Cork and Cork Products

At least $20,000,000 worth of cork products are annually manufactured in the United States, and efforts are being made by annual plantings of cork oaks in 25 States eventually to relieve American industry of its present total dependence upon foreign sources to supply the cork for this production.

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Previous articles on cork (1, 2) have informed the reader about the culture of this product in Spain and experimental plantings in California. It is of interest to point out that plantings of the cork tree are made annually in 25 States in the warmer parts of the United States. This cork-planting program was initiated by the late Charles E. McManus, former President of the Crown Cork & Seal Company, in California in 1939. The widespread interest and response to his efforts in California led Mr. McManus to extend his program into all States where the cork tree might grow and to establish the McManus Cork Project. The purpose of the Cork Project is to add to the natural resources of our country and to provide in the United States a source for at least a part of the nation's cork requirements. In a comparative study of climatic and soil conditions in the cork-producing areas of Europe and Africa with the United States, Ryan (3) has shown that all or parts of 27 States in this country are suitable for growing cork trees. The McManus Cork Project is a long-range program, and it is gratifying to note that results of initial efforts are encouraging.

Cork has numerous important applications. For more than 2,300 years it has served many useful purposes, and for centuries has been a valuable article of commerce. Cork is a necessary material for our national economy both in war periods and in peacetime. For normal manufacturing requirements in the United States about 160,000 tons of cork are imported annually.

In addition to its valuable cork bark, the cork oak produces each year large acorns in generous quantities. This annual crop is used in Europe as a supplemental stock food, and in Portugal alone 200,000 tons of cork acorns are fed to hogs each year. A bushel of cork acorns (about 70 pounds) will make approximately 6.5 pounds of pork.

The cork oak is an evergreen and makes an attractive ornamental shade tree. The tree grows well under favorable conditions, and in four or five years attains attractive size. Its heavy green foliage during the winter months is a delightful contrast to the bare branches of deciduous trees.

Thus, we see, the cork oak returns to its owner much more than many other trees. In addition to wood and shade we obtain from the cork oak, cork, a material essential to our national economy; an annual acorn crop that is excellent for livestock food; and ornamental beauty throughout the year. For these reasons the cork oak may be grown either as an ornamental shade tree or as a forest tree.

Baled cork is brought to the United


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States in large freight boats. The bales vary in weight, ranging from about 150 to 250 pounds. During the transfer from boat to storage shed the bales are classified into groups according to quality.

As with all other materials the characteristics of cork determine its uses. Accordingly, before discussing the uses of cork, a brief summary of the physical and chemical properties is presented.

Structure and Characteristics

Under high magnification the characteristic cellular structure of cork can be seen. The cork cells vary in size but are very small, and they number about two hundred million to the cubic inch. They are filled with air and held together by a natural resinous binding substance.

Professor Lewis (4), of Harvard, has shown that the cork cell possesses fourteen sides, six of them being quadrilaterals and eight of them hexagons. This formation is due to nature's method of giving the cells the greatest possible volume with the least amount of surface while permitting the cells to lie compactly together.

The physical attributes of cork are a direct result of its characteristic air-filled cellular structure. Cork is compressible and resilient, and these properties enable it to give a perfect seal when used as a crown cap liner. Each tiny cork cell functions as an air cushion, permitting the crown cap to be compressed firmly against the mouth of the container and constantly exerting a back pressure, thus making a tight and permanent seal.

When cork is placed under a heavy load the air in the cork cells is compressed and the cork is reduced in thickness. When the load is removed the air in the cells expands to normal volume and the cork returns to its original size. One inch cubes of cork have been subjected to a pressure of 10,000 pounds per square inch without any side spread. After the pressure was released the cork returned to ninety-five per cent of the original height.

Both the natural resinous binder and the air-filled cork cells are impervious to water, giving cork many uses where a water-proof material is required. Cork is also oil-resistant, and on account of its non-capillarity, which results from its unique cellular structure, penetration of cork by liquids in general is extremely difficult. For this reason cork can be used as a bottle closure for innumerable solutions and liquids.

Cork is very light, its specific gravity varying between 0.15 and 0.20. This lightness is due mainly to its air-filled cells. The cork cell walls and the natural cell-binding material are also light weight substances. This property of cork gives it many applications where floats and articles of low density, such as insoles for shoes, are required.

Air in finely divided spaces is the best thermal insulator known, next to a vacuum. The tiny air spaces in cork are responsible for the heat-insulating property of cork. The thermal conductivity of cork is very low, and corkboard is an excellent material for low temperature insulation. This property, coupled with its lightness and its resistance to penetration by water, makes corkboard an ideal insulator for refrigerators and air-conditioned buildings.

Cork with its characteristic air-filled cellular structure makes an efficient machinery isolation material. Vibration and wear are greatly reduced by mounting motors and machines on cork. Sud-

FIG. 1 (*Upper*). Unloading a shipload of cork at an American port.

FIG. 2 (*Lower*). In manufacturing molded inlaid linoleum the pattern is stenciled in the desired colors onto the burlap backing. (*Courtesy Cork Institute of America.*)

den pressures and shocks cause the air-filled cells to quickly compress, and the vibrations are not transmitted through the cork.

When cork is sliced, many of the cells are cut, forming thousands of tiny cups on the surface. In these cups partial vacuums are formed when cork is drawn over or pressed against a smooth surface. This accounts for the high coefficient of friction exhibited, and for the suitability of cork where a material of non-slipping character is essential.

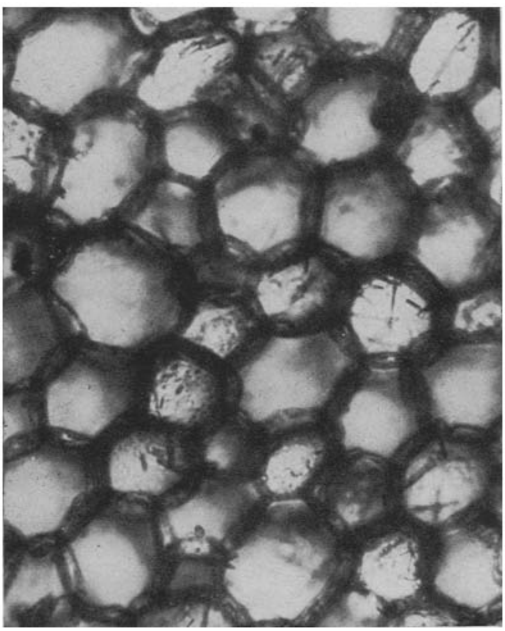

Fig. 3. Photomicrograph of cork showing its characteristic cellular structure. Magnification (500 ×).

The air-filled cells also give cork an important place in modern building. Corkboard is used to insulate against outside noise and to absorb sound formed within and prevent echoes. Radio studios and motion picture studios have found cork to produce excellent acoustical conditions.

These physical characteristics of cork together with its chemical stability are responsible for its many varied applications. And because no other naturally occurring or synthetic material possesses all of these physical properties, cork is today the basis of a large and flourishing industry.

For centuries the stability of cork has been an outstanding chemical characteristic and has made it suitable for many diversified applications. Clean cork of commerce is not affected or changed in composition by contact with water, vegetable, animal or mineral oils, gasoline, many organic solvents and many gases, such as carbon dioxide, hydrogen, nitrogen and air. Cork is highly resistant to fruit and vegetable acids, concentrated hydrochloric acid, animal acids, soaps, mild alkalis, salts and literally thousands of chemical compounds. Its use as a closure for innumerable articles of commerce attests the chemical resistance and durability of cork. No other untreated naturally occurring plant product can be used in contact with so many different materials.

The constituents of cork are responsible for this remarkable stability over such a wide range of conditions. Over fifty years ago cork was found to contain fatty acids. It is surprising to many users of cork to learn that it may contain as high as thirty-five percent of fatty acids (5). Lignin constitutes from twenty to thirty percent of cork. The cell walls are composed of cellulose and substances that closely resemble cellulose. Other chemical compounds in cork are polyterpenes (6) and tannins.

Natural Cork

Numerous articles are manufactured from natural cork. Among these, cork stoppers are, without doubt, the most familiar. For centuries cork has been used as a stopper for jugs, jars and bottles. We read in Virgil's Ode III, 8: "Corticem adstrictum pice demovit amphorae", that is, "remove the cork sealed with pitch from the wine vase". Later on after the invention of the glass bottle in the seventeenth century, the demand for cork stoppers increased rapidly. Such use continued to expand, and in 1892 the now well-known crown cap, a metal closure lined with a cork disc about one-tenth of an inch thick, provided a permanent seal that previously required a two inch cork stopper.

Natural cork is used in hundreds of articles more or less familiar to everyone. Hats and helmets for use in hot tropical climates are often lined with cork. It makes a light head covering and gives protection against the heat. Life preservers are made of natural cork. Pieces are trimmed and shaped to fit the pockets of the canvas jackets. Sometimes two or more pieces are skewered together to give the desired size and shape. Cork-tip cigarettes are the favorite of many. Numerous kinds of cork floats are used on seines and nets and on the individual rod and reel. Measuring gauges for liquids of low density, for example, gasoline, are constructed with floats of natural cork. The "bird" used in the game of badminton is made of cork. Natural cork is used for baseball centers to give resiliency and lightness, on penholders for softness and firmness of grip, and as liners for sealing toilet articles in many types of caps.

FIG. 4 (*Left*). This large cork oak in Union, South Carolina, is an attractive useful shade tree.

FIG. 5 (*Right*). Hon. Jim McCord, Governor of Tennessee, planting a cork tree on the State Capitol Grounds at Nashville.

Natural cork products cost relatively much less today than forty years ago because of modern methods of utilizing the trimmings and other pieces of cork that formerly constituted a huge amount of waste. This portion of corkwood is now ground and purified and used in manufacturing many types of composition cork.

Composition Cork

Composition cork is prepared by coating clean, soft granules of cork with suitable adhesives and curing the adhesive after the coated cork has been placed in molds. The adhesive is applied in such a manner that each cork particle is coated with only a very thin film. Therefore it is apparent that composition cork consists mainly of natural cork. In the photomicrograph of natural cork the cells can be seen held together by a natural resinous adhesive. Composition cork differs from natural cork in that a portion of the binding adhesive is artificial.

The need for composition cork became apparent fifty years ago. The task of making this product was not an easy one, and the early types of composition cork exhibited various imperfections. However, in 1912 Charles E. McManus invented the perfect composition cork for the closure industry. Following this development the use of composition cork rapidly expanded. In addition to extensive use in the beverage fields, composition cork became an important material for manufacturing gaskets of many kinds, shoe innersoles, polishing wheels, friction rolls, cap liners for toilet preparations and numerous other articles.

Composition cork may be prepared in almost any form. It is molded in rods, flat blocks, round blocks and special shapes. The same process is followed in making the rods and blocks, although the size of the cork particles may vary. More adhesive is required to cover a given quantity of finely granulated cork than coarse particle cork, since the surface area to be covered is greater. Among the adhesives generally employed are synthetic resins, animal glues and vegetable glues. The adhesives must be odorless, tasteless and non-toxic when the composition cork is used to seal beverages or food products.

Cork is granulated in special mills which yield pure, clean, resilient granules. The granulated cork is transferred to mixing machines and the proper amount of binder is added. A predetermined quantity of the binder-coated cork is placed in the tube or mold which is then heated. The exact temperature and duration of the heating period depend on the nature of the adhesive binder and the size of the mold.

Composition cork rods are sliced into wafers or discs which form liners for crown caps. For larger caps the liners are stamped or cut from composition cork sheets. The blocks of composition cork are cut into sheets from which hundreds of needed articles are made. Composition cork blocks may be of any practical size, but the weight of the heavy molds and the necessary baking time generally determine the dimensions. Composition cork blocks may be made as large as $5' \times 2\frac{1}{2}' \times 2\frac{1}{2}''$. The sheets are cut into various thicknesses, depending upon the ultimate use. The round blocks are sliced into very long or continuous sheets in a process that revolves the blocks against a sharp knife.

In manufacturing composition cork the unique physical characteristics of natural cork are retained and the chemical properties of the finished product correspond closely to those of the natural material. The artificial adhesives employed are soft, resilient and durable. Each granule of cork which is composed of thousands of tiny air-filled cells held together by the natural cork resin is soft and compressible. Composition cork is manufactured strong and flexible, and it is not attacked by any chemical that does not weaken natural cork.

By varying the density of the blocks composition cork for many purposes can be prepared. Variations in density are effected by altering the type and quantity of adhesive employed, varying the particle size of the granulated cork or

FIG. 6. Bales of cork being inspected in the warehouse.

by employing different amounts of binder coated cork. Through such changes in formulation and manufacture composition cork can be produced to meet a wide range of industrial requirements. Thus composition cork is available in properties and dimensions for many industrial applications that natural cork cannot serve.

Composition cork might well be called

the complement of natural cork. While the manufactured product has in some instances replaced the natural article, at the same time composition cork has supplemented the use of natural cork and greatly broadened the field which cork serves.

Corkboard

The manufacture of corkboard insulation consumes a high percentage of our imports of unmanufactured cork. Natural cork, because of its air-filled cellular structure, is very resistant to the passage of heat. The heating of cork to produce corkboard causes cork to expand and increases this inherent thermal insulating property.

Corkboard insulation was invented in 1892 by John Smith of New York. Some pieces of cork were heated unintentionally in a metallic container and, when cool, were found to be a strong unit mass. Heat had caused some of the resins present in cork to come to the surface of the particles and bond them together. Also, the expansion of the cork under heat forced the particles to spread into the voids and interlock, thereby forming a strongly united mass.

Since the invention of John Smith, many improvements have been made in the manufacture of corkboard insulation. There are several processes employed today, and each is based on the discovery made by Smith over fifty years ago that cork expands when heated and that some of the resins are brought to the surface. Cork is granulated into coarse particles which are transferred to molds and the covers placed on securely. In one process super-heated steam at approximately 600° F is passed through the cork. Another method is by oven baking which is slower and requires from four to six hours at temperatures ranging from 500 to 600 degrees F. Blocks of corkboard vary in thickness up to 15″, and the slabs are cut from one to six inches thick. The usual size is 12″ × 36″, but sometimes corkboard is

FIG. 7 (*Left*). Cork is an excellent low temperature insulation material.

FIG. 8 (*Right*). Composition cork rods are cut into disks which form the sealing liners of crown caps.

manufactured as large as 36″ × 36″. The baking operation removes from cork some of the more volatile constituents, which removal together with expansion yields a product of low density. Trimmed corkboard insulation weighs from 6.5 to 9 pounds per cubic foot.

The air-filled cellular characteristic of corkboard makes it a valuable material for machinery isolation. The resilient corkboard absorbs shock, reduces vibration and prolongs the life of the mounted machine. Machinery isolation corkboard is heavier than insulation corkboard, the density varying up to 24 pounds per cubic foot. The porous surface characteristic of corkboard is excellent for absorbing sound waves and reducing noise. Corkboard has extensive use as an acoustical material, for which purpose the low density product is used.

Linoleum

Linoleum was developed in 1863 by Frederick Walton of Yorkshire, England. Originally the product consisted of oxidized and polymerized linseed oil, cork and a backing of burlap or canvas. Cork is intimately mixed with the tough, rubber-like oil product and the mixture rolled onto burlap sheets. The burlap backing gives strength to the linoleum, while the oxidized oil and cork provide softness and resiliency.

The manufacture of linoleum was begun in the United States in 1873 and now constitutes a large and very important industry. The attractive patterns available today are the result of many developments and improvements during the past eighty-five years, but the composition of linoleum has remained essentially the same. Pigments and resins are employed now along with cork, linseed oil and burlap.

The cork used is of the best grade and is ground to a fine powder. In this condition the cork can be intimately dispersed throughout the oxidized oil and resins, giving a resilient product that can be calendered to a smooth surface. In some light colored linoleums, wood flour is substituted for the tan colored cork flour. Rosin and kauri gum are the resins generally employed. Pigments are added to give the desired shade. Linoleum is manufactured plain and in a large variety of printed patterns and inlaid designs.

Cork Tile

Cork tile is manufactured by baking cork shavings and particles under high pressure. The resins of cork together with the interlocking of the cork particles hold the many pieces in a single mass. The cork is packed by hydraulic presses into strong molds and baked from seven to ten hours at 450 to 600 degrees F. By varying the time and temperature different shades of cork tile can be produced. Dark and light shades are employed in floors to give attractive patterns. Cork tile makes quiet, warm and resilient floors that are very durable.

Trade Statistics

The production of cork products in the United States has risen sharply during the past fifty years. The figures in the following table show this increase:

YEAR	VALUE	YEAR	VALUE
1899	$ 4,392,000	1929	$23,656,117
1909	5,940,000	1933	10,440,000
1914	7,875,000	1937	20,106,544
1921	12,965,256	1939*	19,305,054

* Latest United States Census of Manufactures.

The United States consumes more cork than any other country. To keep this nation supplied and to meet the requirements of other countries, the annual production of corkwood has increased notably in the past thirty years. In Portugal alone the quantity of corkwood harvested in 1936 (120,000 metric tons) was six times the quantity obtained in 1919 (17,969 metric tons).

Cork production in recent years is given in the following table*:

COUNTRY	YEAR	METRIC TONS
Portugal	1941	167,463
Spain	1941	70,000
Italy	1941	13,814
France	1941	13,500
Algeria	1939	33,172
French Morocco	1937	18,500
Spanish Morocco	1942	733
Tunisia	1938	4,516

* Compiled from: Cork Production and International Cork Trade, Ernst Palmgren, Int. Inst. Agri., Rome (1947).

Production of cork was low during the recent world war but is now regaining normal proportions.

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Utilization Abstract

Sugar from Wood. "By the use of a dilute sulphuric acid solution, the cellulose fraction in wood may be converted into a sugar solution. From this sugar solution, four main products may be obtained: sugar, largely glucose, commonly referred to as corn sugar, might serve as a raw material for further chemical processing; molasses, as high as 85 percent glucose, which might be used directly as a source of carbohydrate in stock and poultry feed or as a source of crude sugar; alcohol, which may be produced by the fermentation of molasses or of the crude sugar . . .; and a high-protein yeast feed grown upon the sugar solution."

These developments offer tremendous possibilities for closer and more profitable utilization of the enormous quantities of wood waste on lumbering operations, at sawmills and at wood manufacturing operations. In 1944 the logging waste alone of Douglas fir in Oregon and Washington was found to be 11 million cords or 30% of the total net standing volume of the original stand. The total quantity available from all sources for what might be called a "wood-saccharification" or "wood-sugar" industry is perhaps many times this amount.

This production of sugar, alcohol and protein feed-material from wood waste has been carried on experimentally in Springfield, Oregon, where the extracting plant, previous to its present shut-down for remodeling, produced and sold from wood-sugar, 50,000 gallons of 190 proof industrial alcohol. Its full potential capacity is placed at 1,000 gallons of alcohol per day. (*E. G. Locke, Chemurgic Digest* 7(2) : 8. 1948).