INDUSTRIAL AND SPECIALTY PAPERS

Volume III—Applications

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Foreword

Paper is the generic term for a felted sheet of plant fibers in which its thickness is invariably minute compared with its width and length. Where the sheet has been altered significantly by the addition of nonfibrous materials, either by admixture into the felted fibers or by application of coatings or films to the fibrous web, the product is considered a specialty paper.

This volume of *Industrial and Specialty Papers* is concerned with characterizing the products of this sector of the paper industry—defining what they are, how they are used, and where they are sold. In this part of the industry the distinctive products are many and the basic general information is voluminous, but the "know-how" on specific sheets is often the proprietary information of individual manufacturers. For this reason the experienced personal touch of the editors and authors was necessary to render the material into an integrated, useful compilation of information about specialty papers.

As the needs of our society become more complex, the varieties of such papers become correspondingly more numerous and more sophisticated. The growth of these papers in the fields of communication, reprography, graphic arts, packaging and functional industrial applications attests to their importance in filling real needs.

The field of specialty paper uses many products of the chemical industry. With each new and improved chemical product, new opportunities occur. Since the publication of Robert Mosher's *Specialty Papers* in 1950, the first book of its kind in the English language, advance in all phases of the industry has been so consistent that updating with the present volume is necessary to meet the needs of a wide audience.

The very nature of the specialty paper field is such that no one author would feel qualified to write the entire text on the subject. Editors Robert H. Mosher and Dale S. Davis have wisely selected a group of twenty-one experts to present the available information in a form invaluable to the business man, the technologist, the marketing man, the teacher, and the student. This book is essential reading for anyone presuming to be informed about specialty papers.

Harris O. Ware
Executive Vice President,
Premoid Corporation,
Fellow, Technical Association
of the Pulp and Paper Industry

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chapter 1

Printing Papers

R. H. SIMMONS

Printing is the act of reproducing a design on any surface. This chapter endeavors to relate printing papers to the method of printing, the press, and the ink.

The five basic methods of multiple reproduction or printing are: **(1) silk screen** or **screen printing,** where a stencil is mounted on a screen material and the ink is squeegeed through to make a print; **(2) electrostatic printing,** where the image is electrostatically transferred to the paper; **(3) typographic** or **relief printing,** where the printing area is raised above the nonprinting area; **(4) planographic printing,** where the printing and nonprinting areas are in the same plane; **(5) intaglio printing,** where the printing area is below the nonprinting area.

The relation of the ink and paper to the press for each method of printing is discussed. Because large-scale production of printing is done by the first three methods, only short resumes of silk screen and electrostatic printing are given here. The remainder of the chapter deals with typographic, planographic, and intaglio printing.

SILK SCREEN PRINTING

Silk screen printing has advanced from hand production to fully automatic printing. Screen work can be reproduced on almost any material if the inks are formulated to meet the requirements. The inks are "short" so that they print without running and squeegee with little resistance. A thick film of ink is applied to the image area. The thickness of the ink film is determined by the thickness of the screen material and the mesh size.

ELECTROSTATIC AND ELECTROPHOTOGRAPHIC PRINTING

Electrostatic and electrophotographic printing[1] find considerable use in copying, the preparation of offset masters recording by cathode ray tube, and enlarging from microfilm. Recent developments in mechanical design have brought electrostatic printing into commercial work. The U.S. Army is operating an electrostatic printing press to print multicolor maps.[2] Printers of packaging materials are also adapting the method to printing on irregular shapes.[3]

The typewriter is used to produce masters for duplicating by means of gelatine, liquids, stencils, and offset.

TYPOGRAPHIC OR LETTERPRESS PRINTING

Typographic or letterpress printing is done from relief or raised

Fig. 1-1. Miehle V-50X extra vertical letterpress (*Courtesy of Miehle-Goss-Dexter, Inc.*).

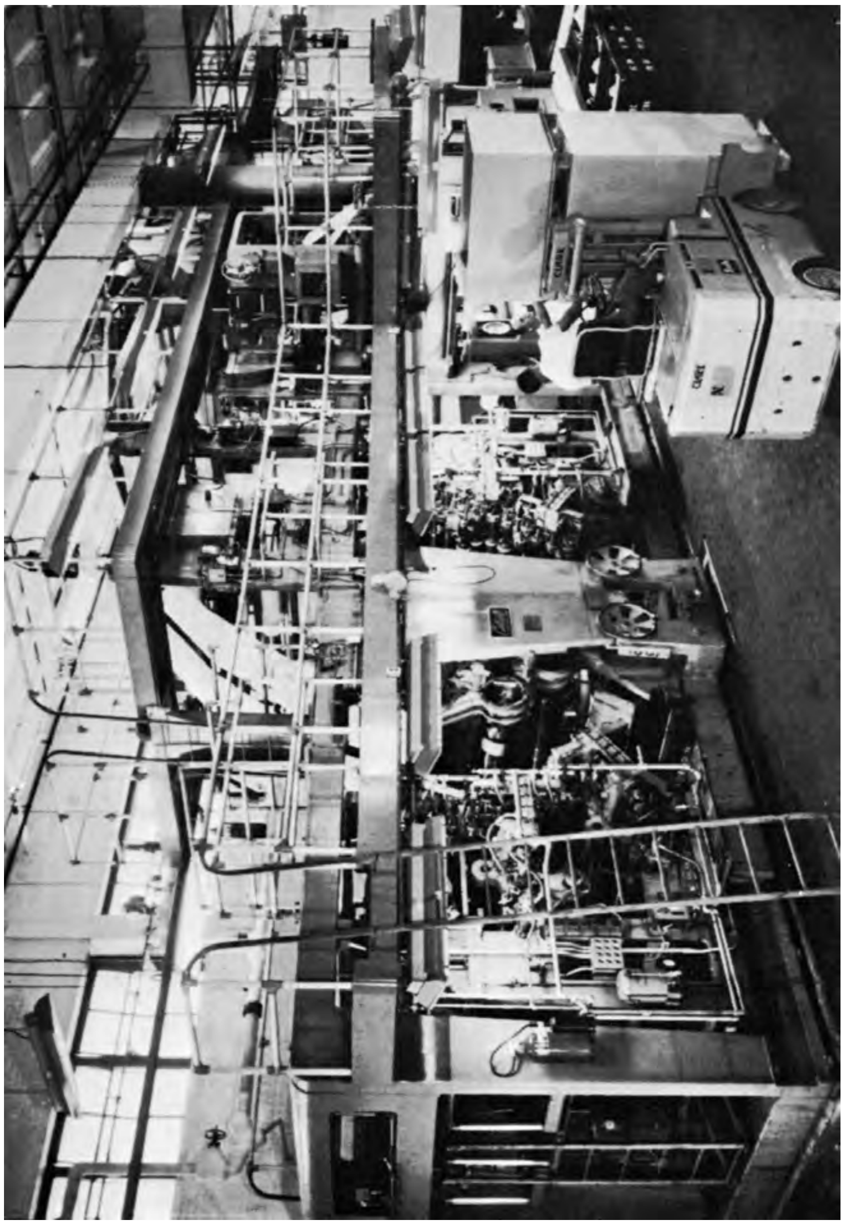

Fig. 1-2. Cottrell double-ender letterpress *(Courtesy of The Cottrell Co., Division of Harris-Intertype Corp.).*

printing areas. (Fig. 1-1 and 1-2). It is the oldest form of printing, dating from 1450 when Johann Gutenberg invented movable type. In early print shops paper was in short supply; handmade rag papers with a laid watermark were all that could be obtained, yet the printer with his single-impression hand press was able to produce an acceptable piece of printing for those days.

As the speed of the presses and the quality of printing advanced, so did the need for better printing papers. They must show increased uniformity in formation, thickness, finish, and receptivity to ink. The invention of the halftone screen gave the printer a tool for reproducing illustrations with enhanced fidelity. To obtain the best results smooth papers are necessary. Perfected process color printing calls for the best uniform paper.

Paper finishes have progressed from antique to machine-finish, English-finish, and supercalendered to coated. Halftone screen rulings are coarse or fine line depending upon the finish of the paper. Newsprint takes from 50-line to 85-line screens; bond, ledger and writing papers, 85-line to 100-line screens; machine-finish and supercalender paper, 100-line to 133-line screens; and coated paper, 120-line to 150-line screens.[4] Highly developed blade coaters now yield smooth finishes with decreased coating material. Research to develop better coated papers is still going on.

Most grades of paper can be printed on typographic presses, which handle roughly half of the printing done today. The presses vary from the hand-fed platen press to the automatic, flat-bed cylinder, and rotary sheet-fed to the high-speed newspaper and multicolor presses. The work can vary from straight type to four- and five-color process printing.

Paper

For all sheet-fed presses the paper must lie flat and be free from wrinkles, tight and loose edges, curl, and extraneous material such as cutter dust and trim. The body of the sheet must withstand the tensions developed in the press. Weak, floppy sheets and curled paper cause hangups, misregister, and even ball ups that damage make-ready and plates. Abnormal curl interferes with proper jogging of the paper in the delivery of the press.

Roll paper for web presses must be uniformly wound with clean-cut edges, free from slitter dust, slivers, and trim. The paper must have uniform formation, thickness, and finish. Variations in thickness produce soft or spongy areas; loosely wound rolls create uneven tension on unwinding. If the roll is loosely wound, telescoping occurs and a movement of the roll to the right or left brings the edges of the web into contact with the side of the press and out of register at the impression cylinder. All splices must be well made and properly flagged.

Rolls with tight or loose edges tend to wrinkle and crease when run through the press. Tight edges can cause the sheet to tear because of the additional tension on the edge. If the edges are tight the middle of the web is longer and sags or bulges. Loose edges are longer than paper in the middle of the web and wave or flop during printing. Both tight and loose edges are the result of uneven tension across the web. If either condition is severe, registration is affected and uneven cutoff at the delivery end of the press occurs.[5]

Inks

Printing inks used on typographic presses vary with the speed of the press, the type of paper, and the requirements of the form being printed. Job press inks should possess as heavy a body as the paper will permit without "picking" or pulling the sheets out of the grippers. The ink must be "short" and buttery with just enough "length" to permit good distribution. As the speed of the press increases, the inks become more fluid with less tack.

Web press inks must be quite fluid consistent with the press speed and the surface strength of the paper. As the speed of the press increases, the uniformity of the paper must improve to give better receptivity to ink. Typographic inks are manufactured so that they print satisfactorily with the various papers required in the finished work.

Typographic inks are classified according to the type of press and the grade of paper used as well as the form that is reproduced. Thus inks are made to operate on job, flat-bed, cylinder, rotary and web presses; on bond, ledger, coated, supercalendered and parchment papers; and on carton stocks. Forms are type, halftone, or solid.

PLANOGRAPHIC PRINTING

Planographic printing is done from a flat surface, i.e. the printing and the nonprinting areas are in the same plane. This process was originally called lithography because the image was drawn with a greasy ink on a smooth block of limestone.

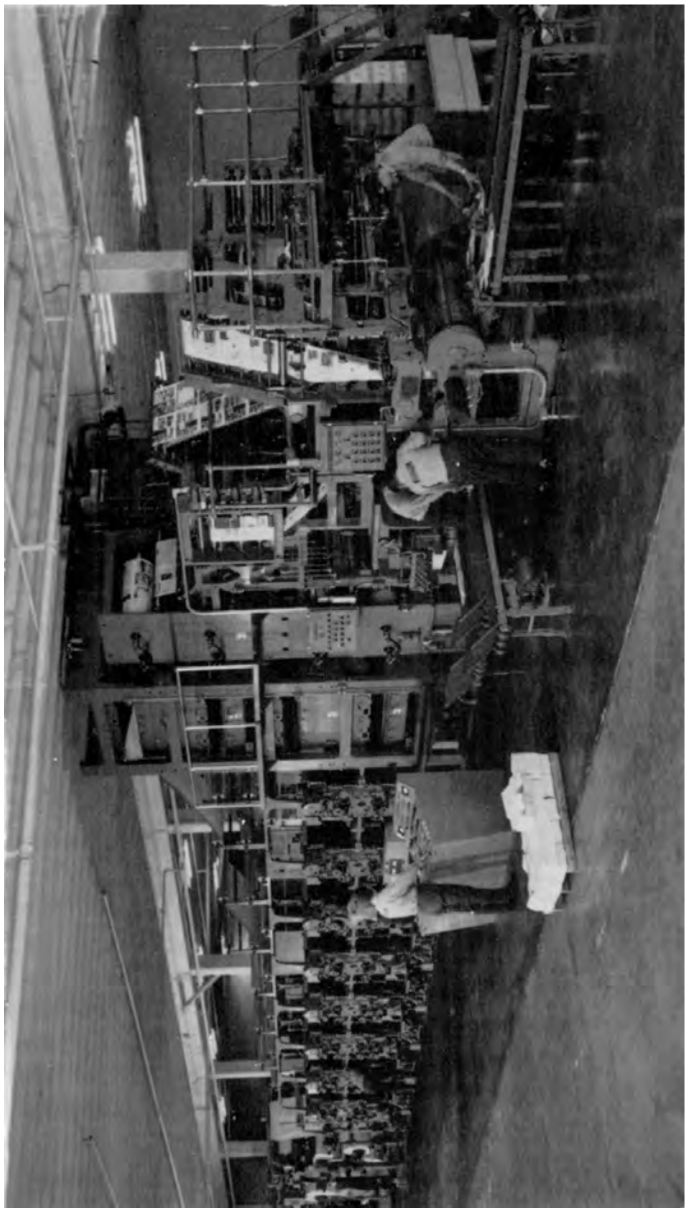

Fig. 1-3. Miehle 49 four-color offset/letterset press (*Courtesy of Miehle-Goss-Dexter, Inc.*).

Lithography

The first printing was directly from the stone to the paper. Then the offset process was developed, in which the printing plate prints on a rubber blanket, which then transfers or offsets the ink to the paper under pressure of the impression cylinder. The cumbersome stone is thus replaced by a thin metal plate, but the process is still called lithography or offset lithography. The inks are lithographic or offset and the paper is specifically for the offset process.

When a lithographic plate is developed, the image or printing area accepts ink and the nonprinting area accepts water. The oil and water immisciblity is the basis of the lithographic process. A plate, a blanket, and an impression cylinder make up an offset press. (Fig. 1-3 and 1-4). The plate is locked into position on the plate cylinder and is alternately dampened with fountain solution and printing ink.

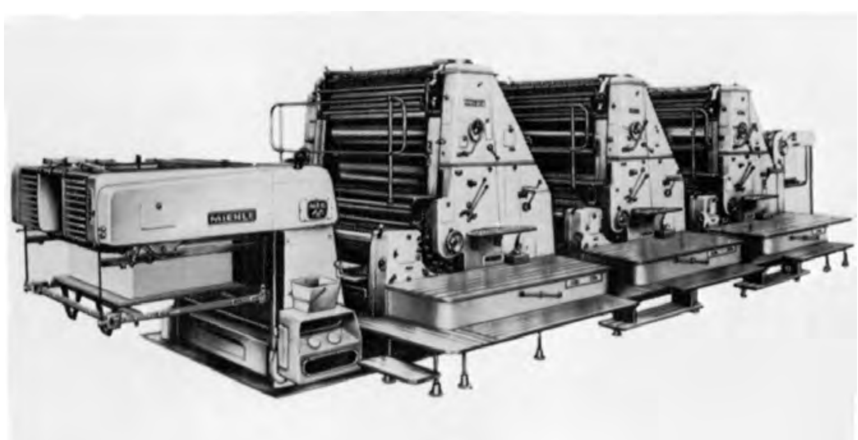

Fig. 1-4. Miehle 49 four-color offset/letterset press

(*Courtesy of Miehle-Goss-Dexter, Inc.*).

The plate cylinder is run in contact with the blanket cylinder until the press is properly inked up. The paper is then fed between the blanket and impression cylinders where the ink is transferred or offset from the rubber blanket to the paper.

The lithographic process is a physical-chemical method of printing. A thin film of ink and a thin film of water are in constant contact. Mixing of the two ingredients, or emulsification, can take place. Factors that affect the quality of printing are bleeding of the ink, washing out of the pigment, sensitizing of the nonprinting areas, and spreading or growing of the image.

Paper

Paper for lithography must lie flat and have good dimensional stability.[6] Paper with curl, loose edges or tight edges tends to wrinkle when passing between the smooth surfaces of the blanket and impression cylinders. Paper with loose edges tends to fan or stretch at the back of the roll. The paper must have a certain amount of water resistance to withstand the effect of the fountain solution. Uncoated papers must be highly sized and coated papers require a water-resistant adhesive to bind the coating. The paper must resist the higher tack of litho inks and the tack developed in the rubber blanket.

Coated papers show a greater tendency to pick when dampened with water than do uncoated papers. Wetting agents are added to some papers to permit better wetting of fillers or coating pigments and thus help distribution in the paper. Small amounts of wetting agents in the paper can break the interfacial tension between the ink and water and can cause emulsification of the ink.

Sheet paper for offset must be trimmed squarely on four sides to permit registration on single impression, two-sided work. The paper must not contain loose particles or dust and must not pick or split. Hickies, small white doughnut-shaped spots with inked centers, can be caused by loose particles, pick, or ink skin. Loose fibers from uncoated papers can attach themselves to the rubber blanket. Because they absorb water, they produce white spots without the inked center.

Ink

The very nature of the printing operation requires highly concentrated ink so that the film of ink carried on the plate can be kept as thin as possible to prevent squashing or slurring under pressure. Because of this concentration of pigment or color, "longer," more viscous vehicles must be used. Some water-resistant varnish is usually incorporated in offset inks to help resist emulsification.[7] Thin inks can "grease" or "scum" and cause difficulty in keeping the work open so that the image tends to thicken and grow. If the ink is not water-resistant the acid of the fountain solution undercuts the image and makes it thin or sharp. The pH and amount of fountain solution to reach the printing plate affect the quality and number of impressions obtained.[8] The cost of preparation of the cylinder and the speed of the press make this process feasible only for long runs.

INTAGLIO PRINTING

Intaglio printing is done from recessed plates and rolls. The printing area is cut or etched below the surface of the plate or roll.

In printing from an engraved plate, it must be rolled up with a heavy film of intaglio or plate ink so that the ink completely fills the engraving. The excess ink is wiped from the surface of the plate, which is then polished to remove any ink that remains on the nonprinting areas. The sheet of paper to be printed is saturated with water and placed over the inked plate, which is then run under the impression roll where the paper is pressed into the engraving in close contact with the ink. The ink adheres to the paper and is pulled out of the engraving, producing the characteristic engraved impression. The ink lies on the surface of the paper and is several thousandths of an inch thick, depending on the depth of the engraving. This method is used for copper or steel plate engraving, largely done by hand.

Die stamping or intaglio printing is divided into two main classes, plate printing and gravure printing, and is done by hand- or power-operated presses. The paper is registered by hand and removed by hand. The ink is quick drying and similar to a heat-set ink. Wedding announcements, letterheads, calling cards, and greeting cards are the normal field for die stamping presses, but special work such as multicolor seals, citations, and diplomas is also done on them.

Plate Printing

Plate printing has been mechanized and mass production is being done on single-color, sheet-fed, and web-fed rotary presses. Many multicolor plate printing presses are in use.

Paper

Plate printing is usually done on high-grade, 100% rag papers, such

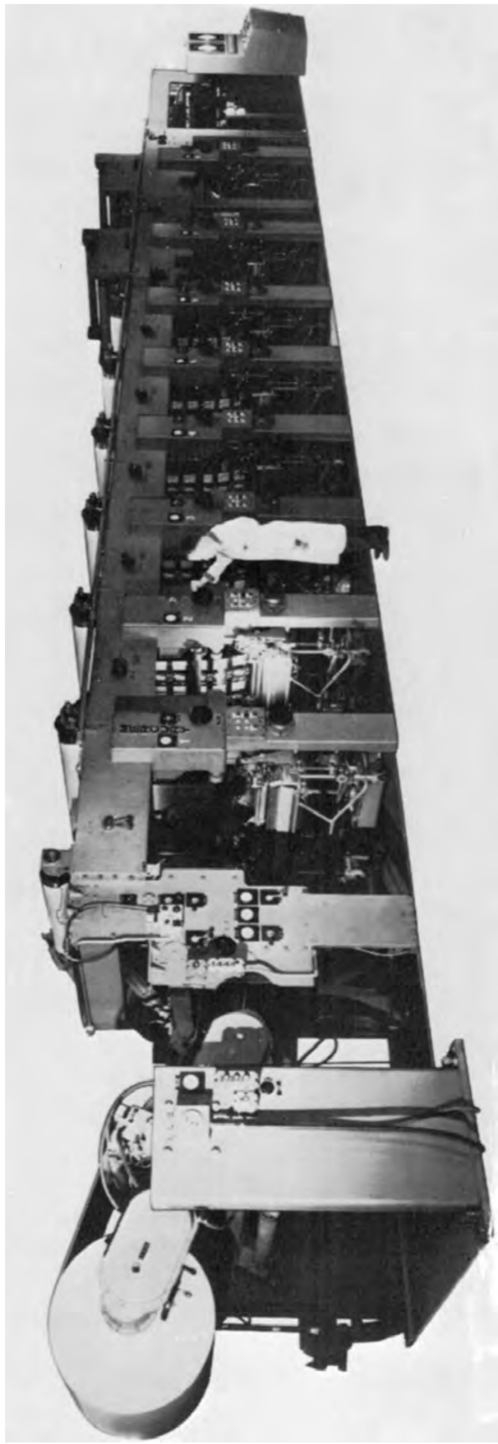

Fig. 1-5. Miehle ten-color light materials, roll-to-roll rotogravure press (*Courtesy of Miehle-Goss-Dexter, Inc.*).

as bond, ledger, and bristols, but others can be used. Securities, currency, and stamps are mass-produced by means of this form of printing.

Ink

Inks for plate printing are "short" and buttery with a maximum concentration of pigment. The harder pigments and extenders are needed in plate printing to assist in wiping and polishing the plates. On web-fed rotary presses, heat-set inks are used.

Gravure Printing

Gravure or rotogravure printing is an intaglio process in that the printing area is etched below the surface of the printing roller on copper cylinders in the forms of square or round cells. (Fig. 1-5 and 1-6). The depth of the cell determines the amount of ink carried and

Fig. 1-6. Cottrell Model V-22 newspaper press (*Courtesy of The Cottrell Co., Division of Harris-Intertype Corp.*).

the depth of the color printed. Most gravure printing is done on web presses, but some sheet-fed gravure presses are used. The cost of preparation of the cylinder and the speed of the press make this process feasible only for long runs.

Paper

The paper must be uniform in formation, thickness, and finish. It must be smooth and the density of the paper must insure good ink receptivity and must not permit the ink to spread or feather. Sunday supplements to newspapers use rotonews or English finish newsprint. Supercalendered newsprint and supercalendered book papers together with coated papers made especially for rotogravure printing are employed for catalogs and magazines. Gravure is being used for printing paperboard for packaging. Because gravure printing is primarily a web-press operation, C. A. Thompson[9] lists some requirements for gravure newspaper rolls and paper:

1. The rolls should be free from defects such as slug holes, calender cuts, calender scabs, edge cracks, turnover, defective mill splices, winder snapoffs, and loose starts at the cores.
2. The paper should have sufficient strength to withstand the tensions and the stresses that are encountered on a rotogravure press.
3. The rolls should be as uniform as possible and should run with no evidence of slack areas, and baggy or loose ends, which result in wrinkles, misregister, or web breaks.

Gravure Inking

Gravure inks are composed of natural or synthetic resins and gums dissolved in volatile solvents together with the proper coloring materials. The inks are thin, almost without tack, and entirely free from gritty or hard particles, which could scratch the cylinder.

Printing is done directly from the cylinder. The paper passes between the etched cylinder and an impression roller, which presses the paper into the engraving. The impression roll is covered with a slightly compressible covering that helps to force the paper into the cells and compensates for slight variations in its thickness. The cylinder is inked by rotating directly in the ink fountain or by some other method that completely fills the cells of the cylinder. The excess ink is removed by a doctor blade to wipe the nonprinting area clean. The ink is removed from the cells by capillary action, pressure, and affinity of the ink for the paper surface.

Tensions

Tensions in gravure presses are greater than those in typographic web presses. Tension, greater between impressions and about three times as great as at the web stand, increases materially just before a break. Because of the economics of gravure printing and the high cost of preparation, the presses are run twenty-four hours a day. A web break takes about half an hour to repair. Nonuniformity across the sheet with baggy paper creating wrinkles, and poorly-made mill splices accounts for a majority of web breaks on gravure presses. A study of the mechanics[10] of the process has shown that the effects of the nip give rise to shear as well as tension stresses in the nip.[11]

Paper Characteristics in Relation to Printing

Consideration is given here to characteristics that must be built into the paper for satisfactory operation because of the demands imposed by the various printing processes.

Physical Strength

Strength is important because the paper must withstand the stress and strain of the printing and binding operations. Strength is not as important in printing as it may be in the ultimate use of the finished product. In building a paper for printing, one must consider the use requirements of the printed article and then consider these in relation to obtaining the printing properties. Maximum strength and a closed formation with a uniform, smooth finish are impossible. Paper to be folded, stitched, or sewed must have sufficient strength to withstand these operations without breaking.

Formation

Formation is basic for printing papers because many printing characteristics depend on it. Formation is the measure of uniformity of distribution of the components of a sheet of paper, more especially the fibrous part. Formation is normally judged when observing the sheet by transmitted light. A cloudy appearance from irregular distribution of fibers is called a "wild" formation. A uniform appearance is called a "close" or "closed" formation and is highly desirable in printing papers. Because printing presses are designed to give a uniform impression across the printing form, a paper uniform in finish, formation, and thickness is necessary to take a uniform impression. A sheet with a closed formation usually has these characteristics, supercalenders uniformly and accepts a smooth coating.

A "wild" formation is the result of long fibers lumping together to produce high and low spots in the papper. If the paper is calendered, the high spots take the pressure of the rolls and develop a polish while the rest of the sheet remains dull. If too much pressure is applied or too much moisture is in the paper, it tends to become somewhat transparent and darkens in color. The sheet becomes crushed and shiny at the high spots. These spots do not accept printing ink readily and it does not penetrate into the paper. The ink dries slowly with a complete gloss holdout and may offset in printing.

The low or dull spots are not calendered as hard as they should be and remain dull areas between the shiny spots. They accept ink readily and absorb it into the paper. The ink sets readily and will not offset, but because of the penetration it appears flat and dull. The combination of penetration on the one hand and transparency on the other may be responsible for showthrough of the printing. A solid printed on this paper dries with a mottled finish of glossy spots and flat spots.

An uncoated paper can be two-sided in color, finish, and ink-receptivity. The wire side is usually slightly rougher and more open than the felt side. The felt side has always been considered the better printing side of paper; manufacturers of printing papers label and pack sheet paper with the felt side up. Decided differences in the two-sidedness of paper may make it necessary to adjust the ink formula so that the printing on the wire side matches that on the felt side in color or finish.

Electronic scanning of a sheet of paper and charting the results on a recorder are the most successful means of determining and recording the formation of paper.[12] Visual comparison of the paper with standard samples is the accepted method for rating formation.

Smoothness

As stated under *Formation*, p.13, smoothness is closely related to the uniformity of the formation and is relative. One sheet is said to be smoother than another when more points on the surface of the first sheet are more nearly in one plane than are those on the surface of the second. The smoother the sheet the better is the contact between the printing plate and the paper.[13]

Levelness

Levelness, closely allied with smoothness, is variation in thickness from one spot to the next, whereas smoothness is overall variation of small surface imperfections.

The smoothness of coated paper is essential for faithful reproduction of four- and five-color process printing, and is measured by four methods:[14]

	Basis	*Instrument*
1.	Air leakage under a smooth ring	Bekk, Bendsten, Gurley, Sheffield, Brecht[15]
2.	Stylus tracing for contour	Brush, Talysurf, Metrsurf, Proficorder
3.	Optical contact with glass	Chapman
4.	Low-angle shadowing	Sheid

Tests with Methods 1, 2, and 4 are not made under printing pressure. Method 3 ignores low spots. The most satisfactory method of determining printing smoothness is to use the Vandercook No. 4 proof press with controlled thickness of ink film, which is less than normal ink coverage. A print made in this manner shows low spots, uneven thickness, and formation.

Compressibility (Printing Softness)

Softness in paper represents the ability of the sheet to compress and conform to the shape of the printing surface under printing pressure. A soft sheet conforms more easily and takes a better impression than does a hard sheet. The soft paper does not require as much pressure to print as does a hard sheet.

To determine this factor the thickness of the paper is measured under a light load and again under a known pressure. The decrease in thickness is the compressibility. When the thickness is again measured after removing the pressure, the return to the original thickness is called recovery or resiliency. The C & R thickness, compression and recovery tester[16] gives an indication of softness under low pressures. The Armstrong indentation machine[16] uses pressures nearer those of printing.

The Gurley-Hill S.P.S. tester,[16] based on the air-flow principle, has an attachment that measures the softness of paper. A specimen is clamped between two smooth circular rings and four steel pins that project 0.002 in. above the surface are set in the lower ring. With no

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