Bulletin No. 5

Coated Papers for Web Offset Printing

WARREN

How will it print?

Coated Papers for Web Offset Printing is being issued by S.D. Warren Company to aid the graphic arts community in dealing with the complexities of the printing process. Information contained in this booklet combines the findings of scientists and the observations of experienced craftspeople.

No scientist will claim that existing knowledge is complete, and no sincere craftsperson will pose as a final authority. The text of this bulletin, therefore, represents merely the considered opinions of experienced and thoughtful analysts.

Coated Papers for Web Offset Printing

How to Select the Right Paper for High Volume, High Quality Color Printing

If you were printing a catalog tomorrow and its quantity exceeded 25,000, chances are you'd choose web offset as your method.

One of the fastest growing of modern printing technologies, if not *the* fastest, web offset is a regular choice for medium to long runs of catalogs, direct mail and promotional brochures, magazines, textbooks and hardcover trade books.

Web offset offers the printing buyer quality, flexibility, and economy. It is generally thought to have surpassed sheetfed offset in ink gloss ...and to provide greater flexibility than gravure in accommodating changes in copy and variations in length of run. Equally important are its great speed and complete in-line finishing capabilities. Together they make web offset a "best-buy" in the medium to long-run category.

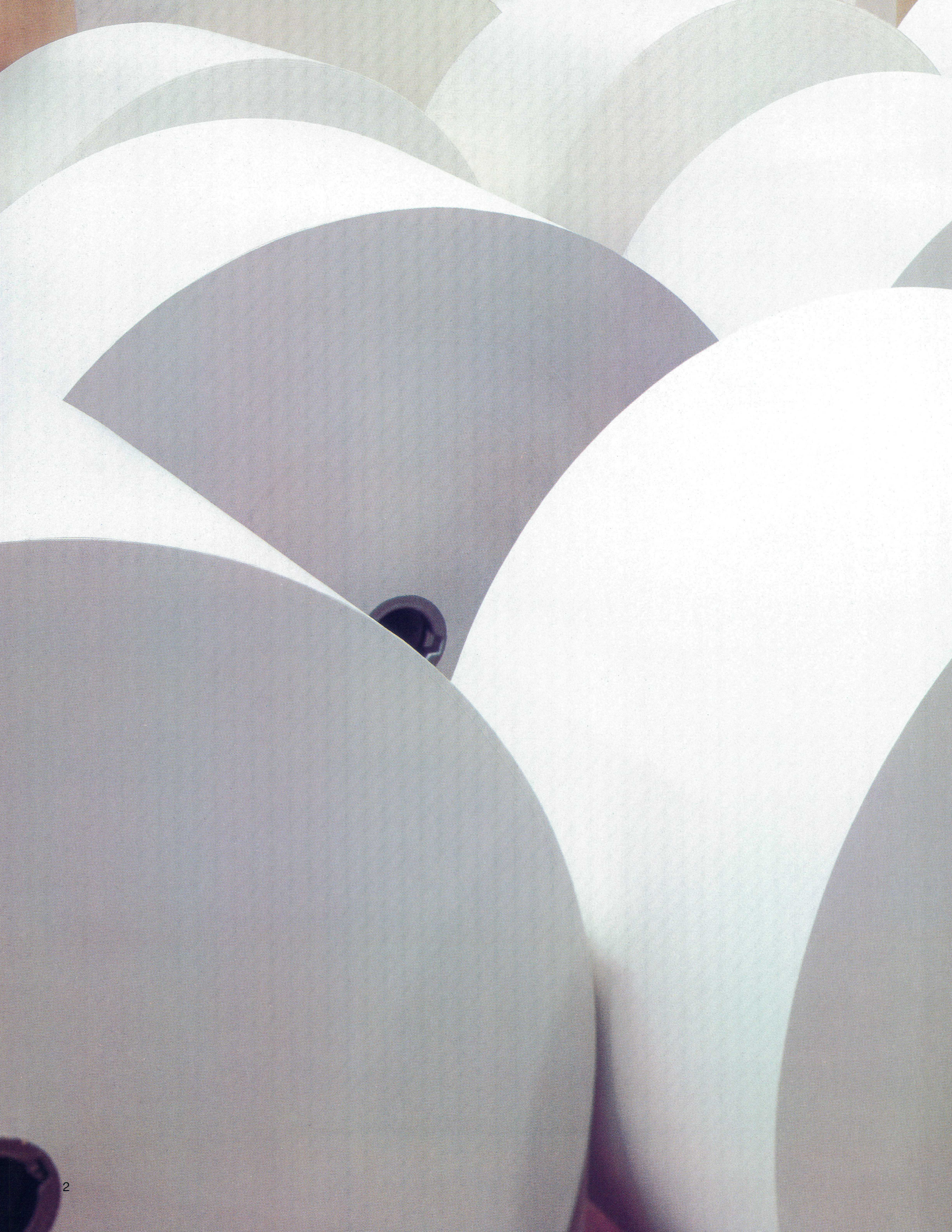
To fully exploit these advantages, however, you must use a paper designed to meet the demands of the web offset process...demands which are considerable.

This booklet will...

- Help you to understand these demands
- Show what properties a paper must have in order to fulfill them
- Describe how different manufacturing processes and materials can affect the suitability of a paper for high quality, high volume web offset printing

Normal paper costs can range from 30% to 50% of a production budget. That percentage may be increased by waste if paper isn't up to the demands of the job. It's clear, therefore, that you must exercise the same care in selecting paper that you would in planning copy, typography, photos, artwork, and design.

For paper is the showcase that enables these other elements not only to get your message across, but to do it with style and impact. In many cases, this may be as important as the specifics of what you have to say.



How This Book is Organized

So you can fully appreciate the challenges your paper faces when being printed by web offset, we begin this book by describing the most common web offset jobs, the specific operations involved, and the characteristics that a paper must have for top performance during these operations.

Next you get background on the materials and processes of papermaking so you can see how "web offset characteristics" can be built into a paper.

Then you are introduced to different paper types and have an opportunity to observe in a variety of printing simulations how each performs under the stresses of web offset.

Finally you learn the five major characteristics to consider in choosing a paper for web offset printing.

The Prominence of Web Offset Printing

The use of web offset is growing in conjunction with two trends. First, advances in its own technology have resulted in better print quality and in greater economy on shorter runs. Second, the markets that web offset is best suited to are expanding at steady rates, particularly in the fields of specialty magazines, direct mail materials, and catalogs.

When multicolor web offset was introduced thirty years ago, paper waste was high because of the complicated makeready process needed to compensate for less than ideal materials. Inks were frequently inconsistent. Many papers were of low brightness. Plates were short lived and plate making cumbersome. The result was often a finished product that looked weak and gray, with colors that might vary throughout a run.

A

C

C

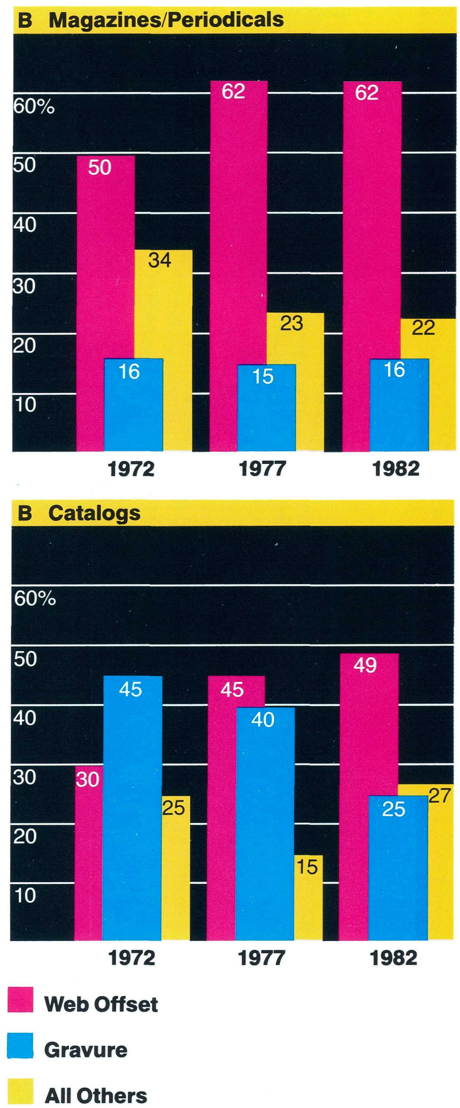
Speed, economy, and a superior finished product have come with automation and better plates, papers, and inks. Yet it is the skilled pressman who controls the system and determines ultimate quality.

A

Running at speeds of up to 25,000 impressions per hour, a web press with in-line finishing can print, fold, and bind within just that single hour what it might take all day to accomplish by a sheetfed press and separate finishing.

B

Web offset and gravure are today's two fastest growing printing methods, with web offset accounting for the largest share of overall printing sales. Steady growth in such markets as books, specialty magazines and demographic editions of weekly magazines, plus catalogs and direct mail materials in quantities of under one million should continue this trend. Source: GATF.



Today the situation has changed completely. Improved inks, blankets, papers, and registration monitoring systems have vastly improved press runnability. Automation and better materials have boosted plate performance and durability...thereby cutting makeready time and paper waste, which, in turn, have reduced the minimum quantity for an economical run to 25,000 copies.

As a consequence of these developments, the demand for web offset printing has grown to the point where it is dominant in several markets. It is now the preferred method for printing specialty magazines and most others with circulations or demographic editions of between 25,000 and 1,000,000; and (in the same quantity range) for catalogs, direct mail materials, and virtually every type of casebound and trade-quality book.

Because these markets themselves are growing with various economic and social trends, web sales should continue to rise. Only gravure is keeping pace by expanding with markets where extremely long runs are involved. In terms of the total printing market, however, gravure's percentages are still quite small when compared to those of web offset.

The Web Offset Process

Imagine a sheet of paper more than a hundred feet long. Now picture it being stretched and contracted...hit with water and ink...driven from room temperature to nearly 300°F in less than three-quarters of a second... dropped to under 100°F in less than one.

That is a fair image of what paper endures as it passes through the multicolor web offset press...a colossal machine able to print a paper roll at over 25 mph. In a three-shift day, this can mean more than enough paper for a round trip between New York and Washington!

The ordeal begins as paper is pulled from the infeed to the first printing unit. (Figure **E**) There water along with ink is transferred to the paper. During the transfer, the paper adheres to blanket to such an extent that the forces required to pull the paper from blanket produce a hard snap. (Figure **A**)

Under the pressure exerted by each successive unit, paper stretches. Then, after the last of the four, five, or six units that a press may have, the paper enters an ink drying oven and shrinks by as much as an eighth of an inch across a 35″ web.

Air temperatures in this oven can exceed 450°F, the level needed to flash off ink solvent and paper moisture. But in this process, the paper's own surface temperature of 250°-300°F is raised high enough to burn your hand. (Figure **B**)

Cooling the paper and setting the inks is the job of the chill rolls, which come next. They drop the paper's temperature by almost 200°F in less than a second.

A

Each of the four to six units on a typical blanket-to-blanket web offset press prints both sides of the web at the same time...squeezing the paper between two blankets with considerable pressure.

B

In the drying oven, ink solvents are flashed off at air temperatures that exceed 450°F, which raise the paper's own temperature to almost 300°F. Then in the chill rolls that follow, its temperature is immediately dropped by about 200°F and the ink is set.

A

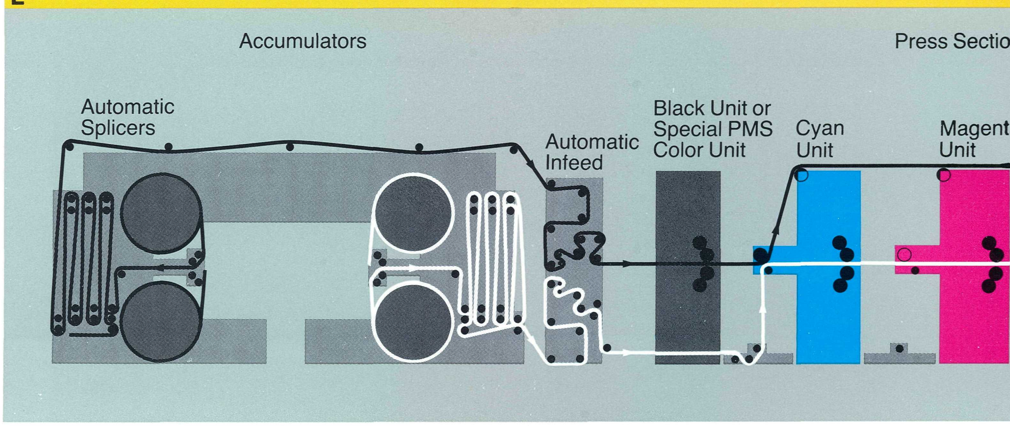
B

E

Splicing and feeding in a new paper web is accomplished without stopping the press by the action of the dancer rollers (or automatic splicers) located just before the infeed, which adjust paper flow until the new web has reached full running speed.

Notice that on the press you see here, two webs are being run. The one shown in black is printed by the first unit (black or special matched color) only. The web shown in white follows the usual path through a five-unit press.

E



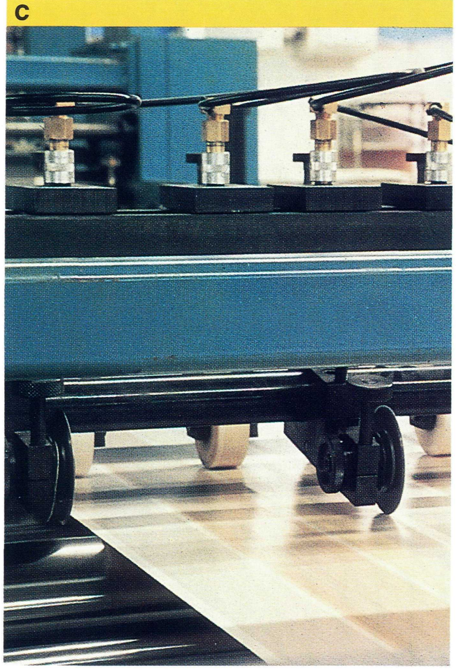
C

With an in-line finishing setup, a job can go from paper roll to completed brochure with cover letter, reply card, and envelope addressed for mailing in one operation. Here the paper web is being slit into two or more ribbons, which will be turned, stacked, and realigned one over the other in preparation for additional operations.

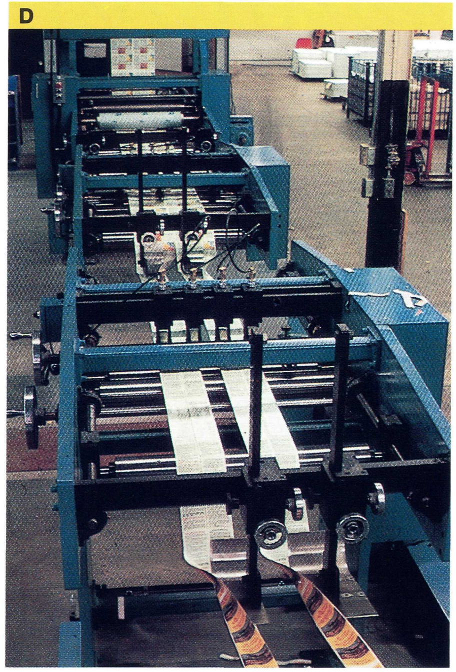
D

The plow folder (foreground) folds the ribbons one or more times along their line of travel. Other finishing operations include gluing, perforating, die-cutting, imprinting, trimming and cutting – to meet whatever requirements the buyer stipulates.

C



D



As if surviving all this weren't test enough of a paper's strength and resiliency, many web presses now include in-line finishing equipment. Thus a job can go from paper roll to complete mailer...folded, gathered, perforated, stitched, stapled or glued...with cover letter, reply card, address label and envelope...all in a single operation. (Figures **C** and **D**)

This is convenient, of course, and economical. But in-line finishing places such additional burdens on paper that, when making your paper choice, you must think not only of what will happen on press, but also of the follow-up.

To be specific, suppose that you're about to release a new product with great potential for being sold by direct mail. You've decided on a mailing package that will include – along with envelope, letter, business reply card and a variety of other inserts – a full-color circular cut to a sheet size of 17" x 22." It will be folded twice, perforated for a coupon, and have a plastic medallion tipped onto its cover.

When selecting a paper for this circular, what should you look for?

Strength

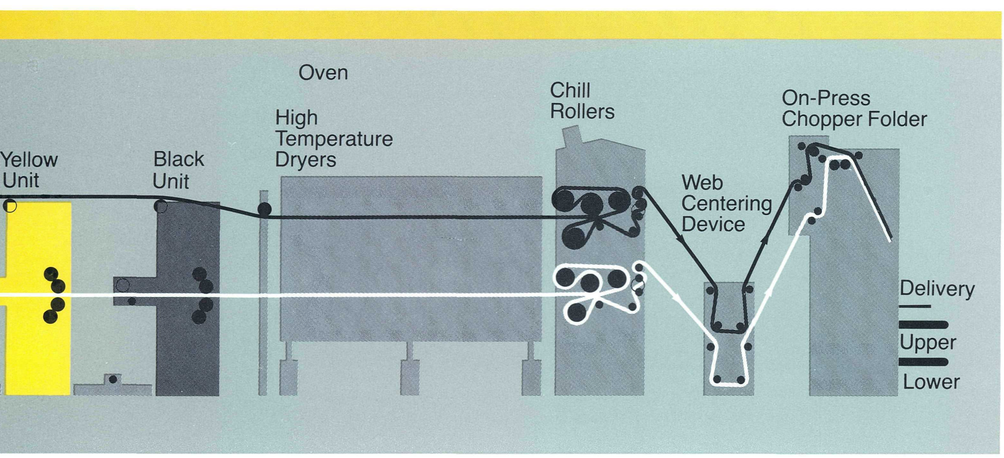
Smoothness and Printability

Brightness

Opacity

And, of course, ***Affordability.***

In the next section of this booklet, you'll learn how to identify each.



Paper Requirements for Web Offset Printing

A

Types of paper strength and printing problems avoided.

Strength

If paper cannot be run through a press without breaks or ruptures, the question of how well it handles an ink film becomes academic. The most basic printing requirement, therefore, is strength.

Paper strength is multidimensional, meaning that it is a combination of properties, some internal and some relating to its surface. (Figure **A**) Internally, for example, there is Mullen or bursting strength, which is the ability to withstand puncture. Although not a major printing concern, it can be crucial in folding, perforating, and other in-line finishing operations.

The importance of tear strength, another internal property, was implicit in the preceding discussion of strains imposed by the web offset process. For these same reasons, paper needs tensile strength…to withstand the stresses that cause breaks in the web.

A

Type	Problem Avoided
Mullen	Puncture
Tear	Tearing
Tensile	Stretching
Bond, internal	Blister and delamination
Bond, internal	Fiber puff or micro-blistering
Print surface	Holes and hickeys

Bonding strength is necessary first to prevent delaminating and blistering, particularly in areas of heavy ink coverage. Second, it helps prevent fiber puff, a condition that occurs when moisture laden fibers or fiber fragments expand under the surface of halftones and heavy solids while in the ink drying oven. Where bonds are weak, these fibers break apart from each other and, although minute, they are visible to the naked eye when viewed by strong side light.

On its surface, paper needs print (or pick) strength. Lack of print strength is evidenced by "holes" where there should be ink. These occur wherever the surface is weak, allowing coating and/or individual fibers to be picked off by the blanket. They remain on the blanket and produce white spots when caused by loose coating or fiber. Hickeys or specks will appear on every impression until either they work their way up through the ink train or the press is stopped and they are washed off. (Figure **B**)

Smoothness and Printability

After determining that a paper can make its way through the press intact, the next considerations are uniformity of process color and quality of halftones, line art, and type. Here smoothness and a suitably tight surface…a paper's printability…are prime requirements, for they largely determine what happens to an ink when applied.

If images are to appear sharp and well detailed, the ink film must be laid down so that dots are of uniform shape and thickness; edges of type and line art must be clean and regular. If colors are to be vivid, pigments and resins in the ink must remain on the paper's surface, not drain into the body of the sheet.

Light is also scattered and colors weakened by a ***rough*** paper. This is because of its many non-uniform surfaces. Black ink film can be especially disappointing. For maximum intensity, black must absorb light; without a smooth surface to support a uniform and non-scattering film, it turns gray. (Figure **C**)

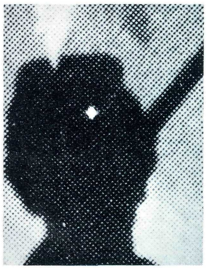
B

A paper must have good print strength to perform successfully on a web offset press. When print strength is lacking, fibers or coating can be pulled from the paper surface by the ink on to the blanket, producing a white void in print. If the fibers or coating are transferred to the plate it will print as a pick out as shown here.

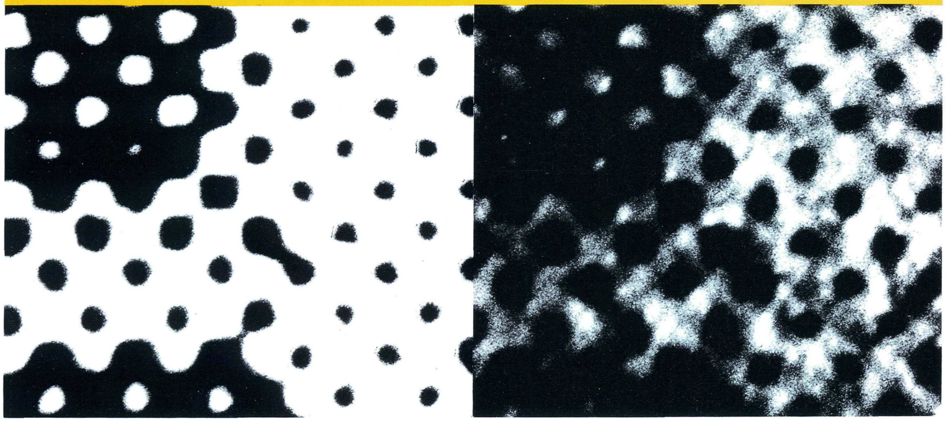
C

Unless a paper's surface is smooth and tight, halftone dots spread, reducing contrast and halftone detail, as shown in the print on the right.

B



C



A

In this simulation, it's easy to see that brightness, or the amount of light a paper reflects, has a major influence on color intensity. Compare the print on the left, made to appear as it would on a high brightness paper, with the one on the right, made to appear as it would on a paper of low brightness.

Brightness

Another property that good print quality depends on is brightness, which is generally thought of as a measure of how much light a paper reflects. Brightness determines contrast, of course, by making blacks and type stand out. But it is even more important for intensifying color.

This is because multicolor printing involves transparent inks, which are designed to produce virtually any color of the spectrum with only cyan, magenta, and yellow. Being transparent, such inks act like filters, transmitting certain lightwaves and absorbing others. So to produce optimum color, transparent inks must be illuminated not only by light striking their surface, but also by light reflecting ***back*** through them from the paper itself.

To understand the process, think of a pane of green glass (a filter) being held up against different backgrounds: a white, a gray, and a black. Which background makes the glass appear brighter? The white one, of course. Why? Because it reflects more light back through the glass than either of the other two.

Paper provides illumination in exactly the same way. The brighter the paper, the more light it reflects, and the more intense the inks appear.

A

Opacity

Opacity prevents type and images printed on one side of the paper from showing through to the other side or to the adjacent pages. This is an important property because show-through is distracting to the reader and can also interfere with the tonal qualities of delicate halftones.

In order to have adequate opacity, a paper must block light from passing through it and being absorbed by type or images on the reverse side. It is this "reverse-side absorption" that produces show-through. To prevent it, a paper must reflect or scatter light from its surface or from within its interior.

Opacity can also be influenced by a paper's weight, brightness, and internal formation.

Affordability

For superior results in high volume multicolor web offset printing, a paper must have all the properties that have been described: strength, a smooth and printable surface, brightness and opacity.

And because paper represents such a large share of the overall production budget, it must also provide these properties at a price/quality level that will be considered a good value.

This is the challenge of papermaking ...the incentive for manufacturers to continue specializing their lines and improving the value of each product. Today a paper buyer has more choices than ever before and, consequently, needs a more thorough understanding of paper types and how each one attempts to achieve a good balance between printing requirements and market value.

Wood, Fiber and Papermaking

A

The distances between these growth rings represent the amount of new material that a tree adds each year. The dark outline of the rings themselves are composed of thick walled summer fibers.

B

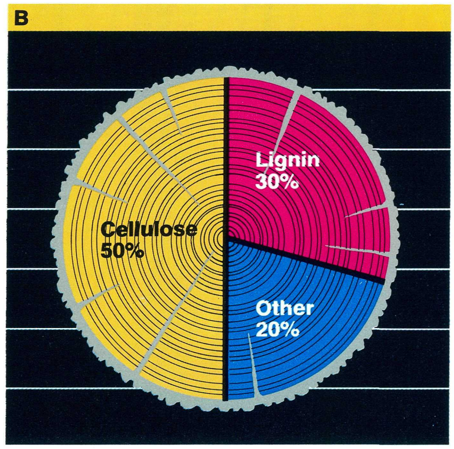
Wood is 50% cellulose fiber, the basic component of paper. The remaining 50% is a combination of materials, which, when used in printing paper, may degrade its quality.

Paper consists mainly of cellulose fibers, which, in their natural state, are tubular structures much finer than a human hair and shorter than a grain of rice.

Although any plant is a potential source of cellulose for papermaking, wood has proved to be the most practical. Cellulose fibers account for 50% of the mass of dry wood, giving a tree rigidity and often serving as its fluid transport system. Another 30% or more of the wood is lignin, the "glue" that binds fibers together. What remains is a combination of carbohydrates, proteins, gums, resins, and fats used in facilitating various growth and maintenance processes. (Figure **B**)

A

B



In the spring and summer of each year, a tree adds a new layer of these materials. Spring fibers, formed during the time of the fastest growth, have large centers and thin walls. Summer fibers, formed when the growth rate has slowed, have smaller centers, thicker walls, and are visible as the outline of the growth rings in a tree's cross section. (Figure **A**)

All fibers run parallel with the trunk. In softwood trees (such as spruce, fir, and pine), they average 3 to 5 millimeters in length and are the primary wood cells, functioning both to conduct fluids and to provide support. (Figure **C**) In hardwood trees (such as oak, poplar, and ash), fibers are shorter, ranging from ½ to 3 millimeters, and provide support only. Sap and water conduction is performed by much larger vessel cells, which are composed of the non-cellulose resins and gums. (Figure **E**)

C

Cellulose fibers, which run parallel with the trunk, are shaped like miniature drinking straws, 100 times greater in length than in width. In softwood, these fibers are the primary wood cells. Spring fibers have large centers and thin walls. Summer fibers have small centers and thick walls. The line of summer fibers is visible as the annual growth ring.

D

Fibers are bonded together by lignin, which runs between their outer walls in a layer called the middle lamella.

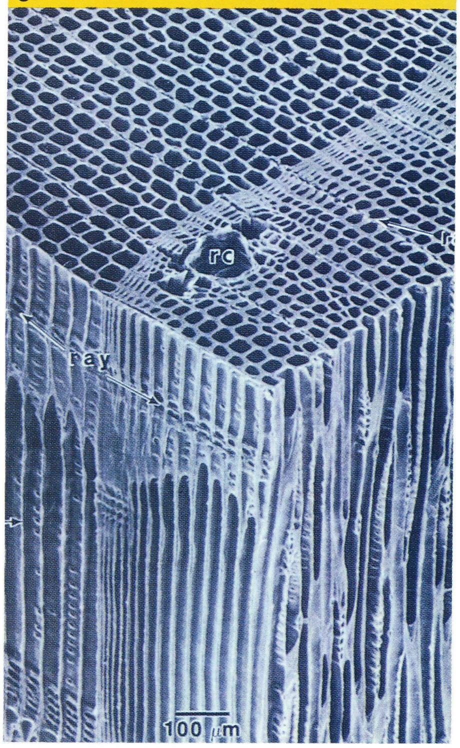
E

In hardwood, large vessel cells appear among the cellulose fibers. Unlike softwood, in which fibers provide both support and fluid conduction, here they are for support only. Vessels carry the water and sap. (Figures **C** *and* **E** *courtesy Syracuse University Press).*

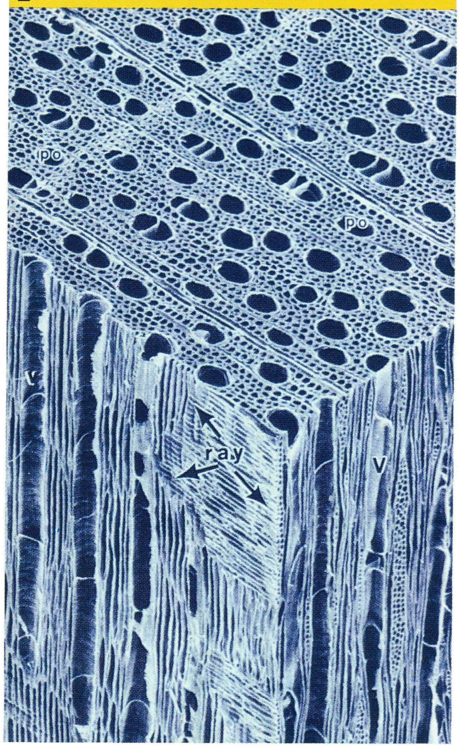
F

Individual whole wood fibers. Top: softwood, averaging between 3 and 5 millimeters in length. Bottom: hardwood, averaging between 1/2 and 3 millimeters.

C

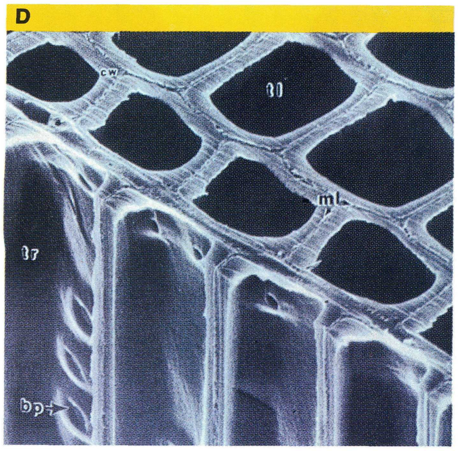


E

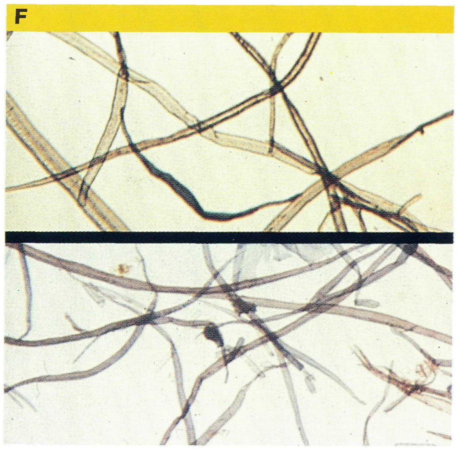


Most of the lignin in wood is found in a thin layer, the middle lamella, that runs between the fiber walls. (Figure **D**) A major challenge in papermaking is to separate the fibers at this point and preserve as many of them as possible, intact and free of lignin and the other wood "impurities." Success here is important because fiber length and purity are two key variables in determining how strong and how bright a paper will be. (Figure **F**)

D



F



Pulping

Converting whole wood into separate fibers is called pulping. As previously stated, it is a critical manufacturing step, for it determines several of a paper's most important qualities.

The two principal methods of pulping are ***chemical*** and ***mechanical.***

Chemical pulping begins with chips, either softwood or hardwood, which are "cooked" under pressure in a dissolving agent to soften their lignin. This releases the individual fibers without a reduction in length. (Figure **A**) Because the process also *removes* most of the lignin (and the other non-cellulose materials as well), fiber is virtually all that the resulting pulp contains. (Figure **C**)

Even though it eliminates impurities, chemical pulping preserves about 50% of the original dry wood for use as paper-making material. And that other 50% of non-cellulose impurities is not wasted.

For in the kraft, or alkaline-based, chemical process, non-cellulose material becomes the fuel for producing steam to cook more wood chips. The chemicals themselves are not discarded after one use. Each is reclaimed, "reactivated," then routed back into the process.

In mechanical pulping, fibers are separated by physical abrasion. (Figure **B**) The most traditional of the mechanical methods, stone groundwood, employs a circular grindstone against which whole logs are forced. Because fibers are tightly bound by lignin, this action generally causes them to fragment and tear, sometimes in chunks, rather than to separate cleanly. The result is a pulp with a high percentage of short, broken fibers, fiber debris, and fiber chunks or bundles. (Figure **D**)

Although this pulp is then washed and screened, very little of the lignin or other impurities are removed, which means a high yield (usually 90% or more of each log) but also a high percentage of materials that may seriously detract from paper quality.

The stone groundwood process suffers from two additional problems. First, it cannot use chips (which are more convenient to work with than logs). Second, it is principally dependent on long fibered and expensive softwood (because hardwood fibers, which are naturally shorter, would be ground too small for most applications in papermaking).

A mechanical method that is able to use both chips and hardwood is ***thermo-mechanical pulping (TMP).*** The essential difference between it and stone groundwood is that in TMP, wood is preconditioned by heat and pressure before it is ground, which softens its lignin. The grinding itself takes place under pressure, which further softens the lignin. Both processes (heat and pressure) make fiber separation less damaging. (Figure **E**)

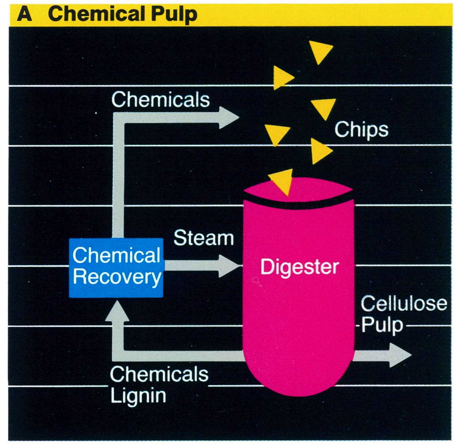
A

Chemical pulp is produced by cooking either softwood or hardwood chips with a dissolving agent in a pressurized digester. Lignin is softened, then extracted with other impurities and the processing chemicals. Lignin and the impurities are burned in the chemical recovery process and the steam produced is used for cooking more chips. The chemicals are recycled.

B

Stone groundwood pulp is produced by forcing whole softwood logs against a grindstone. Although the pulp is then washed, many impurities remain.

A Chemical Pulp



B Stone Groundwood Pulp

C

Most fibers in chemical pulp are whole and undamaged. Impurities are dissolved and washed out.

D

Fibers in stone groundwood pulp are fragmented and often locked in bundles. Lignin and other impurities make up a considerable percentage of the pulp.

E

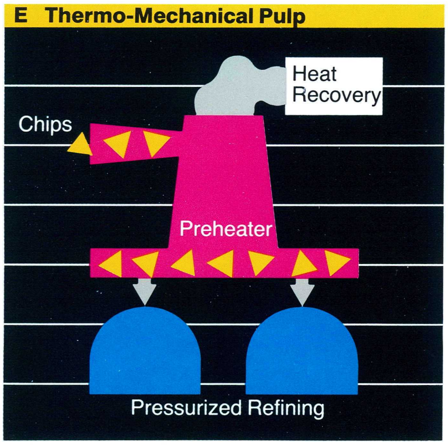
TMP, like chemical pulp, uses wood chips. They are pre-heated to soften their lignin, then ground under pressure.

While each of the mechanical processes mentioned here has unique features, all involve grinding. In general usage, therefore, even TMP is often referred to as "groundwood." Throughout this bulletin, unless groundwood is referred to specifically as "stone groundwood," it should be understood to include TMP. Also note that when the term "free sheet" is used, it refers to a paper that is made exclusively from chemical pulp, that is, one that is free from groundwood.

C

D

E Thermo-Mechanical Pulp



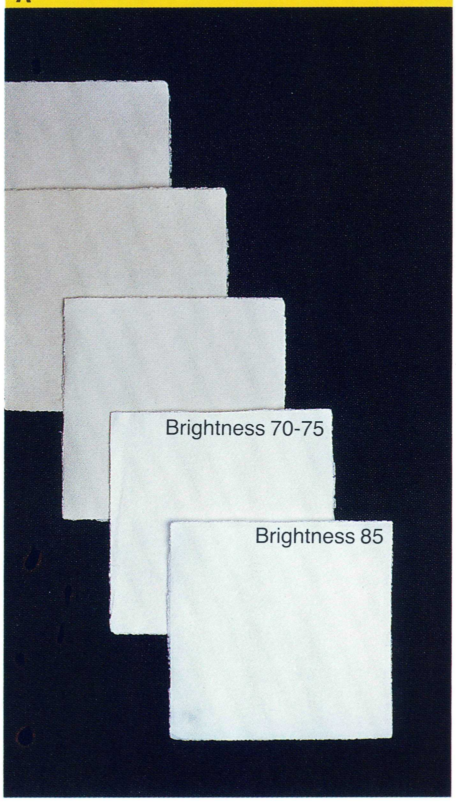
TMP, therefore, contains a higher percentage of long, unbroken fibers than stone groundwood, although they are shorter on the average and more are fractured than those in chemical pulp. Because impurities in TMP remain, the yield is high; but as in stone groundwood, they degrade pulp quality and undermine to some degree the potential advantages of longer fibers. An additional drawback of TMP is its very high energy requirements. Heat recovery systems may someday help to defray this cost; but at present, there are only a few mills in North America where such systems have been installed. To reduce the cost of energy, yet still exploit the advantages of "thermal softening," another mechanical process has recently been introduced: ***pressurized groundwood.*** Like stone groundwood, it uses whole logs, but they are ground in a high pressure atmosphere, creating high temperatures that soften the lignin and liberate more whole, undamaged fibers.

Other mechanical processes ***(semi-mechanical, chemi-mechanical,*** and ***chemical thermo-mechanical)*** are used in the production of corrugated board, newsprint, and packaging materials, but none of these is yet involved, to a significant extent, in the production of better quality coated printing papers.

Bleaching

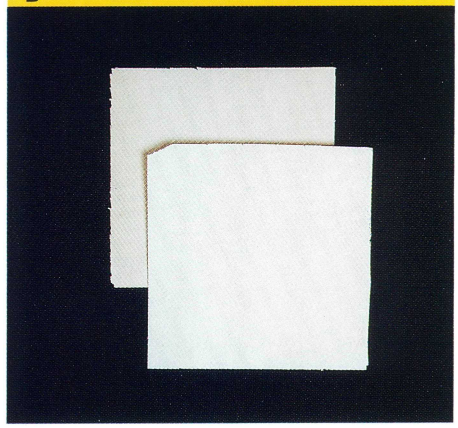
After pulping, fibers are washed to remove dissolved lignin and screened to remove fiber chunks or bundles. But washing does not affect the lignin that has ***stained*** the fibers a dark brown. Because of this staining, the end-product of pulping is usually referred to as "brown stock." Before it can be used in the manufacture of better printing papers, it must be bleached.

A



(The sheets shown here were made from chemical pulp at four stages of bleaching.) The end-product of pulping is brown stock (top), which is thoroughly stained by dissolved lignin. Chlorination (first) dissolves external impurities. Extraction removes internal impurities (second) but recolors the surface. At the end of the hypo stage (third) the pulp is a semi-bleached yellow. The final stage (fourth), brightens the pulp from yellow to blue white.

B



Bleaching groundwood pulp is generally a simpler, single-stage process. Unbleached groundwood (top) is somewhat lighter than chemical brown stock because lignin is not dissolved in the mechanical process. Yet because it is softened by heat in grinding, there is still some residue of lignin, along with a variety of other impurities clinging to the fibers. Bleached groundwood (bottom) is brighter than unbleached but usually less bright than bleached chemical. That shown here has a brightness level of about 70-75.

In the making of a free sheet, bleaching can be a four- to six-stage process. It begins with ***chlorination,*** which dissolves surface impurities. Then there is ***extraction,*** which opens the fiber and removes impurities from within. In that process, however, the fiber's surface is "recolored" so it may look almost as dark, sometimes even darker than it did at the previous stage. It takes another step, ***whitening,*** to reduce this stain to a semi-bleached pale yellow. The final step in making a free sheet, ***brightening,*** turns fiber to bright-white. (Figure **A**)

Bleaching groundwood is generally a simpler, single-stage process. When complete, most bleached groundwood pulp is only as bright as semi-bleached chemical pulp. (Figure **B**)

Stock Preparation

In the actual forming of paper... whether it's to be a free sheet or groundwood-content...the cellulose fibers are drawn together into a thin, somewhat irregular mesh. Depending upon paper type, they may be collapsed or still tubular, whole or broken, flexible or stiff, tightly packed or separated by air spaces, fiber debris, wood impurities, or special additives.

Unlike cloth, whose fibers are bound by the mechanical processes of twisting and weaving, paper forms primarily from chemical bonds, either occurring between the fibers directly or indirectly with the aid of other materials.

Two characteristics of cellulose fiber make such bonds possible. First, it is hydrophilic, which means that cellulose swells in water, becoming flexible, even gelatinous, but without dissolving or losing its shape. Second, the fiber's structure resembles that of a rope, having walls composed of several layers of threads, called fibrils, which wrap round and round in spirals.

Fiber bonding occurs between molecules with extremely short-range attraction. For two fibers to bond, therefore, they must conform to one another and come into very close contact. The strength of their bond is determined by the amount of area over which contact is made, which requires more than just the fibers' exterior surface.

Preparing fibers for bonding actually started with pulping and bleaching. Both processes occur in large quantities of water, where fibers begin to soften. The softer and more flexible they become, of course, the more bonding area they develop and the stronger their bonds will be.

Refining

Refining continues the process. In a slurry containing about 95% water, pulp is pumped between serrated metal disks, which collapse the fibers and rupture their outer walls. Thus flexibility is increased, and many of the fibrils unravel, swelling with water to create additional bonding sites.

At this point, there are important differences between chemical and groundwood pulp and their relative suitability for papermaking.

In refined chemical pulp, the majority of fibers are whole, collapsed, highly fibrillated, and very flexible. These are characteristics that produce a strong paper. And because there is a good mix of shorter hardwood fibers among the longer softwood, such a paper will have a smooth surface.

Also in chemical pulp, lignin and other wood impurities have been dissolved and washed away, and the pure cellulose fibers have been bleached to a bright white shade. It will take only a few additives...internal sizing for water resistance, dye for shade, and/or some mineral pigment for opacity and greater brightness...to complete the combination of materials, known as *furnish.*

With stone groundwood, however, additives serve not only these but several additional functions. Since few of its fibers have remained whole, groundwood furnish lacks long expanses of bonding area that give paper strength. And not having been softened as much as those in a chemical pulp, these fibers are stiff and do not as easily conform to one another. Moreover, fiber bundles, which are difficult to screen out entirely, provide relatively no bonding power at all.

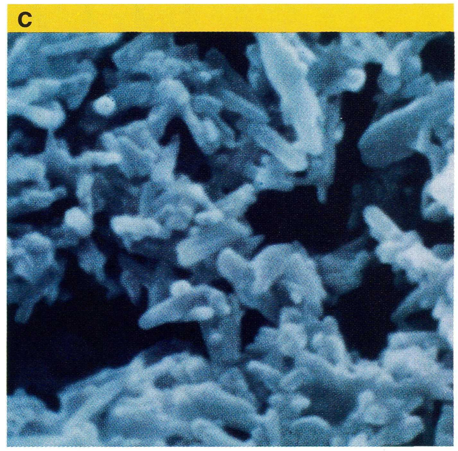
C

Additives such as those shown here (top, calcium carbonate, a pigment which is also used for brightening and protection against acid reactions; middle, titanium dioxide, a pigment and brightening agent; bottom, clay, a pigment) are used to facilitate manufacturing processes and achieve a variety of end-use properties.

Bonding in groundwood, therefore, depends to a large degree on "fines," which are small pieces of fiber that fill in and provide bonding surfaces between the larger fragments. Strength is also improved by the addition of starch to create fiber-to-starch-to-fiber bonds. Yet none of this additional material gives stone groundwood strength enough to be used in coated printing paper by itself. ***Usually it is blended with minimal proportion of 50% of a chemical pulp.***

Brightness is another concern. To counterbalance the darkening effects of impurities and obtain the brightness level needed by a printing paper, bright pigments (such as titanium dioxide, calcium carbonate and clay) must be added.

C



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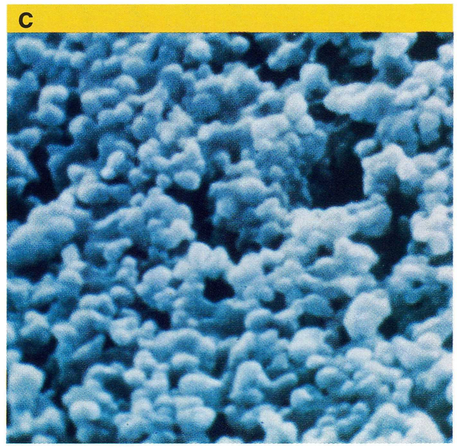

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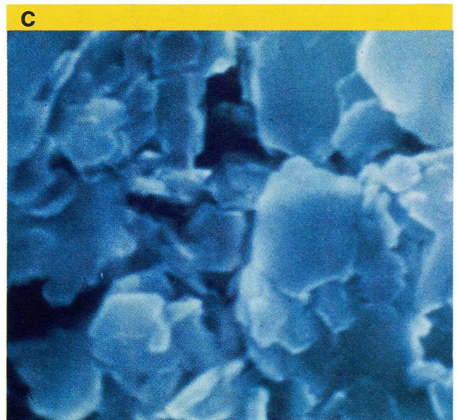


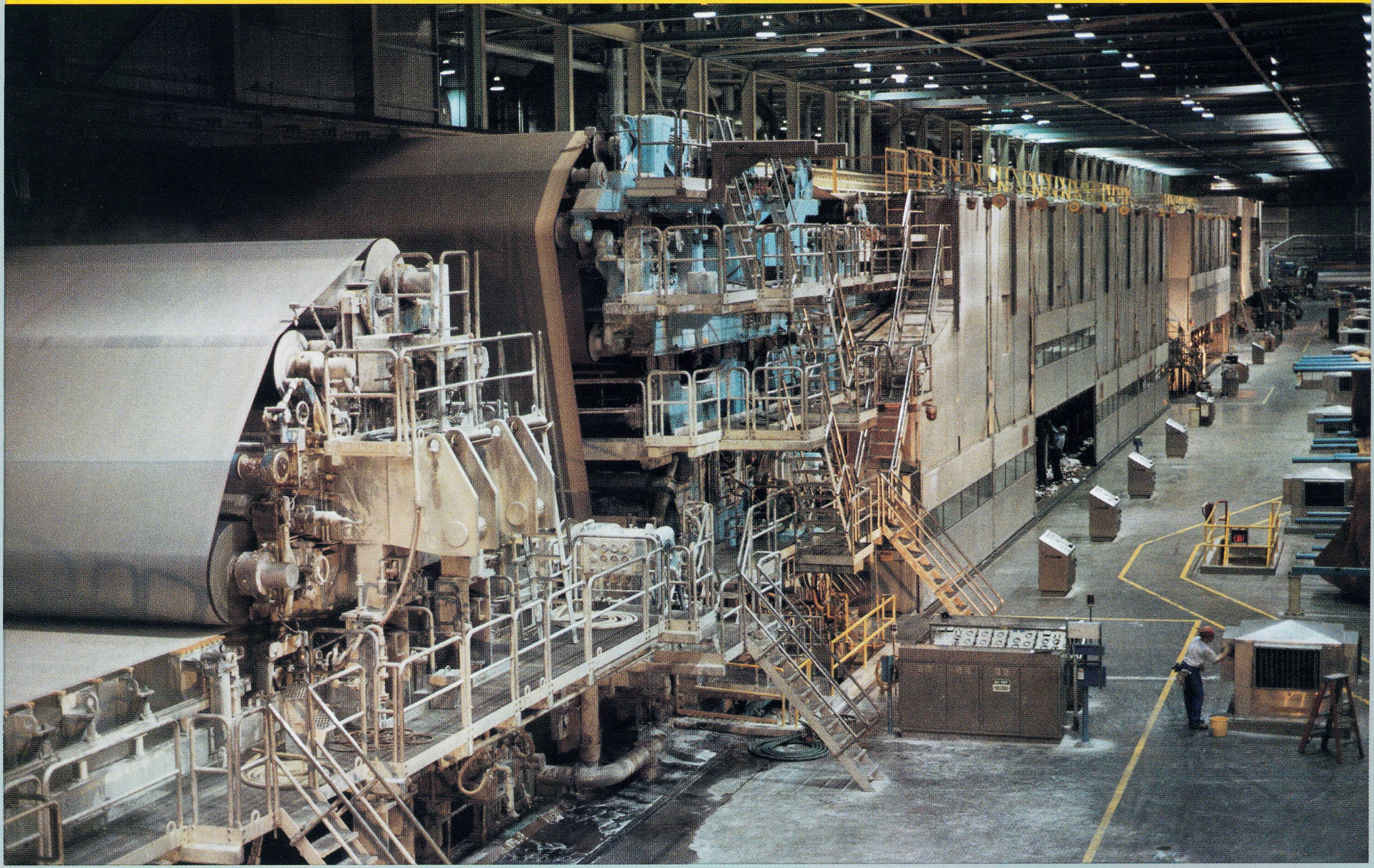
Finally, as with chemical pulp, internal sizing is used to provide resistance to water penetration.

Refined TMP contains a higher percentage of whole fibers than stone groundwood because of the preliminary thermal-softening of its lignin. But this prevents neither fiber tearing nor the presence of many fines. Softened lignin actually is a problem in itself since it adheres in a thick coat to the separated fibers, reducing their ability to absorb water, collapse, and become well fibrillated. For this reason, TMP depends even more than stone groundwood on fines and additives for bonding ability and strength.

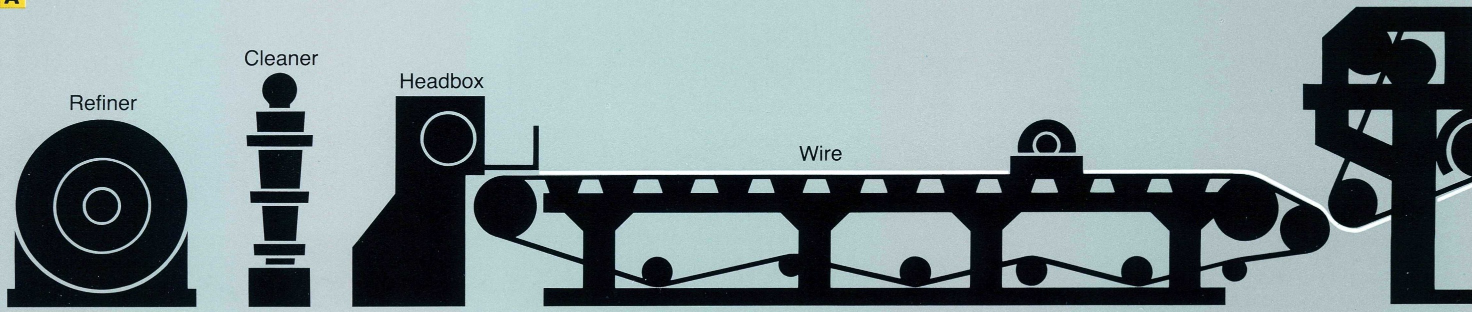
Brightness in TMP may also be more of a problem, for the heat applied in pulping actually darkens the lignin. Again, a pigment such as titanium dioxide is called for, plus sizing as required by all pulps.

Like stone groundwood, TMP is combined with chemical pulp in better printing papers, but for newsprint it is sometimes used alone.

B



A



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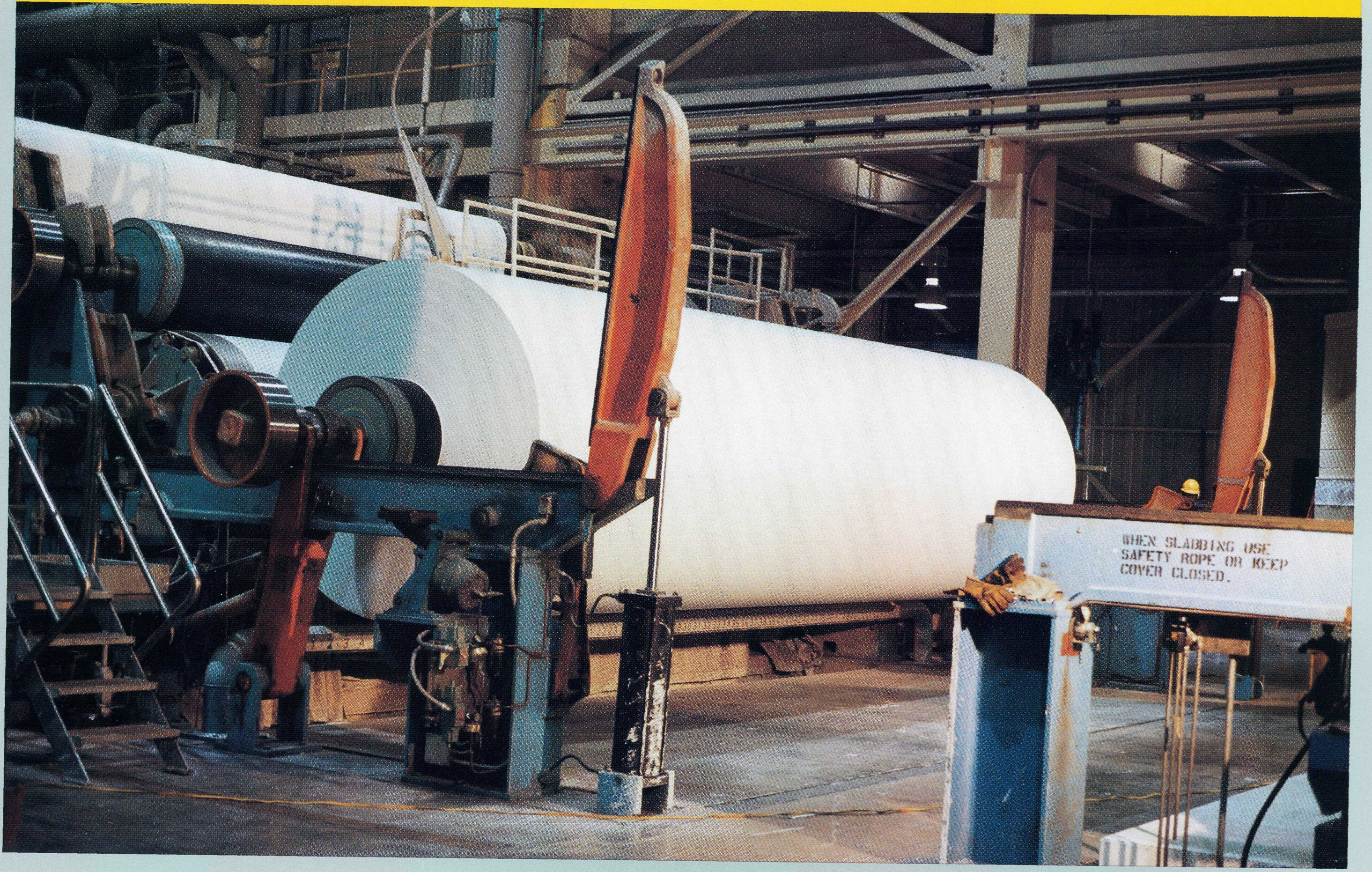
WHEN SLABBING USE
SAFETY ROPE OR KEEP
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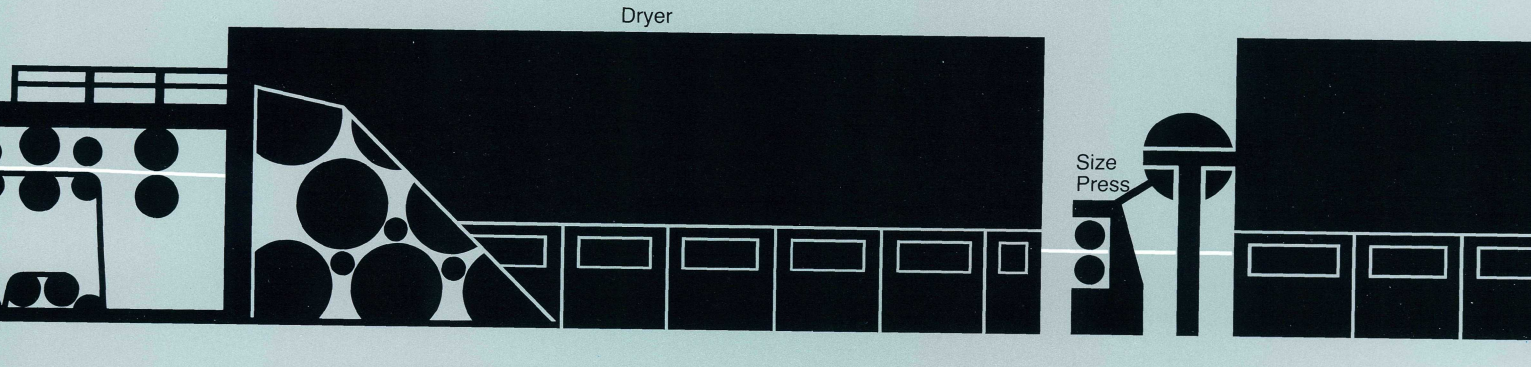

Dryer
Size
Press

B

A paper machine seen from the "wet end." At the extreme left is the headbox, from which furnish is distributed onto the wire (flat area) where a paper web is being formed. The web then moves into the presses (wide rollers, center left) and water content is reduced to about 65%. The largest component of the machine is its drying section, extending to the far right. Here the paper is dried and sometimes coated.

C

Paper machine from the "dry end." This web is being wound either prior to additional finishing processes (calendering, coating, etc.) or for cutting and trimming before shipment. It is 290" wide. The paper machine shown can produce such webs at the rate of 3,000 feet-per-minute.

Forming the Paper Web

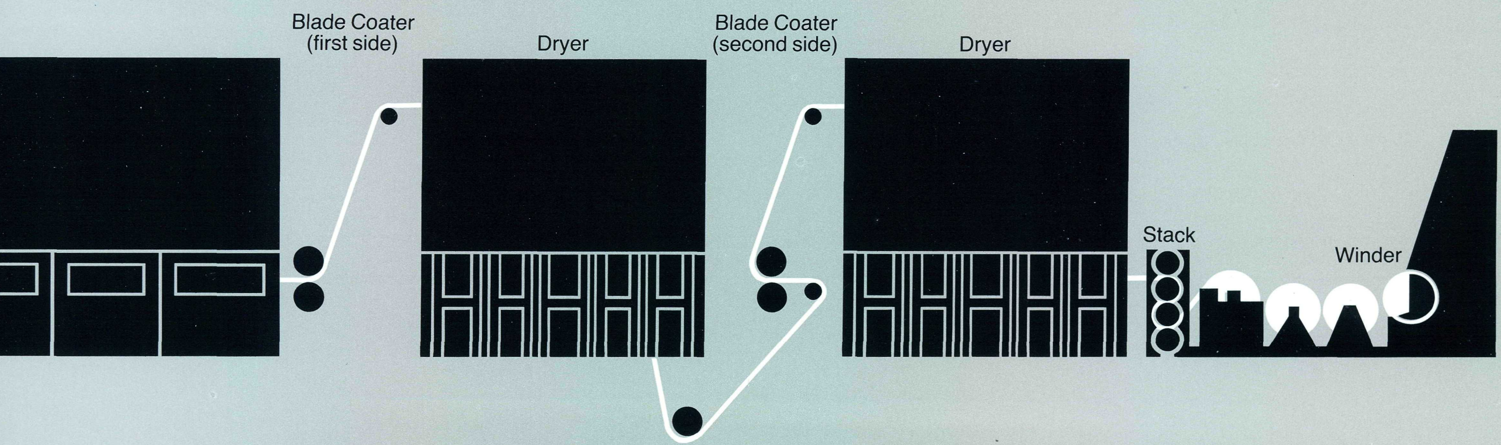
Paper machines can be as long as several hundred feet and are among the most finely tuned instruments used in any industry. Yet they are composed essentially of just four main parts: the headbox, the wire, the press section, and the dryers.

After pulp has been refined in the process just described, it is called a furnish and is 99% water. The type of pulp used (chemical, stone groundwood, or TMP) has virtually no effect on the mechanics or the specific steps involved in making a paper web.

Paper is formed during the first few feet of travel on the machine. (Figure **A**) Furnish is fed from the headbox onto the wire, a continuous fine-mesh screen where about 20% of the water is drained off.

From the wire, the new paper web passes into the press section, where it is squeezed between several pairs of rollers that reduce water content to about 65%. Then the web begins its trip through the dryer section, which is the largest component of the machine. Here the web has its water content reduced to about 5% as it travels through scores of steam heated drums.

On some machines, coaters are also located in this dryer section as shown in the diagram below.



A

A film coater applies materials with low solids content to both sides of the paper simultaneously.

B

A blade coater applies a thick coat of material one side of the sheet at a time. Excess is removed by a flexible trailing blade, which also smooths the coating material.

Coating

Coating is the next step in the manufacture of papers intended for brochures, annual reports, and better quality magazines. This is because the surface of even the finest paper remains somewhat rough and porous as it forms on the machine and begins to dry.

Also present may be some poorly bonded fibers, which can be picked off by a tacky ink and deposited on an offset blanket.

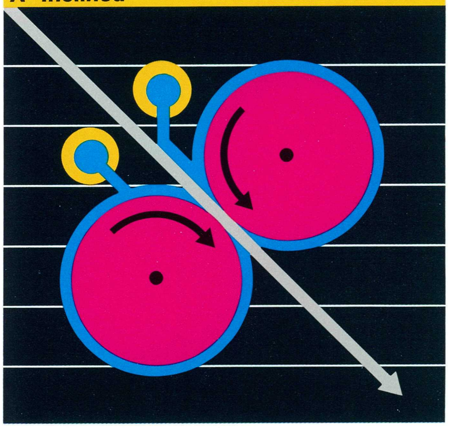
Neither the addition of sizing nor a perfect blend of fibers (short with long in chemical pulp, fines with fragments in mechanical) is sufficient by itself to fill all the crevices and to create a surface that is tight, flat, and smooth enough to produce superior halftones. For that, coating is required.

Coating material contains a mixture of pigments (like clay or calcium carbonate) and adhesives or binders (like starch, casein and latex). Applying this material to paper is like painting wood; it fills the pores and forms a new surface smoother than the original.

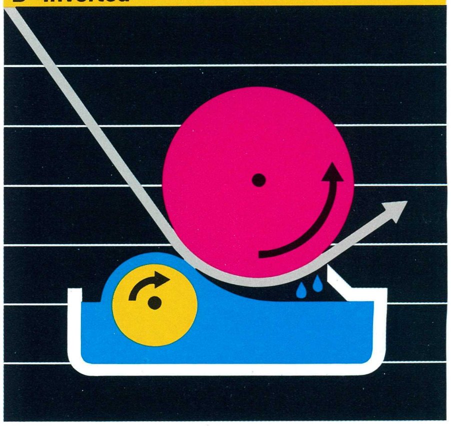
Coating is applied either as part of the basic papermaking process (machine coating) or as a later and separate step (off-machine coating). Within these two general technologies there are many variations, the principal ones being ***film coating, blade coating,*** and a combination of both.

Film coating is actually a pre-coat, like wood primer, although it is the only coating that some papers receive. Coating material is applied simultaneously to both sides of the paper web by a small press located within the drying section of the machine. (Figure **A**) Because the material is applied and smoothed by rollers only, it must be low solids in content (again, like wood primer). Much of a film coating, therefore, is absorbed into the paper, leaving only a thin layer on the surface. (Figure **C**)

A Inclined



B Inverted

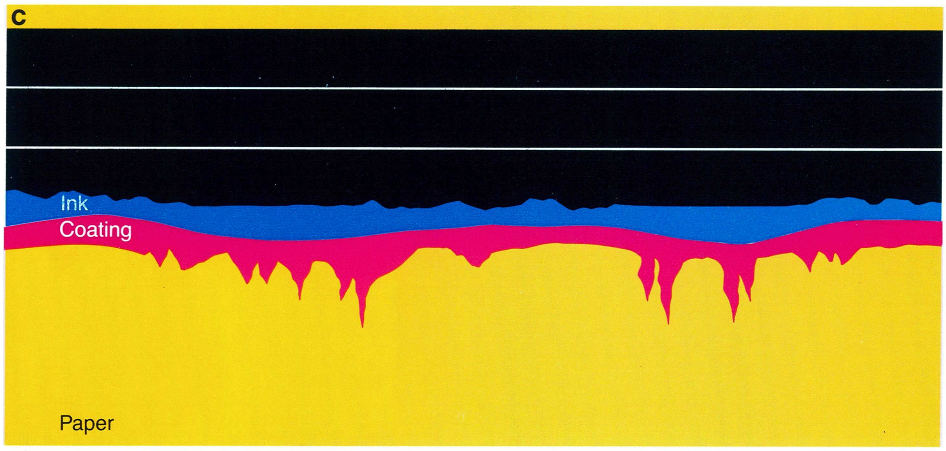


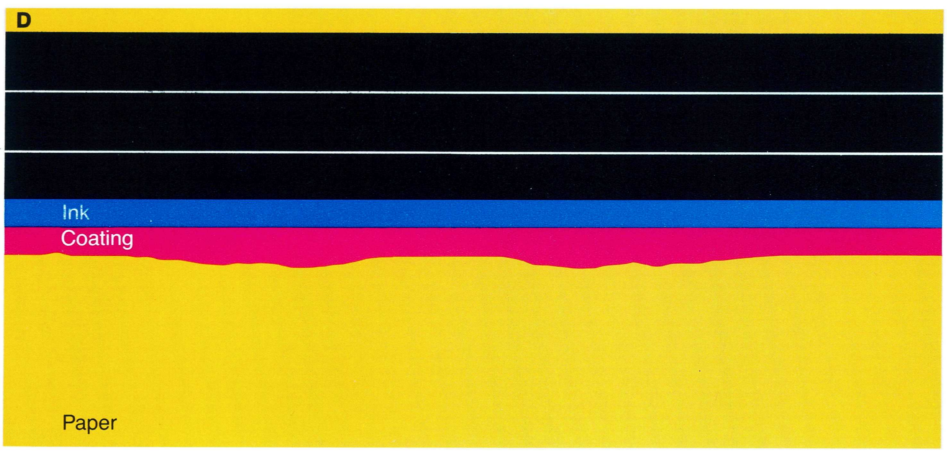
C

Because of the low solid content of the film coating (magenta), most of it flows into the paper (yellow), leaving a thin, uneven layer on the surface. An ink film (blue) printed on this coating will also be relatively uneven. (Highly magnified cross section)

D

With its high solids content, most of the blade coating (magenta) remains on the paper's surface in a layer that can be made up to one-tenth of its thickness. An ink film (blue) printed here will be highly uniform. Papers coated by both blade and film have of course, an even thicker, smoother surface. (Highly magnified cross section)





Blade coating is more like spreading butter or applying the thick final coat of paint that leaves a board's surface smooth and even. With this method, the paper receives a heavy application of material one side at a time. Excess is removed and the remaining material is smoothed by a flexible trailing blade. (Figure **B**) Some of this coating, too, is absorbed into the paper. But because of its high solids content, most remains on the surface to form a layer that can be up to one-tenth the thickness of the paper itself. (Figure **D**)

What's the best surface of all? When a paper is *both* film *and* blade coated, it's sealed by the first and smoothed by the second. And when such coatings are given the benefit of being applied to a smooth, well formed paper base, you can look forward to halftone effects that are truly spectacular.

Types of Paper for Web Offset Printing

A

Tests indicate that a free sheet is generally higher in both internal strength and surface strength than paper made from either stone groundwood pulp or TMP. Here is a chart summarizing the results of tests conducted in Warren's Research Laboratory that compared the print strength of 11 different papers, 5 coated free sheets and 6 coated groundwood-content sheets.

Strength

Both internal strength (Mullen, tensile, and bond) and surface strength (print and resistance to fiber puff) are related directly to fiber bonding. The paper that is the best bonded should also be the strongest.

Whenever the principal paper types are tested (free, stone groundwood, TMP), the free sheet, which has been shown to have the greatest bonding potential, exhibits superior strength in those strength categories that affect web press performance. (Figure **A**)

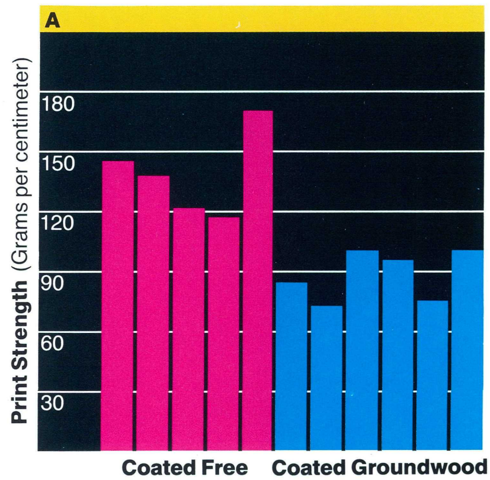
It breaks and tears less often than groundwood or TMP (indicating high tensile and tear), is less subject to blistering (high internal bond), and generally performs better during most in-line finishing operations (high tensile and Mullen).

For evidence of a free sheet's greater surface strength, one can look to comparisons of the same print having been run on a free sheet and then on a groundwood content sheet. Although the results demonstrated on the opposite page will not be duplicated exactly every time one of these papers is used, they are typical enough to indicate a strong tendency.

Lack of print strength shows up as either white specs or "hickeys" in the same locations, impression after impression, throughout a run. This condition is often referred to as "picking." It is caused by loose fibers or bits of coating which are not well bonded and, therefore, can be picked off by the tack of the ink and left on the blanket. Correcting this problem means delays and paper waste.

The press must be stopped and washed, unacceptable impressions discarded, and ink tack reduced, possibly affecting the quality of the print. (Figure **B**)

Fiber puff, commonly associated with groundwood-content paper and sometimes called "heat set roughening," is noticeable only after the printed paper passes through the drying ovens. It appears as a surface roughness, like the raised grain of wood, particularly in areas of heavy ink coverage. It is caused by the escape of paper moisture in the form of steam, which exerts an outward pressure. Where bonds are weak and fibers stiff, they will pop up, making their shapes visible on the paper's surface. (Figure **C**)



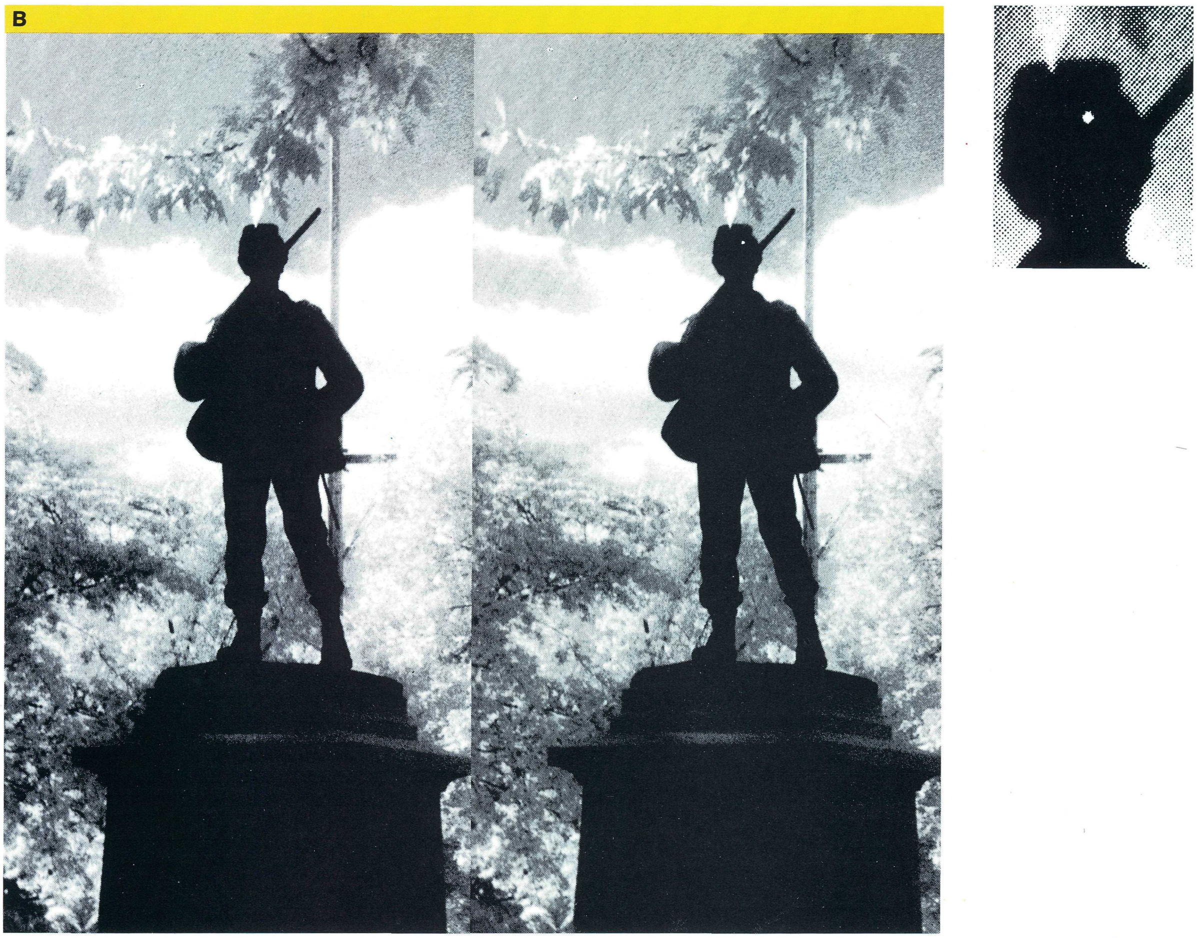
B

To resist the pull of offset inks, which are high in tack, a paper must have good print strength, the product of strong bonds among the fibers on its surface. When surface fibers are not well bonded, the paper suffers from picking, evidenced by the pick out (caused by a tiny bit of loose coating) on the inset at the upper right.

C

Stiff fibers that are poorly bonded become "unseated" by steam released during oven drying and pop up so their shapes are visible on the paper's surface. When viewed by strong side light these fibers can actually be seen to cast shadows among the halftone dots, as in the print on the right. Compare this with the print on a free sheet, left. Both prints are greatly enlarged.

B



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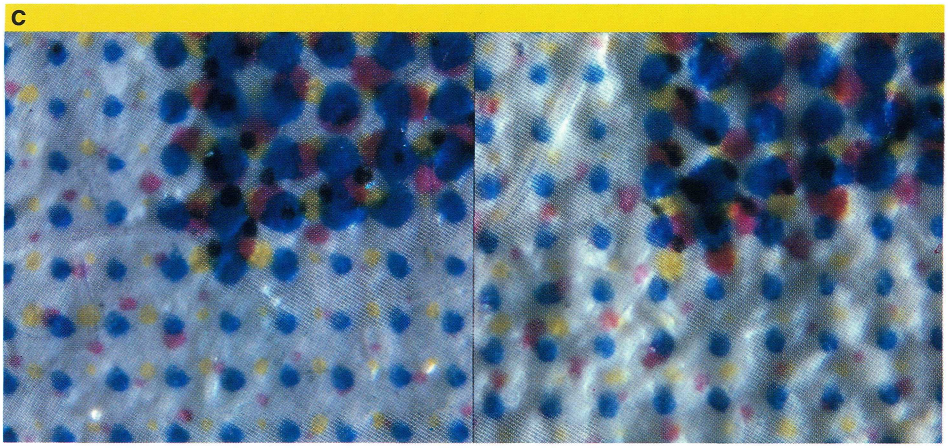


A

On the smooth, tight surface created by blade coating (left), a halftone has good color and detail. The film coated surface (right) allows ink to penetrate and diffuse, light to scatter and therefore to lessen color intensity.

Smoothness and Printability

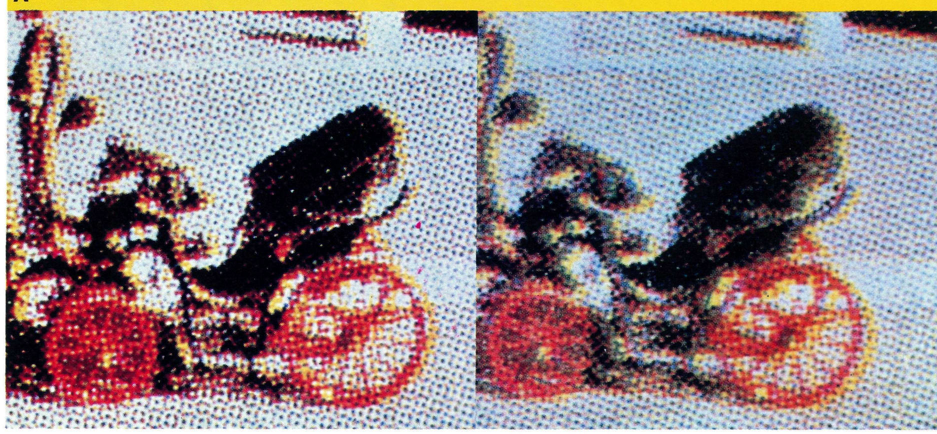
If you want type to be crisp and clean, halftones to be faithful to original art, and solids to be uniform in color, it's essential to choose a paper whose surface is tight and smooth enough to provide good ink holdout and good ink lay.

As explained earlier, these properties are primarily the function of coating, and a good coating can be applied to virtually *any* paper...although the better the paper surface you begin with, the better your final results.

From the comparison in Figure **A** of blade and film coating, it is obvious that the thick, high solids content of the blade coating creates a much smoother, tighter surface than the thin, low solids content of the film coating. Note the greater density, contrast, and detail in the halftone. (Figure **A**)

For the purpose of demonstration, these prints were air dried after printing and not passed through the oven as would be the case in an actual run. It is then – in the oven – that the strength of the paper surface itself would have an effect, as shown in the next pair of prints.

A



Brightness

There are actually two types or degrees of brightness. Initial brightness ensures vivid halftones and legible type at the moment of impression. Long-term brightness maintains the usefulness and good appearance of a printed piece over an extended period of time and under a variety of conditions.

A free sheet, because it contains neither lignin nor other discoloring impurities, can be bleached to a high degree of initial brightness. As is evident in the demonstrations (Figure **B**), it provides both contrast and color enhancement.

A sheet containing groundwood pulp and, consequently, an abundance of non-cellulose materials, may not achieve this level of brightness. Unless additives are included to ensure equivalent brightness, halftones and type printed on it suffer by comparison.

Impurities not only impose a ceiling on how bright a paper can be made but are also unstable, oxidizing in the presence of light, heat, and such common modern-day air contaminants as ozone and the oxides of nitrogen and sulfur. Less affected by impurities, the free sheet holds its value for a much longer time. (Figure **C**)

B

B

A bright sheet gives halftones a vividness (left) that is not matched by a less bright one (right).

C

C

The print on a simulated free sheet (right) remains bright even after prolonged exposure to light. The print on a simulated groundwood-content sheet (left) has yellowed because of deterioration over time of the non-cellulose materials within that sheet.

A

These tests on 50 lb. paper show no clear correlation between the percentage of mechanical pulp and opacity...contrary to the widespread belief that groundwood content is the primary determinant of opacity. Actually, opacity is the product of many ingredients and factors.

B

In chemical pulping the wood yield is not as high as in groundwood. But because it is less energy intensive (actually producing energy as a by-product), chemical fiber does not have to cost appreciably more than groundwood fiber.

Opacity

More a product of fine tuning than of pulping method or basic paper type, opacity is a highly controllable feature. The papermaker, not the proportion of groundwood to chemical pulp, determines how opaque a paper will be.

It is true that groundwood pulp has relatively high opacity because of its lignin content and broken fibers. Lignin absorbs more light than cellulose, and fragments and fines offer more surface for light to reflect from, diffusing its intensity.

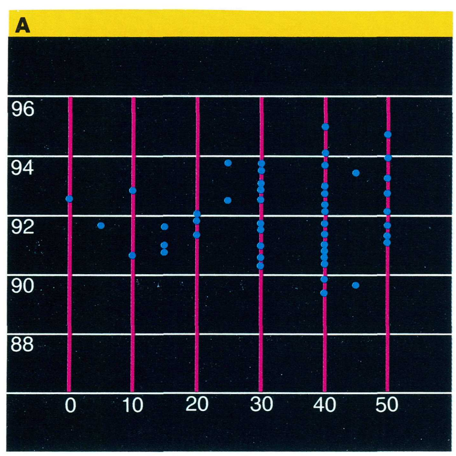
However, tests show that there is no clear correlation between the percentage of mechanical pulp *in paper* and opacity. (Figure **A**)

Other properties commonly associated with opacity are weight and color. But as with percentage of groundwood content, they are not the deciding factors. A paper can be light in weight, very bright, and still be as opaque as another paper that is heavier and less bright. Again, it must be remembered that there are many different ways to control paper opacity.

Affordability

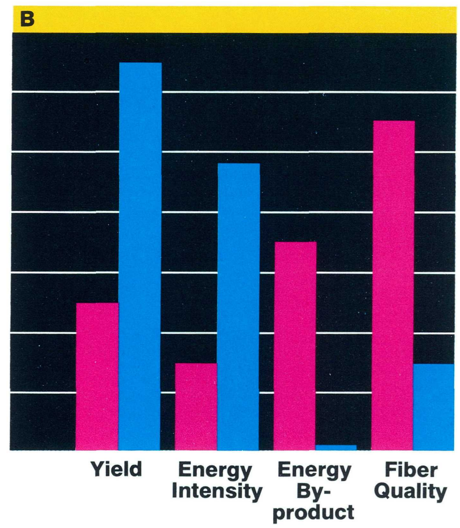
The cost of paper is largely determined by how much a manufacturer pays for three commodities: 1) wood, 2) energy used to convert it, and 3) materials added to obtain certain printing and end-use properties. To be competitive, a manufacturer must balance these commodities skillfully. Higher than average costs for one of them will have to be offset by savings derived from the others.

It has already been shown that groundwood pulps, because they retain non-cellulose materials,



represent a wood yield of more than 90%. Chemical pulp, which is free of impurities, utilizes only about 50%. Yet this initial "penalty" is moderated somewhat by the fact that the chemical process can use chips and hardwood...which are relatively cheap...while mechanical pulping relies (except for TMP) on whole logs and softwood...which are the most expensive sources of fiber.

The yield disadvantage is further compensated for by energy savings. Today 40% of the energy needed to run a large and modern pulp and



paper mill (either chemical or mechanical) can be obtained through the use of biomass: burning the bark, limbs, and other refuse not utilized for their fiber. Additionally, chemical mills can generate still another 50% of their energy by capturing waste impurities from raw wood plus steam and recycled chemicals from the pulping process. (Figure **B**)

This means that the cost of energy in chemical pulping may amount to a very small percentage of the cost of wood. By contrast, in stone groundwood pulping, energy can cost just as much as wood; and in TMP, it usually costs more. (Figure **C**)

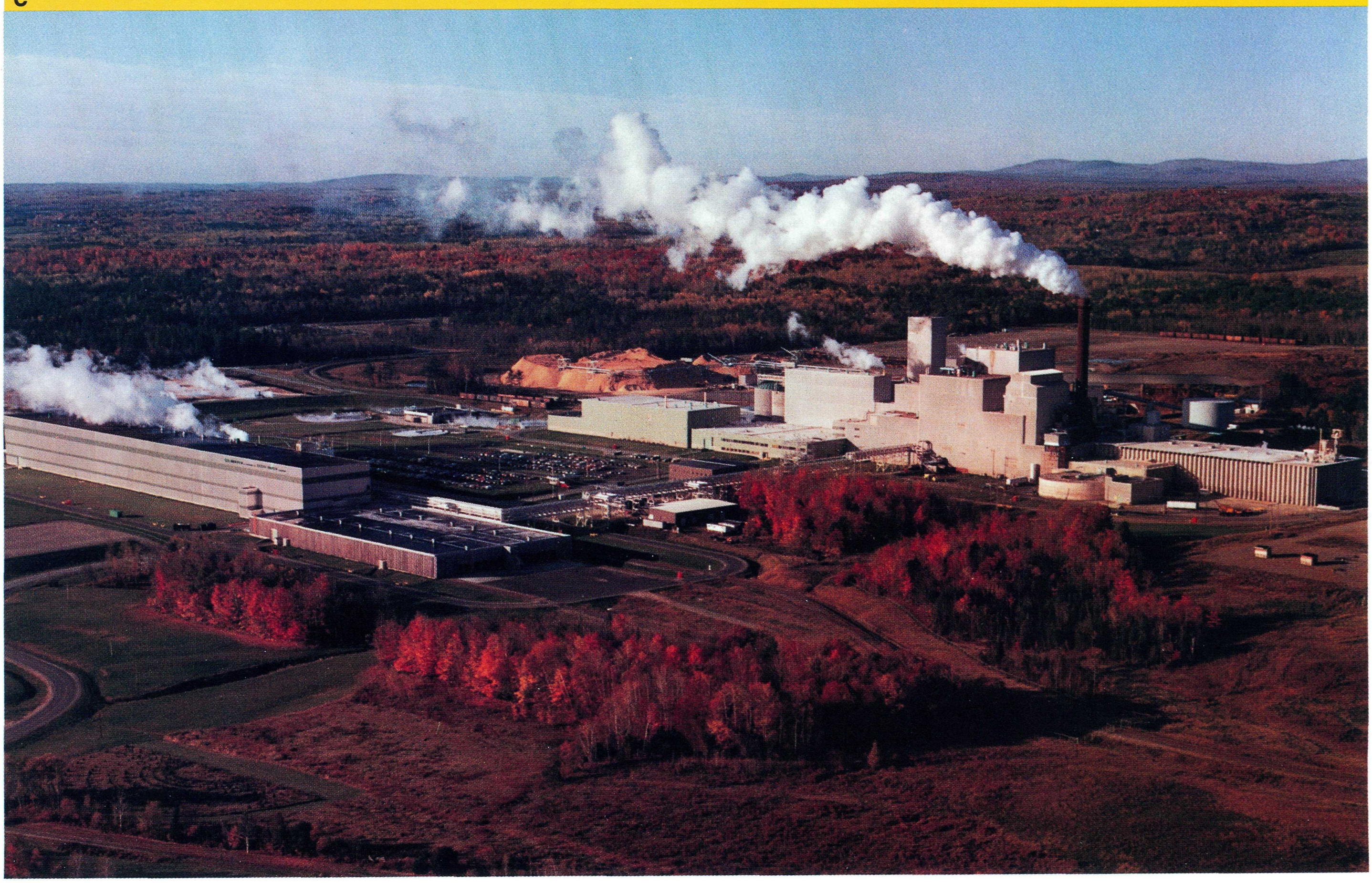
Having less but still some influence on the cost of paper are the additives needed to improve ink and water resistance, internal strength, brightness, opacity, and other properties.

Here again, the manufacturers of chemical paper are able to offset their higher wood costs.

C

Because of energy efficiency, better utilization of materials, and economies of scale, it is now possible for a modern pulp and paper mill to produce a free sheet at a cost usually comparable to the higher grades of coated groundwoods.

C



Free sheets, because of their "built-in" strength and brightness, need far fewer, if any, additives to reach the desired levels of these properties. Only in the area of opacity are additives of much significance.

When all present-day papermaking costs are considered the differences between free sheet and groundwood papers are much less than are generally supposed.

Summary

To give superior results in high volume multicolor web offset printing, a paper must exhibit four properties:

Strength

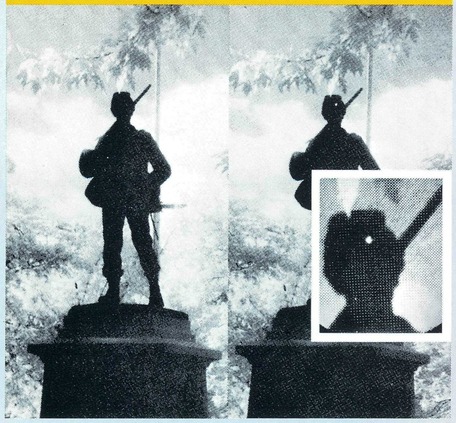
Paper needs strength both for runnability and printability. It must be able to endure the rigors not only of printing but also of in-line finishing.

Internal strength will reduce the chance of breaks, tears, and blistering. Surface strength will prevent fiber puff (or heat-set roughening) and picking.

Underlying the many types of strength that have been discussed are fibers that are whole and well bonded. They have not been fragmented and shortened in pulping...which would have reduced the expanse of their bonding area. They are neither coated with a film of lignin nor are they surrounded by lignin particles or other impurities...conditions which would impede bonding.

Such fibers are typically produced by ***chemical pulping*** and the paper made from them is a ***free sheet.***

A

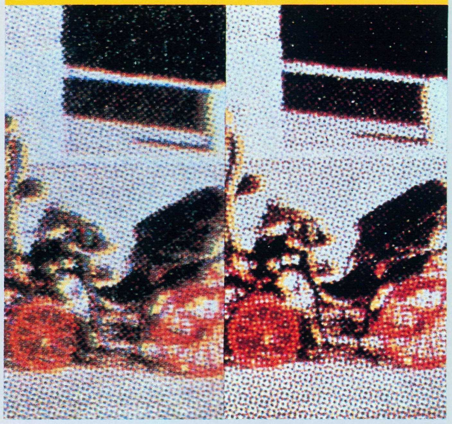


Smoothness and Printability

Printability also depends on how smooth a paper's surface is, which is a function both of paper stock and of its coating.

A smooth coated sheet will provide good dot formation, high ink holdout, and controlled reflection of light. But if the fibers and fiber bonds on the surface of the paper are not sufficiently strong, even the best of coatings will often begin to deteriorate and show either picking or fiber puff before a job is off press.

B



As you have seen, assurance of a base strong enough to protect and sustain a paper's coating is generally better provided by a ***free sheet*** than by a paper containing groundwood.

A

To resist the pull of offset inks, which are high in tack, a paper must have good print strength (left), which comes from strong bonds among the fibers on its surface. Without well bonded surface fibers, paper may exhibit picking (right). This is an example of just one of the kinds of strength a free sheet provides.

B

On the smooth, tight surface created by blade coating (left), a halftone has good color and detail. The film coated surface (right) allows ink to penetrate and diffuse, light to scatter and therefore to lessen color intensity.

C

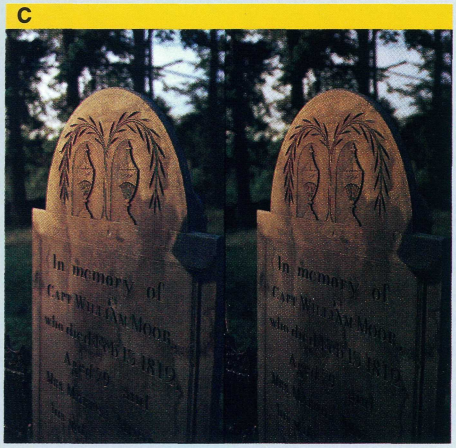
A free sheet can be bleached to a brightness that gives halftones a vividness (left) that is not matched by many groundwood content sheets (right). And the free sheet remains bright even after prolonged exposure to light and air pollutants. Impurities make the difference.

Brightness

Brightness creates contrast and intensifies color. This second function is particularly important because of the transparent inks used in offset printing. They are illuminated by light reflecting *back* through them by the paper itself. Thus the brighter the paper (i.e., the more light that it reflects), the brighter the colors will be.

If a paper is to be made bright initially and then to remain bright over a long period of time and under a variety of environmental conditions, it must be

C



free of lignin and all other discoloring impurities. Because it is only in the chemical process that these impurities are removed, the *free sheet* is naturally brighter than groundwood (requiring few additives, such as titanium)...and it remains brighter during the life of a printed piece.

Opacity

Opacity prevents type and images printed on one side of the paper from showing through to the other side or to the following sheet. This is an important property because show-through is distracting to the reader and can also interfere with the tonal qualities of delicate halftones.

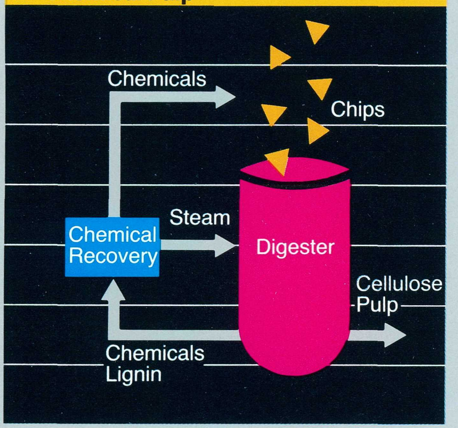
In order to have adequate opacity, a paper must block light from passing through it and being absorbed by type or images on the reverse side. It is this "reverse-side absorption" that produces show-through. To prevent it, a paper must either: *1*) reflect or scatter light from its surface or within its interior, or *2*) absorb light with the materials of which it is composed.

Such properties can be built into many different types of papers. Contrary to the belief that high groundwood content is the only way to achieve high opacity, manufacturers of free sheets can now offer papers that are light in weight, very bright, and still highly opaque. This is because groundwood content is only one of the factors that go into determining opacity.

A

In making a free sheet, a wide variety of economical wood types can be used, chemicals can be recycled, and 90% of the energy needed to run a modern mill can be obtained by using impurities contained in wood, steam (generated by the pulping process itself), plus bark and slash from woodlots and the millyard.

A Chemical Pulp



Conclusion

In addition to how well a paper measures up in these four properties, a buyer must also consider *affordability*.

Suppose that you are considering two papers. The first is known to produce much better results than the second, but it is priced substantially higher. If cost is your only concern, then buying the less expensive one might be justified.

But when it's not just cost, but also the quality of your finished product that's important, then the better performer is usually the wiser choice.

And when the prices of these two papers are not significantly different, the choice is clear.

Advances in papermaking technology, particularly in the areas of energy and raw materials utilization, have appreciably reduced the cost differential between some free sheets and the better groundwood-content papers.

Which then is the better buy? As the demonstrations and information given in this bulletin have shown, the multicolor web offset performance of the free sheet is superior in virtually every way...making it generally the superior value.

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Printed in U.S.A. on Lustro Web Gloss 80 lb. and Lustro Gloss Cover 100 lb.

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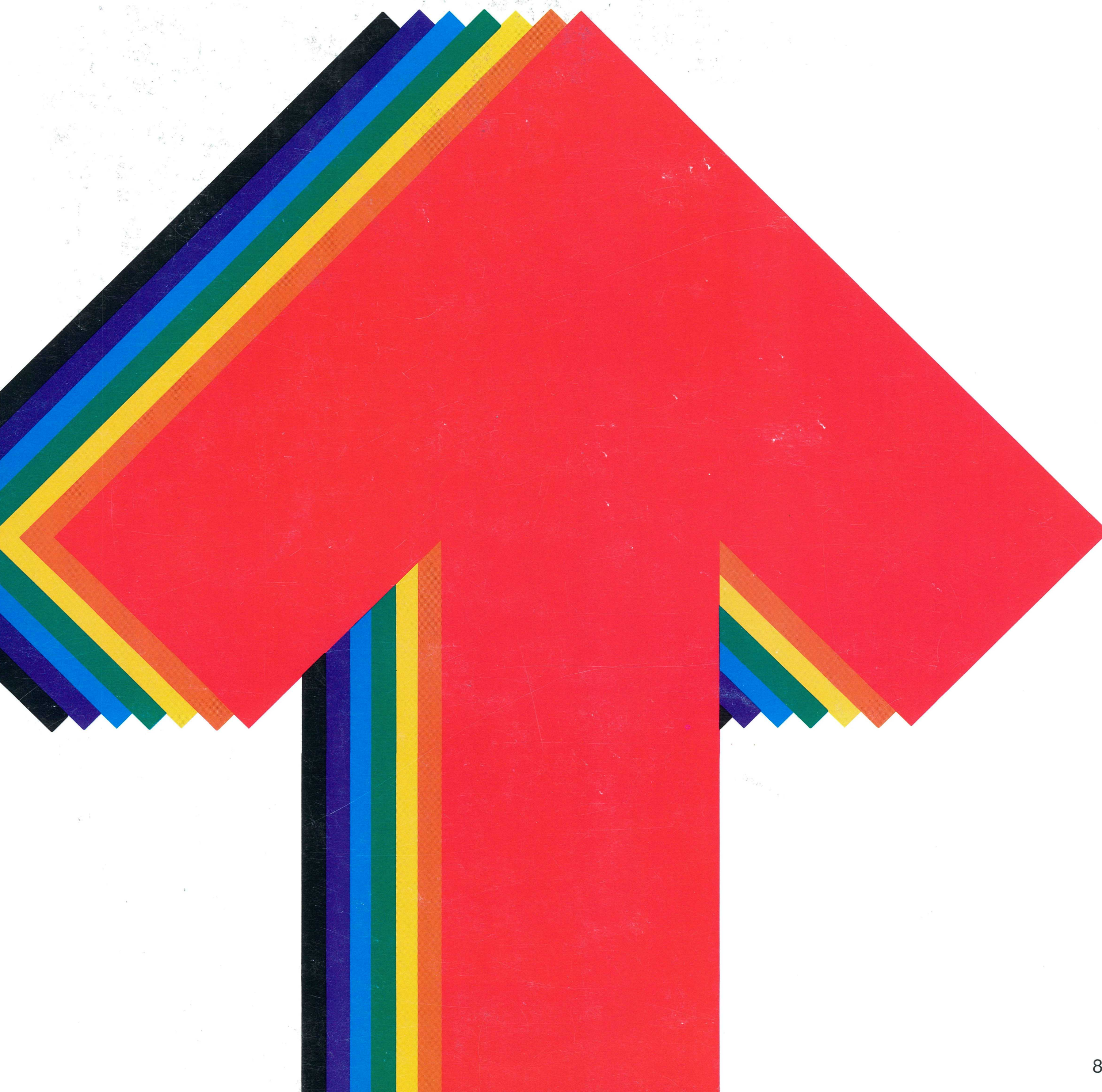

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