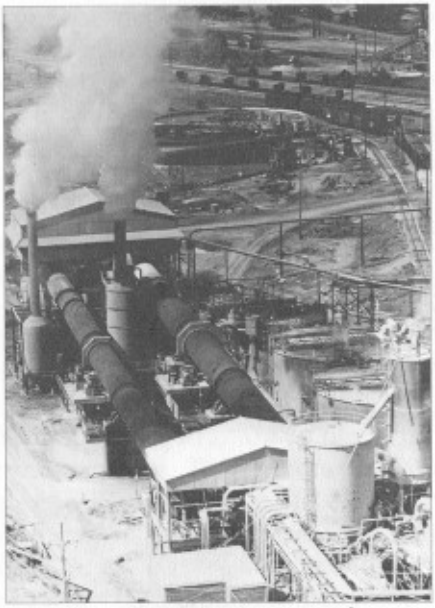
# Why Paper?

Earning this merit badge will give you an appreciation for paper and the industry that makes it. Paper is a product that is vital to modern civilization. In the United States paper is usually taken for granted because it is so commonly used. Everyone considers it expendable. To be sure, disposing of used paper is a big problem. Carelessly discarded and carried by the wind, it litters our countryside. Besides this, the paper industry has been given a reputation as a polluter worse than it ever deserved. Its waste products have an unpleasant appearance and odor, so even small amounts are immediately noticed. To top this, huge clouds of harmless distilled water can be seen coming out of the dryer vents of paper mills while many deadly wastes of other industries are invisible. Modern paper mills that do not pollute are rapidly replacing the few remaining old mills that did. The modern paper industry is a leader in the fight against pollution. Yet paper mills of the United States must compete with foreign mills that pay lower wages and spend much less on pollution control.



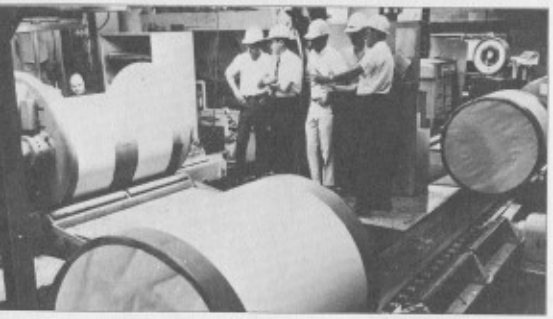
The paper industry has spent hundreds of millions of dollars in eliminating pollution and reusing its waste products. The recovery system shown above burns the spent cooking liquids from the pulping process, recovering lost heat and valuable chemicals in the process. Approximately 40 percent of the steam and electricity needed for a paper mill is generated by burning these wastes.

The paper industry is complex and ever expanding. Paper consumption increases with the standard of living and has steadily increased since paper was invented nearly two thousand years ago. The paper industry is effectively solving its pollution problems and is not about to run out of raw materials as many people believe.

It is hoped that this pamphlet will lead to a better understanding of this great industry and perhaps guide some of the youths of our land into rewarding careers.

Checking growth rates in a paper mill tree farm.

A roll header wraps paper before shipment.



The paper industry operates many highly productive tree farms and today is producing more timber than is being cut.

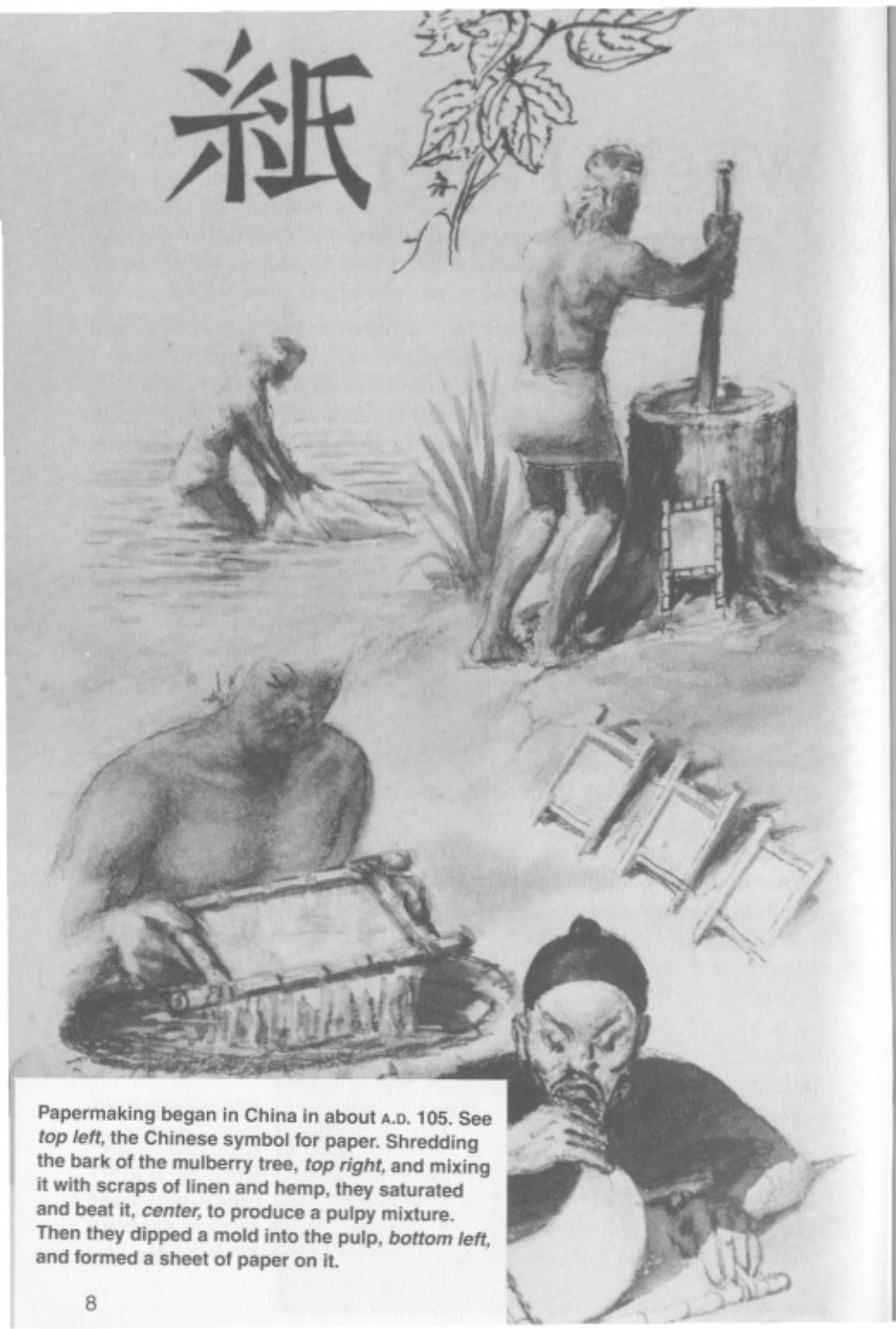
# Where Paper Came From

Human intellectual development progressed with the development of writing. Early writing materials were cumbersome. About 4000 B.C., clay, metal, wax, and skins were used. About 2400 B.C., papyrus, the forerunner of paper, was invented in Egypt. Papyrus is a tall reed that grows along a few rivers such as the Nile, the Tigris, and the Euphrates. The layers of fiber around the plant's pith were stripped off, laid crosswise, and laminated using a flour paste glue and pressure. Since papyrus was a crosswise-layered product, it was not truly paper as we will see later in the book. It is interesting that in Central America a very similar material was made by the Maya Indians and later by the Aztecs. The Mayas' "huun" paper was made from wild fig tree bark and was superior to papyrus. It helped develop the early Central American civilizations as papyrus helped the development of Egypt and Mesopotamia.

In other places where papyrus was not available, split sheepskins were used (about 1500 B.C.). Skins were split, dried, scraped, chalked, and pumiced. Both papyrus and split skins were used in the Roman Empire.

Paper was invented in China about A.D. 105. It was made from fermented and beaten mulberry bark fibers. These fibers were suspended in water and scooped out with a screen made of bamboo splinters tied with horsehair. The papermaking process remained a Chinese secret until A.D. 704 when Arab armies captured a city named Samarkand in western China. Several Chinese papermakers were abducted to Baghdad and put to work making paper. Other raw materials were developed. In A.D. 794 the Chinese workers of Baghdad made paper from linen rags.

Papermaking spread rapidly throughout the Muslim world. Even the art of block printing had, by then, been invented in China and had followed papermaking. However, by that time the Roman Empire had fallen, and the Muslims held Asia Minor and Africa while the Christians held Europe. During the bitter wars (Crusades and Muslim invasions) Europe was cut off from Egyptian papyrus and



Papermaking began in China in about A.D. 105. See *top left,* the Chinese symbol for paper. Shredding the bark of the mulberry tree, *top right,* and mixing it with scraps of linen and hemp, they saturated and beat it, *center,* to produce a pulpy mixture. Then they dipped a mold into the pulp, *bottom left,* and formed a sheet of paper on it.



from the growing paper technology. As late as A.D. 1450, Johannes Gutenberg, the inventor of the printing press, used three hundred sheepskins to print a single Bible.

Paper was first brought to Europe by the Moors that invaded Spain. About A.D. 1150 a paper mill was built in Spain. From there papermaking slowly spread through Europe. England did not produce paper until 1494 (two years after the discovery of America). The English recognized the importance of paper and rapidly took the lead in its manufacture. Paper was soon used for designing English ships. Prior to this, shipyards built oceangoing vessels in a haphazard manner without plans. Thus, paper again influenced world history by contributing to England's superiority on the waves.

English settlements in America developed rapidly, and they soon needed paper in ever-increasing amounts. In 1690 Rittenhouse established the first American paper mill in Philadelphia. Using linen rags as a raw material, this plant made one hundred pounds of paper per day. The process used in this mill was still very crude. Paper pulp was prepared by letting wet rags ferment for six to seven weeks. Rotting loosened the fibers. Unfortunately, it also gave a coffee-brown color. This stock was then cooked in limewater, broken up by stamping, placed in bags, and washed in the stream. One-third of the original stock had rotted and was washed away. The remaining washed product was bleached in the sun, suspended in water, then dipped from the water with a wooden frame that had a screen on the bottom. The frame was shaken as the water drained, leaving a wet mat. These mats were removed from the screens with felt blankets, stacked between the blankets, pressed to remove water, and finally hung in a loft to dry. Paper was made in this manner until the middle of the nineteenth century. Since this process was slow and rags were hard to get, paper was always in short supply.

In 1799 the Fourdrinier paper machine was invented. A pulp suspension was spread on a moving wire screen, and, after the water drained off, a continuous wet sheet was removed. The modern paper machines on which most of our paper is made today are improved Fourdrinier machines.

In 1809 the cylinder machine was invented. On this machine sheets were formed on rolls. Several sheets were pressed together when wet, and a boardlike laminate was formed. The resulting layers can be found in cardboard and book matches.

Drying the wet sheets of paper and board continued to be a serious problem. In 1826 steam-heated cylinders were first used for drying the paper. Unfortunately, this equipment had to be cranked by hand or water power since motors had not yet been invented.

As the process improved, papermakers were limited mainly by the scarcity of rags. During the Civil War some desperate paper mill executives even imported mummies from Egypt to make pulp from the wrappings.

People constantly looked for other sources of fiber including straw, rope, and wood. Wood provided a good source if the individual fibers could be separated. Mechanical and chemical pulping processes were slowly developed during the last century. These processes are described later in this book. Their development overcame the rag shortage and made the modern paper industry possible.

## The Future of Paper

The paper industry is the fourth largest industry in the United States and its productivity is tied directly to our standard of living. Paper production is often recognized as a direct measure of our standard of living because as other industries expand they almost always use more paper in planning, processing, and packaging their new products. Currently the paper industry produces products valued at about $110 billion and their total value is expected to increase at a rate approaching 2 percent per year. In 1989 the United States enjoyed the highest per-capita consumption of paper in the world at 304 kilograms. This is 25 percent higher than the next three countries: Sweden, Japan, and Canada. However, it should be noted that several countries in Asia and Australia have growing economies where pulp and paper consumption is expected to soar.

The Rittenhouse Mill, an early paper manufacturer.

The paper industry started with fibers made from rags, but it can be made from almost any agricultural fiber. In the United States wood fiber (both hardwoods and softwoods) is preferred because of its abundance, low cost, and favorable papermaking characteristics. From wood fiber we make about six thousand different paper products, from soft tissues to dense structural laminates for kitchen counters. New products appear almost daily and the opportunity for future development is almost unlimited because wood fiber is possibly the most versatile fiber known.

New food packaging using aseptic methods, which allow foods to be stored in paper containers at room temperature, is gaining wider acceptance as is the use of paper containers for fast food preparation that can go directly into the microwave or oven.

One exciting development on the horizon is structural products made from wood fiber. Because of the high strength and stiffness of wood fiber, in the future it will find its way into low-cost as well as expensive shelters, furniture, storage buildings, and so on. A host of other applications will also result from research that is showing how to increase the strength, stiffness, and durability of wood fiber.

There are many other new uses for paper and paper combinations such as containers for food, drinks, oils, and chemicals that replace metal cans and fragile glass bottles. Gasket materials made of paper are now replacing asbestos with a more environmentally benign substance.

If this vision for the future surprises you, remember that we live in a time of constant progress and change, and every product on the market today is subject to this change.

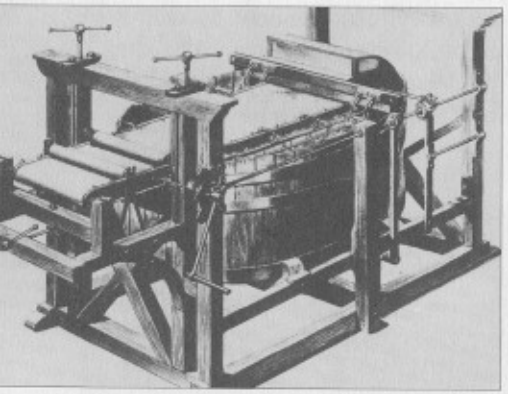
## Will Paper Mills Run Out of Raw Materials?

The answer to this question is *no!* First of all, wood is a renewable resource. Unlike petroleum and ores, wood can be made by planting trees. With good forest management the amount of wood grown and harvested in the United States can be tripled without increasing the forestlands. These forests could still be used for wildlife, recreation, and watershed.

Secondly, huge tropical forests have not been used because there are too many different types of trees that cannot be pulped or cannot be pulped together by the same process. However, if more research was directed toward the pulping of these species, productivity could be increased and diversity maintained in the tropical forests. A great source of pulpwood would result because in the tropics trees grow even more quickly than they do in the southern United States.

Thirdly, there are many other renewable fiber sources. Bagasse, the waste of the sugar industry, yields good papermaking fibers. Bamboo and other grasses are used in some countries. Even seaweeds and fungi are being considered in research projects.

Fourthly, great progress is being made in recycling wastepaper. We can never reach the point where all paper products are made from recycled waste. However, we do not need to. We only need to make enough paper from recycled waste so that the difference between the demand for paper and the supply from recycling can come from trees and other sources. Indeed, paper cannot be recycled again and again, because the paper fibers are shortened during processing. After several reuses the fibers get too short for papermaking and must be discarded either in landfills or burned for energy recovery.



One of the first Fourdrinier paper machines.

# How Paper Is Made

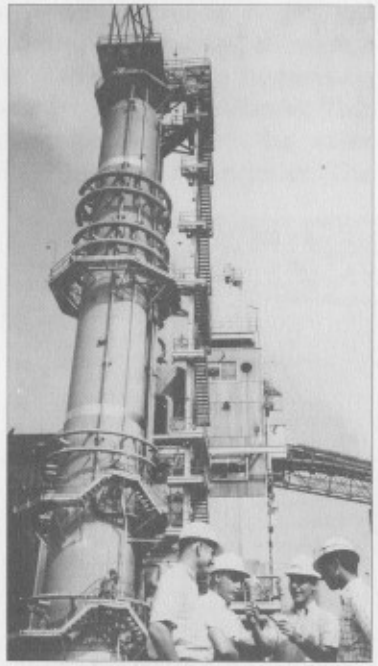
Paper is a mat of fibers. This mat is formed when "roughed up" fibers are laid down in a thin layer and bonded together. The method used for making paper from tree trunks is made up of a series of steps that are grouped into pulping, papermaking, and converting. These are the steps:

## Pulping

1. Separate the little fibers (about ⅛ inch long) that are found in plants. This is done either by breaking them apart mechanically, or by cooking the plant stems in chemicals until they fall apart, or by a combination of these. This step is called pulping. The resulting material is called pulp.
2. Clean the pulp.
3. Bleach the pulp, if desired.

## Papermaking

4. Break up the fibers until they have many little branches (fibrils) sticking out on the sides. This process makes more surfaces for better fiber-to-fiber bonding and is called "refining." It makes the paper stronger.
5. Add dyes, fillers, alum, and other chemicals. These materials influence not only the color but many other properties of paper. Some of these "additives" are put into the pulp in the refiners that roughen the fibers in step 4.



Construction engineers check a continuous digester.

6. Make the paper by spreading pulp suspended in water on a fast-moving screen and draining off the water. The wet paper is then pressed to remove more water and dried on hot rolls.
7. Coat the paper if desired.
8. Cut the paper to the final shape. The paper is now ready for use or for converting.

## Converting

9. Converting is processing the paper to make boxes, cups, plates, bags, and many other things.

# Pulping

Wood is now the main source of papermaking fibers. Pulpwood "sticks" are first debarked by tumbling them in drums or by sets of mechanical knives or by water jets with very high pressure. The bare sticks are then pulped.

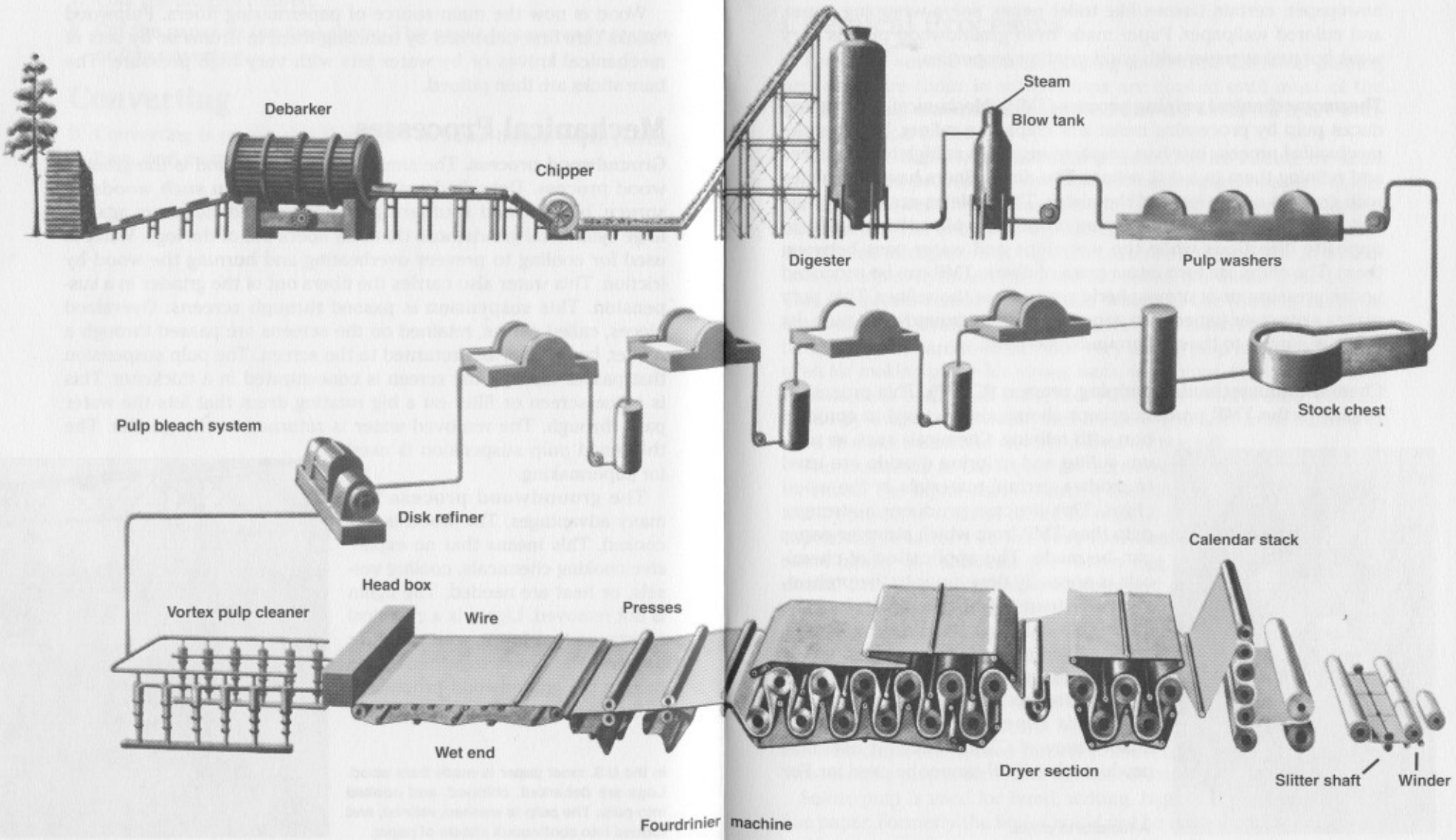
## Mechanical Processes

**Groundwood process.** The simplest pulping method is the groundwood process. Debarked softwood "sticks" from such woods as spruce, balsam, and southern pine are pressed sideways against large cylindrical grindstones that tear fibers out of the logs. Water is used for cooling to prevent overheating and burning the wood by friction. This water also carries the fibers out of the grinder in a suspension. This suspension is passed through screens. Oversized pieces, called shives, retained on the screens are passed through a refiner, broken up, and returned to the screen. The pulp suspension that passes through the screen is concentrated in a thickener. This is a fine screen or filter on a big rotating drum that lets the water pass through. The removed water is returned to the grinder. The thickened pulp suspension is used for papermaking.

The groundwood process has many advantages. The wood is not cooked. This means that no expensive cooking chemicals, cooling vessels, or heat are needed. The lignin is not removed. Lignin is a chemical substance that forms with cellulose to bond the fibers together in the tree. In the groundwood process all

**In the U.S. most paper is made from wood. Logs are debarked, chipped, and cooked into pulp. The pulp is washed, refined, and formed into continuous sheets of paper.**

CHEMICAL PULPING FOR PAPERMAKING—FROM TREES TO PAPER.




Fourdrinier machine

of the wood is used to make paper. This gives us the most paper from each tree.

The disadvantage of this process is that due to the lignin, the paper discolors, especially in sunlight. This pulp is used for making newspaper, certain tissues like toilet paper, some wrapping paper, and colored wallpaper. Paper made from groundwood pulp is very weak but makes paper with good printing properties.

**Thermomechanical pulping process (TMP).** Mechanical pulping produces pulp by processing moist wet chips in a refiner. The thermomechanical process involves presteaming chips at high temperatures and refining them in a disk refiner. The disk refiners have two plates with grooves on the faces of the plates. These plates can be up to six feet in diameter. During the refining process the plates turn rapidly in opposite directions while the wet chips and water pass between them. The chips are torn into a mass of fibers. TMP can be produced under pressure or at atmospheric pressure in the refiner. This pulp makes a stronger paper than paper made from groundwood pulp. Its uses are similar to those of groundwood pulp.

**Chemithermomechanical pulping process (CTMP)**. This process is similar to the TMP process except chemicals are used in conjunction with refining. Chemicals such as sodium sulfite and chlorine dioxide are used to oxidize certain materials in the wood chips. This process produces a stronger pulp than TMP from which stronger paper can be made. The application of chemicals is normally done prior to the preheating and steaming of the chips, but the chemicals can also be added during or after refining. In addition to superior strength, the absorption characteristics of the pulp are much improved over those of TMP. This superior pulp strength and absorbency of CTMP makes it useful in products that TMP cannot be used for. For example, CTMP's use in tissue paper is made possible because the chemicals used in the CTMP process remove resins that are responsible for reduced water absorbency in TMP. CTMP can also be used alone in newsprint and telephone directories.

A handful of chips.

## Chemical Processes

There are several chemical pulping processes. Chemical pulping processes are those in which chips are cooked until most of the tree's bonding materials are removed and the fibers fall apart without mechanical action.

The most important chemical process is the sulfate or kraft process. This process yields some of the strongest papers made. (Kraft is the Swedish word for strength.) Almost any species of wood can be used. The debarked logs are chipped into half-inch chips that are cooked in digesters at high temperature and pressure in a solution of sodium hydroxide and sodium sulfide for about three hours. The chemicals remove the lignin, which is the binding material between wood fibers. After cooking, the pulp is blown into the blow tank. A brown, hard-to-bleach but very strong pulp is produced. It is used for making paper for strong bags, wrappings, tape, paperboard cartons, milk bottles, oil cans, etc. The liquor is recovered, concentrated by evaporating water, and burned. The heat from burning is used to make steam and electric power for the mill.

The chemicals in the liquor are recovered from the furnace slag for reuse. The liquor that is burned contains lignin, carbohydrates, and by-products such as alcohols, organic acids, sulfides, and mercaptans. The latter two are very foul smelling and belong to the same family of chemicals as "rotten egg odor" and "essence of skunk." Much research has been done and great progress has been made in eliminating this odor.

Another common process is the sulfite process, which uses mainly spruce and some hemlock and fir. The liquor for cooking the chips is made by burning sulfur to sulfur dioxide and absorbing the sulfur-dioxide gas in water in a tower filled with limestone. The resulting liquor is a solution of calcium bisulfite and some magnesium bisulfite. The chips are cooked for ten to eleven hours at 220° to 310°F. The resulting pulp is screened, thickened, and bleached.

Sulfite pulp is used for bond, writing, high-grade book, and other fine paper. Formerly the liquor could not be reused and was dumped

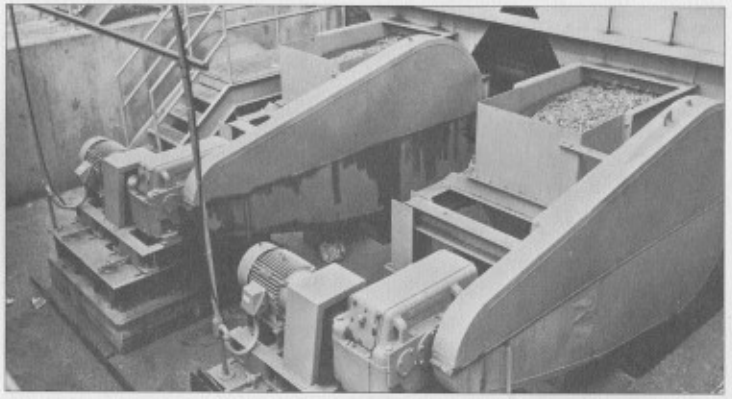
into the nearest stream. Research has shown that it can be used for the manufacture of some by-products such as vanillin, alcohol by fermentation, tanning materials, road binders, cement additives, plastics, etc. However, recovery of chemicals from this liquor is still a problem. As a result, not many mills use this process.

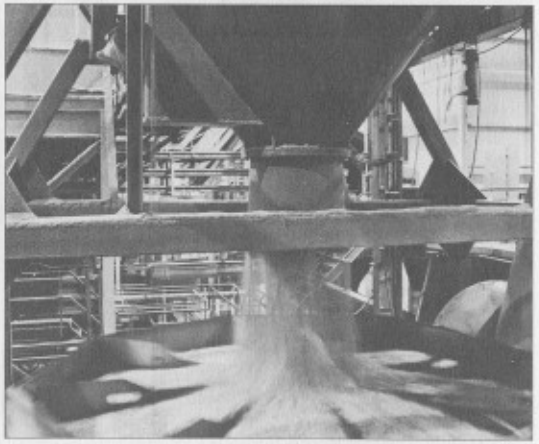
The oldest pulping process—rag pulping—is still used. New rags—scraps from the textile industry—are preferred, but old rags from waste are also used. Old rags must be sorted; synthetics and silk must be removed; and zippers, buckles, belts, and the contents of pockets must be discarded. Sometimes the waste must be sorted by color so that a white product may be obtained.

The rags are cut into small squares; dusted in a mechanical dust remover; cooked in lime, caustic soda, or lime and soda ash for ten to twelve hours at 250° F; then washed, bleached, and rewashed. The resulting pulp is used for the manufacture of fine writing papers, bank notes, security papers, documents, lightweight papers (such as cigarette, carbon, and tracing paper; vellum; and blueprint papers), and for plastic laminates (such as football helmets, shin guards, shoulder pads, plastic gears, and machine components, etc.).

Other pulping processes have been developed to use fibrous materials that would otherwise be wasted or to use special fibers in countries that do not grow pulpwood. These include sugar cane bagasse, straws, bamboo, and other materials of minor importance.

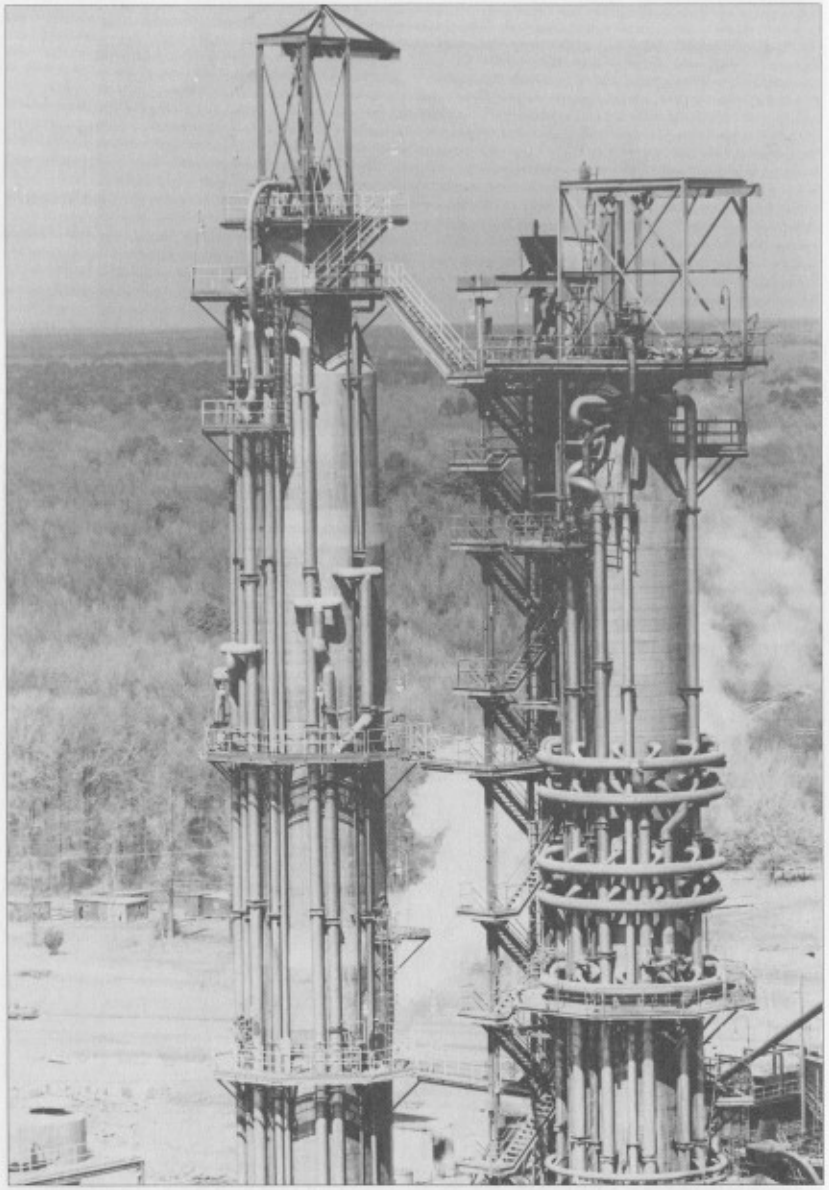
**After the bark is removed, the logs are chipped before being put in the digester for cooking.**





## Semichemical Process

The neutral sulfite semichemical (NSSC) process is the most widely used process in semichemical pulping. It employs sodium sulfite and sodium bicarbonate to produce a pulp of 75 to 80 percent yield. The neutral sulfite cooking liquor is very specific for breaking down lignin. The primary objective in the development of this pulping process in the 1920s was to use more hardwoods and obtain higher yields than possible with other chemical processes. The process is suited only for hardwood species and is not used for pulping softwood species. The advantage of the NSSC process is that it makes a rigid paper. For this reason it is used in the manufacturing of the corrugating medium used in fiberboard boxes.



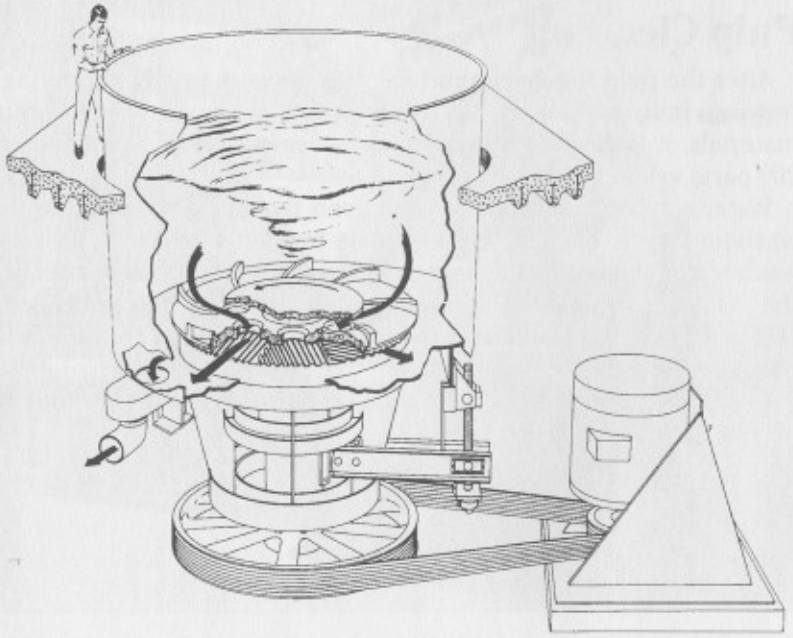
These two continuous digesters are really gigantic pressure cookers that process nearly fourteen hundred tons of chips per day. The chips are fed continuously into the top of the digesters. Steam and chemicals are added and the cooked pulp is discharged at the bottom. The pulp is then ready for washing, bleaching, and refining. The cooking chemicals are recovered and reused.



## Use of Wastepaper

Another source of pulp is wastepaper, which presently furnishes about one-quarter of all pulp fiber used in the United States. Recycled boxboard mills defiber the wastepaper mechanically to make it into paperboard without deinking. In some mills old papers are sorted, shredded, dusted, and cooked in caustic liquor to break the vehicle in the ink so that the ink can be removed. An ever-increasing quantity of wastepaper is repulped and deinked to produce pulp for further paper manufacture. This process has a great future. Getting rid of wastepaper is now a problem. Increased demand for paper products results in a growing need for papermaking fibers. What is more natural than to reuse the waste?

However, the recycle process has several serious disadvantages. Much of the raw material is mixed with undesirable materials of all



A typical pulper is used for recovery of wastepaper. Paper is saturated and drawn between the rotating disk in the bottom to be repulped. Courtesy Noble and Wood Machine Company.

kinds including plastics, glue, foil, wax, metals (staples), and all kinds of dirt and garbage. These must be removed on a large scale without expensive hand sorting. Furthermore, if printing and writing papers are to be made, the inks must be removed. This can be done, but then the ink must be removed from the wash water. Recycling can cause pollution.

Recycling paper is a big job for the paper research groups of today. Much effort is put into cleaning and deinking pulp and into cleaning the wash water. The process must be economical when compared with processes using new fiber from trees. If collecting, sorting, cleaning, deinking, etc., cost more than wood pulping, the company will not be able to compete. Recycled fibers can, of course, be used for making boxes without deinking. Since many boxes are used for food packaging, care must be taken that no toxic materials are recycled. Wastepaper cannot be hand sorted economically, so the use of toxic materials in products like office papers must be restricted.

## Pulp Cleaning

After the pulp has been produced from wood, waste, paper, rags, bagasse (sugar industry waste), bamboo, straw, or other fibrous materials, it is cleaned by screening a suspension of 1 part pulp to 200 parts water.

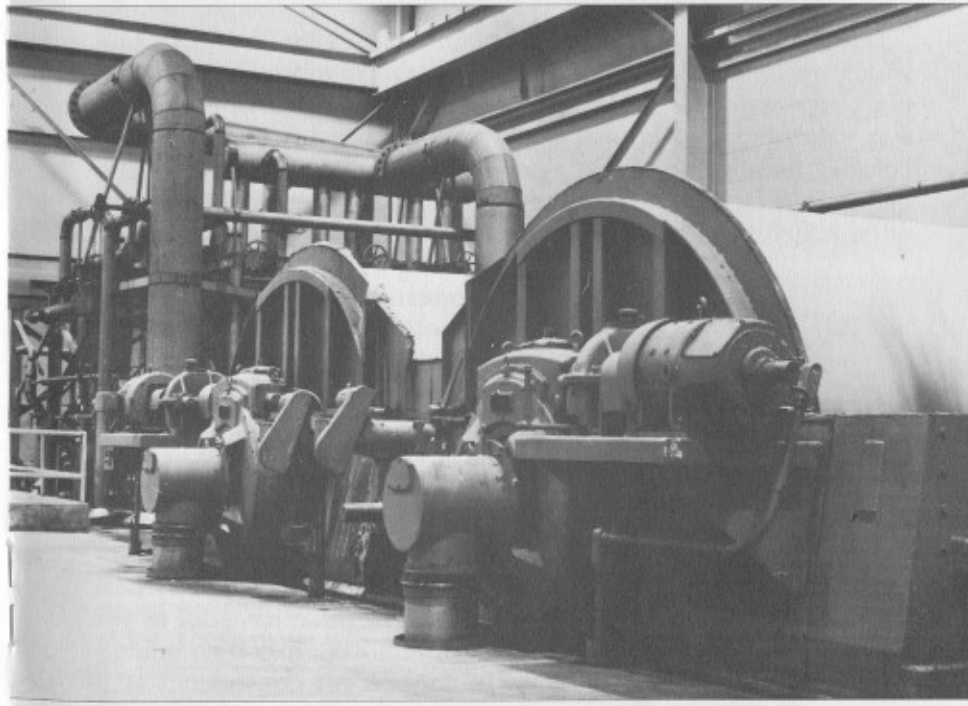
Water-soluble impurities are removed by several countercurrent washing stages. The last wash is made in fresh water, with the used wash water passing to the next to last washer and so on. In this way the pulps get washed in clean water while the impurities are concentrated in as little water as possible to make waste treatment or chemical recovery easier.

In each washing step, the pulp is separated from the water by large, rotating circular screens with fine mesh.

## Pulp Bleaching

To produce white paper, the pulp must be bleached. The bleaching agents are the same as those used for bleaching cloth. They are usually calcium or sodium hypochlorite (household bleach), chlorine dioxide, sodium peroxide, hydrogen peroxide, oxygen, or ozone. These materials either remove the color-causing compounds or make them colorless.

Bleaching is often performed in a series of steps using different chemicals in each state. The operations are carried out in tall vessels called bleaching towers. The bleaching is a continuous operation, with the pulp moving from stage to stage. Each stage has its own chemical addition and washing station.



This continuous pulp washer is used to wash pulp between each step in the bleaching process. After the washing, water is removed as the pulp travels over these large rotating screens.

# Papermaking

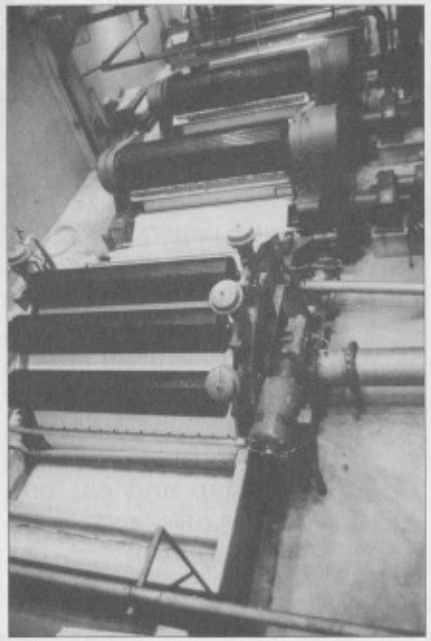
Pulp is made into paper either in the same location as the pulp mill (an integrated mill), or it is dried and shipped to a paper mill. There the pulp is broken up into a suspension in a hydrapulper, which is similar to a large food blender.

Most pulp cannot be used for papermaking as it comes from the pulp mill. It must first be refined and treated to give it the characteristics needed for the paper to be made. Pulp is refined either in beaters or in refiners. The pulp is passed repeatedly between sharp moving bars that cut and abrade the fibers. This improves fiber-to-fiber bonding, making it more uniform, more dense, less porous, and more transparent.

Beaters are also used to blend pulp; to add filler (such as clay), which occupies space between the fibers; to improve the brightness, appearance, and ink reception; to add size (such as rosins and wax emulsions), which makes paper more water resistant; to add coloring agents; and to add alum, which sets the size and dye and prevents their loss during the paper-forming step. Polymers are often added to improve water drainage and the consolidation and bonding of fibers to improve the properties of the final papers. Sometimes wet-strength resins are added. This makes the paper stronger when dry, and it also keeps one-fourth to one-third of its strength when wet.

Hydrapulper like this one repulps dried pulp for papermaking.

The resulting pulp is once more screened and in some cases passed through a centrifugal cleaner to remove heavy particles of dirt that have not as yet been removed. It is then diluted to 0.5 percent consistency (0.5 percent fiber, 99.5 percent water) and pumped to a paper machine.



Pulp is dried by machine for shipment to a distant paper mill.

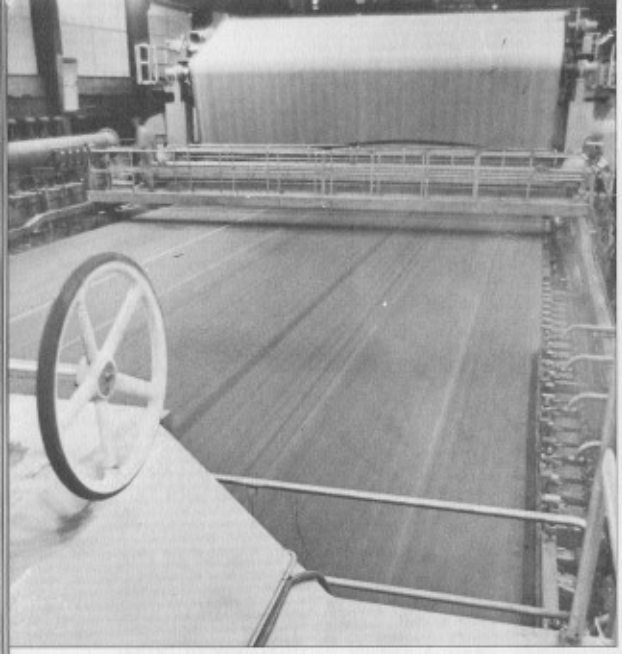
The Fourdrinier papermaking machine is still the most common. It consists mainly of a continuous fine screen, called a wire, on which the pulp suspension is spread. The wire moves at a speed of 200 feet per minute for some specialty paper to 4,000 feet per minute for tissue, and may range from widths of 4 to almost 30 feet.

By the time the paper nears the end of the wire, most of the water has been drained from the mat. The wire then passes over a series of vacuum suction boxes that suck more water from the wet mat through the wire. The wet paper leaves the Fourdrinier wire at a consistency of about 20 percent (20 percent fiber and additives, 80 percent water).

## Water Pressed Out

After leaving the Fourdrinier wire, the wet paper is supported by endless woolen or synthetic loops called felts. The paper on top of the felts is then passed between heavy press rolls to press out as much water as possible. The paper leaves the press section at approximately 40 percent consistency. The rest of the water must be evaporated on steam-heated rolls. Endless felts again carry the paper through and press it against steam-heated rolls on alternate sides. These dryer felts are made of either cotton or synthetic fabric. The water vapor removed from the paper is exhausted through a short stack.

The dried paper is passed through a series of heavy, smooth cast-iron rolls called calendar stacks, which further smooth the surface.

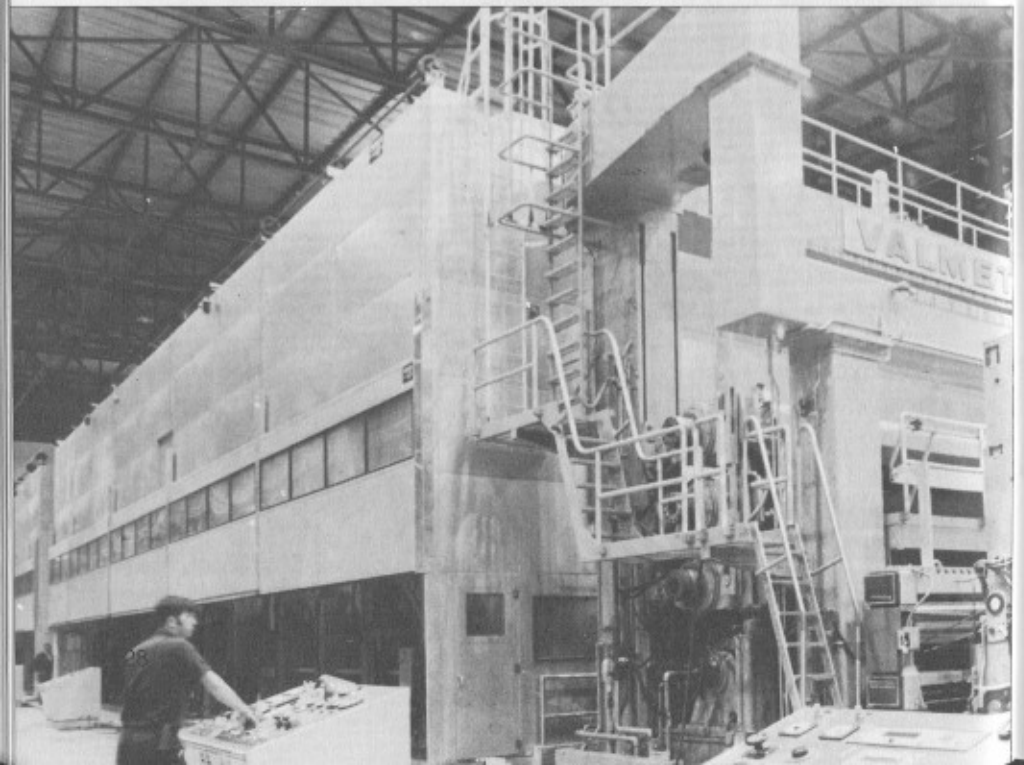


Wet end of a paper machine, *above*.

It is then wound into a large roll. The paper is later rewound and cut to the desired roll sizes for sale or for further processing.

Some papers, such as tissue papers, are dried on a Yankee dryer, a large, rapidly turning drum heated with very hot high-pressure steam. Heated air is blown into the machine to speed drying. Large rolls are rewound and cut into smaller rolls (such as toilet tissue rolls).

Dry end of a large modern paper machine, *below*.



## Paperboard

Paperboard is still made on the cylinder machine. Paperboard consists of several layers of paper. Pulp is pumped to several vats. In each vat a cylinder covered with a fine wire screen turns at the same speed as the rest of the machine. Water passes from the vat through the screen and is removed from the center of the cylinder, leaving a mat of paper on the wire screen. A continuous felt blanket in contact with all cylinders picks up layers of paper, forming a laminated or layered board. This board is passed through a press section similar to that used with the Fourdrinier machine and then dried on steam-heated rolls without dryer felts.

A good grade of pulp is frequently used on the last cylinders to give the outside of the board a good appearance. The second sheet is often made of a slightly poorer grade, while the inner layers are normally reclaimed paper of poor grade. A common example is found in book matches. A book match can be separated into several thin layers of paper. The outer sheet is white or dyed; the inner sheets are dirty gray.

Needless to say, paper machines are changing rapidly. The Fourdrinier machine is being replaced by a number of new models. Some of these are horizontal like the Fourdrinier with wire screens on the top as well as the bottom of the sheet, while others are vertical. In either case water is removed from both sides of the sheet. This helps prevent one-sidedness—both sides of the sheet are formed alike. This is not true when only the underside of the sheet is in contact with the forming wire since the water leaves through that side, taking some small particles with it.

The cylinder machine is also being replaced by new machines that lay down several sheets on top of each other and remove water from both sides after each layer is placed. In addition there are now several types of vatless cylinder machines.

In general, machines are getting wider and faster. Paper speeds as fast as a mile per minute have been reached.

The dryer section is also changing. Some machines have both a multiroll section and a high-temperature Yankee dryer. Some machines have infrared heat lamps in addition to the steam-heated rolls.

As the machines get larger and faster, the air system for removing the water vapor also becomes more complicated. As mentioned

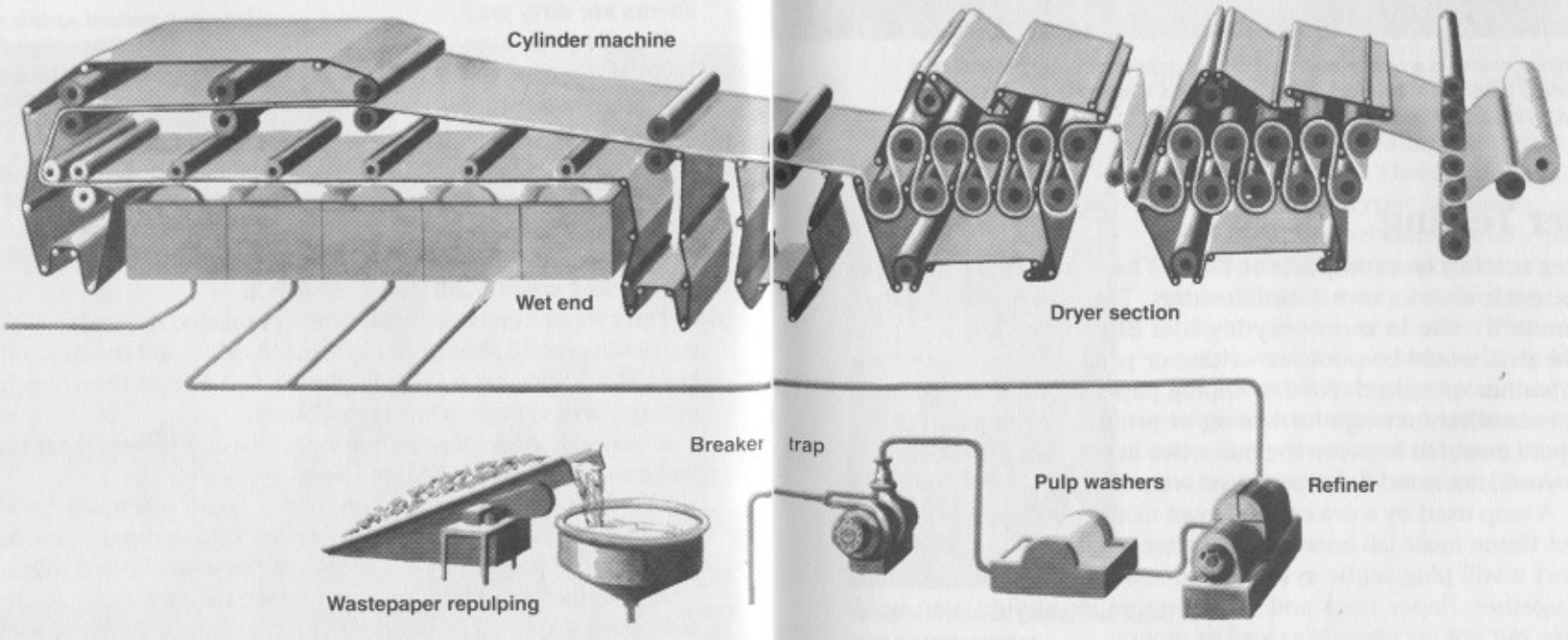
before, a large mill making 1,000 tons of paper per day takes in about 50 million cubic feet of air per hour, heats it so it can pick up the water vapor, and blows it out into the surroundings. This is equal to a 100-mile-per-hour hurricane through a duct 10 feet high by 10 feet wide (100 square feet).

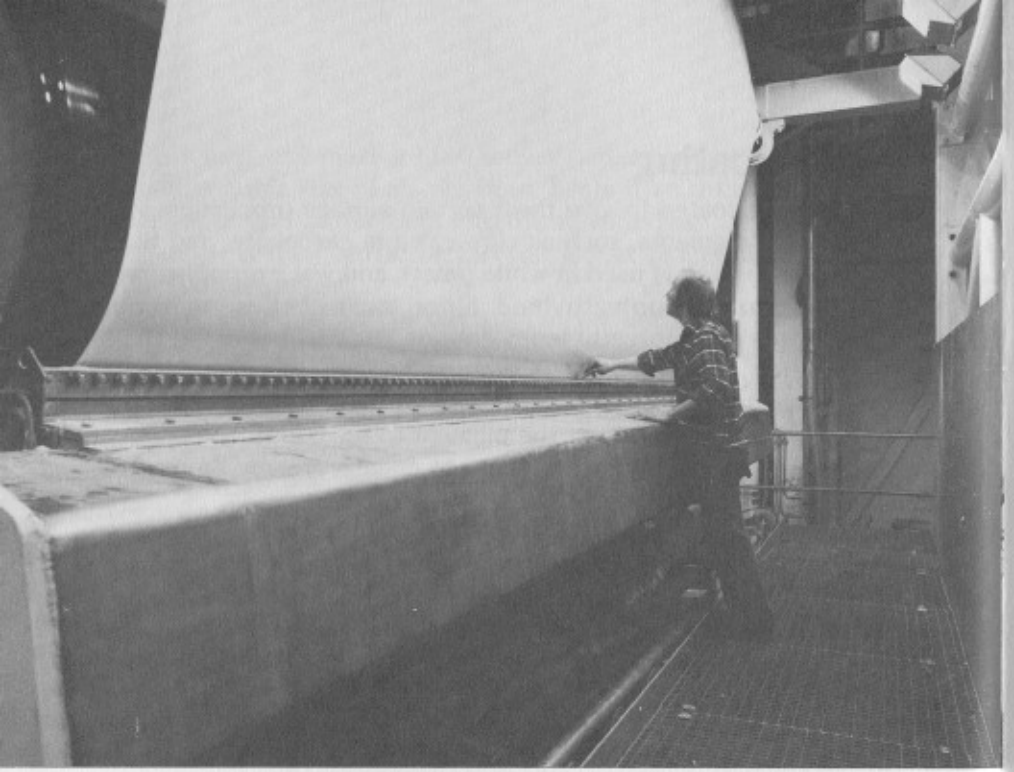
Indeed, as the paper machines get larger and faster and the mills get larger, every part of the mill must also get larger. This means that even small improvements that save very little money become important. If an employee in a 1,000-ton-per-day mill finds a way to save a tenth of a cent per pound of paper made, he saves his company about $700,000 per year. This makes competition for improvements very keen. The paper industry is operating on a low profit margin. A cost difference of a fraction of a cent per pound can make the difference between staying in business or shutting down. This makes paper engineers important. If they fail, their company fails with them.

## Paper Coating

Papers are coated to give them certain surface properties. Most coatings are pigments, such as clay, calcium carbonate, and titanium dioxide (which is used in white paint), and waterproofing materials like wax and polyethylene. Since most of these materials (except wax and polyethylene) cannot stick to paper by themselves, they are "glued" on. Common adhesives or binders are starch, casein (a milk by-product), and synthetic adhesives such as resins and latexes. These fix the pigment to the paper. The pigment and adhesive are dispersed in water to make a creamy liquid. This liquid is put on the paper.

Several methods are used for applying the coating. The paper can be dipped in coating or the coating can be applied by rolls or sprays. The excess may then be removed with a blade or blown away with an air jet. The goal is to make an even film of the right thickness. Uniform thickness is essential for modern high-speed printing operations.





On-machine coater is a continuous part of this paper machine, producing a bright white food board for frozen-food packages. Coating is also frequently done on an off-machine coater.

## Paper Testing

Paper testing is an important field. There are many kinds of papers, each with its own characteristics. The properties of paper determine its use in our everyday life. Blotting paper must be absorbent. It would be poor for writing or printing because the ink would feather or spread. Food-wrapping paper is just the opposite. It is not absorbent enough for writing or printing. Writing and printing papers must fall between the other two in terms of absorbency.

You would not mind if a paper towel were to shrink a little or swell a little. A map used by a sea captain must never shrink or swell.

Toilet tissue must fall apart shortly after it gets wet. If it does not fall apart it will plug septic systems and sewers. Paper money must hold together. Paper bags and wrapping paper should also hold together, but not necessarily as well as money.

Microscope reveals secrets of pulp fiber development.

Laboratory-sized beater develops pulp characteristics.

Documents, legal papers, records, and books must not fade over the years. Newspapers can fade by tomorrow for all we care.

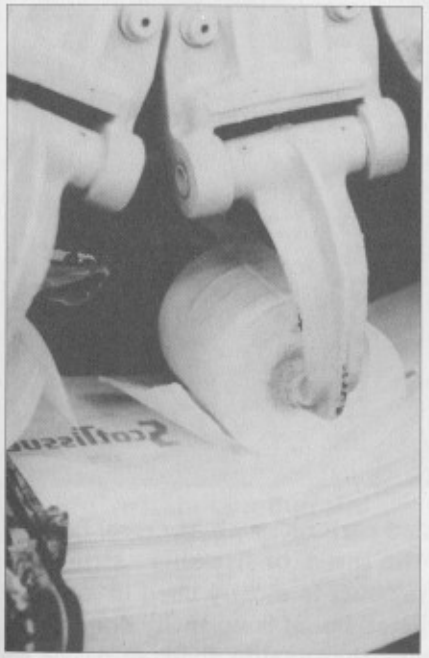
There is no end to paper uses. Each use calls for different properties. Each property must be engineered into the paper and tested for. Just look at the variety of paper products around you. Towels, facial tissues, toilet tissues, diapers, wiping "cloths," napkins, crepe, and others make up one group. Another group is writing, printing, mimeograph, drawing, tracing, magazine, airmail, and notebook paper. Packaging materials such as wax paper, disposable fruit drink/juice containers, milk cartons, plates, cups, cans, frozen-food cartons, bags, and boxes are also a group. There are special papers such as map paper that will not shrink and photographic paper that cannot be made in a plant using surface water—a single particle of radioactive fallout would leave a spot on a picture. There are wallpapers; tapes of many types; smooth, glossy papers; sandpapers and emery papers; grease-proof papers; and blotters. Every use is different; every product is specially made for one use or another. The world of paper is an endless wonderland. No one can know it all. Every time you turn around someone has come up with something new. Every new product must fill a need and must be made in an economical way.

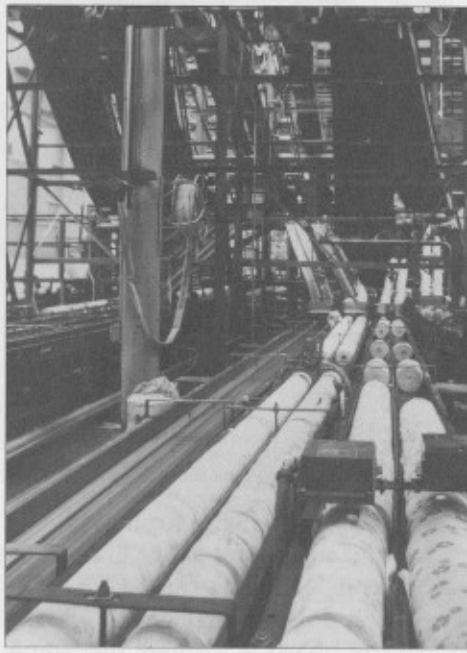
Paper products have a wide range of uses and must be tested to meet the requirements of their specific use. Fine, soft papers are needed for facial tissues and napkins, sturdy paperboard for food containers, specialty paper for hospital gowns, and rugged paper for industry. All our groceries and other products would cost much more without the protective paper packaging that speeds distribution.

# Converting

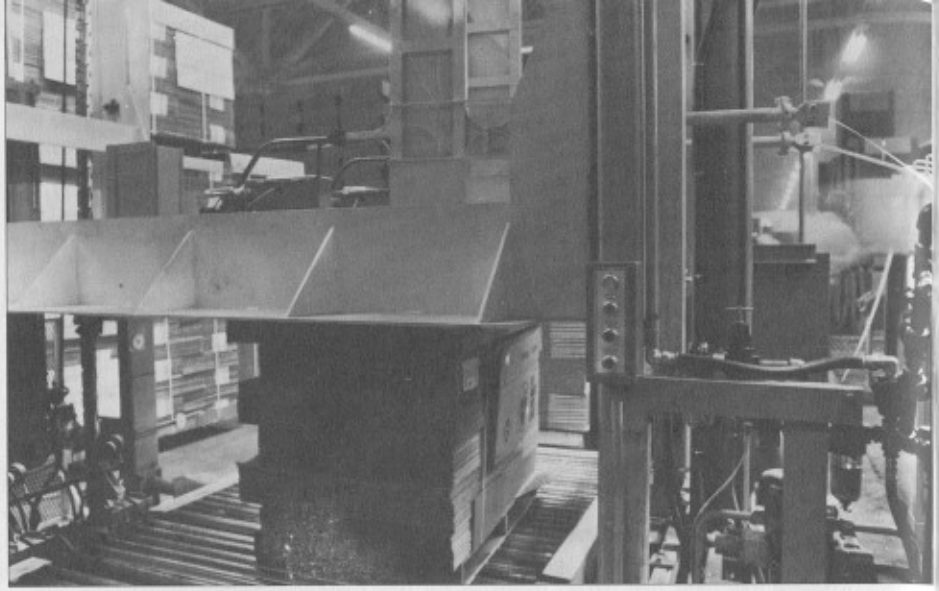
Converting is the process of making paper products from the large rolls of paper coming off the paper machine. Steps include slitting and cutting to achieve the right size; stamping and diecutting to get the right shape; scoring and creasing to provide lines to bend thick paperboard; and folding and gluing to form the final product. Some paper is first coated with liquid starch or plastic, then dried, to provide a good printing surface or a good appearance.

On thin paper printing is done on long rolls before the final product is cut to size and shape. On thick paper, called paperboard, sheets are first cut, then printed on flat presses. Some products are overlaid with a thin sheet of plastic, called laminating. This plastic sheet may have the printing already on it.





Paper or paperboard can be converted into many useful items—from soft household tissues, *above,* to rugged boxes, being made in photos *on the following page.*



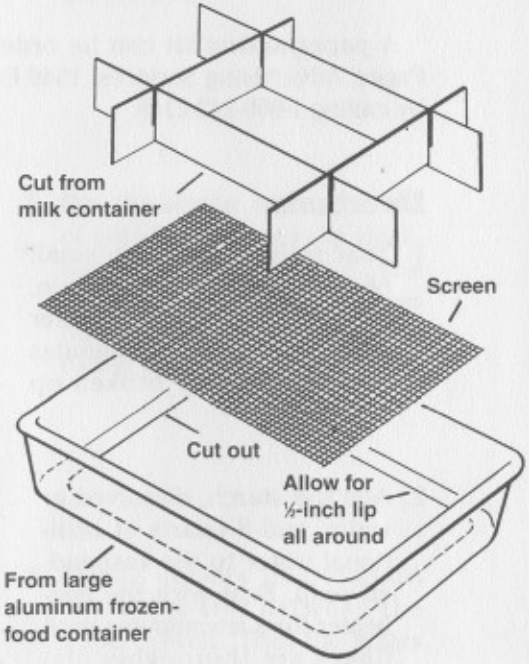
Much paper is formed into "folded cartons" such as cereal boxes, and into corrugated fiberboard, the three- or five-sheet structure usually called "cardboard." This product is mostly used in making shipping boxes. Printing on corrugated board is normally done after the board is formed, but sometimes the outside sheet of paper is printed before the board is made to improve printing quality.

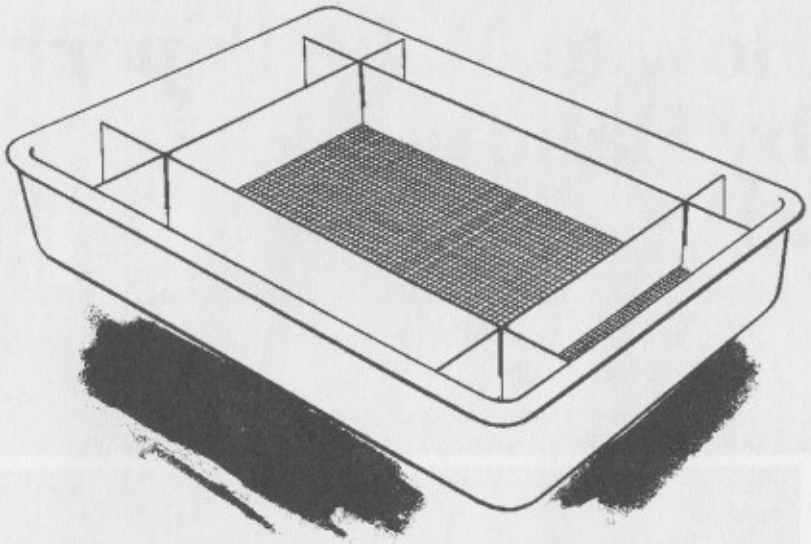
# How to Make Paper by Hand

## Materials Needed

To make paper by hand, you will need these materials:

1. A fine-meshed wire screen. A window screen covered with an old piece of curtain will do.
2. A large aluminum frozen-food container. Trim the screen to fit in the bottom of the pan. Then cut out the bottom of the pan, leaving a lip about ½ inch wide to support the screen.
3. A forming rack or mold to hold pulp in place. This can be made from strips of waxed cardboard cut from a milk container or a frozen-food package. See diagram.
4. A basin that will hold at least 10 quarts of water.
5. Sixty sheets of toilet tissue.
6. Several sheets of paper towels.
7. Laundry starch. One tablespoon of instant starch in two cups of water will provide what commercial papermakers call "size."
8. An eggbeater and a rolling pin.
9. A household electric iron.

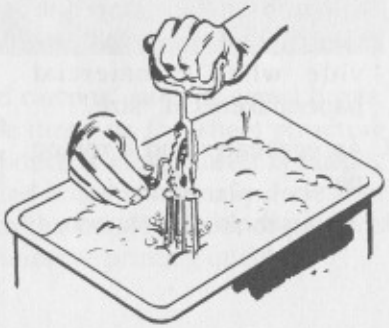




A papermaking kit can be ordered by writing to International Paper, Advertising Services, 1540 East Lake Road, Erie, PA 16533, or by calling 1-800-242-2148.

## Directions

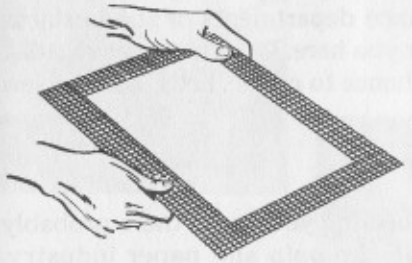
1. Tear toilet tissue into small pieces and place in the basin. Cover with 1½ quarts of water and stir for about ten minutes until thoroughly broken up into pulp.



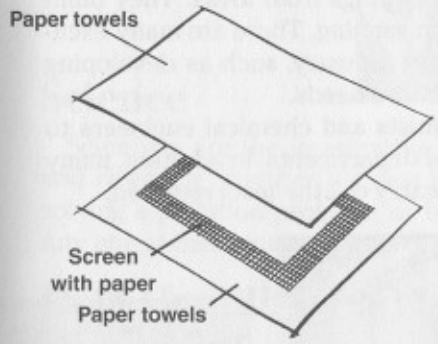
2. Add the starch, dissolved in water, and 8 quarts of additional water to the suspended pulp. Beat with the eggbeater for a few minutes until fibers are thoroughly dispersed in the water.



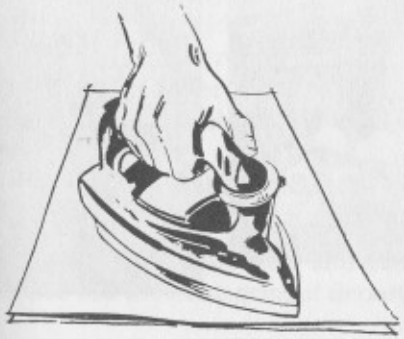
3. Hold the forming rack firmly on the screen and pan, and dip into the pulp mixture; lift to horizontal position. Raise the screen, retaining a thin layer of pulp on top.



4. Clean off the excess pulp outside the forming rack. Lift out the screen on which the pulp has formed.




5. Dry the screen and wet sheet of pulp between several thicknesses of paper towels. The sheet will stick to them. Press out excess water with the rolling pin.



6. Finally, iron-dry (not too hot) the sheet still between the paper towels. Trim the edges with scissors. You now have a sheet of handmade paper.

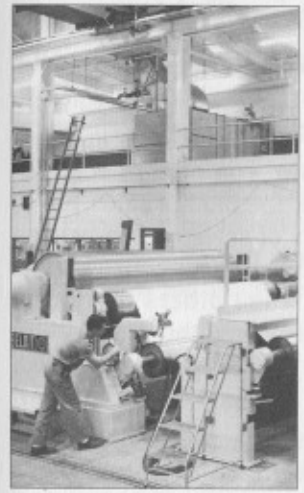
# You and Your Future

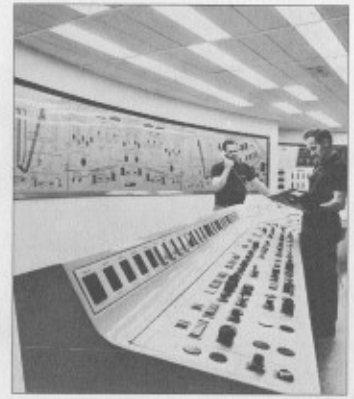
What you plan to do to earn a living throughout your life will become of great importance to you in a few years. Whatever you decide, it should be something that you are suited for and that you enjoy doing. As you visit a plant as part of this merit badge requirement, look and see if this is the kind of industry in which you would like to work. Does the machinery excite you? Or are you impressed with the engineering or maintenance departments or the business office? There are opportunities for you here. Work becomes exciting when it offers a challenge or the chance to create. Let's look at a few opportunities for trained people.

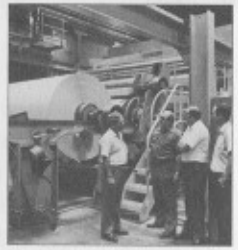
## Engineering

Regardless of what kind of engineering you study, there probably will be an opportunity for you in the pulp and paper industry. Engineers are the people who create things from ideas. They build machinery and plants and keep them running. There are many exciting challenges to be met in the paper industry, such as developing new ways of making paper to meet future needs.

The industry requires many chemists and chemical engineers to run the technical and quality control departments. In addition, many qualified technicians are needed to carry out the tests required.





## Science

Scientists are the imaginative people who do the basic thinking and research, whether it's new products, a new process, a way of solving a pollution problem, or better ways of growing super trees. Any one of these may offer the kind of challenge you are seeking.

## Data Handling and Information Retrieval

Considerable strides have been made during the past few years with regard to widening the range of computer applications in research. Computers can measure the quality of paper and the properties in the paper web. They are also used to operate the giant papermaking machines.

## Business and Management

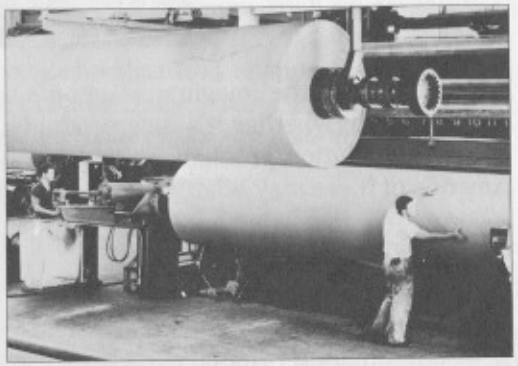
All the plans for running and managing a company are made by people trained in business and management. If this interests you, be sure to see the management department of the company you visit.

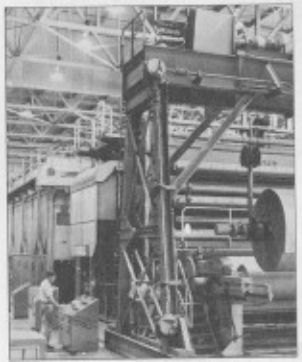
## Sales and Marketing

If working with people rather than things appeals to you, you might decide to enter the field of sales. Some kinds of sales require you to have technical college training, while others do not. In either case, this field offers many exciting opportunities.

## Forestry

If you like to work outdoors and enjoy being in the woods, you might decide that forestry provides the opportunity you want. Not only do foresters supervise existing woodlands and their harvesting and replanting, they also are involved with developing new ways of growing better trees faster.





## Where to Study

Many schools throughout the country offer degrees in engineering, science, business, computer science, etc. There are also colleges and universities that offer degrees in specialized fields such as wood science and technology, pulp and paper engineering, forestry, and graphic communications.

For more information on career opportunities in the paper industry, you should talk with your counselor and/or write to some of these associations for brochures on schools and careers in the industry:

American Paper Institute
260 Madison Avenue
New York, NY 10016

Society of American Foresters
5400 Grosvenor Lane
Bethesda, MD 20814

Society of Wood Science and Technology
One Gifford Pinchot Drive
Madison, WI 53705

Technical Association of the Pulp and Paper Industry
Public Outreach Department
P.O. Box 105113
Technology Park/Atlanta
Atlanta, GA 30348-5113

Graphic Arts Technical Foundation
200 Deer Run Road
Sewickley, PA 15143-2600

# Environmental Concerns

Since the first strong push of environmental awareness in the 1960s, the paper industry has been concerned with its impact on the environment. The industry has had to learn which manufacturing processes were actually harmful to the environment and then learn how to prevent, or at least lessen, the damage. With the knowledge gained, the industry has been able to make vast improvements in pollution abatement.

Millions of gallons of water are used in papermaking. Pulp goes onto the paper machine at about 99.5 percent water, 0.5 percent fiber. The finished paper contains about 5 percent water. The water removed during processing is recycled, additional fibers are recovered, and the excess containing fines, clays, and other fillers is clarified in settling ponds. The solid material in the settling ponds is aerated to encourage biological degradation; nitrogen is added and the remaining sludge is composted and used as a clean fill, in strip mines, or on steep slopes.

Some of the chemicals used in pulping and bleaching have been found to be harmful to the environment in one way or another. Many of these chemicals can be recovered and reused. However, the acid sulfite process has, for all practical purposes, been abandoned because there was no adequate way to recover the pulping chemicals. In the other chemical pulping processes, such as kraft, spent pulping liquor is washed off the pulp. The washings are concentrated by evaporating the water. Sometimes additional useful products such as turpentine or lignin can be recovered. What remains can then be burned to help generate heat or power for the mill. Pulping chemicals can even be recovered from the ash. Recovery and recycling prevents many potentially hazardous chemicals from ever reaching the environment outside the mill.

An enormous amount of energy is necessary to manufacture paper. The industry has had to become more efficient in its manufacturing practices as fuel has become more expensive and concern about air pollution has become greater. Steam from the paper-drying process is recovered by heat exchangers and the heat is used in other areas of the mill. Since papermaking uses so much water, most mills are on lakeshores or along rivers. Water from these sources is used to generate some of the electric power for the mill. Wood waste from the forest, bark stripped from logs, and concentrated spent pulping liquors are all burned as fuel for the mill. The paper industry is somewhat more than 50 percent self-sufficient in energy and will continue to improve in the future.

Researchers continue to try to find better ways to make paper while causing less impact on the environment. Chemical pulping and bleaching processes are being studied that use less harsh chemicals or chemicals that are more easily recovered and reused. Better ways of treating wastewater and smokestack gases are being investigated. More energy-efficient machines and ways of generating power are being developed. Pollution control legislation, high energy costs, and concern for the natural resources upon which the industry depends are causing the forest products industry to spend much time and effort on environmental problems.

# Resources

## Books

Cook, David C. *How Paper Is Made.* Dodd, Mead, 1969.

Eberle, Irmengarde. *New World of Paper.* Dodd, Mead, 1969.

Grummer, Arnold E. *Paper by Kids.* Dillon Press, 1980.

## Pamphlets

These are available from the American Paper Institute, 260 Madison Avenue, New York, NY 10016. A single copy of each is offered free of charge.

*How Paper Came to America* (wall chart, 32" × 22")

*How You Can Make Paper*

*Paper and Paper Manufacture*

*Careers in the Paper Industry: "What's So Special About Paper?"*

*Paper Industry in the U.S.*