For example, a mill producing 10 tonnes of paper per day with a mixture of 70% straw pulp and 30% imported pulp, with 3 months storage capacity, will require an area of 2,000m³ and 16m high. (Small-scale paper-making, IT Publications)

Straw preparation, for example, requires that the straw be cleaned to remove dust and cut into short lengths. Bagasse, on the other hand, will have been reduced to a suitable size at the sugar mill, but the pith will need to be removed. Wood will be chipped to an appropriate size. Specialised equipment is required for this kind of preparation. The material will then usually be transported to the pulping area on a conveyor belt or by hand.

On a global scale there is a large market in pulp. The world trade in 'market pulp' is enormous and large-scale plants will often use a mixture of market pulp and pulp from locally sourced raw materials.

The pulping process

Digestion, the first stage of the pulping process, is the process of removing lignin and other components of the wood from the cellulose fibres which will be used to make paper. Lignin is the "glue" which holds the wood together; it rapidly decomposes and discolours paper if it is left in the pulp (as in newsprint, which is usually made from groundwood* pulp with little or no chemical treatment).

Mechanical pulping. Approximately 15% of the world's pulp is formed using a mechanical process (WRF 1997) whereby the raw material is broken down by attrition into its individual fibres by grinding. This process is not wholly satisfactory, as the fibre are broken into smaller pieces and relatively little lignin is released, resulting in a poor quality, 'woody' paper. The mechanical process is also energy intensive. Mechanical pulp is used for newsprint as the paper is highly absorbent and therefore soaks up ink and dries quickly.

Chemical pulping. Forty two percent of all the world's pulping capacity uses a variety chemicals as part of a high temperature cooking, or digestion, process (WRF, 1997) which breaks down the lignin, freeing the cellulose fibres. This process produces a high quality product, although the type of chemical used will determine the properties of the final product:

- Caustic soda or sodium sulphate will produce a pulp with coarse, strong fibres (known as Kraft) suitable for strong boxes.
- Ammonia or calcium sulphate will produce a finer fibre suitable for high quality printing and writing paper.

For smaller mills the chemical process is usually used, as purchase of dedicated equipment for wood grinding is available only for larger scale operations and is expensive to purchase. Furthermore, suitable types of wood for paper production are seldom available in developing countries.

The prepared stock is fed into the top of a digester and mixed with the cooking chemicals, which are called "white liquor" at this point. Digestion may be carried out on a batch or a continuous basis. For small-scale mills of up to, say, 30 t.p.d., batch cooking is preferred. Batch digesters are able to cope with a variety of stock feeds, for example straw, baggase, cotton and wood, in the same mill. As the stock and liquor move down through the digester, the lignin and other components are dissolved, and the cellulose fibres are released as pulp. After leaving the digester, the pulp is rinsed, and the spent chemicals (now known as "black liquor") are separated and recycled (see later). In a typical rotating spherical batch digester capable of handling 30 t.p.d., the complete process from filling to emptying takes approximately 5 – 7 hrs. (Small-scale Paper Making', ILO, 1985).

Bleaching and Refining

At this point, the "brownstock" pulp is free of lignin, but is too dark to use for most grades of paper. The next step is therefore to bleach the pulp by treating it with chlorine, chlorine dioxide, ozone, peroxide, or any of several other treatments. A typical mill uses multiple stages of

bleaching, often with different treatments in each step, to produce a bright white pulp. Chlorine bleaching generally provides the best performance with the least damage to the fibres, but concerns about dioxins and other by-products have led the industry to move towards more environmentally friendly alternatives.

At this point, the individual cellulose fibres are still fairly hollow and stiff, so they must be broken down somewhat to help them stick to one another in the paper web. This is accomplished by "beating" the pulp in the refiners, vessels with a series of rotating serrated metal disks. The pulp will be beaten for various lengths of time depending on its origin and the type of paper product that will be made from it. At the end of the process, the fibres will be flattened and frayed, ready to bond together in a sheet of paper.

Forming the Sheet

Once the pulp has been bleached and refined, it is rinsed and diluted with water, and fillers such as clay or chalk may be added. In the mechanised process, this "furnish", containing 99% water or more, is pumped into the flowbox of the paper machine. From the headbox, the furnish is dispensed through a long, narrow "slice" onto the "wire", a moving continuous belt of wire or plastic mesh. As it travels down the wire, much of the water drains away or is pulled away by suction from underneath. The cellulose fibres, trapped on the wire as the water drains away, adhere to one another to form the paper web. From the wire, the newly formed sheet of paper is transferred onto a cloth belt (or "felt") in the press section, where rollers squeeze out much of the remaining water. In smaller paper mills the newly formed sheet may be handled manually and stacked one layer on top of another and pressed using a hydraulic press to remove the excess moisture.

Coating, Drying, and Calendering

After leaving the press section, the sheet encounters the drying cylinders. These are large hollow metal cylinders, heated internally with steam, which dry the paper as it passes over them. The sheet will be wound up and down over many cylinders in the drying process. Between dryer sections, the paper may be coated with starch to improve the printing and strength characteristics. After another round of drying, the paper sheet is passed through a series of polished, close-stacked metal rollers known as a "calender" where it is pressed smooth. Finally, the sheet is collected on a take-up roll and removed from the paper machine.

Cutting and Packaging

In many cases, the new paper roll is simply rewound on a new core, inspected, and shipped directly to the customer. Other paper grades, however, may be further smoothed by passing them through a "supercalender" where the sheet is polished by passing between steel and hard cotton rollers (much like ironing fabric), or they may be embossed with a decorative pattern. The paper may also be cut into sheets at the mill, often by automatic equipment which accepts a roll of paper at one end and delivers packages of cut sheets at the other, already boxed and wrapped for shipping.

Box 2

Case Study - TARA

Established in 1988, TARA (Technology and Action for Rural Advancement) has now become a major manufacturer of handmade paper. It is the production and marketing wing of Development Alternatives, an international network dedicated to sustainable development, and operates on four basic principles. It aims to create new, local jobs - particularly for unskilled women and currently employs 35 women and 7 men. It makes products for basic needs and conserves scarce resources, for example, wood and water, through using alternative materials and recycling. It tries to minimise pollution.

Production of Handmade Paper

The basic principles of handmade papermaking are quite similar to those in large mills.

Sorting and dusting. The raw material, in this case mainly rags, is sorted manually to remove buttons, plastic, synthetic fibres and other foreign materials. It is also given a vigorous shake to remove the dust and dirt.

Rag chopping. The sorted material is chopped into small uniform sized pieces.

Digestion and beating. The raw material is mixed with water and inert chemicals, such as chalk, clay, alum or rosin, and beaten in a Hollander beater. This is an oval U-shaped trough, with a heavy roll; the face of the roll carries hard wearing metal bars and similar bars are set into the plate below the roll, which cut the raw material to make the pulp (see figure2). There is also a washing drum, which cleans the pulp and removes the dirty water. The consistency of the pulp determines the quality of the paper which will be made.

There are two methods of sheet formation:

i/ *Dipping Method* (for fine/thin paper). The pulp is diluted with water and put into a masonry trough or vat. The lifting mould (mesh on a wooden frame) is then dipped into the trough, shaken evenly and lifted out with the pulp on it. The consistency of the pulp in the tank should be kept constant.

ii/ *Lifting Method* (all paper and card). A fixed measure of the pulp is poured evenly onto a mould, which is clamped between two wooden deckles (frames) in a water tank and dipped. The mould is then raised, using a lever mechanism, to drain the excess water.

Couching. After the sheet formation is completed, the wet paper is transferred onto a cloth/felt sheet and a stack of interleaved sheets is built up.

Pressing. A hydraulic press is used to remove the excess water from the sheets. Pressing reduces the bulkiness of the paper i.e. the sheets become more compact. This improves the physical properties of the paper and facilitates drying.

Drying. After pressing, between 50 and 65% of moisture remains in the sheets. The sheets are dried by hanging them in open areas of sunlight to remove the rest of the moisture. Solar dryers can speed up this process and reduce the amount of space needed. Coloured paper is sometimes dried in the shade to avoid the bleaching effect of the sun.

Cleaning and Sizing. Small dirt particles and other foreign matter are removed manually with a sharp instrument. The cleaned sheets are given a coating with starch to improve the physical properties of the paper and prevent feathering. This is called sizing and can be done manually with a brush or by the dipping method, where the sheets are immersed in a tub of sizing chemicals.

Calendering. The sheets are placed between metallic plates and passed through spring loaded rollers in a calendering machine. This smoothes the paper and enhances the gloss.

Cutting. The sheets are neatly cut to the required size using a cutting machine.

Paper making equipment - Technical considerations

Services

When considering purchasing or renting premises for setting up a paper-making facility, care should be taken to ensure that there are adequate services provided at the premises, or that these services can be easily accessed.

The paper industry consumes enormous quantities of water. In 1988 the average North American paper mill used 72 cubic metres of water for every tonne of paper produced (m^3/t). This figure can be much higher where water efficiency measures have not been introduced. Although efficiencies in water consumption are improving, there will always be a need for relatively large quantities of water during the paper making process. Most of this water is either reused or returned to the environment after treatment (see later in this section).

The next consideration is adequate power at the site. Papermaking is also an energy intensive industry, especially when the process is mechanised. This energy can come from a variety of sources such as electricity, wood, oil, gas or coal. This energy is used for providing much of the heat energy required. Other residues, such as bagasse or rice husks can also be used as fuel. In large-scale plants, reclamation and incineration of spent chemicals can also provide a significant amount of energy. An electrical supply of sufficient capacity is required in most circumstances for powering motors, pumps, lighting, etc. This can be supplied from the mains where the mains is accessible, from a diesel generator set, or from a renewable energy source (such as hydro-power or wind power), where such power sources are available. Steam raising for the drying process can be carried out using a variety of technologies; oil-fired boiler, steam engine, combined heat and power plants. Careful costing of the available options can bring considerable savings. The energy demand for processing of reclaimed paper is much less than that for virgin wood.

Effluent treatment and disposal is another topic which needs careful attention. The effluent from a paper mill can contain thousands of different chemical species, which, if discharged directly into the environment, would cause untold damage. In medium and large-scale plants specialised recovery equipment is used to reclaim chemicals for reuse or for incineration to provide energy. This is not cost effective in smaller plants and so some form of treatment and/or disposal is required. Biological treatment plants, such as the anaerobic digester, are sometimes used to treat the effluent. This method has the added benefit of producing methane through digestion of the organic matter in the effluent, which can be used to provide as much as 30 % of the mills energy requirement. The remaining sludge can then be disposed of on the land.

Equipment and machinery for paper making

It is outside the scope of this brief to look in any detail at the enormous variety of equipment and machinery that has been developed for assisting in the paper making process. Broader texts exist which deal more comprehensively with machinery suitable for application to small-scale paper making (see the bibliography at the end of this brief). Many developing countries now manufacture papermaking plant indigenously, making cost savings in manufacture and also in import duties. There are also suppliers in industrialised countries that sell second hand equipment.

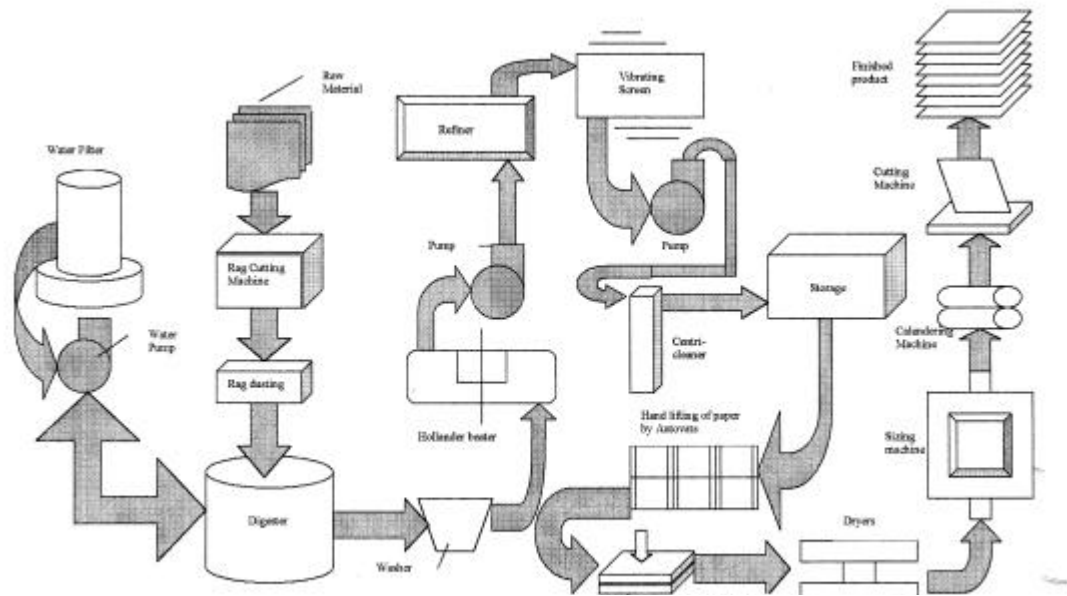


Figure 1: Flow of materials through a typical paper making plant

Figure 1 shows the variety of equipment that is needed for a small hand made paper making process. Much of the machinery required for a mechanised production facility is sophisticated

and expensive. Table 2 shows some examples of the equipment that is used for small-scale paper manufacture.

Machine name	Function
Pulper	An open-topped vessel with impeller which reduces the digested or mechanically reduced stock to a pulp.
Breaker	Similar in function to the pulper but with blades mounted on a roller inside a bath. Only suitable for batch operation.
Beater / refiner	Similar to the breaker in appearance but with a beating action for speciality papers. See fig. 2 below.
Washer	For washing the pulp prior to paper formation.
Refining equipment	For the final treatment of pulp before being sent to the Fourdrinier machine.
De-flaking equipment	Used in the preparation of reclaimed paper, these machines are inexpensive and suitable for use in small mills.
Screen	Situated just prior to the headbox of the paper machine, the screen removes undesirable particles and ensures a uniform suspension of fibres.
Cleaners	Remove sand or grit from the paper stock by centrifugal action.
Fourdrinier machine	Used for the formation of the sheet paper. This is the most common type of paper machine
Headbox or flow-box	The container (similar to a hopper) that feeds the pulp into the paper machine. On smaller machines they usually operate under the pressure of gravity.
Press	Used to expel water mechanically from the freshly formed paper. Often use hydraulic rams to provide the pressure.
Dryer	Commonly, a series of steam heated rotating cylinders which help remove the final 50 – 60% of water which still remains after pressing. Solar drying is another option when producing handmade paper.
Reeling, winding and sheeting equipment, Size press	Handling equipment used for final treatment of paper.
Cutting machine	Machine press for adding starch to the formed sheet paper.
	Used for the cutting of paper into sheets.

Table 4: Machinery used for small-scale papermaking

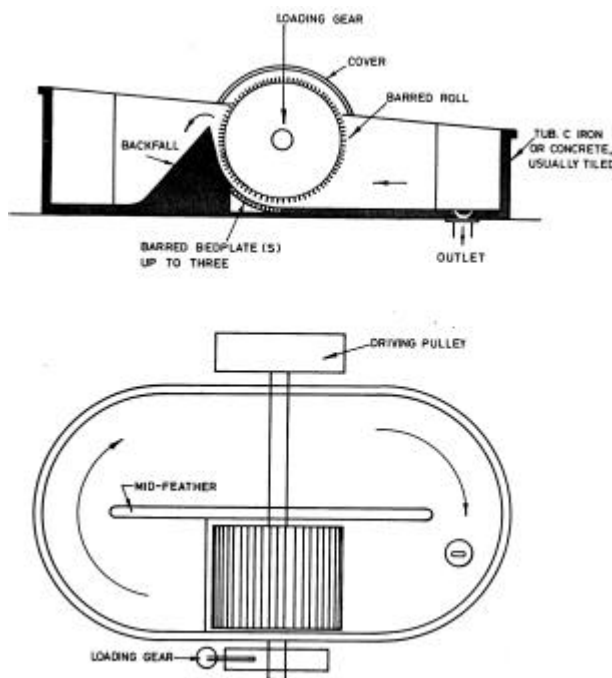


Figure 2: Beater or refiner

Glossary of terms

Cellulose – the material from which all plants, such as trees, wheat stalks, rice-stalks and sugarcane are made.

Fibre – the long, thread-like wisps from which paper is made.

Groundwood – pulp obtained by subjecting wood to grindstones in the presence of water, also known as mechanical pulp.

Flowbox – prepared stock is placed in the flowbox which controls the flow of the pulp through the 'slice' onto the 'wire'

Digestion – cooking of ram fibrous materials to produce pulp.

Size – liquid added to paper to control ink penetration.

Bagasse – the fibre remaining when sugar juices has been extracted from sugar cane.

Furnish – pulp that has been bleached and refined, rinsed and diluted with water, and fillers such as clay or talc may be added.

Slice – the opening through which pulp flow onto the 'wire'. Flow can be under gravity or pressurised.

Wire - a moving continuous belt of wire or, more commonly nowadays, plastic mesh.

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11. Bell, Lillian: *Plant Fibers for Papermaking*
A guide to making paper from natural plant fibres. Includes botanical name, cooking, beating, and sheet forming. SB, 132 pp.
12. d'A. Clark, James: *Pulp Technology and Treatment for Paper*, 2nd Edition
The book for anyone who really wants to understand the process of papermaking. It is a clear, comprehensible explanation of paper chemistry for non-chemists. There are accurate discussions of cotton and flax properties, rare in technical books. HB, 85 pp.
13. Elliot, Marion: *Paper Making*
This is a good substitute for Sophie Dawson's book, *The Art and Craft of Papermaking* which is out of print. Marion Elliot's book is similar in that it provides an overview of the craft, work by various artists, and 13 easy-to-do projects including: embossed writing paper, watermarked lantern, bowls, recycled paper and cast brooches. SB, 96 pp.
14. Hunter, Dard: *Papermaking, The History & Technique of an Ancient Craft*.
The papermaking classic. An excellent, unabridged Dover reprint of the 2nd (1947) edition. SB, 611 pp.
15. La Plantz, Shereen: *Cover To Cover: Creative Techniques for Making Beautiful Books, Journals & Albums*. This is the best overall book about book arts and binding. From simple pamphlets to fairly complex books. HB, 144 pp., 173 full colour, 46 b & w illustrations, 324 drawings and diagrams. Index, Supplies and Information List, Bibliography.
16. Shepherd, Rob: *Hand Made Books: An Introduction to Bookbinding*
Aimed at the amateur with a limited budget, he clearly explains how to make both soft and hard bound bindings for journals, scrap books, portfolios, and Japanese bindings. An excellent book! 80 pp. 100 colour photos, 20 diagrams.

Useful addresses

Development Alternatives,
B-32 TARA Crescent,
Qutab Institutional Area,
New Delhi - 110016,
India.
Tel: +91 11 696 7938
Fax: +91 11 686 6031
(See Box 1)

The World Resource Foundation
Heath House
133 High Street, Tonbridge,
Kent TN9 1DH
Tel: +44 (0)1732 368333
Fax: +44 (0)1732 368337
Web: <http://www.wrf.org.uk>
E-mail: wrf@wrf.org.uk
'The Warmer Bulletin' published 4 times a year.
Fact sheets on various aspects of recycling
including waste paper reuse.

Small Industries Research Institute (SIRI),
PO Box 2106, 4/43 Roop Nagar,
Delhi 110 007, India.
Tel: +91 11291 81 17
Consultancy specialising in small business and
Intermediate Technology's.

ITDG Publishing
103 - 105 Southampton Row
London WC1B 4HH
United Kingdom
Tel: +44 (0)20 7436 9761
Fax: +44 (0)20 7436 2013
E-mail: orders@itpubs.org.uk
Web: <http://developmentbookshop.com/>

The Two River Paper Company,
Pitt Mill, Roadwater,
Watchet, Somerset TA23 0QS,
United Kingdom.
Tel: +44 (0)1984 641028
Fax: +44 (0)1984 640282
The proprietor, Jim Patterson, is a long
time practitioner with a wealth of
knowledge of the paper making process.

International Labour Organisation,
4 Route des Morillons,
CH-1211 Geneva, Switzerland.
Tel: +41 (22) 799 83 19
Fax: +41 (22) 798 86 85
Database on products and processes and
socio-economic aspects of waste and
recycling. Employment generation.

Kathryn Clark –Twinrocker Handmade
Paper
100 East Third Street, P.O. Box 413,
Brookston, Indiana 47923, USA.
Tel: 1-800-757-TWIN (8946)
or (765) 563-3119
Fax (765) 563-TWIN
E-mail: twinrock@twinrocker.com
Suppliers of handmade paper product,
also run courses. Many of the books listed
above are available from their bookshop.

Edwin Amies and Son Ltd.,
33 Amsbury Road,
Coxheath,
Maidstone,
Kent ME17 4DP
United Kingdom
Tel/Fax: +44 1622 745758
Suppliers of hand moulds and deckles for
handmade paper making.

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Useful Internet Sites

<http://www.ipst.edu/amp/index.html> The Robert C. Williams American Museum of Paper Making. A very interesting tour through the history of papermaking.

<http://www.wrf.org.uk> Home page of the World Resource Foundation.

http://twin_rocker.com/Welcome.html Homepage of Twinrocker HandmadePaper On-Line, Twinrocker Hand Papermaking Supplies On-Line, Twinrocker Workshops and Tours

<http://www.nbn.com/youcan/paper/paper.html> Making new paper from recycled paper

<http://www.learn2.com/06/0697/0697.html> Learn 2 - make home-made paper site.

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