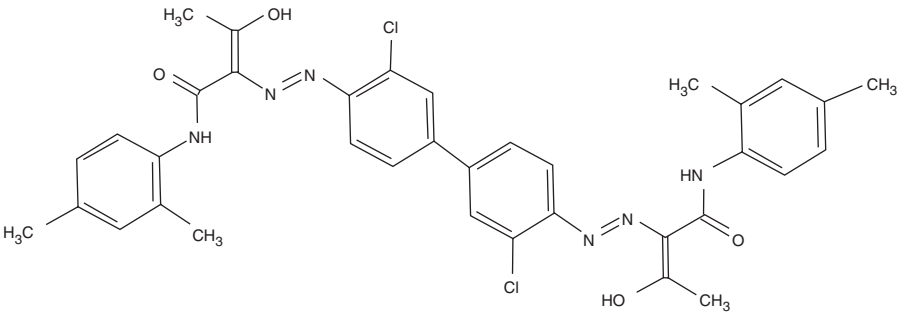

Figure 11 Structure of pigment yellow 13.

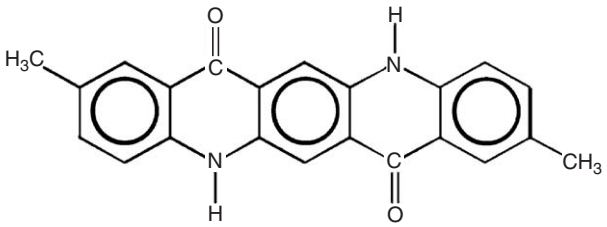

Figure 12 Structure of quinacridone magenta pigment.

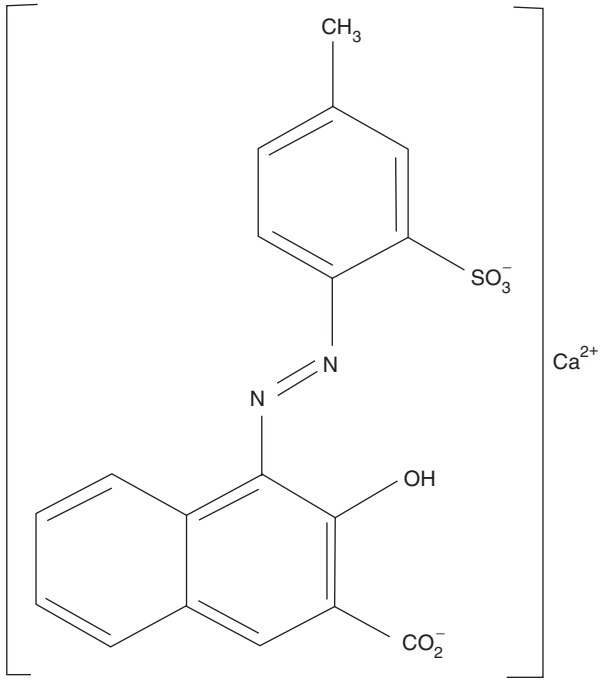

Figure 13 Structure of pigment red 57.

obtained by varying the pH, temperature, and time of heating during oxidation. These were used by printers for all printing inks through the mid nineteenth century, before the discovery of synthetic organic dyes.

See also: **Papermaking**: Paper Grades; The History of Paper and Papermaking; World Paper Industry Overview.

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Packaging Grades

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Introduction

Nasiri Khosrau of Persia (now Iran) recorded the first use of paper as a packaging material in 1035 AD when he observed vendors in Cairo (Egypt) wrapping vegetables, spices, and dry goods in paper. Today, paper continues to be an important material used to

transport, distribute, and market virtually every commodity and manufactured item. Paper competes very successfully with metals, glass, plastics, wood, and textiles, because it has many desirable properties including being biodegradable, recyclable, and renewable. Paper functions in many diverse packaging applications from heavyweight shipping containers to lightweight wrapping papers. This article will concentrate on lightweight specialty papers such as retail paper bags, food wrapping, gift wrapping, spiral-wound paper tubes, label stock, and other specialty items. The cut sheet size for wrapping papers is 24 in. by 36 in., giving a total ream area of 3000 ft^2. Types of paper used to manufacture boxes and containers are discussed elsewhere (*see* **Papermaking**: Paperboard Grades).

Retail Paper Bags

Retail bags are closed-bottom, flexible-walled containers that are capable of carrying many types of dry goods within them. Paper bags are manufactured from kraft paper due to the requirement for high strength. The paper may be bleached or unbleached depending upon the use. The grammage range for lightweight bags is 40–60 $g\,m^{-2}$. For heavier weight bags such as grocery bags that are required to carry as much as 12 kg the grammage range extends to 110 $g\,m^{-2}$.

Historically, bags were fabricated from textiles or animal skins with sewn bottoms. During the early nineteenth century, powdered goods such as flour or medicines were sold in hand-rolled paper sacks called 'pokes.' These early paper bags were actually inverted cones that required only folding to close the bottom. By 1877, paper bags were produced by machines that cut, folded, and either glued or sewed the sides from rolls of paper. Today, paper bags come in four basic shapes: flat, square, satchel-bottom, and self-opening.

Flat paper bags are made from kraft paper that has been glued with a starch-based adhesive to form a tube with its bottom folded and glued. This type of bag is commonly used for candy, greeting cards and many retail items that are small and lightweight. The square-bottom bag is similar to the flat bag except that the paper tube is first folded inwards along the sides to form an expanding gusset before the bottom is folded. When the square bag is opened or filled, the bag has a square or rectangular cross section. In this manner, the square bag can hold thicker and heavier items such as books and newspapers. The satchel-bottom bag also forms a square shape when opened but the bottom is folded into triangles and glued together to form a block bottom that is ideal for packaging flour, rice, sugar, and other dry food items. The satchel-bottom bags, when filled, can stand upright. Finally, self-opening bags have gussets to form square bags and specially folded bottoms that form flat-bottom squares or rectangles. These bags are folded flat but are designed to open with a snap of the wrist and stand by themselves for filling. Grocery bags and sandwich lunch bags are examples of self-opening bags.

Wet strength is an important paper additive for retail bags. Grocery bags in particular must be able to maintain a substantial portion of their strength when brought into contact with wet food and other products.

Multiwall Paper Sacks

Multiwall paper sacks are designed to be exceptionally strong and carry heavy and bulky materials for the building, food, and chemical industries. In essence, multiwall sacks are two or more separate sacks nested together to form a stronger and tougher sack. Five or six total plies of paper (60–110 $g\,m^{-2}$) may be necessary. For paper sacks, kraft paper is used; however, stretch and porosity as well as strength are critical performance criteria.

Stretch or extensibility is important because multiwall sacks are required to withstand numerous impacts during shipping and warehousing without rupturing and spilling their contents. Sack paper's ability to absorb shock during impact is measured by tensile energy absorption (TEA), which is a paper property that combines both strength and stretch. TEA can be thought of as a measure of 'work to burst.' Special extensible sack paper that has been produced through the 'clupak' process greatly enhances TEA and permits the use of lower grammage ranges (50–100 $g\,m^{-2}$) thus saving about 20% fiber by weight. The clupak process, invented by Sanford Cluett, produces extensible paper that is difficult to tear by passing wet paper through a steel and rubber nip that causes fiber crimping in the machine direction. Additional extensibility in the machine direction is produced on the paper machine through using slack draws in the dryer section. Slack draws prevent the sheet from developing dried-in drains leading to limited stretch.

Porosity is important for multiwall paper sacks because air needs to escape through the wall of the bag to permit rapid filling. Sack filling machines are able to fill a 25–50 kg sack in 1 second at temperatures that can exceed 100°C. Sewn-bottom and pasted bottom open-mouthed sacks are used for

low pressure gravity-filling systems. Valve sacks are required when materials must be filled under pressure.

Multilayer sacks may be constructed with plastic liners to prevent moisture contamination. Plastic linings are important for foods and chemicals where the ingredients have to maintain a certain moisture level. Wet-strength resins are also used to control moisture penetration through the paper.

Food Wrapping Paper

Paper intended for the wrapping and serving of food must be manufactured from ingredients that do not adulterate food. This requirement necessitates the use of virgin chemically processed pulps along with paper additives and coatings that are recognized as safe to human consumption. These papers must have some form of wet strength and grease resistance as well as have reasonable printing properties. The basis weight range for food wrapping paper is 28–65 g m^{-2}. General categories of food wrapping paper include: greaseproof, metallized, and foil-backed papers. Special fruit wrapping papers impregnated with preservatives can also be found.

Greaseproof papers are papers that resist the penetration of grease and oils, and are also called moisture resistant papers. Vegetable parchment is a nonporous, homogeneous sheet of cellulose formed from sulfuric acid treating pulp. This material is the traditional form of greaseproof paper but is very expensive by present standards. Surface coating or sizing with wax or synthetic materials is now a more common method of manufacturing greaseproof paper from standard, bleached kraft paper. Food-safe paraffin wax is lightly applied to one side of the sheet. Thicker coatings of wax are also applied when a shiny surface is desirable. Synthetic surface treatments include silicone or polyvinyl alcohol based materials. Highly refined and supercalendered glassine, coated or uncoated, may also serve in this category. Grease or moisture resistance refers to surface treatments that have intermediate grease resistance between uncoated paper and greaseproof paper.

Metallized paper is an excellent packaging material for foods that are sensitive to moisture and light. The metal, usually aluminum, is applied in a very thin layer (0.02–0.05 μm) onto the paper sheet through vacuum deposition that involves vaporizing high purity metal. Due to the high surface free energy of paper, the vaporized metal bonds to the paper surface forming a moisture and gas impenetrable layer. The gloss of a metallized paper sheet is a function of the roughness of the paper. Rough paper surfaces produce matte or dull appearing metal layers, while smooth paper surfaces produce glossy metal layers. High-gloss metal layers are manufactured via indirect or transfer metallizing. In transfer metallizing a polypropylene web is initial metallized. Because the metal does not bond to the polypropylene, the entire metal layer can be transferred to the surface of an adhesive-coated paper sheet. The transferred metal layer has the surface smoothness of the polypropylene sheet. Thus, a high gloss metallized sheet is produced regardless of the original surface of the paper. Before printing, metallized paper is coated with a special primer layer to enhance adherence of the printing inks. Metallized paper is used as packaging materials for a number of food products that include chocolate bars, oily snack foods, candies, and chewing gums.

Foil-backed paper is produced by laminating aluminum foil to paper with an aqueous adhesive. The resultant sheet is attractive, easily printed upon, and has similar barrier properties to metallized paper. However, additional properties such as dead fold and heat retention capabilities that make it ideal for wrapping fast-food items such as hamburgers and other hot sandwiches. Dead fold is a direct property of the aluminum foil. Aluminum metal is very malleable and can be greatly deformed without cracking or losing its barrier capability. When fully annealed, aluminum maintains no 'temper' and retains its shape when deformed. Thus, dead fold gives foil-backed paper an ability to wrap around and temporarily seal a fast-food product from the time of purchase to the time of consumption.

Twisting paper is a novel food wrapping paper that is used primarily for personal-sized confections and cough drops. It has a high machine direction fiber orientation and a grammage range of 25–40 g m^{-2}. Some twisting papers may be metallized with aluminum to improve product attractiveness. Furnish additives include: titanium dioxide for enhanced opacity, and wet strength agents. Twisting papers are slit into very narrow widths to match the size of the confection. A heavier weight, non-food twisting paper is sometimes found making up the handles of paper bags used for shopping though it is now virtually obsolete.

An interesting paper grade that is frequently excluded as a packaging or wrapping grade is tea bag paper. Tea bag paper is a lightweight (grammage range 12–17 g m^{-2}) tissue paper made from very durable and long-fibered pulp such as abaca (banana leaf). This paper has to be porous yet hold the fine-sized tea leaves within the fabricated product.

Synthetic fibers such as polypropylene are frequently mixed into the furnish to produce a heat sealable bag.

Wrapping Papers

Wrapping papers are produced for a variety of purposes. Three major types include kraft wrapping paper, tissue paper, and gift-wrap paper. Kraft wrapping paper is sold in roll widths from 400 to 1200 mm with a grammage range of 50–90 g m^{-2}. It is produced from either unbleached or bleached pulp and is similar to kraft sack paper. When recycled pulp is used, it is sometimes called 'imitation' kraft paper and is dyed brown. Kraft wrapping paper is frequently used in retail transactions involving items that are not prepackaged or as an outer wrapping for food items that have flimsy, easily damaged food-grade packages.

Tissue wrapping paper is a lightweight paper sheet having a grammage range of 14–40 g m^{-2}. The standard tissue wrapping paper has a machine glazed finish due to the use of a high-temperature Yankee dryer that produces high gloss on the bottom side of the sheet. Unglazed tissue may also be produced using lower drier temperatures. Tissue wrapping paper is used to protect fragile or expensive gift items such as glass trinkets, ornaments, and jewelry. Wrapping tissue is made in colors running the spectrum from white to black. White wrapping tissue may have a brightness as high as 80. Special acid-free tissue is available to wrap items that are prone to tarnish, such as silver metal.

Gift-wrap paper is produced in grammages above 36 g m^{-2}, and is coated and calendered to maximize the attractiveness of the printed pattern. The paper's gloss is improved through the lamination of metal foil or the extrusion of a polymer coating. Rolls of gift-wrap are sold in widths of 500–800 mm and lengths of 1–5 m.

Paper Tubes

Spirally wound paper tubes are used in a myriad of packaging products. Some examples include: mailing tubes, snack food cans, and cores for paper roll products. The paper used is made from either virgin kraft or recycled fiber and has a grammage range of 35–95 g m^{-2}.

The process of producing a paper tube begins with slitting paper into narrow (minimally 2 inch) strips from a 50-inch roll. The strips of paper are then coated with a glue and several layers are wrapped into a spiral having an angle of approximately 45°. The final tubes can have typical diameters as great as 48 inches and wall thicknesses as much as 1/2 inch. Depending upon the final dimensions, the tube can be referred to as a tube, a can, or a drum. After gluing, the tubes are first rough cut, then cleaned, and precisely cut. Inside and outside layers can incorporate separate specialty papers that are optimized for barrier and printing properties. When tubes are used as cans or closed packages, the tube ends can be sealed by a variety of methods. In general, a paper top can be glued over the ends, the ends can be sealed by crimping and gluing, or a metal or plastic cap can be inserted.

Paper Cups

Paper cups are essentially single-wrap paper tubes with only one end sealed. The cup is sealed down the side similar to paper bags. The cup bottom may be sealed by either gluing a separate paper end cap or rolling the cup into a cone or convolute tube. Bleached, food-grade quality kraft paper similar to milk carton stock is required. The paper needs to have a high tensile strength, a low cross-machine stretch, and a low ash content. The top edge of a paper cup is rolled under to provide a smooth edge. This cup feature requires that paper cup stock have the ability to delaminate internally and hold the rolled edge.

Paper cup stock also needs to have a high moisture resistance for cold drinks. Wax coatings provide adequate moisture resistance as well as provide good sealing on the seam. However, wax coatings are likely to melt with hot drinks such as coffee and permit liquid leakage. Polymer laminations or extruded coatings are used on cups intended for hot beverages. The polymer coating is used only on one side to provide the moisture barrier and a sealable seam, while the outside of the cup is usually uncoated to provide better heat insulation. Clay coatings are frequently applied to increase printability and opacity. Miscellaneous paperboard items related to the use of paper cups in restaurants are insulating sleeves made from unbleached or recycled fiber and carrier trays. Many paper cups intended for hot drinks have paperboard handles glued to their sides.

Label Papers

Paper is an important method of labeling packages and containers that are nonprintable such as metal tins or cans and bottles. Paper is also an important method of labeling items in the office and at home with pressure sensitive labels. Paper designed for

labels has one surface optimized for printing and the other optimized for the application of an adhesive. Flexographic, gravure, and offset printing are the most important commercial processes used for labeling retail products; however, blank labels used in the office and in the home must be receptive to pen inks and ink-jet printing. Paper label stock may also be clay coated, extrusion coated with plastic or laminated with metal.

Label stock intended for bottles and other liquid packages needs to be water resistant so that the label neither washes off the bottle nor losses its printing during normal usage. The label must also have wet strength sufficient to keep it intact if it is intended for use in recycled bottles where the label must be washed off with strong cleansing alkali. Paper used for these applications is white with ISO brightness above 80%, a gloss above 80%, and a high smoothness. The paper also needs to be stiff, dimensionally stable, and absorbent to adhesives. The paper furnish is derived from hardwood and softwood chemical pulps with a grammage range of 70–75 $g\,m^{-2}$.

Pressure sensitive labels are produced by laminating a printable face sheet on top of a 'release' liner using a suitable adhesive that completely peels away with the label allowing the label to be applied and adhered to another surface. Also known as 'peel and stick,' pressure sensitive labels come in either preprinted or blank forms that are die-cut to form individual labels on a roll or sheet. Pressure sensitive labels are used for: packages, cartons, mailing labels, computer disks, office labeling, and even postage stamps.

The release liner, also known as backing paper, is frequently silicone coated to create a smooth, pinhole-free surface that will not permanently bond with the adhesive of the face stock. The release liner can be either glassine or bleached kraft. Glassine is inferior to bleached kraft in regards to curl and dimensional stability, but its transparency makes it suitable where machine scanners are used to bring die-cut labels into position for printing and automatic labeling of packages. Glassine used for release liners has a grammage range of 30–80 $g\,m^{-2}$ and a caliper of up to 65 μm. Release liners made from bleached kraft have a grammage range of 30–130 $g\,m^{-2}$ with maximum caliper of 100 μm. The extra stiffness, dimensional stability, and bulk of the bleached kraft liners are required for high quality printing requirements. The need for high smoothness often necessitates supercalendering at about 20% moisture content. Silicone in the form of silicone acrylate is off-machine coated using a roll coater and then cured using either electron beam, ultraviolet or oven techniques. Solvent silicone systems are still used but flammability and environmental concerns are making newer aqueous systems more preferable. Modern machines that produce pressure sensitive labels coat and cure the backing paper and then apply the pressure sensitive adhesive directly to the silicone treated side. Simultaneously, the face stock is coated with an adhesive-receptive primer that is then dried. Both sheets are then laminated together to form the final product.

Face stocks can come in a variety of grades from lightweight (65 $g\,m^{-2}$) supercalendered paper to relatively heavy tag-grade paperboard (230 $g\,m^{-2}$). Face stocks may be either bleached or unbleached depending upon the application. Recycled fiber percentages as high as 100% may occur with post consumer waste percentages reaching as high as 50%. Face stocks are printed using a variety of methods including flexographic, letterpress and on-demand printing methods, such as direct thermal, thermal transfer, and laser/ink jet technologies.

See also: **Packaging, Recycling and Printing**: Paper Recycling Science and Technology. **Papermaking**: Overview; Paper Grades; Paper Raw Materials and Technology; Paperboard Grades; Tissue Grades; World Paper Industry Overview. **Pulping**: Bleaching of Pulp; Physical Properties.

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