The use of soybean oil in paints and varnishes is largely an American development and a new one. For more than a century the soybean oil we imported was used for food. Even as late as 1909, soybean oil was practically unknown as a paint oil. At that time, however, some chemists advocated the development of varieties of soybeans that would produce superior drying oils, which, they believed, would stabilize the price of linseed oil.

When soybeans started their climb to become the leading oil crop in this country, they found favor first as a hay crop, then as a source of edible oils, and finally as a source of drying oils. The climb was swift. The paint and varnish industry used 8.5 million pounds of soybean oil in 1933 and 150 million pounds in 1949. Other drying-oil industries used another 100 million pounds to make floor coverings, printing inks, and many other items. The use of soybean oil as a drying oil has thus kept pace with the phenomenal rise in production of soybeans.

Even though the 150 million pounds of soybean oil used in paints and varnishes represents only 11 percent of the total oil produced in 1949, it is 4 percent more than the amount used in 1948 and 57 percent more than the total used from 1943 through 1946. The figures indicate that soybean oil now has attained a definite place in the paint and varnish industry, and that its use no longer depends entirely on fluctuations in the price and supply of linseed oil.

Soybeans generally contain only about 20 percent of oil; the linseed oil in flax amounts to 38 percent.

Almost all the oil is processed by one of three methods—solvent extraction, continuous pressing, or hydraulic pressing. The first method is preferred because it produces an oil that is lighter in color and almost free from foreign material and a meal that is practically free from oil and well suited, therefore, for use in water paints, plastics, and glues.

Soybean oil obtained by any of these methods is considered as crude oil, which must subsequently be refined by one of three methods. Mechanical refining consists of emulsifying the oil with hot water or steam and then centrifuging out the foreign material. Acid refining consists of treating the oil with strong sulfuric acid, which chars the foreign material but not the oil, if handled properly. Alkali refining consists of emulsifying the oil at room temperature with a solution containing a slight excess of alkali over that required for neutralizing the free fatty acids of the oil.

The oil obtained by mechanical or acid refining differs from that obtained by alkali refining in that the free fatty acids retained in the oil serve as pigment-wetting agents and make the paint easier to grind. The oil obtained from alkali refining, because of its light color, is preferred for making oil-modified alkyd varnishes, especially those intended for white enamels. However, the oils obtained from any of the refining methods are suitable for protective coatings if they conform to the requirements of Federal Specification JJJ-O-348 for refined soybean oil.
This specification sets standards for specific gravity, iodine number, saponification number, loss on heating at 105° C., unsaponifiable matter percentage of foreign material, and acid number.

Besides those requirements, the oil must be clear and free from sediment and suspended matter when examined by transmitted light at 65° C. (149° F.). Its color must not be darker than that of a solution of 0.38 gram of reagent potassium dichromate in 100 milliliters of sulfuric acid of specific gravity of 1.84, equivalent to the No. 12 tube of the Gardner color scale (1933).

A bodied oil is one that has been heated at high temperatures to "body," or thicken, it to a siruplike consistency by the formation of polymers, which result when molecules combine with one another. The soybean oil used for kettle bodying must be free from foreign, or break, material and should have a high iodine number. The iodine number denotes the amount of iodine that is absorbed by the oil molecules and is the measure of the degree of unsaturation, or capacity of the oil to oxidize and to polymerize. Soybean oil that has an iodine number of 130 takes twice as long to body to a certain viscosity as linseed oil with an iodine number of 175 when heated at the same temperature. The time required for bodying soybean oil can be reduced by heating the oil to as high a temperature as possible without creating a fire hazard or by using high vacuum. Also, a number of chemicals, such as β-methylanthraquinone, phenanthrene, and diphenylcarboxyanthracene, have been used successfully to accelerate the bodying of oils without injuring their quality.

Bodied soybean oils have been used to replace all or part of the oil vehicle of interior and exterior paints with some success in drying and in durability. Bodied soybean oil that has a viscosity of approximately 5 poises (similar to a very heavy lubricating oil) has been mixed with tung oil in proportions of 70 parts to 30 parts by weight and heated to 550° F. to make a processed oil with better drying qualities than linseed oil. This processed oil, known as a copolymerized oil, can be cooked with ester gum and other inexpensive resins to make high-grade varnishes. The polymers of high-viscosity bodied soybean oil are insoluble in acetone and can be readily separated from the unpolymerized portion for use in making good soybean oil-ester gum varnishes.

Soybean oil gained popularity in the varnish industry in the Second World War when supplies of tung oil were short. Tung oil had been popular since early in the First World War. Before then, most varnishes were made from linseed oil and natural resins. The coatings from these varnishes dried too slowly to meet the demand for fast production of armaments and war equipment. Soon a new type of varnish, Valspar, appeared. It was made from ester gum (a resin obtained by neutralizing rosin acids with glycerol), tung oil, and mineral spirits. It, and others like it, dried rapidly, were waterproof, and made excellent grinding materials for paints and hard-drying enamels.

Oil-modified alkyd varnishes, generally called alkyls, are made commercially in closed vacuum kettles. The process usually consists of heating and reacting a dibasic acid, such as phthalic anhydride, and a polyhydroxy alcohol, such as glycerol, with the fatty acids of vegetable, animal, or marine oils. The oils serve as plasticizers and are required because the resin produced by the reaction of the acid and alcohol is too brittle for use in surface coatings without modification. A unique characteristic of alkyls is that the plasticizer becomes a part of the resin by chemical combination rather than by physical admixture. The first alkyls, known as glyptals, utilized only the fatty acids of linseed oil, but in the early 1930's small amounts of soybean fatty acids began to be used in blends with linseed fatty acids. The production of alkyd
VARNISHES and PAINTS FROM SOYBEANS

The hardest and most durable varnishes have been those made from an oil-reactive, unmodified phenolic resin and soybean oil. The varnishes were made by heating 20 gallons of refined soybean oil and 100 pounds of phenolic resin (Bakelite resin No. 254) together in a stainless-steel open kettle at 600°F, until bodied sufficiently to give a 5-inch string when a few drops were tested on a cold plate.

The cook was then removed from the heat, allowed to cool to 200°F., and thinned with 24 gallons of mineral spirits followed by 5 gallons of toluene. Cobalt driers of the naphthenate type containing 6 percent cobalt metal were added at room temperature and three-eighths of a gallon of drier gave satisfactory drying qualities to the coatings. The time of bodying at 600°F. to a 5-inch string was approximately an hour; the speed of bodying depended on the use of an oil-reactive resin.

Phenolic varnishes made by this formula and procedure dried rapidly overnight to hard, glossy coatings, which were durable and mar proof when tested on floors, launches, bows and arrows, and such. The coatings were highly resistant to hot and cold water, acids, alkalis, gasoline, and alcohol.

Tested comparatively by outdoor weathering, they proved to be more durable than two high-grade commercial varnishes that contain tung oil. Similar varnishes were made with longer oil lengths, but their coatings did not dry so hard and were less resistant than the coatings of the 20-gallon varnish. However, the material costs for varnishes of long oil length are less, and they are easier to apply by brushing. Norelac is another type of varnish that dries by solvent evaporation instead of by oxidation and polymerization.

LITTLE SOYBEAN OIL was used in paints until 1934, when some farmers' cooperative organizations began to distribute exterior paints that contained small percentages of soybean oil and were made by paint manufacturers.
in accordance with the formulas furnished by the cooperatives. Many of the paints were durable in service, but some became discolored because of dirt collection, a feature that prejudiced many users against soybean-oil paints.

The excessive dirt collection was found to be caused partly by the slowness with which the oil dried and partly by the pigment formulations used in the paints. Soybean-oil paints, especially those containing soybean oil exclusively, when formulated with certain pigments, produce coatings that remain tacky for a long time after application, a condition known as residual track. The coatings may tend to soften and become practically liquid when applied in hot and humid weather. That phenomenon is called aftertack. It is obvious that dirt collected on a coating that has developed aftertack would become so deeply imbedded that it could not be washed away without injuring the coating, while the dirt collected on a coating with residual tack would be removed by the periodic self-cleaning of the coating as it disintegrated into a powder or chalk, which is usually readily washed off by rain. However, both residual and after tack can be eliminated almost completely from the coatings of paints that contain even a 100-percent soybean-oil vehicle by including zinc oxide or calcium oxide in the pigment components.

Zinc oxide, in amounts of 25 to 30 percent by weight in the pigment portion of 100-percent soybean-oil paints, has been found to improve coatings with respect to residual and after tack, as well as chalking, checking, and cracking failures. Many paints have been similarly formulated from various percentages of basic carbonate white lead and zinc oxide and either 100-percent raw linseed-oil or 100-percent refined soybean-oil vehicles. The coatings from these paints have given practically equal results when tested comparatively by outdoor weathering for more than 7 years at Urbana and Peoria.

Similar improvements have been noted, not only when zinc oxide was mixed with a single pigment or with a composite pigment, but also when the paints were made in accordance with either the prewar or the conservation paint formulas.

A brief explanation of those formulas may be of value. The prewar formulas used nearly all raw oil in the liquid part of paint. The conservation formulas used equal volumes of raw oil, bodied oil, and paint thinner. They were adopted early in the war to conserve the supply of drying oils. Because the paints made from them have proved generally satisfactory in service, I expect that they will be continued with slight modifications. This type of paint presents greater possibilities for the utilization of soybean oil for several reasons—the fast-drying copolymers of soybean oil and tung oil require thinning before they can be utilized in paints, and the slow drying of soybean oil is partly compensated for by the use of bodied soybean oil because smaller percentages of oil are used in the conservation of paints.

Calcium oxide has improved the drying quality and other qualities of 100-percent soybean-oil paint coatings to a greater extent than zinc oxide, according to results obtained when the coatings from outside white paints or red barn paints were tested comparatively. For example, two comparable 100-percent soybean-oil paint coatings varying only in their pigmentation—(1) 75 percent basic carbonate white lead and 25 percent zinc oxide; (2) 90 percent basic carbonate white lead and 10 percent calcium oxide—have dried free from residual tack in 96 and 32 days, respectively, as determined by fine sand falling off completely from the surface of the coating. The coatings from paints containing more than 10 percent of calcium oxide in their pigments generally dry too hard and brittle for satisfactory service; the optimum amount of calcium oxide is approximately 5 percent.
Besides residual tack, comparative outdoor weathering tests of the outside white and red barn paint coatings containing 100-percent soybean-oil vehicles have proved that coatings containing 5 to 10 percent of calcium oxide are superior to similar coatings containing zinc oxide in such respects as aftertack, color and reflection retention, and durability. In these tests, calcium oxide coatings showed much less dirt retention, yellowing, darkening, cracking, and checking than zinc oxide coatings.

Soybean-oil paints have also been improved in their drying qualities by the utilization of special oils that have been treated by chemical or physical methods. Besides the copolymers of soybean and tung oils previously mentioned, a number of others are obtained by reacting soybean oil with the unsaturated organic compounds from the petroleum industry—styrene, butadiene, cyclopentadiene, terpenes, and vinyls.

Another group of special oils is obtained by replacing the glycerol of soybean oil with pentaerythritol, sorbitol, mannitol, and others. Excellent drying oils are produced when soybean oil is heated with maleic anhydride in various percentages to viscosities suitable for use as either paint or varnish oils. These oils are often reacted further with glycerol or pentaerythritol to neutralize the acids present and thus form a harder drying oil of low acidity.

Other methods for improving the drying qualities of soybean oil are based on the separation of the drying components from the nondrying components of the oil. Two of the methods are vacuum distillation and segregation by furfural or liquid propane. Although expensive equipment is required, good drying oils for paints and also improved nondrying oils for edible use are produced.

Excellent traffic paints, which meet all the specifications of a number of States, have been made from soybean oil treated with maleic anhydride. The specifications were set up on the basis of the performance of traffic paints containing principally tung oil, a waterproof oil that dries fast and hard.

Outside white paint coatings that contain the drying components of soybean oil obtained by the furfural-segregation method have been tested for durability by outdoor weathering in Florida and Illinois. In comparison with similar coatings which contained raw linseed oil, they were better in drying, equal in resistance to chalking, and definitely superior in resistance to dirt retention, checking, and cracking. The iodine values of the drying components of soybean oil and of the raw linseed oil were 170 and 181, respectively.

Water paints that are satisfactory in service tests can be produced from soybean oil or from an alkyd varnish modified with soybean oil, by emulsifying either of them in a mixture of soybean protein, water, borax, and water-dispersible pigments, through the use of high-speed stirring methods. The resin-emulsion paints, among them several widely advertised ones, have become popular for interior decorating, not only because of their excellent hiding power in one coat, but also because they dry rapidly with a minimum of odor, possess good adherence, elasticity, and durability, and have fair resistance to washing. The large sales volume of this type of paint has resulted in the consumption of a large amount of soybean oil.

Soybean oil has now won a definite foothold in the paint and varnish industry.

The shortages and higher prices of the better drying oils have forced the industry to look with more and more favor upon soybean oil. The development of special or treated oils with better drying properties has enabled paint manufacturers to use more or less soybean oil in blends with other oils. The development of the popular oil-and resin-emulsion water paints has made a market for a good deal of soybean oil.

The progress now being made by the
paint and varnish industry in the use of less expensive oils, such as petroleum and tall, may prove a serious factor of competition to the continued use of soybean oil and of its improved drying treatments must be kept competitive with the cost of those oils as well as with that of linseed, tung, dehydrated castor, and other faster-drying oils. The use of small amounts of calcium oxide or lime in pigment formulations appears to be one method for lowering costs and at the same time improving the drying and other qualities of the soybean-oil coatings.

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Synthetic rubbers vary widely in their physical and chemical properties—so much so that scientists are constantly searching for new types for special uses. One of the new specialty rubbers is acrylic rubber, a material whose resistance to heat is so superior to that of most other rubbers that its higher cost is outweighed by its longer life. It also has excellent resistance to lubricating oils. No other rubber has so good a combination of properties. The availability of such a rubber, in itself, stimulates further development. For example, machine designers are constantly striving to develop higher-powered and more compact motors, pumps, transmissions, and so on. Such equipment usually operates at higher temperatures, so that the lubrication problem becomes increasingly difficult. Over-all performance may hinge on the heat and oil resistance of such items as the rubber in the oil seals, valve packings, diaphragms, or gaskets used.

Lactic acid is one of the potential starting materials for making acrylic rubber. It may be recovered from whey, starch, molasses, and sulfite waste liquors and then converted to one of various acrylates used in making acrylic rubber. Designers and manufacturers now are giving most attention to ethyl acrylate rubber. Both groups, however, hope to find one with even better properties, particularly improved flexibility at $-50^\circ$ F. Two other acrylates, butyl acrylate and octyl acrylate, offer the most promise in the direction of improved resistance to low temperatures.

In the development of specialty rubbers, improvement in one property is often at the partial sacrifice of another. Such is the case in butyl acrylate and octyl acrylate rubbers. Improvement in flexibility at low temperatures is accompanied by a tendency to swell and soften in lubricating oils. Scientists of the Department of Agriculture have been investigating acrylic rubber obtained from lactic acid for several years. Recent developments indicate that butyl acrylate rubber offers a suitable compromise between resistance to swelling by oils and flexibility at low temperature.—T. J. Dietz, Eastern Regional Research Laboratory.